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DEVELOPMENT OF A STANDARD GRAIN BREAKAGE TEST

(A Progress Report)

Agricultural Research Service
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DEVELOPMENT OF A STANDARD GRAIN BREAKAGE TEST

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SUMMARY

Two commercial machines were evaluated for measuring the breakage potential of various grains. The Stein Grain Breakage Tester[1] was selected for further study. Two Stein units were compared using corn, soybeans, grain sorghum, and wheat. Although differences were noted between units, they were not considered excessive. Recommendations are made for developing a standard grain breakage test.

INTRODUCTION

A need exists to measure the potential breakage of grain that occurs during handling and transport. An increase of 2 percent broken corn during handling may degrade it from No. 1 to No. 3 with a typical decrease in value of 2 or more cents per bushel. In addition, broken kernels are more susceptible to mold and insect infestation, which results in lower germination and poorer milling quality.

A reliable prediction of grain breakage during normal handling would be beneficial to the grain industry. Breakage testers in use have been reported to give inconsistent results, and there is no standard with which to compare the results.

Considerable work has been done investigating mechanical and rheological properties of grains (*8*).[2] Much of the earlier work was characterized by nonrepeatable tests and results, largely because of the wide variations of grain properties and inadequate test equipment and procedures (*1,4*). As a result, much of the later work was focused on improving methods and equipment (*2*).

Recent work indicates that mechanical strength or resistance to breakage of various grains varies widely with moisture content (*2,9*), variety (*3*), temperature (*5*), type of load (*5*), and orientation of the kernel with respect to the direction of load (*1*).

Besides visible mechanical damage, such as cracked or broken kernels, resulting from impact, investigators have reported decreased germination, stunted or deformed roots, and plants growing from seemingly sound seeds that had been subjected to impact (*6,7*).

A measurement of potential breakage can only be relative, because the actual damage depends on the previously mentioned variables as well as the design and operation of the grain-handling equipment (*6,7*). As of this writing no standard for breakage measurement has been established. A need exists to evaluate the breakage testers presently being used and to establish a standard breakage test.

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

[2] Italicized figures in parentheses refer to Literature Cited, p. 13

PROCEDURE

Mechanical Strength

Initially an attempt was made to measure the mechanical strength of various samples of grain. It became apparent that such tests would have little bearing on this project. Although such tests are important to the study of grain itself, their use in field testing would be impractical.

Individual kernels tested for mechanical strength gave a wide range of values largely because of the varying cross sections of the individual kernels. To determine the physical strength, in terms of pounds per square inch to cause failure, one must know the cross sectional area over which the force is applied. Since this area varies within the kernel itself, the procedure becomes complex.

In actual handling and conveying, the kernels are subjected to loading, impact, and friction in a random manner. In addition, the point of loading on each kernel is random, and this point at which the load is applied has a definite relation to the resulting damage.

Requirements Established for a Breakage Testing Device

The following requirements were established for a practical grain breakage unit:

1. A sufficient sample should be tested to have statistical meaning.
2. Testing should take only a few minutes.
3. Nontechnical personnel should be able to do the test and analyze the results.
4. Results should be consistent from one test to another.
5. Both the equipment and methods should be inexpensive so that they can be used at field locations.

Grain Breakage Testers Evaluated

The grain breakage testers evaluated were (1) the Cargill Grain Breakage Tester, Model No. 2, Serial No. 1, constructed by the Grain Research Laboratory; Cargill, Incorporated, Minneapolis, Minn., and (2) the Stein Grain Breakage Tester, Model CK-2, Serial No. 102 and No. 110, manufactured by the Fred Stein Laboratories, Atchison, Kans.

The Cargill unit has a chamber of rather complex shape (fig. 1) into which the sample is placed. A rubber disk rotating at approximately 3,600 r.p.m. stirs the sample and throws kernels against the side of the chamber.

The Stein unit has a removable chamber the shape of a cup (fig. 2). A steel impeller fits into this cup with a small clearance on the bottom and sides. The impeller rotating at approximately 1,800 r.p.m. causes impact and slinging of the grain.

Sampling Procedure

The procedure outlined below was used for all determinations.

1. Samples were subdivided by cutting with a Boerner sample divider.
2. Samples requiring drying were placed on screens and were air-dried at room temperature. All samples were stored in double-layer plastic bags and sealed until tested.
3. Samples were cleaned by using standard dockage procedures; no handpicking was done, except to remove large foreign material not removed by dockage equipment.
4. Sample weight used for all grains was 100 grams ±0.01 gram for grain sorghum and wheat and ±0.1 gram for corn and soybeans.
5. Samples were placed in the test chamber before starting the tester. This eliminated error by dribbling the sample in while the machine was running.
6. The tests were timed by an electric, synchronous clock that stopped the test after the preset interval.
7. The sample chamber was carefully removed to avoid spillage, and all fine material was removed from the impeller.
8. The sample was placed on a Gamet Shaker Sieve with the proper screen for broken-kernel removal as specified by the official grain standards. Screen sizes used were: Corn, 12/64 in. round; soybeans, 10/64 x 3/4 in. slot; grain sorghum, 5/64 in. triangular; and wheat, 0.064 x 3/8 in. slot. The shaker was controlled by an automatic counter set for 30 strokes.
9. The particles on the screen and caught in the screen were weighed together. This was considered as percentage of sample remaining, or an index of breakage-tendency. The material passing through the screen was weighed and counted as fines.
10. No attempt was made to assess breakage other than the loss of weight. Cracks and splits remaining on the screen were regarded as whole grain.

