DAMAGE TO CORN FROM PNEUMATIC CONVEYING

ARS-NC-5
January 1973

AGRICULTURAL RESEARCH SERVICE • U.S. DEPARTMENT OF AGRICULTURE

CONTENTS

DAMAGE TO CORN FROM PNEUMATIC CONVEYING[1]

by Do Sup Chung, *associate professor*, Chang Joo Chung, *research assistant, Department of Agricultural Engineering, Kansas State University;* and Harry H. Converse, *Agricultural engineer, Agricultural Research Service*

SUMMARY

Mechanical damage to corn during pneumatic conveying was studied. Four variables were investigated: Corn kernel size and shape, corn moisture content, air velocity of the conveying system, and distance the corn is conveyed. The kernel sizes and shapes were: Small-small-flat, large-medium-flat, and a mixture of large-round and medium-round. Corn moisture contents were 12 and 20 percent. The corn was conveyed at four air velocities: 3,960; 5,160; 6,000; and 7,200 f.p.m. (feet per minute), and three conveying distances: 200; 800; and 1,600 feet. Mechanical damage was classified into: Breakage, broken kernels, large cracks, and small cracks.

A high conveying air velocity caused the greatest amount of corn damage. The damage caused by high air velocities was more pronounced in corn at the 12-percent moisture content. The effect of corn kernel size and shape was small. Analysis of the total-damage/conveying-distance relationship showed that the amount of damage to corn of both moisture contents was generally high for the first 200 feet, but decreased rapidly as the conveying distance increased. Analysis of the total-damage/conveying-air-velocity relationship showed that total damage to 20-percent-moisture corn increased proportionally with the increase in air velocity, but that total damage to the 12-percent-moisture corn began a sharp increase at 5,400 f.p.m.

Improper operation of a pneumatic grain conveyor can cause serious damage to corn. The lowest practical air velocity for conveying corn that is consistent with the desired rate of transfer (quantity per hour) should be used. To avoid excessive damage to low-moisture corn, the air velocity should not exceed 5,400 f.p.m.

INTRODUCTION

Recently, farmers and grain-handling firms have become increasingly concerned about economic losses that result from grain damage. Harvesting machinery probably is responsible for most of the mechanical damage to grain, but conveying methods and equipment certainly contribute to grain damage (*1*).[2]

In working with peas and wheat, Segler (*6*) found that the air velocity of the pneumatic conveying system and the moisture content of the grain conveyed were the most critical factors in the amount of grain damage. He also showed that the grain input rate, the conveyor-pipe diameter, and the temperature of the grain were relatively unimportant. Metzer (*4*) investigated the loss of seed viability that results from various operating conditions of pneumatic conveyors. Pearson and Sorenson (*5*) studied the lowered germination of grain sorghum that results from damage to the grain when it is conveyed at high velocity. They also investigated the influence of the moisture content of the grain in establishing a safe range of air velocity.

Several methods have been used to evaluate damage to grain from pneumatic conveyance. The standard germination and cold-soil emergence tests have been used to determine seed viability (*4*

[1]This report covers research conducted by Agricultural Research Service, U.S. Department of Agriculture, in cooperation with the Kansas Agricultural Experiment Station, Manhattan, and is approved as Kansas Station Contribution No. 168.

[2]Italicized numbers in parentheses refer to Literature Cited at the end of the report.

The measurement of grain breakage in the Official Grain Standards of the United States is by the sieving method (*7*). However, no acceptable method has been established for evaluating the quality of commercial grain in regard to the amount of broken or damaged kernels not separated by sieving. Recently, Kaminski (*3*) discussed the need for better standards for the evaluation of grain damage. Since inadequate information is available on the effect that handling equipment and various types of conveyors have on grain damage, little progress has been made in improving handling methods and equipment to minimize grain damage.

This report covers a study of the amount of damage that is caused to pneumatically conveyed corn as a result of the type and condition of the corn conveyed and the operating conditions of the conveying system.

