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Chronic exposure to iron oxide, chromium oxide, and nickel oxide fumes of metal dressers in a steelworks

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Graham Jones, J., and Warner, C. G. (1972). *Brit. J. industr. Med.*, **29**, 169-177. **Chronic exposure to iron oxide, chromium oxide, and nickel oxide fumes of metal dressers in a steelworks.** Occupational and medical histories, smoking habits, respiratory symptoms, chest radiographs, and ventilatory capacities were studied in 14 steelworkers employed as deseamers of steel ingots for periods of up to 16 years. The men were exposed for approximately five hours of each working shift to fume concentrations ranging from 1·3 to 294·1 mg/m^3 made up mainly of iron oxide with varying proportions of chromium oxide and nickel oxide.

Four of the men, with 14 to 16 years' exposure, showed radiological evidence of pneumoconiosis classified as ILO categories 2 or 3. Of these, two had pulmonary function within the normal range and two had measurable loss of function, moderate in one case and mild in the other.

Many observers would diagnose these cases as siderosis but the authors consider that this term should be reserved for cases exposed to pure iron compounds. The correct diagnosis is mixed-dust pneumoconiosis and the loss of pulmonary function is caused by the effects of the mixture of metallic oxides. It is probable that inhalation of pure iron oxide does not cause fibrotic pulmonary changes, whereas the inhalation of iron oxide plus certain other substances obviously does.

The term siderosis was first used by Zenker in 1866 (Hunter, 1955) to describe fibrosis of the lungs associated with the inhalation of iron dust. However, the two cases he examined also had pulmonary tuberculosis which could have been the cause of the fibrosis. Pulmonary fibrosis in knife grinders and needle finishers was at first called siderosis but the condition was shown to be siderosilicosis caused by free silica in the dust from the sandstone grinding wheel. Doig and McLaughlin (1936) described abnormal radiographic findings in the lungs of electric-arc and oxyacetylene welders and suggested that the shadows might be caused by depositions of iron oxide without the presence of fibrosis. The condition became known as welders' siderosis and for many years most published reports suggested that the condition was harmless, with no impairment of general health or respiratory function. Stanescu *et al.* (1967) summarized these reports but listed some more recent papers which had questioned this view and described their own study. Comparing welders who had chest radiographs suggestive of siderosis with healthy unexposed men, they found that although spirographic values were generally within normal range, the arc welders had a statistically significant reduction in static and functional compliance. On the other hand, Kleinfeld *et al.* (1969), in a study of 25 welders exposed largely to iron oxide, found that eight of them had reticulonodular shadowings on the radiographs consistent with siderosis but that the mean parameters of pulmonary function were not significantly different from the mean of a control group.

It appears likely that the apparently contradictory views are caused by the use of the words 'welders' siderosis'. Siderosis describes a condition in which inhaled iron dust is retained in the lungs and causes a radiographic appearance indistinguishable from other forms of pneumoconiosis. Iron oxide alone does not cause fibrosis in the lungs of animals, and from the evidence available it is probable that the same applies in humans (Harding, McLaughlin, and Doig, 1958). However, few if any welders are exposed only to iron oxide. They inhale any other dusts present in their working area, fume of complicated composition from electrodes which are coated with various materials, and dust from the metal on which they work which may not be iron or may contain metals other than iron. Additionally, irritant gases such as the oxides of nitrogen and ozone may be present. Pulmonary changes in welders caused by the inhalation of dust should, therefore, be described as mixed-dust pneunoconiosis or welders' pneumoconiosis. Investigation of cases showing radiographic changes should include respiratory function tests and detailed quantitative and qualitative estimations of the dust and gases in the working environment. In most cases accurate retrospective environmental information is not obtainable and this contributes to the confusion.

In the present study, working conditions for a group of steelworkers had remained unchanged for 16 years and detailed information of their exposure to dust and oxides of nitrogen is available. Symptoms, physical signs, radiographic findings, and tests of pulmonary function of those exposed have been related to the environmental data, thus allowing some meaningful 'cause and effect' deductions to be made.

