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# Health of Ferrous Foundrymen in Illinois

U. S. PUBLIC HEALTH SERVICE

and

ILLINOIS DEPT. of PUBLIC HEALTH

FEDERAL SECURITY AGENCY

1950

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PUBLIC HEALTH SERVICE PUBLICATION No. 31

# HEALTH of FERROUS FOUNDRYMEN in Illinois

*By*

*The Division of Industrial Hygiene*
*U. S. Public Health Service*
*and*
*The Division of Industrial Hygiene*
*Illinois Department of Public Health*

1950

FEDERAL SECURITY AGENCY
Public Health Service
Washington, D. C.

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# FOREWORD

*In the past 30 years, great strides have been made in the control of silicosis, but despite these advances on a broad base, there continue individual instances in which the disease still endangers the health and life of workers. Mounting evidence has pointed to the foundry industry as a remaining source of exposure to silica dust, but at the same time it has been felt by some that the cases still coming to light in this industry are the result of preexisting rather than present improved conditions. In order to determine the actual facts, an investigation was conducted by the Public Health Service in cooperation with the State Department of Public Health in Illinois. It is hoped that the correlated findings of the medical-engineering teams presented in this report may help to clarify this question and aid further in the prevention and control of a serious hazard.*

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Grateful acknowledgment is made to the management and employees of the 18 ferrous foundries covered in this investigation, whose cooperation made this study possible. Appreciation is also expressed to the trade associations and labor organizations that contributed invaluable assistance. We should like to thank particularly Mr. C. C. Murphy, of the Chicago Federation of Labor, AFL; the Illinois State Industrial Union Council, CIO; the Chicago Industrial Union Council, CIO; District 31 of the United Steelworkers of America, CIO; Local 1545 of the United Steelworkers of America, CIO; Region IV of the United Automobile, Aircraft, Agricultural Implement Workers of America, UAW-CIO; the National Foundry Council, CIO; the Chicago Foundrymen's Association, and the Chicago and Vicinity Molders' Conference Board, International Molders' and Foundry Workers' Union of North America, AFL.

The Rockford City Health Department and the Division of Laboratories, Illinois State Department of Public Health, contributed greatly to the progress of the study by making their laboratory facilities available for dust-counting.

Acknowledgment is also made to the Industrial Commission of Illinois, which made available to the investigators data on compensation claims of ferrous foundry workers for chronic pulmonary disease.

Senior Surgeon Ira Lewis, Chief, X-Ray Study Section, Division of Tuberculosis, Public Health Service, assisted materially in interpreting those roentgenograms suspected of showing pulmonary tuberculosis.

Personnel of the Division of Industrial Hygiene, Public Health Service, who also aided in the study include Joseph E. Flanagan, J. Walter Hough, David Zinke, Joseph Fridl, Robert B. Crothers, Frederick Nevins, John K. Brown, Duncan A. Holaday, D. E. Rushing, B. E. Saltzman, N. A. Talvitie, J. A. Sutton, E. P. Floyd, Vernon B. Perone, and Ljubo Lulich, while, from the Division of Industrial Hygiene, Illinois Department of Public Health the efforts of Alfred N. Setterlind, George Winkler, Marvin Scheunemann, and Lawrence S. Hill are gratefully recognized.

# ABSTRACT—SUMMARY

This report presents the clinical and environmental findings of a cooperative investigation into the exposures of ferrous foundry workers to silicosis and other hazards. Extending over a 1-year period, the study was conducted in Illinois by the Public Health Service in cooperation with the State Department of Public Health.

Prior to this study, a preliminary survey had been made of iron and steel foundries in the State. Of a total of 185 foundries surveyed, 18, which were considered as representative of the industry in Illinois, were selected for this study.

Environmental investigations were made in 18 ferrous foundries, in which approximately 1,100 samples of air-borne dust were collected and studied. It was found that 90 percent or more of the air-borne dust in all foundry environments were three microns or less in size. The amount of free silica in the air-borne dust varied with the operation and ranged from 13 percent at coremaking to 29 percent in pouring, shakeout and sand conditioning. On the other hand, the free silica content in the settled dust was found to average 30 percent throughout the foundries. The air-borne dust less than 5 microns in size was found to have a lower percentage of free silica than the larger size fraction.

The percentage of iron in the air-borne dust was found to range from 3 to 9 percent for all operations except casting cleaning, for which the proportion varied from 30 to 38 percent.

Operational dust levels at various foundry activities in general were found to be much lower than those reported in earlier investigations. Mean dust levels at molding, pouring and coremaking operations were found to be under 3 million particles per cubic foot of air. Sand-slinger molding showed a mean dust level of about 19 million particles per cubic foot. Mechanical shakeout operations showed mean dust levels ranging from 10 to 75 mppcf; whereas manual shakeout and sand conditioning produced mean dust levels under 7 mppcf. Cleaning room operations showed mean dust levels under 7 mppcf except at portable grinding and chipping, which had a mean dust level of about 15 mppcf. Other miscellaneous operations showed dust levels under 4 mppcf with the exception of chipping-out cupolas and sand unloading. The high dust exposures at the last two activities were intermittent and of relatively short duration.

Concentrations of aldehydes were of a low order of magnitude. Carbon monoxide concentrations were relatively low in most instances, but high levels occurred for short periods at pouring operations during the winter months.

In general, the foundries studied were clean; housekeeping was adequate; and dust suppression measures were employed. Many of the foundry buildings were well constructed according to modern architectural designs which permitted adequate natural ventilation and natural illumination. Although the majority of the foundries were not completely mechanized, modern production techniques were usually employed.

Many of the foundries did not utilize the latest methods of artificial illumination. The foundries studied gave little consideration to the reduction of noise.

In general, sanitation facilities provided for employees were adequate and maintained in a satisfactory condition. Some improvements were needed in a few plants.

Medical examinations were made of 1,937 males employed in 16 ferrous foundries. From the standpoint of socio-economic status and exposures to hazardous materials in the occupation, these men are believed to comprise an adequate cross-section of ferrous foundry workers in the area studied.

As might be expected, the most significant clinical findings dealt with those of the respiratory system. Pulmonary fibrosis of occupational origin was found in 9.2 percent of the men; in 7.7 percent it was ground glass two stage and in 1.5 percent, nodular. The fibrosis was of about equal frequency in steel and gray iron workers. Among the gray iron foundrymen, the molders showed the highest incidence of nodular fibrosis; whereas, among the steel workers, those performing cleaning and finishing operations had the highest rate. It generally required at least 14 years of exposure to produce nodular silicosis in foundry work. The blood studies indicated that pulmonary fibrosis was associated with increased erythrocyte sedimentation rate and elevated total leucocyte counts. Significantly elevated blood pressure levels were found to be related to increasing degrees of pulmonary fibrosis.

Reinfection type of tuberculosis was found in 0.7 percent of white workers and in 1.7 percent of the Negroes, orders of magnitude similar to those of other studies of adults of both sexes made in the general population in the same area.

The limited examinations made of the eyes revealed no abnormalities which could be ascribed to the occupation. Skin disease, probably of occupational origin, was found in 1.7 percent of the men.

The oral structures were modified in the occupation only to the extent that there was attrition of the tooth surfaces. This was attributed to the dusty nature of the occupation.

The correlation of the clinical and environmental findings reveals that there is reason to believe that dust conditions in the foundries studied have improved in the past 10 to 20 years. Thus, it is likely that in many instances the pulmonary fibrosis observed was due in great part to higher dust concentrations which probably existed 10, 15 or more years previously in the foundries. The conditions noted, however, generally leave room for improvement in the control of silica and other hazards. Based on our observations during the study, the following recommendations are presented:

Exhaust systems and dust collection equipment should be given proper maintenance. When buildings are to be remodeled or new ones built, consideration should be given to the location of various operations in order to minimize the number of workers affected by the high dust producing operations. Very dusty operations should be scheduled when few workers are present. Local exhaust ventilation should be employed when mechanical shakeout equipment is used. Exhaust ventilation should be employed with portable grinding. Adequate ventilation should be provided to prevent excessive concentrations of carbon monoxide during pouring operations and around furnace charging. Particularly noisy machines should be isolated whenever possible, or appropriate acoustical treatment should be employed where they are located. Modern lighting techniques should be employed to improve artificial illumination.

# INTRODUCTION

Studies of the health of ferrous foundry workers have been made during the past two decades in many parts of the world. In most reports of such studies the dust hazard reasonably received major consideration. However, in spite of these many investigations, with resultant recommendations, the dust hazard still appears to be a real one. This was especially brought to our attention by health officials of three Midwestern States.

These officials pointed out that in their respective jurisdictions claims for silicosis among workers in the ferrous foundry industry were continuing in spite of apparent improvement of environmental conditions. They, therefore, requested that the Public Health Service engage in an investigation of the matter. Following preliminary conferences with these officials, and others concerned, it was agreed that the Public Health Service, with the cooperation of the States, would make a study of the health status of the workers in the industry, and that special emphasis would be placed on certain of the diseases which might be related to the occupation. It was further agreed that the study would be made in the State of Illinois together with the Department of Public Health of that State.

Eighteen foundries were studied environmentally; of these, 16 were studied medically. The selection of the plants for study was based on an effort to obtain examples of different types of ferrous foundries; that is, small and large, mechanized and nonmechanized, gray iron and steel, and patently dirty and clean.

Both medical and environmental data were collected during a period of approximately 12 months, beginning in April 1948.

# THE FOUNDRY INDUSTRY

For the year 1947, the latest year for which pertinent information was available, there were 1,936 independent ferrous foundries in the United States, employing a total of 239,272 workers (*1*). Table 1 shows their distribution by State. These foundries, together with all captive[1] ferrous foundries, employed approximately 341,000 production workers.

## Description of Operations

The principal steps in the manufacture of iron or steel castings are as follows: Preparation of molding materials; making of molds and cores; making and pouring of hot metal; removal of castings from the molds and removal of cores; and cleaning of castings.

The preparation of molding materials consists essentially of conditioning the core and molding sands. Core sand is usually prepared in large batches in a rotary mixer by using fresh sand, free from clay, with certain ingredients which may include flour, a cereal binder, a pitch binder, and linseed oil. Molding sands consist of facing sand, which is used on the surface of the mold, and heap sand, which fills up the rest of the mold. Facing sand is prepared either by the fine screening of heap sand or by mixing definite proportions of old sand and fresh sand with various materials, such as sea coal, bentonite, and corn flour. Heap sand is recovered molding sand to which water, a certain amount of fresh sand, and sometimes a clay bond, are added. The wet sand ingredients may be mixed by hand, by moving harrows, or by large mechanical mixers.

Cores are made by introducing sand into wooden or metal molds. Depending on the size and other requirements, cores may be made by bench, floor, or machine molding. Cores are baked usually in a gas-fired oven equipped with mechanical ventilation. After cooling, the core is scraped to remove loose, surface sand and is then ready for use in the preparation of the molds.

Molding consists of embedding a wood or metal pattern in sand. When the pattern is withdrawn, it leaves a hollow space or mold in the shape of the casting desired. Molds for small castings may be made by bench or machine molding, while molds for large castings are usually made on the floor or in a pit. In the preparation of the molds,

[1] A captive foundry makes castings for use by itself or its parent company in the fabrication of other finished or semifinished products, and is not engaged in the production of castings for sale.

*Table 1.—Number of independent ferrous foundry establishments and number of their production workers in the United States according to state, 1947*

| State | Number of establishments | Number of production workers (average for the year) |
|---|---|---|
| Total | 1,936 | 239,272* |
| Pennsylvania | 222 | 30,930 |
| Ohio | 201 | 33,115 |
| Michigan | 149 | 42,802 |
| ILLINOIS | 143 | 23,021 |
| California | 131 | 8,002 |
| New York | 111 | 11,444 |
| Indiana | 105 | 14,820 |
| Wisconsin | 84 | 10,962 |
| Massachusetts | 78 | 4,024 |
| New Jersey | 69 | 7,835 |
| Alabama | 60 | 12,884 |
| Minnesota | 48 | 2,052 |
| Texas | 43 | 2,485 |
| Missouri | 41 | 5,450 |
| North Carolina | 35 | 1,104 |
| Virginia | 33 | 2,657 |
| Iowa | 32 | 1,965 |
| Tennessee | 31 | 4,120 |
| Connecticut | 30 | 3,919 |
| Washington | 27 | 1,079 |
| Oregon | 25 | 1,171 |
| Georgia | 23 | 785 |
| Colorado | 21 | 1,068 |
| Kansas | 20 | 984 |
| All other | 174 | 6,167 |

*Includes all production workers for the United States. The sum of the State numbers below, however, is only 234,845. The difference of 4,427 represents the sum of unpublished State data distributed among the following States: Alabama, Arizona, Arkansas, California, Connecticut, Delaware, Florida, Idaho, Iowa, Louisiana, Massachusetts, Minnesota, Missouri, Montana, Nebraska, New Hampshire, New Jersey, New Mexico, New York, North Carolina, North Dakota, Oklahoma, Rhode Island, South Dakota, Texas, Utah, and West Virginia.

*Source:* Reference 1.

the molding sand may be handled either manually—by shoveling; or mechanically—by dumping from an overhead conveyor or by a sand-slinger machine which throws the sand into the mold. The small finished molds are usually carried to the pouring area by the molder, while large molds are poured in place.

The molten metal that is poured into the molds to form the casting is prepared in a furnace. The type of furnace used depends on the type of metal desired. For gray iron, a cupola is used; for malleable iron, an air furnace; and for steel, an open-hearth or electric furnace. In the operation of the cupola, weighed amounts of pig iron, scrap iron, limestone, and coke are charged in alternate layers. The combustion of the coke, aided by a forced draft, melts the iron, which settles to the bottom. In the operation of the furnaces used for the preparation of malleable iron and steel, the raw materials are essentially the same as in the cupola; however, since the fuel is not mixed with the charge, the amount of impurities in the finished product is decreased. In addition, special care is taken in the amounts of raw materials added, and the composition of the molten metal is more carefully controlled. When the heat is ready, the furnaces are tapped, and the molten metal is transported by ladles to the pouring area. Pouring into the molds is accomplished either mechanically or manually, depending on the size of the castings and the degree of mechanization of the plant.

The flasks, which enclose the mold, are removed immediately after the molds have been poured, and five minutes to several hours later, depending upon their size, the hot castings are removed. Manual methods are normally used in dragging small castings from the sand, and in some plants the larger castings are also removed manually. Mechanical shakeout methods, consisting of vibrators, chain hoists, cranes, vibrator platforms and pneumatic hammers, may be used for large castings. Large cores, gaggers, rods, and the like are removed from the large castings by either manual or mechanical methods. Risers and sprues on small iron castings are removed by a hammer blow. In the case of large iron and all-steel castings this operation is accomplished by an oxy-acetylene torch.

The castings are transported to the cleaning department where sand and excess metal are removed. Most of the sand is removed from the casting by two methods: tumbling and blast cleaning. Tumbling involves the repeated striking of castings against each other and against hardened iron stars in a rotating barrel. Abrasive blasting is accomplished by directing a stream of abrasive particles, such as sand, synthetic abrasive or chilled grit, or shot, against the casting at high velocity. The remainder of the sand and the excess metal may be removed by various operations, including stationary grinding, portable grinding, swing grinding, pneumatic chipping, and burning.

## JOB CLASSIFICATION

Since the differences in the size and type of foundries (gray iron, malleable iron, or steel, and production or jobbing), in the degree of mechanization (manual or mechanical or a combination of both), and in the size of castings made for a diversity of operations, a job classification of the workers must be generalized. All of the workers included in this study of the foundry industry in Illinois were divided into six broad groups according to the location and nature of the work involved. These groups are: coremaking department, molding department, casting cleaning department, shakeout and sand conditioning, maintenance and supervisory, and miscellaneous laborers. In the following pages the operations performed and the machines and materials used by each group are discussed by occupation.

### *Coremaking Department*

The *coremakers* constitute the greatest number of individuals in this group. Their work consists of fashioning cores, using a hollow form (core box) and forcing into it a cohesive mixture of core sand. The work may be accomplished by manual (bench or floor coremaking) or by mechanical methods (machine coremaking). Small cores are made by bench and machine coremaking, and large cores are usually made on the floor. In most foundries the coremakers spend the entire working day at this operation, although in some of the smaller foundries from one to two hours may be spent in pouring or shakeout operations.

The *core oven tenders* load, unload, and fire the oven in which the cores are baked. The various operations of this occupation usually consume the working day.

The *core room laborers* perform a number of different tasks that include scraping cores, mixing core sand, mixing paste, hauling fuel for the oven, sweeping floors, transporting core sand and core boxes, and cleaning core boxes.

Additional core room personnel include *core pasters* and *core assemblers*. Their work consists of scraping core sections, applying paste to the core surfaces to be joined, and fitting the sections together accurately.

### *Molding Department*

In most foundries *molders* constitute the largest number of workers in any single occupation. The primary function of molders is to prepare the sand molds in which metal is cast. Basically, this involves packing sand around a pattern of the desired object and then withdrawing the pattern, leaving in the sand a hollow space in the shape of a casting to be made. The *bench molder* applies facing sand through a hand screen, fills up the flask with heap sand, and tamps the sand in place with a hand or pneumatic rammer. Loose sand is blown from two halves of the mold; the cores are placed, and a parting compound is applied. The mold is assembled and is placed on the floor ready for pouring. *Floor* and *pit molders* perform essentially the same routine except that the molds are much larger and cranes or hoists are

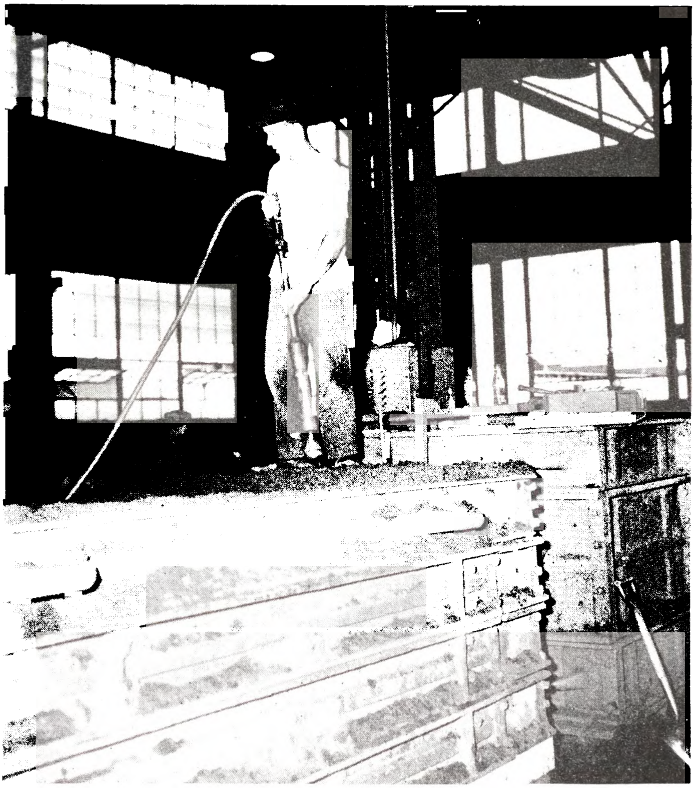


Figure 1.—Tamping sand into a large floor mold with a pneumatic tool. Note the large window space which aids in providing natural ventilation and illumination.

used to lift the flasks and patterns. *Machine molders* operate machines that pack the sand by either squeezing, bumping or jolting.

Some large foundries, especially if floor or pit molds are made, use sand-slinger machines which are controlled by a *sand-slinger operator.* Sand placed in a hopper of the sand-slinger is automatically sifted and carried to the end of an arm, where it is thrown into the flask with enough force to pack it, thus saving hand labor in packing the mold. The sand-slinger operator works with molders who set up and finish the mold.

In many foundries the molder also performs the task of pouring the molds he has made. This task is done usually at the end of the workday and requires from one to two hours.

A number of *laborers* are usually assigned to the molding department to perform unskilled tasks, such as sifting and shoveling sand, carrying equipment and materials to the working area, pouring molds, shifting weights, and removing flasks.

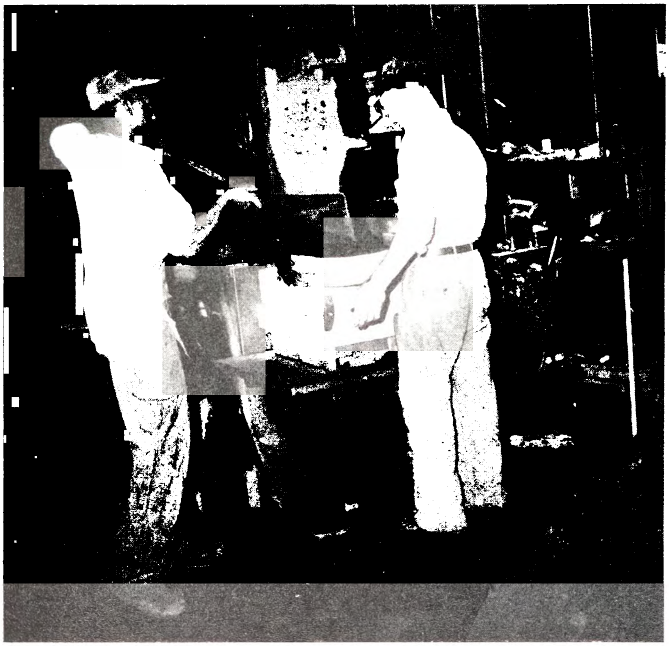


Figure 2.—Machine molding of small castings. Molder's helper at the left is shoveling sand into a screening device to provide facing sand for the mold. Pile of heap sand is in the right foreground.

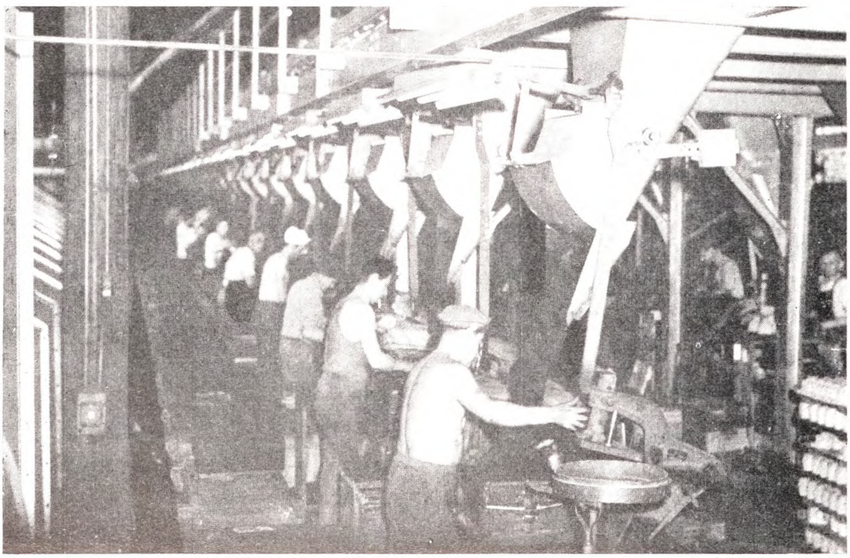


Figure 3.—Line of machine molders. Molding sand is provided by an overhead conveyor system. Finished molds are taken to a central pouring area by the conveyor directly behind the molders.

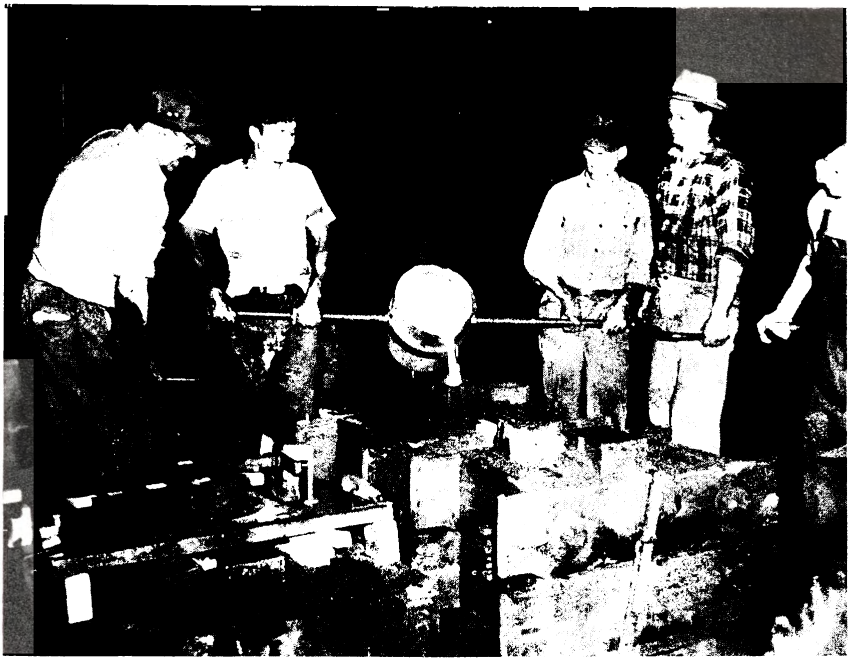


Figure 4.—Manual pouring of hot metal into floor molds.

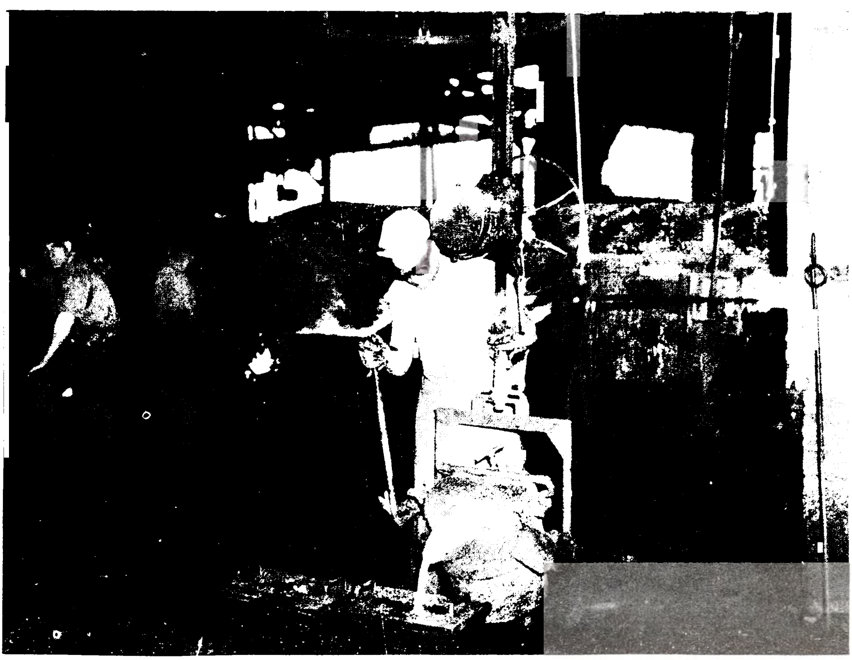


Figure 5.—Pouring small molds at a central pouring station. Note furnace operator tapping air furnace in background.

### *Casting Cleaning Department*

*Tumbler operators* are laborers who load and unload the tumblers and may transport the castings to and from the area. These workers may also have other tasks in the cleaning department or during the pouring operation.

The *wheelabrader operator* runs a machine which cleans castings by both tumbling and blast cleaning methods. This laborer also loads and unloads the machine, and may perform other tasks in the cleaning department.

*Sandblasters* and *tableblasters* use the method of blast cleaning to remove the sand from the castings. Sandblasters may collect and transport the castings to the sandblast room, where they clean the castings. The tableblaster, on the other hand, operates a machine in which castings are carried through a chamber where one or more nozzles direct streams of abrasive-laden air against them. The worker collects and transports the castings, places them on the circular rotating table of the machine, and removes the castings from the table when they are cleaned.

The *grinders* and *chippers* remove the excess metal from the castings and the small amount of sand remaining after precleaning operations. Grinders may be classified according to the mounting of their machines. Thus, there are stand or stationary grinders, swing-frame grinders, and portable grinders. Chippers employ a pneumatic tool to remove metal fins and rough spots from the surface of the castings. In the larger foundries the grinders and chippers usually work at the same job for the entire day. In smaller foundries, or in foundries where large castings are made, the same worker may perform stand, swing, and portable grinding, and pneumatic chipping during the same day.

*Burners* remove gates, risers, and projections from iron and steel castings with an oxy-acetylene torch.

Cleaning department *laborers* perform a number of tasks which include transporting castings, knocking off risers, removing cores, and sweeping floors.

### *Shakeout and Sand Conditioning*

The shakeout operations in most foundries are performed by a group of *laborers* who also may condition or prepare the sand for the next day's work. Shakeout operations vary with the size and degree of mechanization of the foundry and size of the castings. Both manual and mechanical methods are used to free the casting from the mold and to transport it to the cleaning department. Where manual shakeout methods are used, the tasks may include removing flasks, knocking off risers, dragging out castings, loading castings and transporting them

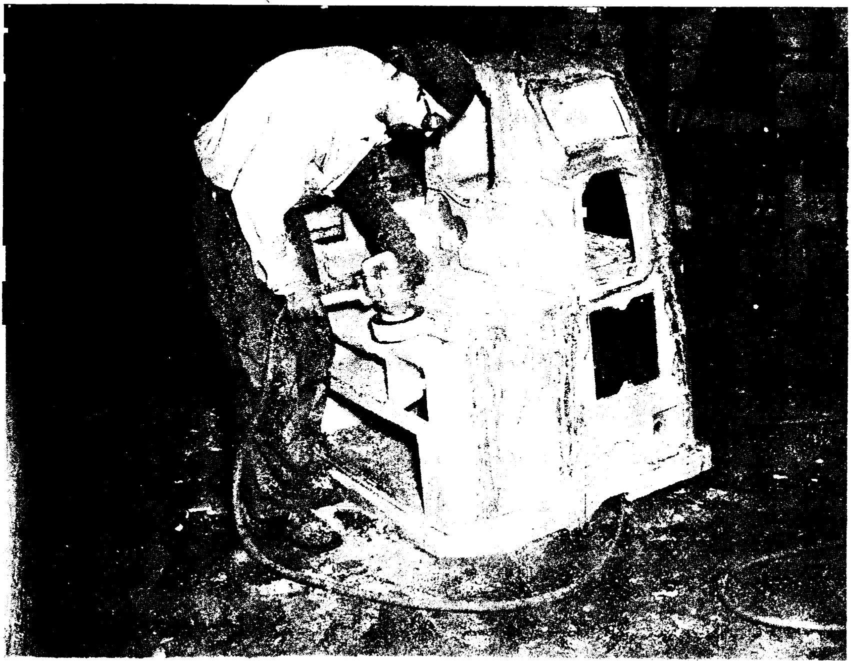


Figure 6.—Removing rough spots from casting by portable grinding.

Figure 7.—Stand (stationary) grinding small castings. Note fluorescent lights and ducts of exhaust ventilation system.

Figure 8.—Removing excess metal from casting by pneumatic chipping.

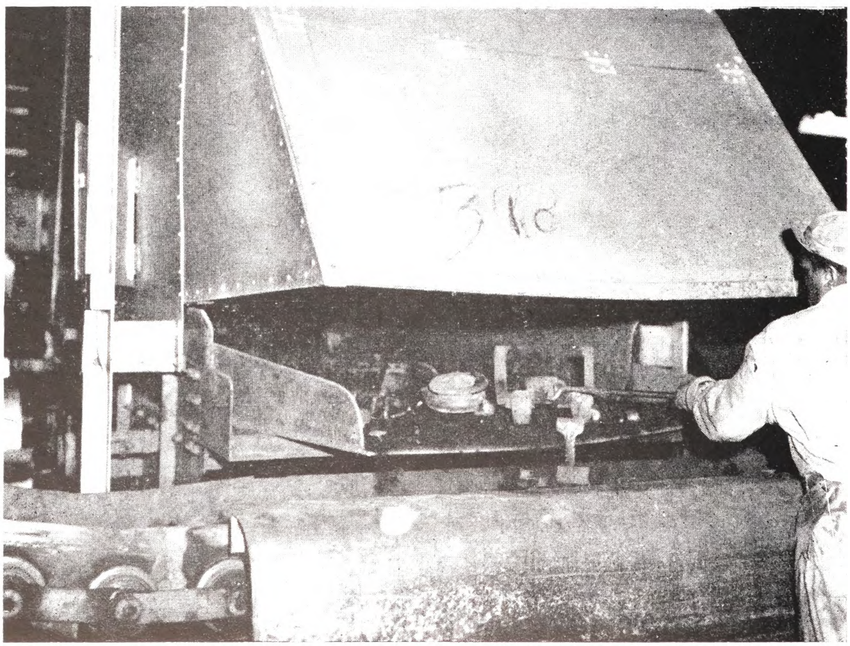


Figure 9.—Castings emerging from a mechanical exhaust ventilated shakeout system. Laborer removes and places large castings in wheel barrow; conveyor system carries small castings to sorting room.

Figure 10.—Shakeout of casting from floor mold using a chain hoist.

to the cleaning department, stacking bottom boards, picking up risers, wetting sand, and cutting the sand by hand. Mechanical shakeout methods may include the use of cranes or hoists to lift and transport the molds and the castings, vibrator platforms to shake the casting out of the mold, pneumatic hammers to knock the sand loose, and vibrator hoists to shake small castings from the molds.

*Sand mixers* prepare the core, facing, and heap sands for use by the coremakers and molders. This work may be done by hand, using a shovel or by the operation of mullers or cutters. The sand mixer may be required to load, unload, and operate the muller, and transport the sand to the place where it is to be used. Some foundries have completely mechanized sand-treatment systems which the operator can control from one location. The amount of time required for the sand-treatment operations varies from plant to plant. In small foundries the sand mixer usually has numerous other tasks, while in large foundries the entire day may be spent at this operation.