DESCRIPTION OF PNEUMATIC CONVEYING SYSTEM

A pneumatic conveying system transports material in suspension, through pipes, by means of an airstream. The system used for the experimental work covered in this report consisted of an air blower with a variable-speed power unit, a rotary air-lock feeder, a conveying pipe, and a cyclone separator. Figure 1 shows a diagram of the system. The blower had the capacity to deliver air at a maximum pressure of 10 p.s.i.g. (pounds per square inch gage) continuously. A calibrated airflow meter (rotameter) was used to meausre air volume, and pressure gages were used to measure static pressure. Corn was introduced into the system through a rotary, drop-through, air-lock feeder. The amount of corn introduced was metered by a cone orifice in a surge hopper located above the feeder. The conveying pipe and elbows were aluminum, with a 1.9-inch inside diameter. The total length of the conveying pipe, from the feeder to the cyclone separator, was 200 feet. The conveying pipe included one 45° elbow and fourteen 90° elbows, each having a 24-inch radius. The elbows represented 45.6 feet of the 200-foot total length of conveying pipe.

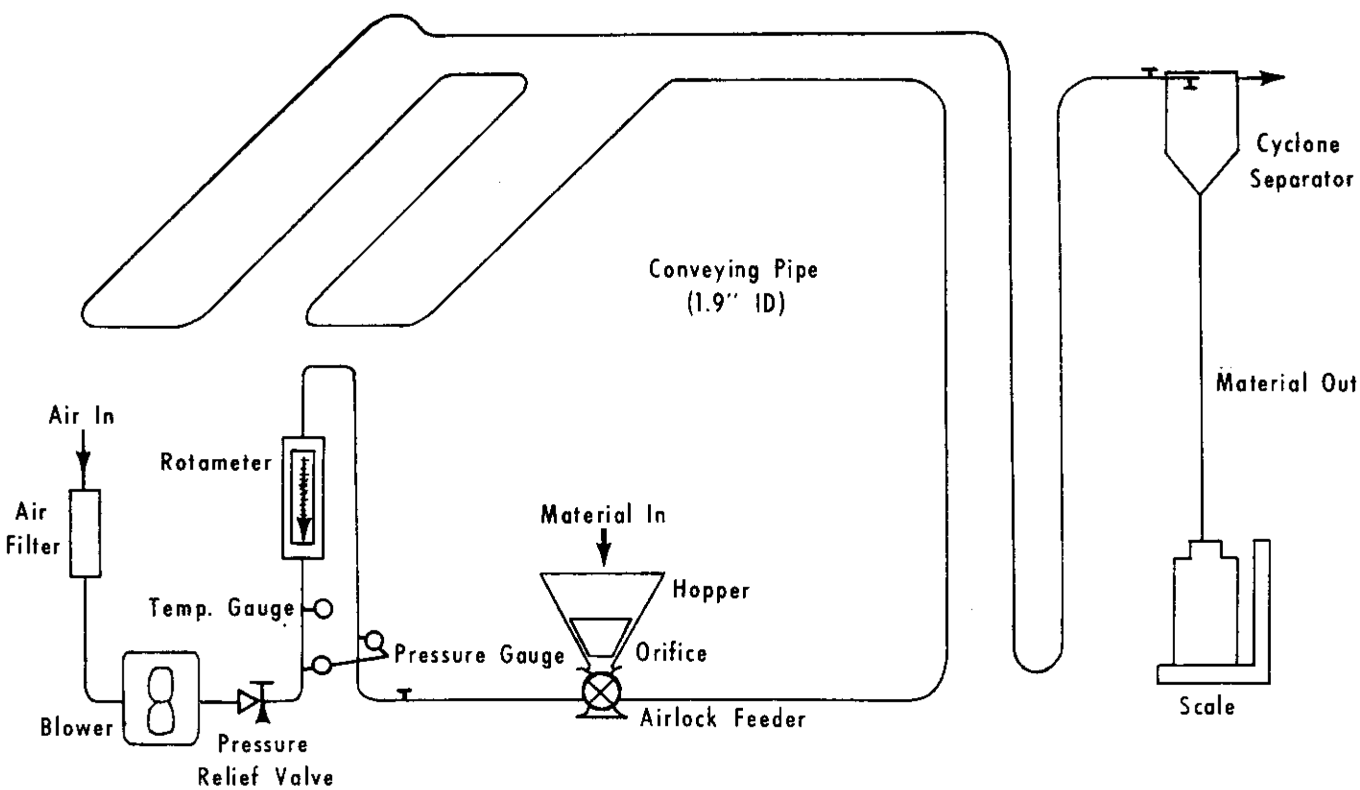

Figure 1.–Diagram of a 200-foot-long pneumatic conveying system.

PROCEDURES

To determine the damage to corn from pneumatic conveying, four variables were selected for study: Corn moisture content, kernel size and shape, air velocity of the conveying system, and distance the corn was conveyed.