Industrial process

Removal from steel ingots of superficial defects, such as cracks, cold drops, inclusions, and the formation of various oxides and other impurities, by burning with oxygen-gas mixture torches is known as scarfing or deseaming. In the present study, two types of ingot were so treated, namely large stainless steel ingots ranging between 7 and 12 tons in weight, and smaller special steel ingots each weighing about 23 cwt.

The gas mixtures and fluxing materials fed to the scarfing guns differed for the two types of ingot. For stainless steels, oxyacetylene gases were used, and very finely powdered pure iron (Swedish sponge iron) was fed into the flame. For the small special steel ingots, oxyferrolene gases were used and iron rod was fed into the gun flame. Ferrolene is town gas mixed with commercial ether vapour.

Deseaming of small ingots was done in front of an extraction booth, which was very efficient in removing the bulk of the fumes to outside atmosphere via an exhausting stack.

Deseaming of large stainless ingots was done in the open steel-making bay, and there was no provision for controlling by exhaust ventilation the fumes produced, these being dissipated into the general atmosphere of the bay.

A schematic diagram of the working areas investigated is shown in Figure 1.

At the beginning of the investigation in 1963, 19 men were employed in the deseaming department, working eight hours a day, six days a week on a three-shift rota. The men wore visors for protection of their eyes but not respirators.

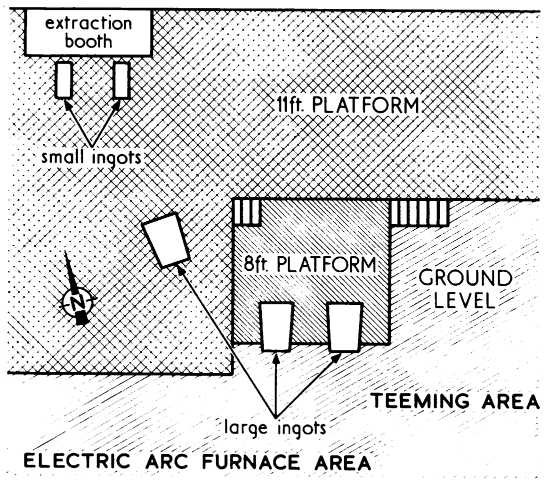

FIG. 1. The layout of the deseaming process as it existed at the time of the investigation. The layout has since been changed.

Methods

Oxides of nitrogen

For measuring the oxides of nitrogen produced during deseaming, gas samples were collected in sampling tubes of 100 ml or 250 ml capacity. Total oxides of nitrogen were estimated by a colorimetric method based on the diazotization of sulphanilic acid by the nitrite produced from the oxides of nitrogen and the development of a red colour after coupling with α-naphthylamine, the results being expressed as nitrogen dioxide. The sensitivity of the method was such that concentrations of nitrogen dioxide could be measured to $<0{\cdot}7$ or $<0{\cdot}3$ part per million, according to the size of sample available.

Fumes during deseaming

Bulk samples for compositional analysis were collected with the Hexhlet sampler.

Samples for determination of the size distribution characteristics of the fume were taken with the standard thermal precipitator.

Samples for the gravimetric estimation of the general airborne burden were collected by the standard filter devised by the Department of Scientific and Industrial Research (DSIR), consisting of two heavy brass cylinders drilled out to hold filter papers of 7 cm diameter when clamped together. The unit, connected in train with a flowmeter and suction pump, sampled air at the rate of 20 litres per minute. Glass fibre papers (Whatman GF/A) were used to collect the fume which represented the total size range of the airborne material.

Personal sampling units were also used for gravimetric estimations. At a sampling rate of 10 to 12 litres per minute, a measured volume of air was drawn through a Whatman GF/A glass fibre paper, diameter 2·1 cm, in an open-ended plastic filter holder having an effective sampling diameter of 1·6 cm, and the total size range of the airborne material was sampled.

