# FIBER BREAKAGE AT COTTON GINS: CAUSES AND SOLUTIONS

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**Abstract**

The causatives and potential solutions to fiber breakage at cotton gins was considered in eight studies which included both single fiber and bulk fiber evaluations. The following findings were the most important across the studies: 1) the force required to break the fiber averaged 1.8 times greater than the force to extract it from the seedcoat but this difference was non-linear and was less at low moisture and more at high moisture contents, 2) during field exposure, fiber breaking strength declines more rapidly than fiber separation force, 3) fiber exposure to temperature above 350 degrees F causes irreversible fiber damage, 4) the adverse effect of fiber exposure to temperatures less than 300 degrees F can be mitigated by the addition of moisture before ginning, 5) when fiber moisture increases one percentage point, fiber breakage decreases 0.5 percentage points, and 6) fiber breakage is much greater at 350 degrees F than at 300 degrees F, and 7) fiber length is reduced at a particular moisture content as drying temperature increases.

## Introduction

The principal historical function of cotton gins is the separation of fibers from their seeds. This is accomplished by applying a tensile force to the fiber so that it breaks free from the seedcoat. It is important to recognize that the individual fibers do not pull out of the seedcoat. Fryxell (1963) describes the base of the typical seed hair (fiber) as having an anvil shaped foot firmly held by the surface cells of the seed coat, and having a constricted shank between the foot and an elbow where the main body of the fiber begins. He describes this as a "weak place" and suggests that it is at this point that the fiber should rupture and be separated from its seed.

But all fibers do not rupture at the preferred location at the seed surface but may break somewhere along the main body axis so that, when the remaining portion of the fiber does separate at the seed surface, there are two or more short fiber fragments instead of a single long fiber. One of the causes of undesired breakage during fiber seed separation is prior fiber wall weakening as a result of microbial attack or, perhaps, from interruption of the growth process. Another cause of breakage is twists or loops that develop during fiber manipulation. When tensile forces are applied, shearing action may occur as the loop is stressed causing breakage with less force than that required for fiber seed separation. Still another type of breakage is that resulting from uneven distribution of force across a section of fiber. This situation arises when the edges of a fiber are not of equal length and this in turn is believed to be caused partly by fiber growth habit, and partly by fiber drying that results in molecular and fibrillar reorientation that produces fiber distortion. It is this latter type of fiber reorientation with ensuing breakage that is the subject of this report.

Smith and Pearson (1950) studied the separation force of 16 varieties of cotton in 1935 and 1936 using a pendulum-type tester. Their work showed that the strength of attachment of fibers (or fiber/seed separation force) on any given area of any particular seed varied from about 0.25 grams to about 5.5 grams.

Federow (1933) stated that "...we have discovered that on the average the strength by which the fibers are held to the seed-coat is about 45 to 50% of the breaking strength of a single fiber ...for American-type cotton, it averages about 45 to 60% of the strength of the individual fiber."

In studies relating to the effect of seed cotton moisture on the productivity of gins and on the quality of the fiber gave figures of from 1.51 to 2.11 grams representing the degree of fiber attachment for cottons of different moisture content, a ratio of only 1.4 to 1 (Sorkin, et al. 1941).

In working with single fibers from Uganda-grown cotton, Lord (1962) concluded that the upper end of the distribution of fiber removal forces overlaps appreciably the lower end of the distribution of fiber breaking loads.

## Purpose

These studies suggest a real need to further investigate the fiber/seed attachment force for cotton, which is the purpose of the studies in this report.

## Methodology, Results and Discussion

### Study 1--Experiment with Single Fibers

The first study determined the practicability of a laboratory-constructed, strain-gage force beam to examine the relative magnitudes of the forces required to separate individual fibers from their seeds and the forces required to break the fibers, or their tensile strength.

For this work, a 4-gage force beam was constructed using 120-ohm gages attached to a hack saw blade, with the electrical output of the force beam being fed directly to one channel of a recording light-beam oscillograph, figure 1.

The force beam was calibrated against Class S laboratory weights. Calibration checks were run before and after each test to ensure that the battery voltage remained constant and that recorder zero had not shifted. The stability of the measuring system was extremely good. The oscillograph galvanometer rest point was adjusted to compensate for the seed weight; and, as a single fiber was slowly pulled from its seed, the light beam traced a force pattern on the recorder chart.

Tests were made on 10 fibers from each of 10 seeds from each of 4 common cotton varieties: Acala 1517 C, Pima S-1, DPL-15, and DPL Smoothleaf. Each seed was prepared by combing and clipping the fibers so that a tuft was left at the chalazal end of the seed. The seed was held on the force beam in a plastic cup with the tuft of fibers protruding through a hole in the bottom of the cup. Each fiber tested was seized at least 1-inch from the seed surface, and after separation, each fiber was examined to determine whether it had broken at the seed surface or at some other point.

Occasionally an individual fiber would break in two without breaking at the seed surface. These fibers were discarded and others were pulled until 10 fibers had broken at the seed surface. After 10 fibers had been pulled from one seed, each fiber was attached to the force beam and pulled until it broke. Then another seed was tested until 10 seeds per variety had been used. Total tests per variety were 100 whole fiber/seed separations and 100 single-fiber breaks.

These data showed that the mean fiber/seed separation force was from 2.0 to 2.3 grams for the four varieties tested, and that the mean fiber breaking force, or tensile strength, was from 3.6 to 4.2 grams, table 1. Attention is called to the wide distribution of the data: Separation force data varied over a range of 1 to more than 5 grams, and tensile strength of individual fibers varied from 1.3 to 8.4 grams within the same variety; however, when the ratio of mean breaking force to mean separation force was calculated, the result was nearly constant at 1.8 for all varieties and agrees with the work

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 2:1347-1357 (2001)
National Cotton Council, Memphis TN

of Federow (1933). These data suggest that the inherent structure of the cotton fiber is such that the ginning process ought to remove the fibers from their seeds without breaking any of them.

**Study 2--Effect of Moisture on Breaking Strength**

The next study was designed to study the effect of moisture content on fiber breaking strength. Pre-conditioning the fibers and performing the tests in a constant humidity chamber controlled the moisture content of the fibers. The humidity levels and fiber moisture levels were controlled by saturated salt solutions; values assigned for relative humidity were those listed by the National Bureau of Standards (1951), and the fiber moistures were based on data developed by Hartshorne (1911). The fibers were preconditioned in the test atmosphere for 3 hours before testing to allow them to come to moisture equilibrium with the atmosphere.

Although the literature contains many references to the equilibrium moisture content of cotton, all of the available references were based on determinations made with cotton that had already been partially processed. None of the available data gave the moisture content of cotton directly from the field. Therefore, a moisture equilibrium experiment was conducted concurrently with the breaking strength work.

For this experiment several pounds of cotton were handpicked shortly after opening and before rain, and were allowed to dry in the laboratory at room conditions. Then the cotton was ginned, and the foreign matter was removed from the lint by processing it twice through the Shirley Analyzer.[2] Forty 1-gram specimens were prepared and divided into two batches of 20. One batch was preconditioned over a desiccant for 48 hours while the other was preconditioned over distilled water. Then four specimens from each batch were suspended over lithium chloride until they ceased to change weight. The remaining specimens were, in sets of 4, allowed to come to moisture equilibrium over magnesium chloride, magnesium nitrate, sodium chloride, and potassium nitrate. This procedure gave four determinations of equilibrium moisture content of raw cotton fibers at four relative humidities. ASTM Method D 2495 (1985) was used to determine the dry weight of each specimen. The results of these determinations are presented in table 2 and figure 2.

