THE EFFECTS OF EVAPORATION IN WHEAT AND MILL STOCKS ON THE PROCESSES OF MILLING

by

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INTRODUCTION

Evaporation is usually considered as the conversion of a liquid into a vapor in an atmosphere whose pressure is less than that of the vapor pressure of the evaporating liquid, that is when evaporation takes place below the boiling point. Some experimental work has been done on the rate of evaporation from free water surfaces and on the evaporation of water from solids. Most of the equations thus derived are correct only under very limited conditions. However there are general laws and formulas in regard to humidity, temperature, and pressure which have been worked out and which may serve as a guide to other experiments.

To understand the problem of evaporation involves an intimate knowledge of thermodynamics as well as a knowledge of the chemical and physical properties of the material under examination. Since experiments with heat transfer must be done under very exact conditions it is readily seen that the application of these heat laws and formulas to the conditions existing in the flour mill is almost impossible for quantitative results. Thus the application of these scientific principles must be very general. That is under certain conditions in the mill it may be assumed that the laws of heat transfer and evaporation will hold true to within certain limits.

Therefore evaporation and its effects on the processes of milling is not a problem without a solution. There are many mills which have some means of partially controlling the evaporation of moisture. Some havs installed very elaborate equipment and others something quite simple, while others control evaporation to some extent by the way in which the milling processes are conducted.

No matter what means of control is used, there is probably no miller who does not wish that he had better control of the moisture in his mill. This dssire is prompted by two objectives. The one a securing of better quality of flour, the other a securing of an increase of total products.

Quantity of products obtained from a given amount of wheat is a matter of dollars and cents to the mill and is certainly a phase which cannot be overlooked in any organization. The methods employed by the millsr are reflected in the quality of the finished products, and any improvement in the finished products shows an improvement in the miller's methods.

It is not the authors purpose here to go into a complete discussion of the methods for the control of evaporation, but rather to show the effects of evaporation in the various operations of the mill under different atmospheric conditions.

To understand the effects of evaporation it is first necessary to know something about the theory of evaporation, the structure of the wheat kernel, and some of the methods in use for the control of atmospheric conditions.

With the above points in mind experiments were conducted both on the small experimental mill and on the large long system mill to determine the rate of evaporation for various mill stocks, the moisture drop on the various operations of the milling processes, and the temperature differences due to mechanical heat and evaporation.

THE THEORY OF EVAPORATION

Matter is recognized as being composed of molecules which are continually in motion. This motion is due to a certain amount of attraction and repulsion among the molecules, which imparts to the molecules a certain amount of kinetic energy. As the word kinetic is taken from the Greek word meaning to move, it is evident that kinetic energy is energy of motion. For example a moving body has a certain amount of kinetic energy equal to $\frac{1}{2}mv^2$, where m is the mass of the body, and v is its velocity.

In physics a change in the form of matter is known as a change in state. For example in the case of water the different states are ice, water, and vapor. The molecules in the different states have different amounts of freedom of motion. Thus in a solid the molecules vibrate about a fixed point while in a liquid they move about from place to place except as they strike against one another. In the gas or vapor state the molecules are relatively far apart giving a greater freedom of motion, and at the same time greater speed.

Any physical change necessitates the transfer of a certain amount of work or energy. In the change of state this energy is required to overcome the attractive forces acting among the molecules, and is expended in the form of heat. There are two units of heat measurement used in commercial work; namely, the calorie (cal.) which is the amount of heat necessary to raise one gram of water from 15°C. to 16°C.; and the British Thermal Unit (BTU) which is the amount of heat necessary to raise one pound of water from 60°F. to 61°F. Due to the fact that almost all commercial data is expressed in terms of the English system, all units used in this paper will be in the English system unless otherwise stated. Thus 144 B.T.U. are required to change one pound of water at 212°F. into steam at 212°F. These two heat quantities being known as the heat of fusion and the heat of vaporization.

As this heat is added the attraction among the molecules becomes less and they move farther apart. As the distance between them increases their freedom of motion is greater hence their speed is greater. If the speed of the molecules is proportional to the amount of heat added, the difference in the speed of the molecules in a liquid and a gas is readily seen by the difference in the latent heat of ice and steam.

It follows that the change of state from water to vapor, known as vaporization or evaporation, is a result of the kinetic energy of the individual molecule. That is the molecules at or near the surface of the liquid have such velocity and direction that they escape into the surrounding atmosphere. As the chance of escape, other things being equal, increases with the velocity of the molecules it follows that the average kinetic energy of the escaping molecules is greater than that of the remaining ones, or that evaporation decreases the temperature, and that the rate of evaporation increases with an increase of temperature. That is, the molecules which pass into the vapor state possess a greater amount of energy in the form of heat than the molecules which remain in the liquid state; therefore the liquid is cooled. If no heat is added, as evaporation takes place, the heat of vaporization is taken from the air in contact with the surface of the water. Thus in an evaporating body of water both the temperature of the water and the temperature of the air in contact with the water is reduced.

