RAPID ESTIMATION OF COTTON STICKINESS

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Abstract

Measurement of the stickiness of cotton is typically accomplished with the Thermodector method which is time-consuming, somewhat objective, and destructive. A new device to rapidly estimate the stickiness of both seed cotton and lint cotton was patented in 1997. This study further evaluated the new device using samples from several sources. Samples were classified into level of stickiness from 0 to 3 based on the Thermodetector as the reference method. The new device differed in accuracy for each study and was generally more effective as stickiness level increased. Across the 219 samples evaluated, 78% of the samples were correctly identified as either sticky or non-sticky.

Introduction

Cotton stickiness interferes with the smooth operation of textile processes such as carding and spinning. These sticky, sugary deposits are produced either by feeding insects or by the cotton plant itself. These insect deposits are often referred to as honeydew. At the gin, reduced ginning rates and poor operation can occur because of sticky cotton. Effects are less pronounced at the gin than those that occur during textile processing. Cotton stickiness can result from sugars present on the fibers and from miscellaneous factors. Sugar is a colloquial term used to describe certain members of the class of compounds called carbohydrates. The sugars present on cotton fibers can be divided into two main types reflecting their origin: (1) physiological sugars produced by the plants, and (2) entomological sugars produced by feeding insects.

The physiological or natural sugars can be subdivided into those originating as (a) a cellulose precursor and as (b) nectary-secretions. Entomological sugars attributable to honeydew cause 80-90% of all cases of cotton stickiness (Sisman and Schenek, 1984). Honeydew from whiteflies is the main cause of sticky cotton (Rimon, 1982). The main honeydew-producing insects attacking cotton grown in the U.S. are the sweet potato whitefly Bemisia tabaci Gennadius and the cotton aphid Aphis gossypii Glover.

Whiteflies and aphids are plant sap-sucking insects that feed by inserting their slender mouthparts (stylets) into the leaf tissue (Anonymous, 1988). Sap is then drawn up into the insect along the stylet food canal. Phloem sap is generally rich in sugars but poor in the amino acids that are essential for insect growth. Whiteflies and aphids therefore have to ingest large amounts of sap to obtain sufficient amino acids for growth. The insects do only a little digestion and the residual solution is stored in the dilated rectum before ejection to the exterior as a droplet of honeydew. The honeydew droplet released is rich in excess sugars. Whitefly sugary deposits contain trehalulose and melezitose (Brushwood, 1998; Byrne and Miller, 1990; and Hendrix, et al., 1992). Whitefly deposits contain about 1.5 to 2 times more disaccharide trehalulose than trisaccharide melezitose. Aphid deposits have melezitose but little or no trehalulose. Droplets are intact on seed cotton but the combing and blending action of gin cleaners spread each droplet over a larger area.

Laboratory Tests for Sugars and Stickiness

Stickiness was originally thought to be directly related to the glucose and fructose content of cotton, and many earlier tests for stickiness involved measurement of the reducing sugars. Sugar contents greater than 0.3% reducing sugars by weight usually suggest that stickiness problems may occur (Elsner et al., 1983) although in Texas a sugar content greater than 0.6% would usually be expected to be sticky during processing. Roberts et al. (1978) stated that stickiness was directly correlated with reducing sugar content and Heuer and Plaut (1985) concluded that stickiness was quantitatively related to the reducing compounds, mainly sugars, which were part of the structure of the fiber. Similarly, Bezouska (1985) showed that reducing sugar content is often used as a measure of the stickiness of raw cotton.

Many simple chemical tests for reducing sugars are available. They generally involve the extraction of cotton lint with water and examining the color reactions of the extract after the addition of certain chemicals (Brushwood and Perkins, 1993). The Minicard test is a mechanical method of testing for stickiness. The test, as utilized in North America, classifies cotton into four levels of stickiness, 0, 1, 2 and 3. A 10-gram sample of cotton is processed through a miniature card (Minicard) and the stickiness of the cotton on the steel delivery rolls is then rated subjectively. Results of the Minicard test are considered to correlate well with stickiness problems in the mill. However, the equipment is expensive and the test is time intensive. Another stickiness test is the Thermodetector (TD) method. In this test, a web of fiber (about 2.5 g) is placed between two sheets of aluminum foil on the bottom plate of a heating press. Pressure is briefly exerted on the top of the sheets using a heating plate at high temperature. A second, longer pressure of a few minutes is then exerted without heat after which the preparation is left to settle. The cotton web is then removed from the aluminum sheets but the sticky spots adhere strongly and remain attached to the sheets. This method has certain

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 1:690-695 (1999)
National Cotton Council, Memphis TN

advantages over the Minicard, and results seem to correlate well with the Minicard test. The Thermodetector is compact and needs little maintenance, and is simpler and less expensive than the Minicard. The test takes about 2-4 minutes per sample using one operator, and has the advantage that permanent records can be obtained as aluminum foil sheets with attached spots. The Thermodetector method is now available in an automated version.