The corn used for the tests was from the 1967 and 1968 crop years. It had been used previously in refrigerated storage tests not related to the tests in this study (2). The corn for both years was harvested by combine. The moisture content of the corn from the 1967 crop was approximately 27 percent at harvest; and from the 1968 crop, approximately 25 percent. In the nonrelated tests, the corn was dried in refrigerated, aerated bins; the 1967 corn to 12 percent, and the 1968 corn to 20 percent.

Corn kernels generally vary in size and shape, depending on the growing history and variety of the corn. For this study, the corn was separated into eight sizes and shapes of kernels with a corn grader.

To obtain uniform samples for testing, the sizes and shapes representing the greatest portion of the corn used in the tests (80 percent) were separated into three categories, as follows: Large-medium-flat, small-small-flat, and a mixture of large-round and medium-round.

To determine the air velocities to be used in the tests, preliminary trial tests were conducted, in which several sizes of corn kernels were conveyed in the system at several air velocities. The lowest velocity selected for use in the tests was 3,960 f.p.m. This velocity was the minimum at which all the kernels and kernel pieces remained suspended in the airstream so that they would move through the conveying pipe. Two intermediate velocities selected for use, 5,160 and 6,000 f.p.m., are within the range recommended for conveying grain in commercial practice. The highest velocity selected, 7,200 f.p.m., is considerably greater than is used in commercial practice.

The conveying distances tested were 200 feet, 800 feet, and 1,600 feet. Since the conveying pipe in the system used for the tests was only 200 feet long, the conveying distances tested were attained by multiple runs of a given test lot. The 800-foot distance required four runs, and the 1,600-foot distance, eight runs.

The four test variables studied are summarized as follows:

Moisture content: 12 and 20 percent.

Size and shape: Small-small-flat, large-medium-flat, and a mixture of large-round and medium-round.

Air velocity: 3,960, 5,160, 6,000, and 7,200 f.p.m.

Distance conveyed: 200, 800, and 1,600 ft.

The damage to corn was classified as follows:

Breakage: Fine pieces of kernels that passed through the 12/64-inch, round-hole sieve of a dockage machine.

Broken kernels: Kernels that were chipped or broken.

Large cracks: Cracks extending through the whole kernels.

Small cracks: Any mark of skin damage other than large cracks.

The total damage was the sum of the four types of damage.

To evaluate the damage caused by pneumatic conveying, it was first necessary to determine the amount of damage in the corn before the tests were run. The initial breakage was removed by screening the corn with a dockage machine. Next, 100-gram samples of each size and shape category for each moisture content were drawn from the test corn, dyed green so that chipped, cracked, or broken kernels could be distinguished from sound kernels, and visually examined. The results were averaged in terms of percentage in relation to the total weight of the test corn (table 1).

The tests were made up of 72 combinations of variables: 3 kernel sizes and shapes x 2 moisture contents x 4 air velocities x 3 conveying distances for each test. Two replications were made for each combination of variables, for a total of 144 conveying tests.

A 7-pound lot of corn was used for each of the tests. After each lot was conveyed the first 200 feet, it was screened by a dockage machine to remove the breakage. The breakage was weighed, and the amount of damage in relation to the weight of the lot was calculated in percentage. The remaining corn in the lot then was passed through a Boerner sample divider to obtain three 100-gram samples for visual examination for the other types of damage—broken kernels, large cracks, and small cracks. This corn was dyed green before the visual examination. The damaged kernels found were then separated into groups according to the type of damage and weighed. The percentage of each type of damage was calculated, as was done for breakage. The remaining corn was conveyed through three more 200-foot runs, a further 600 feet. Then the breakage and other types of damage were determined again, using the same methods as after the

Table 1.—Average[1] percentage of mechanical damage in corn before pneumatic conveying tests

Type of damage	Low-moisture corn (12%)			High-moisture corn (20%)		
	Large- and/or medium-round	Large-medium-flat	Small- small-flat	Large- and/or medium-round	Large-medium-flat	Small- small-flat
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Large cracks	3.25	3.25	2.16	2.65	2.01	0.59
Small cracks	14.47	12.42	10.99	14.34	13.94	14.85
Broken kernels	6.92	7.48	10.15	4.55	6.46	13.28

[1] Average of results from examination of six 100-gram samples.

first 200-foot conveying test. The resulting values were added to those obtained after the first 200 feet to provide values for the 800-foot conveying test. For the 1,600-foot conveying test, the remaining corn was conveyed through four more 200-foot runs, for a total of 800 feet, after which the breakage and other types of damage were again determined by the same methods used after the first 200-foot run. The resulting values were then added to the values obtained for the 800-foot run to obtain total values for the 1,600-foot conveying distance.