Medical investigations

Occupational histories in the steel industry were available for all 19 men giving the length of employment in the deseaming department, whether deseaming or helping, and the periods of time spent working on stainless or special steel ingots. Details of jobs prior to working in the deseaming department were obtained from 15 men.

Fourteen men, including all those with more than four years' exposure, volunteered for medical examination, and medical histories including details of respiratory symptoms and smoking habits were obtained from them.

Ventilatory function tests (forced expiratory volume in one second, $FEV_{1 \cdot 0}$ and forced vital capacity, FVC) were performed on these 14 men in 1963 using a Poulton spirometer. More detailed tests were made on four men who showed radiographic evidence of pneumoconiosis by Cotes in 1964 and 1966 at the MRC Pneumoconiosis Research Unit.

Radiographic examinations of the chest using large films were made on 18 volunteers in 1963 and repeated on the four men showing evidence of pneumoconiosis in 1966 and 1968 by Jackson at the Chest Clinic, Newport, Mon.

Results

Environmental

Twenty-three samples for nitrogen dioxide concentrations were taken during the deseaming of large stainless ingots and 21 samples during the deseaming of small special steel ingots. All these samples were collected in close proximity to the workers, from the main cloud of fumes, and represent potential maximum concentrations. The results given in Table 1 show that oxide of nitrogen levels were low and that the threshold limit value of 5 p.p.m. (Department of Employment and Productivity, 1969b) was exceeded on only two occasions. The findings were consistent with the effects noted by the observers who frequently inhaled the fumes in the working areas and found that although they were warm they could not be described as unpleasant, were not irritant, and did not cause coughing.

TABLE 1

CONCENTRATIONS OF NITROGEN DIOXIDE DURING DESEAMING OPERATIONS

	No. of samples	*Mean (p.p.m.)*	*Range (p.p.m.)*
Large stainless ingots			
Deseaming	23	2·1	<0·7–6·8
(3 high values) ..	(3)	(5·6)	(4·5–6·8)
(20 other values) ..	(20)	(1·6)	(<0·7–2·8)
General body of working area	3	<0·7	<0·7
Small special steel ingots			
Deseaming	21	0·9	0·3–2·4
General body of working area	3	1·0	<0·7–1·3
Control samples outside works	2	<0·3	<0·3

Four bulk samples of fume were collected during the deseaming of large stainless steel ingots and small special steel ingots. After preliminary spectrographic qualitative analysis, which indicated that the main elements present were iron, chromium, nickel, and molybdenum, the four samples were analysed chemically and the results are given in Table 2. From these it is seen that those workers breathing the special steel fume would be inhaling almost pure iron oxide, while those exposed to stainless steel fume would be inhaling a mixture of oxides of iron, chromium, and nickel in the approximate ratios of 6:1:1.

Thermal precipitator samples taken during the deseaming of both large and small ingots showed that most particles were below 2 microns in size, and very few occurred between the sizes of 2 to 5 microns.

Samples of fume were taken using the DSIR filter, the head of which was held just in front of the visor of the worker, ensuring that the samples were representative of the concentrations of fume around

TABLE 2

FUME ANALYSES EXPRESSED AS OXIDES

Sample	*Percentage*			
	Fe_2O_3	*Cr_2O_3*	*NiO*	*MoO_3*
Total stainless steel fume ..	63·8	9·35	11·5	1·95
Respirable stainless steel fume	61·0	12·5	10·4	–
Total special steel fume ..	98·8	0·06	–	–
Respirable steel fume ..	96·9	1·3	–	–

his breathing zone, and the results are given in Table 3. The east end of the working bay was almost completely open to the outside atmosphere, the sheet cladding being mainly removed, and throughout the investigation the wind drifted in from a south-easterly direction. As can be seen from Table 3, concentrations were subject to considerable variation due to this adventitious ventilation, but also at times the worker was able to position himself to advantage in relation to the wind direction. Thus when deseaming the top horizontal face of large ingots, the worker stood up-wind of the main cloud of fume, resulting in a mean concentration of only 13·3 mg/m³. However, when deseaming the vertical face of large ingots or when cutting ends off ingots, the worker could not avoid the brunt of the fumes and the mean airborne concentrations for these operations were respectively 198·4 and 124·5 mg/m³. The deseaming of small ingots produced lower concentrations because of the effect of the exhaust booth. After spells of deseaming, the workers retired for relief to nearby positions only a few yards from the working places and samples of the general atmosphere gave concentrations of 4·6 to 7·3 mg/m³ in the large and small ingot retiring zones respectively.

