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Investigation of a Minor Asbestos Hazard

M. C. S. KENNEDY and R. ROUTLEDGE

From the Department of Respiratory Physiology, City General Hospital, Stoke-on-Trent and the Medical Department, English Electric Company Limited, Stafford

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These developments, as Gilson (1966) has pointed out, have underlined the necessity for further knowledge of the early changes which occur on exposure to low concentrations of asbestos and for attempting to detect very early changes with existing methods of investigation. Over the years the many reports reflect the changes which have taken place in diagnostic methods. The condition of asbestosis is no longer diagnosed on clinical examination alone, and increasing emphasis is being placed on the ancillary aids of radiology and respiratory function tests.

The following investigation on a group of individuals who had been exposed to small amounts of asbestos was, therefore, undertaken to assess whether such exposure had caused radiological, physiological, or clinical changes.

Received for publication December 13, 1966.

Present Investigation

In a large factory in the midlands manufacturing heavy electrical equipment, asbestos was used in two departments. The asbestos used consisted of chrysotile, which was obtained from either Canadian or Rhodesian mines. It was decided to investigate fully the environment and to monitor the personnel in these departments.

Processes

Insulation Department In this department hardboard, consisting of 40% asbestos and 60% resin, was used for insulation purposes (Fig. 1). Although local and general exhaust ventilation was provided when this hardboard was being cut, milled, and shaped, dust containing asbestos was produced.

Transformer Department Reclaimed mill board with 71 to 72% asbestos, china clay, and starch was

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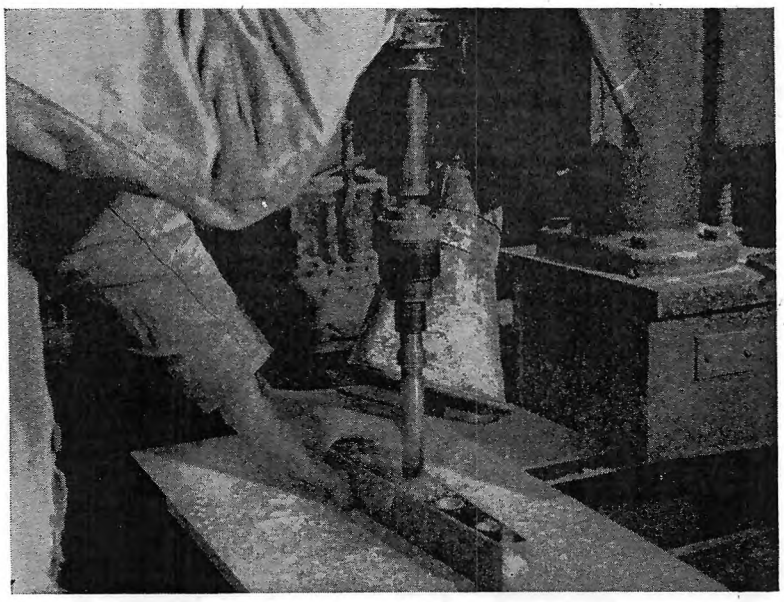

FIG. 1. An operative drilling hardboard (insulation department).

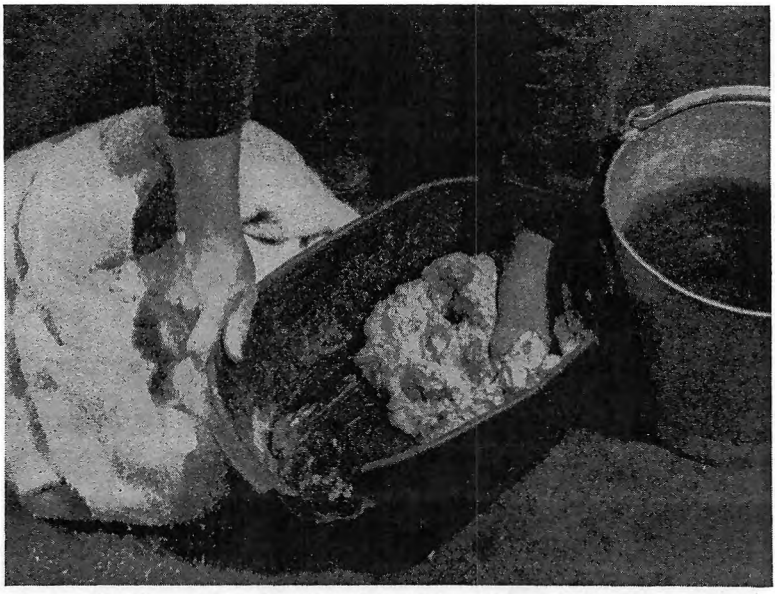

FIG. 2. The dry, reclaimed millboard containing asbestos, china clay, and starch being mixed with water to form a thick paste (transformer department).

