SURVEY OF SEED COTTON CLEANING EQUIPMENT IN MID-SOUTH GINS

Robert G. Hardin IV
USDA-ARS Cotton Ginning Research Unit
Stoneville, MS
Thomas D. Valco
USDA-ARS Office of Technology Transfer
Stoneville, MS
Richard K. Byler
USDA-ARS Cotton Ginning Research Unit
Stoneville, MS

Abstract

The performance of seed cotton cleaning equipment in commercial gins is not well documented. Most research reporting cleaning efficiencies of this machinery was performed in the laboratory under optimal conditions, while commercial gins must often process cotton with high moisture or foreign matter content. A survey was conducted of seed cotton cleaning equipment in Mid-South gins in 2009, and seed cotton samples were collected from selected gins in 2009 and 2010. Most gins surveyed had at least the recommended sequence of seed cotton cleaning equipment, with many having an additional cleaning machine. The data were analyzed to determine factors affecting cleaning efficiency. Overall cleaning efficiency was found to be lower in 2009, than most values previously reported in the literature. The condition of the incoming seed cotton was the likely reason for this low cleaning efficiency, as the seed cotton had high moisture and mote content. Regression analysis indicated that the number of cleaning machines had a significant effect on foreign matter content. Cleaning efficiency for gins in 2010 was higher and closer to previously reported values. Due to the limited amount of data analyzed, no recommendations can be made on using additional seed cotton cleaning equipment beyond the currently suggested machinery sequence.

Introduction

Gin managers have recently shown increased interest in the performance of seed cotton cleaning equipment. This concern has been motivated by several factors. Gins have increasingly used only a single stage of lint cleaning to reduce short fiber content, preserve fiber length, and increase turnout. Although the base leaf grade in the U.S. is four, international customers have favored cleaner cotton, with a leaf grade of three. Previous research has shown that additional seed cotton cleaners can replace some lint cleaning (Columbus and Anthony, 1991). Gin stand capacity has also increased, commonly resulting in higher processing rates of seed cotton through cleaning equipment. The maximum recommended processing rate of seed cotton cleaning equipment is 8.2 bale hr^{-1} m^{-1} (2.5 bales hr^{-1} ft^{-1}) (Baker et al., 1994). The performance of cleaning equipment at rates higher than recommended is unknown.

One challenge faced in developing more efficient cleaning systems is that the performance of seed cotton cleaning equipment in commercial gins is not well documented. Previous research was often conducted using small-scale machinery and performed under conditions that often differ significantly from commercial gins. The recommended sequence of seed cotton cleaning machinery for picker-harvested cotton is a dryer, cylinder cleaner, stick machine, dryer, cylinder cleaner, and extractor-feeder (Baker et al., 1994). A variety of seed cotton cleaning equipment sequences were tested by Anthony (1990) in modeling the performance of ginning machinery with picked cotton. These sequences included the extractor-feeder alone, individual seed cotton cleaners with the extractor-feeder and the standard sequence of seed cotton cleaning equipment. The extractor-feeder removed 40% of the foreign matter in the seed cotton when the other machinery was not used. The addition of a cylinder cleaner or stick machine increased cleaning efficiency slightly, while the standard sequence removed 58% of the foreign matter in the seed cotton. Anthony and Calhoun (1997) also studied the cleaning efficiency of the standard sequence of ginning equipment with 49 picker-harvested cultivars. Seed cotton cleaning efficiency ranged from 45% to 71%, with a mean of 63%. Gillum and Armijo (1997) found that the total cleaning efficiency of a cylinder cleaner, stick machine, and cylinder cleaner processing Pima cotton was 65.1%. This value does not include foreign matter removed by the feeder.

The cleaning efficiency of individual machines has been studied in the laboratory by several researchers. Cocke (1972) found that the cleaning efficiency of a first stage seven-cylinder cleaner operated at a conventional speed with picked cotton was approximately 25%. Read (1972) calculated cleaning efficiency values of individual machines processing picker-harvested cotton. The first stage six-cylinder cleaner operated at conventional speeds removed around 20% of the foreign matter, while the cleaning efficiency of the stick machine immediately following was 16%.

