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Cotton Dust Control Studies: Effects of Engineering Controls, Washing Cotton, and Additives¹

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ABSTRACT

This paper reviews some of the cotton dust control technology studies carried out at North Carolina State University since 1973. The purpose of the investigations has been to examine means for reducing respirable *dust emission during carding*, as well as to evaluate the relative merits of various dust-sampling devices. Typically the results indicate that introducing lint cleaners at the gin reduces dust emission, while the use of two types of feeder/cleaners examined does not. Steaming of ginned cotton reduces the dust emission, while storage of ginned cotton (steamed or unsteamed) beyond three months increases it. Air-cleaning devices such as properly-designed electrostatic precipitators can be quite effective in diminishing the dust concentration in the card room. Similarly, washing of cotton, the use of cleaning devices such as COTTONMASTER®, or the addition of dust suppressants to cotton reduces the emission during subsequent carding. While some of the studies are complete, others are in progress.

Introduction

Studies of cotton dust control technology were initiated at the School of Textiles at North Carolina State University in 1973 and have been carried out in a specially-designed Model Card Room [10]. These investigations have considered the influence of a number of mechanical cleaning processes, as well as a

number of physical and chemical treatments, on the amount of dust emitted from cottons during carding. More specifically, the studies have included the effects of steaming cotton after ginning, the use of lint cleaners at the gin, opening and cleaning devices designed for use in the textile mills, washing of cotton prior to processing in the cotton textile mill, and the use of lubricants and other additives as dust suppressants. The effectiveness of air-filtration and cleaning devices designed for use in cotton textile mills have also been evaluated. During the course of these studies, a rather

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systematic comparison of various cotton dust samplers has been made, and the particle size distribution of the respirable fraction of dust has been characterized. A notable finding is that the humidification system may make a significant contribution to the concentration of respirable-size dust in the ambient air. The studies enumerated above are summarized here. Results of other investigations, made to determine the influence of cultural and genetic variations on the dust-generation potential of cottons, have been reported elsewhere [6, 11].

Experimental and Analytical Procedures

The design of the Model Card Room as well as the normal operating procedures employed to assess the dust-emitting potential of cottons have been described previously [10]. Briefly, the equipment in the Model Card Room consists of a single opener-feeder and a cotton card through which cotton is processed from bale to sliver. A laminar flow of recirculated, cleaned, and conditioned air moves through the room counter to the direction of cotton flow. The dust released into the air during processing is measured with a large variety of gravimetric, short-term, and continuous-monitoring air samplers. A Pneumafil V-cell filter is used as a lint-capture system, collecting dust and lint from four points, three on the card and one on the Evenfeed exhaust. The respirable dust passes through the filter and is exhausted back into the card room.

To carry out proper statistical analyses of the data, normally at least two standard bales of cotton (approximately 480 lb (218 kg) each) are evaluated for each item or factor under study. Generally, a bale is processed on two consecutive days, half a bale each day. Some heavier bales are processed in three parts on as many consecutive working days. The replicate bale(s) is(are) processed in a similar fashion at a later date. By following such procedures, it is possible to determine the variability within and between replicate bales. In practically all instances the variability within bales has been found to be greater than the variability between bales [10, 13]; consequently differences between bales have been ignored in the results presented here.

In most cases the statistical significance of any effect or treatment (on the measured dust concentration) has been assessed by the following AOV model:

$$y = b_0 + T_i + B_j + (TB)_{ij} + \epsilon_{(i,j)} \quad (1)$$

where b_0 denotes the mean dust concentration, T_i = the treatment effect, B_j = the bale effect, $(TB)_{ij}$ = their interaction, and $\epsilon_{(i,j)}$ = the random error. The two or

three observations made on each bale (designated as a "part" or "run") were treated as replicate measurements.

Since the bales of each cotton type are run in random order and carry no common identity, bale effects should not be significant, but bale-treatment interactions might be. A second statistical analysis in which bales are nested within treatments is therefore carried out. The nested analysis is of course the appropriate one for experimental designs in which bales carry no common identity. The crossed model given by Equation 1 is analyzed merely to verify that the first bales of any type processed indeed do not have a common identity. In the analyses involving three or more treatments, Duncan multiple-range tests were utilized to determine which of the treatments were different from each other [19].