Evaporation from Free Surfaces

For milling purposes the moisture content of wheat is usually increased above the normal. That is, the moisture content of the wheat as it goes to the rolls is higher than it is after it has been exposed to atmospheric conditions.

A direct application of the laws of evaporation is not possible in practical milling, because only a small per cent of moisture is evaporated in any one place and the existing conditions throughout the milling process vary from time to time. It is very improbable that any exact equation could be written to show the rate of evaporation from any mill stock. It is possible, however, to use as a basis for this study the knowledge obtained from experiments conducted on evaporation from free water surfaces.

As water vapor has many properties of a gas we may assume that it will, to a large extent, obey the gas laws. From this it follows: that a unit volume of water vapor will produce a very definite pressure known as the vapor pressure; that the weight of a unit volume of saturated water vapor is a very definite quantity which will increase or decrease with the temperature; that the density and the vapor pressure increase with an increase in temperature.

W.S. Carrier (Carrier 1918) states that the rate of evaporation depends on four factors:

(1) The vapor pressure of the moisture in the material corresponding to its temperature.

(2) The vapor pressure of the moisture in the air corresponding to its absolute humidity or dew point temperature.

(3) The effective velocity of the air over the surface.

(4) The physical and chemical properties of the material being dried.

Wheat like other cereal grains is a hydroscopic body. By this we mean a body or substance which absorbs or gives up water from or to the air in accordance with the relative humidity of the air. In the drying of such substances two different and distinct states of the water in the substance must always be taken into consideration. In the first state the water is on the outside of the particles and is free; that is it has a very loose relationship to the substance, and will evaporate with the same ease as water from a free water surface. In the second state the water is held by the surface forces and evaporation will not take place unless more energy is available than in the case of free water. There is a very intimate relationship between this hydroscopic water and the substance in which it is contained. The relationship is on the border line between physical and chemical with free water on the physical side and hydroscopic water on the chemical side. However if relatively large amounts of water are absorbed the capillary action of the substance will convert some of the hydroscopic water into the free water.

In evaporation experiments with hydroscopic materials it is necessary to know the humidity and temperature of the air surrounding the material because the hydroscopic moisture is dependent on these two factors. The relative moisture content of the air may be measured by either the dew-point method or the psychrometric method. The latter depends on the cooling effect produced by the evaporation of moisture in a partially saturated atmosphere. It is measured by the difference in reading obtained by two thermometers one of which has its bulb covered by a wick saturated with water. The differences in the readings is termed as the wet bulb depression. The two thermometers are mounted side by side in the form of a sling which can be rotated by hand. A sling 15 inches long rotated from 150 to 225 r.p.m. gives a velocity of 1200 to 1800 feet per minute. Under such conditions readings can be taken within 1.6 per cent error. If a fan is used and the velocity increased to 3000 feet per minute, the error is less than 1 per cent. Tables have been computed which give the percentage of relative humidity for different wet bulb depression for the various dry bulb readings.

The relative humidity is the ratio of the actual moisture content of the air to the content at the saturation point. The relative humidity differs from the absolute humidity in that the relative is a percentage relationship of saturation, while the absolute is the amount of water, by weight, contained in a cubic foot of air at a definite temperature. For example a cubic foot of air at 70°F. has a moisture holding capacity of 8.064 grains of water at the saturation point. If the wet bulb depression is 10°F. then the capacity is only 4.39 grains, which gives a relative humidity of 55 per cent, and an absolute humidity of 4.39 grains per cubic foot. If the temperature of this air is reduced below 53°F., condensation will take place due to the fact that air at 53°F. can hold only 4.39 grains of water per cubic foot. Hence 53 is called the dew-point.for a wet bulb depression of 10°F and 70°F. dry bulb temperature.

When unsaturated air comes into contact with a free water surface three physical changes take place simultaneously.

Table I Properties of saturated air.

Atmospheric pressure 29.921 in. of mercury.

Temperature degrees F.	Vapor pressure inches of mercury.	Weight of dry air pounds	Weight of vapor pounds.	Total weight of mixture pounds.
20	.1030	.08247	.000177	.08265
30	.1640	.08063	.000276	.08091
40	.2477	.07880	.000409	.07921
50	.3625	.07694	.000587	.07753
60	.5220	.07506	.000829	.07589
70	.7390	.07310	.001152	.07425
80	1.0290	.07095	.001576	.07253
90	1.4170	.06881	.002132	.07094
100	1.9260	.07095	.001576	.07253

Partial table taken from "The Engineers Handbook" published by The Buffalo Forge Co.

Table II Relative humidity, dew-points, and grains of moisture per cubic foot.

Atmospheric pressure of 30 inches mercury.

	Degrees wet-bulb depression											
	9			10			11			12		
Dry-bulb Temperature.	Rel. humidity.	Dew-point	Gm. per cu.ft.	Rel. humidity.	Dew-point	Gm. per cu.ft.	Rel. humidity	Dew-point	Gm. per cu.ft.	Rel. humidity	Dew-point	Gm. per cu.ft.
69	59	54	4.56	55	52	4.25	51	50	3.94	47	48	3.63
70	59	55	4.71	55	53	4.39	51	51	4.07	48	49	3.83
71	60	56	4.94	56	54	4.62	52	52	4.29	48	50	3.96

Partial table taken from "The Engineers Hand-Book" published by the Buffalo Forge Company.