### *Maintenance and Supervisory*

*Maintenance workers* are required to repair, service, and maintain the machinery and equipment in the foundry. Depending on the size of the foundry and degree of mechanization, the following maintenance

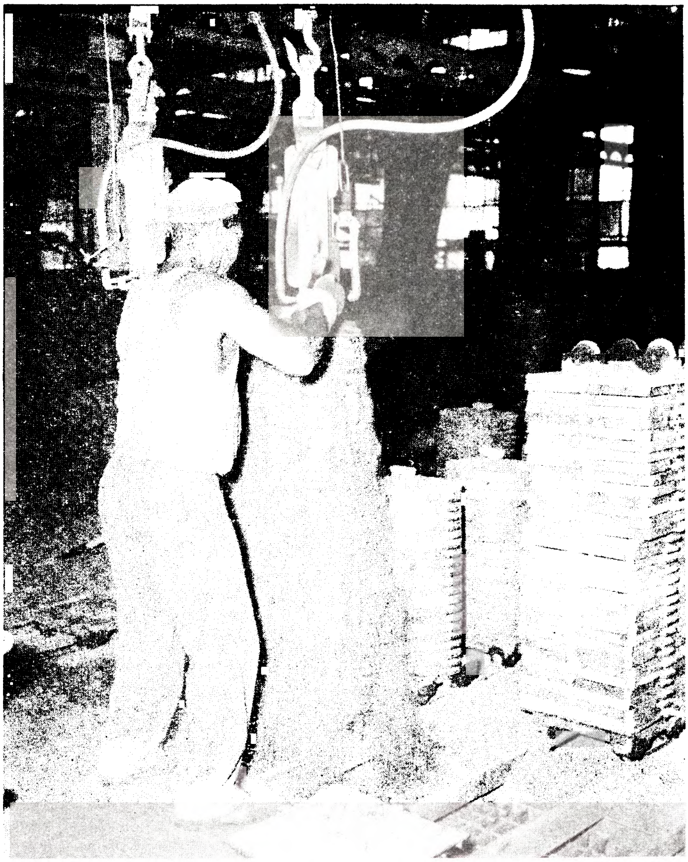


Figure 11.—Shakeout of castings using a pneumatic vibrator hoist. Sand falls through grillwork in floor onto conveyor belt which carries it to the sand conditioning unit.

employees may be necessary: *carpenters, electricians, mechanics,* and *millwrights.* These workers may perform their jobs in all sections of the foundry and usually are not required to do other tasks.

Supervisory personnel includes *superintendents, assistant superintendents, foundry foremen,* and *department foremen.* These men plan, coordinate, and are responsible for work under their direction.

*Shipping* and *receiving clerks* perform various tasks connected with the incoming materials and equipment and the outgoing products.

Office workers perform bookkeeping and timekeeping, maintain correspondence, and do other tasks necessary in the conduct of foundry business. These workers spend little time in the foundry workrooms.

### *Miscellaneous Laborers*

This group includes all the remaining foundry workers who do not qualify for the other five groups. Included in this group are occupations which are sufficiently important from the dust-hazard standpoint to be in a group by themselves, but the small number of workers in these occupations make separate consideration of the occupation unwarranted.

*Furnace workers* include melters, cupola chargers, melter helpers, ladle liners, and brickmasons. The *melters* supervise the work involved in operating a furnace (cupola, air, electric, open-hearth) in which the molten metal is prepared.

The *cupola chargers* weigh and transport the raw materials to the charging platform, where they shovel or dump the constituents of the charge into the cupola. They may also assist in other tasks around the cupola.

The *melter helpers* perform numerous tasks in the operation of the furnace. These include chipping or cleaning out the furnace, repairing furnace, cleaning out slag, preparing slag bed, assisting in tapping furnace, operating bull ladles, and helping to pour.

*Ladle liners* chip out and clean ladles, and prepare and apply the materials necessary to patch or replace the linings of ladles.

*Brickmasons* construct and repair the brickwork of furnaces, stacks, and ovens by spreading mortar and placing bricks according to diagrams or blueprints.

The *crane operators* operate a crane, which runs on overhead rails in the foundry building or in the material yard, to lift and transport heavy objects, such as large flasks, molds, patterns, machines, raw materials, castings, and ladles of molten metal. In most foundries these workers spend the entire day at this occupation.

The *hoist operators,* using a chain or compressed air hoist, perform the same tasks as the crane operators but on lighter loads. These workers usually perform other tasks in the department in which they work.

*Pattern makers* construct patterns of wood or metal which have the shape and size of the desired casting

*Annealers* operate an annealing oven in which castings are heat-treated to form malleable iron.

*Yard men* perform a number of tasks, including unloading sand from box cars, storing and moving materials, helping load and unload trucks, and cleaning up.

*Truck drivers* load, unload, operate, and maintain motor trucks to transport plant products, incoming materials, and supplies.

*Guards* perform the police work in and around the foundry and protect the equipment and material from theft.

*Janitors* and *sweepers* maintain the entire foundry including the supply room, washrooms, and office rooms, in a clean condition.

*From these job descriptions and observations made of various operations in the foundry industry during the course of the study, it appears that the major health hazards to workers are exposure to silica dust, iron dust, carbon monoxide, aldehydes and to such physical agents as heat, rapid changes in temperature, noise, and bad illumination.*

# ENVIRONMENTAL STUDIES

The engineering phase of the ferrous foundry investigation included an evaluation of various environmental factors, such as dusts, gases and other contaminants, noise, illumination, and plant sanitation. The study was extended over a 1-year period to include all weather conditions. This investigation was carried out in 18 Illinois foundries located within a hundred-mile radius of Chicago. The number of employees per foundry ranged from 26 to 400. The size of the castings produced varied from less than one pound to approximately 40 tons. The foundries selected produced gray iron, malleable iron, and steel castings.

The majority of the plants worked only during the day except for shakeout operations, which were commonly done at night. A few of the plants surveyed, however, worked two or three shifts, with shakeout being done on all shifts.

## Collection and Analysis of Samples

### FIELD PROCEDURES

The number of samples collected at each operation was determined by the nature and dustiness of the operation. In the first portion of the survey, three or more dust samples were collected at each operation in each foundry. As the survey progressed, it was decided to collect fewer samples, provided they gave consistent results. For each operation, however, samples were collected on different days as well as at different hours of the day. Approximately 1,100 samples of air-borne dust were collected and counted. In addition, numerous samples were collected for determination of iron, free silica, and particle size. Concentrations of carbon monoxide and aldehydes were also determined.

Depending upon the information desired, three methods were used for the collection of air-borne dusts. The standard technique employing the standard impinger was used in collecting samples for dust counting and particle-size determinations (2). The sampling medium was 100 milliliters of double distilled water. When necessary, impinger tubes were rebored to maintain a flow of 1 cubic foot of air per minute (plus or minus three percent) at a pressure drop of three inches of mercury. Samples were taken in the operators' breathing zones as well as in the general room air for periods of from 5 to 30 minutes.

A vacuum cleaner, equipped with a double thickness paper filter, was used for collection of large amounts of air-borne dust for chemical analysis. These samples were elutriated, and the fractions thus obtained were each analyzed for free silica. The intake to the cleaner was suspended approximately 7 or 8 feet above floor level. The cleaner was operated at a sampling rate of about 30 cubic feet of air per minute and run from 8 to 40 hours, depending upon the dustiness.

The modified electrostatic precipitator (*3*) was used to collect dust and fume at all operations for determination of iron. The precipitator was operated at a sampling rate of 3 cubic feet of air per minute for 5 to 30 minutes.

Samples of settled dust were collected from overhead beams and rafters. These samples were analyzed for free silica and iron.

The National Bureau of Standards carbon monoxide indicator tubes (*4*) were used for determination of carbon monoxide. Tests were made in the operators' breathing zones during pouring operations. Tests were also made throughout the day in the vicinity of the cupola and of the general room air.

Samples of mixed aldehydes were collected in the vicinity of the pouring operation by means of a midget bubbler using sodium bisulfite as a collecting medium. The samples were taken at the rate of 2 liters per minute with an automatically-controlled suction device (*5*). Analysis (*6*) of the mixed aldehydes was performed by the Industrial Hygiene Division, Illinois Department of Public Health, which designed and furnished the apparatus used.

A number of samples of molding, facing, and core sands, and of parting compounds were collected and analyzed for free silica.

The standard light-field counting technique, using Dunn cells and a magnification of 100X, was employed (*2*). Each cell had been carefully ground to provide a cell depth of one millimeter, plus or minus three percent. Double distilled water was used to wash down the sides of the flask and the center tube and to dilute the sample to 250 ml. Samples containing visibly high dust concentrations were further diluted as required. A blank count determination was made for every five samples counted. Cleanliness of all sampling and collecting equipment was maintained so that blank counts did not exceed 8 particles per microscopic field. All dust counts were made in the field within 24 hours after collection.

Four to six impinger samples taken at the same operation at a given foundry were combined for the preparation of slides for particle-size determination. Particle-size distribution was determined with the filar micrometer using an oil immersion objective (*7*).

## LABORATORY PROCEDURES

The samples which were returned to the laboratory for analysis fell into four general groups, according to the type of sample and the method of collection. The four groups follow:

Bulk samples of *parent materials,* including various types of sands and parting compounds, were collected as used in the plants. Some were already powdered, and others were relatively coarse. All were ground to pass through a 100-mesh sieve and thoroughly mixed before the portions for analysis were taken.

Samples of *rafter dusts* were thoroughly mixed, and portions were taken for analysis for the determination of iron. The determinations for free silica were made only on that portion of the sample which passed through a 200-mesh sieve.

*Electrostatic precipitation* was used for the collection of a number of samples of air-borne fume and dust. Although a few of these samples were analyzed for lead and some for free silica, most of them were analyzed only for iron. In all instances the sample was removed from the electrode tube by washing with 30 percent alcohol-water solution, accompanied by vigorous scrubbing with a rubber policeman.

Gross samples of air-borne particulate matter were collected on *filter paper,* as previously described. The samples were removed from the filter paper by repeated washings in alcohol. The paper was placed in a beaker, covered with alcohol, and agitated to loosen the particles. The paper was then removed to another beaker and agitated with another portion of clean alcohol. This procedure was repeated until the paper and the last several portions of alcohol appeared to be clean and free of dust. All alcohol portions were combined and centrifuged to concentrate the particulate material of the sample. The samples were then separated into two particle-size fractions, as described below, and each fraction examined for free silica by the X-ray diffraction technique.

### *Particle-size Fractionation*

The separation of dust samples into particle-size fractions was accomplished by a sedimentation procedure similar to that used by Holden and Hyatt (*8*). Two marks exactly 33 millimeters apart were made upon the side of a 400 milliliter beaker. The lower mark was approximately 20 millimeters above the bottom of the beaker.

The sample was placed in the beaker and redistilled alcohol added to the upper mark. The mixture was agitated to put the dust into suspension, then allowed to settle for 40 minutes. The suspension remaining between the two marks was slowly siphoned into a centrifuge flask by means of a tube connected to a vacuum line. Care was taken that the suspension was agitated as little as possible by the siphoning operation. Clean alcohol was added to bring the level to the upper mark on the beaker, and the procedure of agitating, settling, and siphoning was repeated. This cycle was continued until the upper layer appeared clear.

After siphoning, the upper layer containing the fine particles was centrifuged to bring down all particles, and the clean supernatant liquid was decanted. The same centrifuge flask can be used throughout the sedimentation of a sample regardless of the number of cycles of operation required to give a clear upper layer.

After a final centrifuging and decanting, the two fractions were dried by evaporating off the alcohol and then weighed. The residual dust from the beaker was designated as greater than five microns, and the fines from the siphoned liquor, as less than five microns in effective diameter. The sedimentation procedure was based on the settling rate of quartz to give the separation at the five-micron size. Any materials present with densities appreciably greater or less than that of quartz would accordingly be separated at smaller or larger effective diameters of the particles. Actual particle-size distribution counts were made on both fractions of a few samples selected at random. On the average, the fine fractions were found to have 89 percent of the particles smaller than 5 microns in diameter, and 99 percent smaller than 10 microns. In the coarse fractions the count of particles over 5 microns averaged somewhat more than 50 percent of the total, and 80 percent, on the average, were greater than 2.5 microns in diameter. Due to the much greater density of iron and steel, the fractionating procedure separated particles of these materials into greater than and less than 2.5 micron size fractions. The relatively large number of particles between 2.5 and 5 microns in diameter in the coarse fractions is indicative of the large proportion of fine particles of iron, steel, or other heavy materials in the samples. It is believed that the separation of quartz into fractions above and below 5 microns in diameter was well accomplished.

### *Free Silica*

The *X-ray diffraction* technique was used for the determination of free silica (quartz) in all samples which were separated into the two particle-size fractions and in a few other samples. Beryl was used as an internal standard for the quantification of the photographed pattern. Some samples required treatment with a dilute acid for the removal of interferences, principally iron. The instrument used was a General Electric XRD, type 1, X-ray diffraction apparatus. The film densities were read on a Leeds and Northrup recording microphotometer.

Most of the determinations of free silica in parent materials and rafter dusts were done by a modified *phosphoric acid procedure* (*9*). The method depends upon both time and temperature control during the acid treatment. This method has been found to be accurate and rapid for samples such as were encountered in this study.

### *Iron*

Depending upon the size of the sample and the iron content, two methods were used in the determination of iron. Some samples were analyzed by both methods.

Samples containing relatively large quantities of iron were analyzed by a *titrimetric procedure* (*10*). The iron was separated by a precipitation as the hydroxide which was then dissolved in acid. The iron was reduced with stannous chloride and the excess of the reducing agent oxidized by mercuric chloride. The ferrous iron was then titrated with a standard solution of potassium dichromate using diphenylamine indicator.

Some air-borne materials collected by means of the electrostatic precipitator and other materials low in iron were analyzed for iron by a *colorimetric method* (*11*). The samples were treated with hydrofluoric and perchloric acids and ashed. The ash was taken up in hydrochloric acid, filtered and diluted to volume. An aliquot was treated with alpha-alpha-dipyridyl reagent and the color read in a photoelectric spectrophotometer at 522 millimicrons. The iron concentration was read from a standard curve of transmission values determined from a series of iron standards treated by the same procedure.

### *Lead*

Only a few samples were analyzed for lead. These were all electrostatic-precipitator samples for dust or fume. They were removed from the tube by washing with 30 percent alcohol-water solution and were ashed with nitric acid. The determinations were made by a double extraction, mixed-color dithizone procedure (*12*). The color was measured at 510 millimicrons by a photoelectric spectrophotometer.

## Results of Environmental Studies

### ATMOSPHERIC CONTAMINANTS—Dust

#### *Characteristics*

Foundry dusts, in general, consist of a mixture of various inorganic materials and a small amount of organic substances (*13, 14*). Free silica ($SiO_2$) is an important constituent of this mixed dust which originates principally from the molding and core sands. Analysis of 30 molding sands and 10 core sands taken from various foundries showed an average of 75 percent free silica in molding sand and an average of 86 percent free silica in core sand. Parting compounds furnish another source of silica dust, and an analysis of 16 of these materials showed a range of from 0.5 to 93 percent free silica. Thirteen of these compounds contained less than 8 percent; whereas the other three contained more than 63 percent free silica.

FREE SILICA IN AIR-BORNE DUST.—Table 2 shows the percent by weight of free silica in the air-borne dust by operation for the total sample and for the fraction less than five microns in size. Range and mean values are shown. The median values were essentially the same as the mean.

*Table 2.—Percent by weight of free silica in air-borne foundry dust in 18 ferrous foundries in Illinois according to operation*

| Operation | Number of samples | Free silica percent by weight | | | |
|---|---|---|---|---|---|
| | | Total sample | | Fraction less than 5 microns | |
| | | Range | Mean | Range | Mean |
| Coremaking | 5 | 8–21 | 13 | 6–18 | 12 |
| Molding | 15 | 13–46 | 26 | 5–39 | 15 |
| Pouring | 3 | 18–44 | 29 | 11–25 | 21 |
| Shakeout and sand conditioning | 10 | 20–40 | 29 | 11–44 | 17 |
| All cleaning operations | 12 | 10–27 | 17 | 12–33 | 18 |

These data show that the average percentages of free silica in the total sample for molding, pouring, and shakeout operations were essentially the same, probably because these operations are conducted in the same general area. It is interesting to note that in these operations the mean percent of free silica in dust less than five microns in size is appreciably lower than was found for the total sample. Computations using data from the text table on page 29 and table 2 show the percent of free silica in the dust less than five microns in size to be approximately one-half the percentage found in the fraction above five microns in size. The average percent of free silica in the total sample was only about half as high in the coremaking and cleaning operations as compared with the other operations. No significant difference was found in the percent of free silica in the two size fractions in coremaking and cleaning operations.

FREE SILICA IN SETTLED DUST.—This was determined from samples collected from overhead pipes and beams at least 20 feet above floor level. These samples were collected in the following areas: (1) coremaking, (2) cleaning, and (3) molding, pouring, shakeout, and sand conditioning. Since the last operations are all carried out in the same location, the sample represents a composite dust from all these operations. The results of analysis of these samples for free silica are as follows:

| Area | Number of samples | Free silica percent by weight | |
|---|---|---|---|
| | | Range | Mean |
| Coremaking | 11 | 18–62 | 30 |
| Cleaning | 15 | 21–53 | 30 |
| Molding, pouring, shakeout, and sand conditioning | 28 | 12–51 | 30 |

By a coincidence, the average amount of free silica in the settled dust from the three areas was found to be 30 percent in each case. The results were practically identical with those of the air-borne dust for molding, pouring, shakeout, and sand conditioning (table 2). An appreciable difference was noted in the percent of free silica found in air-borne and settled-dust samples from coremaking and cleaning operations. These results indicate that considerable caution is required in using settled-dust samples to evaluate the composition of a mixed air-borne dust for any individual foundry. Apparently, differential settling of a mixed-density dust has an influence on the composition of settled rafter dusts. If settled dust sampling is done, it is important that representative samples be collected and that a large number be taken to insure maximum reliability. From the data obtained, it is evident that further study of the relationship of settled dust to air-borne dust is needed.

IRON.—Together with its compounds, iron was also evaluated as a constituent of the foundry dust. Results of the analysis of dust samples, collected with the electrostatic precipitator, for iron are shown in table 3. A review of table 3 shows that the iron content of air-borne

*Table 3.—Percent by weight of iron and its compounds (expressed as Fe) in air-borne foundry dust in 18 ferrous foundries in Illinois according to operation*

| Operation | Number of samples | Iron percent by weight | |
|---|---|---|---|
| | | Range | Mean |
| Molding | 7 | 3– 7 | 5 |
| Melting and tapping | 6 | 4–15 | 9 |
| Pouring | 15 | 4–13 | 8 |
| Shakeout | 11 | 2– 7 | 3 |
| Stand grinding | 8 | 8–59 | 38 |
| Pneumatic chipping and grinding | 8 | 13–51 | 30 |

dust was considerably higher at cleaning operations (stand grinding, and pneumatic chipping and grinding) than at other foundry activities. In view of the nature of cleaning operations, these high results were to be expected in the vicinity of the operation. (Two samples collected at welding and burning operations showed 39 and 40 percent of iron, respectively. The operation studied is not routine as a general rule except in steel foundries.) The iron content of the general room air and settled dust in casting cleaning departments was found to be as follows:

| Type of dust | Number of samples | Percent iron | |
|---|---|---|---|
| | | Range | Mean |
| Air-borne | 3 | 7–30 | 18 |
| Settled | 5 | 8–22 | 16 |

A comparison of the iron concentration in the general room air and that found in the immediate vicinity of specific cleaning operations (table 3) indicates that differential settling takes place very rapidly, the iron decreasing from 38 or 30 percent to about 16.

LEAD.—Three samples for lead were collected at one foundry where patterns were made from white metal which contained approximately 75 percent lead. Results of analyses showed 0.06 milligram of lead per cubic meter of air at melting and 0.007 milligram at the finishing operation, which included grinding and routing. Inasmuch as lead exposures in the ferrous foundries studied were intermittent and only rarely encountered, it may be concluded that lead does not constitute a significant hazard in this industry group.

RELATION OF PARTICLE SIZE TO WEIGHT.—This was determined from air-borne dust collected with the vacuum cleaner in the vicinity of various operations. The samples were elutriated, and the percent by weight of the dust less than five microns for the various operations was found to be as follows:

| Operation | Number of samples | Air-borne dust percent by weight | |
|---|---|---|---|
| | | Range | Mean |
| Coremaking | 5 | 25–56 | 46 |
| Molding | 15 | 2–64 | 30 |
| Pouring | 3 | 46–50 | 47 |
| Shakeout and sand conditioning | 10 | 3–48 | 23 |
| Cleaning operations | 12 | 6–72 | 32 |

It will be observed that the greatest percentage of particles less than five microns was found in the pouring and coremaking opera-

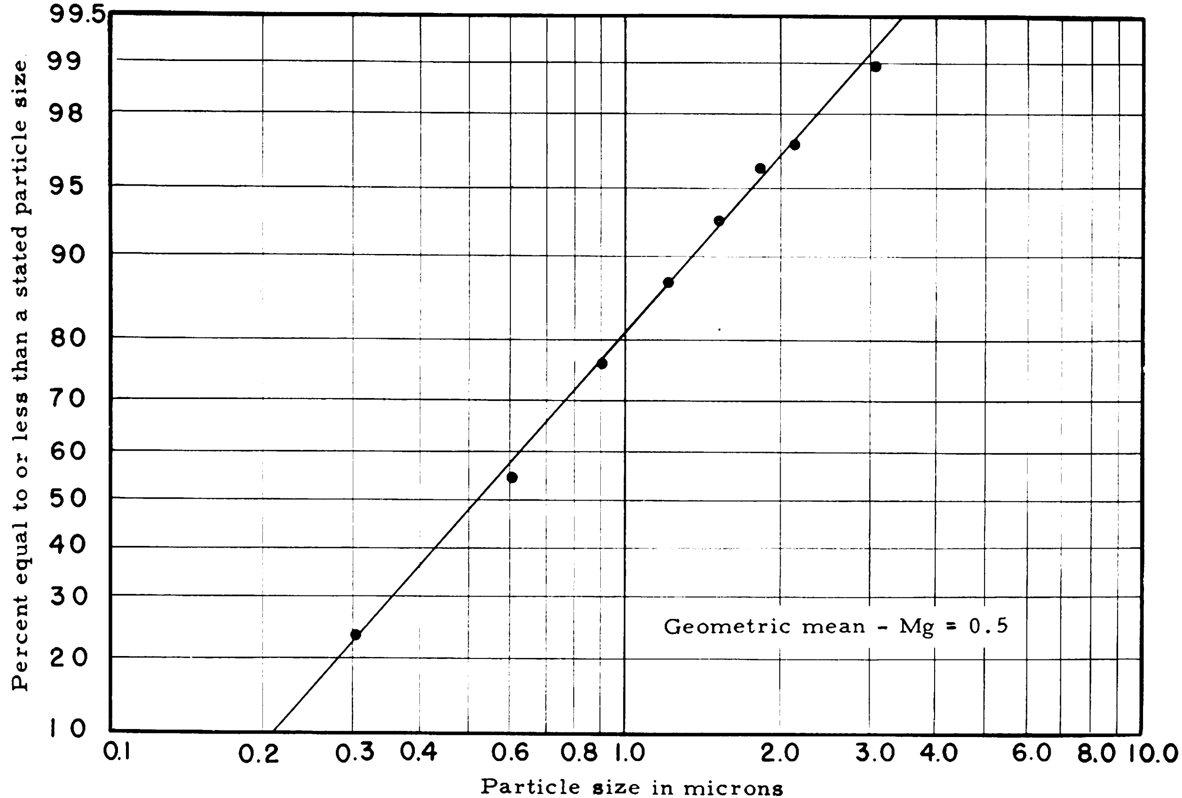



Figure 12.—Particle-size distribution of a typical air-borne foundry dust.

tions. The lowest average value of 23 percent, which was obtained during shakeout and sand cutting, may possibly be explained as resulting from the projection of large particles from the relatively dry sand during extraction of the castings. Similarly, coremaking operations are of such a nature that large particles are less likely to be thrown into the air.

PARTICLE-SIZE DISTRIBUTION.—This was determined for 12 samples prepared as previously described. While these samples were not collected in all 18 foundries, they were selected to give a representative sample of the conditions encountered. Figure 12 presents the particle-size distribution of a typical air-borne foundry dust. The probable percentage of particles within a certain size range may be determined from such a curve. The geometric mean, which is the midpoint size in the distribution, is located at the intersection of the curve with the 50 percent line.

*Table 4.—Particle-size distribution of 12 samples of air-borne foundry dust in ferrous foundries in Illinois according to operation*

| Sample No. | Operation | Geometric mean of total sample (microns) | Percent of total sample equal to or less than indicated size | | |
|---|---|---|---|---|---|
| | | | 3 microns | 1.5 microns | 0.9 micron |
| 1 | Coremaking | 0.5 | 99 | 92 | 73 |
| 2 | Machine molding | .8 | 93 | 83 | 64 |
| 3 | Machine molding | .7 | 99 | 88 | 67 |
| 4 | Floor molding | .6 | 95 | 84 | 70 |
| 5 | Manual shakeout | 1.7 | 73 | 54 | 28 |
| 6 | Mechanical shakeout | 1.6 | 90 | 54 | 15 |
| 7 | Mechanical shakeout and sand conditioning | 1.2 | 94 | 74 | 28 |
| 8 | Manual and mechanical shakeout | 1.4 | 94 | 62 | 14 |
| 9 | Sand conditioning | 1.4 | 86 | 62 | 34 |
| 10 | Cleaning | .8 | 97 | 83 | 61 |
| 11 | Cleaning | .6 | 98 | 84 | 64 |
| 12 | Cleaning | .5 | 99 | 93 | 76 |

*Note:* Sample numbers 3 and 7 were taken at steel foundries, the others at gray iron foundries.

Table 4 summarizes the data on particle size measurements of the 12 samples. Except for two of the samples, 90 percent or more of all particles were three microns or less in size. There is a noticeable difference, however, in the particle-size distribution of dust from shakeout and sand conditioning as compared with dust from molding, coremaking, and cleaning operations, the geometric mean being about twice as high in the shakeout and sand conditioning group. This difference in size distribution is particularly striking in the group of 0.9 micron or less.

### *Dust Concentrations*

Table 5 shows the dust levels found at *coremaking, molding,* and *pouring* operations. With the exception of operations where sand-slingers were used, the average dust concentrations were low—all under three million particles per cubic foot of air. With respect to molding operations, regardless of the type—bench, floor, or machine molding—there was little difference in the dust concentrations found. On the average, dust concentrations at coremaking and pouring operations were lower than at molding. Machine coremaking showed higher average concentrations than hand operations.

*Table 5.—Dust concentrations in coremaking, molding and pouring departments in 18 ferrous foundries in Illinois, according to operation*

| Department and operation | Number of samples | Millions of particles per cubic foot of air | | |
|---|---|---|---|---|
| | | Range | Median | Mean |
| Coremaking department | 56 | 0.1–5.2 | 1.3 | 1.6 |
| Bench coremaking | 39 | 0.1–5.2 | 1.2 | 1.5 |
| Floor coremaking | 9 | 0.1–3.6 | 1.1 | 1.3 |
| Machine coremaking | 8 | 0.9–3.5 | 2.6 | 2.3 |
| Molding department | 155 | 0.1–58.4 | 3.1 | 4.0 |
| Bench molding | 24 | 0.1–10.1 | 2.1 | 2.7 |
| Floor molding | 40 | 0.1–6.2 | 2.7 | 2.6 |
| Machine molding | 57 | 0.4–7.6 | 2.5 | 2.6 |
| Sand-slinging | 14 | 2.8–58.4 | 12.2 | 19.1 |
| Sand-slinger mold finishing | 20 | 1.4–7.7 | 4.6 | 4.7 |
| Pouring department | 32 | 0.1–4.2 | 1.9 | 1.9 |

The range of values found at coremaking, molding, and pouring operations is very narrow when the 14 samples collected at sand-slinging operations are omitted. The highest dust concentration in the remaining 229 samples was 10.1 million particles per cubic foot of air. Sand-slinging showed a range of from 2.8 to 58.4 millions of particles per cubic foot with a mean value of 19.1.

An important source of dust at molding operations was the dry parting compounds. Time studies of machine molding showed that it required about 3 minutes to make a mold; of this time, one-half minute was used in applying the parting compound. During the course of a workday, more than an hour's time was spent at this dusty operation. The results of a time study of a machine molder's dust exposure, as made by the Public Health Service some years ago, are as follows (*15*):

| Activity | Time of exposure in minutes per 9-hour day (A) | Average dust exposure in millions of particles per cubic foot (B) | Millions of particle minutes (A x B) |
|---|---|---|---|
| Parting compound application | 86 | 25 | 2150 |
| Pouring | 34 | 2.5 | 85 |
| Remaining tasks | 420 | 2.0 | 840 |
| Total | 540 | ............... | 3075 |

*3075/540 = 5.7 mppcf weighted exposure; 2150/3075 = 70 percent of exposure due to application of parting compound.*

Thus, the dust concentration during the application of the parting compound was over 10 times that observed at pouring and other tasks. The significance of this concentration becomes evident when the particle-minute exposure of this job is compared with the total particle-minute exposure of the occupation. The important fact revealed is that the parting compound contributes 70 percent of the molder's exposure. If the parting compound contained little or no free silica, the weighted exposure would represent only about 0.5 million particles of free silica per cubic foot of air. In this case, the parting compound contained over 90 percent free silica, and the weighted exposure represented about 4.5 million particles of free silica per cubic foot of air. As previously mentioned, three of 16 Illinois foundries were found to be using a high-silica parting compound. Since high-silica parting compounds have received much adverse publicity in past years, it was surprising that they were still used in some plants.

Table 6 shows the dust concentrations found at *shakeout and sand conditioning* operations. In a few foundries molding, pouring, and shakeout were done more or less continuously. However, in the majority of plants, shakeout and sand treatment were done at night after all other operations had ceased. Generally, the men who did the shakeout also prepared the sand after the castings had been removed from the sand molds. It may be observed from these data that, in general, the shakeout jobs produced far more dust than the sand preparation jobs, and the mechanical methods of performing a task produced from two to five times as much dust as the manual method of operation.

*Table 6.—Dust concentrations in shakeout and sand conditioning department in 18 ferrous foundries in Illinois, according to operation*

| Operation | Number of samples | Millions of particles per cubic foot of air | | |
|---|---|---|---|---|
| | | Range | Median | Mean |
| Removing flasks manually | 27 | 0.1–27 | 2.6 | 3.6 |
| Removing flasks with chain or electric hoist | 19 | .6–99 | 6.1 | 10.8 |
| Dragging-out; knocking-off risers and removing cores manually | 44 | .1–38 | 2.7 | 4.7 |
| Dragging-out with a hoist and removing cores with sledge hammer | 22 | 1.0–240 | 6.3 | 22.9 |
| Shaking-out castings with a vibrator hoist | 13 | 2.2–341 | 12.0 | 75.5 |
| Shaking-out on a mechanical vibrator platform | 18 | .6–39 | 8.7 | 11.0 |
| Cutting and raking sand manually | 15 | .1–7.7 | 2.1 | 3.1 |
| Cutting sand with small riddlers | 19 | .9–30 | 4.5 | 7.0 |
| Cutting sand with a disk | 12 | .2–7.5 | 2.9 | 3.1 |
| Clean-up and odd jobs of very short duration | 33 | .1–9.7 | 1.8 | 1.9 |

The dust concentrations found at the various operations in the *abrasive cleaning department* are shown in table 7. The highest average concentrations were found at portable grinding and the combination job of grinding and chipping. Unlike portable grinding, swing frame grinding was a discontinuous operation in the plants studied.

*Table 7.—Dust concentrations in abrasive cleaning department in 18 ferrous foundries in Illinois, according to operation*

| Operation | Number of samples | Millions of particles per cubic foot of air | | |
|---|---|---|---|---|
| | | Range | Median | Mean |
| Stand grinding | 43 | 0.2–94 | 2.9 | 6.9 |
| Portable grinding | 23 | .2–51 | 10.1 | 15.3 |
| Portable grinding and pneumatic chipping | 13 | 1.1–49 | 6.4 | 12.8 |
| Pneumatic chipping | 17 | .1–10 | 2.7 | 3.2 |
| Swing grinding | 15 | 1.3–46 | 3.1 | 6.6 |
| Wheelabrading | 15 | .5–11 | 2.6 | 3.3 |
| Abrasive blasting (cabinet method) | 10 | .4–26 | 2.1 | 5.6 |
| Tumbling | 20 | .7–15 | 2.6 | 3.2 |

The short period of operation did not permit a buildup of dust, even though exhaust ventilation was not employed. The average dust concentration at stand grinding, wheelabrading, abrasive blasting, and tumbling was influenced by the use of mechanical exhaust ventilation.

Table 8 shows the dust concentrations observed at the various tasks performed in the *melting department.* With the exception of the one task of chipping-out the cupola, the mean dust concentrations ranged from 1.2 to 3.7 million particles per cubic foot of air. The cupola-chipping operation, which lasts 30–45 minutes per day, is perhaps the dustiest of all foundry operations studied.

*Table 8.—Dust concentrations in melting department in 18 ferrous foundries in Illinois, according to operation*

| Operation | Number of samples | Millions of particles per cubic foot of air | | |
|---|---|---|---|---|
| | | Range | Median | Mean |
| Chipping-out cupola | 13 | 4.2–487 | 88.4 | 123.5 |
| Mudding cupola | 6 | .1–10.5 | 2.4 | 3.3 |
| Charging cupola | 28 | .1–3.2 | 1.1 | 1.2 |
| Tapping cupola | 32 | .1–9.1 | 1.9 | 2.2 |
| Cleaning around cupola | 14 | .1–13.5 | 1.8 | 3.7 |

In addition to the plant activities thus far described, there are certain functions performed outdoors which are grouped as *yard activities.* Among these, a relatively infrequent one is unloading sand from railroad cars. In all of the plants studied, this very dusty operation was performed manually. Three samples collected showed dust concentrations ranging from 62 to 121, with an average of 83 million particles per cubic foot of air.

