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MECHANICAL DAMAGE TO WHEAT IN PNEUMATIC CONVEYING

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SUMMARY:

Effects of air velocity and conveying distance on mechanical damage to wheat were determined for two varieties and moisture contents and evaluated by percentage of fine material generated.

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INTRODUCTION

Damage to hard winter wheat from pneumatic conveying was studied in the laboratory. The purpose of the investigation was to determine the effects of air velocity, conveying distance, wheat variety, and harvesting conditions on damage to wheat during pneumatic conveying. Kernel damage in the form of broken kernels and fine grain material reduces the value of wheat when marketed. Handling wheat by pneumatic systems is quite common in grain processing plants and is becoming more common in other segments of the grain industry.

Pioneering and extensive work in the area of damage evaluation in a pneumatic conveying system was done by Segler (9)[2/]. His experiments investigated the influence of air velocity, grain moisture content, grain temperature, pipe size and throughput on grain damage. Gasterstadt (6) was first to point out the occurrence of damage to grain when it is conveyed with too high an air velocity.

In his work on conveying velocities, Alden (1) points out that for a given pipe diameter, the material handling capacity increases as the cube of the velocity. For wheat he recommends velocities of 5,000 to 7,000 feet per minute (f.p.m.). Person and Sorenson (8) found that the minimum air velocities for conveying ranged from approximately 3,000 f.p.m. to 4,700 f.p.m. depending on the grain capacity required.

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2/ Underscored numbers in parentheses refer to REFERENCES, p. 5

Bilanski (2) and co-workers published the terminal velocities of various seed grain. For wheat the average terminal velocity was 29.5 feet per second (f.p.s.).

Bilanski (3), in an attempt to determine the energies and forces involved in damaging grain during threshing, cleaning and conveying, predicted that the history of the grain kernel will affect its damage resistance. For example, the stage of maturity at which the grain was threshed and the storage conditions affected susceptibility to mechanical damage. Fischer (4) suggested that the physical characteristics, such as size, bulk density and degree of hygroscopicity of the material, should be taken into consideration in designing a pneumatic conveyor.

Milner and Shellenberger (7) used X-ray techniques to find internal fissures in weathered wheat. In their studies, changes in physical properties due to weathering, wetting and drying were discussed in terms of radiographical evidence of internal fissures.

TEST PROCEDURE AND EQUIPMENT

Experiments were conducted using a low-volume medium pressure pneumatic conveying system as shown schematically in figure 1. A positive displacement air blower with a maximum pressure of 10 p.s.i.g., a rotary drop-through airlock feeder with a surge hopper and a cyclone separator were components in the system. A circular cone orifice fitted in the surge hopper maintained a uniform feeding rate throughout the experiments. The conveying pipes were 1.9 inches in inside diameter, were 200 feet long and had fourteen 90-degree elbows and one 45-degree elbow; all the elbows had radii of curvature of 24 inches.

The volume of air was regulated by changing the blower speed and was measured with a flow meter made by Fischer and Porter Co. (5). The flow meter was calibrated at its maximum capacity of 180 cubic feet of air per minute at 2 p.s.i.g. and 100 degrees F. The temperature and pressure of the air were measured ahead of the meter to provide data for applying correction factors for air at other pressures and temperatures.

The damage to the wheat from conveying through the system was measured in terms of broken kernel and fines as determined by screening the sample. A Ro-Tap machine was used with a set of Tyler sieves composed of screen numbers 5, 6, 7, 8, 10, 14, 28 and the pan. The damage was based on the percentage by weight of broken kernels and fines passing through the No. 10 mesh screen after the Ro-Tap machine was run for 5 minutes.

Two varieties of winter wheat grown in Kansas, Scout and Ottawa, combine-harvested in 1968 and 1969, were selected for testing on the basis of their particle size, or weight per thousand kernels. The 1968 wheat samples were harvested in the last week of June from Kansas State University experimental field at Hutchinson in Reno county. The samples were stored in bags at room temperature until tested. The 1969 Scout variety was harvested in the last week of June in Stafford county, Kansas. The 1969 Ottawa variety was harvested in the second week of July in Geary and Saline counties after a week's delay due to rainy weather. The wheat from 1969 harvest was tested soon after harvested.