Several samples each of corn, soybeans, grain sorghum, and wheat were tested. No attempt was made to test a large number of samples from different sources, but rather a few samples were tested many times. In this manner the consistency of the results for a given sample could be evaluated. Controlled variables were:

1. Length of test—varied from 2 to 30 minutes.
2. Moisture content of the sample—typically from 9 to 16 percent.

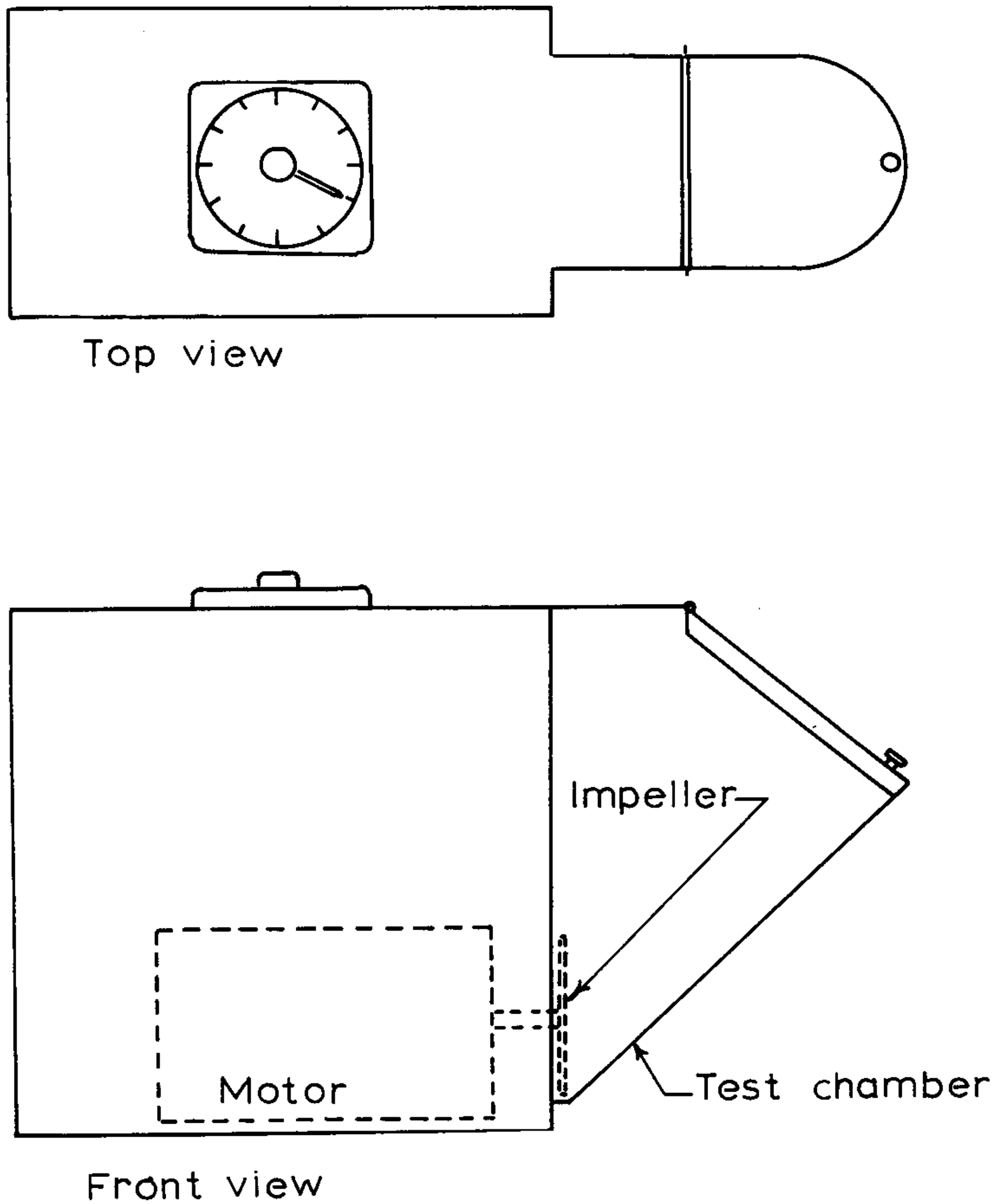

Figure 1.–Diagram of the Cargill Grain Breakage Tester, Model No. 2, Serial No. 1 Dimensions: length, 20 inches; height, 12 inches, and width, 7 inches.

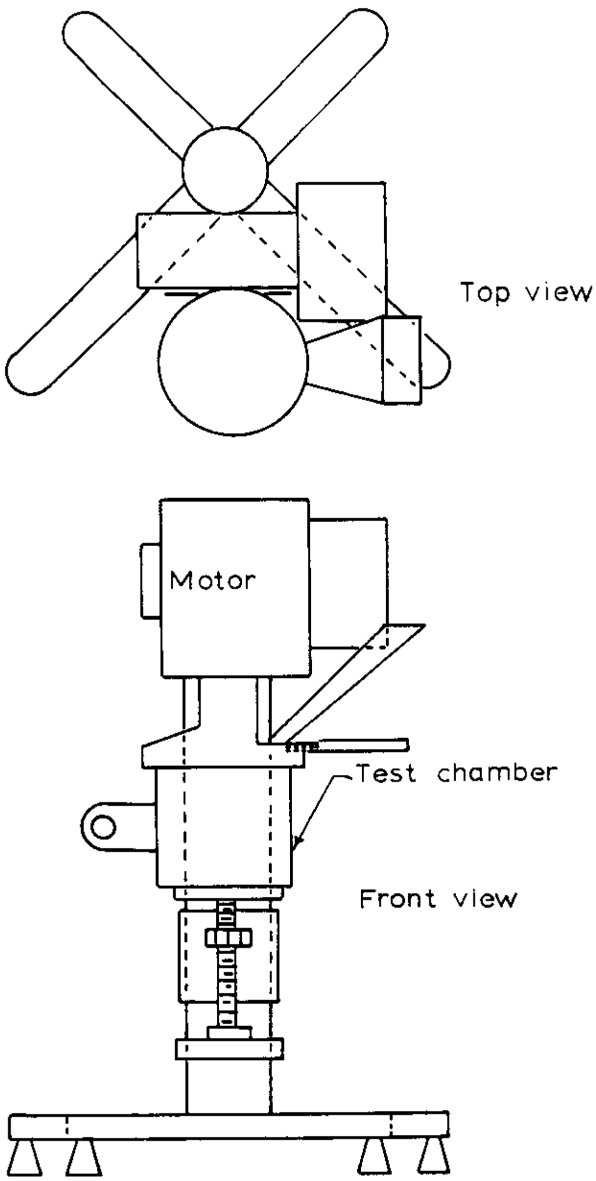

Figure 2.–Diagram of the Stein Grain Breakage Tester, Model CK-2, Serial No. 110. Dimensions: length, 22 inches; height, 15 inches; and width, 14 inches.

