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DUST IN CARD ROOMS: A CONTINUING PROBLEM IN THE COTTON-SPINNING INDUSTRY

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The results are given of environmental and clinical investigations in four card rooms where one of the latest systems of exhaust ventilation to control dust has been installed. The concentration of air-borne coarse dust particles, larger than 2 mm., was reduced by between 80% and 90% around the carding engines. The card rooms consequently looked less dusty. However, the concentrations of medium and fine sized dust particles were not always reduced and were actually increased in some places. In one mill, when the new control system had been running for three years, there was found to be no reduction in the prevalence of non-specific chest symptoms, and there was an increase in the number of those with chest tightness on Mondays, a symptom characteristic of byssinosis. Evidence is given of a similar failure to reduce the dust sufficiently in three other mills where the same exhaust system is installed.

There is an urgent need to extend the limited investigations reported here to a larger number of mills. Meanwhile there is a continuing morbidity and mortality from byssinosis. Until work in card rooms has been made safe and proved to be so, it is necessary to have regular measurement of dust conditions and for the workers to have periodical medical examinations to enable managements to be advised about the hazards in their mills and advice to be given to the individuals affected by the dust.

It has been known for many years that the air-borne dust in cotton card rooms affects the health of the workers, and considerable efforts have been made to control it. In the early part of this century attempts were made to control the dust dispersed when the carding engines were cleaned or 'stripped' with large rotating brushes. There was a noticeable improvement when the brushes were partially enclosed and exhaust ventilation was applied to the enclosures, and again when brush cleaning was replaced by vacuum stripping. In 1915 Collis thought that byssinosis would cease to exist when such devices were installed throughout the industry. Later Dearden, in 1927, and Sir Thomas Legge, in 1934, referred to the satisfactory way in which the dangerous dust in card rooms had been controlled. However, there does not appear to have been any detailed study made of the dustiness of the card rooms or the health of exposed workers after the installation of these systems of control.

Byssinosis became a compensatable occupational disease in 1941. At first the benefit was limited to men who had worked 20 or more years in specified parts of cotton mills and who were totally and permanently incapacitated. Subsequent legislation in 1948 included women workers. The waste cotton industry was included in the scheme in 1951, the qualifying period of employment was shortened to 10 years in 1956, and the degree of disability required before benefit could be claimed was reduced in 1948 and again in 1956. These changes make it difficult to interpret recent trends in morbidity shown by compensation statistics. However, some measure of the existing problem is given by the fact that the average number of claims for byssinosis allowed by the Ministry of Pensions and National Insurance has been 348 per year since the qualifying conditions were last altered in 1956. Over this same period the average number of deaths in which byssinosis was the certified cause was 41 per year.

Since neither enclosed brush stripping nor vacuum stripping was a complete cure for the health hazards

arising from cotton dust, other additional methods of control have been tried. These have included improvements in the enclosure and exhausting of processes in the cotton chamber and blowing room, modifications to the taker-in region of the carding engines, the oiling of cotton, the substitution of pneumatic for manual methods to remove waste from various sources, and finally the continuous extraction of air-borne dust from around the carding engines. To achieve this last object three different exhaust systems have recently been developed, the Shirley Pressure Point System, the Selrow Device, and the Atmospheric Control Ltd. Device.

The first of these to be developed, and the best known, is the Shirley Pressure Point System (Brownsett, 1959). In essence this device is the enclosure of parts of the carding engine, and from this enclosure air is exhausted at three dusty points where there are regions of high air pressure. Tests have been carried out in the Shirley Institute laboratories and in a cotton mill to ascertain the efficiency of the device (Ministry of Labour and National Service, 1957). It was reported that in the laboratory the efficiency of the system in reducing the number of dust particles varied with the particle size, rising from 45% efficiency for particles smaller than 0·5 micron in diameter to 92% efficiency for particles greater than 4 microns in diameter, reducing the total number of air-borne particles with an overall efficiency of 55%. After making certain assumptions, the equivalent figures for tests in a mill were given as 45% efficiency for particles smaller than 0·5 micron in diameter and 88% for particles larger than 4 microns in diameter, giving an overall efficiency of 62%. In the card room where the pressure point system was fitted, it was further noted that 'There was much less visible dust (*i.e.*, dust particles greater than about 100 microns) . . . the atmosphere . . . was not offensive to breathe, and byssinotics . . . did not become distressed'. Unfortunately, no details are given as to how these last assessments were made, to what numbers of persons they applied, or for how long they had been exposed.

Over the past six years the Shirley Pressure Point System has been installed in many cotton mills in Lancashire and has been properly hailed as another major advance in the control of cotton dust.