RESULTS AND DISCUSSION

The test data were analyzed statistically to determine the factors and interactions of factors that significantly contributed to mechanical damage during pneumatic conveying. The effect of size and shape was greater on the 20-percent-moisture corn than on the 12-percent-moisture corn; however, the effects of size and shape were small. Therefore, to simplify the presentation of test results, all the damage data presented herein are weighted averages, based on the combined results of tests with the three categories of size and shape.

The effects on breakage of both the air velocity of the conveying system and the distance that the corn was conveyed are shown in figure 2. For the 12-percent-moisture corn, and increase in air velocity and in conveying distance caused breakage to increase rapidly; however, for the 20-percent-moisture corn, the increase in breakage was small.

Figure 3 shows the broken-kernel damage in 12- and 20-percent-moisture corn when it is conveyed at air velocities varying from 3,960 to 7,200 f.p.m. for distances of 200, 800, and 1,600 feet. An increase in air velocity and in conveying distance increased the amount of broken kernels in corn of each of the moisture contents in about the same proportion as occurred for breakage.

Pneumatic conveying of corn caused less than 5 percent broken-kernel damage in the 20-percent-moisture corn, even at the highest air velocity (7,200 f.p.m.) and the longest conveying distance (1,600 ft.). In tests with the 12-percent-moisture corn, however, the use of the highest velocity and longest conveying distance tested caused about 70 percent broken-kernel damage.

The results indicated that, for corn at both moisture contents, the number of small cracks in kernels generally increased proportionally with the increase in air velocity and conveying distance. For the 12-percent-moisture corn conveyed at the highest air velocity (7,200 f.p.m.), the number of small cracks decreased rapidly after four repeated runs (a total of 800 ft. of conveying distance). The decrease in small cracks was in direct proportion to the increase in broken kernels. For corn of either moisture content, large cracks accounted for only a small percentage of the total damage.

To provide information on the level of the test variables at which the greatest change in damage occurred, curves of the relationships between total damage and conveying air velocities and between total damage and conveying distances were differentiated graphically for the three conveying distances and two corn moisture contents tested (fig. 4).

The graphical differentiation revealed that the increase in total damage to corn at each moisture content was generally high for the first 200-ft. conveying distance, but decreased rapidly as the conveying distance increased.

An analysis of the relationship between total damage and conveying air velocity revealed a difference in damage characteristics for the two moisture levels studies. For each test condition,

