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A CLOSED-LOOP COTTON-MOISTURIZATION SYSTEM FOR COTTON GINNING
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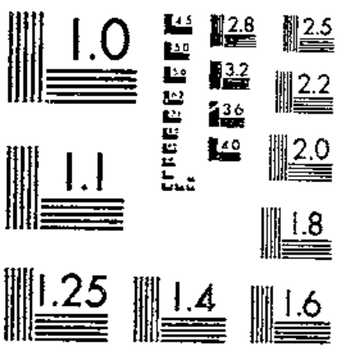

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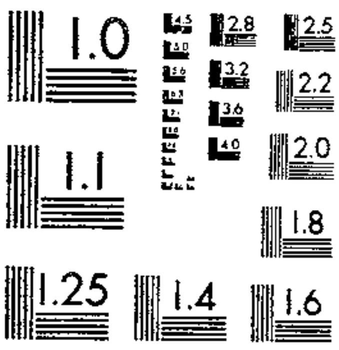

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A CLOSED-LOOP COTTON-MOISTURIZATION SYSTEM FOR COTTON GINNING

Technical Bulletin No. 1513

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UNITED STATES DEPARTMENT OF AGRICULTURE

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A CLOSED-LOOP COTTON-MOISTURIZATION SYSTEM FOR COTTON GINNING

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ABSTRACT

In 1971 and 1972 a pilot model of a closed-loop cotton-moisturization system for cotton ginning was developed and tested. The system proved the feasibility of using closed loops of high-humidity air to restore moisture lost in processing or by natural drying, thus preventing static electricity and subsequent loss of strength and flexibility in the cotton fiber. The 1971 study, in which an air-blast gin stand was used, showed that lint moisture content was increased by about 1.5 percentage points. Classer's grade stayed constant at Low Middling Light Spotted, and the staple length averaged 30.6 (32ds of an in). Dust inside the closed loop ranged from 3.0 to 1.9 mg/m^3 and had no detrimental effect on fiber during the 4-h (four-replication) test. Results from the 8-h (four-replication) 1972 tests, which used a high-capacity brush gin, showed a 0.5 to 0.7 percentage point increase in lint moisture content. Classer's grade and staple stayed constant throughout the test at Strict Low Middling and 1 in. Dust concentrations ranged from 104.7 to 17.5 mg/m^3 inside the closed loop, decreasing rapidly during the first 15 min, then gradually for the rest of the test period. Again, dust had no detrimental effects on fiber. Less dust and short fibers were exhausted to the atmosphere, reducing air pollution from the lint condenser.

INTRODUCTION

Dry cotton fibers are moisturized at gins to control fiber breakage and static electricity. The restoration of moisture lost in processing reduces fiber brittleness and apparently increases tensile strength, thus reducing breakage during ginning and cleaning (*7*).[1] Movement of cotton through

[1] Italic numbers in parentheses refer to items in "Literature Cited," p. 12.

the ginning system generates static electricity on fibers and causes them to be attracted to oppositely charged metal surfaces (*3*), a phenomenon that causes chokes and decreases operating efficiency in cotton gins. Static electricity can be controlled by increasing the electrical conductivity of cotton fibers and thereby preventing the buildup of charges. One method of increasing electrical conductivity is to increase fiber moisture content.

Commercial Moisturization Methods

There are two methods in general use for increasing the moisture content of cotton during ginning (*5*). In the spray method, a fine mist of water is applied directly to the cotton. In the vapor method, cotton is subjected to warm air at a high relative humidity. Commercial applications of these methods include the use of spray nozzles at the lint slide and in conditioning chambers (*2*), piping of high-humidity air to special conditioning chambers (*6*), and the use of high-humidity air in tower driers, inclined cleaners, extractor-feeders, and lint flues. These commercial moisture-restoration techniques are used primarily in production areas where the relative humidity is low.