The Final Report of the Dust in Card Rooms Sub-Committee states: 'We think that the means are now available to ensure the effective control of dust evolved during the carding process and to enable the industry to implement the provisions of Section 47 of the Factories Act, 1937' (Ministry of Labour, 1961).

But the problem remains as to whether these methods will be good enough by themselves to reduce the health hazard to an acceptable minimum.

In some card rooms a striking visible improvement has occurred, and it has even been possible to reduce the number of cleaners employed. However, the critical issue is whether these improvements are accompanied by the removal of enough of whichever fraction of the dust is responsible for causing byssinosis. An endeavour to answer this question is reported below, together with other relevant data.

Mill A

The management of mill A with a card room containing 75 engines spinning coarse grades of cotton (counts ranging from 8's to 30's)* invited us to measure the dust concentration and examine all the workers before and after the Shirley Pressure Point System was installed. In August 1959, just before the new system was installed, a dust survey of the whole card room was made using sets of parallel samplers running throughout a complete shift. One sampler, a Soxhlet, drew air first through a 2 mm. mesh gauze and then through a paper filter. The other, a Hexhlet, drew air first through a horizontal elutriator with a cut-off point at 7 microns and then through another paper filter. It was therefore possible to estimate the concentrations of dust particles of different sizes (Roach and Schilling, 1960). All the workers were interviewed, and the Medical Research Council questionnaire on respiratory symptoms was completed (Medical Research Council, 1960), together with extra questions about byssinosis. The installation of the dust extractors then began and was completed by February 1960. A dust survey was made at this time and repeated a year later in March 1961. Finally, in October 1962, three years after the initial survey, the air-borne dust was measured again, and all the workers were questioned as before.

Dust Concentration.—The mean concentration of air-borne dust in the card room near the carding engines, draw frames, and intermediate frames is given for three size fractions of dust in Table 1. The dust sampling apparatus was placed in different positions each day at the centre of the group of machines attended by one or other of the workers chosen at random. The individual sampling results vary among themselves because of the differences in dustiness at different places in the card room, because of the variation in dustiness from one day to the next, and because of the errors of measurement.

*The count is the number of hanks of 840 yards (768 m.) in 1 lb. (0·45 kg.) of cotton yarn.

TABLE 1

AIR-BORNE DUST CONCENTRATIONS (mg./m.³) IN MILL A

Date	Area of Card Room											
	Among Carding Engines				Among Draw Frames				Among Intermediate Frames			
	< 7μ	7μ-2 mm.	> 2 mm.	Total	< 7μ	7μ-2 mm.	> 2 mm.	Total	< 7μ	7μ-2 mm.	> 2 mm.	Total
Aug. 1959 *	0·5	0·8	4·5	5·8	0·3	0·5	2·8	3·6	0·3	0·3	1·6	2·2
March 1960	0·5	0·4	0·5	1·4	—	—	—	—	0·4	0·3	1·6	2·3
March 1961	0·3	0·7	0·5	1·5	0·4	0·5	1·0	1·9	0·3	0·4	1·3	2·0
Oct. 1962	0·6	0·6	0·7	1·9	0·6	0·6	1·7	2·9	0·6	0·5	1·6	2·7

*Shirley Pressure Point System installed.
Each figure is the mean of about 10 results, each referring to a whole shift sample.

Measurements of the concentration of coarse dust made in this way tend to be the most variable, with a coefficient of variation between 40% and 80%. Measurements of the concentration of fine dust are less variable, having a coefficient of variation between 10% and 45%. The medium sized dust is determined by the difference between the concentration of dust passing the gauze and the concentration of fine dust. It has a coefficient of variation between 15% and 52%.

The principal effect of the exhaust ventilation system was to reduce the concentration of coarse dust particles greater than 2 mm. among the carding engines. There was apparently little sustained effect on the medium and fine sized particles in this area. Among the draw frames and the intermediate frames at the other end of the room from the carding engines, there was some reduction in the concentration of coarse dust, little change in the medium dust, and a marked increase of fine dust by 1962. The highest concentration of total dust in the card room was among the carding engines before the installation, but among the frames afterwards.

Prevalence of Disease.—The number of men and women working in the card room in 1959 and 1962, together with their mean ages, is shown in Table 2. The 16 workers who were present on both occasions and had worked in this card room throughout the period under review are shown separately. The average age increased by about three years between the two investigations.