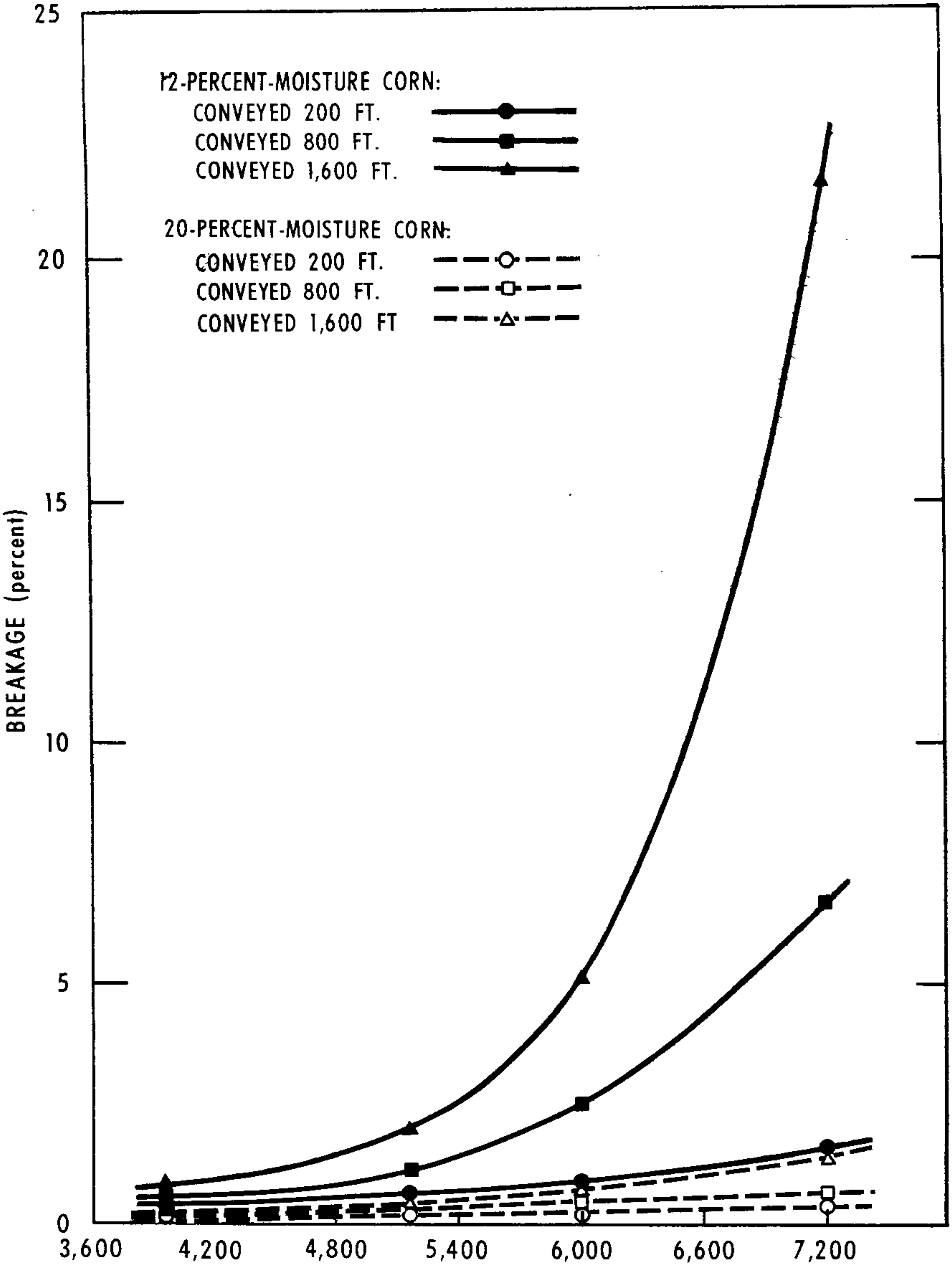

Figure 2.–Breakage during pneumatic conveying at four air velocities and three conveying distances for 12- and 20-percent-moisture corn.

