Paper No. 67-843

DRYERATION - HIGH SPEED DRYING WITH DELAYED AERATION COOLING

By

Ralph A. Thompson and George H. Foster
Agricultural Engineers

Transportation and Facilities Research Division
Agricultural Research Service
U. S. Department of Agriculture
Lafayette, Indiana

For presentation at the 1967 Winter Meeting
AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS
Cobo Hall
Detroit, Michigan
December 12-15, 1967

DRYERATION - HIGH SPEED DRYING WITH DELAYED AERATION COOLING

by

Ralph A. Thompson and George H. Foster

In 1966, two-thirds of the Indiana corn crop was field shelled (1) mainly by the use of corn combines. 1/ The extensive use of high-capacity combines, some capable of shelling up to 5,000 bushels of wet corn per day, tends to reduce the length of the harvest season. A three- to four-week harvest in certain localities with good field conditions has been predicted. These developments have put more pressure on drying equipment to keep pace with the harvest. Since the drying operation is often the bottleneck, the need for increased capacity has frequently resulted in the use of poor drying techniques in an attempt to stay ahead of the flood of wet corn. Also, corn combines can injure wet kernels, making them more perishable. Exporters of corn as well as domestic users have been critical of the quality of artificially dried grain.

DRYING RESEARCH CONDUCTED

Tests were started in 1959 to evaluate drying methods for field shelled corn. Most of the tests were conducted in a tower-type, continuous-flow dryer located at the Purdue Agronomy Farm. Maintenance of market quality was emphasized in the test program. Partial results of this work were reported in 1963 and 1965 (2) (3). The brittleness of field shelled corn dried rapidly was the first problem encountered. The effect of drying temperature on corn destined for the corn refiners was also evaluated. This work showed that corn was damaged for use by refiners when the corn reached temperatures above 140-150°F. When corn was dried to 14 percent from moistures above 20 percent using conventional drying methods, the permissible input air temperature was limited to 200°F or less. However, the brittleness problem persisted even at lower drying temperatures and led to the development of the Dryeration process (4).

Tests conducted both in the field and in the laboratory indicated that rapid cooling of hot corn after drying contributed to its brittleness by producing numerous hairline cracks in the kernel endosperm. These fissures were classified according to pattern (2) and termed "stress cracks." Examination of hot corn before cooling showed relatively few stress cracks. It appeared that much of the damage occurred when the stresses due to rapid cooling were added to the stresses built up during heat drying. Allowing the hot corn to temper (steam in its own vapor) before cooling and relieve some of the drying stress reduced the brittleness of dried corn.

1/ Numbers in parentheses refer to literature cited in the References at the end of this paper.

This paper reports research carried out by the Transportation and Facilities Research Division, Agricultural Research Service, USDA, in cooperation with the Purdue Agricultural Experiment Station.

THE DRYERATION PROCESS

Heated air drying and delayed aeration cooling are combined in the process called Dryeration. Dryeration increases the capacity of existing drying equipment while maintaining corn quality. It may be adapted to either batch or continuous-flow drying.

In conventional dryers, corn is dried by passing heated air through it until the desired moisture level is reached. Residual heat is then removed by forced ventilation with outdoor air until the corn is near ambient temperature.

In the Dryeration process, no cooling is done in the dryer. The process, illustrated in figure 1, consists of three essential steps. First, corn is rapidly dried with heated air to about the 16 percent moisture level. Then drying is stopped while moisture is still being evaporated readily from the corn kernel. The evaporation keeps the corn relatively cool and limits the drying stress.

Second, the corn is removed from the dryer while still hot and allowed to temper a few hours before cooling is started in a supplemental bin equipped for aeration. Tempering equalizes the moisture within the kernel and relaxes the stresses built up during drying.

The third and final step in the Dryeration process is to cool the corn slowly after tempering to use the residual heat in the corn to the maximum in removing more moisture. Slow cooling also minimizes the added stress associated with change in kernel temperature.

DRYERATION TESTS

The development and testing of the Dryeration process extended over a five-year period. The chronology of the development and the objective of each year's test program was as follows:

1. 1962 - Three full-scale tests were conducted to explore the feasibility of the Dryeration procedure.