Both methods are useful at their immediate locations in ginning systems. However, after cotton leaves these high-humidity locations and enters a low-humidity environment, it rapidly loses the moisture that was added by the restoration system. Also, most systems are controlled manually. Consequently, they are often regulated improperly.

Monoflow System

In an attempt to overcome the inherent disadvantages of existing commercial systems, a unique monoflow system was devised at Agricultural Research Service's Southwestern Cotton Ginning Research Laboratory, Mesilla Park, N. Mex., in 1963 (*4*). This system used a single stream of conditioned air to convey seed cotton through the entire seed-cotton cleaning and conditioning system. At each separation point, the humid air was cleaned and used again to convey seed cotton to the next point. The air was finally exhausted to the atmosphere after conveying seed cotton to the last separator on the distributor. Another airstream was used to convey lint from the gin stands to the lint cleaners and eventually to the press. The lint-conveying air was induced into the lint flue from the gin room by the saw-doffing mechanisms in gin stands and lint cleaners. After conveying lint to the final press condenser, the air was filtered, moisturized, and returned to the gin room.

The monoflow system permitted a long exposure to conditioned air so that cotton fibers would have time to approach equilibrium with the relative humidity of the conveying air. This allowed the use of moderate relative humidities that were easier to control and less troublesome than the high relative humidities required by commercial systems. Also, with the monoflow system the number of air exhausts was reduced, thereby reducing a gin's air pollution.

The monoflow concept can be readily incorporated into the design of a new ginning system. However, incorporating the concept into an existing gin system poses some design problems. The seed-cotton-handling portion of the monoflow system could be constructed in an existing gin by rearranging some of the equipment and repiping the seed-cotton-cleaning systems. However, the lint-handling portion of the monoflow system requires that either the air in the gin room be moisture-conditioned or that the lint-conveying air be exhausted to the atmosphere. Conditioning the gin room would require extensive modifications to existing buildings, since most gin buildings are not insulated and are not sealed against moisture loss and air leakages. If the air were exhausted to the atmosphere and not reused, elaborate humidifying and filtering equipment would be required to maintain desired relative humidity and reduce air pollution. This equipment would be expensive and would increase the complexity of the ginning system.

The Closed-Loop Concept

In an attempt to utilize the outstanding advantages of the monoflow system while avoiding installation problems, a closed-loop cotton-moisturization system for lint was constructed and tested at Agricultural Research Service's South Plains Ginning Research Laboratory, Lubbock, Tex., in 1971 and 1972.

The closed-loop concept may be visualized as a series of air-conveying loops between successive operations in a ginning system (fig. 1). An air-conveying loop moves cotton from one operation to the next, and then the air is circulated back to the originating operation for reuse. The air loops can be completely self-contained, or they can be constructed so that a small volume of high-humidity air is added to the loop to recondition the air after its loss of moisture to the cotton. In this case, an equal volume of air would be purged from the loop in order to maintain a constant flow. This concept is most applicable to those systems handling lint between ginning and lint-cleaning operations and from the last stage of lint-cleaning to the press condenser.

This concept differs substantially from conventional lint-handling methods. Normally, outside air is brought into the building and induced into the lint-handling systems to convey lint from one operation to the next. The air is then exhausted back into the atmosphere. With the closed-loop system, conveying air is reused, and only that portion purged from the system is exhausted.

The closed-loop concept also differs from the monoflow system. It is not necessary to pass all of the air in a closed-loop system through a moisture-conditioning device as in the monoflow system, because