Baker et al. (1982) reported on cleaning efficiencies for individual seed cotton cleaners processing stripper-harvested cotton. The cleaning efficiency of a six-cylinder cleaner varied from 9-24%. This variation was likely due to differences in the initial fine foreign matter content of the seed cotton. A stick machine, when used alone with stripper-harvested cotton, had cleaning efficiencies from 57-66%. The cleaning efficiency of a stick machine processing cleaner picker-harvested cotton would typically be much lower, as the cotton tested contained from 26.1 to 40.6% foreign matter, comprised primarily of burs.

Gillum and Armijo (1997) determined that the efficiencies were 25% for a first stage cylinder cleaner, 14% for a stick machine, 14% for a second stage cylinder cleaner, and 8% for a third stage cylinder cleaner. Data for the foreign matter removed by the first and second stage cylinder cleaners also included a small amount of cleaning in the separators.

Whitelock et al. (2007) conducted a survey of seed cotton cleaning equipment in roller gin plants. The surveyed gins used an average of five seed cotton cleaners (not including extractor-feeders directly above the gin stand). Typically, these gins had three cylinder cleaners and at least one stick machine. Other gins also used impact cleaners or additional extractor-feeders. Mean foreign matter content at these gins was reduced from 11.4% at the module to 2.1% at the feeder apron, for a total seed cotton cleaning system efficiency of 82%. Because gentler and less efficient lint cleaners are used in roller gin plants, more seed cotton cleaning equipment is often installed in roller gin plants than saw gin plants. No similar survey has been conducted recently in saw gin plants.

Materials and Methods

Survey

A written survey was distributed to Mid-South gins in 2009. The survey asked managers to list the type, sequence, and width of seed cotton cleaning machinery at their gins. Additional information requested included the number and model of gin stands, average and maximum ginning rates, and total number of bales ginned in 2008. Thirty gins returned surveys. Site visits were conducted at eight additional gins to collect the same information requested on the survey. Two of the gins surveyed had two plants with different machinery widths or sequences; consequently, the individual plants were considered separately.

Sample Collection and Analysis

Samples were collected from gins in 2009 and 2010, to determine the effectiveness of the various arrangements of seed cotton cleaning equipment. Eight gins were sampled in 2009. Seven of these gins were also sampled in 2010, along with seven additional gins. Each gin was visited once during a ginning season, except for one gin in 2009, that was sampled on three different dates. Samples for moisture and foreign matter content determination were collected from the module and at the feeder apron. Additional samples for foreign matter content analysis were collected after individual seed cotton cleaning machines, when feasible. At each gin, three conventional modules or the equivalent– six half-size modules or twelve round modules– were sampled. At each sampling location, five samples were collected from each full-size module, three samples were collected from each half-size module, and two samples were collected from each round module. The actual ginning rate was recorded for the sampled modules and used to calculate the seed cotton cleaning equipment processing rate.

Moisture content was determined by oven drying, while foreign matter content was established by pneumatic fractionation (Shepherd, 1972). Because of the large variance in fractionation samples and the difficulty in collecting samples from different machines at the appropriate times to correspond to the same small region of a module, cleaning efficiency was calculated for each module using the mean value of the fractionation samples from that module. Cleaning efficiency was calculated for individual machines and the entire seed cotton cleaning system using the following equation:

$$CE = \frac{FM_i - FM_f}{FM_i}$$

where

CE = cleaning efficiency
FM_i = initial foreign matter content (% by weight)
FM_f = final foreign matter content (% by weight).

The mixed models procedure in SAS, *PROC MIXED*, was used for statistical analysis (SAS 9.2, SAS Institute, Inc., Cary, N.C.). Seed cotton properties (moisture and foreign matter content) and cleaning efficiency were used as dependent variables. The gin was used as an independent variable in the analysis and the module nested within the gin was used as a random factor in the mixed models. Moisture content and initial foreign matter content were included as covariates in the analysis. Least squares means of dependent variables were calculated for each gin and for the season. Because the 2010 data was incomplete, each season was analyzed separately.

Stepwise regression was performed on the seed cotton properties at the feeder apron and the total cleaning efficiency for 2009, using *PROC REG* in SAS. The independent variables used included the number of cylinder-type cleaners, the number of extractor-type cleaners, moisture content at the module, seed cotton machinery loading rate, and the fractionation data from the module samples. Cylinder-type cleaners included both impact and regular grid bar cylinder cleaners (both horizontal and inclined). Extractor-type cleaners consisted of stick machines and additional extractor-feeders (the extractor-feeder immediately preceding the gin stand was not included). Only two classifications of machinery were used for the regression analysis, due to the limited amount of data. The significance level for entering and removing independent variables from the model was 0.10. This value was chosen to limit the number of variables in the regression model.

