# AIR-BAR COTTON LINT CLEANER

R. Sui, R. K. Byler

**ABSTRACT.** *Saw-type lint cleaners are now the most common lint cleaners used at gins because of their higher cleaning efficiency. Saw-type lint cleaning improves the grade of the fiber and increases the market value for the farmer. However, during the cleaning process the saw-type lint cleaners damage fiber in creating short fibers and neps. An innovative air-bar lint cleaner (ABLC) was designed and built. The ABLC used pressurized air to clean non-lint materials from cotton fiber while the cotton fiber batt was on a rotating saw cylinder. Thus, non-lint materials attached to the fiber were removed by the interaction of blowing force of compressed airflow and centrifugal force created by the rotating cylinder without the fiber making mechanical contact with a solid object, such as a grid bar. The fiber quality could be preserved by reducing the damage from mechanical impact of the fiber against the grid bar during the lint cleaning process. Preliminary testing of the ABLC prototype was conducted. Compared with cotton cleaned using the conventional saw-type lint cleaner, cotton cleaned using the ABLC had better fiber quality properties, including less short fiber content, less trash content, longer fiber length by number, less immature fiber content, lower yellowness, and less lint content in the lint waste.*

***Keywords***. *Cotton lint cleaner, Compressed air, Cotton gin, Fiber quality.*

U.S. cotton is machine-harvested and contains about 13% to 35% foreign matter (Funk et al., 2005). It is desirable for as much foreign matter as possible to be removed from cotton fiber at the gin within fiber-damage constraints. The process of removing foreign matter at the gin involves cylinder cleaners and stick machines before fiber-seed separation to remove large particles of foreign matter from the seed cotton, and lint cleaners after fiber-seed separation to remove smaller particles that remain in the cotton. Two general types of lint cleaners are currently on the market, the air-type and the predominant saw-type. With the saw-type lint cleaner, lint from the gin stand or prior lint cleaner is formed into a batt on a condenser drum and fed onto a saw cylinder through a set of feed rollers. While the fiber batt is on the saw cylinder, it is cleaned by a combination of centrifugal force, scrubbing action between the saw cylinder and grid bars, and gravity assisted by an air current (Anthony and Mayfield, 1994). The scrubbing action is a harsh mechanical process in which fibers in the thinned batt are pulled rapidly across the edges of the grid bars, possibly causing some fibers to break and potentially resulting in lower grades for fiber length and length uniformity (Thomasson et al., 2007). According to Gordon and Bagshaw (2007), a fixed-batt saw lint cleaner caused 10% to 20% increase in the nep level, 0.3- to 0.4-mm reduction in the upper quartile length by weight, and significant increase in short fiber content. The longer and finer a cotton is, the greater the damage (Gordon and Bagshaw, 2007). While it is likely that some fiber damage occurs at the transition between feeder roll and saw cylinder (Gordon and Bagshaw, 2007), it is reasonable to assume that most damage occurs at the grid bars. In fact, the new technology to reduce fiber damage reported by Anthony (2000) was successful in reducing short fiber content simply by disengaging some of the grid bars in the lint cleaners.

As cotton fiber quality has become a more important issue on the world market, researchers have been working to find the causes of fiber damage and to develop new methodologies and mechanical systems to reduce the damage and loss of fiber while retaining the high efficiency of the saw-type lint cleaner. Columbus (1985) studied the effect of lint cleaner saw speed and tooth density on cotton quality. He found that as the saw speed increased, the amount of waste removed during the lint cleaning increased, the lint in the lint cleaner waste increased, and the composite grade increased. Increasing the lint cleaner saw tooth density decreased the composite grade, decreased the upper-half mean length (UHML), and increased the trash grade. Hughs et al. (1992) reported that a prototype coupled lint cleaner had a significantly higher turnout, longer length properties, fewer short fibers, and better uniformity than conventional saw-type lint cleaners. In 1999, Lummus introduced a non-conventional flow-through saw-type lint cleaner that applies individual tufts of fiber directly to the saw through the use of a high-speed perforated air and dust separator cylinder, rather than agglomerating the lint into a batt on a low-speed revolving condenser drum (Rutherford et al., 1999).

Over the years, almost all the significant attempts at developing new lint cleaning technologies have involved variations on the saw-type of lint cleaner: controlling the number of lint cleaners (Griffin et al., 1982), controlling the number of grid bars in contact with the fiber (Anthony, 2000), and controlling fiber moisture content so that the lint cleaners don't cause excessive fiber damage (Byler, 2003). There

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have also been minor modifications to this basic design, such as changes in tooth configuration of the saw cylinder, adding air assist, and adding brushes (Baker et al., 1992; Delhom and Byler, 2009). However, today the ginning industry basically uses the same cleaning principles that were developed in the 1940s.