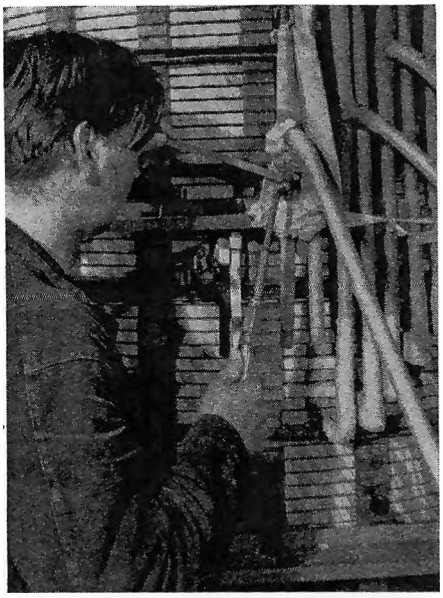

FIG. 3. An operative welding. The transformer windings are protected with asbestos paste (transformer department).

mixed with water to form a thick paste which was used to protect transformer windings when welding operations were carried out on the terminals (Figs. 2 and 3). The heat dried the paste and some asbestos dust was produced locally which could be inhaled by the operative. Exposure to the dust also occurred when the dry asbestos was transferred from the bag to the bucket by hand for mixing and when the dried mix was removed from the welded copper bars with a wire brush.

Dust Sampling Since the dust hazards in the insulation and transformer departments were obviously very different, the dust sampling procedures were modified accordingly and are given below.

Insulation Department Two hexhlet samples were taken in the department. They were not breathing zone samples but were representative of the conditions in the immediate working area of the men. The first sample, taken over a period of two and a half hours, when the operatives were mainly engaged in sawing and filing 'ebony', gave less than 47 μg./m^3. asbestos. The second sample was taken over a period of three hours and during this time the operatives were sawing and drilling bakelized asbestos (one and a half hours) and also working epoxy glass on the router (one and a half hours). This three-hour sample yielded 57 μg./m.^{3} asbestos. The tentative maximum allowable concentration of asbestos in air, using the hexhlet method of estimation, is 100 μg./m^3. (King 1966).

Transformer Department Apart from the initial transfer of asbestos from the bag to the bucket by hand, the mixing was apparently dust-free and a thermal precipitator sample taken during the transfer showed less than 1 fibre per ml. of air. It is possible that the concentration of asbestos in the air is greater when the dried mix is removed by a wire brush from the welded copper bars, but this operation was not seen on the day of the visit. A second thermal precipitator sample was taken while the asbestos mix was used to protect the transformer components during welding, and this also showed less than 1 fibre per ml. of air. Both thermal precipitator samples were taken in the breathing zone of the workmen and both were below any currently accepted maximum concentration.

Investigation of Men Exposed to Asbestos

Methods The 10 transformer fitters and the two insulation workers were examined in detail, and the following points were covered: occupational history; symptomatology; clinical examination; radiology and sputum examination; and physiological investigations.

The physiological investigations included simple spirometry. The total lung capacity and its subdivisions and the helium dilution time were measured by closed spirometry, and the assessment of the transfer factor at rest and on exercise by using the steady-state carbon monoxide uptake method. The ventilatory cost of exercise was assessed using the Hugh-Jones and Lambert (1952) technique at a work level of 300 kg.m./minute. The chest radiographs were read independently and finally jointly.

Relevant Findings The relevant clinical, radiological, and physiological findings are listed in Tables I and II.

Transformer Fitters The 10 transformer fitters had worked with the process described above for periods ranging from 15 to 37 years; their ages ranged from 36 to 54 years. None of them had a history of untoward chest symptoms but two men had minor symptoms of exertional dyspnoea. There was no evidence of clubbing of the fingers.