The prevalence of symptoms in all the workers in the card room interviewed in 1959 and 1962 is shown in Table 3. The prevalence of symptoms in the 16 workers seen on both occasions is shown separately. There was no decrease in the prevalence of symptoms in the total card room population. There was, moreover, an increase in the number with wheezing and with chest tightness on Mondays among the 16 who had been working in this card room throughout the period.

At the second interview, in addition to completing the detailed questionnaire on respiratory

TABLE 3

NUMBER OF WORKERS WITH CHEST SYMPTOMS BEFORE AND THREE YEARS AFTER INSTALLATION OF SHIRLEY PRESSURE POINT SYSTEM IN MILL A

Symptom	1959 (34 workers)	1962 (33 workers)	1959 (16 workers present on both occasions)	1962 (16 workers present on both occasions)
Cough	10	14	6	6
Phlegm	5	5	3	2
Wheezing	17	19	6	9
Breathlessness	10	10	6	7
Catarrh	5	5	2	2
Chest tightness on Mondays	17	19	7	12

TABLE 2

CARD ROOM POPULATION IN 1959 AND 1962 IN MILL A

	Total Card Room Population*				Workers Present in 1959 and 1962	
	1959		1962		No.	Mean Age in 1962
	No.	Mean Age	No.	Mean Age		
Men	7	39	8	43	4	52
Women	27	38	25	41	12	40
Total	34	38	33	41	16	43

*One man working in the card room on both occasions was not interviewed.

symptoms, these 16 workers were asked whether, as far as they could remember, they thought their chests were the same, better, or worse than three years previously. This was done to compare the change in answers given in response to the questionnaire on the two occasions with the person's own recollection of change. The differences between the replies to the questionnaire on the two occasions were summarized in the following way. First, the symptoms of cough, phlegm, wheezing, breathlessness, catarrh, and chest tightness on Mondays were each allocated grades of severity according to the answers given. Byssinosis was graded 0, ½, 1, or 2, and the rest 0, 1, or 2. The six gradings so obtained by the 1959 and 1962 surveys were compared and the differences recorded as showing the same, a better, or a worse condition for each of the symptoms. Then if more of these six symptoms showed a worsening than an improvement, the over-all change was deemed 'worse'. Similarly, if more symptoms showed an improvement than a worsening, the over-all change was deemed 'better'. Equal numbers were recorded as 'same'. The differences between these two methods of assessing change are shown in Table 4. This would be expected to show fewer people giving an identical response to every repeated simple question than would be obtained by one general question. On the other hand, in answer to the questionnaires, nine had more pronounced symptoms, whereas only three volunteered this information from memory; four had less pronounced symptoms, whereas only two volunteered this information from memory.

TABLE 4

CHANGES IN CHEST SYMPTOMS OF 16 WORKERS IN MILL A BEFORE, AND THREE YEARS AFTER INSTALLATION OF THE SHIRLEY PRESSURE POINT SYSTEM

	Changes Assessed By	
	Answers to the Questionnaires	Recollection
Better	4 (25%)	2 (12%)
Same	3 (19%)	11 (69%)
Worse	9 (56%)	3 (19%)

Mill B

Measurements of dust concentration comparable to those obtained in the card room of mill A were also obtained in mill B, which was the mill used in the trials discussed by the Dust in Card Rooms Sub-Committee (Ministry of Labour and National Service, 1957). The card room which the Sub-Committee refer to as the 'bottom card room' and which they used for comparison with their 'Shirley card room' was later also fitted with the Shirley Pressure Point System. A summary of our measurements obtained in this card room in 1956 before the system was installed, and again in 1957 after it had been installed, is given in Table 5.

Throughout the card room there was a reduction of dustiness of coarse and fine dust. The total dust concentration was reduced by some 59% among the carding engines and 51% over-all. The greatest reduction took place in the coarse fraction around the carding engines (84%). Among the carding engines the total dust concentration was reduced from 4·2 mg./m.^{3} to 1·7 mg./m.^{3}. This is in reasonably good agreement with the results from three samples obtained with an electrostatic precipitator, which were reported by the Dust in Card Rooms Sub-Committee. Their results showed 5·3 mg./m.^{3} in the same card room and 1·4 mg./m.^{3} in their 'Shirley card room', the floor above, where the system was first fitted.