Five hundred grams of dockage free wheat were used for each test. Some of the physical and mechanical properties of the test wheat are shown in table 1. The Scout variety tested in 1969 had a higher moisture content than the other three samples. The samples all contained a few broken kernels before conveying through the system.

A factorial experimental design was used with 4 levels of conveying air velocity, 4 levels of conveying length, 2 varieties and 2 crop years. There were 64 (4 x 4 x 2 x 2) treatment combinations for each replication. Three replications were made for each treatment combination.

Air velocities used were 96, 102, 110, and 120 feet per second. The conveying lengths were obtained by conveying the same wheat repeatedly through the 200-foot system.

RESULTS AND DISCUSSION

All four factors, conveying velocity, conveying distance, wheat variety, crop year or age, had significant effects on the extent of mechanical damage caused by pneumatic conveying. Included in the crop year factor were such parameters as harvest maturity, age, and moisture content. The effects of crop year and variety were more important than conveying velocity and length.

The results of these tests are summarized in table 2. The average percentage fines produced in each test are listed according to variety, conveying air velocity, and distance conveyed. Harvest and combine weather conditions were considered normal the first year, while in the second year, the two varieties were harvested at different stages of maturity and under different field conditions. Thus, comparisons between varieties in 1969 are less valid than in the 1968 tests.

The effect of the conveying air velocity in the percentage of fines for the two varieties in 1968 are shown in figure 2. It is apparent that the fines produced are about proportional to the conveying length or distance. For the same test conditions, the fines produced in Ottawa wheat were less than half those produced in Scout.

A similar graphical presentation of the results of the 1969 crop test wheat is shown in figure 3. The relationship of conveying velocity and distance to the percentage of fines was similar to that in the 1968 crop. However, the level of damage according to variety was reversed, with the damage in the Ottawa wheat nearly twice that in the Scout. This suggests that the unfavorable harvesting conditions in 1969 had a more important effect on damage than the variety grown. The higher moisture content in the 1969 Scout variety was likely important in reducing the damage.

Radiographical examination was made to determine the internal cracks and fissures in representative wheat kernels from each lot of test grain. The examination indicated internal cracks present in 30 percent of the 1968 Scout, 28 percent of the 1969 Scout, 20 percent in the 1968 Ottawa, and 91 percent in the 1969 Ottawa varieties. The increased internal damage and number of shrunken kernels in the 1969 Ottawa variety reflects the poor harvesting conditions and contributed to the large percentage of fines.

CONCLUSIONS

The kernel breakage and fines produced in wheat by pneumatic conveying ranged from about 0.1 to slightly over 1.0 percent per thousand feet conveyed when air velocities of 96 to 120 f.p.s. were used. The breakage was about in proportion to the distance conveyed. In all tests the percentage of fines produced increased sharply when conveying air speeds were increased from 110 to 120 f.p.s.

There were significant differences between the fines produced in the two varieties and in the two crop years. The crop year, especially the harvesting conditions for the crop year, appears more important than the variety. The breakage in the Scout wheat was about double that in Ottawa in 1968, but only half that of Ottawa in 1969, when the harvest of the Ottawa wheat was delayed by rainy weather.

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TABLE 1.--Some physical and mechanical properties of test wheat

Variety	Location	Moisture content wet basis 1/	Weight per thousand kernels 1/	Test weight per bushel 1/	Compressive strength 2/	Percentage fines before handling 3/
		Percent	Grams	Lb./bu.	Pounds	Percent
Scout 1968	Hutchinson	10.13	33.4143	62.50	20.065	0.087
Ottawa 1968	Hutchinson	10.07	25.9320	62.15	19.84	0.064
Scout 1969	Stafford county	12.75	31.9233	60.03	17.58	0.079
Ottawa 1969	Geary and Saline counties	10.55	24.1185	57.10	17.06	0.333

1/ Average of 3 replications
2/ Average of 40 kernels
3/ Average of 12 replications

TABLE 2.--Average percentage fines produced by pneumatic conveying of Scout and Ottawa wheat varieties grown in 1968 and 1969