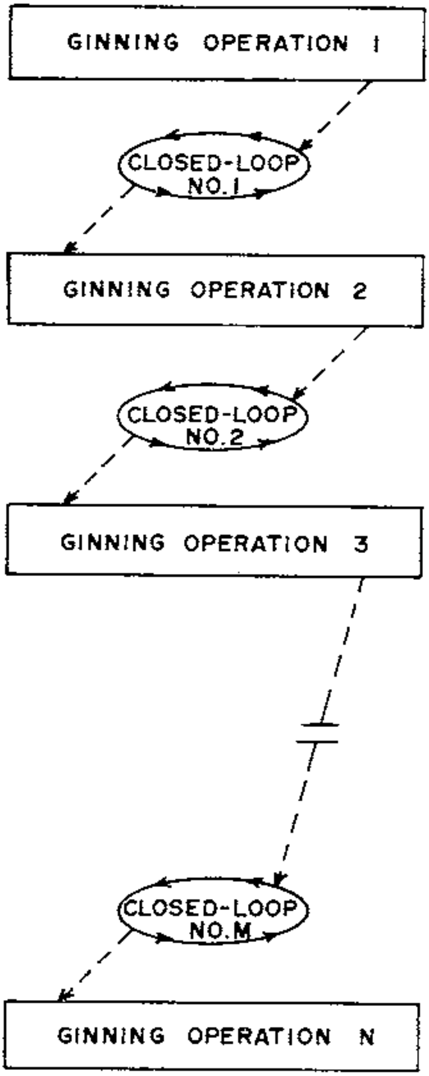

FIGURE 1.—Flow diagram of closed-loop cotton-moisturization concept.

the air in a closed loop is reconditioned by adding a small percentage of high-humidity air. With a closed-loop system, it is not necessary to condition the gin room air, since the conveying and conditioning air is contained in a closed loop of sheet-metal piping.

The closed-loop system also offers the possibility of eliminating much of the expensive air-filtration equipment required by conventional or monoflow systems, and the tests were designed to determine whether a system without air filtration could operate continuously without lowering the quality of the fibers.

1971 TEST

Procedures

A conventional air-blast gin stand with 12-in-diam saws, but reduced in width to 35 saws, was used for this test. The lint cleaner was a conventional saw model that had been reduced to match the gin stand. The closed-loop system was between the gin stand and the lint-cleaner condenser. The smaller models were used to limit the size of the experimental lots and to give more control over the experiment.

A sheet-metal plenum chamber was constructed and placed on the floor under the short flue between the gin stand and the lint cleaner. Exhaust air from the lint-cleaner condenser was discharged into the chamber by means of a standard 21-in-diam axial-flow fan. Air used to doff the gin saws was drawn from the plenum by the air-blast fan (figs. 2, 3). Air induced by the air-blast nozzle was also drawn from the plenum through an opening in the top of the plenum directly under the gin saws.

The exact amount of air circulating in the closed loop was not measured because the very short piping and the numerous elbows made such measurements impractical. However, the air was measured before the plenum chamber and piping had been installed, while the gin stand and lint cleaner were operating normally. The rate measured under these conditions was 1,800 ft^3/min, with static pressure readings of 0.35 and 11.5 inH_2O at the inlet of the lint-cleaner condenser and inside the air-blast chamber, respectively. After the closed loop had been installed, static pressures were adjusted to these values; thus, the 1,800-ft^3/min airflow was considered a good approximation of the amount of air being circulated in the closed loop.

High-humidity air (approximately 100 pct RH) was supplied to the closed loop through a conventional gin humidifier at rates from 147 to 329 ft^3/min. The rate was manually controlled to maintain a temperature and relative humidity in the closed loop of 100° F and 50 to 55 pct, respectively. The conditions inside the loop were monitored by a Hygrodynamic hygrometer indicator, model 15–3001.[2] Theoretically, when a given volume of air was added to the closed loop, an equal volume had to be exhausted to maintain mass-

[2] Trade names are used in this publication solely for the purpose of providing specific information. Mention of a trade name does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture or an endorsement by the Department over other products not mentioned.