3. Amount of precleaning–two lots, one of soybeans and one of corn, were run through a larger screen to remove more broken kernels than by the regular procedure (item 3 above) before testing.
Recorded but largely uncontrolled variables were:

1. Past history of the grain.

2. Environmental conditions, i.e., temperature and relative humidity. All tests were done under room conditions. The sealed samples were stored at room temperature, which varied from 65° to 85° F. High-moisture samples were stored at 35° to 40° but warmed to room temperature before testing.

The two Stein units, Serial No. 102 and No. 110, were controlled by a single electric timer to eliminate any difference in timing between units.

Figure 3 shows typical results for both the Cargill and the Stein units from several samples of the same lot of corn. Both units have a linear relation between length of test and percentage of sample remaining on the screen. In tests of this type, the steeper slope given by the Stein unit is preferred because there is a greater difference in test results for samples with a slightly different tendency to break. Similar results were obtained with soybeans, grain sorghum, and wheat.

Figure 4 compares the results of two lots of artificially dried corn, discolored and damaged by overheating, obtained from commercial elevators with sound corn at nearly the same moisture content. Results are from Stein unit No. 110. The more sample remaining on the sieve the less breakage. The means and standard deviations for these data are shown in table 1. Each of the artificially dried corn lots showed signs of overdrying (heat damage) such as discoloration and stress cracks. In both cases, considerably more breakage occurred in the corn that was artificially dried.

Figures 5, 6, and 7 show the effect of moisture content of the breakage of corn, grain sorghum, and soybeans, respectively, in Stein Unit No. 110. The means and standard deviations for these data are shown in table 1.

The corn samples were brought to the indicated moisture content by air-drying. The data show little difference in corn breakage between 16 and 14 percent moisture up to approximately 20 minutes running time (fig. 5). More breakage occurred with the 16 percent moisture corn than with the 14 percent at 30 minutes running time. Breakage was progressively greater with the corn at 14, 12, and 9.3 percent moisture. Generally, less variations occurred in results at 2 minutes than at longer running times (table 1).

Less breakage occurred in the grain sorghum than in the corn (fig. 6). Lowering the moisture content resulted in increased breakage. Greater differences in the curves were obtained at the longer running times; however, there was only a slight increase in the coefficient of variability at the longer running times (table 1).

Soybeans were very prone to splitting and therefore the maximum running time was shortened to 10 minutes (fig. 7). The high moisture lot was tempered

