A FOLLOW-UP STUDY OF PNEUMOCONIOSIS IN AN IRON FOUNDRY AND SOME INVESTIGATIONS INTO THE EFFECT OF FOUNDRY DUST IN THE LUNGS

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In a survey of health and environmental conditions in the Butterley Foundries (Keatinge and Potter, 1945) one of the principal health risks to which the workers were exposed was found to be pneumoconiosis, and it was estimated that the potential dust risk of fettlers was many times greater than that to which other workers in the foundries were exposed. Sixty foundry men, divided into broad occupational groups, five fettlers, 31 moulders, 24 others, were submitted to x-ray examination of the chest. Two out of the five fettlers examined were affected in comparison with only eight out of the 31 moulders.

Since the publication of this survey a number of other inquiries have been made into the health of foundry workers and the environmental conditions in foundries (Eskildsen, 1949; Gordon, 1950; Vigliani, Parmeggiani, and Zanetti, 1948; Zanetti and Dompè, 1950) but the most extensive has been that undertaken by McLaughlin (1950), in which 2,767 people were examined. McLaughlin and his colleagues however found that in the iron foundry the moulder as compared with the fettler was exposed to a greater risk of silicosis probably due to the use of silica parting powders.

Although several surveys have been made of the health of foundry workers, few follow-up studies appear to have been carried out in Great Britain. Since the last study of the Butterley Foundries was published nearly 10 years ago it was felt that a further survey of the incidence of respiratory disease amongst those examined on a previous occasion might prove instructive; in considering the findings of the present survey, it must be borne in mind that it is iron-founding alone which is carried out at Butterley.

There are three foundries at Butterley: No. 1 Foundry produces small, medium, and light cast-

ings, on a semi-mechanized basis; No. 2 Foundry makes large castings of a general nature; and No. 3 Foundry very light castings on a fully mechanized unit. More than 200 workers are employed in the foundries, of whom 20 are engaged in fettling, 50 in moulding, 16 in core-making, and the remainder in other work. The work done is representative of many branches of iron-founding, and the building and general conditions are of a kind very usual in the industry.

The dust environment in the Butterley Foundries has not altered materially since the previous survey was carried out and is comparable with that recorded in other iron foundries by McLaughlin (1950). Examination of the dust (at Sheffield University) showed obvious large particles, and a fine fraction was separated by suspension in tap water and decanting into a large filter, after the larger particles had sedimented. Samples of the dust after separation of this fine fraction showed that it contained 35 to 36% of total silica, and 38% of iron, (reckoned as Fe_2O_3): chemical analysis (Trostel and Wynne, 1940) gave the percentage of free silica as 24.8% and x-ray analysis gave a figure of 18.5%.

Health Studies

Fifty-three people examined in 1943 and 1944 are still working in the Butterley Foundries and their ages range from 28 to 71; the mean age is 45.3 years. These workers fall into the following broad occupational groups; 41 moulders, eight fettlers, and four core-makers. The incidence of respiratory disease experienced by these people has been assessed by examining their individual record cards which show the duration of each absence due to sickness or injury, clinical examinations, and radiography of the chest.

Absence Due to Respiratory Disease.—A careful note of the amount of time lost by each worker has been kept since 1943 and the nature of the sickness or injury has been recorded when absence from work has been due to these causes.

Although respiratory disease has been the greatest single cause of sickness absence in the period from 1944 to 1952 inclusive, relatively few cases of serious chest affections have been recorded amongst these workers. Thus, absence due to bronchitis took place only on seven occasions in all these years, accounting for an annual average loss of time of no more than 0.34 days per worker. There were three cases of pneumonia giving a loss of time averaging for each year 0.17 days per person and there was no absence as a result of pulmonary tuberculosis. Three employees lost no time due to sickness or accident during the nine years under review.

Clinical Examination.—Although workers engaged in cleaning castings are submitted to annual radiography of the chest, and young persons up to the age of 18 and workers of 65 and over undergo periodic medical examinations, these are not carried out as a routine measure in all employees. Their health is, however, carefully supervised and a review is made of the physical state of those returning to work after absence due to sickness or injury. A clinical investigation is not necessarily required in all cases, but 18 of these 53 workers had been examined during the two years before this survey. Abnormal physical signs due to respiratory disease were found in only three people and all of them were over 60 years of age. Two of these men complained of shortness of breath and cough, and on examination the breath sounds were distant and crepitations were heard at the bases. In another worker the clinical findings were similar and electrocardiography showed the presence of a right bundle branch block.

Radiography of the Chest.—Of the 53 men, four were unwilling to submit themselves to further x-ray examination of the chest; the films of these four workers taken in 1943–44, however, had at that time been regarded as normal and the incidence of respiratory illness amongst them since that time had been negligible. The x-ray classification used has been that adopted by McLaughlin (1950).