Near infrared spectroscopy (NIR) is currently being investigated as a rapid method for measuring reducing sugars on cotton, but Perkins (1980) points out the major drawback with NIR in that it only tests a small volume of cotton. This criticism, however, can be leveled at all methods of measuring sugars and stickiness. Sugars may be unevenly distributed within a cotton bale and their detection depends on the adequacy of the sampling program. Ideally, several large samples should be taken and tested.

Preliminary research suggested that different types of measurements of moisture content such as resistance determinations, oven drying, capacitance determinations, and near-infrared measurements yielded different estimates of moisture content as a function of the amount of sugars that were on the cotton. In cases where the natural sugar was high, oven moisture determined by oven drying appeared to be elevated. In cases where the insect sugar content was high, the near infrared moisture was depressed. The resistance-based moisture meter was unaffected by the level of natural or insect sugar in the cotton. A new apparatus referred to hereafter as the "Stickiness Tester" was developed and patented. It combined measurements of resistance and infrared into one machine (Anthony et al., 1994; Anthony et al., 1995; and Anthony and Byler, 1997). The new device requires only a few seconds to predict the stickiness as compared to several minutes for the Thermodector. In addition, it also predicts the stickiness of seed cotton.

Description of Tests

Three tests were conducted to develop validation data for the Stickiness Tester. In test 1, samples of cotton with varying levels of stickiness were obtained from three sources and tested on several occasions with the Stickiness Tester. The samples were composed of lint and seed cotton with most seed cotton samples having a ginned lint sample from the same material. Thermodetector measurements were made at the Cotton Quality Station, Clemson, SC, using the reference Thermodetector manual method. The samples are summarized as follows:

Thermodetector stickiness level	Number samples	
	Lint	Seed cotton
0 (non-sticky)	11	9
1 (slightly sticky)	25	2
2 (moderately sticky)	8	9
3 (extremely sticky)	1	1

Samples were evaluated with the Stickiness Tester by taking one reading on each of four sides of the sample and averaging the results. Four to eight replications on different days were used. For test 2, 41 samples of seed cotton and 89 samples of lint were used. The samples analyzed for stickiness by Don Brushwood of the Cotton Quality Station, Clemson, SC. Lint removed from subsamples of the seed cotton was used to establish the stickiness with the Thermodetector method. All the samples were classified and analyzed on three occasions using the same procedures as for Test 1. For Test 3, 23 samples were obtained from Michael Watson of Cotton Incorporated, Raleigh, NC, and analyzed on six occasions using the same procedure as for Test 1.

Test Results

The data for Test 1 are summarized in Table 1 for infrared and resistance moisture, and stickiness measurements. Stickiness was predicted from these infrared and resistance moisture measurements. For seed cotton, all of the non-sticky seed cotton samples were correctly identified. For stickiness levels 1, 2, and 3, respectively, 0%, 89%, and 100% were correctly identified by the Stickiness Tester. Seed cotton stickiness tests measurements showed that only 1 of 21 samples was incorrectly categorized and no non-sticky sample was incorrectly identified as sticky. For lint cotton, 91%, 64%, 88% and 100% of the samples were correctly identified for stickiness levels 0, 1, 2, and 3, respectively (Table 3). Further study of Table 1 indicated that six sticky samples (level 1) were incorrectly categorized as non-sticky; one non-sticky sample was incorrectly categorized as sticky.

For the seed cotton in Test 2 (Table 4), 78% of the non-sticky samples were classified correctly as compared to 50%, 55%, and 50% for stickiness levels 1, 2, and 3, respectively (Table 5). For lint data only, those numbers were 80%, 34%, 78% and 60% (Table 6). When the lint and seed cotton data were considered in the same database, these numbers were 76%, 30%, 70%, and 14% (Table 7). Twenty-six (20%) of the 130 samples incorrectly predicted.

For Test 3, moisture data and Thermodector stickiness are at Table 8 and the predicted stickiness is at Table 9. Stickiness levels of 0, 1, and 2 were correctly predicted at 50%, 43%, and 75% of the time with 8 of the samples being incorrectly classified as sticky or non-sticky.