In some comparisons involving only two treatments, a Student's *t*-test for comparing two sample means for unpaired observations is utilized. In this test the standard deviation σ_d for the difference between the two means is calculated from the relation

$$\sigma_d = \sqrt{\sigma^2 (1/n_1 + 1/n_2)} \quad (2)$$

where n_1 and n_2 are the number of observations associated with the first and second treatment means, and σ is the standard deviation between replicate runs (the within-bale standard deviation or experimental error). The value of σ for dust-concentration measurements made with the Vertical Elutriator Cotton Dust Sampler (VE) on 170 bales is $57 \mu\text{g}/\text{m}^3$. For comparing mean dust concentrations based on four measurements each (n_1 and $n_2 = 4$), the value of σ_d from Equation 2 would be $40 \mu\text{g}/\text{m}^3$. The 95% confidence interval for the difference between such means would be $79 \mu\text{g}/\text{m}^3$ ($1.96 \times 40 \mu\text{g}/\text{m}^3$ —the *t*-value of 1.96 applies because σ is known with over 170 degrees of freedom). For averages based on 6 and 8 replicates, the values of σ_d are 33 and $29 \mu\text{g}/\text{m}^3$, respectively.

Dust concentrations measured by the other samplers have shown high correlations with those measured by the VE [6, 13]. In this paper, therefore, only the dust concentrations measured by the VE sampler have been reported, due to their considerable practical significance.

Results and Discussion

EFFECT OF LINT CLEANERS AT THE GIN

The inclusion of lint cleaners in the ginning line has been effective in reducing dust emission during carding [6, 10, 18]. Cottons of controlled quality were

ginned, using zero, one, two, and three lint cleaners, and then processed through the Model Card Room. Results, summarized in Table I, show that the use of lint cleaners at the gin reduces the amount of respirable dust emitted at the carding stage. One lint cleaner produces the most benefit. With additional lint the incremental benefits, though significant, are smaller.

TABLE I. Effect of the number of lint cleaners used at the gin on the dust emission in the Model Card Room.

No. of lint cleaners	VE Dust-concentration, $\mu\text{g}/\text{m}^3$				Average (of a-d)
	a	b	c	d	
0	930	770	870	490	749
1	720	670	610	350	585
2	440	540	380	330	424
3	340	460	340	290	360

Cotton description				
	a	b	c	d
State of Origin	Texas	Texas	Texas	California
Variety	Coker	Stripper	Paymaster	SJ-1
Crop Year	1973	1973	1973	1973

Use of lint cleaners at the gin produces some fiber damage and loss [18]. Therefore, normally only two lint cleaners are employed, as this number is judged to yield an economic optimum. On the other hand, as the respirable cotton dust emitted at the mill becomes a more critical factor in the cost of cotton processing, the use of an additional lint cleaner at the gin could well become economically viable, especially for high-strength fibers [18].

EFFECT OF EXPERIMENTAL FEEDER/CLEANERS AT THE GIN

Feeder/cleaners are devices that remove 50 to 60% of the large trash, such as sticks and burr, from seed cotton before it enters the gin. Experiments were carried out in the Model Card Room to examine the influence of two such experimental devices. The results are presented in Table II. As shown by the data listed in Groups 1a and 1b, the concentration of respirable cotton dust measured in the Model Card Room while processing cotton cleaned by one of the experimental feeder/cleaners was not statistically different from that ginned without the cleaners

(Group 1a). With the second (Group 1b) an actual increase in card-room dust was observed when the feeder/cleaner was used.

TABLE II. Effect of varied conditions at ginning on the dust emission in the Model Card Room.

Group no.	Condition	VE dust conc., $\mu\text{g}/\text{m}^3$	Statistical analysis ^a
1a.	Experimental feeder/cleaner #1	241] NS
	Standard	248	
b.	Experimental feeder/cleaner #2	349] **
	Standard	268	
2a.	Steamed (avg.)	395] ***
	Not steamed (avg.)	550	
b.	Steamed (55 s)	408] NS
	Steamed (82 s)	406	
	Steamed (124 s)	405	
	Steamed (196 s)	361	
3a.	Steamed	207] *
	Not steamed	262	
b.	Stored 0, 1 month	175] **
	Stored, 3, 5, 8 mo.	274	

^aNS - difference not statistically significant.