2. 1963 - A series of nine tests covered the range of drying air temperatures used in previous tests of conventional drying methods. Drying was stopped at final corn moisture contents of 18, 16, and 14 percent to evaluate various combinations of drying air temperature and final moisture content that would produce corn of acceptable quality.

3. 1964 - Direct comparisons were made between the Dryeration process and conventional drying. Also included in this test series were two-stage drying tests where the conventional heated-air drying was interrupted by tempering overnight between stages. An additional tempering period followed the last stage. Corn was dried from 25 to 20 percent moisture during the first stage and from 20 to 15 percent moisture during the second stage. All tests were designed to give a final moisture content of 14 percent. The drying air temperatures were 190, 240, and 290°F.

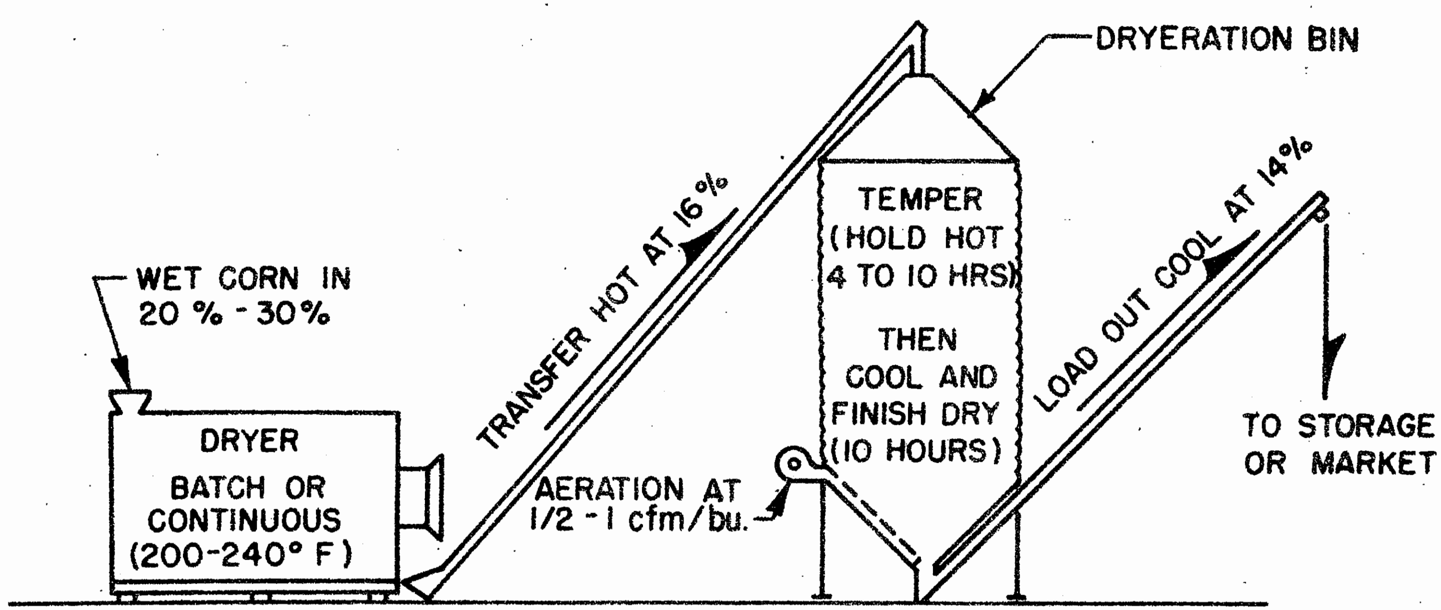

FIGURE 1. SCHEMATIC OF THE DRYERATION PROCESS.

4. 1965 - The tests were directed toward further study of the cooling phase of the Dryeration process. Four airflow rates ranging from 0.2 to 1.0 cubic foot per minute (cfm) per bushel were used to cool the corn after tempering periods of 2, 4, 8, and 12 hours. A drying air temperature of 240°F was used.

5. 1966 - Using the optimum tempering time indicated by the 1965 tests, airflow rates of 0.1, 0.25, and 0.5 cfm per bushel were used to compare upward versus downward airflow during the cooling phase. A drying air temperature of 240°F was used. Some of the test lots were stored in the same bins where they were cooled to evaluate the possibility of eliminating the extra handling step required to move corn through the tempering bin.