Two sets of 200 individual fibers were tested for breaking strength at each of the six moisture levels. Within expected variation, the breaking strength increased linearly from 3.1 grams at 3.6% moisture to 5.0 grams at 13.3%, table 3. These results are in agreement with those of Grant, et al. (1961).

The fiber-seed separation force at different moisture levels was also investigated, using the same conditioning and testing apparatus already described. Cottonseeds were prepared by combing and clipping to leave a tuft of fibers midway between the micropylar and chalazal ends of the seeds. The prepared seeds were preconditioned for 3 days in the test atmosphere before testing began. Two hundred fibers were pulled from each of 3 seeds at each moisture level.

Only fibers longer than 1-inch were tested. One fiber at a time was seized near its free end and gently pulled downward until it broke in two or separated from the seed. Testing of each seed continued until 200 fibers had been separated from the seed at the seed surface. These data showed that the number of fibers that broke in two instead of breaking at the seed surface was inversely related to fiber moisture. Testing at 3.6% moisture caused nearly 21% of the fibers to break, while testing at 12.7% moisture reduced fiber breakage to only 2.1%, table 4.

The separation force data contained an unexpected relationship. Instead of separation force being correlated with moisture content as was the breaking force, the separation force was found to be independent of fiber moisture content from 3.6 to 9.4% moisture by remaining constant at about 1.90 grams with a slight decrease to 1.73 grams at 11.8% moisture and a greater decrease to 1.21 grams at 12.7% moisture, table 4. The cause of the decline in separation force at the higher moistures was never explained, but it was suspected that the seed coat was beginning to soften and, perhaps, some of the fibers were pulling out instead of breaking at the seed surface.

When the breaking force data of table 3 and the separation force data of table 4 were plotted on the same graph, the greater spread between fiber breaking force and fiber/seed separation force at the higher moisture levels over that at lower moistures was obvious, figure 3. This means that inherent fiber length and length distribution would be better preserved by ginning at the higher moisture levels--but cotton gins cannot function satisfactorily on cotton with fiber moisture content that is much greater than 8 or 9%.

**Study 3--Wet Ginning**

A special experiment was devised to find out whether the advantages to length preservation suggested by the single fiber breaking force and separation force investigations could be realized when fiber-seed separation was carried out on a larger scale.

Two batches of cotton from the same stock were ginned using the very best saw ginning, loose-roll methodology, and a saturation moisture content technique. The saw ginned cotton was preconditioned to a fiber moisture content of about 8% and was ginned on a laboratory saw gin with no additional machinery except an extractor-feeder. The saturation moisture cotton was ginned on a specially designed saw cylinder that restrained the fibers while a high-pressure jet of water forced the seeds from the fibers (Griffin and McCaskill, 1969).

Three fiber-length arrays were made on lint ginned by each method. These showed that the water-saturated cotton produced lint with an upper quartile length of 1.45 inches and the 8.2% cotton produced lint with an upper quartile length of 1.36 inches, table 5. The length distributions showed that the 8.2% cotton produced more short fibers than did the saturated cotton; percentage of fibers shorter than 1/2-inch was 9.29 for the 8.2% moisture cotton and 6.30 for the saturated cotton. The difference is attributed to fiber breakage being almost entirely eliminated by forcing fiber-seed separation when the fibers were completely wetted and consequently at maximum strength.

**Study 4--Field Exposure**

Another source of broken fibers during ginning is field damage before harvest. This aspect of cotton production is important because present day cotton production practices require some delay after initial boll opening before harvesting begins. This results in a different harvest pattern than when the crop was handpicked at about the same rate as opening, and accounts for some of the decline in cotton quality in recent years.

An investigation was made into field damage by testing 300 fibers each week for fiber-seed separation force and then testing a random 10% of these fibers for tensile strength after removal from their seeds. One boll on each of 25 plants in the field was tagged at the beginning of dehiscence, and then a one-boll sample was collected at 7-day intervals for 154 days--from August 26 to January 27. One hundred fibers longer than 1-inch were tested from each of three seeds. The strength testing apparatus was the same as that shown in figure 1. The specimens to be tested were conditioned in the test chamber for 3 days immediately after being brought from the field. The test atmosphere was 75% RH at 80 degrees F, which resulted in an equilibrium fiber moisture content of about 9.4% (Hartshorne, 1911).

The data showed overall that both fiber-seed separation force and single fiber breaking strength declined with continued field exposure, and that fiber breaking strength declined more rapidly than separation force, table 6 and figure 4.

The difference in rates of change suggests that more fibers would break as the exposure period increased. This was indeed found to be the case when the percentage of fibers to break during fiber-seed separation was plotted against exposure period, figure 5.

These data imply that late-harvested cotton should gin with a slightly less energy requirement than early harvestings, but that impairment of staple length and spinning properties may be expected as a result of an increase in short fiber content caused by fiber breakage at ginning.

**Study 5--The Effect of Heat Drying on Fiber Breakage**

After completion of the studies of the effects of varieties, moisture content, and field exposure on fiber-seed separation force, tensile strength, and breakage rate, the constant humidity chamber was redesigned and a series of studies was begun with the objective of separating the effects of heat and moisture on fiber breakage.

The initial experiment in this series was conducted using a laboratory constructed, moving bed drier with which drying period could be varied. Drying air temperature was constant (± 5 degrees F of set point) from cotton entrance to exit. Thickness of the seed cotton on the bed was about 3-inches. Seed cotton was passed through the drier with 30-seconds exposure to air at ambient, 100, 150, 200, 250, 300, 350, 400, and 450 degrees F.

The data showed a tendency toward an increasing percentage of fibers to break as the temperature of the drying air increased, but the differences due to treatments were not significantly different at the 95% probability level. Reasons for failure to show significance between even the extreme treatments included: (1) the likelihood that the specimen cottonseed locks were not heated to the same extent due to differences in location within the 3-inch batt during drying; (2) not enough fibers were tested per treatment; (3) and, perhaps of greatest importance, combing fibers after drying probably broke more of the weaker ones and eliminated them from the experiment before the separation tests began.

The experiment was redesigned to test 100 fibers from each of 10 seeds per treatment and to comb and clip the seeds before the heat treatments. The exposure of the remaining fiber tufts to the heated air for 30 seconds ensured more uniform heating of the fibers tested. Heating was accomplished by means of an electric heat gun; the test temperatures were monitored with a thermocouple located in the hot air stream in the same plane with the seeds being treated. Target temperatures for the treatments were: 77, 122, 167, 212, 257, 302, 347, 392, 437, and 491 degrees F. Actual temperatures achieved were within ± 3 degrees F of the target temperatures.

Each seed tested was moisture conditioned for 48 hours in the 75% RH atmosphere before the fiber/seed separation phase of the experiment was conducted.

This experiment showed that the moisture adsorbed by the fibers after heating eliminated increases in fiber breakage due to 30-seconds heating at temperatures up to 212 degrees F, table 7 and figure 6. The trend of breakage to increase as temperature increased was stronger in the range 212-347 degrees F, with the breakage due to the 347 degrees F treatment being significantly greater than the breakage at 212 degrees F and below. Between 347 degrees and 392 degrees F, the breakage rate rose significantly and dramatically, and appeared to begin leveling at about 491 degrees F. Many of the fibers heated for 30-seconds at 347 degrees F, and above, were scorched. This experiment suggested that fiber damage resulting from 30-seconds exposure to temperatures of 347 degrees F, and over, cannot be nullified or compensated by allowing the fiber to regain moisture in 75% RH before fiber/seed separation occurs.