Category I = Normal
Category II = Early reticulation
Category III = Reticulation
Category IV = Nodulation and/or massive shadows

All the films were read independently by three observers, and there was substantial agreement

on the readings between all of them. However, where there has been disagreement, the majority view has been taken and in the few cases in which each observer has given a different reading, the mean has been taken.

Table 1 gives the x-ray findings in the present survey of the 49 members of the group of 53 men previously surveyed in 1943–44 and the distribution is given by x-ray category, age, and length of exposure in years. Table 2 shows the x-ray categories by occupational groups. The x-ray findings are in all but three cases identical with those seen in the 1943–44 films. In two instances there had been progression from Category I to Category II, and in one from Category I to Category III.

TABLE 1
X-RAY FINDINGS IN FOLLOW-UP STUDY OF WORKERS
EXAMINED IN 1943–44

Age (years)	X-ray Category	Length of Exposure in Years			
		10–19	20–29	30+	Total
15–29	I	2	—	—	2
	II	1	—	—	1
	III	—	—	—	—
	Total	3	—	—	3
30–39	I	10	5	—	15
	II	2	—	—	2
	III	1	—	—	1
	Total	13	5	—	18
40–49	I	1	1	5	7
	II	1	2	2	5
	III	—	—	1	1
	Total	2	3	8	13
50+	I	1	—	7	8
	II	—	—	6	6
	III	—	—	1	1
	Total	1	—	14	15
Total	I	14	6	12	32
	II	4	2	8	14
	III	1	—	2	3
	Total	19	8	22	49

TABLE 2
OCCUPATIONAL GROUPS AND X-RAY FINDINGS OF
49 MEN EXAMINED IN FOLLOW-UP STUDY*

Craftsmen	No. at Risk	Category I	Category II	Category III	Total
Moulders	41	28	10	1	39
Fettlers	8	1	3	2	6
Coremakers	4	3	1	—	4
Total	53	32	14	3	49

* Four men out of the 53 at risk were not radiographed again for various reasons.

Laboratory Investigations

In November, 1952, a moulder aged 36 years who had worked in the Butterley Foundries for

FIG. 1.—Section of lobe of the lung of an iron moulder (natural size).

22 years died as a result of an accident at work. From 1943 his health had been good and during these nine years he had been absent on only 33 days (11 days for a carbuncle on the wrist, 17 days for fibrositis, and five days for a "chill"). In 1944 radiographs of the chest had shown only increased linear markings; unfortunately no recent x-ray examination had been made. A necropsy was performed by Dr. I. MacKenzie and the lungs were sent to Sheffield University for further examination. When received, the lungs were largely hardened by formalin but it was possible to distend one lobe for large sections. Macroscopically there was definite but not severe focal emphysema with small, palpable, spidery, black nodules; the hilar lymph nodes were moderately enlarged, very black, and moderately firm. A large section (Fig. 1) of one lobe showed some bullous emphysema with pneumoconiosis. Histological examination (Fig. 2) showed focal emphysema and early collagenous fibrosis in aggregates of pigment alongside bronchioles and small arteries; incinerated sections showed that much of the opaque pigment was iron. Chemical analysis of the lungs after fixation in formol-saline gave the following percentages of dry weight; ash 3.07, total silica 0.54, free silica 0.33, iron (as Fe_2O_3) 0.37.

FIG. 2.—Small pneumoconiotic nodule with associated focal emphysema. Hx. E. $\times 24$.

FIG. 3.—Rat 52/16. Aggregate of cells containing inhaled foundry dust. Reticulin stain. $\times 190$.

FIG. 4.—Rat 52/26. Dust aggregates after injection of a suspension of dust. Reticulin stain. $\times 190$.

FIG. 5.—Rat 52/16. Inhaled foundry dust. Hx. E. $\times 8$.

FIG. 6.—Rat 52/26. Injected foundry dust. Hx. E. $\times 8$.

FIG. 7.—Rat 52/16. Inhaled dust. Radiograph of lung. $\times 8$.
(The areas of collapse in the lower part of the lung are artefacts produced by faulty technique in preserving the specimen.)

The findings in this moulder's lungs showed that there is, or was, a risk of pneumoconiosis in the foundry, but are not of course evidence of the degree of such risk. The pneumoconiosis in this man was perhaps sufficient to produce minimal symptoms but there is no evidence that it had done so.

Fine dust from Butterley Foundries, 50 mg., suspended in 1 ml. saline, was injected intraperitoneally into each of two rats, and 50 mg. of a very pure rouge (Fe_2O_3) into another pair of animals. Eight months later no fibrosis was detectable around aggregates of rouge, but slight fibrosis with an occasional foreign body giant cell was found in relation to aggregates of foundry dust. The two dusts were, however, not strictly comparable in particle size, the foundry dust containing particles larger than any in the rouge.