Small personal sampling units were fixed to the front of the head bands of the visors worn by the deseamers. When so positioned, the unit rested on the bridge of the nose under the visor, and thus a sample at the breathing level of the worker could be taken during full working conditions. The results given in Table 4 again show considerable variation due to the wind, as can be seen by comparing the three sets of samples obtained when cutting large stainless slabs lengthwise. The low mean reading of 9·1 mg/m³ during the deseaming of small ingots again shows the effect of the exhaust booth. While these latter samples were being taken, synchronous samples were taken with the DSIR filter held outside the visor and a mean concentration of 16·2 mg/m³ was noted. Although not intended primarily for this purpose, it appears that the visor was screening off some of the fume to the operator and acting as a 'low-efficiency' mask.

TABLE 3

FUME CONCENTRATIONS OF DSIR FILTER SAMPLES

Operation	*No. of samples*	*Mean (mg/m³)*	*Range (mg/m³)*
Large stainless ingots			
Deseaming			
(end of ingot) ..	4	77·0	51·8–106·3
(top horizontal face)	4	13·3	3·7– 33·4
(vertical side of ingot)	3	198·4	152·5–263·9
Cutting ends off ingot	14	124·5	22·5–274·0
Large stainless slabs			
Cutting ends ..	2	36·8	23·9– 49·7
Small special steel ingots			
Deseaming	24	24·9	5·5– 70·3

TABLE 4

FUME CONCENTRATIONS OF PERSONAL FILTER SAMPLES

Operation	*No. of samples*	*Mean (mg/m³)*	*Range (mg/m³)*
Large stainless ingots			
Cutting ends off ingot	4	70·8	11·3–167·9
Large stainless slabs			
Cutting ends off slab	4	31·6	5·1– 87·5
Cutting slab length-	4	61·4	13·5– 90·9
wise under varying	4	287·7	281·0–294·1
wind conditions ..	3	35·3	17·8– 47·4
Small special steel ingots			
Deseaming	12	9·1	1·3– 17·7

Threshold limit values for the three main constituents of the fume are iron oxide 10 mg/m³, chromium oxide 1 mg/m³, and nickel oxide 1 mg/m³ (Department of Employment and Productivity, 1969b). During the deseaming and cutting of large stainless steel ingots and slabs, all these levels were repeatedly exceeded by a wide margin. Fume, when deseaming small special steel ingots, consisted of almost pure iron oxide, and concentrations as measured by the personal samplers came within the ambit of the TLV for iron oxide.

Medical findings

Occupational histories of 19 men employed in the deseaming department in 1963 are given in Table 5. Cases 1, 4, 7, 8, 9, and 12 had worked in the department for 10 years or more, most or all of the time as deseamers. Of these, cases 1, 8, and 12 worked on large stainless ingots for 14, 7, and 7 years respectively, while cases 4, 7, and 9 had worked mainly on special steel ingots. Case 7 had worked as a coal miner for 18 years and on a tunnel-boring project for 2 years. Case 12 had worked in a brickworks for 3 years and as a welder for 8 years.