Summary

Samples were evaluated in three separate tests with the Stickiness Tester by taking one reading on each of four sides of the sample and averaging the results. Four to eight replications on different days were used. Stickiness was predicted by the Stickiness Tester from infrared and resistance moisture measurements. For seed cotton in Test 1, 100% of the non-sticky samples were correctly identified. For stickiness levels 1, 2 and 3, respectively, 0%, 89%, and 100% were correctly identified. Only 1 of 21 seed cotton samples were incorrectly categorized as non-sticky; no non-sticky sample was incorrectly identified as sticky. For lint cotton, 91%, 64%, 88%, and 100% were correctly identified for stickiness levels 0, 1, 2, and 3, respectively. Six lint samples were incorrectly categorized as non-sticky and one non-sticky sample was categorized as sticky. For the seed cotton in Test 2, 78% of the non-sticky samples were classified correctly as compared to 50%, 55% and 50% for stickiness levels 1, 2, and 3, respectively. For lint data, those numbers were 80%, 34%, 78%, and 60%. When the lint and seed cotton data were considered in the same database, these numbers were 76%, 30%, 70%, and 14%. For Test 3, stickiness levels of 0, 1, and 2, respectively, stickiness levels were correctly predicted 50%, 43%, and 75% of the time.

Disclaimer

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Table 1. Thermodector, predicted stickiness, and resistance and infrared moisture for Test 1.

Cotton[1]	Sample number	Thermo-dector stickiness, rating	Predict-ed sticki-ness, rating	Resis-tance moisture, %	Infra-red moist-ure, %	Oven moisture, %
C	3	2	3	6.1	5.9	6.1
C	21	2	2	6.0	5.8	7.0
C	22	0	0	6.7	6.4	7.3
C	23	2	2	6.0	6.0	7.1
C	24	0	0	6.7	6.8	7.3
C	25	3	3	6.1	5.8	6.6
C	26	0	0	6.7	6.4	6.9
C	27	2	2	6.2	6.0	7.3
C	28	0	0	6.6	6.8	7.5
C	29	2	2	6.2	6.1	7.1
C	30	0	0	6.7	5.8	6.8
C	31	2	3*	6.1	6.0	6.6
C	32	0	0	6.8	6.3	6.8
C	33	2	2	6.1	6.0	7.3
C	34	0	0	6.6	6.3	7.6
C	35	2	2	6.1	6.0	7.4
C	36	1	0*	7.1	6.2	7.3
C	37	2	2	6.1	5.9	7.8
C	38	0	0	6.7	6.5	7.6
C	39	1	2*	6.2	6.0	7.5
C	40	0	0	6.6	6.6	7.4
L	1	2	2	5.8	5.9	6.0
L	2	0	0	6.2	6.5	6.4
L	3	2	2	5.8	5.8	6.1
L	4	0	0	6.2	6.8	6.3
L	5	3	3	5.8	5.8	5.8
L	6	0	0	6.4	6.7	6.3
L	7	2	3*	5.9	5.8	5.8
L	8	0	0	6.3	7.0	5.9
L	9	2	2	6.0	5.8	6.3
L	10	0	0	6.2	6.4	6.5
L	11	2	2	5.9	5.7	6.2
L	12	0	0	6.3	6.5	6.2
L	13	2	2	6.0	5.9	6.2
L	14	0	0	6.2	6.6	6.3
L	15	2	2	6.00	5.9	6.2
L	16	1	0*	6.3	6.4	6.0
L	17	2	2	6.0	5.9	5.8
L	18	0	0	6.5	6.5	6.3
L	19	1	3*	5.9	5.8	5.6
L	20	0	0	6.3	6.9	5.8
L	101	1	0*	6.1	6.7	6.4
L	102	1	0*	6.3	6.3	6.5
L	103	1	1	6.1	5.7	6.5
L	104	1	1	6.3	6.1	6.2
L	105	1	1	6.4	6.0	6.6
L	201	0	1*	6.2	6.2	6.4
L	202	1	1	6.1	5.5	6.6
L	203	1	1	6.2	6.1	6.9
L	204	1	1	6.0	5.4	6.7
L	205	1	1	6.2	5.5	6.6
L	301	1	1	6.2	5.9	6.6
L	302	1	1	6.0	5.8	6.4
L	303	1	1	6.1	5.6	6.7
L	304	1	1	6.4	6.0	6.3
L	305	1	1	6.2	5.9	6.5
L	401	1	1	6.2	6.0	6.4
L	402	1	1	6.3	6.2	6.6
L	403	1	0*	6.2	6.5	6.4
L	404	1	1	6.3	6.2	6.4
L	405	1	1	6.3	6.2	6.1
L	501	1	0*	6.4	6.5	6.3
L	502	1	1	6.2	6.1	6.2
L	503	0	0	6.3	6.4	6.4
L	504	1	1	6.3	5.6	5.9
L	505	1	1	6.3	6.3	6.0

*Misclassified by the Stickiness Tester.