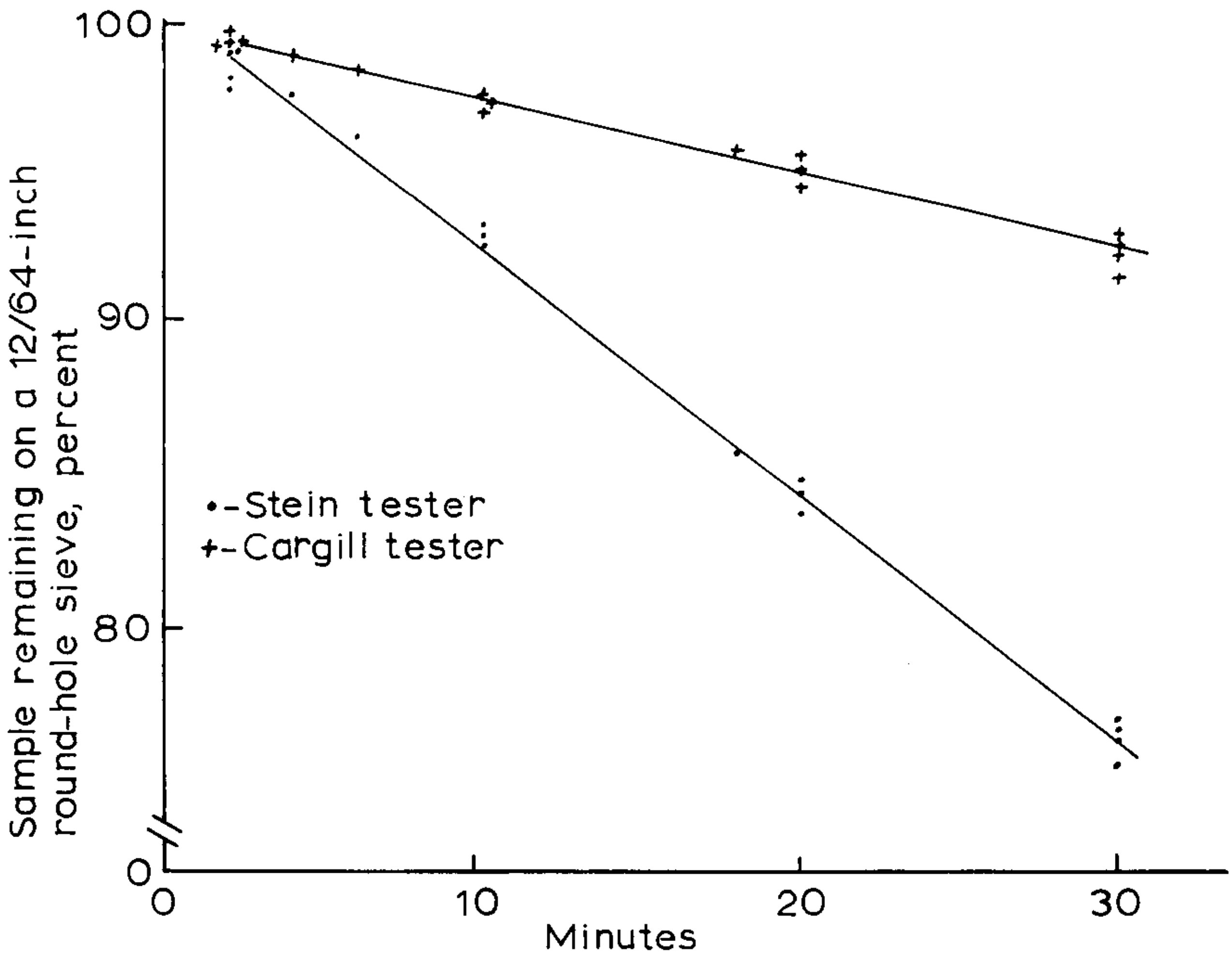

Figure 3.–Comparison of the amount of corn breakage in a Cargill and a Stein breakage tester. Corn was yellow dent and contained 16 percent moisture. Each curve is an average of 3 determinations.

to 16 percent moisture and the low moisture lot was air-dried to 9.4 percent moisture. Considerably more splitting occurred at the lower moisture content than at the high moisture content.

Tables 2 to 5 contain summaries of a series of comparison between the two Stein units, Serial No. 102 and No. 110, on different samples of grain at varying moisture contents. The t-value compares the means of each unit. The means for the two Stein units for corn and soybeans generally were significantly different as opposed to the means for grain sorghum and wheat, which were not significantly different. There was relatively little breakage in the grain sorghum and wheat samples, and, therefore, differences between the means should be small.

The average differences of the means of the two Stein units for the data in tables 2 to 5 are shown in figure 8. The means for the Stein 102 were used as a reference for plotting the variance of the means of the Stein 110. This graph shows that generally the difference between the means of the two Stein units is fairly constant. The differences tend to be slightly larger at the greater breakage levels.

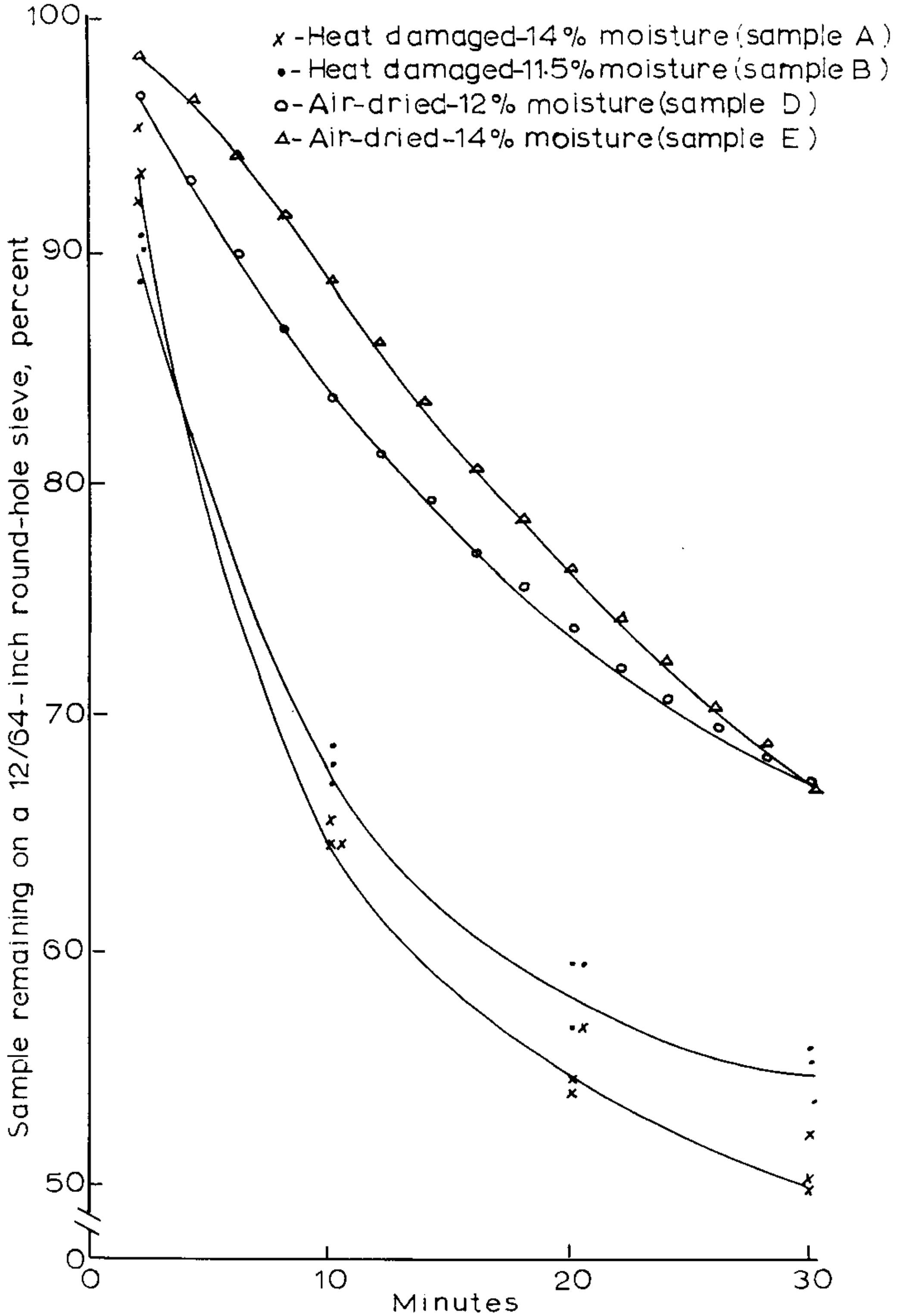

Figure 4.–Amount of breakage of sound and heat-damaged yellow dent corn in Stein unit No. 110. Each curve is an average of 3 determinations.