Conveying air velocity	Distance conveyed	Average percentage fines from three replications			
		Scout		Ottawa	
		1968	1969	1968	1969
Ft./sec.	Feet	Percent	Percent	Percent	Percent
96	0	0.072	0.076	0.060	0.330
	1,000	0.316	0.182	0.106	0.489
	2,000	0.607	0.328	0.226	0.863
	3,000	0.922	0.478	0.330	1.198
	4,000	1.210	0.613	0.452	1.528
102	0	0.102	0.086	0.061	0.326
	1,000	0.345	0.266	0.189	0.646
	2,000	0.644	0.508	0.353	1.111
	3,000	1.021	0.748	0.499	1.559
	4,000	1.357	1.028	0.644	1.999
110	0	0.090	0.070	0.057	0.400
	1,000	0.511	0.290	0.220	0.733
	2,000	0.987	0.551	0.500	1.378
	3,000	1.477	0.831	0.767	1.967
	4,000	2.021	1.111	1.051	2.580
120	0	0.084	0.083	0.076	0.276
	1,000	0.709	0.489	0.335	1.078
	2,000	1.526	0.994	0.711	2.051
	3,000	2.489	1.595	1.087	3.158
	4,000	3.612	2.410	1.506	4.541

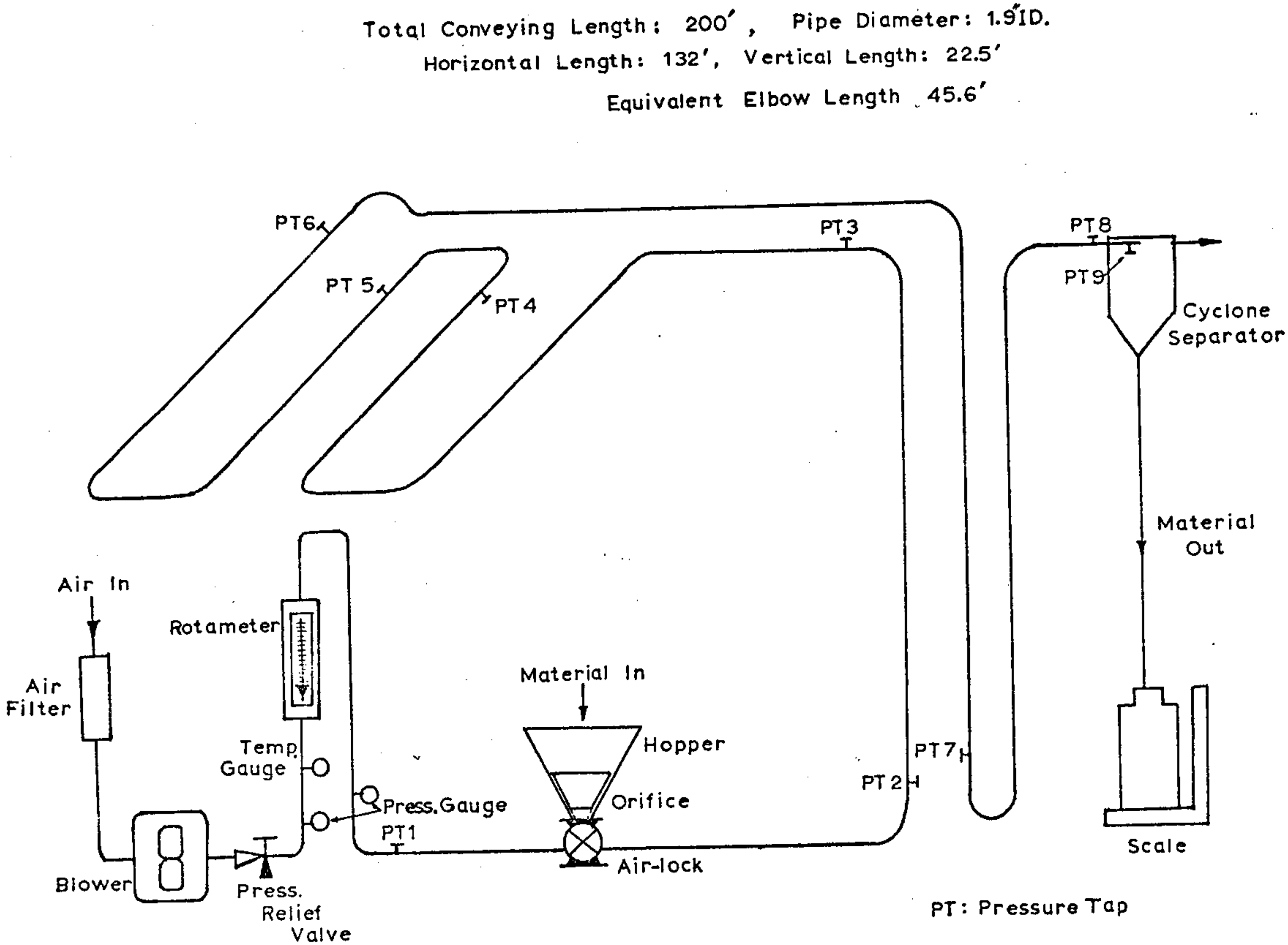

Figure 1.--A schematic diagram of pneumatic conveying system.