[1] C = seed cotton and L = lint

Table 2. Number of of samples and percent classified into stickiness for seed cotton using infrared and resistance moistures for Test 1.

From stickiness	0	1	2	3	Total/percent	Missed*
0	9	0	0	0	9	0
Percent	100.0	0.0	0.0	0.0	100.0	
1	1	0	1	0	2	1
Percent	50.0	0.0	50.0	0.0	100.0	
2	0	0	8	1	9	0
Percent	0.0	0.0	88.9	11	100.0	
3	0	0	0	1	1	6
Percent	0.0	0.0	0.0	100.0	100.0	
Total	10	0	8	3	21	7
Percent	47.6	0	38.1	14.3	100.0	

* Misclassified from sticky to non-sticky or vice versa.

Table 3. Number of samples and percent classified into stickiness for lint using infrared and resistance moistures for Test 1.

From stickiness	Number and percent of stickiness				Total/percent	Missed*
	0	1	2	3		
0	10	1	0	0	11	1
Percent	90.9	9.1	0.0	0.0	100.0	
1	6	16	3	0	25	6
Percent	24.0	64.0	12.0	0.0	100.0	
2	0	0	7	1	8	0
Percent	0.0	0.0	87.5	12.5	100.0	
3	0	0	0	1	1	0
Percent	0.0	0.0	0.0	100.0	100.0	
Total	16	17	10	2	45	7
Percent	35.6	37.8	22.2	4.4	100.0	

* Misclassified from sticky to non-sticky or vice versa.

Table 4. Summary data for test 2.