* - difference statistically significant at 90% level of confidence;

** - difference statistically significant at 95% level of confidence;

*** - difference statistically significant at 99% level of confidence.

EFFECT OF STEAMING COTTON AT THE GIN

Merchant *et al.* [15], as well as Imbus and Suh [12], reported that steaming cotton in the bale before processing reduces the amount of respirable dust emitted during carding. They noted that the biological activity of the dust was also reduced. Inasmuch as lint in the open condition at the gin would be more accessible to steam, it was decided to examine whether steaming at the gin might be more effective than steaming baled cotton. In one experiment four groups of Lockett 4789A cotton grown in Oklahoma in 1973 were steamed for different durations. Four control groups were prepared by exposing them to air at the same pressures and for comparable durations. The results, reported in Table II (Group 2), confirm that steaming reduces the amount of dust emitted during carding; moreover, the reduction does not depend significantly on the duration of steaming.

In another series of experiments the effect of warehouse storage after steaming was investigated. Data in Table II (Group 3) show that the dust emitted by cottons, both steamed and unsteamed, stored for

longer than three months is greater than that emitted by cottons processed soon after ginning. The reduction in dust emission achieved by steaming cotton at the gin was also verified in two additional experiments.

In drier regions of the U.S. cotton belt, moisture in the form of steam is sometimes added to the cotton at the battery condenser. Steaming at this point in the process did not significantly reduce the concentration of dust measured in the card room during processing ($227 \mu\text{g}/\text{m}^3$ for steamed cotton containing 7.2% moisture vs. $232 \mu\text{g}/\text{m}^3$ for cotton not steamed containing 2.7% moisture).

EFFECT OF CLEANING PNEUMAFIL FILTER

The influence of the build-up of a lint-cake on the Pneumafil filter on the dust-concentration measurements was investigated. Normally, the lint is removed from the filter media after every daily run. After processing cotton for $5\frac{1}{2}$ h, during which the dust concentration measured by the VE was $690 \mu\text{g}/\text{m}^3$, the filter media was not cleaned, and the same cotton was processed the following day. The VE concentration the second day was only $290 \mu\text{g}/\text{m}^3$, a drop of 58%. The first- to second-day drops for the other samplers in the room were 58% for the area samplers, 50% for the cyclone samplers, and 53% for the high-volume samplers. For cleaner cottons, which build up lint-cakes more slowly, the day-to-day decreases in dust concentrations are smaller, as would be expected. For example, a cotton that generates $260 \mu\text{g}/\text{m}^3$ (VE) while processing on a freshly-vacuumed Pneumafil filter generates only $200 \mu\text{g}/\text{m}^3$ (VE) with a 5-h cake build-up (a 23% reduction). These results suggest that in normal mill practice it may be desirable to leave some of the cotton dust lint-cake deposited on the filters.

EFFICACY OF COTTONMASTER® AS A CLEANING DEVICE IN THE OPENING LINE

The COTTONMASTER® is a cleaning device developed by J. D. Hollingsworth, Inc. (Greenville, SC) for use in cotton opening lines. The effectiveness of the COTTONMASTER was evaluated on two grades of cottons—Strict Good Ordinary (SGO) and Bright Low Middling (BLM). Two bales of each type were opened by passing them through a line containing an XL cleaner followed by a Rando cleaner. Similarly, two bales of each type were opened by passing them through a line containing an XL cleaner followed by a

COTTONMASTER. The eight bales so opened and cleaned were then processed through the Model Card Room. Results indicate that dust emission during carding was lower from the cotton processed through the COTTONMASTER; at the same time, the cleaner-grade interaction was significant. The practical meaning of these results is illustrated in Table III.

TABLE III. Comparison of cotton-dust concentration measured in Model Card Room while processing cotton precleaned either with COTTONMASTER or Rando Cleaner.

Cleaner	VE Dust concentration, $\mu\text{g}/\text{m}^3$	
		By Grade
COTTONMASTER	381	388 (BLM) 373 (SGO)
Rando	491*	438 (BLM) 544 ^b (SGO)

*Significantly different at the 99% level of confidence.