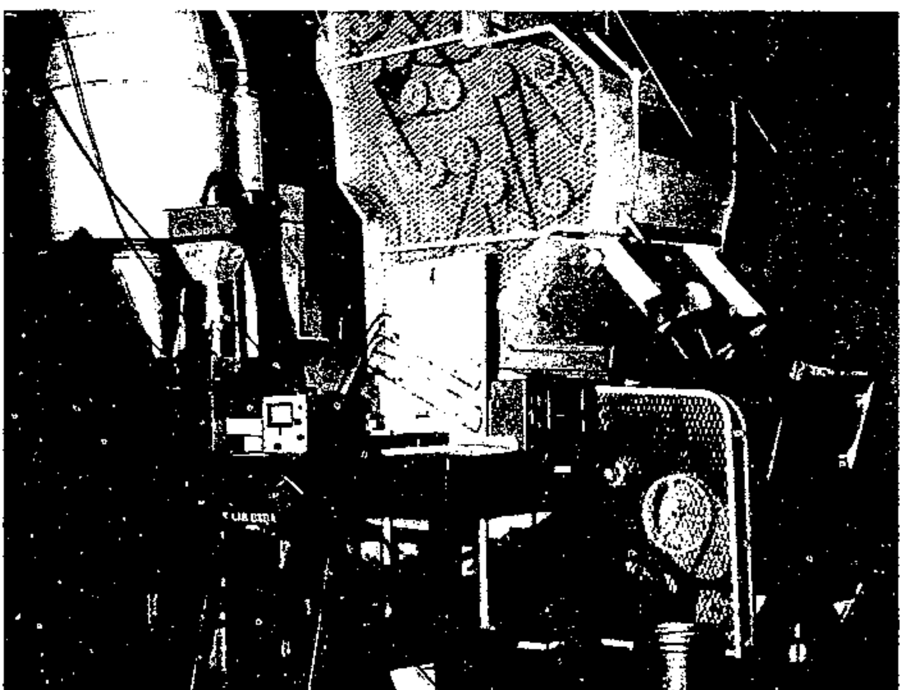

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FIGURE 2.—The 35-saw air-blast gin used in closed-loop cotton-moisturization system.

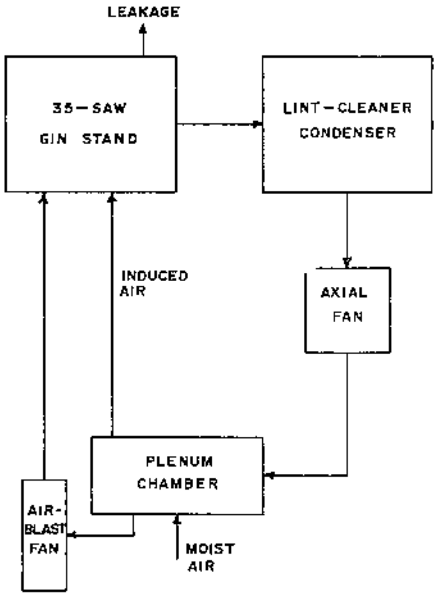

FIGURE 3.—Schematic of 35-saw air-blast gin and closed-loop cotton-moisturization system.

flow equilibrium. In this system, equilibrium was maintained by allowing excess air to escape from the front of the plenum.

A high-volume air sampler was used to take air from the plenum at 15-min intervals during the ginning of the test lots for measurement of the dust concentration. Seed cotton and lint were taken at the same intervals at the feeder apron and at the lint cleaner, respectively. These seed-cotton and lint samples were used for moisture measurements and to obtain fiber-quality data.

The test consisted of 4 h of ginning at a uniform rate of about 300 lb of lint/h. Each hour of ginning time was considered one replication of sampling periods. 'Rilcot 90' cotton was used for the first two replications and 'Paymaster 111' for the last two. All cotton was precleaned through the normal seed-cotton-cleaning system before ginning.