**Study 6--The Effect of Drying Exposure Period on Fiber Breakage**

The discovery of the apparently critical temperature of 347 degrees F led to the expansion of this line of investigation to include the drying exposure period as a variable. An experiment was planned using (1) an exposure period of 3-seconds with drying air temperatures of 347, 392, 437, and 482 degrees F, and, (2) an exposure period of 300-seconds with drying air at 77, 212, 257, 302, 347, and 392 degrees F. One treatment of 30-seconds' drying at 212 degrees F was included to establish whether the 3-seconds and 300-seconds data might be combined with the previous experiment's 30-seconds data.

The seed cotton used in the experiments was from the same stock that was used before, and the method of pre-drying, combing and clipping of seeds was also similar to that used before. Fourteen cottonseeds were prepared and treated at each temperature -time condition; 10 seeds were chosen at random for the fiber-seed separation tests. Preconditioning and single fiber pulling followed the same procedures as used for the 30-seconds exposure tests. One hundred fibers were tested from each seed to make 10 observations of 100 fibers each for each treatment condition.

The experimental lot that was heated for 30-seconds at 212 degrees F gave an almost identical fiber breakage rate as the earlier lot so treated--9.8- and 9.7%, respectively. The extreme similarity of results for identical treatments gave increased confidence that the 3-seconds and 300-seconds exposure data of the latter experiment could be combined with the earlier 30-seconds exposure data for analysis. The combined data are depicted in figure 7, and significant differences are tabulated in table 8.

The data showed that there were no statistically significant differences in fiber breakage rates among temperature treatments up to and including 302 degrees F provided the fibers were allowed to come to moisture equilibrium in 75% RH air before fiber/seed separation. Fiber moisture equilibrium with air at 75% RH is about 9.4% moisture. The specimens dried at 347 degrees F for 3- and 30-seconds gave similar results in that these treatments caused significantly more fibers to break than specimens that were dried at 212 degrees F, and below. Specimens heated at 347 degrees F for 300 seconds showed more fiber breakage than those heated at 302 degrees F. All drying air treatments at 212, 437, and 482 degrees F, whether for 300-, 30-, or 3-seconds, showed significantly more breakage than those lower than 212 degrees F--except for 347 degrees F for 300 seconds treatments--even though the specimens were equilibrated in 75% RH before fiber/seed separation.

The important conclusions drawn from these experiments were that (1) moisture restoration by adsorption in air at 75% RH prevented potential damage done by drying cotton fibers at temperatures up to 302 degrees F, (2) drying at 347 degrees F for as little as 3-seconds irreversibly damaged some of the fibers, (3) and that heating cotton fibers at 392 degrees F resulted in an unacceptable amount of fiber damage. For the ginning industry, this means that the upper operating temperature limit for drying system should not exceed 302 degrees F.

**Study 7--Reducing Fiber Breakage by Adsorbing Moisture**

The 1965 and 1966 work had showed that restoring moisture to about 9.1% moisture content to cottons that had been heat-dried at temperatures up to 302 degrees F would reduce fiber breakage. Immediately, the question arose "To what extent would adsorbing moisture to other levels protect fibers against breakage after heat drying?"

To study this problem, a gas-fired drier with a screen wire-sliding drawer was constructed. The gas input was regulated to give a stable temperature, at which time the screen drawer containing the test specimens was slipped into the hot air stream and withdrawn after 30 seconds exposure. The drier is shown in figure 8. The single fiber testing procedure was the same as for previous experiments.

Drying air temperatures used were targeted as ambient, 122, 212, 302, 392, and 482 degrees F. Actual temperatures recorded were 70, 120, 217, 304, 390, and 495 degrees F. These are sufficiently close to the target temperatures that the latter are used in this report. Forty-eight seeds were combed, clipped, and heated for 30-seconds at each of the temperatures. After heating, each batch of 48 was sealed in glass to await conditioning and testing. Ten seeds from each drying treatment were tested at each of 4 relative humidities after 48-hour preconditioning. One hundred fibers were tested singly from each seed. The entire experiment required testing 24,000 (100 x 10 x 6 x 4) individual fibers. Specimens used were from the same stock of Stoneville 213 variety, handpicked in 1965 and used for the 1965 and 1966 experiments.

Instead of using published data to assume fiber moisture content at the four test atmospheres, an auxiliary experiment was planned to establish more accurate moisture equilibrium moisture content values to use in assessing the effect of temperature treatment on fiber breakage. The hypothesis tested was "When similar cotton are heated for equal periods at different temperatures, their equilibrium moisture regains after 48 hours will be different because the higher temperature treatments will depress the equilibrium moisture content values."

The hypothesis was tested by heating 5-gram specimens of lint for 30 seconds in air at 212, 302, 392, and 482 degrees F and then allowing them to approach moisture equilibrium for 48 hours at relative humidities of 23, 44, 64, and 80%.

Sixteen specimens were required for the experiment. They were preconditioned at 75% RH for 48 hours before being heat dried in the same laboratory-built drier used for heating the fiber breakage specimens. Temperatures achieved during heating were within ± 5 degrees F of the target temperature.

After each lint specimen had been heated, it was subdivided into 10 portions, which were placed in the controlled RH chamber for 48 hours. One chamber was set up for each humidity condition using saturated salt solutions selected from a list compiled by a commercial instrument manufacturer (Anonymous).

Moisture contents were determined by a modification of ASTM Method D 2495 "Method of Test for Moisture in Cotton (Oven-Drying Method)" (Hartshorne, 1911). Glass weighing bottles were used and drying time was 16 hours (overnight) instead of 8 hours.

When the moisture data were analyzed, each temperature treatment was found to produce statistically significant differences in equilibrium moisture contents, table 9. When the data were plotted, the moisture content values for the 212 degrees and 302 degrees F treatments at 80% RH were adjusted slightly to conform with the other data points, figure 9.

These data showed that the hypothesis concerning the inverse relationship between drying air temperature and subsequent equilibrium fiber moisture content was true, and the average amount of depression was found to be 0.0097% per degree Fahrenheit for temperatures higher than 212 degrees F. The difference in moisture content due to heating is considered great enough to be of importance in analyzing single-fiber breakage; that is, changes in breakage rate due to heat treatments might actually be due to changes in equilibrium moisture regain. The results of the single-fiber breakage rate test and the moisture contents established by the special experiment just described are shown in table 10.

Linear regression coefficients for fiber breakage on fiber moisture content were calculated using the least squares method for each temperature treatment. With the exception of the 392 degrees F treatment, they were all within .01 confidence limits of the mean regression coefficient b = -0.502 percentage points broken fibers per moisture content percentage point.

This is interpreted to mean that, for every percentage point increase in fiber moisture content, the fiber breakage rate may be expected to decrease by 0.5 percentage points. For cotton gin operation this argues for minimum drying in order to best maintain inherent fiber length distribution.

Fiber breakage rates at selected moisture contents were calculated by using the general regression equation

$$Y = y + b (X-x)$$

where
- Y = calculated breakage rate, in percent,
- y = observed mean breakage rate for a specific temperature treatment, in percent,
- X = selected moisture content, in percent,
- x = observed mean moisture content for a specific temperature treatment, in percent.

Breakage rates were calculated for each temperature treatment at moisture levels of 3.8, 4.8, 5.7, 6.5, 7.4, 8.2 and 9.1%, and are presented as table 11. Some of these data, with 95% confidence limits, are shown as figure 10. These data showed that breakage rates for fiber heated for 30 seconds at 122 and 212 degrees F were not significantly different from the breakage rate of unheated fibers when the breakage rates were considered at similar moisture levels. But for treatment temperatures of 302 degrees F and above, fiber breakage rates were significantly greater than for unheated fibers at similar moisture contents.