Radiologically four of the 10 men were classified as having normal chest radiographs and five of them had minor basal changes which for the most part consisted of a few scattered pinhead opacities, usually at the right base. One man (no. 6) had three

TABLE I

CLINICAL AND *X*-RAY FINDINGS

Subject	*Age (yrs)*	*Height (in.)*	*Weight (lb.)*	*Years in Work*[1]	*Smoking (cigs/day)*	*Chest Symptoms*	*X-ray Results*		
							Diaphragm Movement (mm.)		*Remarks*
Transformer Workers							*R.*	*L.*	
1	54	70	260	37	< 20	Cough a.m.	60	70	Abnormal mediastinal and heart shadow; hilar shadows +
2	36	66	161	15	Occasional pipe	Nil	40	32	Normal
3	39	67	193	16	0	Mild exertional dyspnoea (grade 2/3)	40	45	? old basal left pleurisy
4	42	71	194	28	40 up to 5 yrs ago now 0	Nil	20	17	A few pinhead opacities right base
5	38	72	233	16	> 20	Cough a.m.	52	55	Slight cardiac enlargement; basal changes
6	45	68	193	28	< 20 up to 1 yr ago now 0	Mild exertional dyspnoea (grade 2/3)	40	38	Left ventricle enlarged; 3 small opacities left upper zone and left mid-zone; some small bilateral basal pinhead opacities
7	38	66	137	24	0	Nil	36	35	A few scattered basal pinhead opacities
8	46	68	158	30	0	Nil	36	52	Normal
9	44	73	232	29	20	Nil	60	62	Normal
10	43	68	174	20	0	Nil	37	39	Normal
Insulation Workers									
11	21	68	140	5	< 20	Mild exertional dyspnoea (grade 2/3)	16	34	Normal
12	47	69	170	23	6	Mild exertional dyspnoea (grade 2/3)	5	5	Pinhead opacities left base; distorted lung pattern right base; bilateral filling costophrenic angles

[1]None of the 12 men had worked in other dusty processes likely to cause lung changes.

small opacities in the left upper zone and left mid-zone, which could possibly have been pleural plaques (Fig. 4). Three men (nos. 1, 5, and 6) had a slight abnormality of either the mediastinum or heart shadow. No asbestos bodies were found on examination of the sputa.

The physiological findings are listed in Table II together with the predicted normal value for each physiological index based on the age and height of the individual. With the wide scatter which occurs in normal individuals about the predicted normal values, we have arbitrarily decided that the various parameters are normal if they fall within 20% of the predicted normal[1]. The ventilatory cost of exercise has been judged to be abnormal if either the exercise ventilation (E.V.) or the standardized ventilation (S.V.) was more than 35 l./minute. The transfer factor was considered to be abnormal if at rest the uptake of carbon monoxide was less than 15 ml./min./mm.Hg. The transfer factor on exercise was considered to be abnormal if the values were less than 25 ml./min./mm.Hg.

In all the 10 transformer workers, the lung volume studies were within 20% of normal with the exception of the inspiratory capacity, which was abnormally small in four men (nos. 2, 3, 4, and 5). The bellows function was abnormal in only two of the 10 men (nos. 3 and 5).

The transfer factor, both at rest and on exercise, was subnormal in two men (nos. 3 and 8). Two further men, whose transfer factor at rest had been normal, had a subnormal transfer factor on exercise (nos. 1 and 5). The ventilatory cost of exercise was

[1]The predicted normal values were estimated using the Tables published by Cotes (1965).