Results

A summary of data obtained in the 1971 test is given in table 1. The difference between moisture content at the feeder when measured by the meter (6.2 pct) and by the oven (7.6–8.1 pct) occurred because the moisture meter was affected principally by the moisture content of the lint, whereas the oven method measured the moisture content of the entire seed-cot-

TABLE 1.—*Average plenum-chamber conditions and cotton-moisture contents in closed-loop system, 1971 test*

Measurement	At start	After a ginning time (min) of— 15	30	45	60
Plenum chamber:					
Temperature ....°F...	103.8	103.8	105.0	105.0	105.0
Relative humidity ....pct...	53.8	54.0	52.5	52.0	51.5
Dust ....mg/m³...	3.0	2.2	1.9	1.9	2.2
Moisture content:					
Meter:					
Feeder ....pct...	6.2	6.2	6.2	6.2	6.2
Condenser ....pct...	7.6	7.8	7.6	7.7	7.6
Oven: feeder (wet basis)...pct...	7.6	7.9	7.8	8.0	8.1

ton mass. The figures on moisture content at the condenser (7.6–7.8 pct) show that the lint moisture content increased 1.4 to 1.6 percentage points during the 2-s exposure to the conditioned air in the closed loop.

Maximum dust in the loop was at the start of the ginning period and decreased with time until it reached a minimum about 45 min later. In the next 15-min period, the dust concentration increased slightly, but never reached the maximum value obtained at the start of the ginning period (fig. 4). The slight increase in dust concentration raised the question of whether the dust inside the loop would continue to build up if the system were operated for a longer period and whether the dust would increase enough to damage fiber quality.

The fiber properties of lint samples used in the test are shown in table 2. The closed-loop system had no detrimental effects upon fiber quality. The slight variations

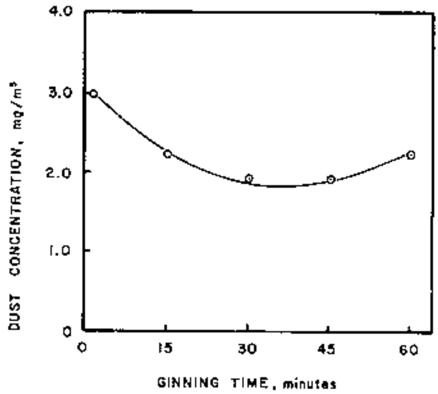

FIGURE 4.—Variation of dust concentration in plenum chamber with ginning time, 1971 test.

within measurements are not statistically significant.

No static buildup was observed.

1972 TEST

Procedures

A high-capacity brush gin with 16-in-diam saws, reduced in width to 16 saws, was used with the lint cleaner described before. Ductwork was fabricated to form a closed loop between the gin stand and the lint cleaner in a manner

TABLE 2.—*Average properties of lint fiber in closed-loop system, 1971 test*

Measurement[1]	At start	After a ginning time (min) of—			
		15	30	45	60
Strength, ⅛-in gage ....g/tex...	20.8	21.4	21.2	20.7	20.0
2.5-pct span length ....in...	0.94	0.94	0.95	0.95	0.94
Length uniformity ....pct...	42.4	41.6	41.3	41.6	41.6
Colorimeter readings:					
Reflectance ....R_d...	70.5	69.9	69.3	70.1	70.2
Yellowness ....$+b$...	8.8	8.7	8.9	8.7	8.9
Lint grade ....index...	80	80	80	80	80
Staple length ....32ds in...	30.6	30.8	30.3	30.9	30.1
Micronaire value	2.7	2.7	2.7	2.7	2.7
Nonlint content ....pct...	8.73	9.30	9.75	9.09	9.09

[1] Variation of means within measurements not significant at 0.05 confidence level.

similar to the 1971 test. Thus, the air used to doff the gin saws circulated through the lint-cleaner condenser and back to the plenum chamber, where the air was picked up again by the doffing brush (figs. 5, 6).

The 1972 test consisted of 8 h of ginning at a uniform rate of about 300 lb of lint/h. Each replication was 2 h of ginning time. The cotton used for the entire test was 'Paymaster 909'. All cotton was precleaned through the normal seed-cotton-cleaning system before ginning.