^bSignificantly different at the 90% level of confidence.

Dust emissions in the card room while processing cottons opened and cleaned by passing them through the Rando were 438 and $544 \mu\text{g}/\text{m}^3$ for the BLM and SGO cottons, respectively. When processed through the COTTONMASTER, the dust emissions from both grades of cotton were reduced to the same level (an average of $381 \mu\text{g}/\text{m}^3$). Thus the improvement achieved when the COTTONMASTER replaced the Rando cleaner was greater with the lower-grade cotton ($171 \mu\text{g}/\text{m}^3$) than with the better-quality cotton ($50 \mu\text{g}/\text{m}^3$).

EFFECT OF WASHING COTTON BEFORE PROCESSING

The effect of washing cotton on the subsequent dust emission during carding have been reported previously [13]. The results of these studies, summarized in Table IV, suggest that washing decreases the dust emission in carding—the higher the washing and rinsing temperatures, the greater the reduction. In particular, scouring at 71°C followed by rinsing at 32°C and steaming, or washing at 82.5°C and rising at 82.5°C reduced the dust concentration in the Model Card Room to essentially that of the background concentration in the room—*i.e.*, almost no additional dust was released.

Washing of cotton greatly reduces the rate at which it can be carded. The processability can be improved by controlling the moisture content of the cotton, use

TABLE IV. Differences in dust concentrations measured on washed cotton (VE sampler, $\mu\text{g}/\text{m}^3$) [13].

Preclean	Treatments									
	None	Once	Twice	Once						
Wash	No	S-71 ^{a*}	No	No	W-60 ^{a*}	W-60 ^a	S-71 ^a	S-71 ^a	W-82.5 ^a	S-82.5 ^a
Rinse	No	82.5 ^a	No	No	60 ^a	60 ^a	82.5 ^a	82.5 ^a	82.5 ^a	32 ^a
Steam	No	Yes	No	No	No	Yes	Yes	Yes	No	Yes
Finish	No	Yes	No	No	No	No	Yes & Bleach	No	No	No
Treatment No.	1	7	2B	2A	3	5	8	6	4	6A
Mean (t_i)	(380 - \bar{t}_i)	(280 - \bar{t}_i)	(280 - \bar{t}_i)	(250 - \bar{t}_i)	(230 - \bar{t}_i)	(230 - \bar{t}_i)	(220 - \bar{t}_i)	(200 - \bar{t}_i)	(170 - \bar{t}_i)	(160 - \bar{t}_i)
1	380	—	—	—	—	—	—	—	—	—
7	280	100 ^c	—	—	—	—	—	—	—	—
2B	280	100 ^c	0 ^a	—	—	—	—	—	—	—
2A	250	130 ^c	30 ^a	30 ^a	—	—	—	—	—	—
3	230	150 ^c	50 ^a	50 ^a	20 ^a	—	—	—	—	—
5	230	150 ^c	50 ^a	50 ^a	20 ^a	0 ^a	—	—	—	—
8	220	160 ^c	60 ^a	60 ^a	30 ^a	10 ^a	—	—	—	—
6	200	180 ^c	80 ^b	80 ^b	50 ^b	30 ^a	20 ^a	—	—	—
4	170	210 ^c	110 ^c	110 ^c	80 ^c	60 ^c	50 ^c	30 ^a	—	—
6A	160	220 ^c	120 ^c	120 ^c	90 ^c	70 ^c	60 ^c	40 ^a	10 ^a	—

*Prefix S denotes scouring and prefix W denotes washing. ^aNot significant at the 90% probability level. ^bSignificant at the 90% probability level. ^cSignificant difference at the 95% probability level.

of a static eliminator at the doffer crush rolls, increasing the relative humidity (RH) of the ambient atmosphere, and replacing the standard licker-in fluted feed roll with a wire-wound feed roll. Processability is further improved by applying finish to the washed cotton; the full implications of this effect remain unexplored.

Mechanical precleaning prior to washing removes a large amount of trash from the cotton but gives rise to some increase in the invisible waste, as measured with a Shirley Analyser. The increase in invisible waste shows up as significantly greater dust emission at high carding rates. Scouring in alkali reduces the trash content further, but water-washing does not. Even so, dust emission during carding from washed cottons is reduced considerably, as much as 50% or more.