A group of 24 young piebald rats was exposed to a dense cloud of foundry dust in a chamber for approximately 40 hours weekly for 37 weeks, and the seven survivors killed after a further five weeks. The thoracic contents were removed with the lungs in an inflated state, fixed in formol-saline, radiographed after 24 hours, and then sectioned. A further group of rats was anaesthetized with ether and given injections through the larynx of a suspension of dust

FIG. 8.—Rat 52/26. Injected dust. Radiograph of lung. $\times 8$.

FIG. 9.—Normal rat. Radiograph of lung for comparison. $\times 8$.

in sterile physiological saline : 200 mg. of dust was injected in four doses during four weeks, and six animals were killed after six and a half months. The thoracic contents were fixed in formol-saline, radiographed, and sectioned.

Microscopical examination showed aggregates of dust related to terminal bronchioles with no associated collagenous fibrosis and only slight or doubtful increase of reticulin fibrils (Figs. 3, 4, 5, and 6). Radiographs of the lungs showed, however, distinct shadows corresponding with the aggregates, larger and coarser in the injected animals than in those that had inhaled the dust (Figs. 7, 8, and 9). These shadows are presumably due to iron oxide and not to fibrosis. (It is interesting to note that the control radiograph of a normal rat lung shows a reticular pattern.) That this dust, in spite of its fairly high content of free silica, did not produce fibrosis in the rats' lungs is not unexpected. These animals do not commonly show fibrosis unless the proportion of silica is very high; negative results in laboratory animals cannot safely be taken as applying to man.

Conclusions

Although the low incidence of respiratory disease amongst the workers in the Butterley Foundries examined in this follow-up study and the absence of evidence of progression in the *x*-ray films of all but a few men suggest that environmental conditions in these foundries do not carry an undue risk for the worker, it must be emphasized that it cannot necessarily be assumed that similar conditions obtain in all iron foundries.

Although histological studies of the lungs of the moulder who died as a result of an accident at work showed evidence of focal emphysema and early collagenous fibrosis, much of the opaque pigment seen in the lungs was undoubtedly iron. Moreover, analysis of the foundry dust showed that a high proportion of it too was iron, and in addition dusting experiments on rats with foundry dust failed to elicit fibrosis although radiographs of the lungs showed distinct shadows presumably due to iron oxide. While it would be unsafe to read too much into these findings, there is certainly some evidence to suggest that the radiographic appearances seen in the films of these foundry workers may be due as much to the presence of radio-opaque dust in the lungs as to fibrosis. Hamlin (1947), as a result of a study of workers in an iron foundry and after dusting experiments with guinea-pigs, rats, and rabbits, considered that *x*-ray observations in his group of workers represented siderosis. Kettle (1932) showed that a coating of iron on quartz particles has an inhibiting effect on their fibrosis-forming pro-

perties in the lung, and the presence of iron in the dust inhaled by workers in iron foundries may account to some extent for Hamlin's findings and those of this survey. However this may be it is not perhaps unfair to claim that the results show the value of continued and constant medical supervision in foundries. The value of positive steps to control dust, whether toxic or not, is, however, unequivocal. Thus the fact that the use of silica parting powders was discontinued many years ago in these foundries and that relatively good control of dust has been instituted in the fettling department must have played their parts in improving the health of these workers. The first method is an illustration of the only certain means of controlling a toxic hazard, namely the substitution of a harmless for a noxious substance, while the second method is an example of the principle of controlling a noxious substance when it is not possible to substitute something harmless for it.

Nevertheless, complacency about the control of dust in the foundry is to be deplored, and it is reasonable to expect that the health of the foundry worker will be still further improved and the risk he runs due to the inhalation of noxious dust reduced as the result of the introduction of the further measures of dust control required by the Iron and Steel Foundries Regulations (Minister of Labour and National Service Statutory Instruments, 1953).

Summary

Recent studies on health and environmental conditions in iron foundries have been briefly reviewed.

A follow-up study has been made of 53 workers previously examined in 1943-44 and still working in the Butterley Foundries.

The incidence of respiratory disease amongst these workers has been low and evidence of progression in the *x*-ray films was absent in all save three of these men.

Naked-eye and histological studies of the lungs of a moulder who died as a result of an accident at work showed evidence of focal emphysema with pneumoconiosis.

The lungs of rats exposed to foundry dust in experiments showed little or no evidence of fibrosis. Radiographs of the rats' lungs showed distinct shadows, presumably due to iron oxide.

Some of the fine changes seen in the *x*-ray films of workers in these iron foundries may be partly due to the presence of radio-opaque dust and not necessarily to fibrosis.

Dust suppression and the use of silica-free parting powders are thought to have played a part in preserving the health of these foundry workers.

Positive steps to control the dust in all foundries are essential to maintain the health of the workers.

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