(1) The temperature of the water is reduced to a definite temperature known as the wet bulb temperature.

(2) A certain amount of water is evaporated, increasing the vapor content of the air and hence the vapor pressure.

(3) The air is cooled a corresponding amount due to the fact that the latent heat of evaporation must be taken from the air as the only source of heat.

The wet bulb temperature, or temperature of evaporation, depends upon the ability of a definite weight of air to give up heat required for the evaporation of sufficient moisture to saturate its space at the temperature to which it is finally cooled. When air is saturated adiabatically, that is without gain or loss of heat, the temperature is reduced as the absolute humidity is increased and the loss of sensible heat is equal to the increase of latent heat due to saturation. As the moisture content of the air is increased adiabatically, the temperature is reduced until the vapor pressure corresponds to the temperature at which point no further heat change takes place. This may be termed as the temperature of adiabatic saturation. When an insulated body of water is permitted to evaporate freely into the air it assumes the temperature of adiabatic saturation. When an insulated body of water is permitted to evaporate freely into the air it assumes the temperature of adiabatic saturation of that air; that is, the wet bulb temperature of the air is identical with its temperature of adiabatic saturation. From this it follows; that the true wet bulb temperature of air depends entirely on the total of the sensible and latent heat in the air and is independent of their relative proportion. In other words the wet-bulb temperature is constant, providing the total heat content of the air is constant.

During the time of evaporation the dry bulb reading gradually falls until at the point of saturation, the wet and dry bulb readings are equal. The difference in the wet and dry bulb readings is known as the wet bulb depression and shows the ratio of the vapor pressure of the liquid and the vapor pressure of the air directly in contact with the surface of the liquid.

By experiment it has been found that the rate of evaporation at any instant per unit of surface exposed is proportional to this difference in vapor pressures regardless of the temperature: that is

$$\frac{dw}{dt} = x\,(e^1 - e)$$

Where e^1 = vapor pressure of the liquid.

e = vapor pressure of the air.

The constant x, which must be determined experimentally seems to vary directly with the molecular weight of the evaporating liquid. As $\frac{dw}{dt}$ is always proportional to (e^1-e) it is evident that evaporation is almost entirely dependent on the surface tension of the liquid, and the rate of evaporation is dependent on the wet bulb depression. A 95° wet bulb depression is equal to a difference in pressures of 1 inch, and at standard barometric pressure each pound of air has the ability to adsorb one and one-half grains of water for each degree Fahrenheit of wet bulb depression.

For a constant difference of vapor pressures the rate of evaporation starts with a fixed minimum in still air and increases in proportion to the velocity and may be expressed as:

$$\frac{dw}{dt} = (a + bv)\,(e^1-e)$$

Where a = rate of evaporation in still air.
b = " " increase with velocity.
e^1 = vapor pressure of the liquid.
e = " " " " atmosphere.

The amount of water evaporated may be expressed by the following equation which is correct for practical purposes.

$$w = 0.093\left(1 + \frac{v}{230}\right)(e^1-e)$$

Where w = pounds of water evaporated per sq. ft./hr.

v = velocity.

In still air v is equal to 0 and the quantity $1 + \frac{v}{230}$

becomes 1, but for a velocity of 230 feet per minute the evaporation is twice as much as in still air and at 460 feet per minute it is three times as much.

However the direction of the air currents is also a factor. That is, evaporation will be the greatest where the maximum amount of air comes in contact with the maximum amount of surface. For example the evaporation will be greatest if the air flow is unparallel or transverse to the surface of the material, as in a purifier, than if the air flow is parallel to the surface of the material.

Experiments have been conducted with velocities from 300 to 2000 feet per minute for both parallel and transverse air flow, and it was found that the rate of evaporation was nearly twice as great for corresponding velocities in the transverse flow as in the parallel flow. Experiments in the commercial drying of food products have shown a relation between the evaporating power of parallel and transverse air currents. In the following equations which have been developed, the evaporation is nearly twice as great for corresponding velocities in the transverse flow as in the parallel flow.

Parallel

$$G = \frac{(95 + 0.425v)}{P} (e_w - e_a)$$

Transverse

$$G \quad \frac{(201 + 0.88v)}{P} (e_w - e_a)$$

Where G = lbs. of water evaporated per square foot per hour.

v = velocity of air.

r = latent heat of vaporization.

e_w = vapor pressure in inches of Hg corresponding to the temperature of the H_2O.

e_a = vapor pressure of moisture in air.

As this process of evaporation takes place, the air in direct contact with the water becomes more nearly saturated. As the degree of saturation reaches one, the air cools to the wet bulb temperature, and the latent heat of the water evaporated is exactly equal to the loss in sensible heat of the air.