The data also showed that the breakage rates for heat treatments 212 degrees F and 302 degrees F were statistically similar. Perhaps the most important observation concerning these data was that fiber breakage rates for heat treatments 392 degrees F and higher caused significantly more fiber breakage than the 212 and 302 degrees F treatments. This is interpreted to mean that 302 degrees F is the highest temperature to which cotton should be subjected in gin drying systems. It must be emphasized that the temperature listed here should be regarded as the maximum temperature even under the most adverse conditions. Normal operating temperatures should be the lowest temperatures that will provide smooth gin operation and produce cotton at the gin stand in the 6-8 1/2% fiber moisture range.

**Study 8--Heating and Moisture Restoration in Actual Ginning Operations**

The final step of the project was to compare the results of heating and moisture restoration in a real ginning situation with the results obtained from the single-fiber breakage tests. This experiment was designed as a 4 x 5 factorial using drying air temperatures of 70, 150, 250, 350 and 450 degrees F, and allowing the heat-treated cottons to come to moisture equilibrium in relative humidities of 21, 48, 64, and 86% before ginning. The humidities were selected to provide fiber moisture contents in approximately equal steps from about 3.4% to about 8.3%.

The heating and drying phase of the experiment was carried out in the full-scale commercial-type research gin where the cotton was processed through two 24-shelf tower driers with the air-cotton mixpoint under manual temperature control. Actual mixpoint temperatures achieved were 70, 150, 250, 360 and 420 degrees F with a tolerance of ±5 degrees F. In commercial gins a temperature gradient exists from the drying system entrance to the exit. In our experiment the exhaust air was never above 135 degrees F, and exposure period of cotton in the driers varied from about 9.5

to 13 seconds with an average of about 11 seconds. Thus the cotton was exposed to the mixpoint temperatures for probably not more than 3 seconds.

Three hundred pounds of seed cotton was processed through the driers at each temperature. Four 30-pound batches were collected from each 300-pound lot after heating and drying; these were stored in sealed aluminum containers to await moisture conditioning and ginning.

The moisture absorption and ginning phases of the study were conducted in the controlled atmosphere research facility (Anthony and McCaskill, 1972). Five 30-pound batches (one from each of the five heating-drying treatments) were conditioned simultaneously for 18-20 hours in the controlled humidity gin and were ginned using only an extractor-feeder and 20-saw gin stand. This treatment was applied four times using room humidities of 21, 48, 64, and 86% at ambient temperatures. Samples of the ginned lint were collected for moisture content and fiber tests.

The moisture content data showed the characteristic depression of equilibrium moisture content, but to a slightly lesser extent than when heat was applied for 30 seconds, table 12. The fiber tests of interest were the span lengths as determined by the Digital Fibrograph method (ASTM 1980). These measurements were made at the U.S. Cotton Quality Laboratory at Knoxville, Tennessee, according to a double precision scheme, which required two tests of three determinations each. The data were initially analyzed using an analysis of variance program composed of temperatures, relative humidities, tests, observations and their combinations plus an error term with 24 degrees of freedom. F tests showed that both 2.5- and 50% span length measurements contained differences at the .01 confidence level due to temperature treatments and to humidities. These data are presented with their treatment identifications in table 12.

Inspection of the span length data reveals an obvious grouping of the data: span lengths for temperature treatments 70, 150, and 250 degrees F are more nearly alike than those for temperature treatments 360 and 420 degrees F. The data for these groups were combined for linear regression analysis. The regression coefficients were found to be similar at a very high confidence level and were, therefore, combined into a single regression coefficient of b = +0.0043 inch per percentage point moisture content.

This regression coefficient was then used to plot the grouped data with 95% confidence limits as shown in figure 11. At this point the effect of temperature on fiber length at similar moisture levels becomes apparent.

The effect of temperature on length was further pursued by adjusting each of the original span lengths (table 12) to span lengths at the average moisture content for each relative humidity regain treatment. In this manner comparisons were made at four moisture levels for the effect of temperature on span length. These data showed that, at moistures less than 7%, nearly always there was a significant difference in span length between the 70 degrees F treatment and the 360 or 420 degrees F treatment, table 13.

When the moisture content groups were combined to consider the overall effect of temperature on fiber length, the evidence is more convincing, table 14. This arrangement of the data showed more strongly the break in length between the 250 and 360 degrees F treatments.

The gin drying experiment provided new evidence to support the recommendation that gin-drying systems should operate under automatic temperature control with a maximum temperature set point of 300 degrees F, and under no circumstances should drying system temperatures exceed 350 degrees F.

This experiment did not show the irreversible fiber damage effect caused by high drying temperatures that was found in the 30-seconds heating single fiber experiments. This, perhaps, was due to the relatively short exposure period, and the likelihood that the temperature of the interior portions of the seed cotton locks did not reach the maximum temperature of the drying air.

The experiment showed that fiber length will be preserved to varying degrees depending upon the amount of moisture adsorbed before ginning, and that, to maintain a specified fiber length after ginning, cotton dried at higher temperatures will require more moisture addition than cottons dried at lower temperatures. For example, referring to figure 11, cotton dried at 250 degrees F, or below, and ginned at 6% moisture would produce fiber with a 2.5-% span length of 1.15 inches; but to produce ginned lint with that same span length, cotton dried at over 360 degrees F would require moisture restoration to about 9%. In the absence of moisture restoration systems in gins, cottons dried at higher temperatures will be shorter than comparable cotton dried at relatively low temperatures because of both moisture content and temperature effects.

## Summary and Conclusions

Several experiments involving tests on single fibers and of fibers en masse were conducted to better understand the nature and causes of fiber damage at cotton gins.

Investigations were made into the amount of force required to separate individual fibers from their seeds, the amount of force required to break single cotton fibers, and the effect of heat and moisture treatments on those parameters. Additional investigations were made using conventional cotton ginning machinery to study the effect of drying air temperature and moisture adsorption before ginning on equilibrium fiber moisture content and the amount of fiber breakage during ginning. In these experiments changes in 2.5% span length were considered to be indicative of fiber breakage. One of the more novel experiments required the construction of a hydraulic gin and the separation of fibers and seeds at saturation moisture content.

The experiments accomplished their purposes and led to the following conclusions:

(1) Data from the four varieties of cotton tested for breaking strength and separation force contained wide variations. The separation force varied over a range of from 1 to more than 5 grams, and the tensile strength of individual fibers varied from 1.3 to 8.4 grams within the same variety. When the mean breaking force was divided by the mean separation force, the quotient was nearly constant at 1.8 for all the varieties. This led to the conclusion that the inherent structure of the cotton fiber is such that the ginning process should remove all the fibers from their seeds without breaking any of them.

(2) Experiments with single fibers being pulled from their seeds at different moisture levels showed a continuing increase in the number of fibers that broke short as the moisture content was decreased. These tests also showed that, even though fiber tensile strength increased with increasing fiber moisture content, the fiber/seed separation force remained constant as fiber moisture increased and actually showed a slight decline at moistures in the 13-15% range. These data indicated that inherent fiber length properties are best maintained by performing the fiber/seed separation at the highest practicable moisture content. For example, ginning at 8% fiber moisture will give better length properties than ginning at 6 or 4% fiber moisture. These data also suggest that the addition of moisture to dry cotton, regardless of whether it were gin dried or harvested during low humidity periods, will improve its length properties.