The ginning time per replication was increased to 2 h because of the question about dust increase that arose in the first experiment. The longer ginning time was expected to show whether the dust concentration in the closed loop would continue to increase with longer operating periods.

The volume of air recirculating through the closed loop was determined by means of a thermistor anemometer probe made at the laboratory. A velocity traverse was performed in a rectangular section of pipe with a cross-sectional area

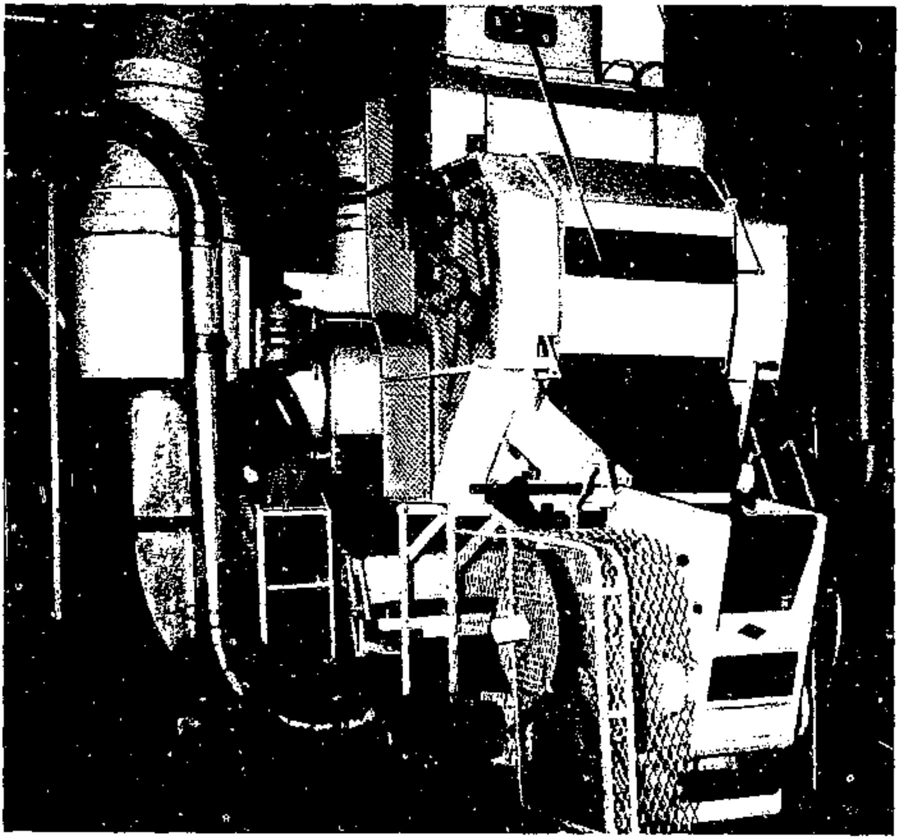

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FIGURE 5.—Brush-doffing 16-saw gin used in closed-loop cotton-moisturization system.

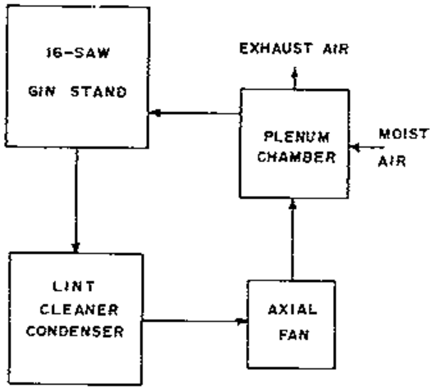

FIGURE 6.—Schematic of 16-saw brush gin and closed-loop cotton-moisturization system.

of 2.25 ft^2. The average velocity in the duct was 468 ft/min; thus, the flow rate inside the closed loop was 1,053 ft^3/min. The static pressure at the condenser inlet was 0.35 inH_2O and the static pressure inside the plenum chamber was 1.0 inH_2O.