TEST PROCEDURE

The corn used in the Dryeration tests was single cross hybrid, field shelled with a corn combine at 24 to 26 percent moisture content. This test corn was usually dried within two days after harvest; otherwise, it was placed in an airtight bin and cooled overnight with refrigerated air to about 45°F. No wet corn was stored more than one week before drying. In the conventional drying method, the corn was reduced to 14 percent moisture content and cooled in the dryer. In the Dryeration method, corn was removed hot at 16 percent moisture except in the 1963 tests. Aeration cooling removed the additional moisture required for safe storage or market.

The hot corn from the dryer was cooled in batches of 300 to 700 bushels. Tempering and cooling was done in Dryeration bins either seven feet square or nine feet in diameter.

Corn samples were taken throughout the test period for moisture determination and for quality tests. Control samples and those taken from the dryer at an elevated moisture content were slowly dried to 14 percent with forced room air in screened-bottom trays.

Measurements to determine the aeration airflow rates were made with anemometers. The air passing through the grain was directed through either an eight-inch diameter pipe or a four-inch nozzle, as appropriate, to determine air velocity.

Temperature measurements were made with thermocouples installed in the continuous-flow dryer and the aeration cooling bins. The thermocouples were connected to a potentiometer that recorded the temperatures each 20 minutes during the tests.

The amount of corn passing through the dryer was determined by use of a six-bushel automatic dump scale.

The dryer held about 400 bushels of corn at one time, about 3/5 in the heating section and 2/5 in the cooling section. When adapted for Dryeration, heated air was diverted into the cooling section and the separate cooling fan blocked. In conventional drying, about 65 cfm of air was supplied to each bushel in the heating section. However, when adapted for Dryeration, the heated airflow rate was about 45 cfm per bushel.

A meter recorded the fuel (LP gas) input to the dryer. An extra burner was used to provide additional heat needed when the dryer was adapted for Dryeration.

EFFECT OF DRYERATION ON CORN QUALITY

Dryeration relates more directly to the reduction of stress cracks and breakage in corn dried by heated air than to any other quality factor. Table 1 shows that the number of checked kernels was reduced from 43.6 to 7.6 percent and breakage from 11.3 to 6.7 percent when Dryeration was used instead of conventional drying and cooling. Considering the average of 5.6 percent breakage in control samples dried with room air, Dryeration reduced the breakage attributable to heated air drying by 80 percent. Damage during field shelling contributed about as much to breakage as conventional drying, as indicated by the high level of breakage in the control samples. Although the two-stage drying method produced less checked kernels than Dryeration, the amount of breakage was slightly more.

TABLE 1.--Stress crack and kernel breakage reduction with Dryeration 1/

Drying method	Checked kernels	Breakage 2/
	Percent	Percent
Conventional drying and cooling	43.6	11.3
Dryeration	7.6	6.7
Two-stage Dryeration	4.9	7.0
Control 3/	1.5	5.6

1/ Based on three tests by each method for drying corn from 25 to 14% moisture in 1964.
2/ Breakage percentages determined on small samples with a laboratory breakage tester.
3/ Control samples dried in screened-bottom trays with air at room temperature.

The damage associated with moving hot corn from the dryer to the tempering bin with augers and bucket elevators was assessed. Samples were obtained with pneumatic spout samplers as the corn moved to and from the dryer and from the tempering bin to storage after cooling. Table 2 shows that the fines associated with Dryeration was less than that in the wet corn from the field sheller. Only a small increase in fines was associated with handling the corn through the tempering bin. It appears that handling hot corn from the dryer does not unduly increase breakage and the production of fines.

TABLE 2.--Fine material produced at different phases of the Dryeration process 1/

Sample	Material passing 12/64" round-hole sieve
	Percent
Into dryer from field sheller	1.4
Out of dryer into tempering bin	1.8
Out of tempering bin into storage	1.9

1/ Based on sixteen tests where corn was dried from 25 to 14% moisture in 1965.