Obs	Cotton	Sample Number	TDH	Moisture, % Resistance	Infrared	Oven	Sugar, %I
1	C	21	2	5.8	5.6	7	.
2	C	22	0	6.4	6	7.3	0.25
3	C	23	2	5.8	6.1	7.1	.
4	C	24	0	6.4	6.6	7.3	0.25
5	C	25	3	5.8	5.4	6.6	.
6	C	26	0	6.5	6.2	6.9	0.25
7	C	27	2	5.9	5.8	7.3	.
8	C	28	0	6.5	6.7	7.5	0.25
9	C	29	2	5.9	5.9	7.1	.
10	C	30	0	6.5	5.5	6.8	0.25
11	C	31	2	5.9	6	6.6	.
12	C	32	0	6.7	6.2	6.8	0.25
13	C	33	2	5.9	5.8	7.3	.
14	C	34	0	6.4	6	7.6	0.25
15	C	35	2	5.8	5.7	7.4	.
16	C	36	1	6.5	6	7.3	0.25
17	C	37	2	5.8	5.9	7.8	.
18	C	38	0	6.5	6.7	7.6	0.25
19	C	39	1	5.9	5.8	7.5	.
20	C	40	0	6.4	6.4	7.4	0.25
21	C	21	2	6.3	6	7	.
22	C	22	0	6.8	6.6	7.3	0.25
23	C	23	2	6.2	5.9	7.1	.
24	C	24	0	6.9	6.9	7.3	0.25
25	C	25	3	6.3	6.2	6.6	.
26	C	26	0	6.9	6.4	6.9	0.25
27	C	27	2	6.4	6.2	7.3	.
28	C	28	0	6.8	6.8	7.5	0.25
29	C	29	2	6.4	6.3	7.1	.
30	C	3	2	6.1	5.9	6.1	.
31	C	30	0	6.8	6.1	6.8	0.25
32	C	31	2	6.2	6.1	6.6	.
33	C	32	0	6.9	6.4	6.8	0.25
34	C	33	2	6.4	6.2	7.3	.
35	C	34	0	6.8	6.5	7.6	0.25
36	C	35	2	6.2	6.2	7.4	.
37	C	36	1	6.9	6.4	7.3	0.25
38	C	37	2	6.3	6	7.8	.
39	C	38	0	6.8	6.4	7.6	0.25
40	C	39	1	6.3	6.2	7.5	.
41	C	40	0	6.7	6.8	7.4	0.25
42	L	1	2	5.8	5.9	6	.
43	L	2	0	6.1	6.2	6.4	0.25
44	L	3	2	5.7	5.5	6.1	.
45	L	4	0	6.1	6.6	6.3	0.25
46	L	5	3	5.6	5.6	5.8	.
47	L	6	0	6.3	6.6	6.3	0.25
48	L	7	2	5.8	5.7	5.8	.
49	L	8	0	6.1	6.9	5.9	0.25
50	L	9	2	5.9	5.8	6.3	.
51	L	10	0	6.1	6.2	6.5	0.25
52	L	11	2	5.8	5.8	6.2	.
53	L	12	0	6.2	6.4	6.2	0.25
54	L	13	2	5.9	5.8	6.2	.
55	L	14	0	6.1	6.5	6.3	0.25
56	L	15	2	5.9	5.7	6.2	.
57	L	16	1	6.2	6.4	6	0.25
58	L	17	2	5.8	6.2	5.8	.
59	L	18	0	6.3	6.4	6.3	0.25
60	L	19	1	5.8	5.8	5.6	.
61	L	20	0	6.1	6.7	5.8	0.25
62	L	1	2	5.8	5.9	6	.
63	L	10	0	6.4	6.6	6.5	0.25
64	L	101	1	6.1	6.7	6.4	.
65	L	102	1	6.3	6.3	6.5	.
66	L	103	1	6.1	5.7	6.5	.
67	L	104	1	6.3	6.1	6.2	.
68	L	105	1	6.4	5.9	6.6	.
69	L	11	2	5.9	5.7	6.2	.
70	L	12	0	6.4	6.6	6.2	0.25
71	L	13	2	6	5.9	6.2	.
72	L	14	0	6.3	6.7	6.3	0.25
73	L	15	2	6.1	6	6.2	.
74	L	16	1	6.4	6.5	6	0.25
75	L	17	2	6	5.8	5.8	.
76	L	18	0	6.6	6.7	6.3	0.25
77	L	19	1	6	5.8	5.6	.
78	L	2	0	6.3	6.7	6.4	0.25
79	L	20	0	6.4	7.1	5.8	0.25
80	L	201	0	6.2	6.2	6.4	.
81	L	202	1	6.1	5.5	6.6	.
82	L	203	1	6.2	6.1	6.9	.
83	L	204	1	6	5.4	6.7	.
84	L	205	1	6.2	5.6	6.6	.
85	L	3	2	6	5.9	6.1	.
86	L	301	1	6.2	5.9	6.6	.
87	L	302	1	6	5.8	6.4	.
88	L	303	1	6.1	5.6	6.7	.
89	L	304	1	6.4	6	6.3	.
90	L	305	1	6.2	5.9	6.5	.
91	L	4	0	6.3	7	6.3	0.25
92	L	401	1	6.2	6	6.4	.
93	L	402	1	6.3	6.2	6.6	.
94	L	403	1	6.2	6.5	6.4	.
95	L	404	1	6.3	6.2	6.4	.
96	L	405	1	6.3	6.2	6.1	.
97	L	5	3	5.9	5.9	5.8	.
98	L	501	1	6.4	6.5	6.3	.
99	L	502	1	6.2	6.1	6.2	.
100	L	503	0	6.3	6.4	6.4	.
101	L	504	1	6.3	5.6	5.9	.
102	L	505	1	6.3	6.3	6	.
103	L	506583	2	5.7	5.6	.	1.22
104	L	506585	2	6	5.9	.	1.4
105	L	509914	1	6.5	6	.	0.78
106	L	510961	1	6	5.7	.	0.71
107	L	510975	1	6.3	6.2	.	0.6
108	L	6	0	6.5	6.7	6.3	0.25
109	L	688329	1	6.3	6.6	.	1.07
110	L	688330	1	6.3	6.2	.	0.89
111	L	688477	1	6.2	6.4	.	0.98
112	L	689022	1	5.9	6	.	0.43
113	L	690750	1	5.5	5.6	.	0.5
114	L	7	2	5.9	5.9	5.8	.
115	L	8	0	6.4	7.1	5.9	0.25
116	L	800410	1	5.6	5.3	.	0.3
117	L	9	2	6	5.7	6.3	.
118	L	999911	1	6.6	6.6	.	0.38
119	L	999912	1	6.4	6.2	.	0.43
120	L	999913	1	6.2	6	.	0.56
121	L	999914	2	6.9	5.8	.	0.46
122	L	999918	3	6.8	6.4	.	1.77
123	L	999922	2	6.6	6.6	.	0.68
124	L	999932	2	6.8	6.6	.	0.84
125	L	999937	2	6.7	6.3	.	0.24
126	L	999942	2	6.5	5.8	.	0.91
127	L	999950	3	6.6	6.3	.	1.04
128	L	999991	1	6.8	6.1	.	0.6
129	L	999992	3	7.1	5.5	.	1.21
130	L	999993	1	6.8	6.2	.	0.58

H Thermodetector stickiness

I Physiological sugar based on Perkins Test.