High-humidity air was supplied to the closed loop by a conventional gin humidifier. In this experiment 100 ft^3/min of moist air was introduced into the plenum. This volume was about 10 pct of the air circulated inside the closed loop. The conditions of the air inside the closed loop were monitored by a Hygrodynamics hygrometer indicator. Equilibrium of airflow inside the loop was maintained by using a small fan to pull 100 ft^3/min from the closed loop.

A high-volume air sampler was used to take loop air for dust concentration determinations during the ginning of the test lots. Seed-cotton samples were taken at the feeder apron for moisture determinations. Samples of lint were taken at the lint-cleaner condenser for moisture measurements and fiber-quality tests. All samples were taken at 15-min intervals.

Results

A summary of the test is given in table 3. The conditioned air in the closed loop increased the moisture content of the lint by 0.5 to 0.7 percentage points. Other research indicates that the equilibrium moisture content of lint under conditions used for this test is about 7.0 pct (*8*). The incoming moisture content of lint was

TABLE 3.—*Average plenum-chamber conditions and cotton-moisture contents in closed-loop system, 1972 test*

Measurement	At start	After a ginning time (min) of—							
		15	30	45	60	75	90	105	120
Plenum chamber:									
Temperature ....°F...	82.5	87.0	89.2	90.0	90.0	90.5	91.5	91.0	91.0
Relative humidity ....pct...	58.5	56.5	55.5	55.2	55.0	54.2	55.0	54.5	54.5
Dust ....mg/m³...	104.7	30.7	19.5	32.6	28.3	31.4	20.9	26.8	17.5
Moisture content:									
Meter:									
Feeder ....pct...	6.6	6.5	6.4	6.4	6.4	6.5	6.4	6.4	6.4
Condenser ....pct...	7.1	7.1	7.1	7.0	6.9	7.0	6.9	6.9	6.9
Oven: feeder (wet basis)..pct...	7.4	7.7	7.7	7.8	7.4	7.6	7.5	7.6	7.6

about 6.5 pct or very near the equilibrium point, thereby limiting the amount of moisture that could be regained.

The highest dust concentration in the loop occurred at the start of the test period, and the lowest value was at the end of the 2-h ginning period. However, the dust concentration was constantly changing, as shown in figure 7. Dust tended to decrease rapidly during the first 15 min of ginning, and then decreased gradually for the remainder of the period. There was no evidence that dust in the closed loop would increase with operating time.

The decrease in dust with time may be partially explained by the fact that the closed-loop system was continuously ventilated by the purging of excess air from the system to maintain mass-flow equilibrium. The volume of the closed-loop piping, condenser, fan, and brush chamber was calculated from dimensions of these components and found to be approximately 100 ft^3. Thus, the 100 ft^3/min of air continuously purged from the closed loop tended to completely ventilate the system approximately 1 time/min. Also, the batt of lint on the condenser drum possibly filtered some of the dust out of the recirculating air, thus lessening the dust inside the closed loop.

The larger dust concentration possibly occurred because less air was circulated in this test than in the first one (1,053 ft^3/min compared to 1,800 ft^3/min). Also, in the first test, excess air escaped the loop at will, but in the second, air was added and lost in equal