Other yard activities, such as preparing charges for the cupola, and unloading scrap and other materials from railroad cars, have low dust exposures. Twenty-four samples ranged from less than 0.1 to 4.9, with a mean of 0.9 million particles per cubic foot of air.

Table 9 shows *frequency distributions* of dust concentrations according to department and operation. Of the 721 samples shown in the table, 141, or about 20 percent, were in the range from 0.0 to 0.9 million particles per cubic foot of air; 260, or about 36 percent, were in the range from 1.0 to 2.9 mppcf; and 190, or about 26 percent, were in the range from 3.0 to 6.9 mppcf. Thus, 82 percent of the samples collected for these specific operations showed dust concentrations of 6.9 mppcf or less. Only 4 percent of these samples were above 31.0 mppcf.

*Table 9.—Frequency distributions of dust concentrations in 18 ferrous foundries in Illinois according to department and operation*

| Operation | Number of samples with indicated range of millions of particles per cubic foot of air | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Total | 0.0–0.9 | 1.0–2.9 | 3.0–6.9 | 7.0–14.9 | 15.0–30.9 | 31.0–62.9 | 63.0 or over |
| | Coremaking Department | | | | | | | |
| Bench coremaking | 39 | 19 | 14 | 6 | 0 | 0 | 0 | 0 |
| Floor coremaking | 9 | 3 | 5 | 1 | 0 | 0 | 0 | 0 |
| Machine coremaking | 8 | 1 | 4 | 3 | 0 | 0 | 0 | 0 |
| | Molding Department | | | | | | | |
| Bench molding | 24 | 5 | 10 | 8 | 1 | 0 | 0 | 0 |
| Machine molding | 58 | 10 | 24 | 23 | 1 | 0 | 0 | 0 |
| Floor molding | 40 | 5 | 18 | 17 | 0 | 0 | 0 | 0 |
| Sand-slinging | 14 | 0 | 1 | 0 | 7 | 4 | 2 | 0 |
| Sand-slinger mold finishing | 20 | 0 | 4 | 12 | 4 | 0 | 0 | 0 |
| | Melting Department | | | | | | | |
| Chipping out cupola | 13 | 0 | 0 | 1 | 0 | 2 | 3 | 7 |
| Mudding cupola | 6 | 3 | 0 | 2 | 1 | 0 | 0 | 0 |
| Charging cupola | 28 | 12 | 15 | 1 | 0 | 0 | 0 | 0 |
| Tapping cupola | 26 | 5 | 17 | 4 | 0 | 0 | 0 | 0 |
| Cleaning around cupola | 14 | 3 | 6 | 3 | 2 | 0 | 0 | 0 |
| General indoor activities | 24 | 6 | 11 | 7 | 0 | 0 | 0 | 0 |
| Outdoor activities | 20 | 13 | 6 | 1 | 0 | 0 | 0 | 0 |
| | Shakeout and Sand Conditioning Department | | | | | | | |
| Removing flasks, manually | 27 | 6 | 8 | 10 | 2 | 1 | 0 | 0 |
| Removing flasks, mechanically | 19 | 1 | 3 | 7 | 6 | 1 | 0 | 1 |
| Dragging out manually | 44 | 7 | 17 | 12 | 6 | 2 | 0 | 0 |
| Dragging out mechanically | 22 | 0 | 7 | 4 | 3 | 4 | 2 | 2 |
| Shakeout with vibrator hoist | 13 | 0 | 1 | 2 | 4 | 2 | 1 | 3 |
| Shakeout on vibrator platform | 18 | 1 | 2 | 4 | 6 | 4 | 1 | 0 |
| Cutting sand, manually | 15 | 3 | 7 | 3 | 2 | 0 | 0 | 0 |
| Cutting sand with riddlers | 19 | 1 | 6 | 6 | 3 | 3 | 0 | 0 |
| Cutting sand with disc | 12 | 2 | 4 | 5 | 1 | 0 | 0 | 0 |
| Odd jobs | 33 | 11 | 18 | 3 | 1 | 0 | 0 | 0 |
| | Cleaning Department | | | | | | | |
| Stand grinding | 43 | 10 | 13 | 15 | 1 | 2 | 1 | 1 |
| Portable grinding | 23 | 1 | 3 | 7 | 4 | 4 | 4 | 0 |
| Grinding and chipping | 13 | 1 | 1 | 5 | 3 | 2 | 1 | 0 |
| Pneumatic chipping | 17 | 3 | 8 | 5 | 1 | 0 | 0 | 0 |
| Swing grinding | 15 | 0 | 7 | 4 | 3 | 0 | 1 | 0 |
| Wheelabrading | 15 | 2 | 8 | 3 | 2 | 0 | 0 | 0 |
| Abrasive blasting | 10 | 3 | 3 | 1 | 2 | 1 | 0 | 0 |
| Tumbling | 20 | 4 | 9 | 5 | 2 | 0 | 0 | 0 |

Obviously the greater proportion of the values for the specific operations was in the lower ranges, with a few exceptions. Dust concentrations for sand-slinging and chipping out cupola operations fell in the higher ranges.

The values for dragging out castings mechanically, shakeout with vibrator hoist, shakeout on vibrator platform, and portable grinding were more or less evenly distributed throughout the various ranges.

*Occupational Weighted Exposures*

Weighted dust exposures are shown in table 10 for certain occupations and occupational groups. The latter was formed principally to facilitate the correlation of the environmental findings with the results of the medical investigations.

Data shown in table 10 were obtained by the following procedures: the first step in all columns involved the calculation of occupational weighted dust exposures for each occupation. For example, if at a certain plant in a given job the workmen spend 5 hours a day at task A, where there is an average dust concentration of 6 million particles per cubic foot, 2 hours a day at task B, where there is a dust concentration of 25 mppcf, and 1 hour a day at task C, where the dust concentration is 2 mppcf, the weighted dust exposure for this occupation in that plant would be:

$$\frac{(5 \times 6) + (2 \times 25) + (1 \times 2)}{8} = 10.25 \text{ mppcf.}$$

The second step for columns A and C involved calculating a median dust exposure using all occupations that fell within a broad occupational group in all 18 plants surveyed. The occupational weighted dust exposures were arrayed in ascending order of dust concentration. For each occupational weighted dust exposure the number of men represented by that exposure was entered. The median dust concentration value was the dust exposure of the middle man in the array.

In columns B and D only certain specific occupations were selected. Again medians were calculated from the occupational weighted dust exposures for these occupations. It is apparent that data in columns A and C do not represent a summation or average of the values shown in columns B and D.

It may be seen from table 10 that the values for the specific occupations at gray iron foundries (column B) and at all foundries (column D) are essentially the same except for certain casting cleaning operations, portable grinding and chipping, swing grinding and cabinet abrasive blasting. The exceedingly high value shown for mechanical shakeout by crane hoist with vibration (98.6) represents an operation encountered in only one plant where large castings were allowed to cool several hours with the result that the sand became dry and shakeout of these castings was very dusty.

*Table 10.—Median weighted dust exposure in gray iron and 18 ferrous foundries in Illinois according to occupational group and certain operations*

| Occupational group and operation | Millions of particles per cubic foot of air | | | |
|---|---|---|---|---|
| | Gray iron foundries | | All ferrous foundries | |
| | Col. A | Col. B | Col. C | Col. D |
| Coremaking | 1.0 | | 1.1 | |
| Bench coremaking | | 1.4 | | 1.7 |
| Floor coremaking | | 1.0 | | 1.0 |
| Machine coremaking | | 1.9 | | 2.0 |
| Molding | 2.7 | | 2.5 | |
| Bench molding | | 1.6 | | 1.6 |
| Floor molding | | 3.1 | | 2.8 |
| Machine molding | | 2.0 | | 2.5 |
| Sand-slinging | | 7.8 | | 9.5 |
| Sand-slinger mold finishing and closing | | 5.4 | | 3.4 |
| Shakeout and sand conditioning | 3.2 | | 3.3 | |
| Manual shakeout | | 3.3 | | 3.3 |
| Mechanical—chain hoist | | 2.6 | | 2.6 |
| Mechanical—electric hoist with vibration | | 6.5 | | 6.5 |
| Mechanical—vibrating platform | | 8.1 | | 8.1 |
| Mechanical—crane hoist with vibration | | 98.6 | | 98.6 |
| Sand conditioning | | 3.0 | | 3.7 |
| Casting cleaning and finishing | 2.7 | | 2.4 | |
| Stand grinding | | 1.9 | | 3.0 |
| Portable grinding and pneumatic chipping | | 7.0 | | 2.7 |
| Swing grinding | | 5.8 | | 1.9 |
| Wheelabrading | | 1.9 | | 2.2 |
| Tumbling | | 3.1 | | 3.1 |
| Cabinet abrasive blasting | | 4.5 | | 8.2 |
| Maintenance and supervisory employees | .9 | | | |
| Laborers and others | 2.1 | | | |

### *Irritant Gases*

Smoke and gases are produced by certain foundry operations and tend to contaminate the working environment. The principal operations evolving these contaminants are the baking of cores and the pouring of molten metal into the molds. In both operations the smoke and gas evolved were a result of the pyrolysis of the organic material incorporated into the cores, and, to a small extent, also present in the molding sand. Various aldehydes were the most important of these irritant gases.

At the core-baking operation, the baking ovens were of tight construction and were usually vented to the outdoors. Some of the ovens were equipped with canopy hoods which were mechanically exhaust ventilated. No perceptible amounts of aldehydes were detected escaping from the ovens into the workrooms except in one instance. In this case, however, baking of the cores was done at night, and no workers were exposed to the gaseous environment.

Twelve tests were made to determine the range of concentration of these different aldehydes during pouring operations. The concentrations ranged from an insignificant value to 3.3 parts of gas per million parts of air by volume. The average value was 1.1 parts per million. These concentrations existed only for the duration of the pouring operation.

### *Carbon Monoxide Gas*

Another important contaminant of foundry atmosphere is carbon monoxide gas. It was present in the gases and smoke which were produced by the pyrolysis of organic material. About 150 measurements of carbon monoxide concentrations were made around cupola operations and also during pouring operations. The concentration of carbon monoxide ranged from 0 to 75 parts of gas per million parts of air at the tapping station of the cupola. The concentration of carbon monoxide ranged from 0 to 50 parts per million at the charging station of the cupola, except at those plants where the charging station was partially enclosed. In such instances, the carbon monoxide concentration ranged from 100 to 400 parts per million. However, since the operation occurred only intermittently and was of brief duration, with a total time of exposure of less than 1 hour per shift, the worker's exposure was short.

Most of the determinations were made at pouring operations where the largest number of workers were involved. Concentrations were consistently low during the summer months when natural ventilation was at an optimum. At those times, the levels of carbon monoxide ranged from 0 to 200 parts per million. In all cases, the average daily exposure was well below 100 parts per million. There was no apparent correlation between the size of the mold and concentration of the gas, probably because of the influence of good natural ventilation when the doors and windows were open.

During the colder months, when doors and windows were kept closed, the levels of carbon monoxide during pouring increased to a range of 100 to 600 parts per million, with momentary levels as high as 800 parts per million. The size of the mold or the amount of coring in the molds appeared to have less influence on the levels of carbon monoxide than the size of the space in which the operation was performed. The duration of exposure to carbon monoxide was limited to the pouring time, which usually did not exceed an hour. Even with the short duration of exposure, there was evidence of a hazard during cold weather.

## DISCUSSION OF ATMOSPHERIC CONTAMINANTS

It is of interest to consider the possible reasons for the comparatively low dust concentrations found in the 18 Illinois foundries studied. Dust concentrations found were definitely lower than those reported in earlier investigations (*16–19*). Except for the study made in Australia, the investigations referred to were made more than 10 years ago. It would be valuable to have a re-study of the foundries covered in these earlier investigations to ascertain whether there has been any appreciable change in dust concentrations. Interestingly enough, engineering investigations of foundries (*20*) conducted since the completion of the field work of this study showed dust concentrations very similar to those contained in this report.

Subsequent to the completion of the field study in Illinois, inspections were made by an engineer of the Public Health Service in a number of foundries in two other states. Visual observations indicated apparent dust concentrations of the foundries in one of these states to be of the same order of magnitude as found in the Illinois foundries. Studies made by the State corroborated this observation. In the other state the foundries visited were observed to be considerably more dusty, and, except in a few instances, modern methods of operation were lacking. State records of investigations over the last 12 years confirmed these impressions.

Although there are wide variations in foundry practices, not only from state to state but also within any given state, there is reason to believe that, in general, there has been a gradual improvement in the control of atmospheric contaminants in the foundry industry. New techniques of operation have been developed which are not only more efficient but which also lend themselves more readily to dust-control methods. Equipment manufacturers have developed and promoted the use of new and more effective devices for the control of air contaminants. In addition, official agencies have promoted measures designed to improve working conditions.

### *Factors Influencing Foundry Environment*

There are many factors which influence the foundry environment. Some of these may be referred to as follows:

ACTIVITY AND SPACE.—The degree of activity has a great effect on the concentration of atmospheric contaminants. Since production, and consequently employment, varies with business conditions, the number of men working in a given area may differ considerably over a period of time. The amount of floor area in the foundries studied varied from less than 200 to over 1,000 square feet per worker.

Since productivity and employment in the foundries studied were at a high level, this factor does not offer an explanation for the low dust concentrations found.

LOCATION AND SCHEDULING OF OPERATIONS.—As previously mentioned in this report, dust produced by one operation may affect the environment in adjoining areas. For example, settled dust in coremaking was found to be of the same average free silica content as in other foundry areas, even though the free silica content of dust produced by coremaking operations was much lower. Similarly, it was observed that a particularly dusty operation influenced the dust level throughout the building. Consequently, where shakeout was done on all shifts, all workers were exposed to more dust than was the case when shakeout was done at night. The majority of the plants studied performed shakeout at night after most of the employees had left the plant. This accounts, at least in part, for the low concentrations found at many of the molding, coremaking, and pouring operations.

SIZE OF CASTINGS AND TONNAGE.—It was observed that the size of casting influenced the dustiness of the foundry. This was particularly so in shakeout operations. Smaller castings were usually removed immediately after pouring, while the sand was still comparatively moist. In the case of larger castings, the necessity to delay the removal of the casting for a longer period of time resulted in the sand drying out and more dust being produced at shakeout. On the other hand, for a given tonnage, shakeout of smaller castings may produce more dust because of the greater number of individual castings which are handled. Therefore, where comparisons of dust levels are made, based on the tonnage of metal poured, due consideration must be given to the size of castings.

DEGREE OF MECHANIZATION.—Mechanization of foundry operations results in increased dust production unless supplemented by proper control measures. Where shakeout and sand-conditioning operations were mechanized without proper local exhaust ventilation, higher dust levels were observed. On the other hand, one of the most completely mechanized plants was found to have very little dust because adequate local exhaust ventilation was employed.

VENTILATION.—Natural ventilation is an important factor in reducing the level of atmospheric contamination. In large buildings with monitors or saw-toothed roofs with adequate openings, and with ample window area in the walls, dust concentrations were usually found to be lower. Natural convective drafts moved through these openings and prevented a build-up of general contamination.

Most foundries were also equipped with mechanical exhaust roof fans. The use of these fans during cold weather, when most doors and windows were closed, was an important factor in reducing general contamination.

General ventilation is useful in preventing a build-up of high concentrations in the *general* workroom air. Local exhaust ventilation will prevent the release of excessive concentrations into the breathing zone of the worker as well as into the general atmosphere. Ventilation of this type was employed in many foundry operations; it was used in the cleaning departments of all foundries studied and in shakeout and sand-conditioning operations at some foundries. Dust concentrations were materially decreased where these exhaust systems were properly designed and maintained.

HOUSEKEEPING AND SUPERVISION.—The importance of good housekeeping practices as an adjunct in maintaining low dust concentrations cannot be overemphasized. Accumulation of dust on overhead beams and rafters, as well as on materials stored in the foundry area, should be prevented. Storage of equipment in an orderly manner and maintenance of floors and aisles free from debris are other factors influencing the dust levels.

Good housekeeping measures were evident, with few exceptions, throughout the foundries studied. Materials and supplies were stacked in designated locations, and, generally, there were well-defined aisles for passage of workers and equipment. Many of the plants removed settled dust from overhead pipes and beams as well as from stacked supplies at periodic intervals to prevent redispersion of such accumulations by vibrations and drafts. Floors were generally kept free of excessive accumulations of sand and dust. Many plants had concrete floors which facilitated good housekeeping. Dirt floors were almost always hard-packed and kept wet to minimize scuffing-up of dust.

Good housekeeping is an indication of good supervision. The blame for poor housekeeping must rest entirely on the shoulders of management. Furthermore, management should see that proper techniques are employed to prevent the unnecessary dispersal of dust from operations. For example, due to lack of proper supervision in some of the foundries, certain molders created clouds of visible dust through the improper application of parting compounds. It was also observed that the indiscriminate use of compressed air created excessive amounts of dusts and that improper mixing and wetting of molding sand definitely contributed to the dustiness of some foundries.

The judicious use of water can do a great deal to reduce the amount of dust getting into the general foundry atmosphere. The proper amount of moisture during sand-conditioning operations, for example, will prevent the building-up of unnecessarily high dust concentrations. There are other instances also where water can play an important part in keeping dust levels low.

It was observed that techniques employed at shakeout, and the scheduling of these operations, played an important part in the dust produced.

*Recommendations*

1. Local exhaust ventilation should be employed where mechanical shakeout equipment is used.
2. Exhaust ventilation should be employed with portable grinding operation.
3. Exhaust systems and dust-collection equipment should be given proper maintenance at all times.
4. The best possible housekeeping program should be enforced at all times.
5. High-silica (over 8 percent) parting compounds should not be used.
6. Where buildings are to be remodeled or new ones built, consideration should be given to locating the various operations in such a manner as to minimize the number of workers affected by dust.
7. Consideration should also be given to scheduling of operations, such as shakeout or sand-conditioning, in order to minimize the number of workers affected by a dusty operation.
8. Adequate ventilation should be provided to prevent excessive concentrations of carbon monoxide during pouring operations and around furnace charging.

## NOISE

The environmental study included an evaluation of sound *intensities* and *frequencies*. The objective of this phase of the investigation was to determine these sound characteristics within the foundries studied.

According to recent investigators, noise levels of intensities below 80 decibels are believed not to produce acute or chronic aural damage; but above this level, damage may occur, the severity and incidence of which is probably directly proportional to the intensity of the noise (*21, 22*). The amount of aural damage seems to be correlated, furthermore, with the frequency of the sound. The greatest effect occurs in the higher tonal levels and is particularly pronounced in the frequency area of 4000 vibrations per second (*23, 24*).

### *Methods of Measurement*

Intensity readings were taken with General Radio sound level meter type 795–B. An extension cable was used to minimize sound distortion and to facilitate the measurement of sound adjacent to the worker's environment. Microphones used were of the piezo-electric type utilizing a bimorph crystal. Sound frequencies were analyzed with a General Radio sound analyzer type 760.

### *Findings*

Table 11 shows the range and average noise level readings, in decibels, in twelve ferrous foundries in Illinois by location. These data are presented for each foundry and subdivided into three major departments—coremaking, molding, and cleaning.

COREMAKING DEPARTMENT.—Sound *intensities* in coremaking departments are usually influenced by other operations located in the same general vicinity. For example, there was no separation of the core department from the molding and cleaning departments in foundry No. 4, and, as a result, the noise levels in the core department were considerably higher than in the core departments of other foundries. On the other hand, since the core department in foundry No. 16 was separated from the cleaning department by a wall having a high transmission loss, a considerable reduction in noise intensities was found.

The two major noise-producing sources in the core department proper are coremaking machines and fans used to ventilate the core ovens. Four of the core departments studied did not have coremaking machines. Of this group, foundry No. 5 had the highest sound intensities, which were due to the exhaust fan on the core oven. Except for No. 5, as shown in table 11, higher noise levels were found in those core departments with core machines.

The *frequency* levels found in the coremaking department varied considerably. In many cases, the major frequency resulted from the exhaust fan. In other cases, the major frequency was due to compressors and other machinery located in adjoining areas. In still other instances, it was due to molding and cleaning operations. The frequencies were of a low order of magnitude, about 100 cycles per second.

MOLDING DEPARTMENT.—As in the case of the coremaking department, the physical location of the molding department with regard to

## Table 11.—Minimum, maximum and average noise level readings, in decibels, in 12 ferrous foundries in Illinois by location

| Department and operation | 1 Min. | 1 Max. | 1 Av. | 2 Min. | 2 Max. | 2 Av. | 3 Min. | 3 Max. | 3 Av. | 4 Min. | 4 Max. | 4 Av. | 5 Min. | 5 Max. | 5 Av. | 6 Min. | 6 Max. | 6 Av. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Coremaking department: | | | | | | | | | | | | | | | | | | |
| Bench coremaking | 78 | 80 | 79 | 68 | 76 | 73 | 70 | 86 | 74 | 84 | 91 | 88 | 72 | 76 | 74 | 64 | 68 | 66 |
| Machine coremaking | 78 | 80 | 79 | 70 | 76 | 74 | 75 | 86 | 78 | 86 | 91 | 88 | — | — | — | 66 | 70 | 68 |
| General room | 78 | 80 | 79 | 68 | 76 | 73 | 70 | 86 | 75 | 84 | 91 | 88 | 72 | 76 | 74 | 64 | 70 | 69 |
| Molding department: | | | | | | | | | | | | | | | | | | |
| Bench molding | 70 | 72 | 71 | 72 | 90 | 75 | 70 | 80 | 72 | — | — | — | — | — | | 78 | 82 | 80 |
| Bench machine molding | 75 | 81 | 78 | 75 | 94 | 76 | — | — | | 83 | 98 | 85 | 63 | 98 | 72 | 80 | 90 | 85 |
| Floor molding | 68 | 70 | 69 | 75 | 78 | 76 | 68 | 80 | 70 | — | — | — | 65 | 67 | 66 | 76 | 81 | 77 |
| Floor machine molding | | — | — | — | — | | — | — | — | | | | — | — | — | — | — | |
| Sand-slinging | — | — | | | | — | | — | — | — | — | — | — | | | — | | — |
| General room | 75 | 81 | 78 | 72 | 90 | 76 | 68 | 80 | 70 | 83 | 86 | 85 | 63 | 68 | 66 | 79 | 82 | 80 |
| Cleaning department: | | | | | | | | | | | | | | | | | | |
| Swing grinding | — | — | — | | — | — | (*) | (*) | (*) | | — | | | — | — | | — | — |
| Stand grinding | 88 | 92 | 90 | (*) | (*) | (*) | (*) | (*) | (*) | 91 | 93 | 92 | 96 | 98 | 97 | 72 | 84 | 80 |
| Portable grinding | (*) | (*) | (*) | (*) | (*) | (*) | (*) | (*) | (*) | 85 | 96 | 90 | 96 | 98 | 97 | — | — | |
| Pneumatic chipping | 90 | 94 | 92 | (*) | (*) | (*) | (*) | (*) | (*) | 85 | 96 | 91 | — | — | — | — | | — |
| Tumbling | 92 | 94 | 93 | (*) | (*) | (*) | (*) | (*) | (*) | 91 | 93 | 93 | 97 | 103 | 100 | 88 | 92 | 90 |
| Wheelabrading | — | — | | — | — | — | — | — | — | 93 | 93 | 93 | — | | — | 79 | 84 | 80 |
| Rotoblasting | — | — | — | — | — | — | — | — | — | — | — | — | 93 | 96 | 94 | — | — | — |
| Sandblasting | | — | | (*) | (*) | (*) | (*) | (*) | (*) | | — | — | (*) | (*) | (*) | — | — | — |
| Burning | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | |
| General room | 86 | 94 | 89 | 88 | 92 | 90 | 86 | 90 | 88 | 93 | 96 | 94 | 91 | 103 | 97 | 72 | 92 | 87 |

| Department and operation | 7 Min. | 7 Max. | 7 Av. | 8 Min. | 8 Max. | 8 Av. | 9 Min. | 9 Max. | 9 Av. | 14 Min. | 14 Max. | 14 Av. | 15 Min. | 15 Max. | 15 Av. | 16 Min. | 16 Max. | 16 Av. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Coremaking department: | | | | | | | | | | | | | | | | | | |
| Bench coremaking | 62 | 68 | 64 | 66 | 68 | 67 | 68 | 74 | 71 | 68 | 72 | 70 | 68 | 74 | 70 | 56 | 58 | 56 |
| Machine coremaking | — | — | | — | — | — | 74 | 76 | 74 | 83 | 88 | 85 | 78 | 82 | 80 | — | — | — |
| General room | 62 | 68 | 64 | 66 | 68 | 67 | 68 | 76 | 74 | 68 | 88 | 72 | 68 | 82 | 72 | 56 | 58 | 56 |
| Molding department: | | | | | | | | | | | | | | | | | | |
| Bench molding | 66 | 68 | 67 | 79 | 82 | 80 | 74 | 79 | 76 | 66 | 70 | 68 | 68 | 72 | 70 | 50 | 59 | 56 |
| Bench machine molding | — | | — | | | | 80 | 90 | 85 | 84 | 90 | 86 | 68 | 86 | 78 | | — | — |
| Floor molding | 66 | 70 | 68 | 79 | 82 | 80 | 80 | 84 | 82 | 66 | 72 | 70 | 68 | 82 | 76 | 48 | 58 | 52 |
| Floor machine molding | 68 | 92 | 69 | | | | | — | | | — | — | 78 | 82 | 80 | — | — | — |
| Sand-slinging | 68 | 70 | 69 | — | — | — | | — | — | — | | | (*) | (*) | (*) | — | — | — |
| General room | 66 | 92 | 68 | 79 | 82 | 80 | 74 | 90 | 82 | 68 | 72 | 70 | 68 | 72 | 70 | 48 | 58 | 55 |
| Cleaning department: | | | | | | | | | | | | | | | | | | |
| Swing grinding | | — | — | | | — | — | | — | 84 | 86 | 85 | — | — | — | — | — | — |
| Stand grinding | 90 | 94 | 92 | 86 | 88 | 87 | 80 | 82 | 81 | 76 | 80 | 78 | 76 | 88 | 80 | 72 | 86 | 74 |
| Portable grinding | 84 | 104 | 93 | (*) | (*) | (*) | — | — | — | (*) | (*) | (*) | 80 | 88 | 84 | — | — | — |
| Pneumatic chipping | 84 | 104 | 94 | (*) | (*) | (*) | | — | | 92 | 106 | 94 | 90 | 96 | 92 | 82 | 90 | 88 |
| Tumbling | (*) | (*) | (*) | 90 | 93 | 91 | 85 | 85 | 85 | (*) | (*) | (*) | 92 | 96 | 94 | 72 | 78 | 76 |
| Wheelabrading | 76 | 78 | 77 | | | | 79 | 81 | 82 | (*) | (*) | (*) | — | — | — | — | — | — |
| Rotoblasting | | — | — | — | — | — | — | | — | (*) | (*) | (*) | — | — | — | — | | — |
| Sandblasting | — | — | | (*) | (*) | (*) | — | — | | (*) | (*) | (*) | 92 | 96 | 94 | 70 | 90 | 74 |
| Burning | — | — | — | — | — | — | — | — | — | 80 | 86 | 82 | — | — | — | — | | — |
| General room | 76 | 94 | 91 | 88 | 93 | 90 | 79 | 81 | 82 | 80 | 90 | 86 | 76 | 96 | 88 | 72 | 84 | 81 |

*Note:* A *dash* indicates that the operation did not exist at the time of the survey.
An *asterisk* indicates that the operation existed but no readings were made.
No readings were made in foundries 10, 11, 12, and 13.

other operations had a distinct bearing on the noise level. This is again illustrated in foundry No. 4, where there is no physical separation between the molding and the cleaning departments. The same conditions apply to No. 8. The sound intensities were considerably higher in these molding departments than in the others surveyed. However, in foundry No. 16, where a wall with a high transmission loss separated the molding department from the cleaning department, there was a considerable reduction in sound intensities. In foundry No. 6, the molding department was located next to the cleaning department and separated by a wall having a low transmission loss, which resulted in above average sound intensity in the molding department. The major sources of sound-producing equipment in the molding department were bench and floor molding machines and sand-slinging machines. This is illustrated in foundry No. 7. When the machines were not in operation, the sound levels averaged 66 decibels, but when the floor molding machine was in operation, the intensity increased from 68 to 92 decibels. In foundry No. 9, high intensities were obtained from the large number of molding machines.

The sound frequencies in the molding room are extremely complex and very difficult to measure. This is due to the intermittent operations of the various types of machines used in the molding department and in some cases to the sounds originating from sources other than in the molding area. The frequencies were of a low order of magnitude, about 100 cycles per second.

CLEANING DEPARTMENT.—Cleaning department operations, without exception, were the greatest source of noise in the foundries studied. As mentioned previously, the cleaning department frequently contributed considerably to the noise of the other departments. The cleaning department of foundry No. 5 yielded higher sound intensities than the other foundries studied. The department was small, the walls were of stone construction, and numerous cleaning machines were in operation within this small area. There was no acoustical treatment within the room, and the stone walls reflected the noise, thus producing the high sound intensities observed. It is interesting to note that, because of the high transmission loss of the walls in this particular foundry, the molding and core departments were relatively quiet. As would be expected, the sound frequencies were extremely complex and difficult to evaluate. The frequencies ranged from 30 to 860 cycles per second.

It was noted that no type of acoustical treatment was used in any of the foundries studied. No attempt was made to isolate particularly noisy machines or operations. With the exception of two or three individuals who put cotton in their ears, employees did not seem to use any personal protective devices to reduce noise levels.

### *Recommendations*

1. Consideration should be given in all foundries to provide walls with a high transmission loss to separate the cleaning department from the other departments.
2. Exhaust fans used in ventilating the core ovens should be properly designed, mounted, and maintained to produce a minimum noise level.
3. In foundries where a series of molding machines are adjacent to each other and are located in a large area, proper sound conditioning should be applied at appropriate areas to reduce the sound intensities.
4. Particularly noisy machines, such as the tumbling barrels in the cleaning department, should be isolated whenever possible, or appropriate acoustical treatment should be employed where they are located.
5. Workers in the cleaning department, as well as the machine coremakers and sand-slinger operators in the molding department, should wear a proper type of ear plug.
6. A maintenance program should be enforced to keep the equipment in the optimum state of repair.

## ILLUMINATION

Another environmental factor evaluated was illumination. Since proper lighting is known to play an important role in reducing eye strain, increasing production, and minimizing industrial accidents (*25–27*), data on the quality and quantity of illumination were obtained in the present study. Light intensity readings were taken with a Weston Meter Model 614 equipped with a Viscor filter. The technique employed in making the readings was similar to that recommended by the Illuminating Engineering Society (*28*).

### *Findings*

The results of the findings are presented in tables 12 and 13. There were numerous factors which influenced the light intensities in various foundries. These included the amount of natural and artificial illumination, maintenance of lighting systems, and reflection factors of walls, ceilings, and machinery. Since all of these factors played an important part, it is impossible, in evaluating the lighting conditions of any one foundry studied, to determine which factors had the greatest influence on the findings.

Several of the foundries had saw-toothed, monitor or skylight roof construction, which permitted maximum daylight illumination in the interior of the building. In addition to window area in the roof, a majority of the foundries also provided large window areas in the

*Table 12.—Average illumination readings, in footcandles, in 14 ferrous foundries in Illinois, by location*

| Department and operation | Foundry number | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4A | 4B | 5 | 6 | 7 | 8 | 9 | 10 | 13 | 14 | 15 | 16 |
| Coremaking department: | | | | | | | | | | | | | | | |
| Bench coremaking | 49 | 8 | 11 | 41 | 11 | 17 | (*) | 10 | 35 | 12 | 4 | 10 | 22 | 11 | 26 |
| Machine coremaking | 49 | 22 | (*) | — | 5 | — | (*) | — | — | 33 | 5 | 6 | 11 | — | — |
| Floor coremaking | — | (*) | 3 | 14 | — | — | — | 7 | — | — | 4 | — | — | 6 | — |
| General room | 49 | 14 | 4 | 30 | 7 | 17 | (*) | 8 | 19 | 23 | 4 | 6 | 15 | 9 | 9 |
| Molding department: | | | | | | | | | | | | | | | |
| Bench molding | 100 | 25 | 11 | 146 | — | — | 3 | 26 | 12 | 20 | 2 | 3 | 6 | 12 | 10 |
| Machine molding | 15 | 28 | — | — | 32 | 74 | 15 | 5 | — | 24 | 2 | 4 | 5 | 11 | — |
| Floor molding | 33 | 14 | 8 | 21 | — | 25 | 16 | 7 | 11 | 22 | 10 | 10 | 11 | 10 | 8 |
| Sand-slinging | — | — | — | 41 | — | — | — | 7 | — | — | 10 | 10 | — | 10 | — |
| General room | 42 | 17 | 9 | 53 | 32 | 34 | 11 | 12 | 12 | 21 | 5 | 7 | 11 | 11 | 9 |
| Cleaning department: | | | | | | | | | | | | | | | |
| Swing grinding | — | — | 11 | 14 | — | — | — | — | — | — | 6 | 4 | 10 | — | — |
| Stand grinding | 18 | (*) | 11 | 6 | 11 | 20 | 20 | Under 2 | Under 2 | 35 | 6 | 3 | 5 | 11 | 6 |
| Portable grinding | 16 | (*) | 12 | 14 | 3 | 29 | — | do | 5 | — | 6 | 12 | 10 | 9 | — |
| Pneumatic chipping | 16 | (*) | 12 | 14 | 3 | — | — | do | 5 | — | 6 | 12 | 10 | 9 | 9 |
| Tumbling | 23 | (*) | 10 | 5 | 2 | 2 | 5 | do | 4 | 28 | — | 13 | 7 | 9 | 9 |
| Wheelabrading | — | — | — | 9 | 4 | — | 10 | do | — | 10 | — | 4 | 5 | — | — |
| Rotoblasting | — | — | — | — | — | 12 | — | — | — | — | — | 4 | 6 | — | — |
| Sand blasting | — | (*) | (*) | 10 | — | (*) | — | — | 7 | — | — | 1 | — | 25 | (*) |
| Burning | — | — | — | — | — | — | — | — | — | — | 1 | 12 | 10 | — | — |
| General room | 21 | (*) | 11 | 13 | 6 | 15 | 8 | Under 2 | 4 | 29 | 6 | 8 | 9 | 11 | 7 |

*Note:* A *dash* indicates that the operation did not exist at the time of the survey.
An *asterisk* indicates that the operation existed but no readingss were made.
No readings were made in foundries 11 and 12.

walls. None of the windows was observed to be equipped with devices to regulate the amount of light at the working level.