The above discussion holds true only for moisture at the surface or moisture in very porous substances. In the more dense materials the evaporation is limited by the diffusion of the moisture from the interior to the surface and is different for different mill stocks.

The above equations hold very exactly for low wet bulb depressions, while for high depressions there is a maximum rate for any temperature.

The Effect of Evaporation on the Milling Properties of Different Stocks

The wheat berry consists of three main parts; the bran, the germ, and the endosperm. Modern milling is possible because of the differences in the physical properties and the effect of water on the different parts. The bran coat, being composed to a large extent of fiber, is very harsh and brittle when dry, but if its moisture content is increased it becomes very tough. The fat and oil contained in the germ causes it to flake when passed between the rolls rendering its separation very easy. The endosperm is composed almost entirely of starch and protein and has a granular structure. This makes the entire endosperm very friable and very easily separated from the bran and germ.

In the practical operation of a mill the problem is not so simple. When water is added to toughen the bran, the same water will also mellow the endosperm causing some of it to adhere closer to the bran coat. On the other hand if not enough water is added the bran will chip on the break rolls and a quantity of fine bran particles will be mixed with both the break flours and the resulting middlings.

From this it follows that the range of moisture which gives satisfactory results is rather narrow. No matter how carefully the moisture content is controlled, some of the endosperm will adhere to the bran and some of the bran will chip. Many of these bran chips are so small that they pass through the purifiers with either the sizings or the primary middlings stocks. Down toward the tail end of the system these small bran particles become more numerous requiring closer grinding in an endeavor to remove adhereing endosperm and to flatten the branny portions that they may be scalped off.

Both in the purifier and in the elevators there is a large amount of air used. Especially is this true in the purifier where the particles are in a current of air whose vapor pressure is very low. Evaporation is thus facilitated and the moisture content of the stocks going from the purifiers to the rolls is very materially reduced. As was stated above, drying these bran particles causes them to become very brittle and when passed between the smooth rolls they are shattered into pieces small enough to pass through the bolting cloths along with the flour. This has a deleterious effect on both the color and the ash content of the flour, and the resulting moisture loss will decrease the weight of total products. Therefore it should follow that if the evaporation could be controlled at important places the results would show an improvement in the color of the flour, a lowering of the ash, and a lessening of the loss of weight of total products.

An article in "Die Mühle" (Milling 1929) states that the loss through evaporation is greater for wheat of high moisture content. For example two samples of wheat, one containing 16 per cent and the other 17.35 per cent moisture, were milled. The difference in the initial moisture was 1.35 per cent but the difference in moisture loss was 6 per cent, the wheat of higher moisture content having the greater loss. The reason given was that more work was required to reduce the grain of high moisture content and consequently milling was done at a higher temperature.

Woölcott (Woölcott 1921) found that if he started with 16 per cent at the first break rolls he obtained only 11 per cent in the stocks on the low grade rolls, or a loss of 5 per cent. After humidifying the air in the mill he was able to mill wheat at 14.5 to 15.0 per cent moisture and still obtain satisfactory moisture in the products.

Shollenberger (Shollenberger 1921) found that there was a direct relation between the relative humidity and the weight of the total products. With each increase in relative humidity there was an appreciable decrease in milling loss, the ash content diminished regularly and the bread having the best color and texture was made from flour milled in an atmosphere of 60 to 70 per cent relative humidity.

Thus it would seem that if the evaporation from the mill stocks was decreased to a minimum, wheat of a lower moisture content could be used at the first break rolls.

This would permit a higher extraction and still leave sufficient moisture in the products of the break system to assure proper reduction and bolting. Under these conditions the fine bran particles would contain enough moisture that they would retain their toughness and merely be flattened out rather than ground as they pass through the smooth rolls.

CONTROL OF EVAPORATION

The control of evaporation in the mill is a problem which the operative miller has not solved satisfactorily because it has always been a question whether the gain would compensate for the cost of installation of apparatus.

The first attempt to control the conditions in the flour mill was the construction of better buildings. These were built tighter and contained heating plants which controlled the temperature. The mill proper was shut off from the rest of the building to eliminate air currents as much as possible. In some mills the air from the metal dust collectors was returned to the mill. This saved much heat and also served to return the moist air of the dust collecting system to the mill.

The universal method of controlling losses in the mill has been and still is the use of an excess amount of tempering water. Due to wide variations in atmospheric conditions this has never been satisfactory. The amount of water that one day will give good results may on another day be too much or too little. Then there is the danger of having the moisture content of the bran too high. This condition will result in having to either dry the bran or pack it in larger sacks, both of which cost money.

The idea of controlling the relative moisture content of the air in the mill brought forth many different methods. Both live steam and water sprays were introduced in the air of the mill. Some were connected with fan systems and some were not. Most of these methods were more or less crude, "home made" pieces of apparatus, and were only partially satisfactory.

At the present time there are, on the market, automatically controlled machines for the control of atmospheric condition in the mill. With these machines it is possible to introduce the air by two methods: the conditioned air may be introduced into the different parts of the mill or it may be introduced into the machinery. In the latter case the ducts for the conditioned air together with the ducts of the different exhausts form a continuous system. With these machines it is possible to hold the moisture content and the temperature of the air very nearly constant.