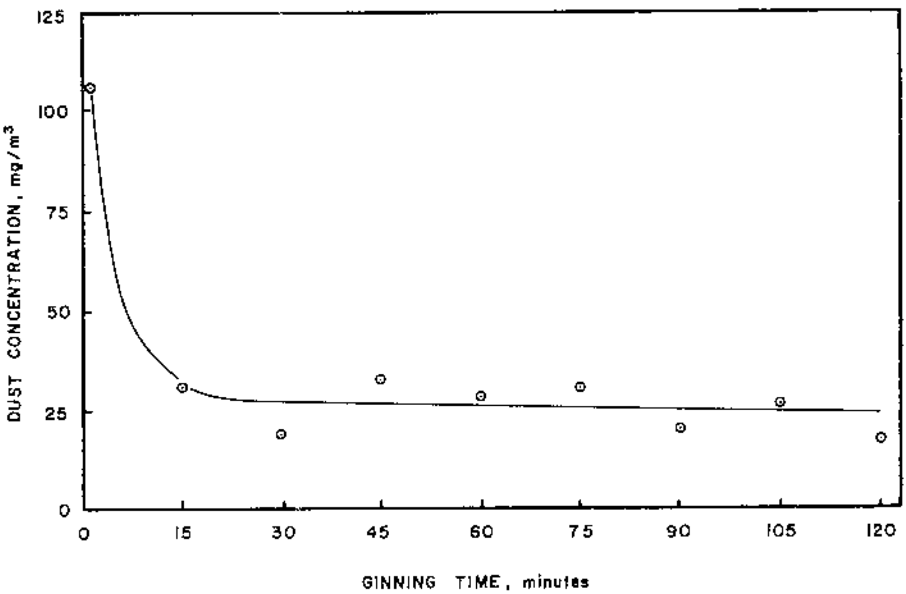

FIGURE 7.—Variation of dust concentration in plenum chamber with ginning time, 1972 test.

volumes. The cotton used in the two experiments was also different, and this could have had a definite effect on the amount of dust in the cotton. Air purged from the closed loop contained approximately 130 mg of dust/m³ of air, which is about the same as contained in normal condenser exhaust after filtration by an in-line air filter (*1*).

The fiber property data for the 1972 test are shown in table 4. With the exception of length uniformity, all fiber data showed no significant difference among sampling periods. Variations in length uniformity did not appear to be related to dust concentrations or length of sampling periods. Thus, the dust in the closed loop did not adversely affect the fiber properties measured in this test. There was no visual indication of static charge buildup.

CONCLUSIONS

The closed-loop cotton-moisturization concept was found to be feasible for increasing lint moisture content during lint cleaning at cotton gins. Proper control of lint moisture content alleviates problems associated with static electricity and reduces the possibility of fiber breakage. The closed-loop system also reduced the amount of dust and short fibers exhausted to the atmosphere even though no air filters were used. This shows a potential for significantly reducing the amount of air-pollution-abatement equipment required to satisfactorily control particulate emissions from lint-cleaning systems. Dust concentrations inside the closed loop tended to decrease with time and did not adversely affect any of the fiber properties studied.

TABLE 4.—*Average properties of lint fiber in closed-loop system, 1972 test*

Measurement[1]	At start	After a ginning time (min) of—							
		15	30	45	60	75	90	105	120
Strength, ⅛-in gage . g/tex	22.3	22.2	22.0	22.6	22.2	22.6	22.4	22.4	22.0
2.5-pct span length . . . in	.97	.98	.98	.96	.97	.98	.97	.97	.97
Length uniformity . . . pct	46.2	46.0	46.5	48.0	47.2	46.2	45.8	47.0	46.5
Colorimeter readings:									
Reflectance . . . . . R_d	78.8	77.5	78.5	78.0	78.4	78.4	78.1	78.6	78.1
Yellowness . . . . . $+b$	9.3	9.3	9.2	9.2	9.2	9.2	9.4	9.2	9.2
Lint grade . . . . . index	94	94	94	94	94	94	94	94	94
Staple length . . . 32ds in	32	32	32	32	32	32	32	32	32
Micronaire value	3.2	3.2	3.2	3.1	3.2	3.2	3.2	3.2	3.2
Nonlint content . . . . pct	4.63	4.55	4.38	4.45	5.05	4.95	4.30	4.50	4.38

[1] Except for "length uniformity," variations in means within measurements were not significant at the 0.05 confidence level.

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