In the foundry industry it is particularly necessary to supplement natural illumination with artificial lighting because the inherent dustiness of the work reduces the transmission of natural illumination. Table 13 shows the types of lamps and reflectors by department in the foundries studied. All reflectors observed were of the direct type. In the majority of the foundries the lighting systems were antiquated and poorly designed.

To obtain maximum benefit from illumination sources it is necessary to maintain proper reflection factors in the interior of the building. The recommended reflection factors generally accepted are 90 percent for ceilings, 60 percent for walls, and 30 percent for machinery. It may be seen in table 13 that the reflection factors found in the foundries studied were considerably below these recommended values.

The importance of proper maintenance cannot be overemphasized. Systems which are adequate when installed deteriorate rapidly unless proper maintenance is provided. A definite schedule of maintenance work should be established to insure that wall and roof windows,

*Table 13.—Factors affecting artificial illumination in the core, molding and cleaning departments in 14 ferrous foundries in Illinois*

| Foundry No. | Department | Factor | | | | | |
|---|---|---|---|---|---|---|---|
| | | Type of lamp | Type of reflector | Reflection factor (approximate percent) | | | Maintenance |
| | | | | Ceiling | Wall | Machinery | |
| 1 | Core, molding, and cleaning | Incandescent | Direct | 50 | 10 | 5 | Fair. |
| 2 | do | do | do | 10 | 10 | 5 | Good. |
| 3 | Core, and cleaning | do | do | 60 | 50 | 5 | Poor. |
| 3 | Molding | Mercury | do | 60 | 50 | 5 | Do. |
| 4A | Core | Incandescent | do | 20 | 20 | 10 | Fair. |
| 4A | Molding, and cleaning | Mercury | do | 20 | 20 | 10 | Do. |
| 4B | Core, molding, and cleaning | Incandescent | do | 20 | 20 | 10 | Do. |
| 5 | do | do | do | 40 | 60 | 5 | Fair. |
| 6 | Core, and molding | Incandescent | do | 20 | 20 | 10 | Poor. |
| 6 | Cleaning | Fluorescent | do | 20 | 20 | 10 | Do. |
| 7 | Core | Incandescent | do | 10 | 10 | 10 | Do. |
| 7 | Molding, and cleaning | do | None | 10 | 10 | 10 | Do. |
| 8 | Core, molding, and cleaning | Fluorescent | Direct | 10 | 10 | 10 | Do. |
| 9 | Core, and cleaning | Incandescent | do | 15 | 10 | 10 | Good. |
| 9 | Molding | Fluorescent and incandescent. | do | 15 | 10 | 20 | Do. |
| 10 | Core, molding, and cleaning | Incandescent | do | 15 | 30 | 10 | Fair. |
| 13 | do | do | do | 30 | 30 | 10 | Poor. |
| 14 | do | do | do | 10 | 10 | 5 | Fair. |
| 15 | Core, and molding | do | do | 10 | 10 | 10 | Do. |
| 15 | Cleaning | Incandescent and mercury. | do | 10 | 10 | 10 | Do. |
| 16 | Core, molding, and cleaning | Fluorescent and incandescent. | do | 15 | 15 | 10 | Poor. |

*Note:* No observations were made in foundries 11 and 12.

reflectors, lamps, and accessories are kept clean and in proper adjustment and good repair. One method of determining how often this should be done is to check the illumination periodically with a light meter. The system should be maintained so that the light intensities do not fall below 75 percent of the original intensities.

A program for the group replacement of lamps could be established in conjunction with the cleaning program. The output of light decreases as the filament of a lamp slowly sublimes. Replacement at

70 percent of average life is oftentimes adopted as the economical point for group replacement, for at this point less than 10 percent of the lamps should normally have failed. The most economical schedule will differ in accordance with conditions and requirements for each specific installation.

### *Recommendations*

1. To insure a maximum of natural illumination in one-story buildings, the window area, including walls and roof, should be at least 30 percent of the floor area.
2. Windows should be provided with adjustable devices to regulate the quantity of light on the working area.
3. Modern lighting techniques should be employed to improve artificial illumination.
4. Proper reflection factors should be provided on ceilings, walls, and machinery.
5. An adequate program of maintenance should be instituted.

## SANITATION FACILITIES

A sanitation survey was conducted in 16 of the 18 foundries studied. The survey did not include facilities provided for office workers or employees in departments other than those connected with foundry operations.

Information was obtained on the following items: source of water supply, type of drinking water facilities, type of washing and toilet facilities, waste disposal, and adequacy and housekeeping of all sanitation facilities.

### *Water Supply*

Public water supplies were used in 13 plants, and private supplies in three plants for drinking and industrial purposes. One of the 13 plants supplemented the public supply with a private well. A public water supply was available to 81.3 percent of the workers. Since these water supplies are under the supervision of the Illinois State Department of Public Health, no attempt was made to determine their hygienic condition.

### *Drinking Water Facilities*

Approved types of drinking fountains were provided in 13 of the 16 plants. Six of the 13 plants also provided non-approved fountains in addition to the approved type. Three plants provided only nonapproved fountains, which consisted essentially of faucets connected directly to the water lines. In addition to the nonapproved fountains, open-water containers were observed in two of these three plants. The number of approved type drinking fountains was found to be adequate for the number of employees in the majority of the plants.

### *Washing Facilities*

The Illinois Health and Safety Act (*29*) and the American Foundrymen's Code on Sanitation (*30*) require that the following washing facilities be provided for employees:

| *Number of employees per shift* | *Number of lavatories* |
|---|---|
| 1 to 15 | 1 |
| 16 to 30 | 2 |
| 31 to 50 | 3 |

For each additional 25 employees or fractional part thereof, there shall be provided 1 additional lavatory. The lavatories may consist of individual units, wash sinks, or circular fountains. Where wash sinks or circular fountains are used, twenty-four inches of outside rim of a wash sink and seventeen inches of a circular fountain shall be the equivalent of one lavatory.

These two codes also require that one shower be provided for each twenty foundry employees per shift.

Hand-washing facilities were found to be adequate in all plants surveyed. All were equipped with hot and cold water, but two plants did not furnish soap. Although the codes do not require plants to supply towels, five plants furnished towels for hand washing. Three plants were found to have one less than the required number of showers. Fifteen plants provided an individual clothes locker for each employee in the foundry area.

### *Toilet Facilities*

The following toilet facilities are required by the above codes:

| *Number of employees per shift* | *Number of toilets* |
|---|---|
| 1 to 9 | 1 |
| 10 to 24 | 2 |
| 25 to 49 | 3 |
| 50 to 74 | 4 |
| 75 to 99 | 5 |
| Over 99 | 1[1] |

[1] For each additional 30 employees.

In addition to the number of toilets, 1 urinal is required for not less than 10 men or more than 75 on any 1 shift, with 1 additional urinal for each 75 men.

Two plants provided 1 less urinal, and 4 plants provided 1 less toilet than required by the codes. All toilets and urinals were found to be standard flush type, and, in general, the space provided and the temperature of the rooms were found to be satisfactory.

A number of the plants provided more washing and toilet facilities than the minimum requirements and maintained them in a very satisfactory manner. A few plants provided recreational facilities in the large shower or locker room.

Women were employed in the foundry areas in only two of the 16 plants surveyed. Adequate toilet and washing facilities were provided.

*Waste Disposal*

Thirteen of the 16 plants discharged sewage and industrial wastes into municipal sewage disposal systems. Two plants discharged sewage and industrial waste, without treatment, into nearby rivers; and 1 plant used a septic tank for treatment prior to discharging the waste into a stream.

*Housekeeping*

General housekeeping of locker rooms and toilet and washing facilities was arbitrarily rated as good, fair, or poor. Although the 16 plants were not surveyed by the same person, every effort was made to arrive at comparable ratings. Nine of the plants were rated good; 2, fair; and 5, poor.

*Summary*

In general, sanitation facilities provided for foundry employees were found adequate, and the majority were maintained in a satisfactory manner. In a few of the plants surveyed, some improvements are needed with special reference to improved housekeeping and the installation of additional facilities to meet the minimum sanitation requirements.

## Summary of Environmental Studies

Findings of the environmental investigations made in 18 Illinois ferrous foundries are presented. The data show the character and composition of parent material and of air-borne and settled dusts; operational dust levels; occupational weighted dust exposures; and the concentration of other atmospheric contaminants, such as aldehydes and carbon monoxide. Measurements of illumination and noise levels, and an evaluation of sanitary facilities are presented and discussed.

It was found that 90 percent or more of the air-borne dust in all foundry environments were 3 microns or less in size. The amount of free silica in the air-borne dust varied with the operation and ranged from 13 percent at coremaking to 29 percent at pouring, shakeout, and sand conditioning. On the other hand, the free silica content in the settled dust was found to average 30 percent throughout the foundries. The air-borne dust less than 5 microns in size was found to have a lower percentage of free silica than the larger size fraction.

The percentage of iron in the air-borne dust was found to range from 3 to 9 percent for all operations except casting cleaning, for which the proportion varied from 30 to 38 percent.

Operational dust levels at various foundry activities in general were found to be much lower than those reported in earlier investigations. Mean dust levels at molding, pouring, and coremaking operations were found to be under 3 million particles per cubic foot of air. Sand-slinger molding showed a mean dust level of about 19 mppcf. Mechanical shakeout operations showed mean dust levels ranging from 10 to 75 mppcf; whereas manual shakeout and sand conditioning produced mean dust levels under 7 mppcf. Cleaning room operations showed mean dust levels under 7 mppcf except at portable grinding and chipping which had a mean dust level of about 15 mppcf. Other miscellaneous operations showed dust levels under 4 mppcf with the exception of chipping-out of cupolas and sand unloading. The high dust exposures at the last two activities were intermittent and of relatively short duration.

Concentrations of aldehydes were of a low order of magnitude. Carbon monoxide concentrations were relatively low in most instances, but high levels occurred for short periods at pouring operations during the winter months.

In general, the foundries studied were clean; housekeeping was adequate; and dust suppression measures were employed. Many of the foundry buildings were well constructed according to modern architectural designs which permitted adequate natural ventilation and natural illumination. Although the majority of the foundries were not completely mechanized, modern production techniques were usually employed.

Many of the foundries did not utilize the latest methods of artificial illumination. The foundries studied gave no consideration to the reduction of noise.

In general, sanitation facilities provided for employees were adequate and maintained in a satisfactory condition. Some improvements were needed in a few plants.

# MEDICAL STUDIES

## Review of the Literature

Studies of the health of ferrous foundry workers have generally centered on the diseases of the respiratory tract, and, more especially, on the effect of the dust of the occupation on the lung parenchyma (*16, 17, 31–58*). There have been a few studies on the general health of these workers, the most notable examples being those of Collis (*59*) and Macklin and Middleton (*42*) in Great Britain; but, these also discuss chiefly the lung diseases. Since the bulk of the literature on the health of the ferrous foundry workers refers to lung changes, these will be discussed at this time.

It might be expected that comparison of the chest findings in the present study could be made with the other reports. The previous reports served well the purposes for which they were intended. However, for reasons which will soon be apparent, for only a limited number may comparisons of incidence rates of pulmonary fibrosis be made with the present report. Table 14 shows the findings in regard to pulmonary fibrosis as reported in these previous foundry studies in which such information was recorded. It was with a great deal of trepidation that this table was prepared, since in many instances appreciable license was necessarily taken in interpreting the data in those published reports. It will be noted from table 14 that a gross separation is made between the first 12 reports and the latter nine. Among the reasons for this separation, noted in *italics* in the table, are: (1) Selection for examination of workers of certain occupations only, as in studies 13, 15, 16, and 17; (2) selection for examination of workers who had the longest periods of exposure in the industry, as in studies 17 and 18; (3) examination did not include a roentgenograph, as in studies 13 and 21; (4) use of roentgenography was limited to certain workers, as in study 19; (5) size of the sample was very small, as in studies 14 and 15; and (6) the type of foundry studied was not stated in the published report, as in study 20.

It is pointed out that, although the data from the reports listed in the upper portion of table 14 resemble the present study in many respects, both in methods used as well as criteria for diagnosis of degree of observed pulmonary fibrosis, even in these there appear differences from the study now being reported. Again, these differences are, in each instance, indicated in the table by *italics*. It is well, there-

## *Table 14.—Data selected from previous*

| Study No. | Year of report | Investigators | Country of study | Type of foundry | | | Occupational groups studied | Number of workers studied |
|---|---|---|---|---|---|---|---|---|
| | | | | Ferrous | | Non-ferrous | | |
| | | | | Iron | Steel | | | |
| 1 | 1935 | Warfield (*31*) | U. S. (Wisconsin) | Yes | *No* | No | All | 691 |
| 2 | 1937 | Osmond (*32*) | U. S. (Pennsylvania) | Yes | Yes | No | do | 686 |
| 3 | 1937 | Kelly and Hall (*33*) | U. S. (New York) | (*) | (*) | (*) | do | 403 |
| 4 | 1938 | Sander (*34*) | U. S. (Wisconsin) | Yes | Yes | No | do | 4,035 |
| 5 | 1938 | Trice and Easom (*17*). | U. S. (North Carolina) | Yes | Yes | *Yes* | 8 foundries — all; 16 foundries—*selected workers with 20 years or more exposure.* | 546 |
| 6 | 1938 | Greenburg, Siegal, and Smith (*35*). | U. S. (New York) | Yes | Yes | *Yes* | All | 4,066 |
| 7 | 1939 | Sander (*36*) | U. S. (Wisconsin) | Yes | Yes | *Yes* | do | 8,377 |
| 8 | 1942 | Brown and Klein (*37*). | U. S. (Washington, D. C.). | *No* | Yes | *Yes* | do | 454 |
| 9 | 1943 | Feil (*38*) | France | Yes | Yes | No | do | 119 |
| 10 | 1945 | Keatinge and Potter (*39*). | Great Britain | Yes | *No* | No | do | *60* |
| 11 | 1945 | Riley, Butler, and Goren (*40*). | U. S. (Washington, D. C.). | *No* | Yes | *Yes* | do | 842 |
| 12 | 1946 | Velicogna (*41*) | Italy | (*) | (*) | (*) | do | 120 |
| 13 | 1923 | Macklin and Middleton (*42*). | Great Britain | Yes | Yes | No | *Casting cleaners (some degree of selection used).* | 1,153 |
| 14 | 1931 | Komissaruk (*43*) | Austria | Yes | *No* | No | All | *40* |
| 15 | 1932 | Landau (*44*) | Germany | (*) | Yes | No | *Casting cleaners* | *39* |
| 16 | 1933 | Landau (*45*) | Germany | Yes | Yes | No | *Casting cleaners* | 126 |
| 17 | 1934 | Gudjonsson (*46*) | Denmark | (*) | (*) | (*) | *Casting cleaners* | 186 |

See footnotes at end of table.

| Classification of pulmonary fibrosis | | Percent of workers with pulmonary fibrosis | | | | | Remarks |
|---|---|---|---|---|---|---|---|
| | | Diffuse | Nodular | | | | |
| | | | Total | Stage | | | |
| Diffuse | Nodular | | | 1 | 2 | 3 | |
| No | *Yes* | | 17.5 | 8.9 | 8.2 | 0.4 | The hazardous occupations, in descending order, were sandblasters, molders, chippers, laborers, cranemen, coremakers. Roentgenograms only. |
| Yes | Yes | 15.1 | 10.1 | | | | Stereoroentgenograms used. After 20 years of exposure found 44 percent silicosis. The hazardous occupations, in descending order, were steel chippers, iron chippers, molders, coremakers, cranemen. |
| Yes | Yes | 7.5 | 1.2 | 1.2 | 0 | 0 | Surveyed 3 foundries. Physical examination and roentgenograms used. |
| No | *Yes* | | 7.0 | 6.3 | 0.7 | 0 | Casting cleaning produced highest incidence, 28 percent. Steel foundry produced more silicosis than iron foundry. The average exposure time required to develop silicosis was 25 years. The hazardous occupations, in descending order, were sandblasters, chippers and grinders, molders, coremakers. |
| Yes | Yes | 8.2 | 1.5 | 1.5 | 0 | 0 | Twenty-four foundries studied. Physical examinations and roentgenograms used. *Stereoroentgenograms for those with 20 years' average exposure.* The high incidence in molders was believed due to their longer employment. |
| Yes | Yes | 4.5 | 2.7 | 2.2 | 0.4 | 0.1 | Eighty foundries studied. *Roentgenogram only used.* Chippers had highest rate. |
| Yes | Yes | 21.0 | 5.8 | | | | Seventy-five foundries surveyed. This was an extension of study reported in 1938 by same author (*34*) and including the original 4,035 foundrymen studied (*60*). Greater incidence observed in steel foundries. |
| Yes | Yes | 11.2 | 2.4 | 2.2 | 0.2 | 0 | Physical examinations and 14 x 17-inch roentgenograms used. |
| Yes | Yes | 5.9 | 5.9 | | | | Roentgenograms used. Casting cleaners had highest rate. |
| Yes | Yes | 22.0 | 0 | 0 | 0 | 0 | Physical examination and roentgenograms used. The most hazardous occupation was casting cleaning. |
| Yes | Yes | | 2.1 | 1.8 | 0.2 | 0.1 | Same foundry reported by Brown and Klein in 1942 (*37*). *Probably included diffuse fibrosis with stage 1 nodular. Roentgenographed on 4 x 5-inch stereofilms; 14 x 17-inch films used for confirmation only.* |
| Yes | Yes | 3.3 | 5.0 | | | | Physical examination and roentgenograms used. Separate group of sandblasters described. Of 27 sandblasters, found silicosis in 55 percent. |
| No | *Probably advanced.* | See remarks. | 47.0 | | | | No roentgenographic examination made. *Over 55 percent worked with sandstone grinding wheels.* |
| No | *Yes* | | 30.0 | | | | Roentgenograms used. Small foundry. |
| No | *Yes* | | 51.3 | | | | Noted rapidly progressing tuberculosis as the cause of death. All cases were disabled and ill for some time. Roentgenograms used. |
| Yes | Yes | 19.0 | 69.1 | 36.5 | 25.5 | 7.1 | Rate very much higher in steel than iron. Stage 3 silicosis observed. |
| Yes | Yes | 8.6 | 18.7 | 13.9 | 3.2 | 1.6 | Roentgenograms used. *Did not include those under 3 years' exposure.* Found no tuberculosis. Correcting for age and duration of exposure, found older workers more likely to develop silicosis. |

### Table 14.—Data selected from previous studies

| Study No. | Year of report | Investigators | Country of study | Type of foundry: Ferrous: Iron | Type of foundry: Ferrous: Steel | Type of foundry: Nonferrous | Occupational groups studied | Number of workers studied |
|---|---|---|---|---|---|---|---|---|
| 18 | 1934 | McConnell and Fehnel (*46*). | U. S. (Wisconsin) | Yes | Yes | No | All (*selected workers*) | 210 |
| 19 | 1935 | Kuroda (*47*) | Japan | (*) | Yes | No | *All* | 314 |
| 20 | 1935 | Pope and Zacks (*48*). | U. S. (Massachusetts) | (*) | (*) | (*) | do | 1,614 |
| 21 | 1948 | Vigliani, Parmeggiani, and Zanetti (*49*). | Italy | Yes | Yes | *Yes* | All (includes steel fabricators). | 25,253 |

[1] Prepared by Senior Surgeon Harry Heimann and Assistant Surgeon C. J. Buhrow.

*Note:* Dashes (--) indicate that data are not available. The use of *italics* is explained in the text on page 55.

* Type of foundry was not stated.

** The 11.4 percent includes diffuse fibrosis.

fore, in comparing the different reports noted, to consider the indicated variations. It is further pointed out that, in interpreting the recorded findings as to the occurrence of diffuse and nodular fibrosis, license was used in some instances. In general, however, it is felt that the interpretations from the published reports were made without bias so that an approach might be made to a comparison with the data for the present study.

With the above in mind, omitting from further consideration at this time studies numbered 13 to 21, inclusive, the following interesting facts may be noted from the table: (1) The reported incidence of pulmonary fibrosis among foundry workers varied from 2.1 to 26.8 percent; (2) whereas diffuse pulmonary fibrosis (defined in a later section) varied in incidence from 3.3 percent to 22 percent of the workers, nodular silicosis was variously reported as ranging from zero to 17.5 percent (in most of these reports of the nodular type the disease was limited to nodular stage one or two, a few instances of stage three or conglomerate silicosis being reported in this industry by relatively few observers, as in reports 1, 6, and 11); (3) steel foundry work was reportedly more likely to cause silicosis than was iron foundry work, and casting cleaners were the most frequently affected; and (4) it generally required about 20 years to develop nodular silicosis in the foundry industry.

| Classification of pulmonary fibrosis | | Percent of workers with pulmonary fibrosis | | | | | Remarks |
|---|---|---|---|---|---|---|---|
| | | | Nodular | | | | |
| | | Diffuse | Total | Stage | | | |
| Diffuse | Nodular | | | 1 | 2 | 3 | |
| Yes | Yes | 13.3 | 31.4 | 30.0 | 1.4 | 0 | Roentgenograms used. *Selected cases in order to show seriousness of condition.* Included five workers of nonferrous foundry. |
| | | | 8.0 | | | | Of 715 examined, *only 314 roentgenographed; probably selected.* The average exposure time to develop silicosis was 18 years. Steel casting cleaners had 6.6 percent silicosis. |
| (**) | Yes | (**) | **11.4 | | | | Seventy-five percent of workers examined on voluntary basis. Physical examinations and roentgenograms used. Surveyed 10 foundries. |
| Yes | Yes | 1.5 | 0.75 | | | 0 | *Fluoroscopic examinations* of chest made. Steel foundries were worst with incidence of 5 percent of both diffuse and nodular fibrosis. |

**Authors' note: An important new work, "Industrial Lung Diseases of Iron and Steel Foundry Workers," by A. I. G. McLaughlin and coworkers, H. M. Stationery Office, London, 1950, appeared after compilation of the above table.**

## Methods of Study

For the year 1947, the latest year for which pertinent information was available, there were 1,936 independent ferrous foundries in the United States, employing a total of 239,272 workers (*1*). (See also table 1.) These foundries, together with all captive foundries, employed approximately 341,000 production workers. In the 16 foundries with which the present report is concerned, the total employment was a little over 2,000, of whom 1,937, all males, were medically studied.

### PERSONNEL AND FACILITIES

Utilized in the study was a total of nine physicians, two or three of whom were in the field at any one time. It was the physician's duty to obtain the occupational and medical history, to make the medical examination, and to supervise the work of the medical technicians. The medical technician's responsibility was to make the necessary chest roentgenogram and to study the urine and blood of the worker. Specialists in dermatology assisted in one phase of the study in evaluating the health hazards to the skin. Two dentists, one of whom was in the field at any one time, were part of the medical study team; it was their function to evaluate the manifestations of disease which might appear in the mouth of the worker.

Thus, a medical team in the field consisted of two or three physicans, one dentist, and one medical technician. The field team was enlarged by the addition of an extra physician or technician when it was desired to complete the work especially rapidly at a plant.

The team performed its work at the plant sites by using a suitably equipped house-trailer and a special dental examination truck. The medical trailer, measuring approximately 8 by 28 feet, was partitioned into two medical examination rooms and a clinical laboratory. One of the medical examination rooms contained the roentgen ray equipment. The dental truck was constructed to house the usual dental examination equipment, including a dental roentgen unit. Both the medical trailer and dental truck were moved from plant to plant as needed. Although both of these units were the basic facilities used for the medical studies, from time to time a suitable room was provided by plant management to supplement these facilities. In such instances, the extra space was used as the clinical laboratory.

The medical team and equipment arrived at each plant at a time prearranged by conference between officials of the Illinois Department of Public Health and the plant management. The trailer and truck were placed at a convenient location in the foundry yard, and connections were made with electric current and water. The team was then ready to begin its examinations.

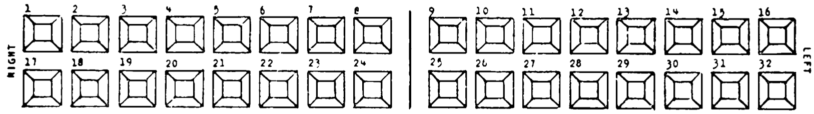
The foundry workers were notified through their labor organizations that all examinations were to be on a voluntary basis. Management cooperated to the fullest extent, providing suitable persons to assist in the assignment of the workers for the medical examinations. The time taken for each examination varied from 25 to 40 minutes, with an average of about 30 minutes. Men from all shifts were studied.

## THE MEDICAL EXAMINATION

Figure 13 shows the dental form used, and figure 14 the medical form, each indicating the extent of the examination made. A manual of instructions for use of the forms was provided each person of the study team. The complete form, including occupational history, was filled in by the examining physician. The oral examination form was filled in by the dentist. The laboratory data were recorded as each test was completed. Data from the chest roentgenograms were recorded later.

Following the completion of the examination by the physician, the worker was ushered to the roentgen ray unit, where a picture was made of his chest. All roentgen ray exposures were made on 14 by 17-inch films for a half of a second at 72-inch target distance, using appropriate voltage and amperage dependent upon the anterior-posterior diameter of the chest. One exposure at deep inspiration was

| ORAL EXAMINATION | | Date | Case No. |
|---|---|---|---|
| Name | Color | Sex | Age |




Remarks

| Calculus 0 1 2 3 4 | Type of Calculus 1 2 3 | Periclasia 0 1 2 3 4 | Enamel |
|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| LIPS | Normal | Abnormal | GLANDS | Normal | Abnormal |
| Inflammation | | L G 1 2 3 | Other Conditions | | |
| Fissure | | | | | |
| Keratosis | | L G 1 2 3 4 | TONGUE | Normal | Abnormal |
| Other Conditions | | | Fissure | | |
| | | | Keratosis | | L G 1 2 3 4 |
| GINGIVAE RIDGES | Normal | Abnormal | Varicosity | | |
| Gingivitis | | L G 1 2 3 | Other Conditions | | |
| Color Change | | | | | |
| Tissue Tonus | | | MANDIBLE | Normal | Abnormal |
| Keratosis | | L G 1 2 3 4 | Exostosis | | |
| Other Conditions | | | Other Conditions | | |
| ORAL MUCOSA | Normal | Abnormal | NEOPLASM | Present | Absent |
| Inflammation | | L G 1 2 3 | | | |
| Keratosis | | L G 1 2 3 4 | TEETH AND SUPPORTING STRUCTURES | | |
| Other Conditions | | | No. of Teeth Missing | | |
| | | | No. of Teeth Replaced | | |
| PALATE | Normal | Abnormal | No. of Teeth Carious | | |
| Inflammation | | L G 1 2 3 | No. of Teeth Restored | | |
| Keratosis | | L G 1 2 3 4 | Bridges | | |
| Exostosis | | | Dentures | | |
| Other Conditions | | | | | |
| VELUM | Normal | Abnormal | DENTAL NEED | | |
| Inflammation | | L G 1 2 3 | No. of Teeth Requiring Filling | | |
| Other Conditions | | | No. of Extractions Indicated | | |
| | | | No. of Bridges Indicated | | |
| UVULA | Normal | Abnormal | Partial Dentures | Upper | Lower |
| Inflammation | | L G 1 2 3 | Full Dentures | Upper | Lower |
| Other Conditions | | | Prophylaxis | | |

Figure 13.—Oral examination form (modified).

made for each worker. Some difficulty in the roentgenography was occasioned by the fact that the source of electric current was not constant because of the starting or stopping of electrical equipment within the plants. Some pictures were thus lost and this fact, among others, accounts for the discrepancy between the number of medical examinations made and the number of chest films recorded, as observed in table 15. In general, the roentgenograms that were interpreted were of good quality.

For technical reasons it was considered advisable to develop all the films at the Public Health Service laboratories in Washington. Following this, the films were interpreted by two physicians, working independently of each other. Where differences in interpretation existed, the two readers conferred for a decision. In all instances, the

USPHS FOUNDRY STUDY
MEDICAL RECORD (condensed)
(Page 1)

No.:
Establishment:

GENERAL:
Name______ Address______ Age____
Date______ Birthplace______ Age began wk.____ M S W D Sep.
Sex: M F Race: W Nw Time:______ Hours on shift____; since food____
Pres. shift: From______ to______. Wkly hrs.: Usual______ Max.______
Family physician______

OCCUPATIONAL HISTORY

| Specific job | Department or industry | Time: Foundry (yrs.) | Time: Other (yrs.) | Remarks |
|---|---|---|---|---|
| Pres. | | | | |
| Prev. | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | Total | | | |

Chron. dis. in family: Tbc.____ Silicosis____ Other______

HABITS: (Encircle positive items) Alcohol: B W L Tobacco: Cts. Cgrs. P. Ch. Sn.
Drugs:______ Hours sleep:____ Baths:______

PREVIOUS ILLNESSES, INJURIES, OR OPERATIONS:
Pneum.______ Sin. infec.______ Hernia______
Tbc.______ Hrt. dis.______ Oper. & Inj.______
Bronch.______ Skin dis.______ V. D.______
Pleur.______ Rheum.______ Other (Spec.)
Asthma______ Colds past yr.______
Summary______

SYMPTOMATOLOGY:
GENERAL: Weak______ Mal.______ Drowsy______ Allergy______ Nervous______
EYES: Pain____ Disch.____ Tear.______ Photophobia______ Vis. dist.______
EARS: Hear.____ Tinn.____ Disch.______ Pain______ Other______
NEURO-M.: Vert.____ Parest.______ HA______ Insom.______ Irritab.______
Musc. weak.______ Musc. pain______ Jnt. pain______
CARDIO-RESP.: Palp.______ Dysp.______ Edema______ Syn.______
Chest pain______ Hoarse______ Cough______ Expec.______
Hemopt.______ C. Cold______ Epist.______
GI: Abd. pain______ N or V______ Anor.______ Diar.______ Const.______
GU: Dysuria______ Hemat.______ Noct.______ Freq.______ Disch.______
SKIN:______
OTHER AND REMARKS:______

Figure 14 (front).—Medical examination form (condensed).

films were interpreted with the medical records available, but these records were only referred to when necessary for proper interpretation of the more obscure cases.

Following the taking of the chest film, the medical technician made examinations of the blood and urine. The worker was asked to void his urine into a suitable container, in the presence of the technician. The urine was studied for the presence of albumin by the heat and acetic acid test and for the presence of glucose by Benedict's qualitative solution. Microsopic review of the centrifuged urinary sediment was made of those specimens showing albumin.

Obtaining 10 cubic centimeters of blood by puncture of the antecubital vein, the technician placed about 5 cubic centimeters into a test tube for the serological test for syphilis and the remaining 5 cubic centimeters into a tube containing 6 milligrams of ammonium oxalate

MEDICAL RECORD (condensed)
(Page 2)

PHYSICAL EXAMINATION:

APPEARANCE:
Development G P Nutrition G P
Pallor Jaundice Cyanosis
Ht.____ Wt.____ Pulse____
Resp. rate______ Temp.______

EYES:
Dist. vis. - Assisted: R 20/ L 20/
Pupils - Irregular
Unequal
Fail to react to light
Fail to react to accom.
Lids -
Conjunctiva and sclera -
Cornea
Cataract -
Exophthalmos -
Strabismus

CHEST AND LUNGS:
Chest - Assym. Flat Barrel
Funnel Pigeon Grooved
Spine - Scoliosis R L
Kyph. Lordo.
Inspection______________
Palpation______________
Percussion______________
Auscultation______________

CARDIOVASCULAR:
Apex beat - Palpable
Outside midclav. line
Interspace
Heart sounds - $A_2$ > = < $P_2$
Murmur - Syst. Diast. Presyst. apic.
Rhythm irregular basal
Blood pressure - /

EARS:
External ear -
Purulent disch. -
Drums -
Hearing -

NOSE:
Marked obstruction -
Enlarged turbinates -
Septum deviation -
Perforation of septum

THROAT:
Tonsils - Absent Present
Infected 1 2 3
Pharynx - Inflamed 1 2 3
Ulceration

NECK:

EXTREMITIES:
Skeletal Abnormalities -
Hands and nails -

Reflexes -
Patellar: Incr. Decr. Abs.
Ankle: Incr. Decr. Abs.
Peripheral vessels:
Beaded Sclerotic Tortuous
Gait -

Adenopathy -
Cervical
axillary

SKIN:

POSITIVE FINDINGS:______________________________

X-RAY INTERPRETATION:
Film condition - G F P
Lung field markings - Linear 1 2
GG 1 2
Nod. 1 2
Conglom.