Results and Discussion

Survey

Nearly all Mid-South gins surveyed had at least the standard sequence of equipment for seed cotton cleaning and a significant number had an additional cleaner (table 1). Most commonly, the additional cleaner was gravity-fed following the second stage cylinder cleaner. Several gins used horizontal airline cylinder cleaners as the first cleaning machine (cylinder cleaner + standard and three cylinder cleaner sequences). The categorization of gins when sampled was based on the machinery actually being used at the time samples were collected, since some gins had bypassed the stick machine.

Table 1. Seed cotton cleaning equipment at surveyed gins.

Machinery Sequence	Gins Surveyed	Gins Sampled-2009	Gins Sampled-2010
Standard	22	2	2
Standard + Impact	8	1	4
Cylinder Cleaner + Standard	4	1	2
Standard + Cylinder Cleaner	2	1	0
Three Cylinder Cleaners	2	2	3
Standard + Additional Extractor-Feeder	2	1	1
Two Cylinder Cleaners	0	0	2

Surveyed gins had a wide variety of ginning rates and processing rates through the seed cotton cleaning equipment (table 2). The highest processing rates were observed through the horizontal airline cylinder cleaners used in some gins; however, manufacturers have recommended higher processing rates through these machines. The average processing rates through the first stage cylinder cleaner and stick machine were near the maximum recommended rate of 8.2 bale hr^{-1} m^{-1} (2.5 bale hr^{-1} ft^{-1}). The average processing rate at ten gins exceeded this recommended rate, although 21 gins were capable of exceeding the recommended rate when operating at rated capacity. Processing rates through the second stage cylinder cleaner and additional cleaners were lower, as some gins used wider equipment or additional machines, with as many as four second-stage cylinder cleaners. Processing rates through the extractor-feeders were typically much lower. If higher processing rates through previous equipment had a negative impact on cleaning efficiency, the lower rates through the extractor-feeders may compensate for this decreased efficiency.

Table 2. Ginning and processing rates at surveyed gins.

Rate		Average Rate			Maximum Rate		
		Mean	**Min**	**Max**	**Mean**	**Min**	**Max**
Ginning (bale/hr)		33.7	16	58	39.1	16	70
Processing (bale hr^{-1} m^{-1} [bale hr^{-1} ft^{-1}])	Horizontal airline cylinder cleaner	13.34 (4.07)	11.48 (3.50)	15.03 (4.58)	15.36 (4.68)	12.30 (3.75)	19.68 (6.00)
	1st stage cylinder cleaner	8.04 (2.45)	4.92 (1.50)	13.12 (4.00)	9.36 (2.85)	6.15 (1.88)	14.76 (4.50)
	Stick machine	8.04 (2.45)	4.92 (1.50)	13.12 (4.00)	9.32 (2.84)	5.90 (1.80)	14.76 (4.50)
	2nd stage cylinder cleaner	7.68 (2.34)	4.61 (1.41)	13.12 (4.00)	8.90 (2.71)	5.74 (1.75)	14.76 (4.50)
	Additional cleaner	7.26 (2.21)	4.10 (1.25)	11.07 (3.38)	8.31 (2.54)	4.92 (1.50)	13.94 (4.25)
	Extractor-feeder	4.61 (1.41)	2.56 (0.78)	7.52 (2.29)	5.34 (1.63)	3.14 (0.96)	8.47 (2.58)

2009 Samples

Gins sampled in 2009, included all equipment sequences observed in the survey. The calculated processing rates through the first stage cylinder cleaner at the sampled gins averaged 8.00 bale hr^{-1} m^{-1} (2.44 bale hr^{-1} ft^{-1}), with a range of 5.87-10.17 bale hr^{-1} m^{-1} (1.79-3.10 bale hr^{-1} ft^{-1}). The sampled gins exhibited the same trend as all surveyed gins, with a slight decrease in processing rates through the second stage cylinder cleaners and additional cleaners, and much lower processing rates through the extractor-feeders.