The kernel temperature of the corn leaving the dryer was substantially less than that of the drying air (table 3). The difference between the two temperatures diminished as the corn was dried to a lower moisture content. Thus, a higher drying air temperature is permissible when the corn is removed from the dryer at a higher moisture content. For example, table 3 shows that corn dried to 18 percent with 277°F air had the same kernel temperature as corn dried to 16 percent with 232°F air.

TABLE 3.--The relationship of the moisture content and the temperature of corn discharged from the dryer 1/

Drying air temperature	Corn temperature leaving dryer at moisture contents of -		
	18%	16%	14%
°F	°F	°F	°F
187	127	128	138
232	142	148	156
277	148	155	160

1/ Based on tests conducted in 1963 with 25% moisture corn.

Both excessive corn temperatures during drying and the drying method affected the millability of the corn, as shown in table 4.

The use of 290°F drying air produced corn temperatures of 160°F or above and an unacceptable milling score. The low milling score from the two-stage test at 290°F may have resulted from holding the hot corn overnight between passes. The final corn temperatures were the same in the single stage and two-stage Dryeration tests.

TABLE 4.--Effect of grain temperatures on milling properties of corn dried with conventional method and with Dryeration 1/

Drying air temperature	Conventional drying and cooling		Dryeration		Two-stage Dryeration	
	Corn temperature	Millability score 2/	Corn temperature	Millability score 2/	Corn temperature	Millability score 2/
°F	°F		°F		°F	
190	148	92.6	134	89.2	134	88.4
240	171	80.2	151	82.0	151	82.8
290	186	58.4	160	74.4	160	47.4

1/ Based on 1964 tests where corn was dried from 26 to 14% moisture. The corn temperatures were an average taken at the discharge of the heat section of the dryer.

2/ Measured by prime starch method developed by Watson (5). Score of 80 and above is acceptable. The scores of control samples dried without heat averaged 89.7.

Effect of Tempering Time and Cooling Rate on Corn Quality

Tests were conducted in 1965 to determine (1) the optimum tempering time between the drying and cooling stage of the process and (2) the effect of the cooling time and airflow rate on both moisture removal and corn quality.

Table 5 shows the highest number of sound kernels occurred with a tempering time of 12 hours. Tempering times over 12 hours were not included in the tests, but may prove desirable if the brittleness of the dried corn is the major consideration. At tempering times of over 2 hours, there was a slight reduction in milling score.

TABLE 5.--Effect of tempering time on quality 1/

Tempering time	Sound kernels (without stress cracks)	Millability score
Hours	Percent	
2	43.8	90.2
4	54.1	86.2
8	60.2	87.3
12	63.0	87.1

1/ Average of four 1965 tests at each tempering time.

Table 6 shows that the lowest cooling rate tested (0.2 cfm per bushel) produced the highest percentage of sound kernels.

TABLE 6.--Effect of cooling rate on quality 1/

Cooling airflow rate	Approximate cooling time 2/	Sound kernels (without stress cracks)	Millability score
cfm/bu	Hours	Percent	
0.2	30	64.0	84.8
0.35	18	51.7	87.3
0.5	12	52.8	88.4
1.0	6	52.6	90.4

1/ Average of four 1965 tests at each airflow rate.
2/ Number of fan hours required to cool all the corn to 70°F or below.

Tables 5 and 6 show that the highest milling scores were obtained with the shortest tempering time and the shortest cooling period. While excessive brittleness was prevented by increasing the length of the tempering and cooling periods, the damage to milling quality tended to increase.

The efficient utilization of the residual heat in the hot, dried corn is the key to the success of Dryeration. Maximizing the moisture removal in the cooling stage not only adds to process efficiency but also permits stopping the heated air drying at the highest possible moisture level. Thus, the amount of moisture removed during the cooling phase is an important consideration along with the corn quality factors.

Table 7 shows the amount of moisture (in percentage points) removed from hot corn when aerated in the Dryeration bin at different moisture contents. With an increase in drying air temperature, the grain temperature was higher (see tables 3 and 11) at a given moisture level leaving the dryer and the amount of moisture removed was increased. The moisture content of the hot corn affected the amount of moisture removed less than the corn temperature.