Mill C

Comparable measurements of air-borne dust concentrations have also been obtained recently by Mr. J. W. Skidmore during an investigation of another mill (mill C). These results are summarized in Table 6. The concentration of dust among the carding engines was first measured in October 1960, a few months before the Shirley Pressure Point System was installed, and again in 1963. A marked improvement in total dust concentration was observed on the second occasion. This was again

TABLE 5

AIR-BORNE DUST CONCENTRATIONS (mg./m.^{3}) IN 'BOTTOM CARD ROOM' OF MILL B BEFORE AND AFTER DUST EXTRACTION

Date	Area of Card Room											
	Among Carding Engines				Among Draw Frames				Among Intermediate Frames			
	< 7μ	7μ-2 mm.	> 2 mm.	Total	< 7μ	7μ-2 mm.	> 2 mm.	Total	< 7μ	7μ-2 mm.	> 2 mm.	Total
1956	0·16	0·9	3·1	4·2	0·21	1·1	3·2	4·5	0·16	0·9	3·1	4·2
1957	0·07	1·1	0·5	1·7	0·18	1·3	0·9	2·4	0·10	0·9	1·2	2·2

Each figure is the mean of about 14 results, each referring to a whole shift sample.

TABLE 6

AIR-BORNE DUST CONCENTRATIONS (mg./m³.) AMONG CARDING ENGINES IN MILL C

Date	Mean Concentration			
	< 7μ	7μ-2 mm.	> 2 mm.	Total Dust
Oct. 1960	0·6	1·2	3·9	5·8
June-July 1963	0·5	0·3	0·5	1·3

Every figure is the mean of about five results, each referring to a whole shift sample.

largely due to a fall in the concentration of coarse dust, though a considerable fall also occurred in the concentration of medium sized dust. However, there was little decrease in fine dust.

Mill D

Further evidence is available from mill D which completed the installation of the Shirley Pressure Point System in 1960. No measurements were made before the installation. However, in January 1961, 68 out of 78 workers in the card room were interviewed. Of those seen, 33 (48·5%) still had symptoms of byssinosis. Moreover, one of these was a girl whose only exposure to cotton dust had been for nine months in this card room, with the exhaust ventilation system in operation all the time. A dust survey made the following July (1961) showed that the mean concentration of total dust over the whole card room was 3·7 mg./m.³, made up of 2·9 mg./m.³ of coarse, 0·5 mg./m.³ of medium, and 0·3 mg./m.³ of fine dust.

Discussion

Following the installation of the Shirley Pressure Point System there was a fall in total dust concentration throughout most areas of the card rooms of mills A and B, and also among the carding engines of mill C. This fall was predominantly due to a decrease in the concentration of coarse particles and to some extent in mill C to a decrease in medium sized particles. There was little change in the concentration of fine dust in mills A and C, but there was a marked fall in the concentration of this size dust in mill B. In mill B, the exhaust air from the hoods was passed through fabric sleeve filters and dispersed outside the mill.

It was noted that in mill A the air outlet for the ventilation system was sited low down and too close to one of the air inlets, thus causing a degree of recirculation. The concentration of fine dust in the air intake duct was 0·23 mg./m.³, although the general level in the neighbourhood around the mill was only 0·11 mg./m.³ at this time. Subsequently, the erection of a new building close to the mill increased the eddy currents between other outlet and intake ducts. When an exhaust system is installed it is necessary to disperse the exhaust air above roof level or to filter it.

The slight rise in the concentration of dust which apparently took place between March 1960 and October 1962 at this mill was also associated with a lowering of the quality of the cotton processed and an increased through-put of cotton in the card room. If the capacity of an exhaust system is calculated on existing levels of dustiness, any changes in the process which give rise to more dust being liberated by the carding engines may overload the system.

Nevertheless, it is to be noted that in mill C, where there was no contamination of the air intake and the quality of cotton processed was the same throughout, there was little reduction in fine dust concentration, although the weight concentration of total dust was reduced by approximately 80%.

In mill A the prevalence of symptoms was studied together with dust measurements. It is disappointing to note that there was little change in the chest symptoms associated with bronchitis, although this may in part be due to the workers being three years older. The specific byssinotic symptom of chest tightness on Mondays had increased three years after the installation of the Shirley Pressure Point System. This is in marked contrast to the observation that people with byssinosis lose their Monday chest tightness if they leave cotton mills and work elsewhere where there is no cotton dust, such as in rayon mills (Tiller, 1958).

The changes in symptoms over three years were assessed both by comparison of the answers to two sets of questions concerning present symptoms asked at the beginning and end of the survey and by a single question at the end asking the worker if he could remember any change. Though the numbers are small, the differences in the changes recorded by these two methods indicate that caution should be used in accepting at their face value statements concerning health conditions which are dependent on memory.