Foreign matter content was high at many gins in 2009 (table 3), likely due to the unfavorable weather conditions experienced during harvest. The total foreign matter and individual component content before and after seed cotton cleaning was significantly different, although the percentage of motes removed was small. Seed cotton cleaning equipment is not primarily designed to remove motes, as gin stands and lint cleaners typically remove most motes from the fiber. Significant variation existed between gins in both the foreign matter content of the incoming seed cotton and the seed cotton after cleaning. Likely causes of this variation included weather, cultivar, and the seed cotton cleaning machinery used. Variation in moisture content between gins was also significant.

Table 3. Seed cotton fractionation results- 2009.

Component	Module			Feeder Apron		
	Mean	**Min**	**Max**	**Mean**	**Min**	**Max**
	% by weight					
Clean seed cotton	90.86	86.60	93.32	94.46	92.05	96.20
Hulls	2.50	1.90	3.97	0.62	0.14	1.20
Sticks	0.44	0.26	0.87	0.25	0.11	0.37
Motes	3.52	2.21	5.70	3.06	2.03	4.92
Leaf	1.14	0.76	1.61	0.37	0.27	0.47
Pin trash	0.19	0.06	0.71	0.03	0.02	0.05
Total foreign matter	7.81	5.37	12.12	4.34	2.69	6.45
Moisture content (w.b.)	10.28	8.03	12.64	9.06	7.61	10.73

Cleaning efficiency for total foreign matter and individual components is shown in table 4. Differences between gins were significant for total and all component cleaning efficiencies, except for sticks and motes. Gins typically removed a large percentage of hulls, leaf, and pin trash, although the proportion varied widely between gins.

Table 4. Cleaning efficiency of gins- 2009.

Component	Mean	Min	Max
	—% by weight—		
Total	44	34	56
Hulls	75	57	93
Sticks	29	-2	59
Motes	12	-1	26
Leaf	65	51	74
Pin trash	72	56	93
All components except motes	69	54	84

The cleaning efficiency of individual machines is shown in table 5. Samples could not be collected at all locations at all gins, so the number of gins used to calculate the mean cleaning efficiency is shown. Efficiencies for the cylinder cleaners and stick machine are comparable to the results from previous laboratory studies. The negative value for the minimum cleaning efficiency shown for the second stage cylinder cleaner is likely a result of large variance of the samples and was not significantly different from zero. The gin sampled was only a significant effect in the model for the second stage cylinder cleaner efficiency. Only one gin was significantly different from the others, possibly resulting from a different arrangement of cleaning machinery preceding the second stage cylinder cleaner.

Table 5. Cleaning efficiency of individual machines- 2009.

Machine	Number of Gins	Mean (%)	Min (%)	Max (%)
1st stage cylinder cleaner	4	18	15	21
Stick machine	4	21	17	24
2nd stage cylinder cleaner	6	11	-6	18
Extractor-feeder	7	9	2	19

The only gins with an extractor-feeder cleaning efficiency significantly greater than zero were not operating stick machines when samples were collected; consequently, the extractor-feeder was the first extractor-type cleaner in the seed cotton cleaning machinery for these gins. However, the gin did not have a significant effect on the extractor-feeder cleaning efficiency. Cleaning efficiency was calculated for the additional cleaning machines installed after the standard equipment sequence– an impact cleaner, cylinder cleaner, or extractor-feeder. The effect of these machines on foreign matter content was not statistically significant. However, with limited data, conclusions should not be drawn about the utility of these additional machines.

The regression analyses indicated that the number of cleaning machines and initial foreign matter content of various components significantly affected the final foreign matter content of samples and the cleaning efficiency of the gins (table 6). For the feeder apron clean seed cotton content and cleaning efficiency, a positive estimate for a regressor indicated that higher values resulted in cleaner seed cotton. For the total and component foreign matter content, a positive estimate for an independent variable signified that higher levels yielded increased foreign matter content.

Both the clean seed cotton and total foreign matter content had high R^2 values. The number of seed cotton cleaners had a positive effect on foreign matter removal. Not surprisingly, lower initial foreign matter content also resulted in lower final foreign matter content. The initial mote content affected both the final clean seed cotton and total foreign matter content, while the initial stick content was a significant variable in the regression analysis for final clean seed cotton content. These two components were not removed efficiently by seed cotton cleaning equipment, so higher initial contents of these components tended to result in increased foreign matter or decreased clean seed cotton content at the feeder apron.

Table 6. Regression analyses for seed cotton component content at the feeder apron and cleaning efficiency- 2009.