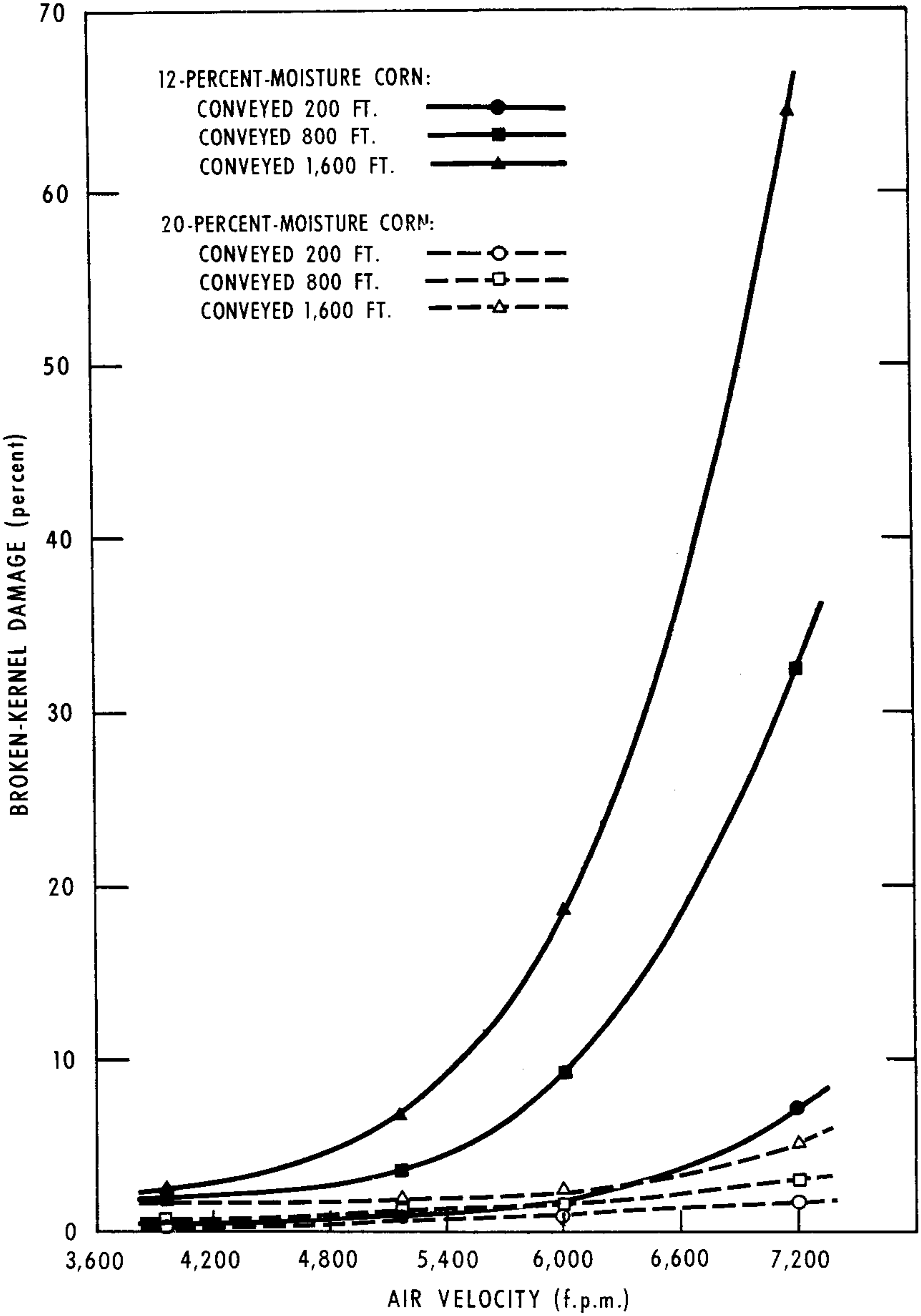

Figure 3.—Broken-kernel damage during pneumatic conveying at four air velocities and three conveying distances for 12- and 20-percent-moisture corn.