TABLE 7.--The moisture removed during delayed aeration cooling of hot corn 1/

Drying air temperature	Percentage loss of moisture during cooling--corn leaving dryer at moisture percent of -			
	18	16	14	Ave.
°F	Percent	Percent	Percent	Percent
187	1.9	1.8	1.5	1.7
232	2.1	2.2	2.0	2.1
277	2.7	2.7	2.1	2.5
Ave.	2.2	2.2	1.8	

1/ Based on tests conducted in 1963 with 25% moisture corn. Aeration was maintained at an airflow of about 0.5 cfm per bushel.

Table 8 shows that the amount of moisture removed increased with tempering time up to 8 hours. Considering airflow rates, the maximum moisture removal occurred at 0.5 cfm per bushel. The reduced moisture removal at the low airflow rates may be attributable to the conductive heat losses that extend over the longer cooling period. Also, low airflow rates removed less water because more moisture accumulated in the corn near where the air exhausted.

TABLE 8.--Effect of tempering time and cooling airflow rate on the percentage points of moisture removed during aeration of hot corn 1/

Cooling airflow rate	Moisture removed after tempering time (hours) of - 2	4	8	12	Ave.
cfm/bu	Percent	Percent	Percent	Percent	Percent
0.2	0.5	0.8	1.8	0.3	1.1
0.35	1.3	1.7	2.0	1.4	1.6
0.5	2.1	2.0	2.0	1.7	2.0
1.0	2.0	2.0	1.8	1.5	1.8
Ave.	1.5	1.6	1.9	1.2	

1/ Based on 1965 tests with corn leaving the dryer at 16% moisture content.

A comparison of upward and downward airflow for cooling hot corn showed that the direction of airflow affected the moisture distribution in the bin after cooling was completed. More moisture accumulated in the top layers of corn with upward airflow (table 9), particularly at the lower airflow rates. When upward airflow was used, moisture condensed on the underside of the bin roof and dripped back on the corn surface or ran down the bin sidewall. An

TABLE 9.--Effect of airflow rate and direction of air movement on the vertical moisture gradient after cooling 1/

Cooling airflow rate	Airflow direction	Moisture content at grain depth of - Surface	1-1/2 ft	3 ft	5-1/2 ft	8 ft	12 ft	Ave. 2/
cfm/bu					Percent			
0.1	Upward	32.8	15.1	14.2	13.9	14.3	14.3	14.3
0.1	Downward	15.2	13.5	14.0	14.5	15.7	15.0	14.5
0.25	Upward	34.7	14.4	13.9	14.1	14.5	13.7	14.1
0.25	Downward	14.6	13.7	13.3	14.0	14.5	13.9	13.8
0.5	Upward	22.6	14.0	14.1	14.2	14.4	3/	14.1
0.5	Downward	16.8	13.9	13.1	12.9	14.6	3/	13.6

1/ All data are an average for two 1966 tests with the exception of upward airflow at 1/10 cfm per bushel where only one test was conducted.
2/ Averages computed without including the surface moisture content.
3/ Grain depth limited to 10 feet.

area of slightly higher corn moisture extended down 3 feet below the corn surface at the center of the bin. At the bin wall, corn with excessive moisture extended 3 to 5 feet below the corn surface. Serious molding and grain damage occurred when the corn was not moved and mixed after aeration cooling. No difficulty was experienced with the relatively small amount of wet corn when it was mixed with the dry corn. Studies by Condon (6) showed that 80 percent of the moisture equalization between wet and dry kernels occurred within 48 hours after mixing and before serious molding developed.

With downward airflow, the corn was slightly wetter near the bin bottom. Disregarding the surface layer, the corn reached nearly the same average moisture level with either upward or downward airflow.

INCREASED CAPACITY AND EFFICIENCY WITH DRYERATION

Increased drying capacity with Dryeration results from (1) eliminating the cooling time in the dryer, (2) reducing the amount of moisture removed in the dryer, (3) improving the total efficiency of the process, and (4) using higher drying air temperatures.

For the Dryeration tests, the cooling section at the bottom of the tower-type, continuous-flow dryer was converted and added to the drying section so that the entire column was used for drying. The cooling was transferred from the dryer to the Dryeration bin. With a batch dryer, the cooling time of 30 to 45 minutes is eliminated.