The relevant past medical histories, smoking habits, and respiratory symptoms of 14 men interviewed in 1963 are given in Table 6. Of the four men (cases 2, 3, 12, and 19) who complained of persistent cough and sputum, three were smokers and the other had been a heavy smoker up to six months before interview. Four men (cases 1, 3, 8, and 9) complained that they were more dyspnoeic on exertion than they thought they should be. Case 3 was a smoker with

TABLE 5

RADIOGRAPHIC FINDINGS IN RELATION TO EMPLOYMENT

Case no.	*No. of years employed in deseaming department (prior to 1963)*		*No. of years prior to 1963 working on:*		*Other relevant dust exposure*	*ILO pneumoconiosis category*
	Helper	*Deseamer*	*Stainless*	*Other ingots*		
1	–	16	14	2	None	3
2	3	–	1	2	Coal miner 16 yr	½
3	–	7	1	6	Coal miner 8 yr, clay level labourer 4 yr	0
4	1	10	–	11	Coal miner 2 yr	1
5	4	–	4	–	[1]	Not available
6	2	–	–	2	[1]	0
7	–	16	1	15	Coal miner 18 yr, tunnel boring labourer 2 yr	3
8	–	15	7	8	None	2
9	2	12	3	11	None	3
10	6 mth	–	3 mth	3 mth	None	0
11	3 days	–	–	–	None	0
12	2	8	8	2	Brickwork labourer 3 yr, electric welder 8 yr	1
13	Foreman 9		–	–	None	0
14	1	–	6 mth	6 mth	None	0
15	1	–	–	1	[1]	0
16	1	–	–	1	[1]	½
17	6	–	–	6	None	0
18	2	–	–	2	Coal miner 19 yr	2
19	3	3	1	5	Coal miner 1 yr	0

[1]Not obtained

persistent cough and sputum but the other three had no cough and were either non-smokers or ex-smokers.

Ventilatory function tests were carried out in 1963 on this group of 14 deseamer operatives and the results are given in Table 6. These were within the normal range except for case 19 who had symptoms of cough and sputum and a past history of asthma and spontaneous pneumothorax.

Eighteen men had their chests *x*-rayed in 1963 and the films were read by Gilson at the MRC Pneumoconiosis Research Unit. His findings are given in Table 5. Cases 1, 4, 7, 8, 9, 12, and 18 showed definite signs of pneumoconiosis and cases 1, 7, 8, 9, and 18 were placed in ILO categories 2 or 3 (Figs 2 and 3). Of these, case 18 left the works and the district in 1963 but the others remained in employment.

It was decided to study cases 1, 7, 8, and 9 in more detail, and the results of ventilatory function tests performed by Cotes in 1964 and 1966 are given in Table 7. In his opinion, the findings in case 1 of low $FEV_{1\cdot0}$ and FVC readings with a diminished transfer factor were consistent with interstitial fibrosis showing between 1964 and 1966. Cases 7 and 8 were within the normal range and case 9, with low $FEV_{1\cdot0}$ and FVC readings, showed evidence of a mild restrictive defect.

Cases 1, 7, 8, and 9 had further chest *x*-rays taken in 1966 and 1968, and Jackson reported that the films showed no change for better or worse when compared with the original films taken in 1963.

In 1964 estimations of the nickel content in urine were made for case 1 by Gwynne Morgan, who in four estimations found 0·060, 0·070, 0·064, and 0·068 p.p.m., giving a mean value of 0·065 p.p.m. within the normal range.

Discussion

The first knowledge that the deseaming process was causing ill-effects to the operators came as a result of a mass miniature radiography survey when one of them (case 9) was found to have an abnormal film suggestive of pneumoconiosis. A large film confirmed the diagnosis, and in the absence of any previous history of exposure to dust it seemed probable that his working conditions were responsible for the condition. Because of this the works management ordered a full investigation, the results of which have been described in this paper.