Emphysema - 1 2 3
Calcification - Hilar Parenchymal
Heart or aorta enlarged - 1 2 3
Diaphragm - Adhesions Oblit. Angles
Other______________________

LABORATORY FINDINGS:
Serodiagnostic test______________
(Specify name)
BLOOD
Sed. rate__________
Hemato.__________
RBC__________
WBC__________
Hb.__________

URINE:
Appearance______________
Sp. gr.______________
Album.______________
Glyco.
Microscopic -
RBC____/ hpf WBC____/hpf
Casts____/hpf

VITAL CAPACITY:______________

Signature______________________

Figure 14 (back).—Medical examination form (condensed).

and 4 milligrams of potassium oxalate as the dry anticoagulant for the other studies (*61, 62*). Blood smears were made of the fresh blood.

All the serological tests for syphilis were made by the Illinois Department of Public Health. The Kahn test was done routinely and confirmed as necessary by other tests. The blood smears were stained with Wright's stain for later study. The erythrocyte and leucocyte counts were made by standard methods, and the hemoglobin estimations were done by the use of the Haden-Hausser hemoglobinometer (*63*). The blood sedimentation rate, later corrected for hematocrit determinations, was made by using Wintrobe tubes (*62*), with readings taken at the end of one hour. The blood contained in the same Wintrobe tube was then centrifuged for 30 minutes at 2,500 revolutions per minute, and the hematocrit reading recorded. The Wintrobe indexes (*62*)—the mean corpuscular volume, the mean corpuscular hemoglobin, and the mean corpuscular hemoglobin concentration—were calculated from the erythrocyte count, the hemoglobin estimation, and the hematocrit by using a suitable nomogram. The vital capacity reading was then made, allowing the worker to make three tests. The highest of the three was recorded as the vital capacity. A standard water replacement type of spirometer was used for this purpose.

After being processed by the technician, the foundrymen were examined by a dentist. With the aid of a good source of light, examinations were made of the teeth as well as the other structures in the oral cavity. Bite-wing roentgenographic exposures were made of a representative number of the workmen.

*Table 15.—Major medical studies made of male workers in 16 ferrous foundries in Illinois*

| Study | Number of workers |
|---|---|
| Physical examinations | 1,937 |
| Chest roentgenograms | 1,824 |
| Oral examinations | 1,903 |
| Visual acuity | 1,742 |
| Vital capacity | 1,864 |
| Urine | 1,655 |
| Blood: | |
| Erythrocyte counts | 591 |
| Leucocyte counts | 1,529 |
| Hemoglobin estimations | 1,528 |
| Hematocrit determinations | 1,921 |
| Erythrocyte sedimentation rates | 1,921 |
| Kahn tests | 1,894 |

The major medical studies and the number of workers associated with each are shown in table 15. With the exception of the erythrocyte counts, all examinations were made routinely on each worker who presented himself. The erythrocyte counts were not begun until examinations were made at the eleventh plant. Except for the erythrocyte counts, the variation in number of the different types of examinations is due in part to the inadvertent omission of certain tests or the refusal of workers to take them—difficulties usually attendant at such studies. As indicated previously, the 16 ferrous foundries studied employed about 2,000 persons, of whom 1,937 were medically studied.

## Results of Medical Studies

Each medical record was reviewed, interpretations of the data were made as necessary, and, finally, the material was analyzed. Medical findings were correlated with each other, and certain medical findings were correlated with environmental data when it appeared that these procedures would be useful.

### CHARACTERISTICS OF EXAMINED WORKERS

Socio-economic influences are known to be of significance in health and disease. Thus, the place of birth, race, age, sex, marital status, personal habits, hours of work, time in foundry work, and occupation were analyzed.

#### *Birthplace*

Of the workers questioned, and for whom this information was recorded, 980, or 51 percent, were born in the State of Illinois or in the immediately adjacent states. The remaining 49 percent were born in states distant from Illinois or in foreign countries. Of the distant states represented, the nonwhite population weighted the data toward the southern part of the country. The 498 foundrymen who were foreign-born were predominantly from southern and eastern Europe. When the individual plants were considered for the number of persons born in foreign lands, the rate was found to vary markedly, ranging from 8 percent to 70 percent.

#### *Race*

Of the 1,937 medical examinations made, 1,341, or 69 percent, were of white persons, and 31 percent were of nonwhite, all Negroes. The percentage of workers of the different races that might be employed in foundries in the United States will be found to vary with many factors, among which is the section of the country. For example, in a study of 4,066 foundrymen made in New York State (*35*), nonwhite workers constituted 4.4 percent of the total.

#### *Age*

Table 16 shows the age distribution of the foundry population studied. The median age was 40.7 years, which is similar to that observed for open-hearth steelworkers recently studied by the Public Health Service (*64*). It is to be noted that, whereas the nonwhite workers show a maximum frequency at the 25 to 29-year age group, the white population shows two maximums at age groups 30 to 34 and 55 to 59 years. This has been observed in other studies made by the Public Health Service in the past. Wide variation of age grouping was observed from plant to plant. Compared with industrial

*Table 16.—Age distribution of examined male workers in 16 ferrous foundries in Illinois, according to race*

| Age (years) | Number | | | Percent | | |
|---|---|---|---|---|---|---|
| | Total | White | Nonwhite | Total | White | Nonwhite |
| Total | 1,937 | 1,341 | 596 | 100.0 | 100.0 | 100.0 |
| Under 20 | 45 | 31 | 14 | 2.3 | 2.3 | 2.4 |
| 20–24 | 171 | 84 | 87 | 8.8 | 6.3 | 14.6 |
| 25–29 | 208 | 112 | 96 | 10.7 | 8.4 | 16.1 |
| 30–34 | 270 | 176 | 94 | 13.9 | 13.1 | 15.8 |
| 35–39 | 246 | 153 | 93 | 12.7 | 11.4 | 15.6 |
| 40–44 | 201 | 130 | 71 | 10.4 | 9.7 | 11.9 |
| 45–49 | 172 | 112 | 60 | 8.9 | 8.3 | 10.1 |
| 50–54 | 189 | 146 | 43 | 9.8 | 10.9 | 7.2 |
| 55–59 | 191 | 169 | 22 | 9.9 | 12.6 | 3.7 |
| 60–64 | 165 | 154 | 11 | 8.5 | 11.5 | 1.8 |
| 65 or over | 79 | 74 | 5 | 4.1 | 5.5 | .8 |

workers in the United States as a whole (*65*), the foundry workers of this study as a group ranked about five years older.

### *Sex*

Although the present study limited its examinations to males, it is not to be inferred that women are not employed in the ferrous foundry industry. For the month of September 1949, for example, approximately five percent of the workers in the ferrous foundries of the United States were women (*66*).

### *Marital Status*

Eighty percent of the workers were married; 14 percent, single; and the remainder, widowed, separated or divorced. This was similar to other industrial groups recently studied by the Public Health Service.

### *Personal Habits*

It is of some interest that on the subject for which greatest inaccuracy might be expected—that is, imbibition of alcoholic beverages—the data obtained followed very closely those recorded by other examiners of the Public Health Service for a comparable industrial group (*64*). In the present study, 17 percent denied the use of alcoholic beverages; 33 percent admitted the use of only beer and wine; 50 percent said they drank beer, wine, and stronger spirits. The degree to which they indulged in these beverages was not determined. Although the use of alcoholic beverages varied from plant to plant, a positive association was found between the percentage of foreign-born workers in a plant and the taking of alcohol in any form, generally as wine.

Eighty-five percent of the workers said that they used tobacco in some form. Of these, 80 percent smoked, and the other 5 percent used snuff or chewed tobacco. The older age groups did less smoking and more chewing or snuffing of tobacco. These data conform to our findings in similar occupational groups which we have studied.

Hours spent in sleep were recorded as eight or nine by 68 percent of the foundrymen. A few spent only 5 hours in sleep, while 5 percent slept 10 hours each day. The longer hours of sleep occurred more commonly among the older foundrymen.

Fifty-three percent of the workers said that they took daily baths. This was appreciably higher than in two other cleaner industries that we recently studied.

### *Hours of Work*

In a consideration of disease states, such as silicosis, due to long industrial exposure, it would be expected that the time spent in a given industrial environment would be directly related to the disease condition which might be created by that environment. Thus, not only is the number of years spent in the industry of consequence, but the weekly number of hours spent on the job may also be important. The number of hours of work per week spent in the occupation by most of the persons in the present study group was 40.

Since the number of hours per week spent in foundry work during the war years (1940–45) might have been sufficiently different to have caused certain abnormalities in our findings, the wartime experience was also considered in the study. Information available indicated that, during those years, ferrous foundrymen worked an average of 48 hours per week. The difference between the peacetime hours and the wartime hours is a factor of 20 percent. Thus, the 5-year war period, when converted for present purposes into peacetime years, would constitute six years of exposure, a difference of only one year. This appears to be of doubtful significance in the present study in view of the many years of exposure necessary to produce pulmonary fibrosis in this industry.

### *Years in Foundry Work*

The significant factor of years worked in ferrous foundries is shown in table 17. It is felt that an adequate sample, from this point of view, is represented in the study group, since 12.5 percent had spent 30 years or more in foundry work; 24.8 percent, 20 years or more; and 45.1 percent, 10 years or more. As might be expected, close correlation was found between increasing age and years spent in foundry work. It was

*Table 17.—Distribution of years in ferrous foundries of examined male workers in 16 foundries in Illinois, according to race*

| Years in ferrous foundries | Number | | | Percent | | |
|---|---|---|---|---|---|---|
| | Total | White | Nonwhite | Total | White | Nonwhite |
| Total | [1] 1,937 | [1] 1,341 | 596 | 100.0 | 100.0 | 100.0 |
| Less than 5 | 690 | 330 | 360 | 35.6 | 24.6 | 60.4 |
| 5– 9 | 373 | 259 | 114 | 19.3 | 19.3 | 19.1 |
| 10–14 | 240 | 193 | 47 | 12.4 | 14.4 | 7.9 |
| 15–19 | 153 | 122 | 31 | 7.9 | 9.1 | 5.2 |
| 20–24 | 139 | 119 | 20 | 7.2 | 8.9 | 3.4 |
| 25–29 | 99 | 84 | 15 | 5.1 | 6.3 | 2.5 |
| 30–34 | 92 | 86 | 6 | 4.7 | 6.4 | 1.0 |
| 35–39 | 70 | 68 | 2 | 3.6 | 5.1 | .3 |
| 40–44 | 46 | 45 | 1 | 2.4 | 3.4 | .2 |
| 45 or over | 34 | 34 | 0 | 1.8 | 2.5 | 0 |

[1] One with years in ferrous foundries not stated.

observed that the nonwhite workers on the average had spent fewer years in the industry than had the white.

### *Occupation*

Questioning the men about their occupations prior to foundry work elicited the following interesting facts. Twenty-three percent of the men had come to the foundry from work in agriculture, forestry, or fishing. Approximately 4 percent came from trades where there might have been excessive dust in the occupation. Of special importance are considerations of the employment at the time of the examination and of the workers' previous occupations in foundries. These are the two factors which must be given prominence in the correlations to be made with health status.

Separate consideration is given to *present* occupation and *principal* occupation. It will be at once apparent that those disease conditions dependent for their development on long periods of exposure might be correlated with principal occupation; whereas, those conditions dependent for their genesis on very recent occupational exposure should have only the present occupation considered. The principal occupation represents the particular broad occupational group followed for the greatest number of years while working in foundries. If the individual foundryman worked at two or more occupations for the same number of years, the most recent is considered as the principal one. Analysis was made of each medical history, and the principal occupation determined, the present occupation being easily observed from those records.

Table 18 shows the division of the 1,937 men into various detailed occupations. Since the gray iron and steel foundries differ somewhat in this regard, separation of the two is made in the table.

Consideration of each of the job classifications separately in the correlations with the medical findings would have resulted in such small numbers of workers as to make such correlations of doubtful value. For this reason the job classes were grouped into larger segments. This classification has the further advantage that for each of four of the six categories the environmental conditions are essentially similar for the job classes included under that category. The six major occupational groups are: coremaker, molder, cleaning and finishing, shakeout, maintenance and supervisory, and laborer and other. The latter two are the heterogeneous groups.

Tables 19 and 20, using the six occupational groups, show a distribution of the foundry workers by principal and present occupation, respectively. It will be observed from the tables that the percentage of workers in the various occupational groups does not differ much when comparison is made between present and principal occupations. There appears to be a tendency, noted for both races and for each of the age groups, for the present occupation to have fewer molders, cleaners and finishers, and more of the groups of maintenance and supervisory workers and laborers. In further evaluating the relationship of present to principal occupation of the individual foundryman, it was generally found that in over 80 percent of instances the present and principal occupations were identical.

## MEDICAL FINDINGS

### *Previous Illness*

Inquiry concerning certain previous illnesses revealed that 20 percent of those examined had had pneumonia (lobar or bronchial) or pleurisy, 4 percent had chronic bronchitis, and 1.5 percent had heart disease. In 13 percent there existed one or more of the following chronic diseases of the cardiorespiratory system: bronchial asthma, heart disease, nasal sinusitis, and chronic bronchitis.

### *Present Symptoms*

As indicated in the medical examination form, figure 13, specific inquiry was made into a series of symptoms which the worker might have had at the time of the examination. It was noted that the workers admitted most frequently to having symptoms of cough, dyspnea, and muscular or joint pains. Some of this information will be considered again when the dust effects on the lungs are discussed.

*Table 18.—Number of workers in detailed principal occupations of male workers in 16 ferrous foundries in Illinois according to type of foundry and race*

| Principal occupation | Gray iron foundries | | | Steel foundries | | |
|---|---|---|---|---|---|---|
| | Total | Race | | Total | Race | |
| | | White | Non-white | | White | Non-white |
| Total | 1,267 | 930 | 337 | 670 | 411 | 259 |
| COREMAKER | 149 | 141 | 8 | 95 | 73 | 22 |
| MOLDER | 416 | 328 | 88 | 131 | 72 | 62 |
| CLEANING AND FINISHING | 180 | 126 | 54 | 162 | 101 | 61 |
| Cleaning and finishing department workers, unspecified | 25 | 18 | 7 | 33 | 20 | 13 |
| Swing grinder | 3 | 2 | 1 | 34 | 24 | 10 |
| Chipper and grinder, other than swing grinder | 69 | 50 | 19 | 40 | 24 | 16 |
| Sand blaster | 16 | 8 | 8 | 18 | 7 | 11 |
| Tumbler operator | 6 | 4 | 2 | 0 | 0 | 0 |
| Burner | 3 | 3 | 0 | 28 | 21 | 7 |
| Stationary grinder | 48 | 36 | 12 | 9 | 5 | 4 |
| Other cleaning and finishing department workers | 10 | 5 | 5 | 0 | 0 | 0 |
| SHAKEOUT | 161 | 69 | 92 | 65 | 15 | 59 |
| Sand conditioning worker | 7 | 5 | 2 | 7 | 0 | 7 |
| Sand mixer, hand | 3 | 1 | 2 | 0 | 0 | 0 |
| Sand mixer, machine | 15 | 12 | 3 | 11 | 5 | 6 |
| Shakeout | 136 | 51 | 85 | 47 | 10 | 37 |
| MAINTENANCE AND SUPERVISORY | 103 | 101 | 2 | 69 | 64 | 5 |
| Maintenance men, unspecified | 16 | 16 | 0 | 19 | 17 | 2 |
| Carpenter | 8 | 8 | 0 | 1 | 1 | 0 |
| Electrician | 0 | 0 | 0 | 5 | 5 | 0 |
| Mechanic | 1 | 1 | 0 | 3 | 3 | 0 |
| Millwright | 2 | 1 | 1 | 11 | 11 | 0 |
| Office worker | 8 | 8 | 0 | 2 | 2 | 0 |
| Shipping, receiving clerk | 12 | 12 | 0 | 5 | 3 | 2 |
| Supervisory employee | 35 | 34 | 1 | 18 | 18 | 0 |
| Guard, watchman | 1 | 1 | 0 | 4 | 3 | 1 |
| Pattern maker | 20 | 20 | 0 | 1 | 1 | 0 |
| LABORER AND OTHER | 258 | 165 | 93 | 145 | 86 | 59 |
| Melter | 0 | 0 | 0 | 22 | 14 | 8 |
| Cupola man | 67 | 41 | 26 | 1 | 1 | 0 |
| Electric furnace operator | 1 | 1 | 0 | 12 | 9 | 3 |
| Reverberatory furnace operator | 1 | 1 | 0 | 1 | 0 | 1 |
| Annealer | 5 | 4 | 1 | 0 | 0 | 0 |
| Pourer | 38 | 11 | 27 | 8 | 1 | 7 |
| Brickmason | 3 | 2 | 1 | 1 | 1 | 0 |
| All other production workers | 13 | 10 | 3 | 18 | 16 | 2 |
| Crane operator | 16 | 14 | 2 | 30 | 22 | 8 |
| Sweeper, cleaner, janitor | 6 | 4 | 2 | 4 | 2 | 2 |
| Yardman, truck driver | 27 | 20 | 7 | 4 | 4 | 0 |
| Laborer | 81 | 57 | 24 | 44 | 16 | 28 |

*Table 19.—Principal occupation of male workers in 16 ferrous foundries in Illinois according to age and race for gray iron and steel foundries*

| Principal occupation | Number | | | | | | | | Percent | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | White | | | | Nonwhite | | | | White | | | | Nonwhite | | | |
| | Total | Age | | | Total | Age | | | Total | Age | | | Total | Age | | |
| | | Under 35 | 35–54 | 55 or over | | Under 35 | 35–54 | 55 or over | | Under 35 | 35–54 | 55 or over | | Under 35 | 35–54 | 55 or over |
| **Gray iron foundries** | | | | | | | | | | | | | | | | |
| Total | 930 | 298 | 353 | 279 | 337 | 171 | 144 | 22 | 100 | 32.0 | 38.0 | 30.0 | 100 | 50.7 | 42.8 | 6.5 |
| Coremaker | 141 | 50 | 57 | 34 | 8 | 3 | 3 | 2 | 100 | 35.5 | 40.4 | 24.1 | 100 | 37.5 | 37.5 | 25.0 |
| Molder | 328 | 77 | 127 | 124 | 88 | 38 | 44 | 6 | 100 | 23.5 | 38.7 | 37.8 | 100 | 43.2 | 50.0 | 6.8 |
| Cleaning and finishing | 126 | 40 | 45 | 41 | 54 | 26 | 27 | 1 | 100 | 31.7 | 35.8 | 32.5 | 100 | 48.1 | 50.0 | 1.9 |
| Shakeout | 69 | 22 | 31 | 16 | 92 | 50 | 34 | 8 | 100 | 31.9 | 44.9 | 23.2 | 100 | 54.3 | 37.0 | 8.7 |
| Maintenance and supervisory | 101 | 38 | 39 | 24 | 2 | 0 | 2 | 0 | 100 | 37.6 | 38.6 | 23.8 | 100 | 0 | 100.0 | 0 |
| Laborer and other | 165 | 71 | 54 | 40 | 93 | 54 | 34 | 5 | 100 | 43.0 | 32.8 | 24.2 | 100 | 58.1 | 36.5 | 5.4 |
| **Steel foundries** | | | | | | | | | | | | | | | | |
| Total | 411 | 105 | 188 | 118 | 259 | 120 | 123 | 16 | 100 | 25.6 | 45.7 | 28.7 | 100 | 46.3 | 47.5 | 6.2 |
| Coremaker | 73 | 23 | 38 | 12 | 22 | 10 | 10 | 2 | 100 | 31.5 | 52.1 | 16.4 | 100 | 45.5 | 45.4 | 9.1 |
| Molder | 72 | 22 | 24 | 26 | 62 | 25 | 32 | 5 | 100 | 30.6 | 33.3 | 36.1 | 100 | 40.3 | 51.6 | 8.1 |
| Cleaning and finishing | 101 | 20 | 52 | 29 | 61 | 20 | 38 | 3 | 100 | 19.8 | 51.5 | 28.7 | 100 | 32.9 | 62.2 | 4.9 |
| Shakeout | 15 | 2 | 7 | 6 | 50 | 26 | 22 | 2 | 100 | 13.3 | 46.7 | 40.0 | 100 | 52.0 | 44.0 | 4.0 |
| Maintenance and supervisory | 64 | 16 | 33 | 15 | 5 | 3 | 1 | 1 | 100 | 25.0 | 51.6 | 23.4 | 100 | 60.0 | 20.0 | 20.0 |
| Laborer and other | 86 | 22 | 34 | 30 | 59 | 36 | 29 | 3 | 100 | 25.6 | 39.5 | 34.9 | 100 | 61.0 | 33.9 | 5.1 |

*Table 20.—Present occupation of male workers in 16 ferrous foundries in Illinois according to age and race for gray iron and steel foundries*

| Present occupation | Number | | | | | | | | Percent | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | White | | | | Nonwhite | | | | White | | | | Nonwhite | | | |
| | Total | Age (years) | | | Total | Age (years) | | | Total | Age (years) | | | Total | Age (years) | | |
| | | Under 35 | 35–54 | 55 or over | | Under 35 | 35–54 | 55 or over | | Under 35 | 35–54 | 55 or over | | Under 35 | 35–54 | 55 or over |
| | Gray iron foundries | | | | | | | | | | | | | | | |
| Total | 930 | 298 | 353 | 279 | 337 | 171 | 144 | 22 | 100 | 32.0 | 38.0 | 30.0 | 100 | 50.8 | 42.7 | 6.5 |
| Coremaker | 149 | 56 | 59 | 34 | 8 | 3 | 3 | 2 | 100 | 37.6 | 39.6 | 22.8 | 100 | 37.5 | 37.5 | 25.0 |
| Molder | 310 | 76 | 120 | 114 | 76 | 34 | 38 | 4 | 100 | 24.5 | 38.7 | 36.8 | 100 | 44.7 | 50.0 | 5.3 |
| Cleaning and finishing | 108 | 35 | 38 | 35 | 58 | 27 | 30 | 1 | 100 | 32.4 | 35.2 | 32.4 | 100 | 46.6 | 51.7 | 1.7 |
| Shakeout | 69 | 20 | 30 | 19 | 88 | 48 | 31 | 9 | 100 | 28.9 | 43.5 | 27.6 | 100 | 54.6 | 35.2 | 10.2 |
| Maintenance and supervisory | 123 | 38 | 49 | 36 | 3 | 1 | 2 | 0 | 100 | 30.9 | 39.8 | 29.3 | 100 | 33.3 | 66.7 | 0 |
| Laborer and other | 171 | 73 | 57 | 41 | 104 | 58 | 40 | 6 | 100 | 42.7 | 33.3 | 24.0 | 100 | 55.8 | 38.4 | 5.8 |
| | Steel foundries | | | | | | | | | | | | | | | |
| Total | 411 | 105 | 188 | 118 | 259 | 120 | 123 | 16 | 100 | 25.6 | 45.7 | 28.7 | 100 | 46.3 | 47.5 | 6.2 |
| Coremaker | 66 | 18 | 36 | 12 | 27 | 12 | 13 | 2 | 100 | 27.3 | 54.5 | 18.2 | 100 | 44.4 | 48.2 | 7.4 |
| Molder | 71 | 23 | 25 | 23 | 55 | 22 | 28 | 5 | 100 | 32.4 | 35.2 | 32.4 | 100 | 40.0 | 50.9 | 9.1 |
| Cleaning and finishing | 88 | 15 | 46 | 27 | 60 | 18 | 39 | 3 | 100 | 17.0 | 52.3 | 30.7 | 100 | 30.0 | 65.0 | 5.0 |
| Shakeout | 14 | 2 | 5 | 7 | 43 | 24 | 16 | 3 | 100 | 14.3 | 35.7 | 50.0 | 100 | 55.8 | 37.2 | 7.0 |
| Maintenance and supervisory | 83 | 24 | 41 | 18 | 4 | 2 | 1 | 1 | 100 | 28.9 | 49.4 | 21.7 | 100 | 50.0 | 25.0 | 25.0 |
| Laborer and other | 89 | 23 | 35 | 31 | 70 | 42 | 26 | 2 | 100 | 25.9 | 39.3 | 31.8 | 100 | 60.0 | 37.1 | 2.9 |

### *Weight Deviation*

The foundrymen were weighed clad in their work clothes except their shirts. Calculation of the weight deviation for each worker from the average weight of insured men of similar age and height (*67*) yielded the distribution of percentage deviations reflected in table 21. The table shows, furthermore, that the percentage weight deviations of the present study group were distributed in a manner similar to those of the open-hearth steelmen, another industrial group studied by the Public Health Service (*64*).

*Table 21.—Distribution of male workers in 16 ferrous foundries in Illinois by percent weight deviation from the average weight of men of their height and age according to life insurance tables,[1] compared with open-hearth steelworkers*

| Percent weight deviation from average | Number | | Percent | |
|---|---|---|---|---|
| | Foundry workers | Open-hearth steelworkers[2] | Foundry workers | Open-hearth steelworkers[2] |
| Total | 1,678 | 322 | 100.0 | 100.0 |
| 25 to 34 below | 7 | 3 | .5 | .9 |
| 15 to 24 below | 131 | 20 | 7.8 | 6.2 |
| 5 to 14 below | 409 | 77 | 24.4 | 23.9 |
| ±5 | 479 | 100 | 28.5 | 31.1 |
| 5 to 14 above | 337 | 68 | 20.1 | 21.1 |
| 15 to 24 above | 183 | 38 | 10.9 | 11.8 |
| 25 to 34 above | 83 | 11 | 4.9 | 3.4 |
| 35 or more above | 49 | 5 | 2.9 | 1.6 |
| Mean (percent) | +2.7 | +2.2 | | |
| Standard deviation (percent) | 14.0 | 13.3 | | |

[1] Reference *67*.
[2] Reference *64*.

### *Eye Findings*

By the use of the Keystone Telebinocular (*68*), tests for acuity of distant vision were made of 1,742 foundrymen. All tests were made with the worker wearing the corrective spectacles he used at his work. This served the purpose of testing his occupational visual acuity.

Other than possible effects upon vision from infrared rays emanating from the hot metal, seriously doubted by some observers (*69*), adverse effects on the eye might be found in this industry as a result of the dust floating in the air or the fast-moving particulate matter thrown into the air by certain of the chipping, grinding, and polishing processes. To the extent that examination was made for eye effects of infrared rays, no significant abnormalities were observed in this study. Particulate matter in the air of the working environment may cause damage to the conjunctiva and cornea and, less frequently, to the deeper eye structures. When such damage occurs to the cornea, it may in some instances be painless but result in dystrophic changes (*70–72*).

Study of the distribution of the visual acuity findings, divided according to the degree of dustiness of the industrial exposure in the principal occupation and according to the presence in the workroom air of high-speed particles involved in the operation concerned, appeared to show no differences. Although it is recognized that the proper use of eye protective equipment will appreciably lower the incidence of eye injuries, no weight was given in this evaluation to the wearing of eye protective apparatus.

To test further the possibility that the degree of dustiness of the occupation may have caused damage to the eyes, the incidence of certain eye symptoms and signs was correlated with the occupations of the foundrymen at the time of the examination. It was found that neither the symptom of photophobia nor the objective sign of conjunctival congestion was significantly related to any of the six major job categories, in spite of the fact that the dustiness of these job categories varied, as shown in table 9.

### *Nose*

The examination of the nasal cavity was made with the use of a good light and a nasal speculum. In many workers accumulations of the foundry dust were found at the nares and deeper inside the nasal cavity. In three instances the cartilaginous septum was found to be perforated. A review of the medical records of the three foundrymen so affected showed that one had had a submucous resection of the septal cartilage, which could have accounted for the condition. No apparent reason for the condition could be found in the other two workers, whose principal occupations were coremaker and casting cleaner, respectively.

### *Hernia*

During the examination, a check was also made for inguinal hernia by observation and palpation of the scrotal sac as well as both inguinal canals, with the worker in the standing position. Considering previously existent hernias as well as those brought to light at the time of the examination, a rate of 11 percent was found. No relationship was found between the presence of hernia and occupation.

Inguinal hernia was present at the time of the physical examination in 2.3 percent of the workers. For a large series of iron and steel workers recently reported, the incidence of hernia on examination was

4.3 percent (*73*). The difference in the findings for the two series of men may possibly have been due to the differences in the examiners and the criteria used in the two studies.

### *Skin*

Dermatologists participated in the study to the extent of conferring with the regular examining physicians, reviewing the dermatologic data recorded on the medical examination forms, and visiting the foundry in which an outbreak of dermatitis occurred. The medical records showed that, at the time of the examination, 251 foundrymen had some type of skin disease, which was most likely industrial in origin in 33 instances, or in 1.7 percent of the total examined. The 33 cases were distributed as follows: occupational contact dermatitis, 12; heat rash, 18; and occupational acne, 3. The cases were distributed in a random manner through all of the occupational groups.

In the course of the study one of the plants had an outbreak of contact dermatitis. The cases all occurred among coremakers and were shown by patch tests to be caused probably by a phenol-formaldehyde resin which was being newly used as the sand-binding material. With the institution of the customary protective measures, such as protective clothing, barrier creams, and personal cleanliness, new cases ceased to occur. It may be of interest to observe that, since the completion of the field studies of this investigation, other instances of dermatitis outbreaks among coremakers have come to the attention of the Public Health Service. In all cases, the occurrence of disease was halted by the adoption of protective measures

### *Joint and Muscle Pains*

Reports of joint pains as well as muscular aches and pains have been related to occupations involving exposure to high environmental heat, as in the foundry industry, where the worker may be exposed to rapid changes of temperature. Correlation of complaints of muscle and joint pains with occupational group, both for principal and present occupation in which exposure to elevated temperatures varied from group to group, failed to show that any one group had these complaints significantly more frequently than any other.

### *Cardiovascular-renal Disease*

Blood pressure readings, made after a five to ten minute rest period with the worker seated, are shown in table 22, compared with similarly obtained data in the open-hearth steel industry (*64*). While the difference between the blood pressures of the two groups of workers is not spectacular, it may be noted that for each age group the blood pressures of the foundrymen were consistently below those for the open-hearth steelmen. Since there was an observed racial variation of blood pressure, the white workers having somewhat higher readings than the nonwhite, a test was made of the blood pressures of only the white foundrymen and the blood pressures of the white open-hearth steelmen. This, again, suggested that in the present study group the blood pressures were slightly lower for all age groups.

*Table 22.—Mean systolic and diastolic blood pressures of male workers in 16 ferrous foundries in Illinois compared with male open-hearth steelworkers, according to age*

| Age (years) | Systolic blood pressure (mm Hg) | | Diastolic blood pressure (mm Hg) | |
|---|---|---|---|---|
| | Foundry workers | Open-hearth steelworkers[1] | Foundry workers | Open-hearth steelworkers[1] |
| Total | 129.4 | 132.7 | 81.1 | 84.0 |
| Under 25 | 118.5 | 121.7 | 73.5 | 77.3 |
| 25–29 | 121.3 | 124.1 | 76.3 | 80.5 |
| 30–34 | 124.4 | 126.0 | 79.4 | 81.7 |
| 35–39 | 124.7 | 126.9 | 80.3 | 81.7 |
| 40–44 | 129.1 | 130.7 | 82.8 | 85.4 |
| 45–49 | 129.1 | 132.1 | 82.0 | 85.4 |
| 50–54 | 134.6 | 138.8 | 84.3 | 85.9 |
| 55–59 | 140.7 | 148.8 | 87.0 | 90.4 |
| 60 or over | 144.1 | 147.3 | 85.7 | 85.5 |

[1] Reference *64*.

Blood pressures of over 140 mm systolic or 90 mm diastolic, or both, were found in 240 foundrymen, or 13.2 percent. When these were distributed according to principal occupation and years in that occupation, no association was evident.

Study was made of those foundrymen whose blood pressures were recorded as either 160 mm systolic or higher or 100 mm diastolic or higher, or at both of these elevated levels. As would be expected, the 201 foundrymen so affected were specially of the older age groups. When the data were corrected for age, it was found that the elevated blood pressures showed a positive association with increasing degrees of pulmonary fibrosis, the reason for which was not apparent. See table 23.

It is of interest to note that there was a progressive increase in the incidence of elevated blood pressures as the hours at work increased. This refers especially to those examinations made during the day shift and is in conformity with the recognized diurnal blood pressure variation (*74, 75*).

*Table 23.—Roentgenographic pulmonary markings of the 201 males in 16 ferrous foundries in Illinois who had systolic blood pressure of 160 mm of mercury or over and/or diastolic blood pressure of 100 mm of mercury or over, according to age*

| Age (years) | Total[1] | Roentgenographic pulmonary markings | | | | |
|---|---|---|---|---|---|---|
| | | Normal and linear one | Linear two | Ground glass one | Ground glass two | Nodular |
| | Number with elevated blood pressure | | | | | |
| Total | 201 | 28 | 65 | 47 | 36 | 8 |
| Under 40 | 24 | 4 | 11 | 6 | 2 | 0 |
| 40–59 | 113 | 19 | 39 | 23 | 18 | 5 |
| 60 or over | 64 | 5 | 15 | 18 | 6 | 3 |
| | Percent of all foundry workers | | | | | |
| Total | 10.4 | 5.1 | 8.9 | 12.5 | 25.7 | 28.6 |
| Under 40 | 2.6 | 1.1 | 2.9 | 4.4 | 10.5 | 0 |
| 40–59 | 15.0 | 12.8 | 13.5 | 13.0 | 22.8 | 27.8 |
| 60 or over | 26.2 | 14.3 | 23.1 | 29.0 | 38.1 | 30.0 |

[1] Includes persons with roentgenographic pulmonary markings not stated.