Dependent Variable	R^2	Significant Variables	Estimate	*P*-value
Feeder apron clean seed cotton content	0.73	Extractors	0.88	<.0001
		Module mote content	-0.42	<.0001
		Cylinder cleaners	0.72	0.0023
		Module clean seed cotton content	0.16	0.0108
		Module stick content	-0.61	0.0724
Feeder apron hull content	0.36	Extractors	-0.40	<.0001
		Module pin trash content	0.64	<.0001
		Module hull content	0.11	0.0005
		Processing rate	-0.18	0.0160
Feeder apron stick content	0.06	Module stick content	0.19	0.0067
		Processing rate	-0.072	0.0822
Feeder apron mote content	0.79	Cylinder cleaners	-0.69	<.0001
		Module mote content	0.64	<.0001
		Extractors	-0.36	0.0029
Feeder apron leaf content	0.31	Module leaf content	0.096	<.0001
		Processing rate	-0.083	0.0002
		Extractors	-0.055	0.0025
		Cylinder cleaners	-0.073	0.0080
		Module stick content	0.069	0.0219
Feeder apron pin trash content	0.26	Cylinder cleaners	0.024	<.0001
		Extractors	0.0097	0.0007
		Module clean seed cotton content	-0.0018	0.0007
Feeder apron total foreign matter content	0.67	Extractors	-0.83	<.0001
		Module mote content	0.37	0.0005
		Module clean seed cotton content	-0.18	0.0012
		Cylinder cleaners	-0.63	0.0073
Cleaning efficiency	0.32	Extractors	0.077	0.0054
		Module pin trash content	0.12	0.0862

The only other regression model with a large R^2 explained the variation in final mote content. Higher initial mote contents resulted in higher final mote contents. Both types of cleaning machinery reduced the mote content, although the effect of cylinder-type cleaners was larger. While less of the variation in hulls, sticks, or leaf was explained by the regression models, additional cleaning machines tended to reduce the final content of the component and higher initial contents of the individual components were associated with increased final content. With pin trash, gins with additional cleaners had higher final contents. This result may be due to cleaning machinery breaking up larger foreign matter components, such as leaf and hulls, into pin trash. Alternatively, since final pin trash content was near zero at all gins, variability between samples may have caused the positive correlation between the number of cleaning machines and the final pin trash content.

Cleaning efficiency was only affected by the number of extractor-type cleaners used and the initial pin trash content. The initial pin trash content was likely a significant variable only because one gin with high cleaning efficiency processed cotton containing much more pin trash than the other gins. This relationship is likely coincidental, not causal.

This analysis did not find moisture content to have a significant effect on the cleaning efficiency or the content of any component of seed cotton at the feeder apron, unlike previous research (Anthony, 1990; Whitelock et al., 2007). One potential explanation for this result was that all gins processed cotton with high moisture content, although there was some variation in the actual moisture content. If additional data with lower moisture content cotton were included, moisture content may have been a significant effect. The unusually high moisture content in 2009, may have contributed to lower cleaning efficiencies than reported in past laboratory studies (Anthony, 1990; Anthony and Calhoun, 1997; Gillum and Armijo, 1997).

2010 Samples

Fractionation has been completed for five of the gins sampled in 2010 (table 7). Additional samples need to be analyzed before a valid statistical comparison can be made between the two seasons. However, foreign matter content in the module was lower than 2009, and the gins sampled removed more of the foreign matter. Weather generally remained warm and dry during the 2010 harvest.

Table 7. Seed cotton fractionation results- 2010.

Component	Module			Feeder Apron		
	Mean	Min	Max	Mean	Min	Max
	% by weight					
Clean seed cotton	92.47	91.44	93.76	96.58	95.92	97.63
Hulls	1.27	0.47	1.72	0.26	0.02	0.51
Sticks	0.49	0.41	0.62	0.20	0.07	0.30
Motes	2.34	1.64	2.83	1.58	1.08	2.01
Leaf	2.00	1.72	2.42	0.48	0.28	0.68
Pin trash	0.13	0.10	0.17	0.04	0.03	0.04
Total foreign matter	6.29	4.69	7.22	2.56	1.58	3.24
Moisture content (w.b.)	7.93	5.77	9.71	6.87	5.71	7.61

The cleaning efficiency of gins in 2010, is shown in table 8. The total cleaning efficiency was higher in 2010 than 2009; however, the removal efficiency of individual components was generally similar to 2009. While a slightly larger percentage of motes were removed in 2010, than in 2009, the mote cleaning efficiency was much lower in both years than the cleaning efficiency of other components. Because the initial mote content was much lower in 2010, the overall cleaning efficiency was much higher.