In view of the findings, it is interesting to consider why the process had continued for 16 years under these conditions. The main reason was that the working atmosphere was non-irritant to the res-

TABLE 6

MEDICAL HISTORIES, SMOKING HABITS, RESPIRATORY SYMPTOMATOLOGY, AND VENTILATORY FUNCTION TESTS (1963)

Case no.	Age in 1963 (yr)	Relevant past medical history	Smoking habits	Respiratory symptoms			% Predicted		
				Cough	Sputum	Dyspnoea excessive on exertion	$FEV_{1\cdot0}$	FVC	$\frac{FEV_{1\cdot0}}{FVC}$ %
1	47	Nil	Ex-smoker 2 yr, previously 20-25 cigs	No	No	Yes	78	79	108
2	60	Nil	Smoker: 20-30 cigs	Yes	Yes	No	77	80	104
3	49	Bronchitis aged 2	Ex-smoker 6 mth, previously 20-40 cigs	Yes	Yes	Yes	74	87	93
4	56	Typhoid fever	Non-smoker	No	No	No	110	113	108
5[1]									
6[1]									
7	57	Nil	Ex-smoker 26 yr, previously moderate	No	No	No	100	98	112
8	36	Diptheria aged 7	Non-smoker	Yes	No	Yes	95	100	98
9	48	Nil	Ex-smoker 20 yr, previously moderate	No	No	Yes	80	83	105
10	17	Nil	Non-smoker	No	No	No	98	98	101
11	17	Rheumatic fever aged 9	Ex-smoker 2 yr, previously smoked for 6 mth aged 15	No	No	No	98	93	104
12	45	Nasal catarrh for many years	Smoker 20+ cigs	Yes	Yes	No	83	103	84
13	46	Nil	Non-smoker	No	No	No	76	90	89
14	19	Pneumonia as a baby, rheumatic fever aged 3	Non-smoker	No	No	No	113	113	104
15[1]									
16[1]									
17	61	Hypertension	Smoker 20 cigs	No	No	No	83	105	88
18[1]									
19	53	Asthma aged 16-29 Spontaneous pneumothorax aged 29 and 42	Smoker 10-13 cigs	Yes	Yes	No	63	86	79

[1] Not examined

piratory tract, as confirmed by the low nitrogen dioxide readings, the observers' experience, and the absence of symptoms of cough and sputum among deseaming employees, except in the case of four cigarette smokers. Approximately seven years previously, exhaust ventilation had been provided for the deseaming of small special ingots, and those employed at the time said that working conditions had improved very considerably after this. Additionally, at that time it was accepted that many processes in the steel industry were dusty and there was no knowledge that deseaming processes elsewhere had produced harmful effects.

Deseamers on each type of ingot were exposed to the fume concentrations shown in Tables 3 and 4 for about five hours on a normal shift. Depending on the wind direction and velocity, those working on small ingots would inhale some fumes from large stainless ingots. Helpers would inhale lower concentrations than deseamers. Before the installation of exhaust ventilation, those men employed in the department for more than seven years would have been exposed to