HUMIDIFIERS AS SOURCES OF RESPIRABLE DUST

Based on measurements made in the Model Card Room, it was concluded that a significant fraction of the respirable dust in the atmosphere of a cotton textile mill could be contributed by the humidification system. As shown in Table V, when the opening-carding system is operating normally (27.5°C, 50% RH) but without cotton being processed and with the Pneumafil system shut off, the dust concentration in the card room was measured to be 312 $\mu\text{g}/\text{m}^3$. With the spray nozzles of the humidifier system switched off, the concentration dropped to 40 $\mu\text{g}/\text{m}^3$. With the Pneumafil lint-capture system operating (but no cotton being processed), the dust concentrations measured were 188 and 61 $\mu\text{g}/\text{m}^3$ with and without

TABLE V. Dust concentrations measured in the Model Card Room without feeding cotton to the opening-carding system.

Conditions			Sampler (concentrations in $\mu\text{g}/\text{m}^3$)					
Humidifier operating	Lint-capture system operating	No. of runs	Vertical elutriator	Area	High volume	Cyclone		Andersen
						<10 μm	Total	
Yes	No	3	312	239	277	244	291	315
No	No	3	40	44	74	89	123	67
Yes	Yes	4	188	178	221	174	270	216
No	Yes	4	61	74	117	73	161	94

the humidifier operating, respectively. Calculations based on the airflow rate in the Model Card Room, water-flow rate to the humidifier, and the amount of solids dissolved in the water agreed very well with the increase in the "respirable dust" observed with and without the humidification system operating [2].

EFFECT OF ADDITIVES AS DUST SUPPRESSANTS

Other investigators have suggested that the emission of cotton dust during carding could be reduced by spraying certain chemical compounds on the cotton before processing [4, 17]. To test this hypothesis systematically, the commercial and experimental formulations listed in Table VI were selected for evaluation. The additive fluids were sprayed on cotton partially opened by passing through a Bramwell feeder and a breaker-picker. The flow rates of spray and the cotton were controlled to obtain the desired "add-ons." Since in most cases about one-half of the fluid spray escaped into the atmosphere, the actual add-ons are approximately one-half the nominal values reported.

Results are shown in Table VII. Milube N-32, Lutex 1557, and Nopocostat CDC-1 at 0.75% add-on appear to yield fairly satisfactory results. A more precise statement of their influence requires a detailed statistical analysis of the data, which will be carried out and reported in the future.

EFFECT OF ELECTROSTATIC PRECIPITATOR AIR-CLEANING DEVICES

Two types of electrostatic precipitators (ESP) have been evaluated for their ability to reduce the cotton-dust concentration in the Model Card Room. The first is a free-standing modified ESP (TEPCO Model 2500

TABLE VII. Effect of additives as dust suppressants in carding.

Nominal add-on ^a , %	VE dust concentration, $\mu\text{g}/\text{m}^3$				
	Milube N-32	Lutex 1557	Packlube 495	Nopocostat CDC-1	Tex-spray
0.0 (control)	1110	1040	870	1180	1230
0.25 (0.35) ^b	510	510	1180	480	920
0.50 (0.7) ^b	280	380	1250	390	620
0.75 (1.03) ^b	320	300	860	320	300
1.0 (1.41) ^b	220	220	1020	340	330

^aActual add-ons approximately 1/2 of nominal.

^bThese add-on values apply to Packlube 495 only, which contains approximately 15% active ingredients.

Air Cleaner, modified by Diversified Control Systems, Inc., Greensboro, NC). The first section of the device contained a specially-designed wire-mesh prefilter to collect lint from the room air before the air entered the ESP. The lint collected on the prefilter is removed periodically by an automatically activated system. The air-flow rate through this equipment was 2200 ft³/min—slightly higher than the 2000 ft³/min normally flowing through the card room. Under these conditions the dust concentration in the room, as measured by the VE sampler, dropped as much as 25%.

The second such device evaluated was a SMOG-HOG manufactured by United Air Specialists, Inc. (Cincinnati, OH). It consists of a mechanical prefilter (to stop large particles), an airfoil ionizer (to electrostatically charge the airborne dust particles), a collection cell (where grounded plates collect the particles, stripping them from the air), an after-filter (which improves the air distribution and traps any agglom-

TABLE VI. Characteristics of materials evaluated as dust suppressants.