In addition to the blood pressure records, the medical study included, in the single examination of each worker, the following for evaluation of cardiac status: (1) Medical history; (2) medical examination, including palpation and auscultation of the heart; (3) blood Kahn serological test for syphilis; and (4) the chest roentgenogram taken at 6-foot target distance. It is recognized that to make a diagnosis of heart disease would require other pertinent data, such as an electrocardiogarm as well as study of the worker on more than one occasion. With the limitations imposed by these facts, however, each clinical record was reviewed and an opinion recorded as to the presence or absence of heart disease; and, if heart disease were suspected, record was made of its etiological diagnosis according to the criteria of the New York Heart Association (*76*). It was found that the data were, in general, similar to the cardiac findings in other studies made by the Public Health Service in recent years.

The cardiac status in silicosis has been studied by many investigators (*77–89*). However, this has centered about right-sided cardiac hypertrophy due to advanced silicosis; that is, conglomerate silicosis. In the present study, only one case of this stage of the lung disease was observed, and thus it would not be expected that cardiac complications would be prominent.

The studies made of the kidneys were limited to urine examinations. Albuminuria was present in 28 single specimens examined. The examination of the urinary sediment, restricted to those urines having albumin, showed a significant number of erythrocytes in 10 specimens, excessive number of leucocytes in 6, and hyaline or finely granular casts in 8. The occupational distribution of the workers who manifested albuminuria was a random one. Their age distribution was not remarkable. As might be expected, it was found that hypertension was associated with albuminuria in some instances. Study of the records of these cases showed no unusual factors in either occupation or medical history.

At this point it is noted that the urine examinations were positive for the presence of glucose in 0.5 percent, or eight cases, an incidence which was similar to that of other studies of industrial groups recently made by the Public Health Service. Seven were for white persons and one for a nonwhite worker. Four were known diabetics who were under therapy for the disease.

### *Blood Studies*

The Kahn serological test for syphilis was done on all blood specimens submitted to the laboratories of the Illinois State Department of Public Health. Satisfactory tests were made for 1,894 of the foundrymen and were reported as positive for 87, or 4.6 percent. Classified by race, it was found that 2.1 percent of the single blood specimens of the white foundrymen gave positive Kahn tests, and 10.3 percent of the nonwhite gave positive tests. This is in harmony with other published reports. (*90, 91*).

The erythrocyte counts of the foundrymen are shown in table 24 compared with those of the open-hearth steelmen recently studied (*64*). It appears from this table that the erythrocyte counts in the present study group were significantly lower than in the other group.

On the other hand, the total leucocyte counts of the foundrymen compared with those of the open-hearth steel workers, shown in table 25, were not significantly different.

Hemoglobin values are recorded in table 26, compared with similar data for open-hearth steel workers. The data indicate that the hemoglobin values for the foundrymen were significantly lower than those of the open-hearth steelmen.

Correlations with occupation of erythrocyte counts, leucocyte counts, and hemoglobin estimations, respectively, showed no association.

Since erythrocyte counts and hemoglobin estimations, respectively,

*Table 24.—Erythrocyte counts for male workers in 16 ferrous foundries in Illinois compared with male open-hearth steelworkers*

| Erythrocyte count (millions per mm³) | Foundry workers | Open-hearth steelworkers[1] | Foundry workers | Open-hearth steelworkers[1] |
|---|---|---|---|---|
| | Number | | Percent | |
| Total | 591 | 350 | 100.0 | 100.0 |
| Under 4.2 | 50 | 0 | 8.6 | 0 |
| 4.2 | 15 | 1 | 2.5 | .3 |
| 4.3 | 24 | 1 | 4.1 | .3 |
| 4.4 | 32 | 3 | 5.4 | .9 |
| 4.5 | 26 | 3 | 4.4 | .9 |
| 4.6 | 48 | 8 | 8.1 | 2.3 |
| 4.7 | 42 | 24 | 7.1 | 6.9 |
| 4.8 | 61 | 59 | 10.3 | 16.8 |
| 4.9 | 60 | 58 | 10.2 | 16.6 |
| 5.0 | 74 | 80 | 12.5 | 22.8 |
| 5.1 | 68 | 68 | 11.5 | 19.4 |
| 5.2 | 44 | 34 | 7.4 | 9.7 |
| 5.3 | 25 | 8 | 4.2 | 2.3 |
| 5.4 | 7 | 3 | 1.2 | .8 |
| 5.5 or over | 15 | 0 | 2.5 | 0 |

[1] Reference *64*.

*Table 25.—Distribution of total leucocyte counts for male workers in 16 ferrous foundries in Illinois compared with open-hearth steel-workers*

| Total leucocyte count per mm³ | Number | | Percent | |
|---|---|---|---|---|
| | Foundry workers | Open-hearth steelworkers[1] | Foundry workers | Open-hearth steelworkers[1] |
| Total | 1,529 | 350 | 100.0 | 100.0 |
| Less than 5,000 | 23 | 1 | 1.5 | .3 |
| 5,000– 6,900 | 295 | 66 | 19.4 | 18.8 |
| 7,000– 8,900 | 513 | 134 | 33.5 | 38.4 |
| 9,000–10,900 | 371 | 86 | 24.3 | 24.5 |
| 11,000–12,900 | 212 | 55 | 13.8 | 15.7 |
| 13,000–14,900 | 91 | 7 | 5.9 | 2.0 |
| 15,000 or over | 24 | 1 | 1.6 | .3 |

[1] Reference *64*.

*Table 26.—Hemoglobin values for male workers in 16 ferrous foundries in Illinois compared with open-hearth steelworkers*

| Hemoglobin (grams per 100 cc of blood) | Foundry workers | Open-hearth steelworkers[1] | Foundry workers | Open-hearth steelworkers[1] |
|---|---|---|---|---|
| | Number | | Percent | |
| Total | 1,528 | 350 | 100.0 | 100.0 |
| Under 13 | 21 | 0 | 1.4 | 0 |
| 13 | 71 | 4 | 4.6 | 1.1 |
| 14 | 250 | 39 | 16.4 | 11.2 |
| 15 | 550 | 102 | 36.0 | 29.2 |
| 16 | 421 | 117 | 27.6 | 33.4 |
| 17 | 181 | 74 | 11.8 | 21.1 |
| 18 | 34 | 14 | 2.2 | 4.0 |

[1] Reference *64*.

were found to be lower for the total foundry population studied when compared with the open-hearth steelmen, and specific occupations in the foundry did not account for the difference, it would appear that factors other than the industry were probably responsible for this situation. For example, geographic differences between the locations of the two groups and dietary influences may be responsible for the blood variations.

Comparative data for hematocrit levels were available for male shipyard workers (*92*) and are shown in table 27, together with hematocrit levels for the foundrymen. No significant differences are manifest

*Table 27.—Hematocrit readings for male workers in 16 ferrous foundries in Illinois compared with male shipyard workers*

| Hematocrit reading (percentage of packed red blood cells) | Number | | Percent | |
|---|---|---|---|---|
| | Foundry workers | Shipyard workers[1] | Foundry workers | Shipyard workers[1] |
| Total | 1,921 | 2,457 | 100.0 | 100.0 |
| Less than 37 | 28 | 6 | 1.5 | .3 |
| 37 and 38 | 38 | 20 | 2.0 | .8 |
| 39 and 40 | 89 | 60 | 4.6 | 2.5 |
| 41 and 42 | 150 | 165 | 7.8 | 6.7 |
| 43 and 44 | 211 | 376 | 11.0 | 15.3 |
| 45 and 46 | 354 | 569 | 18.4 | 23.2 |
| 47 and 48 | 378 | 566 | 19.7 | 23.0 |
| 49 and 50 | 330 | 411 | 17.2 | 16.7 |
| 51 and 52 | 212 | 187 | 11.0 | 7.6 |
| 53 and 54 | 95 | 79 | 4.9 | 3.2 |
| 55 or over | 36 | 18 | 1.9 | .7 |

[1] Reference *92*.

between the two groups. Similar observations were made for corrected erythrocyte sedimentation rates as shown in table 28.

*Table 28.—Corrected sedimentation rates of erythrocytes for male workers in 16 ferrous foundries in Illinois compared with male shipyard workers*

| Corrected sedimentation rate (mm in 1 hour) | Number | | Percent | |
|---|---|---|---|---|
| | Foundry workers | Shipyard workers[1] | Foundry workers | Shipyard workers[1] |
| Total | 1,921 | 2,178 | 100.0 | 100.0 |
| Less than 10 | 981 | 1,222 | 51.1 | 56.1 |
| 10–14 | 489 | 433 | 25.5 | 19.9 |
| 15–19 | 270 | 258 | 14.1 | 11.8 |
| 20–24 | 86 | 121 | 4.5 | 5.6 |
| 25 or over | 95 | 144 | 4.8 | 6.6 |

[1] Reference *92*.

Various studies of occupational diseases have indicated significant or suggestive alterations from normal of the mean corpuscular volume, the mean corpuscular hemoglobin, and the mean corpuscular hemoglobin concentration (*93–96*). Calculations of these indexes (*62, 97, 98*), made for the present study group, are shown in tables 29, 30, and 31. A comparable industrial group was not available to us.

*Table 29.—Mean corpuscular volume of blood of male workers in 16 ferrous foundries in Illinois, according to race*

| Mean corpuscular volume (cu. microns) | Total | Race | | Total | Race | |
|---|---|---|---|---|---|---|
| | | White | Nonwhite | | White | Nonwhite |
| | Number | | | Percent | | |
| Total | 588 | 388 | 200 | 100.0 | 100.0 | 100.0 |
| Less than 86 | 38 | 27 | 11 | 6.5 | 6.9 | 5.5 |
| 86– 89 | 48 | 32 | 16 | 8.2 | 8.3 | 8.0 |
| 90– 93 | 82 | 52 | 30 | 13.9 | 13.4 | 15.0 |
| 94– 97 | 114 | 81 | 33 | 19.4 | 20.9 | 16.5 |
| 98–101 | 98 | 55 | 43 | 16.7 | 14.2 | 21.5 |
| 102–105 | 89 | 54 | 35 | 15.1 | 13.9 | 17.5 |
| 106–109 | 36 | 27 | 9 | 6.1 | 6.9 | 4.5 |
| 110–113 | 44 | 34 | 10 | 7.5 | 8.7 | 5.0 |
| 114–117 | 13 | 10 | 3 | 2.2 | 2.6 | 1.5 |
| 118–121 | 14 | 8 | 6 | 2.4 | 2.1 | 3.0 |
| 122 or over | 12 | 8 | 4 | 2.0 | 2.1 | 2.0 |

*Table 30.—Mean corpuscular hemoglobin of blood of male workers in 16 ferrous foundries in Illinois, according to race*

| Mean corpuscular hemoglobin (gram x $10^{-12}$) | Total | Race | | Total | Race | |
|---|---|---|---|---|---|---|
| | | White | Nonwhite | | White | Nonwhite |
| | Number | | | Percent | | |
| Total | 589 | 389 | 200 | 100.0 | 100.0 | 100.0 |
| Less than 27 | 1 | 1 | 0 | 0.2 | 0.2 | 0 |
| 27 | 1 | 1 | 0 | .2 | .3 | 0 |
| 28 | 11 | 5 | 6 | 1.8 | 1.3 | 3.0 |
| 29 | 42 | 20 | 22 | 7.1 | 5.1 | 11.0 |
| 30 | 116 | 70 | 46 | 19.7 | 18.0 | 23.0 |
| 31 | 137 | 90 | 47 | 23.3 | 23.2 | 23.5 |
| 32 | 159 | 115 | 44 | 27.0 | 29.6 | 22.0 |
| 33 | 70 | 48 | 22 | 11.9 | 12.3 | 11.0 |
| 34 | 30 | 23 | 7 | 5.1 | 5.9 | 3.5 |
| 35 | 4 | 3 | 1 | .7 | .8 | .5 |
| 36 | 8 | 5 | 3 | 1.4 | 1.3 | 1.5 |
| 37 | 6 | 4 | 2 | 1.0 | 1.0 | 1.0 |
| 38 | 2 | 2 | 0 | .3 | .5 | 0 |
| 39 | 2 | 2 | 0 | .3 | .5 | 0 |

*Table 31.—Mean corpuscular hemoglobin concentration of blood of male workers in 16 ferrous foundries in Illinois, by race*

| Mean corpuscular hemoglobin concentration (percent) | Total | Race | | Total | Race | |
|---|---|---|---|---|---|---|
| | | White | Nonwhite | | White | Nonwhite |
| | Number | | | Percent | | |
| Total | 636 | 422 | 214 | 100.0 | 100.0 | 100.0 |
| Less than 27 | 22 | 14 | 8 | 3.4 | 3.3 | 3.7 |
| 27 | 27 | 19 | 8 | 4.2 | 4.5 | 3.7 |
| 28 | 45 | 27 | 18 | 7.1 | 6.4 | 8.4 |
| 29 | 66 | 44 | 22 | 10.4 | 10.4 | 10.3 |
| 30 | 77 | 43 | 34 | 12.1 | 10.2 | 15.9 |
| 31 | 41 | 29 | 12 | 6.4 | 6.9 | 5.6 |
| 32 | 78 | 51 | 27 | 12.3 | 12.1 | 12.6 |
| 33 | 85 | 57 | 28 | 13.4 | 13.5 | 13.1 |
| 34 | 63 | 40 | 23 | 9.9 | 9.5 | 10.8 |
| 35 | 48 | 32 | 16 | 7.5 | 7.6 | 7.5 |
| 36 | 31 | 25 | 6 | 4.9 | 5.9 | 2.8 |
| 37 | 19 | 16 | 3 | 3.0 | 3.8 | 1.4 |
| 38 | 19 | 14 | 5 | 3.0 | 3.3 | 2.3 |
| 39 | 7 | 5 | 2 | 1.1 | 1.2 | .9 |
| 40 or over | 8 | 6 | 2 | 1.3 | 1.4 | 1.0 |

Since differences were noted in the total erythrocyte counts between the foundrymen and the open-hearth steelmen, special study was made of the records showing arbitrarily selected degrees of variation from normal. The six records showing elevations above 5.7 millions per cubic millimeter and the seven showing depressions of 3.5 millions or less per cubic millimeter were reviewed.

The six cases with the high erythrocyte counts had no common factor, either in their medical or work histories, which might have accounted for the condition. They did not show any remarkable degree of pulmonary fibrosis, since all the workers involved had degrees of fibrosis limited to ground glass one or less. (See figure 15 and accompanying text for classification of degrees of pulmonary fibrosis.)

Of the seven records indicating that low erythrocyte counts were present in the workers, in two, the anemia was probably related etiologically to cardiovascular-renal-hypertensive disease, and, in three others, it was possibly of dietary origin. In one, it was probably due to urinary blood loss of unknown etiology, and, in the final case, no reason for the anemia was manifest.

Correlations of all the blood studies with degrees of pulmonary fibrosis appear later in this report.

### *Vital Capacity*

Estimation of pulmonary failure based on vital capacity determination is at best a doubtful procedure (*99*). However, since the use of the more accurate methods of measuring pulmonary capacity and its various components (*100–103*) was not feasible in this investigation, it was believed that vital capacity studies might be of some value. The vital capacity records were used as actual readings, rather than making calculations as to their *percentage of normal* (*104–107*). This was done since the study group provided its own control by virtue of the fact that dustiness varied with occupation as did the degree of pulmonary fibrosis observed.

Table 32 shows the vital capacity readings distributed by age groups. It is apparent from this table that these data are in accord with similar data reported by others (*99*), with an anticipated decrease in vital capacity with increasing age.

Compared with the vital capacity data of a recent study of a somewhat younger age group in which a similar pulmonary dust hazard did not exist in the occupation, and correcting for the factor of age, no significant differences were observed. When the foundrymen were divided into those who smoked tobacco and those who did not, it was found that the vital capacity observations were similar for the two groups.

*Table 32.—Vital capacity of male workers in 16 ferrous foundries in Illinois, according to age and race*

| Vital capacity (liters) | White | | | | | | Nonwhite | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total | Age (years) | | | | | Total | Age (years) | | | | |
| | | Under 30 | 30–39 | 40–49 | 50–59 | 60 or over | | Under 30 | 30–39 | 40–49 | 50–59 | 60 or over |
| | Number | | | | | | | | | | | |
| Total | 1,284 | 219 | 317 | 234 | 305 | 209 | 580 | 192 | 179 | 130 | 63 | 16 |
| Less than 3.0 | 163 | 4 | 8 | 19 | 57 | 75 | 74 | 16 | 14 | 23 | 17 | 4 |
| 3.0–3.9 | 605 | 70 | 125 | 127 | 173 | 110 | 366 | 110 | 122 | 89 | 38 | 7 |
| 4.0–4.9 | 430 | 119 | 140 | 77 | 71 | 23 | 128 | 60 | 42 | 16 | 6 | 4 |
| 5.0 or over | 86 | 26 | 44 | 11 | 4 | 1 | 12 | 6 | 1 | 2 | 2 | 1 |
| | Percent | | | | | | | | | | | |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Less than 3.0 | 12.7 | 1.8 | 2.5 | 8.1 | 18.7 | 35.9 | 12.8 | 8.3 | 7.8 | 17.7 | 27.0 | 25.0 |
| 3.0–3.9 | 47.1 | 32.0 | 39.4 | 54.3 | 56.7 | 52.6 | 63.1 | 57.3 | 68.2 | 68.5 | 60.3 | 43.8 |
| 4.0–4.9 | 33.5 | 54.3 | 44.2 | 32.9 | 23.3 | 11.0 | 22.1 | 31.3 | 23.5 | 12.3 | 9.5 | 25.0 |
| 5.0 or over | 6.7 | 11.9 | 13.9 | 4.7 | 1.3 | .5 | 2.0 | 3.1 | .5 | 1.5 | 3.2 | 6.2 |

Examination was made of the vital capacities by principal occupational groups and years in those occupations. No important association was found. Correlation of vital capacities with observed degrees of pulmonary fibrosis appears later in this report.

### *Chest Roentgenograms*

In evaluating the effect of dust on the lungs, the chest roentgenogram is of paramount importance. This is especially true in exposures to silica dust, as in the present study. Many investigations of the effects on the lungs of silica dust inhalation have amply documented the importance of the roentgenographic findings. It is not to be inferred, however, that correlative medical data, such as history and physical examination, as well as occupational history, are not to be obtained. On the contrary, these data are of great significance, especially for differential diagnosis.

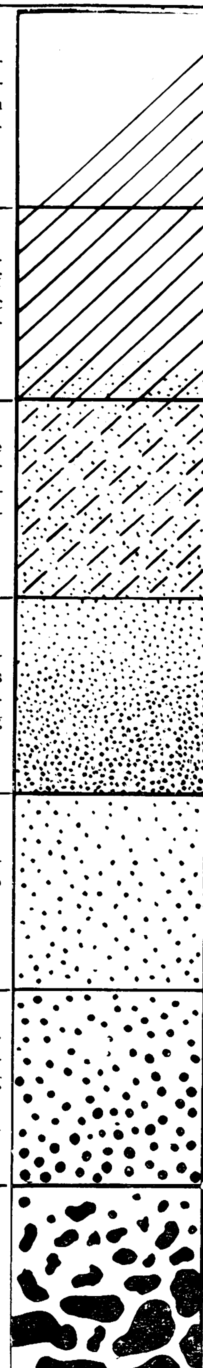
All films, as indicated above, were interpreted by each of two physicians working independently. Where difference of opinion of the interpretation existed, it was resolved by conference between the two interpreters. Assistance from experts in the field of pulmonary tuberculosis studies was obtained for reading those films which were considered suspicious of that disease.

As in previous studies of the industrial pulmonary dust diseases made by the Public Health Service, the findings were classified according to intensity of linear fibrosis, appearance of graininess (ground glass), and nodulation. Figure 15 shows graphically the scheme used to represent the various stages in the progression of the pulmonary fibrotic state due to silica dust inhalation. Figures 16 to 22, inclusive, typical of roentgenograms from the present study, are shown, together with the pertinent clinical data for each.

Generally, films indicated as normal, linear exaggeration one, and linear exaggeration two, may be considered as being within normal limits or due to lung changes unrelated to the dustiness of the occupational environment. The ground glass one appearance may or may not be due to the dust in the environment. Films showing the ground glass two appearance, with the history of exposure to silica dust and with other medical findings essentially negative, are strongly suggestive of an effect due to the dust of the occupational environment. Generalized nodulation and conglomerate masses of nodules appearing in the roentgenogram, together with the data of an occupational exposure to silica dust and the other medical data, signify lung changes due to the dust.

PULMONARY TUBERCULOSIS.—The criteria for interpreting the stage of reinfection type of pulmonary tuberculosis in this study were those of the National Tuberculosis Association (*108*). The degree of activity of the suspected tuberculous cases was classified as probably active, probably inactive, or of doubtful activity, dependent upon the general characteristics of the roentgenographic shadows as well as upon the clinical data. Pulmonary tuberculosis was suspected from the roentgenogram in 25 workers. Review of the clinical records of the workers together with the roentgenograms revealed that the disease was probably active in 5, probably inactive in 8, and of doubtful activity in 12. It is recognized that activity of pulmonary tuberculous lesions cannot be evaluated on the basis of one roentgenographic examination and one medical examination, especially in the absence of sputum studies. The sputum examinations were omitted from this study since it was felt that obtaining such specimens would introduce difficulties which the value of such single specimens would not counterbalance. The data concerning the findings for pulmonary tuberculosis must, therefore, be accepted with caution. Further, it is noted that in at least some instances the onset of the disease may have preceded the time the worker was employed in the foundry industry. This factor could not be fully evaluated since pre-employment chest roentgenograms were not available to us.

Figure *15*. Scheme Representing the Sequence of Lung-Field Markings in a Typical Case of Uncomplicated Silicosis.



| | | |
|---|---|---|
| LINEAR | Normal lung markings and first degree exaggeration of linear pulmonic markings. | This is the range of markings usually seen on roentgen examination of chests of persons who have never worked in a dusty trade. |
| | Second degree exaggeration of linear pulmonic markings, with or without beading. | |
| GRANULAR | First degree diffuse ground glass or grainy appearance, not obliterating linear markings. | These are the earliest markings in the sequence of dust-induced changes which can be generally differentiated from the lung changes that usually accompany advancing age, chronic bronchitis, and heart failure. |
| | Second degree diffuse ground glass or grainy appearance, obliterating linear markings. | |
| NODULAR | First degree disseminated nodules up to size of miliary tubercles. | Cases with nodular markings which may be diagnosed as stage one or stage two silicosis. |
| | Second degree disseminated nodules exceeding one millimeter in size, emphysema present usually. | |
| CONGLOMERATE—COALESCENT CONGLOMERATE SHADOWS | | May be diagnosed as stage three silicosis. |

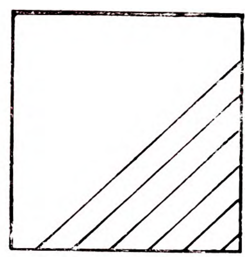
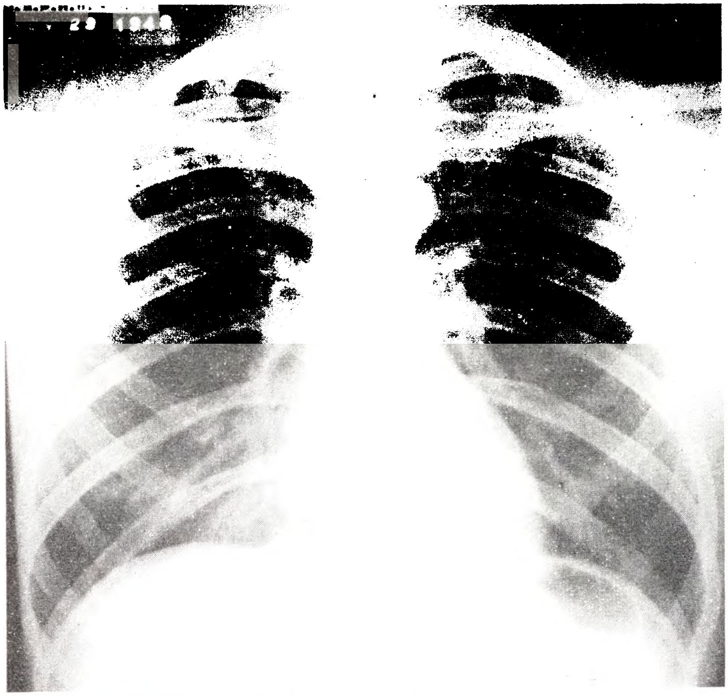


Figure *16*. A typical roentgenogram showing normal lung markings. Schematic presentation shown on right.

*Case 2–19,* age 20, white male, was born in Illinois. He was employed three months as floor molder's helper and three months as laborer in a gray iron foundry. His previous medical history was negative except for a tonsillectomy and sprained knee.

His only complaint was occasional abdominal pain associated with exertion. His physical examination was not remarkable. Blood pressure was 120/70. His temperature was 98.6° F., pulse 60, and respiration 14 per minute. Urine examination was negative. The hemoglobin estimation was 17 grams. His white blood cell count was 9,000 with a differential count of 55 percent neutrophils, 37 lymphocytes, and eight percent monocytes. The corrected erythrocyte sedimentation rate at the end of one hour was one millimeter and hematocrit was 42 percent. The mean corpuscular hemoglobin concentration was 40 percent. His vital capacity was 4.6 liters. His chest roentgenogram was read as normal.



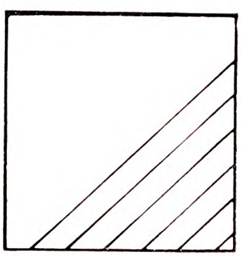


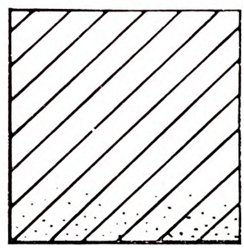
Figure *17.* A typical roentgenogram showing linear one stage of "fibrosis." Schematic presentation shown on left.

*Case 15–40,* age 25, Negro, male. He was a shakeout man in a gray iron foundry for two and one half years.

Physical examination was negative. Blood pressure was 130/82. His temperature was 98.6° F., pulse 72, and respiration 20.

The urine examination was negative. The erythrocyte count was 5.32 million, hemoglobin determination 16 grams, and white blood cell count 9,300 with a differential count of 66 per cent neutrophils, three percent eosinophils, 28 percent lymphocytes and three percent monocytes. The corrected erythrocyte sedimentation rate was eight millimeters at the end of one hour and the hematocrit was 54 percent. The mean corpuscular volume was 102 cubic microns, mean corpuscular hemoglobin 30 micromicrograms and mean corpuscular hemoglobin concentration 30 percent. The Kahn test was negative. His vital capacity was 2.4 liters. His chest roentgenogram was read as showing linear one stage of "fibrosis."

Figure *18.* A typical roentgenogram showing linear two stage of "fibrosis." Schematic presentation shown on right.

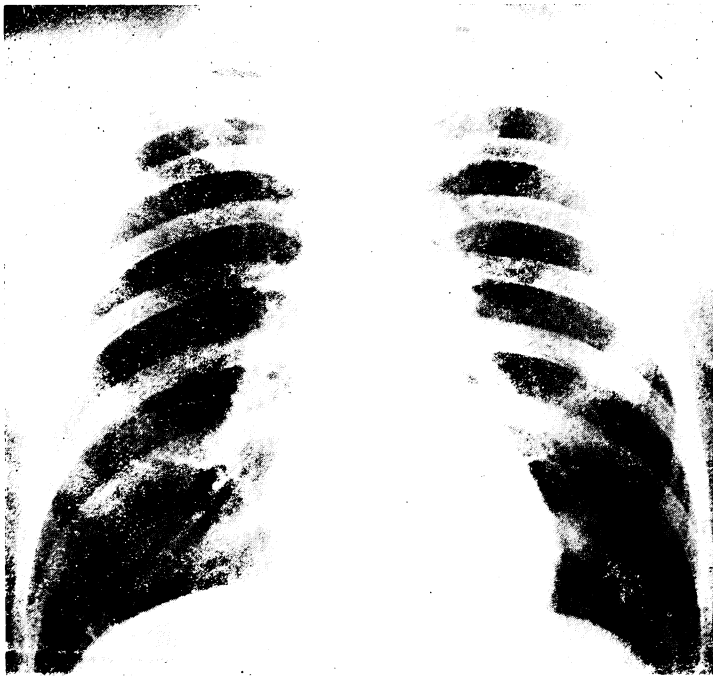


*Case 1–46,* age 31, Negro, male. A molder's apprentice in a gray iron foundry for three years. Before that he was a sawmill laborer for two years, truck driver one year, and army technician three years.

Physical examination was negative. Blood pressure was 120/80. His temperature was 98.8° F., pulse 80, and respiration 28.

Hemoglobin examination showed 18 grams, and the white blood cell count was 8,000 with a differential count of 69 percent neutrophils, one percent eosinophils, 24 percent lymphocytes and five percent monocytes. The corrected erythrocyte sedimentation rate was one millimeter at the end of one hour and the hematocrit was 46 percent. The mean corpuscular hemoglobin concentration was 39 percent. Kahn test was negative.

His vital capacity was 3.5 liters and his roentgenogram showed linear two pulmonary "fibrosis."



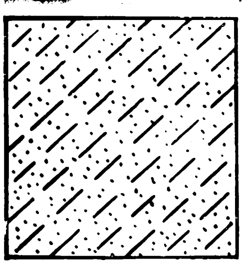


Figure *19*. A typical roentgenogram showing ground glass one stage of "fibrosis." Schematic presentation shown on left.

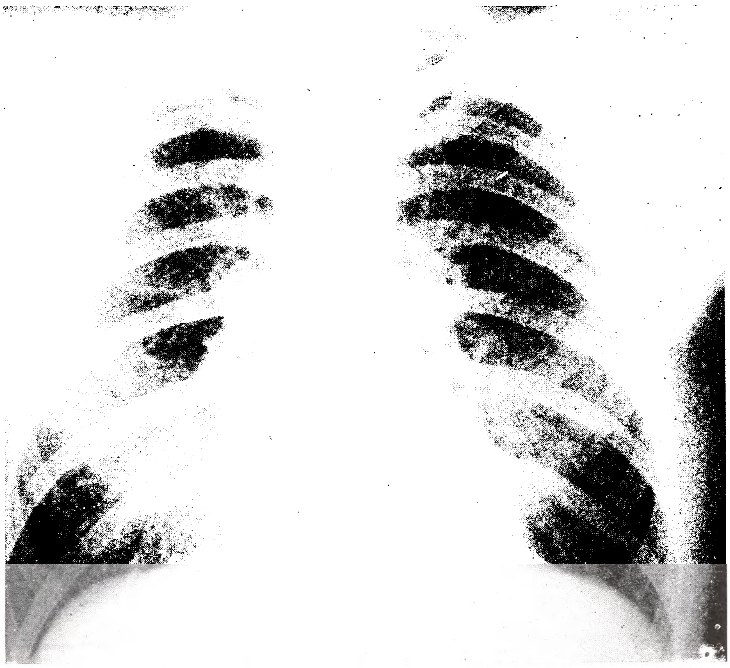
*Case 5–23,* age 72, white male. He was a bench molder in gray iron foundries for 50 years.

He complained of occasional pain in his left shoulder. Examination showed him an obese individual with a barrel chest and kyphosis.

Heart sounds were distant with an occasional extrasystole. Blood pressure was 148/78. The temperature was 98.8° F., pulse 80, and respiration 28.

The hemoglobin estimation was 16 grams and the white blood cell count was 13,000 with a differential count of 65 percent neutrophils, two percent eosinophils, one percent basophils, 22 percent lymphocytes, and 10 percent monocytes. The corrected erythrocyte sedimentation rate was nine millimeters at the end of one hour and hematocrit was 47 percent. The mean corpuscular hemoglobin concentration was 33 percent. The Kahn test was negative.

His vital capacity was 3.3 liters. The roentgenogram was read as showing ground glass one pulmonary "fibrosis."



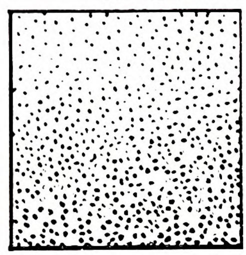


Figure *20.* A typical roentgenogram showing ground glass two stage of "fibrosis." Schematic presentation shown on right.

*Case 4–9,* age 32, male, married, was born in Illinois. He was employed as coremaker for 11 years in a gray iron foundry. His previous history was negative with the exception of fractures of the left forearm and right ring finger.

Physical examination showed evidence of moderately impaired hearing of the left ear, inflammation of the nasal mucosa, and infected tonsils. Blood pressure was 118/80. His temperature was 98.6° F., pulse 74, and respiration 20.

The urine examination was negative. He showed a hemoglobin of 17 grams and a white blood cell count of 9,000 with a differential count of 74 percent neutrophils, 23 percent lymphocytes and three percent monocytes. His corrected erythrocyte sedimentation rate was eight millimeters at the end of one hour and hematocrit was 44 percent. The mean corpuscular hemoglobin concentration was 39 percent. The Kahn test was negative.

His vital capacity was 3.5 liters and his roentgenogram was read as showing ground glass two pulmonary "fibrosis" with hilar calcification.

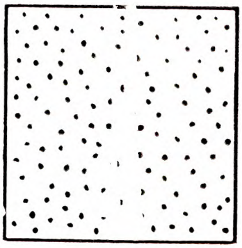


Figure *21.* A typical roentgenogram showing nodular one stage fibrosis. Schematic presentation shown on left.

*Case 10–161,* age 58, white male. He was a cleaner and finisher (grinder) for 39 years in a steel foundry. Except for a mastoidectomy in 1926 and an appendectomy in 1945, his past history was negative.

He had no complaints on examination. Physical examination showed marked nasal septum deviation and scarring of both eardrums with impaired hearing in the right ear. Blood pressure was 160/80. His temperature was 98.8° F., pulse 76, and respiration 18.