The objective of this research was to create a novel lint cleaning method and use it to develop a new type of cotton lint cleaner that removes non-lint materials in cotton with less damage and loss of cotton fiber.

## Materials and Methods

### Invention Concept

A novel concept device for cotton lint cleaning at gins was created (Sui, 2010). The concept device could be stated as follows: While cotton fiber batt is on a rotating saw cylinder, non-lint materials attached to the fiber can be removed from the fiber by the interaction of blowing force of compressed airflow and centrifugal force created by the rotating cylinder without the fiber making mechanical contact with a solid object so that the fiber will not be damaged during the cleaning process. A nozzle array or similar devices can be configured to use compressed air generating a layer of concentrated airflow to jet toward the cotton batt on the saw cylinder. Pressure and direction of the airflow, and the distance between the nozzle array and the saw cylinder, are crucial parameters which can be adjusted to optimize the cleaning efficiency.

### System Design

Based on the concept described above, an experimental air-bar device was developed for a new type of lint cleaner (air-bar lint cleaner or ABLC; figs. 1a, 1b, and 1c). The air-bar device consisted of a nozzle array made of eight flat nozzles and two manifolds. Each manifold contained four nozzles (Model No. 394, Silvent Advanced Air Nozzle Technology, Potage, Ind.). Air inlets in two manifolds were connected via a three-way connector, and air entry was connected to a compressed air source through an air hose. Maximum operating pressure of the nozzle array was 1.0 Mpa (143.0 psi). Blowing force of each nozzle was 4.7 N (17 oz) with air consumption of 26 $Nm^3/h$ (15.3 scfm) at an air pressure of 413.7kPa (60 psi). The nozzle array was mounted onto an aluminum alloy plate with one metal bracket at each end. The bracket was designed to adjust airflow direction of the nozzle array and the distance from the array to the saw cylinder. Dimensions of the air-bar were 483 mm L × 127 mm W × 51 mm D (19 in. L × 5 in. W × 2 in. D). To build the ABLC prototype, one of the conventional flow-through saw-type lint cleaners at the micro-gin (Anthony and McCaskill, 1972) was modified by replacing the first grid bar with the air-bar device while there was no change made in the other four grid bars of the lint cleaner. The horizontal distance between the tip of the nozzle array and the saw teeth was 9.5 mm (0.375 in.). The angle of the nozzle array toward the saw cylinder was adjusted to zero for the test reported herein.

An air compressor (Ingersoll Rand, www.ingersoll-rand.com, Davidson, N.C.) was used to provide pressured air for the air-bar. An air regulator was implemented between the compressor and the air-bar to control the air pressure.