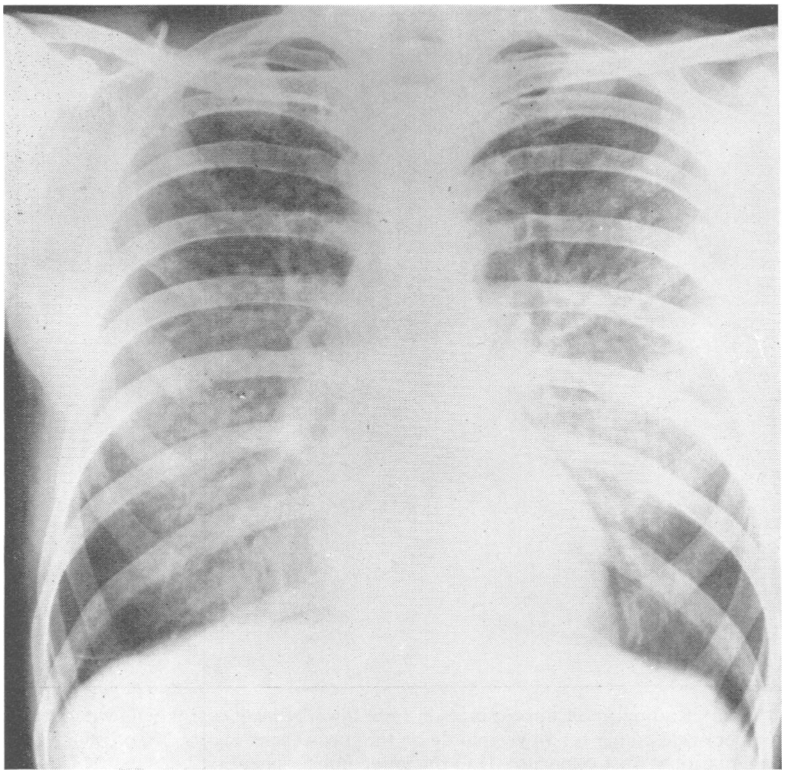

FIG. 2. Case 1, radiographic appearances of worker who had worked as a deseamer for 16 yr (14 yr on the stainless steel ingots and 2 yr on the special steel ingots). No other relevant occupational dust exposure. ILO pneumoconiosis category 3.

high concentrations of iron oxide when working on small special ingots, and during this period concentrations in the resting areas would also have been considerably higher.

A study of the radiographic findings in relation to the time of employment as deseamers or helpers (Table 5) shows that the six men employed for 10 years or more (cases 1, 4, 7, 8, 9, and 12) all showed definite signs of pneumoconiosis. Additionally, those with 14 to 16 years' service (cases 1, 7, 8, and 9) were most severely affected, being classified as ILO categories 2 or 3. Case 18, who had left the works after only two years' employment as a deseamer's helper, was classified as ILO category 2, but this was attributable to his previous employment as a coal miner for 19 years. Case 7 was a coal miner for 18 years but none of the other cases with radiographic signs of pneumoconiosis had been exposed to dust previously. There is, therefore, no doubt that the radiographic changes in cases 1, 4, 8, 9, and 12 were caused by inhalation of the fumes previously described. The extent of the contribution made by the fumes to the findings in case 7 is a matter of conjecture.

The detailed and repeated pulmonary function studies on cases 1, 7, 8, and 9 showed that two of them were in the normal range but the other two had measurable loss of function, moderate in one case and mild in the other. Case 8 was a nonsmoker, cases 7 and 9 had not smoked for 26 and 20 years respectively, and although case 1 was an exsmoker of only two years' standing he did not complain of cough or sputum production. Consequently, the loss of function was not attributable to cigarette smoking.

Relating dust exposure to radiographic findings and pulmonary function readings for individual cases we can reach the following conclusions:

Case 1, after 16 years' exposure to fume mainly composed of iron oxide, chromium oxide, and nickel oxide in the ratio 6:1:1, showed ILO category 3 pneumoconiosis and moderate loss of pulmonary function consistent with interstitial fibrosis.