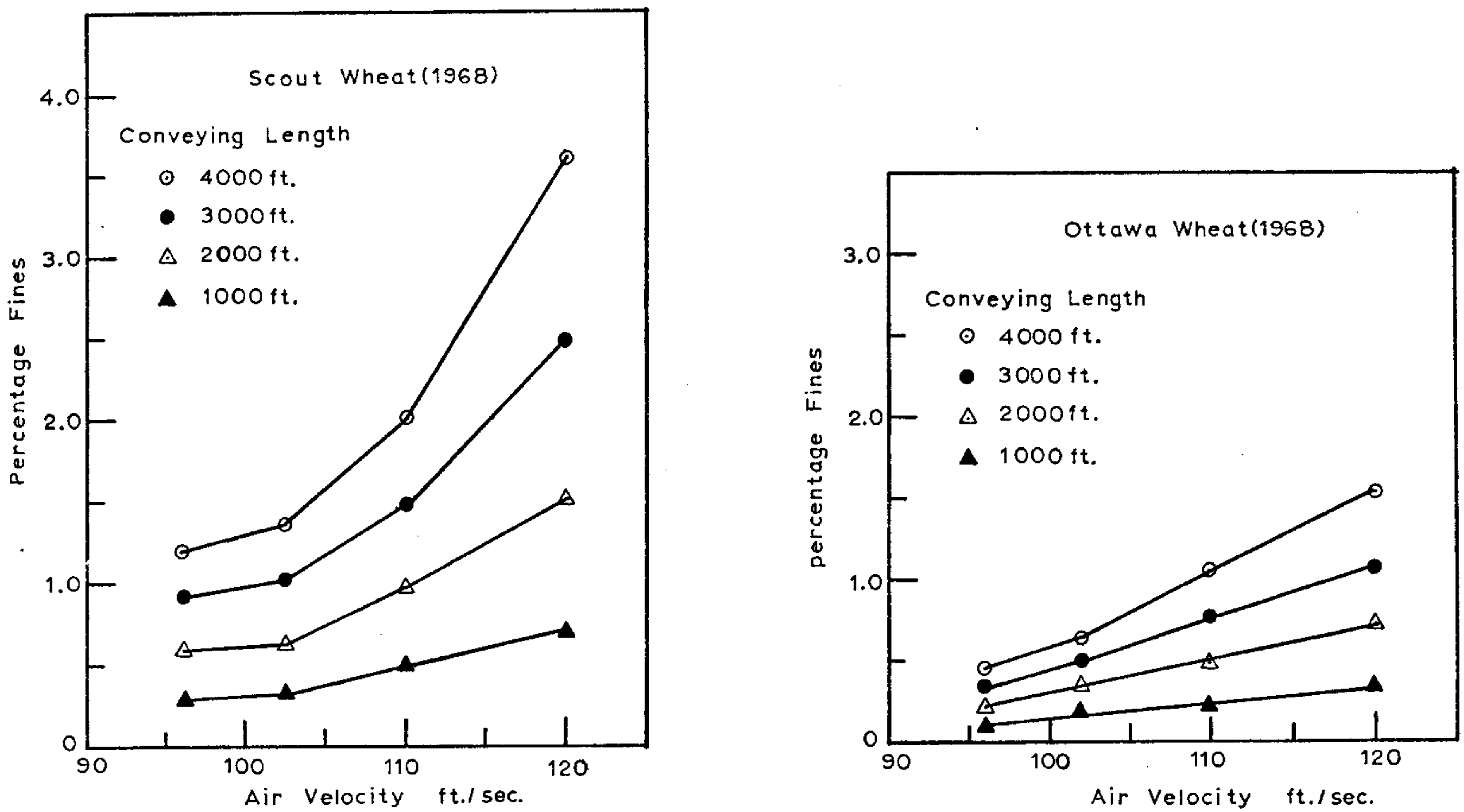

Figure 2.--Effect of conveying air velocity and length on the percentage fines produced in 1968 wheat.