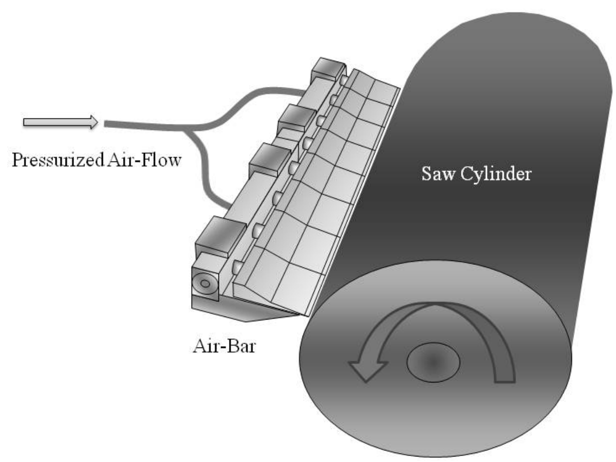


**Figure 1a. Air-bar device and the saw cylinder.**

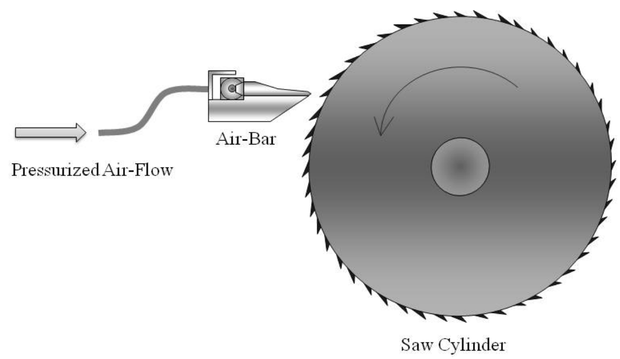


**Figure 1b. Air-bar device and the saw cylinder (side-view).**

**Figure 1c. Air-bar device as installed in cotton lint cleaner.**

### ABLC Test

To evaluate the ABLC prototype, a preliminary test was conducted at the USDA-ARS Cotton Ginning Research Unit (CGRU) at Stoneville, Mississippi, on 6 October 2010. To compare the performance of the ABLC with the conventional saw-type lint cleaner (STLC), another STLC identical to the ABLC except for the first grid bar, was employed in the test. The ABLC and the STLC were arranged allowing either of them to be selected for use with ginned samples. Ten bags of seed-cotton (variety: Stoneville-4427 B2RF) were randomly selected as samples for the test. Each bag weighed about 20 kg. One bag was ginned at each run. After a bag was ginned with the ABLC, the next bag was ginned with the STLC. This resulted in a total of five runs with the ABLC and five with the STLC. In the ginning process, only one lint cleaner (ABLC or STLC) was used, and all ginning equipment and conditions involved, except the lint cleaner, were identical. The sequence included dryer 1, cylinder cleaner, stick machine, dryer 2, cylinder cleaner, extractor feeder gin stand, and ABLC or STLC (fig. 2). No heat was used in the dryers.

### Fiber Quality Assessment

For each run, five subsamples of lint were collected after lint cleaning for Advance Fiber Information System (AFIS) analysis, five subsamples for High Volume Instrument (HVI) test, and five samples for moisture content (MC) measurement. Additionally, lint cleaner waste was collected and the total lint of each sample was weighed. AFIS (Zellweger Uster, 1997) and MC analysis of the subsamples were conducted in the CGRU lab. The HVI test was made at the USDA-ARS Southern Regional Research Center (SRRC) in New Orleans, Louisiana. The lint cleaner waste was analyzed using a Shirley Trash Separator at CGRU. American Society for Testing and Materials (ASTM) standard procedures were followed in fiber quality tests.

### Data Analysis

The data from AFIS and HVI tests of the samples were analyzed using one-way ANOVA and a Tukey post-hoc test with SAS to compare the effect of the ABLC and the STLC on fiber quality. The ratio of lint cleaner waste weight to lint weight was calculated for each sample. Shirley separation data of the lint cleaner waste were analyzed for the ratio of trash to lint to find the effect of the ABLC on the lint cleaner waste in comparison with the STLC. The ANOVA analysis of MC data was performed to evaluate if the moisture content of the samples cleaned using the ABLC differed from that using the STLC.

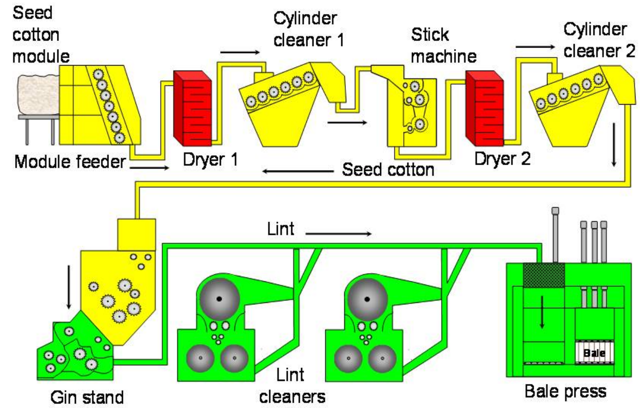


**Figure 2. Gin layout and the ginning sequence used in the air-bar lint cleaner test.**

## Results

### AFIS Test

Table 1 indicates means and significant differences between lint cleaner treatments based on AFIS measurements. A one-way ANOVA test revealed that the short fiber content by weight (SFC(w)) in the samples differed significantly as a function of the lint cleaner ($F (1, 48) = 7.59$, $p = 0.0083$). The ABLC generated lower SFC(w) (M = 9.81, SD = 0.58) than the STLC (M = 10.28, SD = 0.62). The one-way ANOVA test also indicated significant differences due to the lint cleaner on the trash ($F (1, 48) = 5.82$, $p = 0.0197$), IFC ($F (1, 48) = 8.7$, $p = 0.0049$), and fiber length by number ($F (1, 48) = 4.19$, $p = 0.0462$). There was less trash (M = 126.28, SD = 22.50) in samples cleaned by ABLC than that (M = 142.24, SD = 24.24) in the samples by the STLC. The samples cleaned by ABLC contained less immature fiber (M = 8.06, SD = 0.46) than that by STLC (M = 8.42, SD = 0.40). Mean of the fiber length by number of the samples cleaned by the ABLC (M = 0.74, SD = 0.01) was greater than that of the samples by the STLC (M = 0.73, SD = 0.01). However, the