Table 1.–Means, standard deviations, and coefficients of variation for samples of corn, grain sorghum, and soybeans, by length of test time[1]

Grain tested	Moisture content	Samples	Length of test in minutes: 2			10			20			30		
			$\bar{X}$	S	C.V.	$\bar{X}$	S	C.V.	$\bar{X}$	S	C.V.	$\bar{X}$	S	C.V.
Corn:	*Percent*	*Number*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Sample A[2]	14.0	3	93.8	1.52	1.6	65.1	0.44	0.7	55.2	1.48	2.7	50.0	2.11	4.2
Sample B[2]	11.5	3	89.9	.93	1.0	67.3	1.95	2.9	58.8	1.70	2.9	54.9	1.26	2.3
Sample C	9.3	5	94.4	.97	1.0	79.2	1.48	1.9	70.7	1.88	2.7	65.7	2.20	3.3
Sample D	12.0	4	97.0	.29	.3	85.0	2.44	2.9	75.3	2.78	3.7	68.8	3.14	4.6
Sample E	14.0	4	98.6	.27	.3	89.6	1.49	1.7	78.1	3.23	4.1	69.5	5.14	7.4
Sample F	16.0	8	98.2	.41	.4	90.6	1.28	1.4	79.9	3.38	4.2	63.2	5.56	8.8
Sorghum:														
Sample A	10.6	8	97.8	.38	.4	94.4	.33	.3	90.5	.39	.4	87.3	.32	.4
Sample B	12.4	8	97.8	.20	.2	95.3	.28	.3	91.9	.54	.6	89.0	.45	.5
Sample C	14.8	8	98.7	.29	.3	96.6	.36	.4	94.2	.40	.4	92.0	.64	.7
Soybeans:														
Sample A	9.4	9	79.8	2.40	3.0	62.4	2.18	3.5	—	—	—	—	—	—
Sample B	11.7	8	91.1	2.87	3.2	79.8	2.52	3.2	—	—	—	—	—	—
Sample C	16.0	9	96.9	1.20	1.2	89.4	3.04	3.4	—	—	—	—	—	—

[1] Data are plotted in figures 4 to 7.
[2] Heat damage.

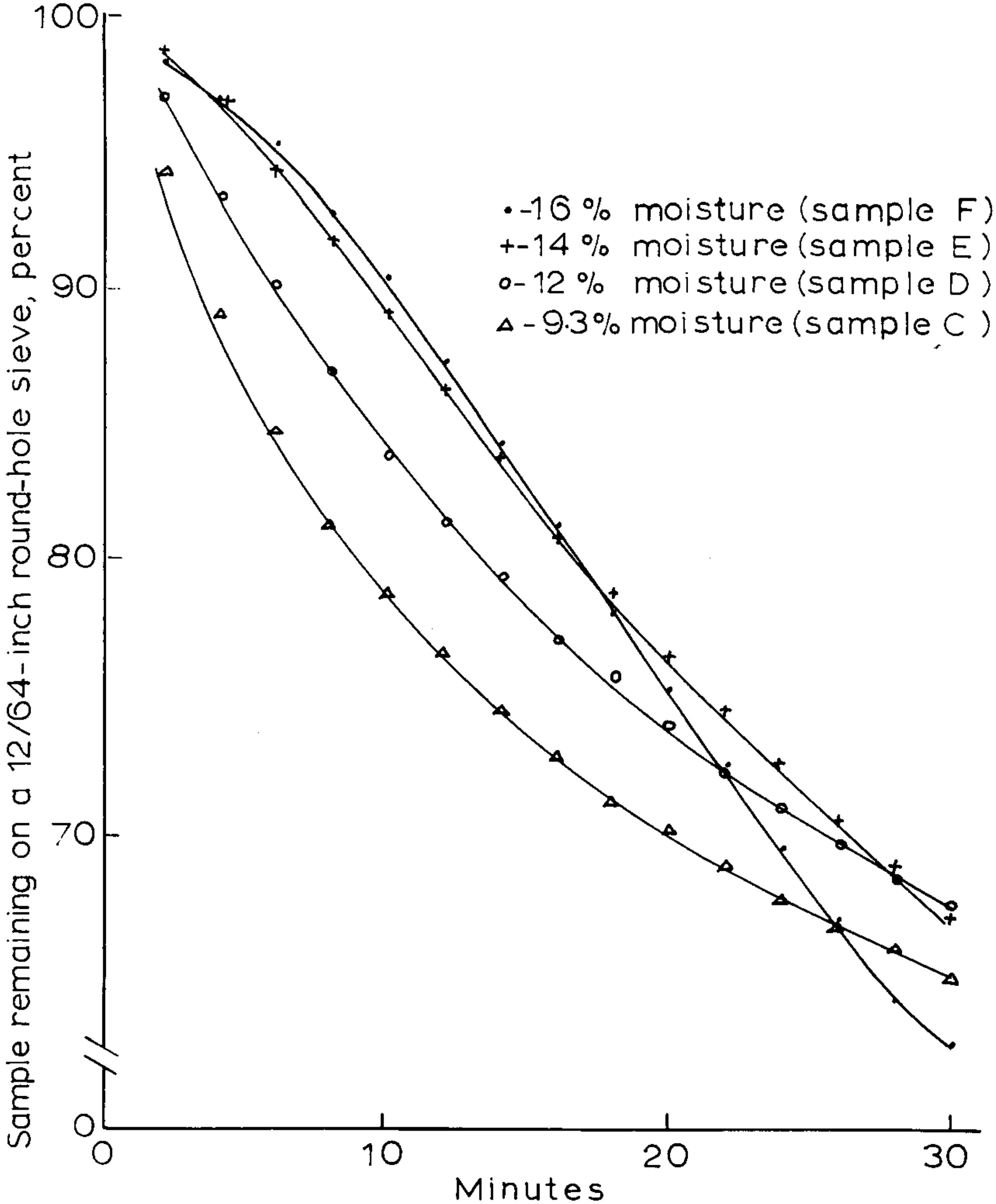

Figure 5.–Effect of moisture content on breakage of corn in Stein unit No. 110.