(3) A wet ginning experiment whereby the fibers were removed with high pressure water confirmed the conclusion that ginning at the highest moisture content possible would give maximum fiber length protection, the reason being that the fibers were at maximum breaking strength while the force required for fiber/seed separation remained at a low level.
(4) Experiments designed to show the effect of field exposure on fiber breakage during ginning showed that prolonged exposure in the field caused the single fiber breaking force to decline at a greater rate than fiber/seed separation force. This means that delayed harvesting will result in producing ginned lint with inferior length properties when compared to cotton harvested on a timelier schedule.
(5) Carefully controlled experiments to relate single fiber breakage to drying air temperature showed no change in fiber breakage due to drying at temperatures 70 degrees F to about 212 degrees F, then a slight increase in the breakage rate as treatment temperatures increased to the 300-350 degrees F range, and an intolerable increase in the breakage rate when the drying air temperature was increased to 400 degrees F and higher.
(6) A final series of experiments was performed to determine the extent to which moisture restoration before ginning might overcome the potential fiber length shortening caused by high temperature drying. These investigations confirmed that drying temperatures of about 350 degrees F and higher, are more critical with respect to fiber length preservation than temperatures up to 250 degrees F. The experiments showed that moisture restoration before ginning would improve the fiber length of cottons dried in gin drying systems, but that more moisture was required to maintain a specified 2.5% span length for cotton dried at 360 degrees F, and above, than for cotton dried at 250 degrees F, or below.
(7) These experiments showed that there is a temperature effect, as well as a moisture content effect, that influences the length of cotton ginned at a particular moisture content. The length of lint ginned at a particular moisture content tends to decrease as drying air temperature is increased.
(8) The effects of drying air temperatures in the 250-350 degrees F range were not so well defined as the effects at both higher and lower temperatures.

## Recommendations

As a result of the experiments reported here and the conclusions drawn from them, it is recommended to the U.S. cotton ginning industry:

(1) Gin drying systems should be equipped with automatic controls that will limit temperatures at the air-cotton mixpoints to a maximum of 300 degrees F,
(2) Gin drying systems should be operated at temperatures to produce cotton at the gin stand with fiber moisture content in the 6 1/2 - 8% range, and
(3) Moisture should be applied to dry cotton to raise the fiber moisture level into the 6 1/2 - 8% range before fiber/seed separation.

## Disclaimer

Mention of a trade name, proprietary product, or specific machinery 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.

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Table 1. Separation and breaking force data for individual cotton fibers, experiment 61-29-501[1]

| Item | Cotton Variety: DPL Smoothleaf | DPL 15 | Pima S-1 | Acala 1517C |
|---|---|---|---|---|
| Fibers tested,---- -------no. | 109 | 122 | 116 | 113 |
| Fibers broken on seed,---no. | 9 | 22 | 16 | 13 |
| Rate of breakage, -------pct. | 8.2 | 18.0 | 13.8 | 11.5 |
| Mean separation force,----g. | 2.0 | 2.1 | 2.2 | 2.3 |
| Separation force range,---g. | 1.0-4.2 | 1.0-3.7 | 1.0-5.3 | 1.0-4.2 |
| Mean breaking force,------g. | 3.6 | 3.8 | 4.2 | 4.1 |
| Breaking force range,-----g. | 1.6-7.1 | 1.3-8.4 | 1.3-7.7 | 1.5-8.3 |
| MBF/MSF[2], ratio | 1.8 | 1.8 | 1.9 | 1.8 |
| MSF/MBF[2], ratio | .56 | .55 | .52 | .56 |

[1]Ambient room conditions; fiber moisture content estimated at 6-7%.
[2]MBF = mean breaking force
MSF = mean separation force

Table 2. Equilibrium moisture content of raw lint cotton as a function of relative humidity at 70 degrees F, experiment 64-42-11

| Preconditioning | Replication | Relative humidity: 12% | 33% | 54% | 75% | 93% |
|---|---|---|---|---|---|---|
| | | Moisture content wet basis, % | | | | |
| Over desiccant | 1 | 2.28 | 4.21 | 5.83 | 8.02 | 12.99 |
| | 2 | 2.32 | 4.22 | 5.84 | 8.08 | 13.19 |
| | 3 | 2.33 | 4.28 | 5.88 | 8.11 | 13.26 |
| | 4 | 2.43 | 4.32 | 5.91 | 8.38 | 13.32 |
| | Average | 2.34 | 4.26 | 5.86 | 8.15 | 13.19 |
| Over water | 1 | 2.93* | 5.51 | 7.29 | 9.49 | 13.88 |
| | 2 | 3.52 | 5.82 | 7.39 | 9.55 | 13.90 |
| | 3 | 3.62 | 6.01 | 7.59 | 9.62 | 14.02 |
| | 4 | 4.71* | 6.51 | 7.62 | 9.63 | 14.30 |
| | Average | 3.57 | 5.96 | 7.47 | 9.57 | 14.02 |
| Pooled data | Average | 2.96 | 5.11 | 6.66 | 8.86 | 13.60 |

*Discarded lowest and highest values.

Table 3. The effect of moisture content on breaking strength in grams of individual fibers[1]

| Test group | Moisture content, %: 3.6 | 4.9 | 6.5 | 10.0 | 11.7 | 13.3 |
|---|---|---|---|---|---|---|
| A | 3.1 | 3.8 | 3.6 | 3.8 | 4.8 | 4.9 |
| B | 3.1 | 3.4 | 3.4 | 4.1 | 4.8 | 5.1 |
| Combined | 3.1 | 3.6 | 3.5 | 4.0 | 4.8 | 5.0 |

[1]Each datum in groups A and B is the average of 200 observations; variety Auburn 56.

Table 4. The effect of relative humidity and fiber moisture content on fiber breakage and fiber/seed separation force, experiment 62-90-30[1]

| Item | Relative humidity, %: 20 | 36 | 52 | 75 | 88 | 92 |
|---|---|---|---|---|---|---|
| Fiber moisture content, % | 3.6 | 4.8 | 6.4 | 9.4 | 11.8 | 12.7 |
| Broken fibers, % | | | | | | |
| Replication A | 19.4 | 14.2 | 10.7 | 7.8 | 6.1 | 2.0 |
| Replication B | 20.3 | 14.5 | 9.5 | 8.3 | 5.7 | 2.4 |
| Replication C | 22.2 | 14.2 | 10.3 | 8.3 | 6.1 | 2.0 |
| Combined | 20.6 | 14.3 | 10.2 | 8.1 | 6.0 | 2.1 |
| Separation force, grams | | | | | | |
| Replication A | 2.05 | 1.86 | 1.76 | 1.99 | 1.88 | 1.12 |
| Replication B | 1.86 | 2.14 | 1.94 | 2.02 | 1.69 | 1.21 |
| Replication C | 1.75 | 1.67 | 2.02 | 1.92 | 1.63 | 1.29 |
| Combined | 1.89 | 1.89 | 1.91 | 1.98 | 1.73 | 1.21 |

[1]Each replicate value is the mean of 200 fibers tested.

Table 5. Fiber array data showing the effect of fiber-seed separation at conventional moisture content and at saturation, experiment number 62-27-101[1]

| Length group[2] (inches) | Proportion of cotton ginned at moisture content of: 8.2% (%) | Saturation (%) |
|---|---|---|
| 1/16 | 1.23 | 0.96 |
| 3/16 | 2.29 | 1.47 |
| 5/16 | 2.87 | 2.01 |
| 7/16 | 2.90 | 1.88 |
| 9/16 | 2.81 | 2.32 |
| 11/16 | 4.44 | 3.55 |
| 13/16 | 5.99 | 4.42 |
| 15/16 | 9.78 | 6.38 |
| 17/16 | 10.28 | 7.71 |
| 19/16 | 10.74 | 8.92 |
| 21/16 | 24.46 | 21.37 |
| 23/16 | 17.30 | 23.91 |
| 25/16 | 4.91 | 12.50 |
| 27/16 | 0.00 | 2.60 |
| Total | 100.00 | 100.00 |

[1]Each value is the average of 3 determinations.
[2]Cotton fibers are arranged according to length at 1/8-inch intervals.