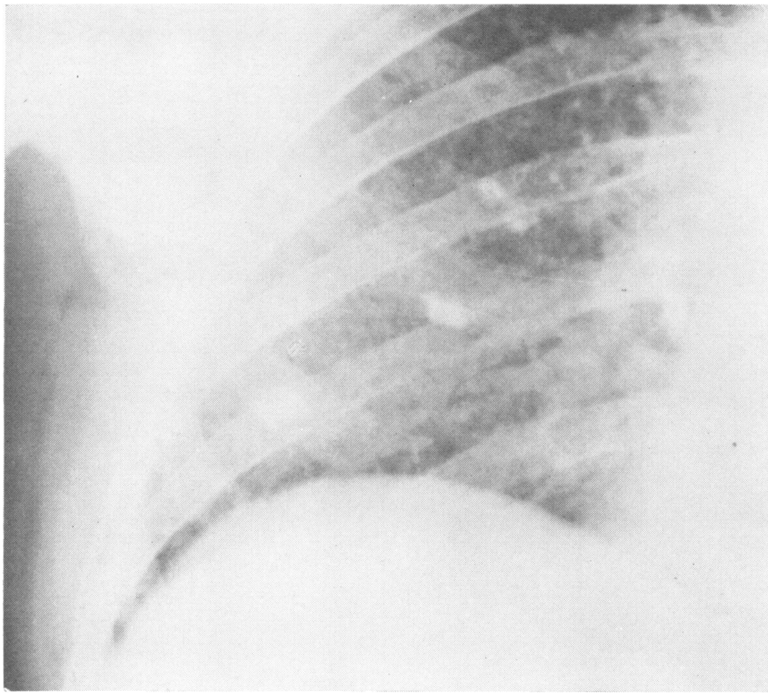

FIG. 3. Radiographic appearances in right lower zone of case 9, who worked as a helper or deseamer for 14 yr, mainly on the special steel ingots. No other relevant occupational dust oxposure. ILO pneumoconiosis category 3.

Case 7, with a previous history of 18 years as a coal miner and two years' tunnel boring, after 16 years' exposure to fume, mainly iron oxide, showed ILO category 3 pneumoconiosis with evidence of old tuberculosis and apical opacities consistent with complicated coal miners' pneumoconiosis and pulmonary function readings within the normal range.

Case 8, after 15 years' exposure to fume, about half of which was iron oxide and half mixed oxides, showed ILO category 2 pneumoconiosis and pulmonary function readings within the normal range.

Case 9, after 14 years' exposure to fume, three-quarters of which was iron oxide and one-quarter mixed oxides, showed ILO category 3 pneumoconiosis with slight loss of pulmonary function, indicating a mild restrictive defect.

None of these cases had pure exposure to iron oxide and consequently they cannot be described as

TABLE 7

PULMONARY FUNCTION TESTS ON FOUR SELECTED CASES

Case no.	*Date of examination*	$FEV_{1\cdot 0}$ *(litres)*	*FVC (litres)*	$\frac{FEV_{1\cdot 0}}{FVC}\%$	*Transfer factor* ($ml\ min^{-1}\ torr^{-1}$)
1	1964	1·99 (3·1)	2·85 (3·9)	70 (74)	19 (23)
	1966	1·66	2·56	65	15
7	1964	2·88 (3·0)	4·38 (4·0)	66 (70)	24 (26)
	1966	2·60	4·22	62	21
8	1964	3·24 (3·5)	3·88 (4·3)	84 (78)	24 (28)
	1966	3·06	3·83	80	23
9	1964	2·66 (3·4)	3·73 (4·4)	71 (74)	25 (25)
	1966	2·42	3·42	71	23

The figures in parentheses for the 1964 entries represent average normal values as applicable to each individual at that date.

siderosis. Cases 1, 8, and 9 had mixed-dust pneumoconiosis (due to the oxides of iron, chromium, and nickel) and case 7 had coal miners' pneumoconiosis complicated to an unknown degree by the inhalation of mainly iron oxide fumes.

However, many observers would diagnose them as siderosis because the main constituent of the fumes was iron oxide. This misuse of the word in relation to the two cases with impaired pulmonary function would further confuse the issue as to whether iron oxide can cause pulmonary fibrosis. We conclude that it is probable that inhalation of pure iron oxide never leads to fibrotic pulmonary changes, whereas the inhalation of iron oxide plus certain other substances obviously does.

Both chromium and nickel compounds have been shown to be carcinogenic. An increased incidence of lung cancer has been noted in those employed in the production of chromate and bichromate from chromite ore, but there is no corresponding evidence to show a similar increase in incidence among users (Department of Employment and Productivity, 1969a). The Hygienic Guide Series for nickel (1966) summarizes the published reports of carcinogenic and toxic effects. Extraction of nickel from the ore had led to a significant increase of cancer of the lung and sinuses. Animal experiments have shown the carcinogenic effect of powdered nickel. In this study, no cases showed evidence of lung cancer after 19 years. The longest and heaviest exposure to chromium oxide and nickel oxide occurred in case 1, who was exposed to concentrations of nickel ranging from 1 to 30 mg/m^3 for approximately five hours per shif. for 14 years.

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