TABLE II

RESULTS OF PHYSIOLOGICAL INVESTIGATIONS

Subject		Ventilation (l./min.)			Lung Volumes (ml.)					Bellows Function			Transfer Fac (ml./min./mm.	
		R.V.	E.V.	S.V.	T.L.C.	V.C.	R.V.	$\frac{R.V.}{T.L.C.} \times 100$	I.C.	Ind. M.B.C. (l./min.)	Direct M.B.C. (l./min.) O.R.*	Direct M.B.C. (l./min.) 40*	Rest	Exer
Transformer Workers														
1	a	9·9	44	44	7,438	5,060	2,378	32%	4,345	108·9	118·8	123·2	18	20
	b				6,900	4,300	2,400	35%	3,700	122	122	122		
	c				+8%	+17·6%	−1%	−8·6%	+17%	−10%	−3%	+1%		
2	a	8·8	29·7	26·4	6,303	4,785	1,518	24%	2,860	121	132	124·2	27	35
	b				6,200	4,400	1,800	29%	4,000	128	128	128		
	c				+1·7%	+8·7%	−1·6%	−17%	−28%	−5%	+3%	−3%		
3	a	11	36·3	45·1	5,977	4,070	1,907	32%	2,750	93·5	110	102·3	12	22
	b				6,200	4,400	1,800	30%	3,900	125	125	125		
	c				−3·7%	−7·5%	+6%	+6·6%	−29%	−25%	−12%	−18%		
4	a	11	35·2	38·5	6,393	4,510	1,883	29%	3,300	128·7	123·2	123·2	25	28
	b				7,100	4,900	2,100	31%	4,200	137	137	137		
	c				−10%	−8%	−10%	−6·5%	−21%	−6%	−22%	−10%		
5	a	12·1	38·5	38·5	7,130	4,620	2,510	35%	3,080	115·5	96·8	114·4	21	25
	b				7,300	5,050	2,200	30%	4,350	143	143	143		
	c				−2%	−8·5%	+14%	+16·6%	−29%	−19%	−32%	−20%		
6	a	11	26·4	26·4	6,860	4,840	2,020	29%	4,180	112.2	100·1	114·4	13	29
	b				6,500	4,300	1,900	32%	3,900	122	122	122		
	c				+5·5%	+12·5%	+6·3%	−9%	+7%	−8%	−18%	−6%		
7	a	7·7	20·9	24·2	7,700	5,885	1,815	24%	3,740	136·4	140·8	115·5	19	36
	b				6,100	4,300	1,800	30%	3,900	125	125	125		
	c				+26%	+37%	+0·8%	−20%	−4%	+9%	+13%	−8%		
8	a	11	30·8	27·5	7,191	4,621	2,571	26%	3,960	102·3	114·4	123·2	12·5	22·5
	b				6,500	4,300	1,900	32%	3,900	122	122	122		
	c				+10·6%	+7·5%	+35·3%	−18·7%	+1%	−16%	−6%	+1%		
9	a	12·1	37·4	33	9,190	5,940	3,251	35%	5,115	132	165	140·8	14	27
	b				7,500	5,200	2,250	32%	4,200	140	140	140		
	c				+22·5%	+14%	+44·5%	+9·4%	+22%	−6%	+18%	+0·6%		
10	a	11	26·4	24·2	7,114	4,895	2,219	31%	3,740	122·1	92·4	118·8	19	38
	b				6,450	4,500	1,900	31%	4,100	125	125	125		
	c				+10·4%	+8·8%	+16·8%	±0%	−9%	−2%	−26%	−5%		
Insulation Workers														
11	a	9	29	26	6,140	4,180	1,960	32%	2,090	102·3	110	88	15	19
	b				6,450	5,000	1,550	24%	4,300	146	146	146		
	c				−5%	−16·4%	+26·5%	+33·3%	−51%	−30%	−25%	−40%		
12	a	12·1	34·1	30·8	7,700	4,510	3,190	41%	3,520	111·1	101·2	101·2	20	22
	b				6,700	4,450	2,150	33%	3,900	125	125	125		
	c				+15%	+1·3%	+48%	+24%	−10%	−11%	−19%	−19%		

*O.R. = At subject's own respiratory rate.
40 = At a rate of 40 breaths/min.
a, result; b, predicted normal, c, change.