The hemoglobin determination was 14 grams and white blood cell count 10,300 with a differential count of 63 percent neutrophils, four percent eosinophils, 28 percent lymphocytes and five percent monocytes. The corrected erythrocyte sedimentation rate was 11 mm at the end of one hour and hematocrit was 38 percent. The mean corpuscular hemoglobin concentration was 37 percent. The Kahn test was negative.

The vital capacity was 3.5 liters and his roentgenogram was read as showing nodular one pulmonary fibrosis.

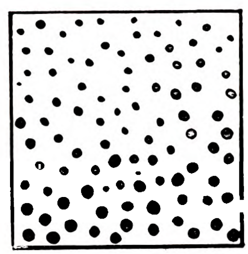


Figure 22. A typical roentgenogram showing nodular stage two fibrosis. Schematic presentation shown on right.

*Case 9–112,* age 57, white male. He was a bench molder for 36 years in a gray iron foundry.

Examination of his chest showed somewhat limited motion, decreased resonance and diminished breath sounds. Blood pressure was 156/90. His temperature was 98.4° F., pulse 60, and respiration 18.

The hemoglobin estimation was 13 grams and the white cell count was 9,400 with a differential count of 62 percent neutrophils, two percent eosinophils, 34 percent lymphocytes and two percent monocytes. The corrected erythrocyte sedimentation rate was 38 mm at the end of one hour and the hematocrit was 34 percent. The mean corpuscular hemoglobin concentration was 38 percent. The Kahn test was negative.

His vital capacity was 4.1 liters and his roentgenogram was read as showing nodular two pulmonary fibrosis.

## Table 33.—Selected data for examined male workers in 16 ferrous foundries in Illinois suspected of having pulmonary tuberculosis

| Case No. | Race | Age (years) | Foundry | | Principal occupation | | Roentgenographic pulmonary markings | Cough | Stage of disease |
|---|---|---|---|---|---|---|---|---|---|
| | | | Type | Service (years) | Title | Service (years) | | | |
| | | | | | Pulmonary tuberculosis, probably active | | | | |
| 14 309 | White | 59 | Steel | 26 | Laborer and other | 26 | Linear fibrosis 2 | No | Moderately adv. |
| 13 127 | do | 66 | Gray iron | 45 | Molder | 45 | do | No | Do. |
| 10 207 | do | 60 | Steel | 30 | Laborer and other | 21 | Linear fibrosis 1 | Yes | Do. |
| 14 169 | Nonwhite | 35 | do | 6 | Shakeout | 6 | Linear fibrosis 2 | Yes | Minimal. |
| 02 047 | White | 63 | Gray iron | 31 | Maintenance and supervisory | 31 | do | No | Do. |
| | | | | | Pulmonary tuberculosis of doubtful activity | | | | |
| 10 045 | White | 54 | Steel | 30 | Molder | 30 | Linear fibrosis 2 | No | Moderately adv. |
| 03 020 | do | 29 | Gray iron | 6 | Laborer and other | 6 | Linear fibrosis 1 | No | Do. |
| 14 048 | do | 59 | Steel | 16 | Maintenance and supervisory | 16 | Ground glass 1 | No | Minimal. |
| 02 073 | do | 58 | Gray iron | 5 | do | 5 | Linear fibrosis 2 | No | Do. |
| 14 032 | do | 63 | Steel | 6 | Coremaker | 6 | do | No | Do. |
| 14 021 | do | 60 | do | 18 | Laborer and other | 18 | Linear fibrosis 1 | Yes | Do. |
| 13 927 | do | 63 | do | 37 | Molder | 37 | do | Yes | Do. |
| 14 329 | Nonwhite | 48 | do | 3 | Maintenance and supervisory | 3 | do | No | Do. |
| 10 157 | White | 67 | do | 6 | Laborer and other | 6 | do | No | Do. |
| 09 097 | do | 38 | Gray iron | 23 | Coremaker | 17 | do | No | Do. |
| 09 020 | do | 62 | do | 42 | Maintenance and supervisory | 28 | do | No | Do. |
| 04 098 | Nonwhite | 38 | do | 3 | Laborer and other | 2 | Normal | Yes | Do. |
| | | | | | Pulmonary tuberculosis, probably inactive | | | | |
| 14 049 | White | 63 | Steel | 20 | Maintenance and supervisory | 12 | Ground glass 2 | Yes | Moderately adv. |
| 15 066 | do | 67 | Gray iron | 31 | Molder | 31 | Ground glass 1 | No | Do. |
| 01 040 | do | 54 | do | 27 | do | 27 | Ground glass 2 | No | Minimal. |
| 13 223 | Nonwhite | 49 | Steel | 15 | Cleaning and finishing | 14 | Ground glass 1 | Yes | Do. |
| 10 091 | White | 62 | Gray iron | 49 | Molder | 49 | Ground glass 1 | No | Do. |
| 14 157 | do | 57 | Steel | 25 | Maintenance and supervisory | 23 | do | No | Do. |
| 14 974 | do | 54 | do | 16 | Cleaning and finishing | 14 | Linear fibrosis 2 | Yes | Do. |
| 09 012 | do | 72 | Gray iron | 47 | Molder | 41 | Linear fibrosis 1 | Yes | Do. |

Table 33 shows the pertinent data for the cases of pulmonary tuberculosis. It will be observed that the reinfection type of the disease was found in 21 white workers and in 4 nonwhite, which yields a rate of 0.7 percent for the white and 1.7 percent for the nonwhite workers. While it is recognized that the methodology pursued in another study for pulmonary tuberculosis incidence in the area in which the foundries were located was somewhat different from that used in the present study, the data from the other survey are presented because of their possible interest. In that survey the rates for suspected pulmonary tuberculosis, based upon almost 300,000 roentgenograms, were reported as 1.75 percent for white adults of both sexes and 1.32 percent for the nonwhite (*109*). In regard to this difference in rates, the importance of the fact that the nonwhite men were generally employed in the foundry industry for a shorter period of time than the white men cannot be evaluated at this time. The age distribution of the tuberculous workers in the present study ranged from 29 to 72 years, with an occurrence of 19 cases in the over-50 age group.

The relationship of the dustiness of the occupation in the foundry industry to the incidence of pulmonary tuberculosis has been discussed by many investigators (*17, 34, 35, 110–113*). In the present study the relationship of pulmonary tuberculosis incidence to that of pulmonary fibrosis was tested for significance, and none was found. In the same vein, it is noted that tuberculous infection was not observed as a complication among the workers with nodular silicosis.

Study was made to determine whether or not dustiness of occupation was itself associated with an increased incidence of pulmonary tuberculosis. Comparison was thus made between the two categories of cleaners and finishers, and coremakers, of which the former was exposed to appreciably more dust than the latter. In these two work categories, it was found that for employees whose roentgenograms showed markings read as normal, linear one, and linear two, conditions regarded as not being related to the dust, no differences existed for the incidence of pulmonary tuberculosis. This was found for those with less than 10 years in the occupation as well as those whose work experience extended beyond 10 years. These data indicate that dustiness of occupation, as it occurred in the ferrous foundry industry in this study, was probably not associated with a greater or less likelihood for the development of pulmonary tuberculosis.

Pulmonary tuberculosis was found more frequently among the steel than the gray iron foundrymen. Thus, whereas the steel foundrymen made up 30 percent of the total study group of 1,937 men, they constituted 60 percent of the cases of tuberculosis. It was found that the probability that such a distribution of the tuberculous cases between the two groups might occur by chance alone was one in a hundred, indicating that the difference was significant.

PULMONARY FIBROSIS.—Chest roentgenograms were made of 1,824 of the 1,937 workers examined in this study. Using the classification and criteria described in figure 15, it was found that 36, or 2.0 percent, manifested normal lung markings; 517, or 28.3 percent, showed linear one markings; 728, or 39.9 percent, showed linear two markings; 375, or 20.6 percent, ground glass one; 140, or 7.7 percent, ground glass two; 24, or 1.3 percent, stage one nodular; 3, or 0.16 percent, stage two nodular; and 1, or 0.05 percent, stage three nodular, or conglomerate silicosis.

Since we examined only those foundrymen who were at work at the time of the study, it is quite likely that the incidence of pulmonary fibrosis observed was lower than had actually occurred in the industry. Obviously, those with manifest lung disease, which might have been found previous to our study, had left the employment. For example, a review of Illinois compensation records of ferrous foundry workers who had instituted claims for chronic pulmonary disease during the years 1941–47 showed there were 89 cases. Of these, 58 were for silicosis; 23, for silico-tuberculosis; and 8, for tuberculosis. Only 15 of the claimants were over 60 years of age.

The data on the incidence of pulmonary fibrosis, compared with studies made by the Public Health Service in other industries (*114–115*) having a silica hazard, and for which similar data were available, are shown in table 34. It appears from this table that the foundrymen have a somewhat greater tendency than either the coal miners or metal miners to develop the ground glass two roentgenographic appearance relatively early. However, among the foundry workers, there is a lesser tendency for the disease to progress to the nodular stage. Thus, after 20 years of exposure in the occupation, the foundrymen show a 20.9 percent incidence of ground glass two stage of fibrosis and 4.9 percent incidence of nodular silicosis; whereas, the corresponding rates for the metal miners are 5.8 and 21.4 percent. Among the coal miners the rates for roentgenograms showing ground glass two and nodular fibrosis are 7.8 and 2.6, respectively.

At this point it might be well to consider the subject of iron deposition in the lungs and its possible relationship to the roentgenographic appearance of silicosis, a matter which has evoked international interest for some years. The earliest notation on this point that we could find in the medical literature dates back to 1919 to a personal communication in which Holland (*117*) mentioned this possibility, since he recognized the relative opacity of iron to roentgen rays. Holland's reference was to the possible occurrence of this condition in iron miners.

Iron mining was thus the first industry in which this possibility was considered. Other occupations that have received attention in this

*Table 34.—Roentgenographic pulmonary markings of male workers in 16 ferrous foundries in Illinois compared with male workers in Utah coal mines[1] and Utah metal mines[2] according to years in industry*

| Industry | Total | Roentgenographic pulmonary markings | | | | |
|---|---|---|---|---|---|---|
| | | Ground glass two | Nodular | | | |
| | | | Total | Stage 1 | Stage 2 | Stage 3 |
| **Number: all years** | | | | | | |
| Foundries | 1,823 | 140 | 28 | 24 | 3 | 1 |
| Utah coal mines | 489 | 12 | 3 | 2 | 1 | 0 |
| Utah metal mines | 719 | 22 | 38 | 13 | 10 | 15 |
| **Number: under 10 years** | | | | | | |
| Foundries | 966 | 19 | 1 | 1 | 0 | 0 |
| Utah coal mines | 200 | 0 | 0 | 0 | 0 | 0 |
| Utah metal mines | 389 | 4 | 0 | 0 | 0 | 0 |
| **Number: 10–19 years** | | | | | | |
| Foundries | 387 | 23 | 4 | 4 | 0 | 0 |
| Utah coal mines | 173 | 3 | 0 | 0 | 0 | 0 |
| Utah metal mines | 227 | 12 | 16 | 8 | 3 | 5 |
| **Number: 20 years or over** | | | | | | |
| Foundries | 470 | 98 | 23 | 19 | 3 | 1 |
| Utah coal mines | 116 | 9 | 3 | 2 | 1 | 0 |
| Utah metal mines | 103 | 6 | 22 | 5 | 7 | 10 |
| **Percent: all years** | | | | | | |
| Foundries | 100.0 | 7.7 | 1.5 | 1.3 | 0.2 | 0 |
| Utah coal mines | 100.0 | 2.5 | .6 | .4 | .2 | 0 |
| Utah metal mines | 100.0 | 3.1 | 5.3 | 1.8 | 1.4 | 2.1 |
| **Percent: under 10 years** | | | | | | |
| Foundries | 100.0 | 2.0 | 0.1 | 0.1 | 0 | 0 |
| Utah coal mines | 100.0 | 0 | 0 | 0 | 0 | 0 |
| Utah metal mines | 100.0 | 1.0 | 0 | 0 | 0 | 0 |
| **Percent: 10–19 years** | | | | | | |
| Foundries | 100.0 | 5.9 | 1.0 | 1.0 | 0 | 0 |
| Utah coal mines | 100.0 | 1.7 | 0 | 0 | 0 | 0 |
| Utah metal mines | 100.0 | 5.3 | 7.1 | 3.5 | 1.3 | 2.2 |
| **Percent: 20 years or over** | | | | | | |
| Foundries | 100.0 | 20.9 | 4.9 | 4.0 | 0.6 | 0.2 |
| Utah coal mines | 100.0 | 7.8 | 2.6 | 1.7 | .9 | 0 |
| Utah metal mines | 100.0 | 5.8 | 21.4 | 4.9 | 6.8 | 9.7 |

[1] Reference *114*.
[2] Reference *115*.

regard have been silver polishing, welding, boiler scaling, and, finally, foundry work. The literature (*118–120*) on the subject concerning iron miners is to a large extent contradictory. Some data indicated that iron of itself caused fibrosis; others showed that the iron compounds modified the roentgenographic appearance of fibrosis due to silica. Experimental work done with the compounds from iron mines have similarly been contradictory (*121, 122*). Rouge (ferric oxide), when inhaled by silver polishers in their occupation, has been shown to produce a roentgenographic appearance of "diffuse fibrosis"; autopsy, however, failed to show fibrotic changes (*123*). Animal experimentation with rouge manifested similar results (*124*).

Electric arc welders are known to be exposed in some instances to appreciable amounts of iron and compounds of iron in the form of fume. Cases have been reported by different investigators (*125–133*) in which it was suggested that the roentgenographic appearances of "fibrosis and nodulation" were in fact due to focal deposition of iron rather than actual fibrotic changes. In five instances, autopsies were available confirming this concept (*126, 134, 135*). There have been some who have disagreed with the concept and who have held the belief that the lung changes were truly fibrotic and were due to the silica or asbestos present in the welding rods (*136, 137*). Results of physiologic tests in cases of welders' siderosis have not been consistent (*138–140*).

Boiler scalers who are exposed to appreciable amounts of iron compounds as well as free silica have been shown to develop pulmonary "fibrotic" changes which, on roentgenography, have appeared much more extensive than autopsy data were able to confirm (*141–147*). It was believed that here, too, deposition of iron caused the roentgenographic appearance.

Finally, in the case of foundry workers, it is suggested that deposition of iron accounts for modification of the silicotic process as well as production of part of the chest roentgenographic appearance itself (*56, 127, 128, 148–151*). This, it has been alleged, is especially the case in casting cleaners.

The foregoing data seem to point to the following facts: (1) That electric arc welders who may be exposed to high concentrations of welding fumes may develop iron deposition in the lungs which in some instances is roentgenographically very difficult to distinguish from nodular silicosis, but which is not associated with pulmonary fibrosis; and (2) that in exposure to iron and silica dust together, there may be a modification of the fibrotic process by the simultaneous presence of the two agents, the iron causing a slowing of the fibrotic process.

In the present investigation, the matter of iron deposition in the lungs received limited attention. The incidence of the various degrees of pulmonary roentgenographic markings was compared for cleaners and finishers, and sandblasters, of which the former were exposed to relatively higher levels of iron dust, as shown by example in table 3. This comparison failed to show that the exposure to the larger amounts of iron resulted in appreciably more marked pulmonary roentgenographic markings.

The 11 roentgenograms of the casting cleaners and finishers which showed nodulation were reviewed and compared with a similar group of roentgenograms of foundry workers whose exposure to iron was very much less. Again no differences were apparent in the two sets of roentgenograms. From the limited study of this problem it would appear, therefore, that the data in the present survey do not support the concept that the factor of iron is of significance in the roentgenographic appearance of the lungs in foundry workers. It is pointed out, however, that 28 cases, the number of workers in the present study who showed nodular fibrosis, were too few to permit a more thorough evaluation of this problem. Only when adequate autopsy material becomes available for such cases will this matter possibly be satisfactorily clarified.

The medical records of the 28 persons whose chest roentgenograms showed nodular fibrosis were reviewed, and the significant data from these case records are shown in table 35. The men ranged in age from 45 to 73 years; 23 of them were over 50 years of age. It will be observed from the table that all were white persons. The absence of nonwhite workers in this series may possibly be explained by the fact that the nonwhite had spent significantly fewer years in foundry work as observed in this study.

Examination of the occupational histories of the group revealed that 18 were gray iron workers and 10, steel workers, a ratio similar to that of these groups in the entire study. Of the 18 iron workers, 14 had the principal occupation of molder, two were cleaners and finishers, one was a laborer, and one, a shakeout man. Of the steel foundrymen, 9 were cleaners and finishers, and 1 was a laborer. The time spent in the principal occupation by each of the men approximated closely the total years each had spent in foundry work; that is, 14 to 52 years. There were 2 men whose years in foundry work were less than 14; 1 had 13, and the other five years of foundry experience. The first of these had been a burner for a significant part of his life in foundry work and may fall into the category of persons exposed to appreciable amounts of iron fume, a group so well described by Hamlin (*149*). For the second worker, whose experience in the foundry was allegedly five years, there were many reasons why his history was considered unreliable.

Three of the workers with nodular fibrosis gave a history of prob-

*Table 35.—Selected data for examined male workers in 16 ferrous foundries in Illinois showing nodular roentgenographic pulmonary markings*

| Case No. | Race | Age (years) | Foundry | | Principal occupation | | Cough | Blood pressure | Vital capacity (liters) | Sedimentation rate (mm in 1 hour) | Hemoglobin (grams per 100 cc of blood) | Total leucocyte count |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Type | Service (years) | Title | Service (years) | | | | | | |
| | | | | | Nodular three | | | | | | | |
| 16-025 | White | 70 | Gray iron | 52 | Molder | 52 | No | 160/ 94 | 2.4 | 5 | 15 | 9,700 |
| | | | | | Nodular two | | | | | | | |
| 09-112 | White | 57 | Gray iron | 36 | Molder | 36 | No | 155/ 90 | 4.1 | 8 | 13 | 9,400 |
| 10-154 | do | 59 | Steel | 34 | Cleaning and finishing | 34 | No | 160/112 | 3.6 | 1 | 16 | 11,400 |
| 11-022 | do | 59 | Gray iron | 21 | Molder | 14 | No | 150/ 86 | 3.0 | 7 | 15 | 5,100 |
| | | | | | Nodular one | | | | | | | |
| 13-077 | White | 64 | Gray iron | 45 | Molder | 45 | No | 180/100 | 2.4 | 15 | 16 | 9,400 |
| 11-003 | do | 50 | do | 40 | do | 40 | No | 130/ 84 | 3.8 | 17 | 14 | 9,200 |
| 10-161 | do | 58 | Steel | 39 | Cleaning and finishing | 39 | No | 160/ 80 | 3.5 | 11 | 14 | 10,300 |
| 11-001 | do | 60 | Gray iron | 38 | Molder | 38 | No | 120/ 70 | 4.2 | 9 | 16 | 11,100 |
| 16-001 | do | 62 | do | 36 | do | 36 | No | 128/ 76 | 3.3 | 25 | 14 | 5,100 |
| 04-050 | do | 65 | do | 35 | do | 35 | No | 90/ 70 | 3.0 | 13 | 14 | 14,000 |
| 04-027 | do | 57 | do | 35 | do | 35 | ---- | 130/ 84 | 2.4 | 32 | 15 | 11,400 |
| 11-002 | do | 63 | do | 34 | do | 34 | Yes | 156/102 | 3.3 | 27 | 17 | 10,600 |
| 13-113 | do | 67 | do | 37 | do | 32 | No | 156/ 96 | ---- | 8 | 12 | 8,000 |
| 13-125 | do | 56 | do | 33 | do | 32 | No | 150/ 90 | 2.5 | 31 | 14 | 4,400 |
| 13-139 | do | 57 | do | 32 | do | 31 | No | 140/ 82 | 2.3 | 17 | 13 | 9,000 |
| 14-143 | do | 57 | Steel | 31 | Cleaning and finishing | 31 | No | 122/ 80 | 3.4 | 13 | ---- | ---- |
| 10-164 | do | 65 | do | 30 | Laborer and other | 30 | No | 150/ 80 | 3.0 | 21 | 16 | 11,200 |
| 10-122 | do | 54 | do | 28 | Cleaning and finishing | 28 | No | 136/ 90 | 3.9 | 8 | 15 | 12,300 |
| 14-138 | do | 53 | do | 35 | do | 26 | No | 132/ 90 | 3.6 | 10 | ---- | ---- |
| 14-068 | do | 57 | do | 27 | do | 25 | Yes | 95/ 70 | 2.8 | 9 | ---- | ---- |
| 04-045 | do | 45 | Gray iron | 25 | Molder | 25 | No | 154/100 | 4.1 | 9 | 14 | 11,600 |
| 03-010 | do | 48 | do | 24 | Cleaning and finishing | 24 | No | 140/ 80 | 4.5 | 12 | 15 | 11,400 |
| 09-070 | do | 47 | do | 23 | Laborer and other | 23 | No | 156/100 | 3.4 | 11 | 15 | 8,800 |
| 02-016 | do | 45 | do | 18 | Cleaning and finishing | 18 | No | 120/ 82 | 3.5 | 11 | 15 | 9,000 |
| 14-115 | do | 54 | Steel | 15 | do | 15 | Yes | 140/100 | 4.1 | 7 | ---- | ---- |
| 14-128 | do | 73 | do | 14 | do | 14 | Yes | 135/ 80 | 3.8 | ---- | ---- | ---- |
| 10-173 | do | 46 | do | 13 | do | 7 | No | 122/ 80 | 3.4 | 15 | 16 | 11,800 |
| 13-276 | do | 60 | Gray iron | 5 | Shakeout | 5 | No | 150/ 90 | 2.4 | 14 | 13 | 6,200 |

ably significant inorganic dust exposure in other activities prior to their foundry experience; one was employed in brick and tile manufacturing, one performed welding, and the third worked in a brick yard.

Among the 18 gray iron foundrymen with nodular fibrosis there were 14 molders; 11 with nodular stage one, 2 with nodular stage two, and 1 with nodular stage three. The remaining gray iron foundrymen were two cleaners and finishers, one laborer and one shakeout man, all with nodular one stage of fibrosis. Of the 10 steel foundrymen, 8 cleaners and finishers had nodular stage one fibrosis, one cleaner and finisher had nodular stage two, and one shakeout man had nodular stage one fibrosis. It thus appears that for the iron foundrymen the molders have a higher incidence of nodular silicosis; whereas, for the steel workers the cleaners and finishers have the higher incidence. The high incidence rate for the molders among the gray iron foundrymen is probably due to their long exposure. Of the two iron foundrymen, with nodular two fibrosis, one had more than 25 years' experience. The one man with conglomerate silicosis had 52 years in his occupation as a molder. Six of the nine steel workers with nodular one stage of fibrosis had 25 years or more of experience. The one steel worker with nodular two fibrosis had 34 years in his principal occupation.

Review of the symptoms of this group revealed that four complained of cough and one of chest pain. It is of interest to note that in no instance was dyspnea recorded. Vital capacity ranged from 2.4 to 4.5 liters, with the distribution of the vital capacity records for the group similar to that of the total group studied, when correction was made for age. Comparison of the various hematologic studies for this series with those of the entire group of foundrymen showed no significant differences when correction was made for age.

### *Correlation of Pulmonary Fibrosis with Other Data*

PULMONARY FIBROSIS AND PREVIOUS OCCUPATION.—As mentioned above, there were 73 foundrymen, approximately four percent, whose work histories included periods during which their employments were in dusty trades, other than foundry work. Of these, 67 had been miners; 56 in coal and 11 in miscellaneous kinds of mining. Of the remaining six, one had worked in a coal mine and a pottery; one, as a stone cutter; two, in stone quarries; and two, in rock crushing.

The medical and historical data for each of these men were reviewed. On the basis of the general knowledge of the degree and nature of the dustiness of their former trades, as well as upon the time spent in the former and present occupations, efforts were made to determine what influence the former dusty occupation probably had upon the degree of pulmonary fibrosis observed in the present study. It was believed that in only a relatively small number was there a likelihood that the former occupation was etiologically of importance. All of these had ground glass roentgenographic changes, some having ground glass one and some, ground glass two. It is of some interest to note that, of the 28 foundrymen showing nodular fibrosis, only three had work histories of previously limited dust exposure; one had been employed in a brick yard; and a second, in brick and tile manufacturing; the third was a worker who had been a welder previously.

On the basis of the foregoing data, it is not felt that previous occupation in a dusty trade, other than in foundries, had a significant influence on the degree of pulmonary fibrosis observed in this study. Further evidence lending support to this observation was found by comparing the frequency in this study of the occurrence of previous dusty occupations of groups showing varying degrees of pulmonary fibrosis.

It is not possible to evaluate fully for the foundrymen studied previous dustiness in ferrous foundry work. As has previously been stated in this report, there is good reason to believe that dust conditions in general in the foundry industry have improved in the past 10 to 20 years. The lower dust levels found in our study and another recent study (*20*), as compared to those found in earlier investigations, tend to bear this out. Thus, it is likely that in many instances the pulmonary fibrosis observed was due in great part to higher dust concentrations which probably existed 10, 15, or more years previously in foundries.

PULMONARY FIBROSIS AND PRINCIPAL OCCUPATION.—Tables 36 and 37 show the incidence rates of pulmonary fibrosis, as observed by roentgenogram, for the various occupational groups of the ferrous foundrymen according to years of experience. It will be observed from these tables that pulmonary fibrosis, in the degrees of ground glass two and nodular, occurred in 10.0 percent of the total of gray iron workers, and for the steel workers a percent of 7.9 was yielded; the difference between these two rates was not statistically significant and is contrary to many previous reports of foundry studies (*32, 36, 38, 49*). In both types of ferrous foundry workers there was a progressive increase of incidence rates with increasing years of exposure from less than ten to over 20 years. Further, the fact that no significant difference was found between the incidence rates of pulmonary fibrosis between gray iron foundrymen and steel foundrymen was not due to any difference in years of exposure between these two groups, each considered as a whole, since the average number of years of experience of gray iron foundrymen and of steel foundrymen respectively was approximately the same in this study.

Reference is now made to column A of table 10 from which it will be observed that the weighted dust exposures as defined were 3.2 mppcf for shakeout men, 2.7 for cleaners and finishers, 2.7 for molders,

*Table 36.—Distribution of males in 16 ferrous foundries in Illinois with respect to degree of roentgenographic pulmonary markings according to years in principal occupation for gray iron and steel foundries*

| Principal occupation | Total | | Years in principal occupation | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Less than 10 | | 10 to 19 | | 20 or over | |
| | Roentgenographic pulmonary markings | | | | | | | |
| | Ground glass one or less | Ground glass two and nodular | Ground glass one or less | Ground glass two and nodular | Ground glass one or less | Ground glass two and nodular | Ground glass one or less | Ground glass two and nodular |
| | Total | | | | | | | |
| Total | 1,654 | 168 | 1,023 | 27 | 331 | 38 | 390 | 103 |
| Shakeout | 199 | 11 | 166 | 5 | 23 | 5 | 10 | 1 |
| Cleaning and finishing | 286 | 38 | 202 | 7 | 64 | 15 | 20 | 16 |
| Molder | 436 | 84 | 214 | 6 | 94 | 8 | 128 | 70 |
| Laborer and other | 353 | 23 | 267 | 7 | 52 | 5 | 34 | 11 |
| Maintenance and supervisory | 155 | 5 | 82 | 1 | 38 | 3 | 35 | 1 |
| Coremaker | 225 | 7 | 92 | 1 | 60 | 2 | 73 | 4 |
| | Gray iron foundries | | | | | | | |
| Total | 1,056 | 117 | 670 | 17 | 182 | 21 | 204 | 79 |
| Shakeout | 140 | 8 | 118 | 4 | 14 | 4 | 8 | 0 |
| Cleaning and finishing | 159 | 9 | 125 | 1 | 26 | 4 | 8 | 4 |
| Molder | 313 | 77 | 147 | 4 | 68 | 5 | 98 | 68 |
| Laborer and other | 223 | 14 | 178 | 6 | 30 | 5 | 15 | 3 |
| Maintenance and supervisory | 90 | 3 | 46 | 1 | 22 | 1 | 22 | 1 |
| Coremaker | 131 | 6 | 56 | 1 | 22 | 2 | 53 | 3 |
| | Steel foundries | | | | | | | |
| Total | 598 | 51 | 353 | 10 | 149 | 17 | 96 | 24 |
| Shakeout | 59 | 3 | 48 | 1 | 9 | 1 | 2 | 1 |
| Cleaning and finishing | 127 | 29 | 77 | 6 | 38 | 11 | 12 | 12 |
| Molder | 123 | 7 | 67 | 2 | 26 | 3 | 30 | 2 |
| Laborer and other | 130 | 9 | 89 | 1 | 22 | 0 | 19 | 8 |
| Maintenance and supervisory | 65 | 2 | 36 | 0 | 16 | 2 | 13 | 0 |
| Coremaker | 94 | 1 | 36 | 0 | 38 | 0 | 20 | 1 |

and 1.0 for coremakers, all for gray iron foundrymen. Thus, all other factors being equal, it might be expected that the frequency of the occurrence of pulmonary fibrosis would be in proportion to those weighted dust exposures. From tables 37 and 10 it is noted that, in the gray iron foundrymen, among the four occupational groups of

*Table 37.—Percent of male workers in gray iron foundries in Illinois with roentgenographic pulmonary markings of ground glass two or nodular according to years in principal occupation (derived from table 36)*

| Principal occupation | Total | Years in principal occupation | | |
|---|---|---|---|---|
| | | Less than 10 | 10 to 19 | 20 or over |
| Total | 10.0 | 2.5 | 10.3 | 27.9 |
| Shakeout | 5.4 | 3.3 | 22.2 | 0 |
| Cleaning and finishing | 5.4 | .8 | 13.3 | 33.3 |
| Molder | 19.7 | 2.6 | 6.8 | 41.0 |
| Laborer and other | 5.9 | 3.3 | 14.3 | 16.7 |
| Maintenance and supervisory | 3.2 | 2.1 | 4.3 | 4.3 |
| Coremaker | 4.4 | 1.8 | 8.3 | 5.4 |

shakeout men, molders, cleaners and finishers, and coremakers, the incidence rates of pulmonary fibrosis show a trend in the expected direction; that is, as the weighted dust exposures decrease, the rates for pulmonary fibrosis decrease. This trend is probably somewhat more apparent when the groups of molders, and cleaners and finishers, the two occupational classes having similar dust exposures, are considered together.

The major aberration observed in table 37 is that there are no cases of pulmonary fibrosis among the shakeout men after 20 years at this occupation. This is in part probably due to the fact that there were only eight shakeout men with such a length of experience.

It is pointed out that there was a higher incidence rate for fibrosis among the molders than among cleaners and finishers, in both of which the weighted dust exposures were similar. This difference may possibly be accounted for by the fact that molders had more years of experience in their occupation. Further, the iron content was appreciably higher for the cleaners and finishers than it was for the molders. The part that iron itself may have played in the roentgenographic appearances observed cannot be evaluated at this time. This matter was discussed in detail in another section of this report.

Knowledge of particle size distribution of inorganic dust which may be inhaled is of importance in the evaluation of the effects of the dust. In this study such measurements were made and appear in table 4. It is doubted that the moderate variations noted are of physiological significance for the airborne dust of the ferrous foundry.

PULMONARY FIBROSIS AND HISTORY OF FAMILIAL TUBERCULOSIS.—It is generally accepted that not all persons equally exposed to silica dust develop silicosis. Similarly, not all persons equally exposed to tubercle bacilli develop the reinfection type of pulmonary tuberculosis (*152–155*). The basis of susceptibility and immunity is not fully understood in either of these instances. In the present study, it appeared useful to test whether or not, in both instances, a similar mechanism might be operative. Since heredity is accepted by many as a factor in susceptibility to tuberculosis, the incidence of pulmonary fibrotic changes due to the silica dust in the ferrous foundries was tested against the occurrence of a history of familial tuberculosis. No such relationship was found since those whose lungs showed the degree of fibrosis of ground glass two or evidence of further advanced fibrosis, had a familial pulmonary tuberculosis incidence not significantly different from those who did not have such roentgen evidence of pulmonary fibrosis.

PULMONARY FIBROSIS AND OTHER DISEASE ENTITIES OF RESPIRATORY AND CARDIOVASCULAR SYSTEMS.—The diseases considered were bronchial asthma, chronic nasal sinusitis, pleurisy or pneumonia, chronic tracheobronchitis, and heart disease. These diseases, when tested separately, as well as a group, failed to show significant correlation with the occurrence of pulmonary fibrosis.

PULMONARY FIBROSIS AND CERTAIN SYMPTOMS, PULSE RATE, AND WEIGHT DEVIATIONS.—The pulmonary roentgenographic findings were correlated with the symptoms generally believed to be most frequently associated with silicosis; namely, dyspnea, cough, and chest discomfort (or pain). Only cough and dyspnea were found to be positively associated with the degree of pulmonary fibrosis to the extent that such fibrosis occurred in this study.

The pulse rates did not show association with the degrees of pulmonary fibrosis.

The findings in this study of the deviation of the weight from the average were discussed previously. When the data were distributed according to observed degrees of pulmonary fibrosis, no association was evident. This is not surprising in view of the fact that in this study there was only one case of conglomerate silicosis and no instances of silico-tuberculosis.

PULMONARY FIBROSIS AND FREQUENCY OF COMMON COLD.—Data on the frequency of the common cold were divided into two groups, of which the first represented those workers who gave histories of having had two or less colds during the previous year and the second represented those who had had more than two colds during that time. Recognizing the difficulty of obtaining reliable information about common cold frequency beyond the previous year, we believed that one might, for present purposes only, consider the frequency of this disease for the past year as representing possibly its frequency in other years as well. These data, when correlated with the observed pulmonary fibrotic conditions, failed to show association. Thus, it would seem that the history of frequent common colds, as here defined, does not make more or less likely the development of pulmonary fibrosis from exposure to siliceous dust as found in the present study.