**Table 1. Effect of the lint cleaners on the selected AFIS fiber quality.**

| AFIS Fiber Property | ABLC Prototype Mean[a] | ABLC Prototype SD | Saw-Type Lint Cleaner Mean | Saw-Type Lint Cleaner SD | Pr > F | Description of Fiber Property |
|---|---|---|---|---|---|---|
| Nep size (μm) | 680.00a | 13.10 | 681.96a | 15.50 | 0.6313 | Mean size of all neps |
| Nep (cnt/g) | 255.40a | 28.41 | 258.64a | 22.37 | 0.6562 | Total nep count per gram |
| Total trash (cnt/g) | 595.76a | 90.05 | 662.60b | 113.77 | 0.0256 | Total trash count per gram |
| Dust (cnt/g) | 469.28a | 69.79 | 520.48b | 92.84 | 0.0323 | Dust count per gram (<500 μm) |
| Trash (cnt/g) | 126.28a | 22.50 | 142.24b | 24.24 | 0.0197 | Trash count per gram (>500 μm) |
| VFM (%) | 2.16a | 0.39 | 2.48b | 0.45 | 0.0116 | Visible foreign matter percent by weight |
| L(w) (in) | 0.92a | 0.01 | 0.92a | 0.01 | 0.1090 | Average length of fibers computed on a weight basis |
| UQL(w) (in) | 1.11a | 0.01 | 1.11a | 0.01 | 0.2608 | Upper quartile length by weight |
| SFC(w) (%) | 9.81a | 0.58 | 10.28b | 0.62 | 0.0083 | Percentage of fibers, calculated by weight, that are shorter than 12.7 mm |
| L(n) (in) | 0.74a | 0.01 | 0.73b | 0.01 | 0.0462 | Mean length of fibers calculated by number |
| SFC(n) (%) | 28.10a | 1.30 | 29.03b | 1.25 | 0.0126 | Percentage of fibers, calculated by number, that are shorter than 12.7 mm |
| Fineness (millitex) | 162.16a | 1.72 | 160.84b | 2.06 | 0.0175 | Mean fiber fineness (weight per unit length) |
| IFC (%) | 8.06a | 0.46 | 8.42b | 0.40 | 0.0049 | Percentage of fibers with less than 0.25 maturity |
| Maturity ratio | 0.87a | 0.01 | 0.86b | 0.01 | 0.0023 | Ratio of fibers with ≥0.5 circularity ratio divided by amount of fibers with a ≤ 0.25 circularity |

[a] Means in rows with the same letter were not significantly different at 0.05 level (n = 25).

effect of the lint cleaner on the fiber length by weight and upper quartile length by weight was not significant at 0.05 level. No significant effect on the nep size was found.

### HVI Test

Selected HVI test results are illustrated in table 2. A one-way ANOVA test indicated the micronaire (Mic) in the samples did not differ significantly as a function of the lint cleaner ($F(1, 248) = 0$, $p = 0.9454$). The mean of the micronaire with both the ABLC and STLC was 4.00. However, the effect on the short fiber index ($F(1, 248) = 6.67$, $p = 0.0104$) and the yellowness ($F(1, 248) = 25.03$, $p<0.001$) were significant. Mean of the short fiber index of samples with the ABLC (M = 9.42, SD = 1.07) was lower than that with the STLC (M = 9.79, SD = 1.19). Mean of the yellowness with the ABLC (M = 8.58, SD = 0.25) was lower than that with the STLC as well (M = 8.73, SD = 0.23). No other quality measurements were significantly different.

### Shirley Separation

Results of the analysis of lint cleaner waste data are illustrated in table 3. The ABLC had a higher turnout than the STLC. The mean of the ratio of lint cleaner waste to lint with the ABLC (M = 0.0172, SD = 0.0170) was less than that with the STLC (M = 0.0243, SD = 0.0059). However, a one-way ANOVA test showed the ratio did not differ significantly as a function of the lint cleaner ($F(1, 8) = 0.41$, $p = 0.5419$). It was very likely that the Run 5 of the ABLC was an outlier in the ratio of lint cleaner waste to lint (table 3). If the outlier was removed, the ratio became significantly different ($F(1, 7) = 13.38$, $p = 0.0081$). Shirley data showed that there was 43% less cleaned lint in the lint cleaner waste using the ABLC than that using the STLC, and that 35% of lint cleaner waste from the ABLC was cleaned lint compared with 50% from the STLC. The ANOVA test revealed that the lint content in lint cleaner waste from the ABLC was significantly lower than that from the STLC ($F(1, 8) = 77.78$), $p < 0.0001$). This indicated that the ABLC removed less fiber than the STLC during lint cleaning process.