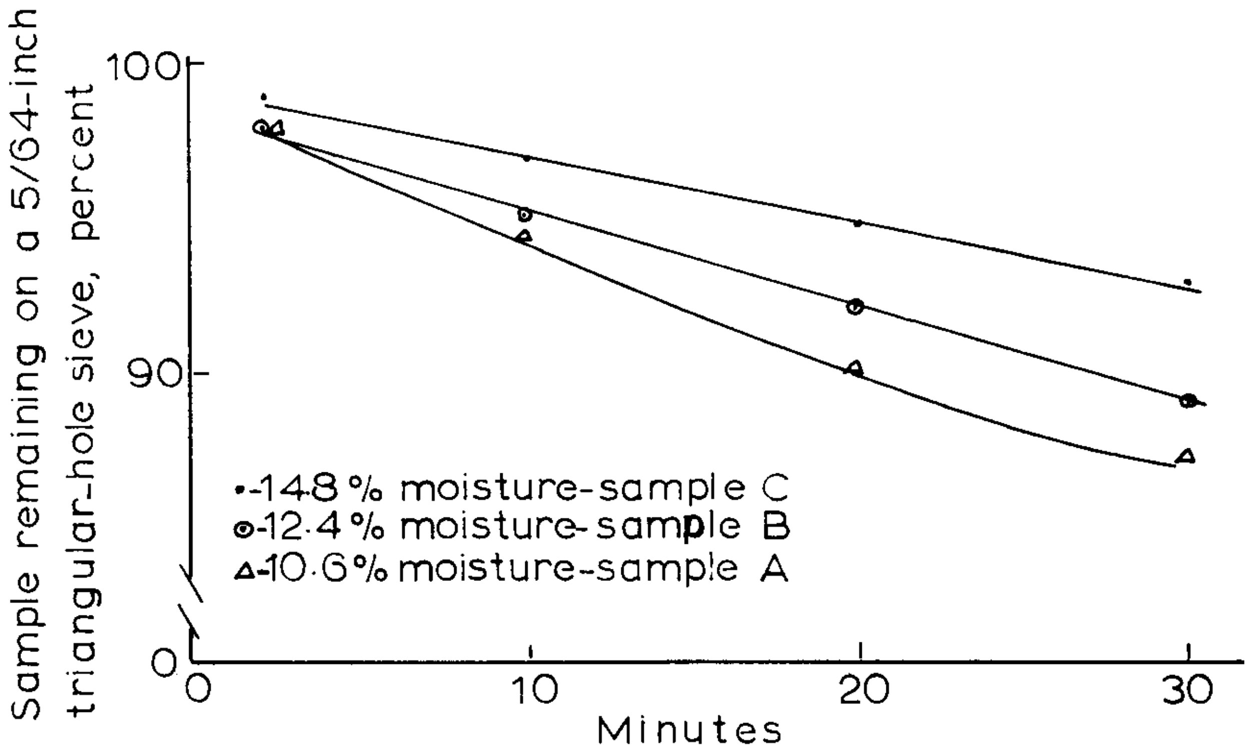

Figure 6.–Effect of moisture content on breakage of grain sorghum in Stein unit No. 110.

Table 2.–Comparison of Stein Grain Breakage Testers with corn (2-minute tests)

Grain history	Moisture content	Tests	Stein No. 102		Stein No. 110		t-value
			Mean	Standard deviation	Mean	Standard deviation	
Composite sample:	*Percent*	*Number*	*Percent*	*Percent*	*Percent*	*Percent*	
Air-dried	9.4	12	93.36	0.588	91.79	0.751	**5.692
From field.	16.4	13	98.55	.369	97.95	.399	**3.980
Commercial damaged	11.8	5	73.00	1.964	70.40	1.202	2.524
Do	12.3	5	82.26	1.868	77.32	1.746	*4.320
Do	13.2	7	78.56	2.514	74.6	1.305	*3.698

*Difference between the means is significant at the 0.05-percent probability level.

**Difference between the means is significant at the 0.01-percent probability level.

Table 3.–Comparison of Stein Grain Breakage Testers with sorghum (2-minute tests)

Grain history	Moisture content	Tests	Stein No. 102		Stein No. 110		t-value[1]
			Mean	Standard deviation	Mean	Standard deviation	
Composite 1968 harvest, Kansas State University Agronomy Farm	*Percent* 13.2	*Number* 8	*Percent* 98.28	*Percent* 0.310	*Percent* 98.20	*Percent* 0.267	0.518
Do	13.0	8	98.68	.315	98.58	.219	.737
Do	13.2	8	98.55	.180	98.54	.213	.106

[1] Difference between the means is not significant.

Table 4.–Comparison of Stein Grain Breakage Testers with soybeans (2-minute tests)

Grain history[1]	Moisture content	Tests	Stein No. 102		Stein No. 110		t-value
			Mean	Standard deviation	Mean	Standard deviation	
Collected at truck:	*Percent*	*Number*	*Percent*	*Percent*	*Percent*	*Percent*	
From field	11.2	13	90.34	2.340	83.83	4.477	**4.647
Air-dried	8.0	7	55.40	1.483	49.29	2.126	**6.237
Tempered	15.1	7	98.00	1.145	95.30	3.016	2.214
Do	14.6	7	96.76	1.384	95.51	3.947	.791
Collected at combine	11.3	15	94.05	1.898	90.11	4.709	**3.006
Handpicked	9.9	6	85.83	2.762	73.45	5.538	**4.900
Collected at combine	11.2	6	97.03	1.193	94.57	1.834	*2.755
Do	11.1	5	96.80	.846	94.70	.831	*3.962

[1] Clark variety from the Kansas State University Agronomy Farm, 1968 harvest, was used for all tests.
* Difference between the means is significant at the 0.05-percent probability level.
** Difference between the means is significant at the 0.01-percent probability level.