There are several mills which have these automatic air conditioners in operation and some of them seem to give good results. However there is much room for improvement in atmospheric control. The main difficulty is that few mills are so constructed that they could install one of these machines without a great expense.

EXPERIMENTS ON THE SMALL EXPERIMENTAL MILL

The rate of evaporation from various mill stocks was determined on representative samples obtained on the small experimental mill. A uniform lot of 1929 wheat containing 12.05 per cent protein and 11.9 per cent moisture was cleaned on an experimental separator and scoured once on a Eureka experimental scourer. The samples were 1000 gm. each of the cleaned wheat. They were tempered in tin cans with tight covers for various lengths of time, varying from 4 to 72 hours. It was intended that all the tempered samples should contain 15.5 per cent moisture but due either to losses in sampling or to losses in tempering, the moisture content of the tempered wheat varied.

The milling was done on an experimental roller mill with a No. 16 Dawson corrugation. The wheat was ground with a roll setting corresponding to that of first break and immediately without sifting, the stock was again ground on the same rolls with a setting corresponding to third break. Immediately after the second grinding the stock was sifted over a stack of sieves, 24 W, 50 GG, and 70 GG. in a rotomatic sifter for one minute. Six bottle samples were taken: one of the tempered wheat; one of the first grinding; one of the overs of the 24 [illegible]; one of the overs of the 50 GG.; one of the overs of the 70 GG. and one of the throughs of the 70 GG.

In order to decrease evaporation losses to a minimum, both the rolls and the sifter were kept covered during the grinding and sifting, and the transfer from one to the other was made as quickly as possible.

A small portion from each of the bottle samples was weighed into small aluminum pans. Ten gm. of the wheat, 2 gm. of the overs of the 24 [illegible]. and 5 gm. of the other four stocks were used. In each case the weight was just enough to make a thin layer on the bottom of the aluminum pan which was 7 cm. in diameter and 2 cm. deep. A moisture determination was made on the remainder of each bottle sample by the vacuum oven method.

The entire procedure was conducted in a room in which the atmosphere was controlled by a Carrier automatic air control machine. The temperature did not vary over a range of more than 5 degrees and the relative humidity over a range of 4 per cent. The small aluminum pans and their contents were exposed to the atmosphere of the room for 2 hours during which time they were weighed, to the third place on an analytical balance, every 15 minutes. The evaporation or absorption of moisture was recorded as loss or gain in weight and converted to per cent of moisture.

There were three series of these tests made. The first series was tempered for 4, 8, 12, 16, 20, 24, 36, 48, 60, and 72 hours and was ground and weighed at a room temperature of 90°F. and a relative humidity of 60 per cent. The determinations in this set were made in triplicate in order to learn whether different stocks behaved the same at all times under similar conditions. In the graphing of the moisture loss from these triple samples the curves did not exactly coincide, but they were similar, showing that the trend was characteristic.

A study of the data obtained in this series, (Table III) seems to show that the length of the temper has no effect on the loss through evaporation. That is stocks with the same initial moisture content lose about the same per cent of moisture regardless of the length of temper. However, if the amounts evaporated from different stocks vary, also if we take the rate of evaporation over the first hour of the period by averaging the rates of all the tempers for each class of stock we find there is a difference. That is, if the moisture loss is plotted on a graph with time as abscissas and moisture per cents as ordinates, and the ordinate of the curve is divided by the abscissa, we get the slope of the curve which shows the relative rate.

Table III Evaporation in wheat and mill stocks tempered for various lengths of time at a constant temperature of 90°F. and a relative humidity of 60 per cent expressed in per cent loss of moisture.

Time exposed minutes	0	15	30	45	60	75	90	105	120
Length of Temper Hours.									
	Evaporation from Whole Wheat.								
4	15.60	0.10	0.30	0.50	0.70	0.90	1.10	1.20	1.35
8	15.30	0.10	0.40	0.60	0.75	0.90	1.10	1.20	1.30
12	14.70	0.10	0.30	0.50	0.50	0.80	0.90	1.10	1.20
20	14.70	0.20	0.40	0.60	0.70	0.80	0.90	1.00	1.20
24	15.30	0.20	0.30	0.50	0.60	0.80	0.90	1.00	1.20
36	15.30	0.10	0.30	0.55	0.70	0.80	1.00	1.05	1.10
48	15.40	0.15	0.40	0.50	0.70	0.80	1.00	1.10	1.30
60	15.00	0.10	0.40	0.55	0.70	0.85	1.00	1.10	1.20
72	15.50	0.20	0.35	0.50	0.70	0.85	1.00	1.10	1.20
	Evaporation from Ground Wheat.								
4	15.40	0.50	0.90	1.15	1.60	1.90	2.15	2.30	2.50
8	15.40	0.45	0.90	1.40	1.70	1.90	2.10	2.30	2.40
12	15.10	0.60	0.90	1.30	1.70	1.90	2.10	2.40	2.50
20	14.40	0.40	0.50	0.70	0.90	1.40	1.60	1.70	1.80
24	15.00	0.40	0.60	0.80	1.10	1.30	1.50	1.80	2.00
36	15.40	0.40	0.75	1.10	1.40	1.60	1.80	1.90	2.00
48	15.40	0.50	0.90	1.30	1.60	1.80	2.00	2.10	2.40
60	15.20	0.50	1.00	1.30	1.60	1.80	2.00	2.10	2.30
72	15.50	0.40	0.90	1.20	1.50	1.70	1.90	2.00	2.20

Table III Continued.