The findings in mill A cannot be entirely explained as a faulty installation of the Shirley Pressure Point System. First, without an environmental survey the existing conditions would probably not have been noticed or rectified. Secondly, there was also a high prevalence of byssinotic symptoms in mill D after the installation of a similar system and where there was no question of recirculation of exhaust air. Further, in mill B, the physiological response to cotton dust had not completely disappeared after the installation of the Shirley Pressure Point System (McKerrow, McDermott,

Gilson, and Schilling, 1958). The fall in forced expiratory volume ($F.E.V._{0\cdot75}$) during a Monday was only reduced from 8·7% to 3·7%, whereas Tiller and Schilling showed that when workers are completely removed from cotton dust the F.E.V. of even those who had a previous history of byssinosis showed no significant change on a Monday (Tiller and Schilling, 1958).

These conclusions conflict in some ways with those in the Final Report of the Dust in Card Rooms Sub-Committee of the Joint Advisory Committee of the Cotton Industry (Ministry of Labour, 1961) which states, in relation to exhaust ventilation devices, including the Shirley Pressure Point System: 'Where the installation is complete the improvement in working conditions is very marked and we have also received reports of improvement in the well-being of operatives'.

Our findings are that the Shirley Pressure Point System, installed in the four mills referred to, certainly improved the appearance of the card rooms, but there was no evidence that it markedly alleviated the hazard of byssinosis. It may be that we were unfortunate in the mills we observed and that the Shirley Pressure Point System is more effective elsewhere. In an earlier paper it has been shown that the total dust concentration needs to be less than 1 mg./m.^{3} before it becomes likely that the conditions are safe from the risk of byssinosis (Roach and Schilling, 1960). Neither in the mill trials reported by the Dust in Card Rooms Sub-Committee nor in the four card rooms reported here was this target achieved either in the card rooms as a whole or among the carding engines in these rooms (Table 7). It is perhaps, therefore, not

TABLE 7

MEAN CONCENTRATIONS OF TOTAL AIR-BORNE DUST (mg./m.^{3})

Mill	Without Dust Extraction		With Dust Extraction	
	Carding Engines	Whole Room	Carding Engines	Whole Room
A	5·8	3·9	1·6	2·1
B	4·2	4·3	1·7	2·1
C	5·8	—	1·3	—
D	—	—	4·3	3·7
Shirley trials	5·3	—	1·4	—

altogether surprising that byssinosis still occurs in mills where the Shirley system is installed. Nevertheless, we cannot believe it is beyond the skill of ventilation engineers to design more effective control appliances for the carding engines and also for other machines in the card room which liberate dust.

There is obviously an urgent need to repeat and extend our studies in other mills. This is in fact being done as part of a prospective study of byssinosis in a group of Lancashire mills.

It is now recognized that byssinosis is a world-wide problem occurring in all the processes from ginning to spinning (Editorial, 1962). In the light of this and in view of the number of cotton operatives who are becoming disabled each year, it might be fruitful to consider also the more radical approach to prevention suggested by the Departmental Committee Report in 1932, namely the removal of a greater proportion of the plant debris from the cotton when it is ginned. It has recently been shown that it is that portion of the air-borne dust which is derived from plant debris that is most important in causing byssinosis (Nicholls, 1962).

It is also worth recalling that the same committee 30 years ago recommended that:

> 'As a measure of prevention, a medical examination and re-examination would appear to be necessary in order to prevent (*a*) persons already suffering from respiratory abnormalities from being accepted for employment in a carding process and (*b*) persons susceptible to the action of card room dust from being so employed for an unduly prolonged period.
>
> Such an examination would reveal operatives who had become partially affected or those who were in danger of becoming permanently disabled by reason of the respiratory disease which we are satisfied is due to their employment.'

The 1932 report also stated:

> 'As there are practical difficulties in providing for the periodical testing of the amount and nature of the dust in a card room or of that which is given off at any point of a carding engine, a sickness rate remaining abnormal amongst operatives employed in any card room should be regarded as prima facie evidence that either the dust is not being efficiently removed in the blowing room processes and/or that the ventilation, either of the card room generally or that applied to certain points of the carding engine, is not efficient.'

There is no reason why regular medical examinations should not be required by statute as they are in other hazardous occupations, although the form they should take in the cotton industry, and by whom they should be done, needs careful consideration. The results of such examinations, taken collectively, would enable managements to be advised about the hazards in their mills, while the individual results would enable intelligent advice to be given to those affected, thus providing safeguards similar to those available to workers in other hazardous occupations. Also, there are no longer any practical difficulties in making the necessary

environmental measurements; indeed, regular measurements of dust conditions are just as desirable as the regular measurement of temperature and humidity, already required by law in cotton mills. In the meantime the awards of compensation for byssinosis provide more than prima facie evidence that dust in card and blow rooms is still a problem.

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