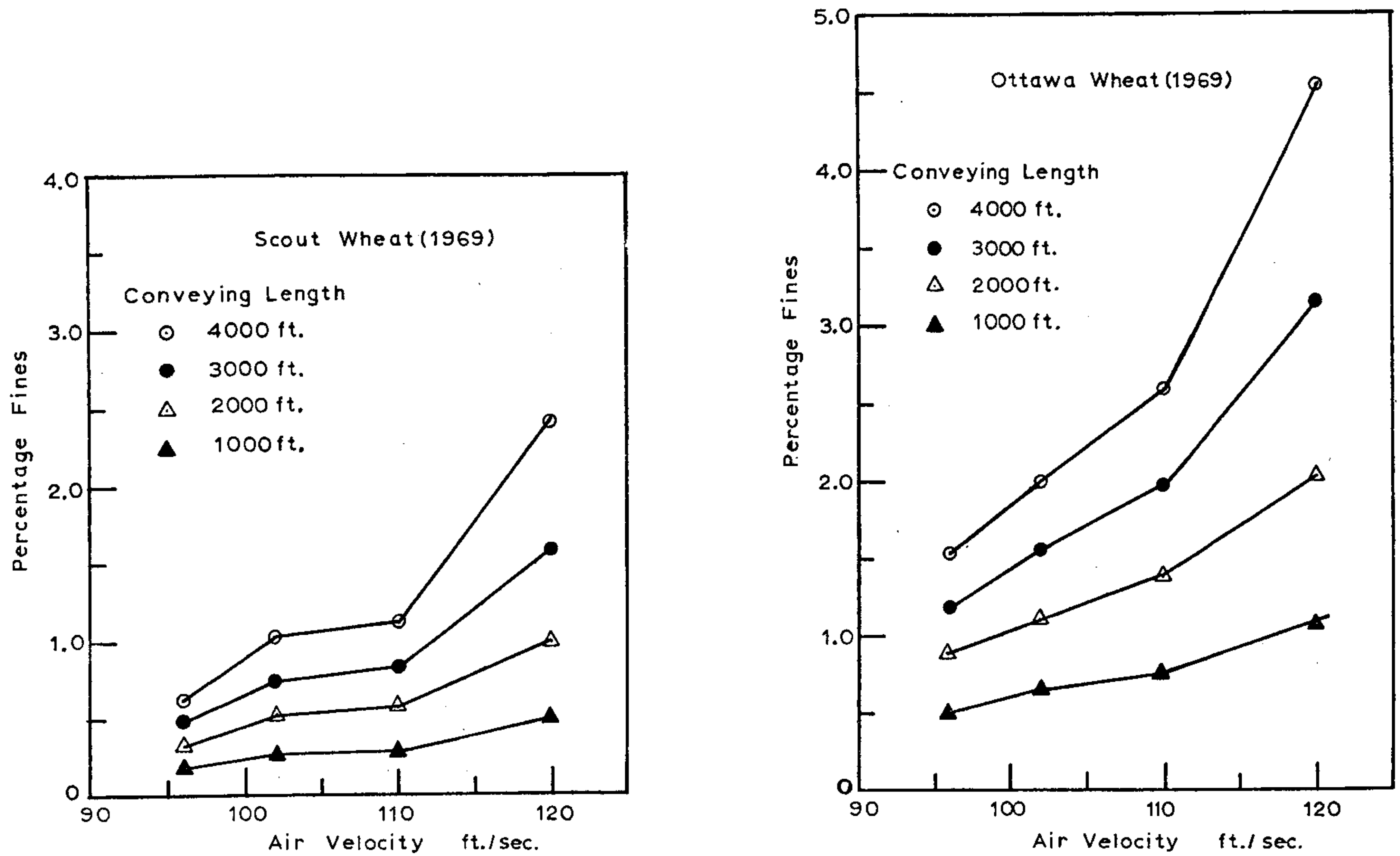

Figure 3.--Effect of conveying air velocity and length on the percentage fines produced in 1969 wheat.