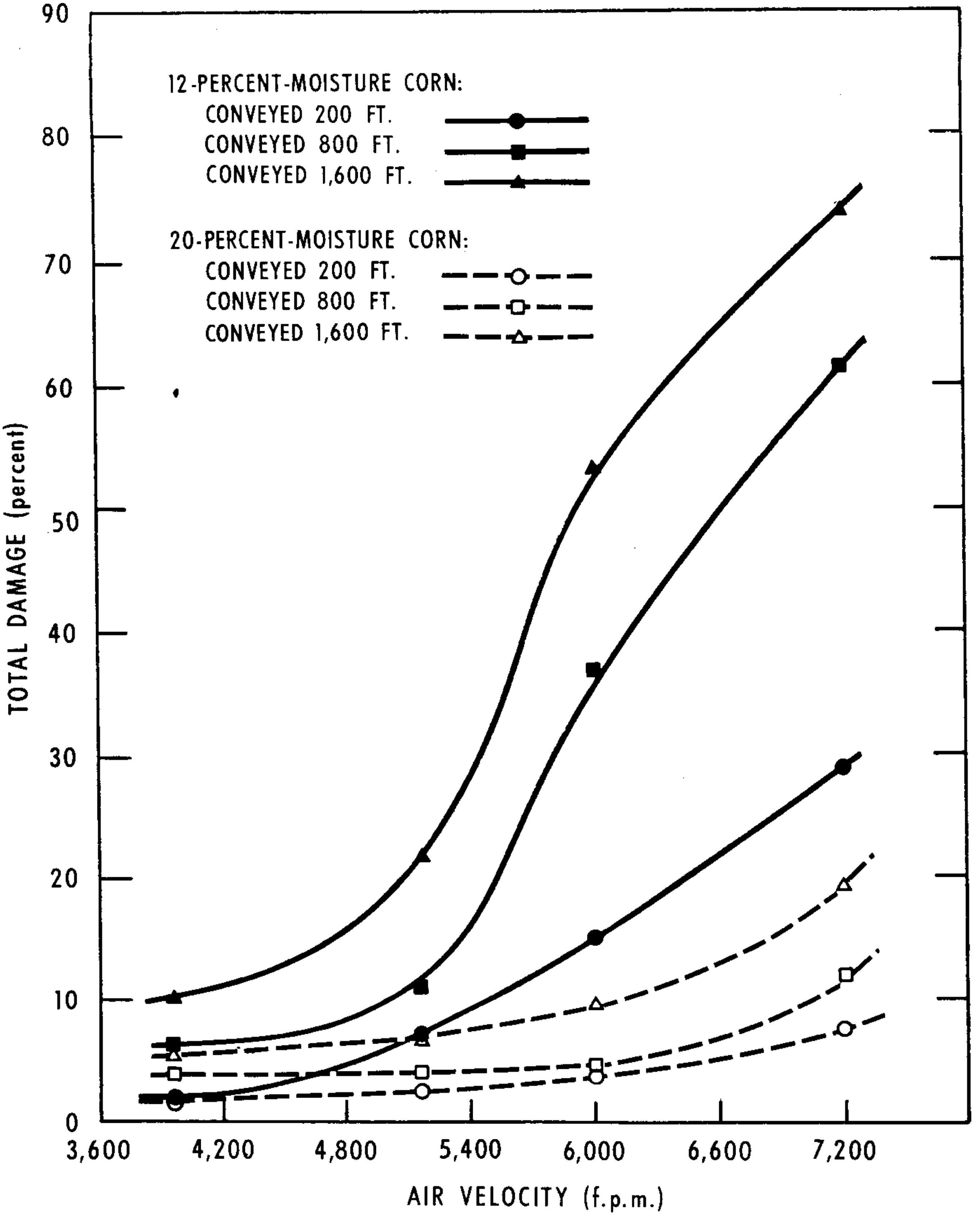

Figure 4.—Total damage during pneumatic conveying at four air velocities and three conveying distances for 12- and 20-percent-moisture corn.

the total damage from conveying was much higher in the 12-percent-moisture corn than in the 20-percent-moisture corn. For the 20-percent-moisture corn, the rate at which total damage increased was almost proportional with the increase in air velocity, regardless of the conveying distance. The total damage was comparatively low—less 20 percent—even at the highest air velocity tested (7,200 f.p.m.); therefore, successive handling of the high-moisture-content corn with a pneumatic conveyor set at the highest air velocity did not cause excessive damage. However, with the 12-percent-moisture the total damage rate began to increase sharply at about 5,400 f.p.m.

An attempt was made to predict the relationship between total damage and breakage, but total damage for a given breakage varied so widely that a reasonable prediction was not possible. However, it was found that a linear relationship exists between breakage and broken-kernel damage, though with two distinct trends. This relationship was determined by plotting breakage against broken-kernel damage on semilogarithmic graph paper (fig. 5).

The broken-kernel damage to corn that results from pneumatic conveying can be approximated from figure 5 when the amount of breakage is known. If breakage is 2 percent (the maximum limit permissible for U.S. Grade No. 1 corn), the additional damage in broken kernels can be estimated to be 13 percent from the relationships shown in figure 5.

In operating a conveying system similar to the one used in this investigation, the limits of conveying air velocity and conveying distance can be set according to the amount of damage permissible. Table 2 shows the estimated limits for these variables to satisfy the grade requirements for No. 1 and No. 2 corn.

Table 2.–Estimated limits of conveying-air velocity and conveying distance that would not cause damage to exceed grade requirements for No. 1 and No. 2 corn

Grade	Maximum breakage permissible	High moisture (20%)		Low moisture (12%)	
		Air velocity	Conveying distance	Air velocity	Conveying distance
	Pct.	*F.p.m.*	*Ft.*	*F.p.m.*	*Ft.*
		7,200	< 800	7,200	< 200
1	2	6,000	< 1,600	6,000	< 400
		5,160	> 1,600	5,160	< 1,400
		---	---	3,960	> 1,600
		7,200	< 1,400	7,200	< 300
2	3	6,000	> 1,600	6,000	< 700
		---	---	5,160	< 1,600
		---	---	5,160	< 1,600
		---	---	3,960	> 1,600