### Moisture Content

Analysis of the MC data showed no significant difference between the MC of the lint samples cleaned by the ABLC and that by the STLC ($F(1, 48) = 0$, $p = 0.9701$). The mean of the MC of the samples with ABLC (M = 4.73, SD = 0.20) was almost the same as that with the STLC (M = 4.72, SD = 0.18).

## Discussion

STLC is now the most common lint cleaner because of its higher cleaning efficiency, improving the grade classification of the cotton fiber, and increasing the market value in the current marketing system. However, STLC damages fiber in creating short fibers and neps, and reduces bale weights (Mangialardi and Anthony, 1998). The operating principle of the ABLC reported in this article is fundamentally different from the STLC. The ABLC removes non-lint materials without mechanical contact between the fiber and the air-bar so that the fiber is not damaged by the bar. Preliminary test results indicated that the ABLC was superior to the conventional STLC in terms of preserving fiber quality including SFC, turnout, and fiber length.

The ABLC used in this test only replaced one grid bar with one air-bar. More than one air-bar could be used in one ABLC, and better performance could be expected with multi-air-bar lint cleaners. The operating efficiency and effectiveness of the ABLC could be affected by many factors such as the pressure and direction of the airflow, distance between the air-bar nose and the saw cylinder, and physical properties of the saw teeth. This article reported only on the first phase of ABLC development, proof of concept.

**Table 2. Effect of the lint cleaners on the selected HVI fiber quality.**

| HVI | ABLC | | STLC | | | |
|---|---|---|---|---|---|---|
| Fiber Property | Mean[a] | SD | Mean | SD | Pr > F | Description of Fiber Property |
| Mic | 4.00ᵃ | 0.08 | 4.00ᵃ | 0.07 | 0.9454 | Measure of fiber fineness and maturity |
| SFI (%) | 9.42ᵃ | 1.07 | 9.79ᵇ | 1.19 | 0.0104 | Short fiber index |
| +b | 8.58 ᵃ | 0.25 | 8.73 ᵇ | 0.22 | <0.0001 | Yellowness of fibers |

[a] Means in rows with the same letter are not significantly different at 0.05 level (n = 125).

**Table 3. Results of Shirley separation of lint waste.**

| Lint Cleaner | Run | Lint Cleaner Waste/Lint | Lint Cleaner Waste (g) | Cleaned Lint (g) | Visible Waste (g) | Cleaned Lint/ Lint Cleaner Waste |
|---|---|---|---|---|---|---|
| ABLC | 1 | 0.0103 | 74.53 | 26.70 | 46.56 | 0.3582 |
| | 2 | 0.0141 | 123.94 | 44.62 | 77.30 | 0.3600 |
| | 3 | 0.0047 | 29.37 | 8.93 | 19.93 | 0.3041 |
| | 4 | 0.0100 | 69.50 | 24.73 | 43.34 | 0.3558 |
| | 5 | 0.0470 | 339.17 | 128.00 | 205.24 | 0.3774 |
| STLC | 1 | 0.0249 | 173.20 | 78.76 | 91.56 | 0.4547 |
| | 2 | 0.0183 | 121.97 | 62.79 | 57.20 | 0.5148 |
| | 3 | 0.0215 | 161.01 | 81.04 | 76.92 | 0.5033 |
| | 4 | 0.0160 | 140.85 | 72.59 | 66.42 | 0.5154 |
| | 5 | 0.0310 | 227.12 | 115.93 | 109.38 | 0.5104 |

## Summary and Conclusions

An air-bar lint cleaner (ABLC) was developed at the USDA-ARS's Cotton Ginning Research Unit at Stoneville, Mississippi. The ABLC is a new type of lint cleaner that uses pressurized airflow to remove non-lint materials from lint cotton at the gin. There is no mechanical interaction between the fiber and the air-bar of the ABLC in the lint cleaning process, so no fiber damage occurs at the bar. Preliminary tests of the ABLC prototype were conducted and superior results were indicated compared with the conventional saw-type lint cleaner (STLC) in terms of preserving cotton fiber quality at the same production rate. Cotton cleaned using the ABLC had better fiber quality properties, including less short fiber content, less trash content, longer fiber length by number, less immature fiber content, lower yellowness, and less lint content in the lint waste compared with cotton cleaned using the STLC. These promising results suggest that the ABLC has significant potential to be used in the cotton industry. More tests and adjustments of relevant parameters of the ABLC will be needed to improve its performances.

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