Table 5.–Comparison of Stein Grain Breakage Testers with wheat (2-minute tests)

Grain history[1]	Moisture content	Tests	Stein No. 102		Stein No. 110		t-value[2]
			Mean	Standard deviation	Mean	Standard deviation	
Variety Commanche, Hays, Kans.	*Percent* 10.3	*Number* 6	*Percent* 98.77	*Percent* 0.103	*Percent* 98.65	*Percent* 0.187	1.330
Variety Parker, Hays, Kans.	10.9	7	98.64	.181	98.53	.198	1.125
Variety Guide, Hays, Kans.	10.6	4	97.95	.129	98.08	.171	1.214
Composite sample, Kansas State University Agronomy Farm	11.8	11	[3] 98.60	[3] .300	98.40	.127	2.036

[1] 1968 harvest.
[2] Difference between the means is not significant.
[3] Stein 102 impeller changed from tests above.

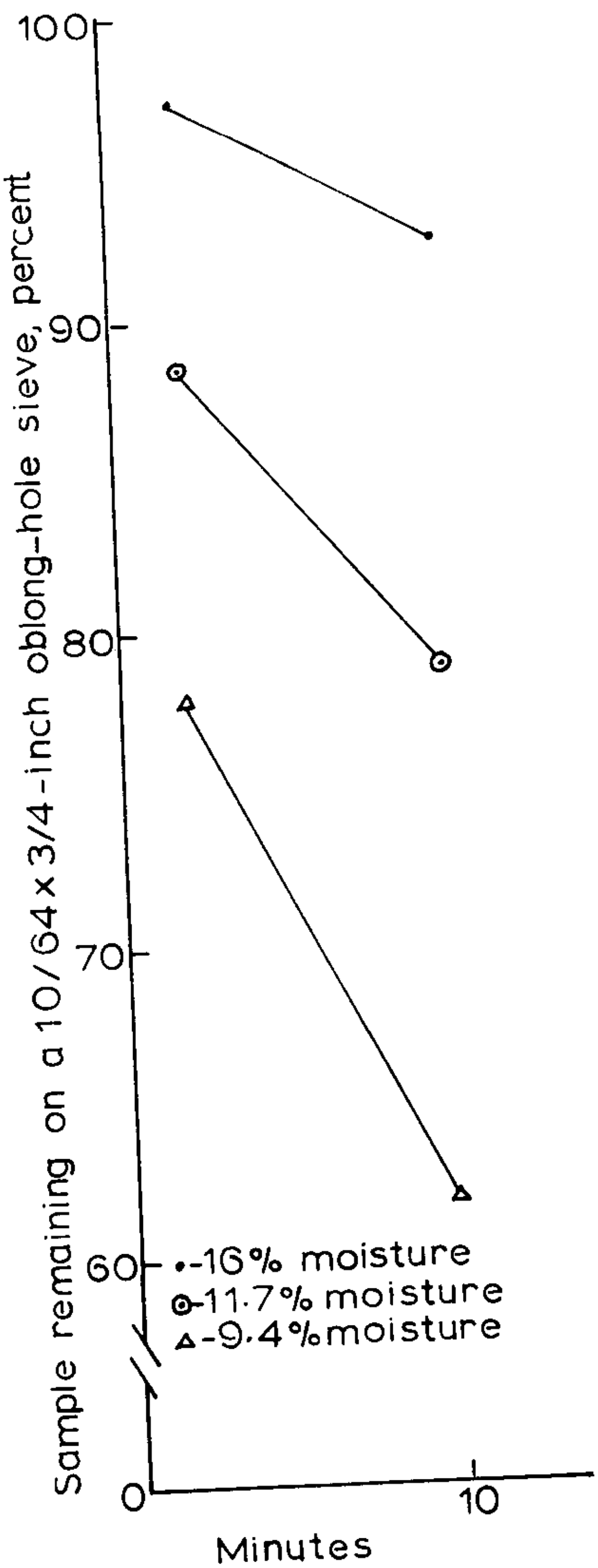

Figure 7.–Effect of moisture content on breakage of soybeans in Stein unit No. 110.

DISCUSSION AND CONCLUSIONS

The Cargill unit was judged unsatisfactory for the following reasons:

1. The rubber disk results in a small rate of damage, which gives a shallow slope damage curve that is difficult to interpret.
2. The complex chamber would be difficult to control in manufacture, and different shaped chambers could give conflicting results.
3. The sample cannot be removed without tipping the entire machine on end.
4. The rubber disk has a limited life, which will affect the tests as the rubber wears.
5. The entire machine must be dismantled to change disks.
6. The unit cannot be run for more than 30 minutes, because of overheating in both the motor and chamber. The motor heating could be relieved by redesign, but the chamber heat is due to friction of the disk on the grain and could affect the results.

The Stein unit was satisfactory except for the small funnel for introducing the sample into the chamber. In general, the unit is simple in design, is easy to operate, and has a steep breakage-tendency curve that gives good readability.

Some problems, however, were encountered in the comparison of the two Stein units. In the initial series of tests, a difference was found in the two machines. Since the impeller on No. 102 showed considerable wear, a new set of impellers was purchased. However, the new impellers were of slightly different design than the original ones. And the set screw holes were not in the same position on all the impellers; this had the effect of varying the clearance between the impeller and the bottom of the sample container, which would change the characteristics of the machine. This problem was correctable by drilling and tapping a new set of screw holes. The new impeller was somewhat rough as received, and approximately 2 hours of total running time was required for it to take on a polish. The results of unit No. 102 were repeatable after the new impeller had acquired a polish. Unit No. 110 was being used by several researchers in a grain-testing laboratory; hence, it was impractical to modify the unit.

Since in a further test the machines still consistently disagreed with each other, the differences were attributed to differences in wear, design, and manufacture. These do not appear to be serious problems, since:

1. The wearing parts of the machine are easily replaceable.
2. The design of the machine can be standardized.
3. The manufacturing tollerances can be reduced with proper tooling.