Table 8. Cleaning efficiency- 2010.

Component	Mean	Min	Max
	—% by weight—		
Total	59	52	72
Hulls	71	23	99
Sticks	53	5	87
Motes	32	21	38
Leaf	75	60	86
Pin trash	69	56	78
All components except motes	75	63	86

Conclusions

Most Mid-South gins had at least the recommended sequence of seed cotton cleaning equipment. Nearly half of these gins had an additional cleaner installed, either a horizontal airline cylinder cleaner as the first machine or a gravity-fed cleaner before the extractor-feeder. The average processing rate was near the maximum recommended rate and a number of gins were capable of exceeding this rate.

Seed cotton samples collected in 2009, indicated a much lower cleaning efficiency, 44%, than reported in the literature. The cleaning efficiencies of cylinder cleaners and stick machines were similar to values found by previous researchers. The incoming seed cotton had extremely high moisture content (10.28%) and mote content (3.52%). Because motes were not removed efficiently by seed cotton cleaning equipment, the initial mote content had a significant effect on the final foreign matter content. Other variables with a significant effect on the final foreign matter content were the initial clean seed cotton content and the number of cleaning machines. Moisture content did not have a significant effect on foreign matter content in 2009; however, all gins processed unusually wet cotton. Sampled gins had processing rates up to 10.17 bale hr^{-1} m^{-1} (3.10 bale hr^{-1} ft^{-1}); however, processing rate did not significantly affect cleaning efficiency or final foreign matter content.

Cleaning efficiency was much higher in 2010 (59%) and similar to previously reported efficiencies. Most components were removed with an efficiency similar to 2009, but the lower initial mote content resulted in an improved overall cleaning efficiency. Additional data from 2010, needs to be analyzed to make additional comparisons between the two seasons and draw conclusions regarding factors affecting cleaning efficiency in commercial gins.

The currently recommended sequence for seed cotton cleaning equipment in picker-harvested gins is a cylinder cleaner, stick machine, and cylinder cleaner. No changes to these recommendations can be made based on this data, although there may be situations in commercial gins where using additional or fewer cleaning machines would yield higher returns for producers. Additional analysis and research will be conducted to identify optimum machinery sequences for different scenarios.

Acknowledgements

The authors would like to thank the participating gins for their cooperation.

Disclaimer

Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the U.S. Department of Agriculture and does not imply approval of the product to the exclusion of others that may be available.

References

Anthony, W.S. 1990. Performance characteristics of cotton ginning machinery. Trans. ASAE 33(4):1089-1098.

Anthony, W.S. and D.S. Calhoun. 1997. Processing cotton cultivars with conventional gin machinery. Appl. Eng. in Agric. 13(5):565-576.

Baker, R.V., W.S. Anthony, and R.M. Sutton. 1994. Seed cotton cleaning and extracting. In Cotton Ginners Handbook, pp. 69-90. Agricultural Handbook 503. Washington, D.C.: USDA Agricultural Research Service.

Baker, R.V., P.A. Boving, and J.W. Laird. 1982. Effects of processing rate on the performance of seed cotton cleaning equipment. Trans. ASAE 25(1):187-192.

Cocke, J.B. 1972. Effect of processing rates and speeds of cylinder-type cleaners on ginning performance and cotton quality. ARS 42-199. Washington, D.C.: USDA Agricultural Research Service.

Columbus, E.P. and W.S. Anthony. 1991. Feasibility of substituting seed cotton cleaning for lint cleaning. Trans. ASAE 34(6):2340-2344.

Gillum, M.N. and C.B. Armijo. 1997. Pima seed cotton cleaning for maximum profit. Trans. ASAE 40(3):513-518.

Read, K.H. 1972. Cylinder cleaner speed influences cleaner efficiency. Cotton Gin and Oil Mill Press 72(24):6-7.

Shepherd, J.V. 1972. Standard procedures for foreign matter and moisture analytical tests used in cotton ginning research. Agriculture Handbook No. 422. Washington, D.C.: USDA Agricultural Research Service.

Whitelock, D.P., C.B. Armijo, G.R. Gamble, and S.E. Hughs. 2007. Survey of seed-cotton and lint cleaning equipment in U.S. roller gins. J. Cotton Sci. 11(3):128-140.