Table 10 shows that the capacity for drying 25 percent corn was nearly doubled when the experimental continuous-flow dryer was changed from conventional operation to Dryeration. Two-stage drying added little to the capacity.

TABLE 10.--Effect of Dryeration on capacity of the continuous-flow dryer 1/

Drying air temperature	Drying capacity 2/		
	Conventional drying and cooling	Dryeration	Two-stage Dryeration
°F	Bu/hr	Bu/hr	Bu/hr
190	82	149	156
240	104	189	175
290	138	237	255

1/ Based on three tests by each method in 1964.
2/ For comparison, the capacity was adjusted to a moisture reduction of 25 to 14%.

The increased capacity in Dryeration is due, in part, to discharging the corn from the dryer when it has about two percentage points of excess moisture. This excess moisture is removed during the cooling process, in an amount primarily dependent on the corn temperature. Table 11 shows that an average of 1.7 percentage points of moisture were removed when the corn temperature was at 128°F; and 2.5 percentage points when the temperature was increased to 152°F.

TABLE 11.--Effect of corn temperature on moisture reduction during delayed aeration cooling 1/

Drying air temperature	Corn temperature	Moisture reduction	
		Average	Range
°F	°F	Percent	Percent
190	128	1.7	1.5--1.9
240	142	2.1	1.7--2.3
290	152	2.5	2.0--3.1

1/ Based on three tests at each temperature for drying from 25 to 14% moisture content in the 1964 tests.

There is sufficient residual heat in corn at 140°F to remove 3 points of moisture if all the available heat is utilized (7). Aeration cooling of hot corn is characterized by high moisture removal per unit of air. The air leaving the hot grain is saturated for the first part of the cooling period at a temperature essentially equal to that of the hot corn (normally 130-150°F). For an exhaust air condition to equal this in a deep-layer, bin drying system, the air would have to enter the grain at nearly 500°F. In other words, the moisture holding capacity of the air in aeration cooling is increased the same as though it were heated to 500°F. This is why outside air conditions have little effect on aeration cooling of hot grain.

Table 12 shows that drying efficiencies were improved by 15 to 23 percent when comparing Dryeration with conventional drying and cooling. This increased efficiency is attributed to better use of the hot air in the dryer, use of the residual heat in the corn leaving the dryer, and removal by aeration cooling of the moisture most difficult to remove. Using two stages of heat drying with an extra tempering period between stages increased the efficiency slightly in some tests, but not in others.

TABLE 12.--Effect of Dryeration on efficiency of the continuous-flow dryer 1/

Drying air temperature	Drying efficiency 2/		
	Conventional drying and cooling	Dryeration	Two-stage Dryeration
°F	Percent	Percent	Percent
190	56	79	84
240	56	73	71
290	62	77	84

1/ Based on three tests by each method for drying from 25 to 14% moisture content in 1964.

2/ Drying efficiency, % = $\frac{\text{Heat equivalent of water removed from grain}}{\text{Heat available for drying}} \times 100$

APPLICATION OF THE DRYERATION PROCESS

Dryeration has been widely adopted by both corn producers and elevator operators. Some have been interested only in increasing drying capacity, while others have shown interest primarily in improved grain quality. Exporters of corn have been most interested in reduced breakage.

Recommendations in Applying Dryeration

The following points should be kept in mind with the Dryeration process:

1. Use a drying air temperature that will give a corn temperature of 140-150°F at the moisture content leaving the dryer.

2. Distribute fine materials as the corn enters the Dryeration bin. The hot fine material is usually sticky and is more likely to accumulate and pack under the grain spout than cool, dry material.

3. Use a minimum tempering time of 4 hours in the Dryeration bin, but not in excess of 10 hours.

4. Use an airflow rate of between 0.5 and 1.0 cfm per bushel for cooling the hot corn in the Dryeration bin.

5. Air should be moved upward in the Dryeration bin. This permits cooling to begin immediately after the bin is filled, provided filling takes at least 4 hours. The last corn in the bin will be tempered for about four hours before the cooling front reaches it.

6. Cooling should continue until the average corn temperature is 70°F or below. To reduce all the corn in the bin below 70°F, the required cooling time is nearly twice that necessary to reach an average grain temperature of 70°F.