Table 6. The effect of field exposure on fiber-seed separation force, single fiber strength, and fiber breakage rate, experiment number 63-29-32[1]

| Field exposure (days) | Separation force (grams) | Tensile break force (grams) | Broken fibers (%) |
|---|---|---|---|
| 0 | 1.74 | 5.05 | 3.0 |
| 7 | 1.83 | 4.67 | 5.7 |
| 14 | 1.61 | 5.98 | 3.8 |
| 21 | 1.76 | 5.36 | 5.0 |
| 28 | 2.03 | 5.91 | 4.5 |
| 35 | 1.94 | 4.37 | 6.0 |
| 42 | 1.80 | 4.39 | 5.4 |
| 49 | 1.26 | 4.17 | 5.4 |
| 56 | 1.50 | 4.20 | 7.1 |
| 63 | 1.45 | 3.68 | 7.1 |
| 70 | 1.30 | 3.90 | 7.6 |
| 77 | 1.58 | 4.38 | 6.2 |
| 84 | 1.65 | 4.53 | 8.2 |
| 91 | 1.86 | 4.62 | 8.2 |
| 98 | 1.40 | 3.66 | 7.2 |
| 105 | 1.47 | 4.12 | 6.2 |
| 112 | 1.17 | 2.91 | 8.2 |
| 119 | 1.31 | 4.35 | 8.8 |
| 126 | 1.09 | 3.76 | 8.2 |
| 147 | 1.05 | 3.01 | 9.6 |
| 154 | 0.81 | 3.21 | 10.7 |

[1]Separation force data is the mean value of 300 fibers tested. Tensile break force data is the mean value of 30 fibers tested.

Table 7. The effect of 30-seconds heating at temperatures 77 - 482 degrees F on the percentage of fibers to break during fiber-seed separation[1]

| Treatment temperature (degrees fahrenheit) | Broken fibers (%) | 95-% confidence limits (%) |
|---|---|---|
| 77 | 9.4 | 7.4 – 11.4 |
| 122 | 9.0 | 7.0 – 11.0 |
| 167 | 10.0 | 8.0 – 12.0 |
| 212 | 9.7 | 7.7 – 11.7 |
| 257 | 11.9 | 9.9 – 13.9 |
| 302 | 12.5 | 10.5 – 14.5 |
| 347 | 14.2 | 12.2 – 16.2 |
| 392 | 27.5 | 24.5 – 30.5 |
| 437 | 32.0 | 29.0 – 35.0 |
| 482 | 32.4 | 29.4 – 35.4 |

[1]N = 1000. One hundred fibers pulled from each of 10 seeds per treatment.

Table 8. Table of significant differences at the 95- and 99% probability levels for rates of fiber breakage in percent due to heating treatments, experiments 65-42-82 and 66-42-82[1]

| Temp/ time[1] | Fiber breakage, % | Temperature/time for [1,2] Fiber breakage, %, of | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 302/30 | 347/30 | 347/3 | 347/300 | 437/3 | 392/3 | 482/3 | 392/300 | 392/30 | 437/30 | 482/30 |
| | | 12.5 | 14.2 | 14.5 | 17.1 | 18.2 | 18.3 | 19.1 | 23.6 | 27.5 | 32.0 | 32.4 |
| 122/30 | 9.0 | 0 | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** |
| 77/30 | 9.4 | NS | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** |
| 212/30 | 9.7 | NS | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** |
| 77/300 | 9.7 | NS | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** |
| 167/30 | 10.0 | NS | 0 | ** | ** | ** | ** | ** | ** | ** | ** | ** |
| 212/300 | 10.2 | NS | 0 | 0 | ** | ** | ** | ** | ** | ** | ** | ** |
| 257/300 | 11.4 | NS | NS | NS | ** | ** | ** | ** | ** | ** | ** | ** |
| 257/30 | 11.9 | NS | NS | NS | ** | ** | ** | ** | ** | ** | ** | ** |
| 302/300 | 12.3 | NS | NS | NS | ** | ** | ** | ** | ** | ** | ** | ** |
| 302/30 | 12.5 | - | NS | NS | ** | ** | ** | ** | ** | ** | ** | ** |
| 347/30 | 14.2 | | - | NS | NS | 0 | 0 | ** | ** | ** | ** | ** |
| 347/3 | 14.5 | | | - | NS | 0 | 0 | ** | ** | ** | ** | ** |
| 347/300 | 17.1 | | | | - | NS | NS | NS | ** | ** | ** | ** |
| 437/3 | 18.2 | | | | | - | NS | NS | ** | ** | ** | ** |
| 392/3 | 18.3 | | | | | | - | NS | ** | ** | ** | ** |
| 482/3 | 19.1 | | | | | | | - | ** | ** | ** | ** |
| 392/300 | 23.6 | | | | | | | | - | 0 | ** | ** |
| 437/30 | 32.0 | | | | | | | | | - | ** | ** |
| 482/30 | 32.4 | | | | | | | | | | - | NS |

[1]Temperature is degrees F and time is seconds, i.e. 122/30 is read as heating at 122 degrees F for 30-seconds.
[2]Temperature/time values of 77/300, 167/30, 212/300, 257/30 and 302/300 at fiber breakage levels of 9.7, 10.0, 10.2, 11.4, 11.9 and 12.3 were not significant at the 5% level of probability.
NS = Not significant at 95% probability level.
* = Significant at 95% probability level.
** = Significant at 99% probability level.

Table 9. Equilibrium moisture content of raw cotton fibers treated by exposure to heated air for 30 seconds, experiment 68-42-85[1]

| Relative humidity (%) | Air temperature, degrees Fahrenheit | | | |
|---|---|---|---|---|
| | 212 (%) | 302 (%) | 392 (%) | 482 (%) |
| 23 | 4.01a | 3.74b | 3.51c | 3.16d |
| 44 | 5.61a | 5.33b | 5.09c | 4.69d |
| 64 | 7.22a | 7.01b | 6.70c | 6.44d |
| 80 | 9.27a | 9.26a | 8.79b | 8.60b |

[1]Moisture content attained after 48 hours equilibration. Values on the same line followed by different letters are different at the .01 significance level.

Table 10. The effect of heated air treatment on subsequent equilibrium fiber moisture regain and single fiber breakage at four relative humidities, experiment 67 69-42-85[1]

| | 23% RH | | 44% RH | | 64% RH | | 80% RH | |
|---|---|---|---|---|---|---|---|---|
| Air temperature[2] (°F) | Content (%) | Breakage (%) | Content (%) | Breakage (%) | Content (%) | Breakage (%) | Content (%) | Breakage (%) |
| 68 | 4.0 | 12.8 | 5.5 | 9.9 | 7.4 | 9.9 | 9.4 | 8.7 |
| 122 | 3.9 | 12.8 | 5.4 | 10.4 | 7.1 | 10.2 | 8.9 | 10.1 |
| 212 | 3.8 | 13.9 | 5.3 | 11.5 | 6.7 | 11.1 | 8.6 | 11.2 |
| 302 | 3.5 | 15.1 | 5.0 | 14.2 | 6.5 | 13.3 | 8.3 | 12.4 |
| 392 | 3.4 | 18.4 | 4.9 | 18.5 | 6.3 | 16.6 | 8.1 | 13.0 |
| 482 | 3.1 | 25.1 | 4.5 | 22.3 | 6.0 | 22.7 | 7.9 | 21.3 |

[1]Content data are means of 10 observations. Fiber breakage data are means from 10 replications of 100 fibers each.
[2]Test specimens were heated for 30 seconds at the temperatures listed.