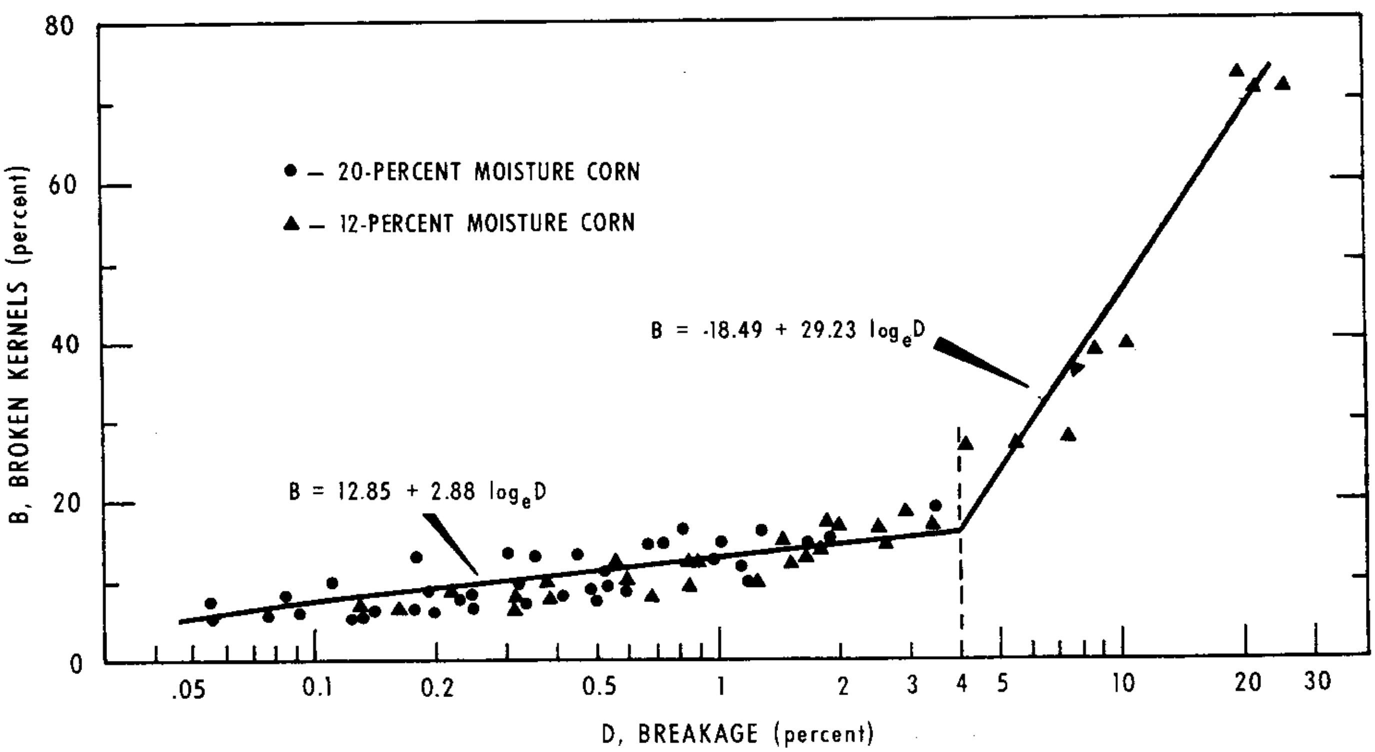

Figure 5.–Relationship between the percentage of breakage removed from pneumatically conveyed corn by sieving and the percentage of broken kernels remaining in the sample.

In some instances, corn quality factors, in addition to U.S. grade factors, are important. If total damage is the most important consideration, the appropriate operating conditions can be estimated from table 3, which shows the conveying distances and velocities permissible to stay within two limits of damage from pneumatic conveying.

If operated improperly, a pneumatic grain conveyor can cause serious damage to corn. In the interest of conserving energy and maintaining reasonable operating costs, farmers and grain-handling firms should use the lowest practical air velocity for conveying corn that is consistent with the desired rate of transfer (quantity per hour). To avoid excessive damage to low-moisture corn, air velocity should not exceed 5,400 f.p.m.

Table 3.–Estimated limits of conveying-air velocity and conveying distance that would not cause total damage beyond given percentages

Total damage permissible	High moisture (20%)		Low moisture (12%)	
	Air velocity	Conveying distance	Air velocity	Conveying distance
Pct.	*F.p.m.*	*Ft.*	*F.p.m.*	*Ft.*
	7,200	500	7,200	0
10	6,000	1,600	6,000	0
	---	---	5,160	600
	---	---	3,960	1,400
	7,200	1,600	7,200	0
20	6,000	1,600	6,000	300
	---	---	5,160	1,400
	---	---	3,960	1,600

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AGRICULTURAL RESEARCH SERVICE
NORTH CENTRAL REGION
PIONEER INDUSTRIAL PARK
2000 WEST PIONEER PARKWAY
PEORIA, ILLINOIS 61614