7. Corn should be moved from the Dryeration bin after cooling so that the wet kernels on the surface and near the bin sidewalls will be mixed with the dryer corn in the bin. Moisture equalization between the wet and dry kernels reduces the danger of serious molding and grain damage.

8. If the corn must be stored in the Dryeration bin, downward airflow should be used after the top corn is tempered for 4 hours. This eliminates some of the problem of moisture condensation on the roof and bin walls. Aeration should be continued throughout storage when outdoor conditions are favorable.

Problems with Dryeration

Vapor-laden exhaust air from the cooling bin travels up the fill spout and into the distributor and elevator head. It condenses on cold metal surfaces and either runs back into the cooling bin or down the spout to a storage bin, or drips out of the load-out spout. This moisture causes fine material to collect in handling and conveying equipment, occasionally leading to corrosion and operational difficulty. The condensate may freeze in cold weather and cause diverter valves and distributor heads to stick.

A cooling front should be moved through the hot corn within 24 hours of the time that the last hot corn was placed in the bin. Sour odors may develop if cooling is delayed.

Several problems may arise with downward airflow in the Dryeration bin. One problem occurs when exhausting warm, moist air through the fan. This reduces by about 40 percent the pounds of air moved by the fan and increases the required cooling time. Condensed moisture collects in the bottom of the fan housing when exhausting through centrifugal fans and impairs operation. The exhaust of a centrifugal fan should be placed in the bottom horizontal position so that any collected moisture can drain from the scroll.

Other problems that may occur with downward airflow are given in a new publication by McKenzie and others (8). This report details the application of Dryeration to farm and small elevator drying installations.

SUMMARY

Dryeration combines high speed drying with aeration for improved grain quality and increased drying capacity. With Dryeration, hot corn is removed from the dryer, allowed to temper for a few hours in a separate bin, and then cooled slowly with aeration. The brittleness of the dried corn decreased with increased tempering and slower cooling. Dryeration reduced the breakage attributed to drying by 80 percent.

The capacity of the continuous-flow dryer used in the tests was nearly doubled when the cooling section was converted to an additional heat section and used in the Dryeration process. Corn was dried from 25 to 14 percent moisture in the tests.

Two-stage drying with a tempering period after each stage added little to either the capacity or corn quality obtained with Dryeration.

Corn heated to 140°F in the dryer and allowed to temper lost an average of about two percentage points of moisture during aeration cooling. A combination of 8 hours tempering and aeration at 0.5 cfm per bushel provided the highest moisture removal.

Cooling hot corn with upward airflow resulted in moisture condensation on the bin roof that either dripped back on the corn surface or ran down the bin sidewalls. The amount of condensation was greater at the lower airflow rates. Serious molding and damage developed on the corn surface and near the bin wall. This was prevented by moving and mixing the corn promptly after cooling.

REFERENCES

1. Straszheim, Robert E., et al. Indiana 1966 Corn for Grain. USDA Statistical Reporting Service Mimeo, March 1967.

2. Thompson, Ralph A. and Foster, George H. Stress Cracks and Breakage in Artificially Dried Corn. USDA Mkt. Res. Report 631, October 1963.

3. Foster, G. H. Drying Market Corn. Proceedings, 20th Annual Hybrid Corn-Industry Research Conference, 1965.

4. Foster, G. H. Dryeration - A Corn Drying Process. AMS 532, U. S. Dept. of Agriculture, April 1964.

5. Watson, Stanley A., et al. Peripheral Cells of the Endosperm of Grain Sorghum and Their Influence on Starch Purification. Cereal Chemistry, 32:165-182, 1955.

6. Condon, James J. Mold Growth and Moisture Equilibration in Blends of Shelled Corn. Unpublished M.S. thesis, Purdue University, August 1967.

7. Foster, G. H. Moisture Changes During Aeration of Grain. Transactions of the ASAE, 10:(3)344-347, 351, 1967.

8. McKenzie, B. A., Foster, G. H., Noyes, R. T., and Thompson, R. A. Dryeration -- Better Corn Quality with High Speed Drying. Purdue Cooperative Extension Service Bulletin AE-72, December 1967.