Table 11. The effect of heated air treatment on single fiber breakage rate after moisture absorption[1]

| Air temperatures[2] (°F) | Fiber breakage, %, at moisture content, % | | | | | | |
|---|---|---|---|---|---|---|---|
| | 3.8 (%) | 4.8 (%) | 5.7 (%) | 6.5 (%) | 7.4 (%) | 8.3 (%) | 9.1 (%) |
| 68 | 11.9a | 11.4a | 10.9a | 10.4a | 9.9a | 9.4a | 8.9a |
| 122 | 12.2a | 11.7a | 11.2a | 10.7a | 10.2a | 9.7a | 9.2a |
| 212 | 13.2ab | 12.7a | 12.2a | 11.7a | 11.2ab | 10.7ab | 10.2ab |
| 302 | 14.9b | 14.4b | 13.9b | 13.4b | 12.9b | 12.4b | 11.9b |
| 392 | 17.6c | 17.1c | 16.6c | 16.1c | 15.6c | 15.1c | 14.6b |
| 482 | 23.7d | 23.2d | 22.7d | 22.2d | 21.7d | 21.2d | 20.7c |

[1]Each entry was calculated from the regression equation Y = y + b (X - x) using the data of table 10.
Entries in the same column followed by different letters are significantly different at the 0.5 confidence level.
[2]Test specimens were heated for 30 seconds at the temperatures listed.

Table 12. The effect of gin drying and subsequent moisture adsorption by seed cotton on fiber moisture content and span length of ginned lint, experiment 71-40-1[1]

| Moisture absorption conditions (RH, %) | Drier temperature (°F) | Moisture content (%) | 2.5% span length (inches) | 50% span length (inches) |
|---|---|---|---|---|
| 21 | 70 | 3.26 | 1.147 | 0.513 |
| 21 | 150 | 3.18 | 1.133 | .508 |
| 21 | 250 | 3.09 | 1.140 | .508 |
| 21 | 360 | 2.98 | 1.130 | .505 |
| 21 | 420 | 2.87 | 1.118 | .487 |
| 48 | 70 | 6.19 | 1.153 | .520 |
| 48 | 150 | 5.90 | 1.150 | .517 |
| 48 | 250 | 5.54 | 1.145 | .512 |
| 48 | 360 | 5.15 | 1.132 | .503 |
| 48 | 420 | 4.92 | 1.135 | .502 |
| 64 | 70 | 7.48 | 1.165 | .537 |
| 64 | 150 | 6.62 | 1.153 | .522 |
| 64 | 250 | 6.32 | 1.145 | .525 |
| 64 | 360 | 6.26 | 1.133 | .513 |
| 64 | 420 | 6.11 | 1.137 | .502 |
| 86 | 70 | 9.41 | 1.163 | .537 |
| 86 | 150 | 9.36 | 1.162 | .537 |
| 86 | 250 | 9.05 | 1.162 | .542 |
| 86 | 360 | 8.77 | 1.152 | .530 |
| 86 | 420 | 8.73 | 1.152 | .530 |

[1]Drying air temperature was measured at cotton-air mixpoint in each of two commercial-type tower driers. Moisture content determinations were made as directed in ASTM Method D2495, modified. Span length determinations were made as directed in ASTM Method D1447.

Table 13. The effect of gin drying at five temperatures on 2.5- and 50% span length, experiment 71-40-1[1]

| | **2.5-% span length[2] Fiber moisture content, %** | | | | **50-% span length[2] Fiber moisture content, %** | | | |
|---|---|---|---|---|---|---|---|---|
| **Drying air temperature (°F)** | **3.08 (inches)** | **5.54 (inches)** | **6.56 (inches)** | **9.06 (inches)** | **3.08 (inch)** | **5.54 (inch)** | **6.56 (inch)** | **9.06 (inch)** |
| 70 | 1.146a | 1.150a | 1.161a | 1.161a | 0.512a | 0.517a | 0.533a | 0.535a |
| 150 | 1.133ac | 1.148ab | 1.153ab | 1.161a | .507a | .515a | .522ab | .536a |
| 250 | 1.140ab | 1.145ab | 1.146bc | 1.162a | .508a | .512a | .526ab | .542a |
| 360 | 1.130bc | 1.134b | 1.134c | 1.153a | .505a | .505a | .514b | .531a |
| 420 | 1.119c | 1.138ab | 1.139c | 1.153a | .488b | .505a | .504b | .531a |

[1]Span lengths adjusted to average moisture content after moisture regain at four relative humidities before ginning.
[2]Entries in the same column followed by different letters are significantly different at the .05 level or better.

Table 14. The effect of gin drying at five temperatures on 2.5- and 50-% span length, pooled moisture groups, 71-40-1[1]

| **Drying air temperature (°F)** | **2.5-% span length[2] (inches)** | **50-% span length[2] (inch)** |
|---|---|---|
| 70 | 1.155a | 0.524a |
| 150 | 1.149a | .520ab |
| 250 | 1.148a | .522a |
| 360 | 1.138b | .514b |
| 420 | 1.137b | .507c |

[1]Each entry is the average of 4 moisture groups of 6 determinations each.
[2]Entries in the same column followed by different letters are significantly different at the .05 level or better.

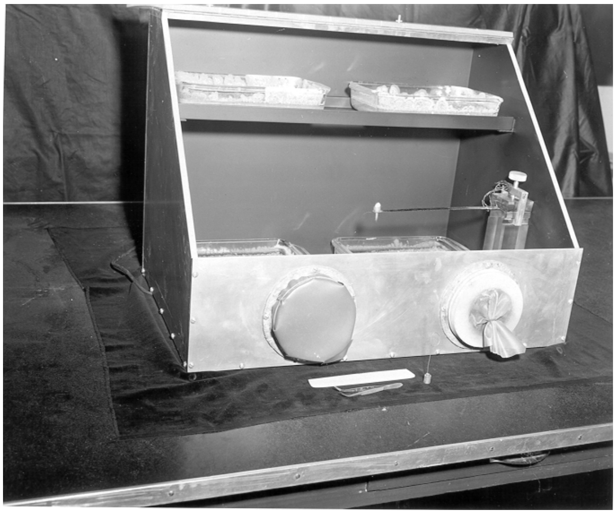

Figure l. Conditioning cabinet and force beam for determining fiber/seed strength of attachment and breaking strength of individual fibers.

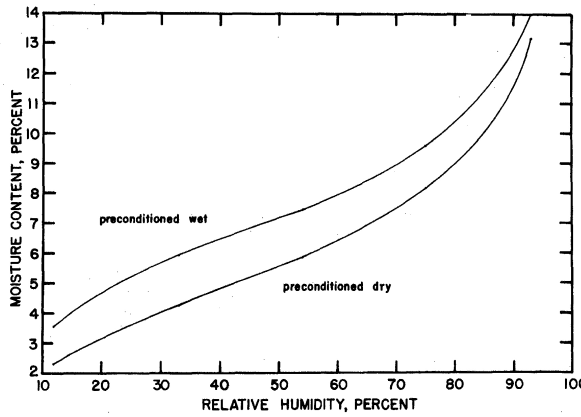


Figure 2. The equilibrium moisture content (wet basis) of raw cotton fibers as a function of relative humidity at 70 degrees F.