Evaporation from Overs of No. 24 Wire.

4	15.80	0.90	1.60	2.10	2.55	2.90	3.10	3.80	3.40
8	15.70	0.70	1.60	2.10	2.50	2.70	2.80	2.90	2.90
12	15.20	0.60	1.30	1.70	2.20	2.40	2.60	2.80	2.90
20	14.30	1.10	1.40	1.80	2.00	2.20	2.30	2.30	2.40
24	15.60	0.40	0.80	1.30	1.60	1.80	2.00	2.20	2.40
36	15.60	0.65	1.30	1.85	2.30	2.45	2.60	2.70	2.70
48	15.30	0.70	1.40	2.00	2.40	2.60	2.80	2.90	3.00
60	15.00	0.80	1.80	2.20	2.50	2.75	2.90	2.90	3.00
72	15.60	0.30	0.80	1.30	1.60	1.80	1.90	1.90	1.90

Evaporation from Overs of 50 GG.

4	15.40	0.40	0.80	1.10	1.30	1.60	1.80	1.90	2.00
8	15.30	0.30	0.90	1.10	1.40	1.60	1.70	1.90	2.00
12	14.80	0.40	0.70	1.00	1.40	1.50	1.70	1.90	2.00
20	14.30	0.50	0.90	1.20	1.30	1.60	1.60	1.70	1.80
24	15.00	0.30	0.60	0.90	1.10	1.30	1.40	1.70	1.80
36	15.10	0.30	0.75	0.95	1.25	1.45	1.60	1.70	1.70
48	15.20	0.80	0.80	1.05	1.35	1.45	1.65	1.75	1.95
60	15.00	0.30	0.70	1.00	1.20	1.30	1.40	1.40	1.50
72	15.30	0.50	0.70	1.00	1.30	1.50	1.60	1.70	1.80

Table III Continued.

Evaporation from Overs of 70 CC.

4	15.30	0.20	0.60	0.90	1.10	1.40	1.55	1.70	1.80
8	15.10	0.20	0.80	1.00	1.20	1.35	1.55	1.70	1.70
12	14.90	0.20	0.50	0.70	1.10	1.20	1.40	1.60	1.70
20	14.40	0.50	0.80	1.00	1.20	1.40	1.50	1.60	1.70
24	15.30	0.60	0.90	1.10	1.30	1.50	1.70	1.90	2.10
36	15.10	0.20	0.35	0.80	1.00	1.10	1.30	1.35	1.40
48	15.30	0.30	0.60	0.90	1.10	1.25	1.40	1.55	1.70
60	15.00	0.30	0.80	1.00	1.20	1.40	1.60	1.60	1.70
72	15.10	0.40	0.60	0.85	1.05	1.20	1.30	1.40	1.60

Evaporation from Throughs of 70 CC.

4	15.20	0.40	0.70	1.00	1.20	1.50	1.70	1.80	1.90
8	15.30	0.30	0.90	1.05	1.30	1.50	1.65	1.70	1.80
12	14.80	0.40	0.70	0.90	1.30	1.40	1.60	1.80	1.80
20	14.40	0.50	0.70	0.90	1.10	1.30	1.40	1.50	1.60
24	15.30	0.30	0.60	0.80	1.00	1.20	1.30	1.60	1.80
36	15.10	0.40	0.70	0.95	1.20	1.35	1.50	1.50	1.55
48	15.10	0.40	0.80	1.05	1.35	1.45	1.60	1.70	1.90
60	15.00	0.40	0.90	1.20	1.40	1.50	1.70	1.80	1.90
72	15.00	0.50	0.75	1.10	1.25	1.40	1.55	1.60	1.75

Whole wheat . . .	0.397
Ground " . . .	0.727
Overs 24 W. . . .	1.225
" 50 GG. . .	0.645
" 70 GG. . .	0.570
Throughs 70 GG. .	0.617

The rate of change of the slope of the curve for moisture drop is different for different stocks.

The second series of samples were tempered in a box where the temperature was held, by an automatic thermostat, at 110°F. for 4, 8, 16, 20, 36, and 72 hours. The samples from this series were also weighed in an atmosphere of 90°F. and 60 per cent relative humidity. A study of the data from this series (Table IV) also shows that the length of temper has no effect on the amount of evaporation. The loss of moisture in the samples of the two series, with corresponding moisture contents, totaled almost the same. The relative rates of evaporation calculated as before stated during the first hour of the period was:

Whole wheat . . .	0.342
Ground wheat . .	0.691
Overs of 24 W. .	1.058
Overs of 50 GG. .	0.583
Overs of 70 GG. .	0.483
Throughs of 70 GG.	0.566

Table IV Evaporation in wheat and mill stocks tempered for various lengths of time at a constant temperature of 110°F. and a relative humidity of 90 per cent expressed in per cent loss of moisture.