Commercial name/source	Viscosity (25–26°C), cP	Specific gravity (26°C)	Other characteristics
Milube N-32 ^a	25.	0.855	clear, light yellow, nonionic lubricant
Lutex Additive 1557 ^b	19.42	0.865	compounded surfactants and hydrocarbons, light straw, nonionic
Nopocostat CDC-1 ^c	50.5	0.884	clear, pale yellow, nonionic liquid
Packlube 495 ^d	1.	0.843	water emulsion, 15% active ingredients
Texspray ^e	11.8	0.87	light-pale paraffinic distillate oil

Sources: ^aICI Americas Incorporated, Wilmington, Delaware 19897. ^bLutex Chemical Corporation, Chattanooga, Tennessee 38406. ^cDiamond Shamrock Corporation, 350 Mt. Kimbell Avenue, Morristown, New Jersey 07960. ^dTar Heel State Chemical Company, 603 Randolph Street, Thomasville, North Carolina 27360. ^eTexaco, Incorporated, 135 East 42nd Street, New York, New York 10017.

erated contaminants still airborne), and finally a blower that moves the air through the equipment.

Normally, the lint-capture system of the Model Card Room collects the lint-laden air from three collection points on the card and one on the Evenfeed exhaust and passes it through a Pneumafil V-cell filter. The air is then exhausted into the room through four diffusers located along the top of the entrance filter wall. For the installation of the SMOG-HOG, two of the diffusers were sealed off, and the entrance chamber of the SMOG-HOG was connected with appropriate ducting to the remaining two diffusers. The cleaned air was then exhausted into the room. The air flow through the device was approximately 1500 ft³/min. The SMOG-HOG was evaluated using a particularly dirty cotton; it was able to reduce the dust concentration in the room from an average of 810 µg/m³ to 264 µg/m³—an improvement of about 67%.

PARTICLE-SIZE DISTRIBUTION OF COTTON DUST

Particle sizing of respirable cotton dust collected in the Model Card Room has been carried out using Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM). In the first studies using SEM, dust samples were collected by the VE sampler on standard poly(vinyl chloride) (PVC) membrane filters [5]. Particle diameters were measured using Martin's method [14], and those smaller than 0.32 µm diameter were grouped together because it was difficult to size them accurately. The distributions obtained in this way were bimodal, with modes of 0.32 and 1.0 µm. If the particles of diameter less than 0.32 µm in any sample were ignored, however, the remaining distribution was accurately characterized by a log-normal distribution. Typically, the geometric mean and standard deviation of the diameters were found to be of the order of 1.22 µm and 1.81, respectively. Later studies [1, 3] of dust collected on 0.4-µm pore-size Nucleopore filters using SEM showed that the smallest resolution could be improved to 0.19 µm, and that the distributions were either unimodal or bimodal. The unimodal distributions were characterizable by a single log-normal distribution; the bimodal, by two such distributions. The largest particles measured were of the order of 6–8 µm. Typical geometric mean diameters ranged between 2.63 to 3.34 µm, and standard deviations ranged between 2.18 and 2.5 [3].

In yet another study [16] the freely-settled dust collected on carbon-coated grids in the Model Card Room was analyzed by TEM. The smallest Martin's diameter measurable was 0.04 µm. Particles diameters

ranged from 0.04 µm to 1.0 µm, and were found to fit a unimodal log-normal distribution. Since collection of dust by free settling is extremely sensitive to aerodynamic conditions in the room, interpretation of the meaning of the specific values of the statistical parameters of the distribution is difficult.

EVALUATION OF SHORT-TERMED SAMPLERS

During the course of these studies three short-termed samplers have been evaluated [7–9]. These are the TSI (Thermo-Systems, Inc., St. Paul, MN) "Piezo-balance" Aerosol Mass Monitor; the GCA (GCA Corp., Bedford, MA) Respirable Dust Monitor RDM 101-4; and the Royco (Royco Instruments, Inc., Menlo Park, CA) Model 225/518 High Concentration Particle Counter.