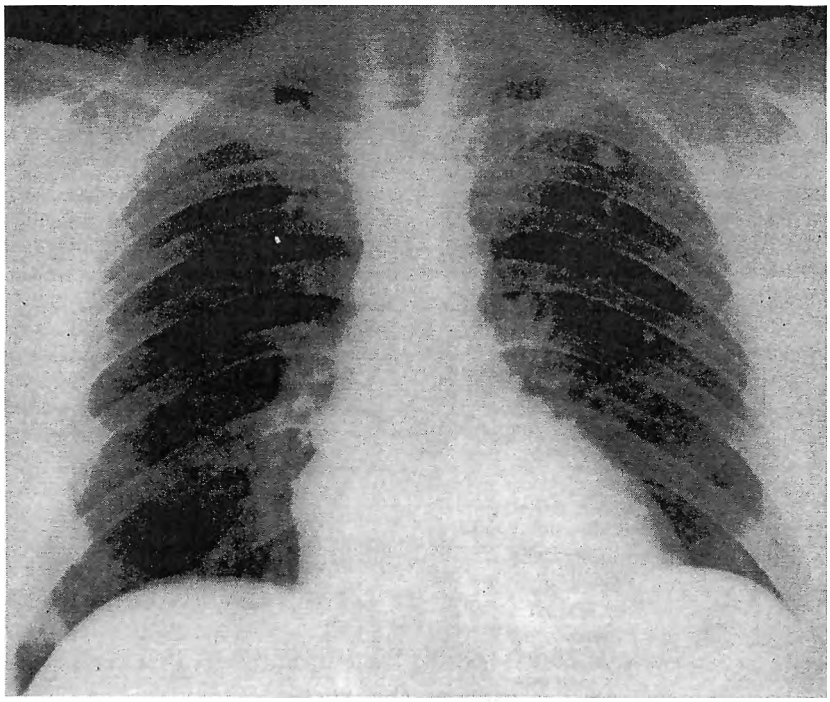

FIG. 4. Postero-anterior film of a man aged 45 (No. 6, Tables I and II) showing three small shadows in the left upper zone which are probably pleural plaques.

in excess of normal in five of the 10 men (nos. 1, 3, 4, 5, and 9).

Insulation Workers In general, the two insulation workers showed far more abnormality than the transformer fitters.

One of the insulation workers aged 21 years (no. 11), who had worked for only five years in the insulation process, had a normal radiograph but showed the greatest physiological change of any of the men investigated. He had abnormal lung volume, *viz.*, a raised residual volume, an increased R.V./T.L.C. ratio, and a greatly decreased inspiratory capacity (51% less than normal). His ventilatory capacity or bellows function, as measured both indirectly and directly, was between 25% and 40% below the predicted normal. His transfer factor, as measured at rest, was within normal limits but did not increase normally on exercise. His ventilatory cost of exercise was within normal limits.

The other insulation worker aged 47 years (no. 12), who had worked for 23 years in the process, had radiological evidence of pinhead opacities at the left base and a distorted lung pattern suggestive of destructive emphysema at the right base. He also had bilateral filling of the costophrenic angle. As regards the physiological tests, the residual volume and the R.V./T.L.C. ratio were over 20% more than the predicted normal values. The bellows function or ventilatory capacity, as measured either indirectly or directly, was reduced but was within 20% of the predicted normal value. The transfer factor at rest and on exercise was low and the ventilatory cost of exercise was slightly raised.

Discussion

Williams and Hugh-Jones (1960b) have investigated, in detail, advanced cases of asbestosis and in their study they found that the following parameters of lung function were frequently disordered:

1. standardized ventilation (S.V.) was increased when performing the standardized Hugh-Jones exercise tolerance test;

2. the maximum breathing capacity was usually reduced;

3. the most striking change in the lung volume studies was the reduction in the inspiratory capacity;

4. the diffusing capacity was reduced in all their cases except two.

In their investigation these authors found that the changes in the ventilatory capacity often bore no relation to the changes in the diffusing capacity. Furthermore, they found considerable observer variability in grading asbestosis radiologically, and often the radiological findings bore no relation to the physiological changes. Thus, since both the radiological and physiological findings can vary so much in men exposed to a severe asbestos hazard, it is very difficult to be dogmatic about the findings in our investigation where the men were exposed to only a minor asbestos hazard. Bearing this in mind, we would make the following observations about the 10 transformer workers and the two insulation workers.

The 10 Transformer Workers In general, one can say that five of the 10 transformer workers show very minor basal changes radiologically which would often be recorded as normal changes at routine screening sessions. The transfer factor findings are a little difficult to assess in view of the low level of exercise the employees were asked to do. However, most of the transfer factor results at rest are within normal limits though below normal on exercise in four men (nos. 1, 3, 5, and 8).

When the diffusing capacity or transfer factor is defective on exercise, one expects this abnormality to be associated with an increased ventilatory cost for standardized exercise. This occurred in three of these men (nos. 1, 3, and 5). Two of the four men (nos. 3 and 5) with a reduced transfer factor on exercise and an increased ventilatory cost of exercise also had a reduced inspiratory capacity and an appreciable reduction in the indirect maximum breathing capacity. It is interesting that these two employees show minor basal radiological changes and are among those with the shortest exposure to asbestos dust.