Table 5. Summary prediction data for seed cotton in Test 2.

From TD rating	0	1	2	3	Total	Missed*
0	14	4	0	0	18	4
	77.78	22.22	0.00	0.00	100.00	
1	1	2	0	1	4	0
	25.00	50.00	0.00	25.00	100.00	
2	0	4	10	3	17	0
	0.00	23.53	58.82	17.65	100.00	
3	0	1	0	1	2	0
	0.00	50.00	0.00	50.00	100.00	
Total	15	11	10	5	41	4
Percent	36.59	2.83	24.39	12.20	100.00	

*Indicates classified as sticky when not sticky or as not-sticky when sticky, regardless of level.

Table 6. Number of samples and percent classified into Thermodetector stickiness for Test 2 for lint.

From TD rating	0	1	2	3	Total	Missed*
0	16	4	0	0	20	4
	80.00	20.00	0.00	0.00	100.00	
1	8	14	9	10	41	8
	19.51	34.15	21.95	24.39	100.00	
2	2	0	18	3	23	2
	8.70	0.00	78.26	13.04	100.00	
3	0	0	2	3	5	0
	0.00	0.00	40.00	60.00	100.00	
Percent	29.21	20.22	32.58	17.98	100.00	

*Indicates classified as sticky when not sticky or as not-sticky when sticky, regardless of level.

Table 7. Number of samples and percent classified into Thermodetector stickiness for seed cotton and lint in Test 2.

From TD rating	0	1	2	3	Total	Missed*
0	29	3	1	5	38	
	76.32	7.89	2.63	13.16	100.00	9
1	11	13	8	13	45	11
	24.44	28.89	17.78	28.89	100.00	
2	4	4	28	4	40	4
	10.00	10.00	70.00	10.00	100.00	
3	2	1	3	1	7	2
	28.57	14.29	42.86	14.29	100.00	
Total	46	21	40	23	130	26
Percent	35.38	16.15	30.77	17.69	100.00	

*Indicates classified as sticky when not sticky or as not-sticky when sticky, regardless of level.

Table 8. Summary data for Test 3.

Observations	Resistance	Infrared	Cotton	Sample #	TD* Clemson
24	6.5	6.8	L	1	3
24	6.2	6.9	L	2	1
24	6.5	6.5	L	3	1
24	6.8	6.2	L	4	0
24	6.4	6.9	L	5	1
24	6.4	6.7	L	6	0
24	6.3	6.8	L	7	0
24	6.5	6.1	L	8	1
24	6.3	6.9	L	9	0
24	6.7	7.3	L	10	0
24	6.2	6.3	L	11	3
24	6.4	6.9	L	12	1
24	6.3	6.9	L	13	0
24	6.6	6.6	L	14	3
24	6.3	6.8	L	15	1
24	6.4	6.4	L	16	2
24	6.7	6.6	L	17	1
24	6.5	6.1	L	18	2
24	6.3	6.4	L	19	2
24	6.6	6.5	L	20	0
24	6.8	6.5	L	21	0
24	6.4	6.2	L	22	2
24	6.3	6.2	L	23	3

* Thermodetector stickiness

Table 9. Prediction of stickiness based on Clemson Thermodector evaluation of Test 3.

From TD rating	0	1	2	3	Total	Missed*
0	4	4	0	0	8	4
	50.00	50.00	0.00	0.00	100.00	
1	2	3	1	1	7	2
	28.57	42.86	14.29	14.29	100.00	
2	0	0	3	1	4	0
	0.00	0.00	75.00	25.00	100.00	
3	2	0	2	0	4	2
	50.00	10.00	50.00	0.00	100.00	
Total	8	7	6	2	23	8
Percent	34.78	30.43	26.09	8.70	100.00	

*Indicates classified as sticky when not sticky or as not-sticky when sticky, regardless of level.