The TSI instrument was evaluated with preseparators having theoretical cut-off diameters of 15 and 10 µm. When equipped with a vertical elutriator preseparator with a 15-µm diameter cut-off and compared with the VE, the dust concentrations were related by the regression equation:

$$VE = 0.118 + 1.463 \text{ TSI} \quad (r = 0.93) \quad (3)$$

When the TSI instrument was equipped with an impactor having a 10-µm cut-off diameter, the relationship found on a different set of runs was given by

$$VE = 0.029 + 1.459 \text{ TSI} \quad (r = .94) \quad (4)$$

Statistically, Equations 3 and 4 are equivalent, indicating that no more dust is collected by the TSI when fitted with a 15-µm preseparator than when fitted with a 10-µm preseparator. It was further found that the dust concentrations measured with the TSI instrument equipped with the 10-µm cut-off preseparator were essentially equal to those obtained with the cyclone sampler, which collects particles smaller than 10-µm diameter.

The GCA instrument equipped with a vertical elutriator designed for 15-µm cut-off diameter as a preseparator was also compared with the VE sampler. For the same group of runs included in Equation 3, the dust-concentration measurements of these two samples were related by the following equation:

$$VE = 0.078 + 1.611 \text{ GCA} \quad (r = 0.92) \quad (5)$$

The VE-GCA relationship, unlike that of the VE-TSI, is not consistent between different data groups, and the coefficients of the regression equation can vary [7–9]. Dust-concentration measurements with the TSI

and GCA instruments when both were equipped with 15- μ m cut-off preseparators were found to be identical within experimental error.

Equations 3–5 were found to be valid for VE dust concentrations measured in the Model Card Room up to about 1 mg/m³. These relationships break down at higher values of dust concentrations.

PARTICLE SIZING *via* LIGHT SCATTERING

As discussed earlier, the particle-size distribution of cotton dust collected on suitable filters in the VE sampler can be measured from SEM photomicrographs of the dust particles—a rather tedious and time-consuming procedure. The Royco light-scattering equipment, on the other hand, provides a relatively easy means of determining the size distribution in real time. The instrument is equipped with a module capable of counting particles in five selected size ranges. By counting a second time in other diameter ranges, the number of cells for the distribution analysis can be increased to more than five. The particle-size distribution of cotton dust measured with the Royco instrument was found to agree very well with that obtained by SEM analysis of the dust collected on the VE sampler when at least seven cells were contained in the Royco measurements [9]. In order to measure a larger number of cell intervals on the Royco instrument without having to recalibrate, the output of the light sensor has been linked to a ND-PSA Particle Sizing Analyzer and ND-60 Multi-Channel Analyzer (Nuclear Data, Inc., Schaumburg, IL). With this instrumentation a highly automated and detailed analysis of the particle-size distribution can be made almost continuously and in real time. Results of studies with these facilities will be reported in the future.

Concluding Remarks

In the preceding pages the salient results of several studies made over a period of nearly eight years related to developing cotton dust control technology has been collected and reported. Further research with the same objectives and towards the same goals continues at NCSU. Planned studies include evaluating the effects of blending cotton with polyester fiber, the effects of adding dust-suppressant lubricants to high-micronaire cottons, and the effectiveness of additional novel filtration systems and cleaning devices.

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X-Ray Orientation Measurements of Cotton Fibers Using Yarn Samples

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ABSTRACT

The x-ray orientation of fibers could be estimated with the sample in the form of yarn. The ratio of the x-ray orientation to the same measure in yarn form seems to have a correlation with yarn count. Also, as count increases, the orientation of fibers as measured in the form of yarn approaches the orientation of the free fiber. This paper suggests a quick, nondestructive estimation of fiber orientation which may have extensive application in production-monitoring and archeology.

Introduction

As part of a program for analyzing fabrics of archeological interest, some fabric samples have been collected from Madras Museum and subjected to x-ray analysis. Since the specimens belonged to a

pre-industrial era, and all fabrics were hand-spun and hand-woven and of varying counts from 6s to 80s, the physical properties of the fibers were of interest. One internal parameter investigated was the x-ray orientation of these fibers. Since isolating fibers from yarn was almost impossible, due to constant breakage, we measured the orientation of the fibers from the yarn