PULMONARY FIBROSIS AND BLOOD FINDINGS.—Reports on the blood findings in pulmonary fibrotic conditions due to inorganic dusts, especially silica, have appeared from time to time in the medical literature (*156–165*). In a study reported from the Public Health Service (*166*), suggestive data of a positive relationship in this regard were reported for erythrocyte sedimentation rate and for differential leucocyte count. The hematologic data collected in the present study permitted further extension of these observations.

It was found that, whereas no correlation with degree of pulmonary fibrosis existed for erythrocyte count, hematocrit value, hemoglobin estimation, mean corpuscular volume, mean corpuscular hemoglobin, and mean corpuscular hemoglobin concentration, significant correlations were found between the degree of lung changes and the total leucocyte count as well as with the corrected erythrocyte sedimentation rate (tables 38 and 39). As the degree of pulmonary fibrosis increased for the group, the total leucocyte counts were elevated, and the corrected erythrocyte sedimentation rates were found to be more rapid. Similar observations have been made by others and have been variously interpreted (*157, 158*).

The present data do not warrant the opinion that the blood changes observed indicate infection superimposed on the pulmonary fibrosis. Rather, it appears that the lung fibrosis may itself be associated with an elevated leucocyte count and an increased erythrocyte sedimentation rate, confirming an opinion expressed in recent publications on this subject (*157, 158*). It is of interest to note that for the 28 cases of nodular silicosis the corrected sedimentation rate after one hour was over ten millimeters in 16 persons and under ten millimeters in 11 persons. The one worker with conglomerate silicosis had a sedimentation rate of five millimeters.

It is recognized that conglomerate silicosis, a condition sometimes associated with an increase of erythrocyte count and hemoglobin, occurred in only one instance in the present study. Thus, it is to be noted that to the degree that pulmonary fibrosis was found in this study, there was a tendency for the erythrocyte sedimentation rates to be accelerated and the total leucocyte counts to be elevated.

Consideration was given to the possibility that the presence of complicating pulmonary tuberculosis could have been responsible for the accelerated erythrocyte sedimentation rate. This factor appeared to be of doubtful importance in the present study for the following reasons: (1) Tuberculosis was not found in any of the 28 cases of

*Table 38.—Total leucocyte counts for male workers in 16 ferrous foundries in Illinois according to roentgenographic pulmonary markings*

| Total leucocyte count per mm³ | Total | Roentgenographic pulmonary markings | | | |
|---|---|---|---|---|---|
| | | Normal, linear one, or linear two | Ground glass one | Ground glass two | Nodular |
| | Number | | | | |
| Total | 1,425 | 976 | 306 | 120 | 23 |
| Less than 5,000 | 22 | 17 | 2 | 2 | 1 |
| 5,000–6,900 | 279 | 209 | 59 | 8 | 3 |
| 7,000–8,900 | 479 | 354 | 94 | 29 | 2 |
| 9,000–10,900 | 340 | 221 | 76 | 35 | 8 |
| 11,000–12,900 | 195 | 111 | 49 | 27 | 8 |
| 13,000–14,900 | 88 | 52 | 22 | 13 | 1 |
| 15,000 or over | 22 | 12 | 4 | 6 | 0 |
| | Percent | | | | |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Less than 5,000 | 1.5 | 1.7 | 0.7 | 1.7 | 4.4 |
| 5,000–6,900 | 19.6 | 21.4 | 19.3 | 6.6 | 13.0 |
| 7,000–8,900 | 33.6 | 36.3 | 30.7 | 24.2 | 8.7 |
| 9,000–10,900 | 23.9 | 22.7 | 24.8 | 29.2 | 34.8 |
| 11,000–12,900 | 13.7 | 11.4 | 16.0 | 22.5 | 34.8 |
| 13,000–14,900 | 6.2 | 5.3 | 7.2 | 10.8 | 4.3 |
| 15,000 or over | 1.5 | 1.2 | 1.3 | 5.0 | 0 |

nodular fibrosis observed; (2) the erythrocyte sedimentation rates observed for the 25 cases of pulmonary tuberculosis found in this study ranged from 5 to 23 millimeters, with a mean of 13 millimeters; and (3) these cases were too few to affect the average of the sedimentation rates observed for the relatively large number of cases of diffuse pulmonary fibrosis studied.

Increased speed of settling of erythrocytes occurs in many disease states and is therefore a nonspecific test, as is the occurrence of leucocytosis or an elevated temperature. Thus, in general, it is used to call attention to occult diseases or as a means of gauging the progress of recognized disease states. In the present study, the presence of certain of such disease states, which could have given rise to an acceleration of the sedimentation rate, was likely. Nevertheless, there is no reason

*Table 39.—Corrected sedimentation rates of erythrocytes for male workers in 16 ferrous foundries in Illinois according to roentgenographic pulmonary markings and age*

| Corrected sedimentation rate (mm in 1 hour) | Total | Roentgenographic pulmonary markings | | | |
|---|---|---|---|---|---|
| | | Normal, linear one, or linear two | Ground glass one | Ground glass two | Nodular |
| | Number, under 40 years | | | | |
| Total | 892 | 739 | 134 | 19 | 0 |
| Less than 10 | 556 | 474 | 70 | 12 | 0 |
| 10 or over | 336 | 265 | 64 | 7 | 0 |
| | Number, 40 years or over | | | | |
| Total | 917 | 534 | 235 | 116 | 32 |
| Less than 10 | 369 | 239 | 88 | 32 | 10 |
| 10 or over | 548 | 295 | 147 | 84 | 22 |
| | Percent, under 40 years | | | | |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | ---------- |
| Less than 10 | 62.3 | 64.1 | 52.2 | 63.2 | ---------- |
| 10 or over | 37.7 | 35.9 | 47.8 | 36.8 | ---------- |
| | Percent, 40 years or over | | | | |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Less than 10 | 40.2 | 44.8 | 37.5 | 27.6 | 31.3 |
| 10 or over | 59.8 | 55.2 | 62.5 | 72.4 | 68.7 |

to suspect that such disease states would be more frequent in those with pulmonary fibrosis than they would be in those without pulmonary fibrosis. This last hypothesis was tested and was found to be the fact. Thus, it is felt that the elevated sedimentation rate was probably due to the pulmonary fibrosis itself as it was found in the present study.

PULMONARY FIBROSIS AND VITAL CAPACITY.—To the degree that pulmonary fibrosis was observed in the present study, it is doubtful that one would anticipate a decrease in vital capacity below normal.

Further, it must again be noted that the men examined were performing hard labor, which they could not do with any ease had they manifested signs of respiratory failure. It is not surprising, therefore, to find that vital capacity in the study did not show a decline with increasing degree of pulmonary fibrosis. Similar observations have been made by others (*99*).

Thus, as shown earlier in this report, the degree of dustiness in the occupation as well as duration of employment was coincident with decrease of the vital capacity. Nevertheless, this alteration was apparently not due to the development of pulmonary fibrosis.

PULMONARY FIBROSIS AND TOBACCO SMOKING.—When tested, the data failed to show a relation between the smoking of tobacco and the lung roentgenogram findings.

## DENTAL FINDINGS

Data were gathered to determine the possible effects of the direct action of atmospheric contaminants on the oral structures and to note any oral changes that may have resulted from systemic disturbances of occupational origin. In addition to these data, pertinent information was obtained on general oral health status.

Oral examinations were performed on 1,903 employees of the 16 ferrous foundries. The dental examination was performed concurrently with the medical examination, utilizing standard dental equipment. The conditions were recorded on the form shown as figure 14, and were limited to those which could be observed with the aid of a plane mouth mirror and a diagnostic light properly adjusted to assure maximum illumination. Bite-wing roentgenograms were obtained from a number of the men examined.

The age distribution of the white and nonwhite workers who had a dental examination is given in table 40. It will be noted that the

*Table 40.—Number and percent of male workers in 16 ferrous foundries in Illinois who were given dental examinations, according to age and race*

| Age (years) | Number | | Percent | |
|---|---|---|---|---|
| | White | Nonwhite | White | Nonwhite |
| Total | 1,312 | 591 | 100.0 | 100.0 |
| Under 25 | 112 | 101 | 8.5 | 17.1 |
| 25–34 | 280 | 188 | 21.4 | 31.8 |
| 35–44 | 272 | 163 | 20.7 | 27.6 |
| 45–54 | 256 | 103 | 19.5 | 17.4 |
| 55 or over | 392 | 36 | 29.9 | 6.1 |

distributions are not similar. Thus, 29.9 percent of the white males are 55 years of age or over, as compared with only 6.1 percent of the nonwhite males.

### *Dental Caries*

In an effort to determine whether or not any racial differences existed relative to dental caries, the white and nonwhite were divided into those with teeth, and those who were edentulous. Table 41 shows, according to age group, the number of untreated carious, missing, and filled teeth per one hundred persons. These data are presented on the basis of 32 teeth per person.

In the group under 25 years of age the two races show about the same number of untreated carious teeth, but with advancing age the nonwhite exceed the white in each age group. Generally, the nonwhite males had more untreated caries than the white. With respect to missing and filled teeth, respectively, the reverse is shown. It is of further

*Table 41.—Number of untreated carious teeth, missing teeth, and filled teeth per 100 males and number of edentulous persons among workers in 16 ferrous foundries in Illinois according to age and race*

| Age (years) | Edentulous | Nonedentulous | | | |
|---|---|---|---|---|---|
| | Number of males | Number of males | Number of teeth per 100 males | | |
| | | | Untreated caries | Missing | Filled |
| | | | White | | |
| Total | 207 | 1,105 | 229 | 911 | 360 |
| Under 25 | 0 | 112 | 277 | 401 | 490 |
| 25–34 | 5 | 275 | 208 | 630 | 592 |
| 35–44 | 32 | 240 | 229 | 857 | 399 |
| 45–54 | 47 | 209 | 216 | 1,180 | 216 |
| 55 or over | 123 | 269 | 241 | 1,248 | 144 |
| | | | Nonwhite | | |
| Total | 28 | 563 | 294 | 458 | 158 |
| Under 25 | 0 | 101 | 275 | 203 | 183 |
| 25–34 | 0 | 189 | 264 | 284 | 202 |
| 35–44 | 6 | 156 | 315 | 529 | 124 |
| 45–54 | 16 | 87 | 354 | 769 | 132 |
| 55 or over | 6 | 30 | 267 | 1,150 | 40 |

*Note:* Based on 32 teeth.

interest to note that for all age groups the white males had nearly twice as many teeth missing and more than twice as many filled as the nonwhite.

In addition to comparing the data of the white and nonwhite groups, the rate of decayed, missing, and filled teeth for white male foundry workers is evaluated. For such evaluation, data for male foundry workers are compared with similar information from a study of mine and smelter workers (*167*). In making this comparison the third molars are excluded; consideration is thus given to 28 teeth for each mouth. The pertinent data are presented in table 42. It will be noted that, for all ages of the four industrial groups studied, the foundry workers have less untreated carious teeth. For each group studied, there is in general a steady decline in the number of untreated carious teeth with advance in age. For each respective age group the foundry workers have fewer teeth missing than the coal miners, metal miners, and smelter workers. When consideration is given to all age groups combined, the foundry workers have more teeth missing than the other groups, a condition attributable to the greater proportion of foundry workers who were 55 years of age and over.

For all ages, the rate of filled teeth for the foundry worker is less than that of the metal mine and smelter workers but more than was observed among the coal miners. In the two age groups under 35 years, the number of teeth filled per hundred males for the foundry worker is greater than was observed in the metal, coal mine, and smelter workers, respectively, with the exception of the 25–34 year age group of smelter workers who presented a slightly higher rate of filled teeth. For age groups 35–44 and over, the metal mine and smelter workers have a higher rate of filled teeth than the foundry workers. Considering each age group, the foundry workers had a higher rate of filled teeth than the coal miners.

For all industries there is a gradual increase in the rate of missing teeth with advancing age. Generally speaking, the rate of filled teeth and carious teeth per hundred males steadily decreases with advancing age. It follows, therefore, that with the advance in age, fewer teeth remain to become carious or filled. When consideration is given to all three factors—decayed, filled, and missing teeth combined for respective age groups—the foundry workers have a slightly more favorable experience, with the exception of coal miners in age groups under 34 years.

Roentgenography was used on a limited number of workers to determine the number of interproximal caries which had penetrated the enamel, in addition to those found by an examination with a mouth mirror and diagnostic light. For this purpose, 788 plates, containing two quadrants with the upper and lower biscuspids and molars, were

*Table 42.—Number of untreated carious teeth, missing teeth, and filled teeth per 100 white males among workers in 16 ferrous foundries in Illinois according to age compared with metal mine, coal mine, and smelter workers*

| Age (years) | Number of workers examined | Number of teeth per 100 males | | |
|---|---|---|---|---|
| | | Untreated caries | Missing | Filled |
| | Foundries | | | |
| Total | 1,312 | 172 | 1,010 | 272 |
| Under 25 | 112 | 234 | 220 | 470 |
| 25–34 | 280 | 198 | 463 | 504 |
| 35–44 | 272 | 176 | 874 | 317 |
| 45–54 | 256 | 152 | 1,277 | 163 |
| 55 or over | 392 | 146 | 1,547 | 89 |
| | Metal mines[1] | | | |
| Total | 690 | 272 | 840 | 373 |
| Under 25 | 83 | 363 | 283 | 425 |
| 25–34 | 308 | 328 | 529 | 431 |
| 35–44 | 162 | 230 | 946 | 352 |
| 45–54 | 90 | 171 | 1,576 | 290 |
| 55 or over | 47 | 285 | 2,083 | 128 |
| | Coal mines[1] | | | |
| Total | 459 | 289 | 927 | 230 |
| Under 25 | 70 | 389 | 297 | 291 |
| 25–34 | 155 | 358 | 498 | 273 |
| 35–44 | 131 | 268 | 994 | 281 |
| 45–54 | 82 | 160 | 1,888 | 61 |
| 55 or over | 21 | 81 | 2,014 | 52 |
| | Smelters[1] | | | |
| Total | 1,216 | 239 | 899 | 404 |
| Under 25 | 113 | 414 | 281 | 455 |
| 25–34 | 395 | 320 | 496 | 515 |
| 35–44 | 347 | 212 | 939 | 420 |
| 45–54 | 256 | 138 | 1,386 | 276 |
| 55 or over | 105 | 76 | 1,763 | 188 |

[1] Reference *167*.

*Note:* Edentulous persons are included, and rates are based on 28 teeth.

selected from 394 persons roentgenographed. Selection of the plates was made on the basis of definite interpretation of the picture of each of the teeth present in all four quadrants. The interproximal surfaces of the upper and lower teeth included for interpretation were those between the distal surfaces of the first bicuspids and the mesial surfaces of the third molars.

The 394 persons whose bite-wing roentgenograms were selected for study represented all age groups. With the use of a mouth mirror and diagnostic light, the examination of all the teeth present showed a total of 898 untreated carious teeth. The interpretation from the roentgenograph of the posterior areas previously described revealed the presence of 198 more untreated interproximal carious lesions. This figure represents 22 percent more carious lesions than were observed with the use of mouth mirror and diagnostic light alone.

### *Selected Abnormalities of Oral Cavity*

Information reported in the study also included data on abnormalities and pathological conditions affecting the soft tissues and supporting structures of the oral cavity. Data presented in table 43 are based on the abnormalities or pathological conditions of the oral structures affecting the lip, oral mucosa, tongue, palate, gingiva, uvula, and velum.

The abnormalities are reported according to number and percent of persons affected. The conditions reported are limited to keratosis, leukoplakia, fissures, herpes simplex, inflammation, and varicosities. These data are presented principally with the thought that they may be of value as baseline information in future studies since comparable data were not available.

In all instances, with the exception of the oral mucosa and tongue, the white males experienced more keratosis of the structures listed than the nonwhite. For the nonwhite, keratosis occurred on the buccal oral mucosa along the inter-dental line. This may be attributed to the local mechanical irritation caused during mastication by the forcing of the oral mucosa over the occlusal surface by the muscles that support the buccal mucous membranes. There were no cases of leukoplakia observed among the nonwhite group.

A fissured, or scrotal tongue, is a condition described as a congenital malformation affecting the surface of the tongue by presenting deep furrows; one furrow may extend anteroposteriorly, and others, laterally over the entire surface (*172*). For the group studied little racial difference existed with reference to this condition, as the white showed an incidence of 6.0 percent and the nonwhite, 6.1 percent.

A tortuous distention of the ranine veins and their venules, referred to as varicosities of the tongue, was observed in 41.0 percent of the white and 13.0 percent of the nonwhite. It is stated that such a condi-

*Table 43.—Number and percent of males showing selected abnormalities of oral cavity among workers in 16 ferrous foundries in Illinois according to race*

| Abnormality | Race | | | |
|---|---|---|---|---|
| | White | | Nonwhite | |
| | Number | Percent | Number | Percent |
| Lip: | | | | |
| Keratosis | 299 | 22.8 | 61 | 10.3 |
| Leukoplakia | 8 | 0.6 | 0 | 0 |
| Herpes | 18 | 1.4 | 4 | .6 |
| Oral mucosa: | | | | |
| Keratosis | 211 | 16.2 | 113 | 19.1 |
| Leukoplakia | 18 | 1.4 | 0 | 0 |
| Tongue: | | | | |
| Keratosis | 10 | 0.8 | 5 | .8 |
| Fissure | 79 | 6.0 | 36 | 6.1 |
| Varicosities | 538 | 41.0 | 77 | 13.0 |
| Palate: Keratosis | 239 | 18.2 | 26 | 4.4 |
| Gingiva: | | | | |
| Inflammation | 665 | 50.7 | 251 | 42.5 |
| Keratosis | 129 | 9.9 | 8 | 1.3 |
| Uvula: Inflammation | 733 | 55.9 | 290 | 49.1 |
| Velum: Inflammation | 213 | 16.2 | 47 | 7.9 |

*Note:* Edentulous persons are included except for inflammation of the gingiva.

tion appears most frequently after middle age (*168*) and is probably due to old age atrophy (*169*). It was observed that of the white males who were less than 45 years of age 11.7 percent had varicosities of the tongue, as opposed to 71.0 percent for those 45 years of age or over; for similar age groups the nonwhite had only 6.2 and 38.8 percent. The number of white males affected for each of the two age groups was nearly twice that which was observed for the respective nonwhite group, while the rate of increase for both groups with the advance in years was almost the same.

It is observed that for inflammation of the gingiva, uvula, and velum the white in all cases had a higher rate than the nonwhite. Generally speaking, with the exception of keratosis of the oral mucosa, the nonwhite presented a lower rate for all abnormalities of the structures listed than the white.

### *Attrition*

The air-borne dusts to which the foundry workers were exposed contained free silica, mixed silicates, iron, and traces of organic substances. During talking, and either habitual or occasional mouth breathing, these dusts enter the oral cavity, and those with abrasive qualities may affect the teeth, resulting in attrition or the wearing away of tooth structure.

*Table 44.—Number and percent of males showing attrition of the teeth among workers in 16 ferrous foundries in Illinois according to age, compared with steelworkers*

| Age (years) | Open-hearth[1] and steel wire[2] workers | | | Foundry workers | | |
|---|---|---|---|---|---|---|
| | Total examined | With attrition | | Total examined | With attrition | |
| | | Number | Percent | | Number | Percent |
| Total | 530 | 70 | 13.2 | 1,668 | 329 | 19.7 |
| Under 35 | 215 | 9 | 4.2 | 676 | 18 | 2.7 |
| 35–44 | 117 | 13 | 11.1 | 397 | 46 | 11.6 |
| 45–54 | 116 | 18 | 15.5 | 296 | 84 | 28.4 |
| 55 or over | 82 | 30 | 36.6 | 299 | 181 | 60.5 |

[1] Reference *64*.
[2] Unpublished data.
*Note:* Edentulous persons are excluded.

In an effort to ascertain the extent that air-borne dusts may have affected the foundry workers' teeth, a comparison was made of the percent of workers affected in this industry with similar information in other industries. Differences in the incidence of attrition for each group were noted. For this purpose, the data from a study conducted among open-hearth furnace (*64*) and steel wire workers (*170*) were combined and are presented with data of the foundry workers in table 44. It will be observed that 19.7 percent of the foundry workers have attrition, as compared to 13.2 percent for the open-hearth and steel wire workers. For the foundry workers there is a rapid increase from 2.7 to 60.5 percent of the persons with attrition in the age groups from under 35 years to 55 years and over, while the comparison group increased from 4.2 percent to 36.6 percent for the same age groups.

The percentage of persons affected with attrition is less for the foundry workers in the group under 35 years of age and approximately the same in the age group 35 to 44, but there appears a marked difference in the age groups of 45 and over when compared to corresponding ages of the open-hearth and steel wire workers. Among the foundry workers, 12.9 percent more persons in ages 45 to 54 years and 23.9 percent more in the age group 55 years and over are affected with attrition. Since these absolute differences are statistically significant, they suggest that extrinsic factors present in the foundry workers' environment may be responsible for this difference.

From the foregoing, it is noted that attrition of the teeth was experienced by more foundry workers than other industrial workers selected for comparison. To determine the extent to which such extrinsic factors as abrasive air-borne dusts may contribute to the wearing away of the teeth of the foundry workers, a study was made of the different occupations where the dust concentrations were known to vary. For this purpose, the workers were divided into four occupational categories; namely, coremakers, molders, cleaners and finishers, and a miscellaneous group consisting of maintenance and supervisory employees, laborers and others, and shakeout men. The number and percent of persons with attrition and the number of years in their principal occupation are presented in table 45. Since no significant difference with regard to attrition was noted between the white and nonwhite groups who had the same number of years in the same occupation, these groups were combined in comparing the different occupational categories. It is recognized that different individuals have varying degrees of hardness of tooth structure. However, it is reason-

*Table 45.—Number and percent of males showing attrition of the teeth among workers in 16 ferrous foundries in Illinois according to years in principal occupation*

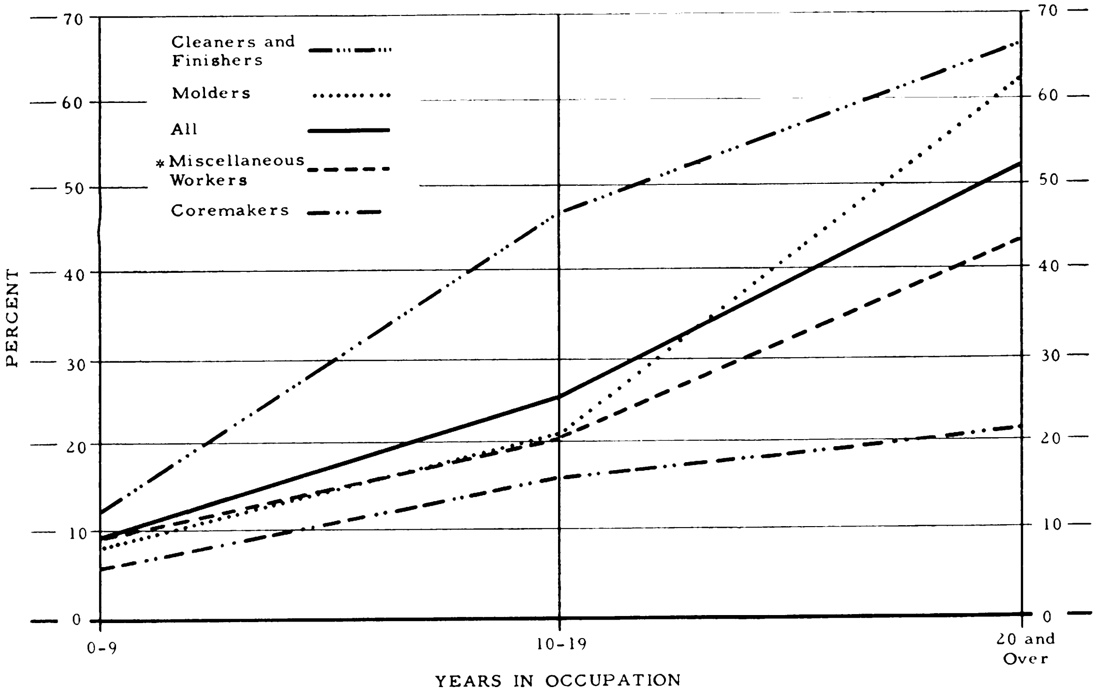
| Years in principal occupation | Total | Coremaker | Molder | Cleaning and finishing | Miscellaneous[1] |
|---|---|---|---|---|---|
| | Number with attrition | | | | |
| Total | 327 | 24 | 127 | 75 | 101 |
| 0–9 | 99 | 5 | 18 | 26 | 50 |
| 10–19 | 79 | 9 | 18 | 31 | 21 |
| 20 or over | 149 | 10 | 91 | 18 | 30 |
| | Percent of all foundry workers | | | | |
| Total | 19.6 | 12.6 | 27.4 | 24.7 | 14.2 |
| 0–9 | 9.3 | 5.7 | 7.8 | 12.3 | 9.3 |
| 10–19 | 25.4 | 16.1 | 20.7 | 47.0 | 20.6 |
| 20 or over | 51.9 | 21.3 | 62.8 | 66.7 | 44.1 |

[1] Includes shakeout, maintenance and supervisory, and laborer and other.
*Note:* Edentulous persons are excluded.

able to assume that workers with varying degrees of tooth hardness were equally distributed in each occupational group. Also, a certain amount of increase in attrition with age may be attributed to the natural function of mastication. Because of the close positive association between age and years in principal occupation, it is assumed that differences shown in table 45 will take into account the age factor as well as the experience factor.

It is observed that the total percentages of persons having attrition for the four occupational groups increase as follows: Coremakers, 12.6 percent; miscellaneous group, 14.2 percent; cleaners and finishers, 24.7 percent; and molders 27.4 percent. With regard to the number of years in the principal occupation, there is an increase in the rate of persons having attrition for each of the four occupational categories, and it will be observed that this rate of increase differs for the different occupational groups. For the coremakers, for whose occupation the dust concentration was known to be the lowest, the incidence of attrition was found to be 5.7, 16.1, and 21.3 percent for groups with 0–9, 10–19, and 20 years and over, respectively, in their principal occupation. On the other hand, for the cleaners and finishers and the molders, for whose occupations the dust concentration was found to be higher, a more rapid increase in the percent of persons affected with attrition was observed. The corresponding experience group percentages for the cleaners and finishers are 12.3, 47.0, and 66.7 percent; and for the molders, 7.8, 20.7, and 62.8 percent. Figure 23 graphically shows the increase in the percent of persons affected with attrition for the four stated occupational groups by number of years in such occupation.

It will be observed that, for all the four groups exposed 0–9 years in their principal occupations, the differences in the percent of persons with attrition are relatively not great. For workers exposed between 10 and 19 years, the cleaners and finishers show a marked increase over the molders, coremakers, and miscellanoous group in the percent of persons so affected. For exposures of 20 years and over, the incidence among molders increases more rapidly than among the other groups and approximates that experienced by the cleaners and finishers; little change in incidence is noted for coremakers. It is interesting to note that the miscellaneous group of employees, who work for different intervals in various parts of the plant, where they are subject to both high and low dust concentrations, experience attrition of a degree closely paralleling that which was found for all occupational categories combined. Thus, it may be stated that the abrasive dusts in the atmosphere, to which the foundry workers were exposed, accentuated the wearing away of tooth surfaces and that the attrition varied directly with the concentration of the abrasive dust in the atmosphere and the duration of such exposure. The upper and lower anterior teeth were most often affected, and in some cases as much as




*Includes shakeout, maintenance and supervisory, laborer and other.
Note: Edentulous persons are excluded.

**Figure 23.**—Percent of males showing attrition of the teeth among workers in 16 ferrous foundries in Illinois according to years in principal occupations. (To facilitate reading each set of 3 points has been joined by a straight line.)

one-third to two-thirds of the clinical crown of both anterior and posterior teeth was involved. There was no evidence of an increase of sensitivity due to the loss of tooth structure. No teeth were observed in which the pulp was exposed as a result of attrition. As is shown in figure 24, secondary dentine formation compensates for the loss of tooth structure, thus preventing pulp exposure.

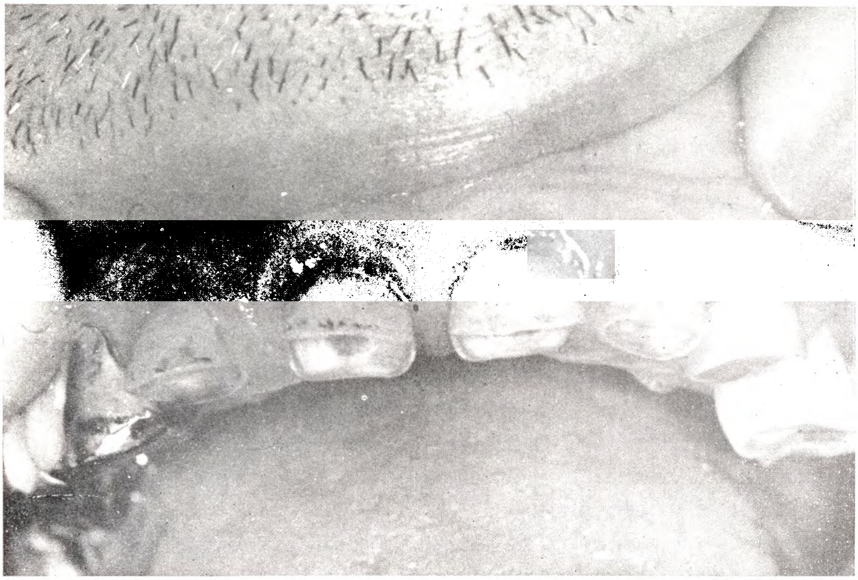


Figure 24.—Severe attrition and evidence of deposition of secondary dentine observed in a 53-year-old white male foundry worker whose principal occupation for 23 years was molder.

### *Garlic-like Breath*

Small amounts of tellurium are sometimes added to molten iron. During the process some of the tellurium is volatilized into the atmosphere. Persons inhaling air containing a sufficiently high concentration of this element for a reasonable length of time have been reported to present the following symptoms: garlic odor of the breath, dryness of the mouth, metallic taste, somnolence, loss of appetite, garlic odor, and partial suppression of the sweat (*171*).

In one of the plants studied it was noted that 63.4 percent of the workers had a garlic-like odor of the breath. A consultation with the plant manager revealed that, in special cases, tellurium was added to molten iron; the last such occasion had been 30 days prior to the clinical study. Since tellurium was not being used at the time of the study, data relative to its atmospheric concentration were not available. With the exception of garlic breath, symptoms sometimes associated with this exposure were not observed.

## Summary of Medical Studies

From the 16 ferrous foundries, employing about 2,000 persons 1,937 males were medically examined.

The adequacy of the sample from the points of view of age distribution, years spent in foundry work, and occupational distribution was believed to be satisfactory. Of the group, 69 percent were white persons, and 31 percent, nonwhite.

The limited examination of the eyes and their functioning revealed no abnormalities which could be attributed to the occupation.

Skin disease, probably of occupational origin, was present in 1.7 percent of the foundrymen.

Significantly elevated blood pressure levels were related to increasing degrees of pulmonary fibrosis.

Neither the cardiac nor renal findings were remarkable in this study.

Positive serological tests for syphilis were found in 2.1 percent of the white and 10.3 percent of nonwhite foundrymen.

For the entire group of workers studied, total leucocyte count, hematocrit, and erythrocyte sedimentation rate were not at variance with comparable industrial groups. The erythrocyte counts and hemoglobin estimations appeared to be lower than those of open-hearth steelworkers. These latter observations did not appear to have an association with occupation.

Vital capacity estimations showed a correlation with age and no correlation with degree of pulmonary fibrosis.

Reinfection type of pulmonary tuberculosis, considering both active and inactive to the degree that such was determinable from the limited nature of the medical examination, was found in 0.7 percent of white workers, and in 1.7 percent of the nonwhite workers. These percentages appeared to be similar to those of other studies of adults of both sexes made recently in the area in which the present study was performed.

Significant pulmonary fibrosis of occupational origin, as determined by roentgenogram and the historical and clinical data, was found in 9.2 percent of the foundrymen; in 7.7 percent it was ground glass two stage and in 1.5 percent, nodular in type. Of the instances of pulmonary nodular fibrosis, 1.3 percent of all the foundrymen were in stage one; 0.15 percent, in stage two; and 0.05 percent, in stage three.

To the limited degree that the pulmonary effects of iron and its compounds were evaluated, it was felt that they did not appear to play a significant role in this study.

The instances of nodular pulmonary fibrosis occurred with about equal frequency in the steel and gray iron foundrymen. In general, it required 14 or more years of exposure to develop nodular silicosis in the ferrous foundry industry. Symptoms were of minor significance in the instances of nodular pulmonary fibrosis observed in this study.

Nodular pulmonary fibrosis occurred predominantly among the molders in the gray iron foundrymen group and among the cleaning and finishing workers in the steel foundrymen group.

Although previous levels of dustiness in the foundry industry probably were of significance in the occurrence of pulmonary fibrosis as observed in this study, evidence is adduced to indicate that exposure in other dusty trades, prior to the worker's entry into foundry work, had very little if any bearing on such pulmonary fibrosis.

Increasing degrees of pulmonary fibrosis were associated with increasing speed of erythrocyte sedimentation and with progressively increasing total leucocyte counts. No association existed between degrees of pulmonary fibrosis and erythrocyte count, hematocrit values, hemoglobin estimation, mean corpuscular volume, mean corpuscular hemoglobin, and mean corpuscular hemoglobin concentration.

Dental status in terms of decayed, missing, and filled teeth of the white foundry workers was observed to be similar to that of other industrial workers studied.

Data concerning selected abnormalities of the soft tissues and supporting structures are presented.

The abrasive dusts in the atmosphere of the foundry accentuated the wearing away of tooth surfaces.

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