In short, we consider that two of the 10 transformer workers show minor radiological and some physiological changes suggestive of early asbestosis. One man was a non-smoker, the other a heavy cigarette smoker (>20 cigarettes/day).

The Two Insulation Workers Both the insulation workers show a great increase in the R.V./T.L.C. ratio and a considerable reduction in their ventilatory capacity. One of these two men (no. 11) has the lowest transfer factor of the whole group, the highest R.V./T.L.C. ratio, the greatest impairment of inspiratory capacity and maximum breathing capacity, and has been 'at risk' for the shortest time. Although this man had a normal chest radiograph, the physiological findings showed definite evidence of impaired pulmonary function. It is probable that the inhalation of asbestos dust has been the cause of some at least of the abnormal findings in these two insulation workers.

Those patients showing abnormal pulmonary function studies are listed in Table III. From this Table it can be seen that there is abnormality of four or more parameters of lung function in four patients only, *viz.*, nos. 3, 5, 11, and 12. All these patients showed the following features: an abnormally low carbon monoxide uptake on exercise, a decrease in the inspiratory capacity, and a decrease in the Indirect M.B.C. Three of these four patients showed an increase in the ventilatory cost of exercise, and three of them showed an increase in both the residual volume and in the R.V./T.L.C. ratio.

In general, the index of pulmonary function most deranged in these men was the inspiratory capacity (Table II).

Leathart (1960), in his study of 10 cases of asbestosis and 11 radiologically normal asbestos workers, found that a low vital capacity accompanies fibrosis of the lungs in asbestos workers and

TABLE III

ASBESTOS WORKERS WITH ABNORMAL PULMONARY FUNCTION

Test	*Subject (see Tables I and II)*
D_L at rest 15 ml./min./mm.Hg or less	3 6 8 9 11[1]
D_L on exercise 25 ml./min./mm.Hg or less	1 3 5 8 11[1] 12
Inspiratory capacity reduced	2 3 4 5 11[1] (12)
Maximum breathing capacity reduced	(1) 3 5 11[1] (12)
E.V. and S.V. raised (35 l./min. or over)	1 3 4 5 9 (12)
R.V. raised and increased R.V./T.L.C. ratio	(5) 11[1] 12

[1]Individual showing the greatest abnormality.
Values between 10 and 20% abnormal were obtained for subjects given in parentheses.

suggested that the vital capacity of all exposed workers should be measured at regular intervals and that a progressive decline should be taken as a warning of impending disease. In our series the vital capacity was, in all cases, within 20% of the predicted normal whereas there were five men who had a marked reduction in the inspiratory capacity. Thus, if the changes we have observed are the result of the inhalation of asbestos dust, it is probable that a reduction in the inspiratory capacity may be a more sensitive and earlier index of change than the vital capacity. The findings of Williams and Hugh-Jones (1960a and b) and those of Thomson, Pelzer, and Smither (1965) support this view.

Our observation that the total lung capacity was not decreased in any of the men examined indicates that lung fibrosis, if present, was not extensive. If lung fibrosis was present one would assume that there would be some degree of associated emphysematous change, in view of the finding that the R.V. as well as the R.V./T.L.C. ratio was substantially increased in three of the four men showing the greatest derangement of pulmonary function.

We feel that probably there is no point in discussing these results further at this stage until follow-up investigations have been carried out on this group of men. However, the results so far agree with the observations of Williams and Hugh-Jones that the finding of lung changes specific for an interstitial fibrosis in patients with an exposure to asbestos is suggestive evidence of asbestosis, whatever the radiological appearances.

Clearly, the minor asbestos hazard to which the men were exposed was only intermittent and occasional in the case of the transformer workers. In the case of the two insulation workers, the exposure was greater and more frequent. However, we think it has been useful to assess this minor hazard fully before it has had time to produce severe biological changes.

The hazard has now been reduced in both departments. In the transformer department mica paper scrap has been substituted for asbestos, and in the insulation department the ventilation has been redesigned and greatly improved.

This investigation was initiated by Dr. George Ritchie, H. M. Medical Inspector of Factories, and we wish to record our gratitude for his continued help and collaboration.

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