Time exposed minutes	0	15	30	45	60	75	90	105	120
Length of Temper Hours.									
	Evaporation from Wheat.								
4	14.70	0.10	0.30	0.30	0.70	0.80	0.90	1.00	1.10
8	15.30	0.20	0.40	0.60	0.70	0.85	1.00	1.15	1.25
16	15.00	0.15	0.30	0.45	0.60	0.75	0.90	1.00	1.15
20	15.20	0.20	0.40	0.60	0.80	1.00	1.15	1.30	1.40
36	14.90	0.20	0.40	0.55	0.70	0.90	1.10	1.20	1.30
72	15.40	0.10	0.30	0.45	0.60	0.80	0.90	1.05	1.20
	Evaporation from Ground Wheat.								
4	14.70	0.40	0.80	1.20	1.50	1.65	1.80	1.90	2.00
8	15.00	0.30	0.80	1.10	1.40	1.60	1.80	1.90	2.05
16	15.50	0.50	0.80	1.10	1.40	1.70	1.90	2.00	2.20
20	15.00	0.30	0.60	0.90	1.30	1.45	1.70	1.80	2.00
36	14.70	0.45	0.90	1.20	1.50	1.70	1.90	2.05	2.10
72	14.90	0.50	0.85	1.00	1.20	1.50	1.70	1.80	1.90
	Evaporation from Overs of No. 24 Wire.								
4	14.90	0.50	1.30	1.60	2.00	2.00	2.10	2.20	2.20
8	15.10	0.90	1.60	1.90	2.20	2.40	2.50	2.65	2.70
16	14.90	0.40	1.05	1.60	2.00	2.30	2.50	2.60	2.75
20	15.60	0.90	1.40	1.90	2.40	2.65	2.80	2.85	2.90
36	14.90	0.80	1.40	1.90	2.10	2.40	2.60	2.70	2.75
72	15.10	0.70	1.30	1.70	2.00	2.25	2.35	2.60	2.65

Table IV Continued.

Evaporation from Overs of 50 CC.

4	14.60	0.30	0.70	1.00	1.10	1.30	1.30	1.40	1.50
8	14.90	0.40	0.80	1.00	1.20	1.40	1.50	1.70	1.75
16	14.60	0.30	0.65	0.95	1.20	1.45	1.60	1.80	1.85
20	15.30	0.40	0.60	0.90	1.20	1.40	1.60	1.70	1.80
36	14.70	0.30	0.70	1.00	1.20	1.40	1.55	1.65	1.65
72	15.00	0.35	0.70	0.80	1.10	1.25	1.40	1.60	1.70

Evaporation from Overs of 70 CC.

4	14.70	0.20	0.50	0.80	0.90	1.00	1.10	1.15	1.20
8	14.80	0.30	0.65	0.85	1.00	1.15	1.30	1.40	1.50
16	14.60	0.10	0.50	0.80	1.00	1.20	1.30	1.45	1.55
20	15.00	0.20	0.40	0.80	1.00	1.20	1.35	1.45	1.45
36	14.70	0.20	0.60	0.35	1.00	1.20	1.35	1.50	1.55
72	14.80	0.20	0.50	0.70	0.90	1.00	1.20	1.30	1.40

Evaporation from Throughs of 70 CC.

4	14.80	0.40	0.70	0.90	1.10	1.20	1.20	1.30	1.40
8	14.60	0.50	0.80	0.95	1.10	1.30	1.40	1.60	1.60
16	14.40	0.40	0.70	1.00	1.20	1.40	1.50	1.70	1.75
20	15.00	0.50	0.70	0.80	1.20	1.45	1.60	1.70	1.70
36	14.60	0.50	0.80	1.10	1.20	1.45	1.60	1.70	1.75
72	14.90	0.30	0.60	0.80	1.00	1.10	1.20	1.30	1.40

The different rates of evaporation in this series are just a little lower than in the first series. This might be due to the fact that the average moisture content of the second series was somewhat lower than that of the first. However the relative rates of evaporation correspond very closely in the two series which would seem to show that heat used ahead of the first break rolls has no appreciable effect on the rate of evaporation. Comparing the rate of evaporation in the three middlings samples, the overs of the 50 GG. seem to show a higher rate of evaporation due to the increased area exposed by the large percentage of germ and bran chips, and the rate was higher in the throughs of the 70 GG. than in the overs. The reason for the latter is not apparent.