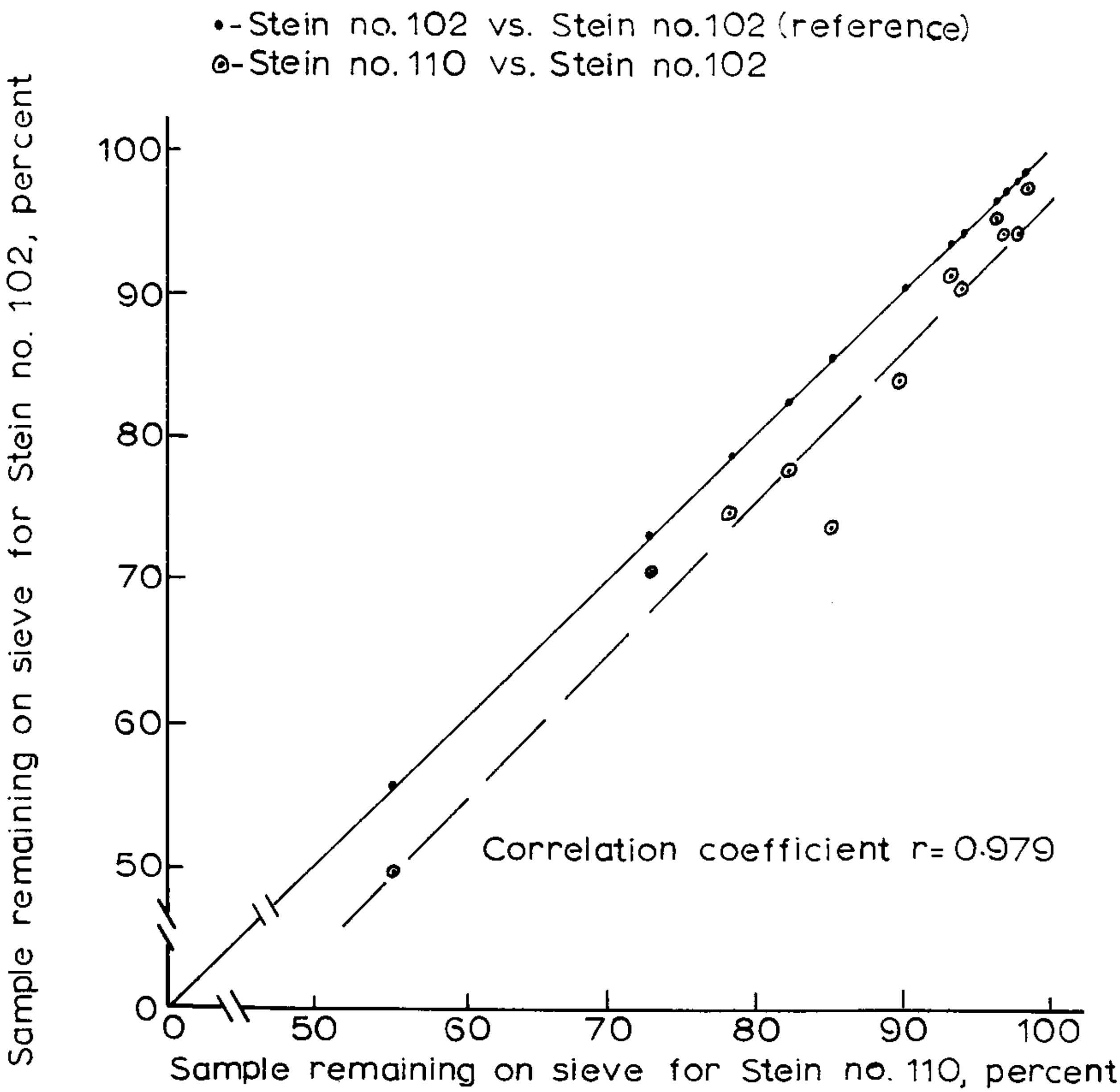

Figure 8–Means of Stein unit No. 102 versus means of Stein unit No. 110.

In spite of the limited nature of this study, both in number of machines and samples, and with differences between the machines, the results indicate that the Stein breakage tester, model CK-2, or a similar type of machine, can be used to predict the breakage-tendency of grain. The emphasis is on "breakage-tendency," since the actual breakage depends both on the physical condition of the grain at the time it is handled and on the actual conditions of the handling system.

A standard procedure should be established regardless of the details, so that each station can reproduce the results of others. The recommended procedure is as follows:

1. Weigh 100 grams of grain from a properly selected sample.

2. Place the grain in the machine, and set the automatic timer for 2 minutes.

3. Sieve the sample in the proper sieve for broken kernels (corn, 12/64 in. round; soybeans, 10/64 x 3/4 in. slot; grain sorghum, 5/64 in. triangular; wheat, 0.064 x 3/8 in. slot).

4. Weigh the part of the sample remaining on and caught in the screen. Consider this a percentage of sample remaining, or an index of breakage-tendency.

The procedure is simple enough to be adapted for field use, yet it should give adequate results for the type of test involved. The procedure is arbitrary; the sample of 100 grams and time of 2 minutes could be varied in a standard test. However, 100 grams of grain loads the machine adequately and eliminates the need to calculate percentage of sample remaining. The time of 2 minutes appears adequate for most grains.

RECOMMENDATIONS

If the grain industry feels that a test of the breakage tendency of grain is desirable, then a manufacturer of such equipment should be approached for bids on a limited number of standardized machines with the understanding that if accepted for use in the industry the same standards would be adhered to in later production. These standard machines would then be tested by the Grain Division, Consumer and Marketing Service, to determine their degree of agreement; if found acceptable, they would be put into use at selected locations.

In order to establish a standard index of breakage tendency a large number of samples are required. This can best be accomplished by placing standardized machines at various grain centers around the country and, by a standard procedure, collecting breakage data on the grain moving through commercial channels. This would consist of a breakage test and dockage test when the grain moved into the market channel and the same tests when the grain arrived at its destination. Large quantities of data from such tests could then be computer analyzed to establish a breakage index.

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