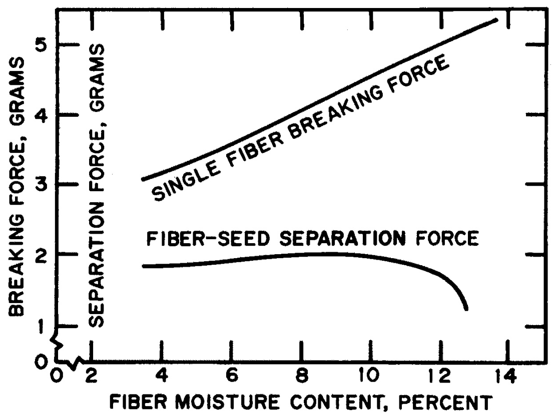


Figure 3. The effect of equilibrium moisture content on the force required to break individual cotton fibers and to effect fiber-seed separation.

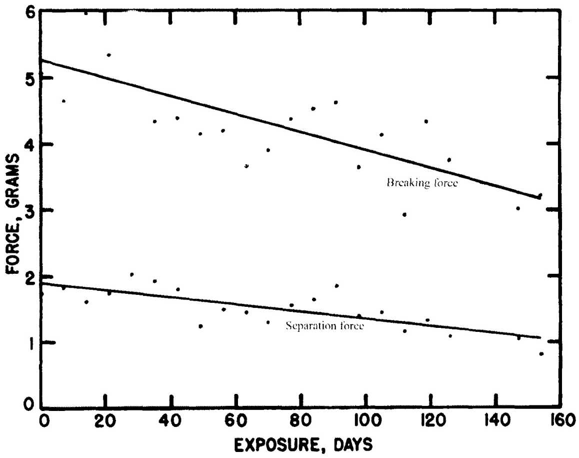


Figure 4. The effect of field exposure on single fiber breaking force and fiber-seed separation force.

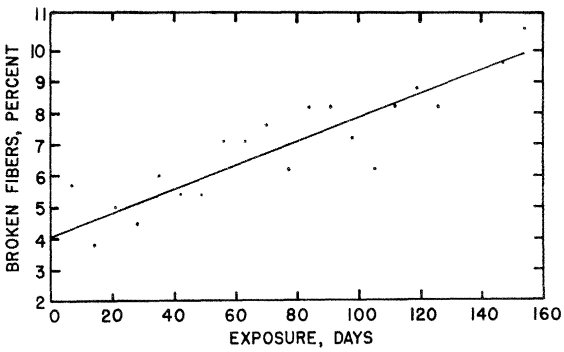


Figure 5. The effect of field exposure on the number of fibers to break during fiber-seed separation.

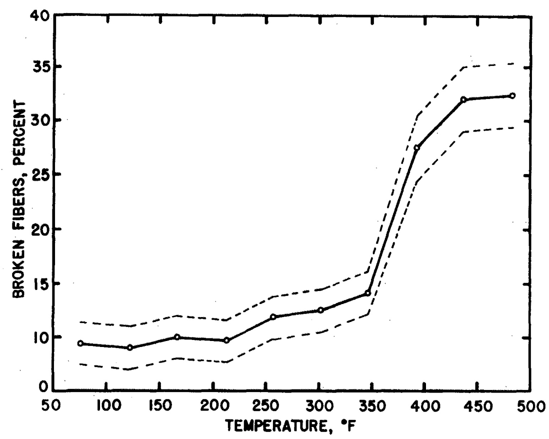


Figure 6. The effect of 30 seconds exposure to heated air on the percentage of fibers to break during single fiber/seed separation, with 95% confidence limits, experiment 65-42-82.

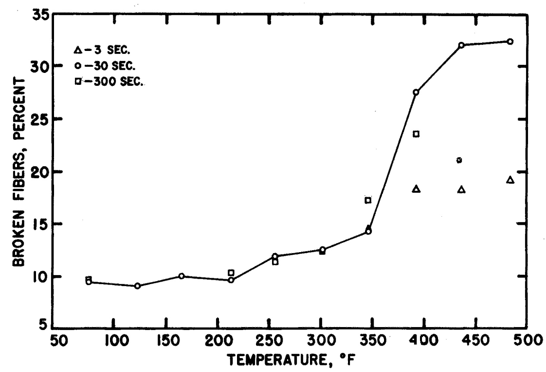


Figure 7. The effect of 3, 30, and 300 seconds exposure to heated air on the percentage of fibers to break during single fiber-seed separation. Experiments 65-42-82 and 66-42-82.

Figure 8. Laboratory constructed drier for close control of temperature and exposure period (67-42-85).

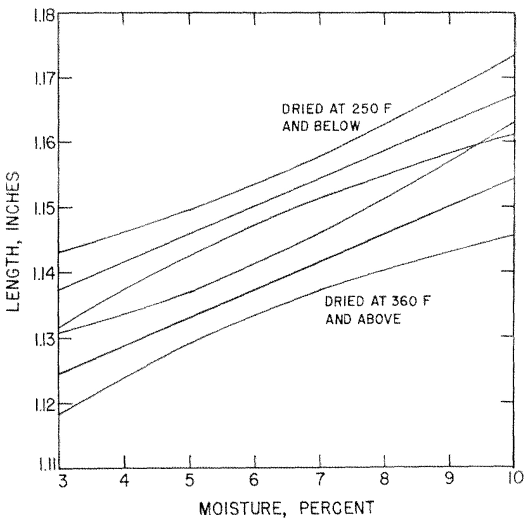


Figure 9. The effect of drying seed cotton at high and low normal temperatures and ginning after moisture restoration on 2.5% span length, with .05 confidence limits, experiment number 71-40-1.

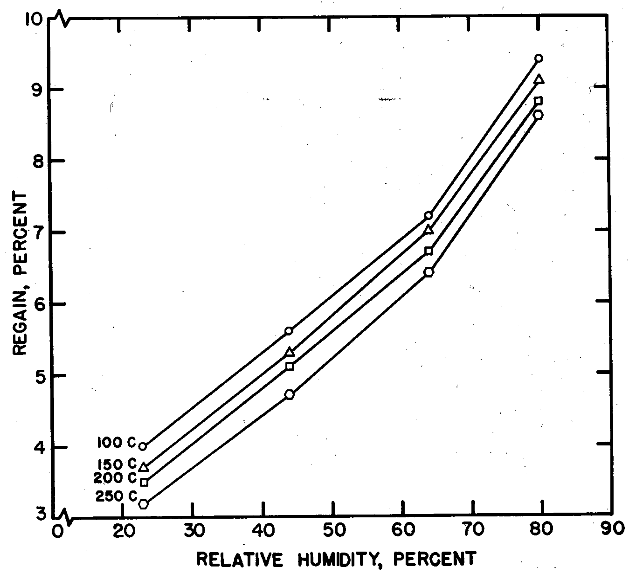


Figure 11. The effect of 30 seconds heating at 20, 100, 150, 200, and 250 C on subsequent moisture equilibrium, experiment 68-42-85.

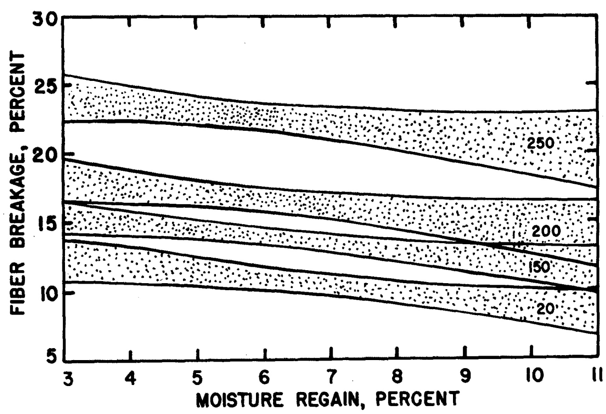


Figure 10. The effect of drying air temperature on fiber breakage rate in the fiber moisture range 3-10%, experiments 67/68-42-85.