In the third series (Table V) the wheat was tempered for 4, 12, 24, 36, 48, and 72 hours. These samples were ground and weighed in an atmosphere of 90°F. and a relative humidity of 35-40 per cent. The moisture loss was so rapid that it was very difficult to get results that checked. However if we assume from the results of first two series that the length of tempering time has no effect on the rate of evaporation, we can take an average of the rate of evaporation for the different lengths of temper.

Table V Evaporation in wheat and mill stocks tempered for various lengths of time at a constant temperature of 90°F. and a relative humidity of 35-40 per cent expressed in per cent loss of moisture.

Time exposed minutes	0	15	30	45	60	75	90	105	120
Length of Temper Hours.			Evaporation from Wheat.						
4	13.76	0.50	1.00	1.40	1.80	2.00	2.20	2.50	2.60
12	14.10	0.60	1.00	1.40	1.80	2.10	2.30	2.50	2.70
24	13.44	0.20	0.50	0.80	1.00	1.10	1.30	1.70	1.90
36	13.87	0.30	0.60	0.90	1.10	1.30	1.55	1.75	1.90
48	13.54	0.40	0.70	1.10	1.40	1.60	1.90	2.10	2.30
72	13.60	0.40	0.70	1.10	1.40	1.60	1.80	2.00	2.20
			Evaporation from Ground Wheat.						
4	13.42	1.20	2.00	2.90	3.70	4.05	4.40	4.90	5.50
12	13.56	1.50	2.50	3.50	4.20	4.70	5.10	5.40	5.60
24	13.19	0.80	1.20	1.80	2.30	2.75	3.10	3.50	3.70
36	13.51	0.50	0.90	1.30	1.50	1.65	1.80	1.90	2.00
48	13.12	0.90	1.70	2.50	3.10	3.50	4.10	4.40	4.70
72	13.14	0.90	1.80	2.30	2.30	3.40	3.85	4.20	4.45
			Evaporation from Overs of No. 24 Wire.						
4	13.84	2.20	3.80	4.50	5.30	5.50	5.70	5.90	5.90
12	13.74	3.00	4.30	5.30	5.80	6.05	6.20	6.35	6.45
24	13.70	1.70	2.50	3.60	4.10	4.55	4.80	5.10	5.20
36	14.05	2.00	3.10	4.70	6.30	7.20	8.50	9.50	10.50
48	13.52	1.00	2.50	3.40	4.00	4.40	4.60	4.80	4.90
72	13.73	1.80	3.85	4.10	4.85	5.10	5.50	5.60	5.70

Table V Continued.

Evaporation from Overs of 50 CC.

4	13.39	1.30	2.20	3.20	3.80	4.00	4.40	4.80	4.90
12	13.56	1.70	2.70	3.60	4.50	4.80	5.10	5.40	5.65
24	13.24	0.60	1.10	1.70	2.20	2.60	3.10	3.40	3.60
36	13.55	0.80	1.10	1.80	2.30	2.70	3.20	3.50	3.85
48	13.27	0.50	1.40	2.10	2.70	3.40	3.80	4.00	4.30
72	13.35	0.90	1.90	2.50	3.20	3.60	4.05	4.30	4.50

Evaporation from Overs of 70 CC.

4	13.66	1.30	2.00	2.90	3.60	3.85	4.20	4.50	4.70
12	13.80	1.60	2.80	3.70	4.30	4.70	5.00	5.25	5.40
24	13.52	0.80	1.20	1.30	2.20	2.90	3.30	3.60	3.60
36	13.90	0.70	1.10	1.70	2.30	2.70	3.20	3.50	3.90
48	13.49	0.80	1.60	2.30	2.90	3.50	3.80	4.10	4.40
72	13.75	1.86	3.90	4.15	4.90	5.15	5.55	5.65	5.75

Evaporation from Throughs of 70 CC.

4	13.85	1.80	2.50	3.40	4.10	4.30	4.60	4.90	5.10
12	13.87	1.70	2.70	3.60	4.25	4.50	4.90	5.20	5.35
24	13.90	1.10	1.60	2.30	2.70	3.30	3.60	3.90	4.10
36	14.22	0.90	1.40	2.00	2.50	2.90	3.40	3.80	4.20
48	13.60	1.00	1.60	2.30	2.90	3.60	3.80	4.10	4.30
72	13.79	1.10	1.70	2.30	3.00	3.50	3.95	4.30	4.45

Whole wheat	0.712
Ground wheat	1.475
Overs 24 W.	2.523
Overs 50 GG. . . .	1.560
Overs 70 GG. . . .	1.680
Throughs 70 GG. . .	1.615

If the rates of evaporation of this series are compared with those of the first two series we find that they are from two to three times as great. However among each other they vary in the same proportion as in the first two series. That is, the rate in the ground wheat is about twice that of the whole wheat, and the rate in the overs of the 24 W. is in the neighborhood of three times that in whole wheat. The rates of the three middlings samples are about the same as that for the ground wheat.

EXPERIMENTS ON THE LARGE MILL

To obtain data concerning evaporation under conditions found in the commercial mill, several tests were made on the 65 barrel college mill. This mill has four breaks, six reductions, and two tailings rolls. There are four purifiers and the separations are made on Wolf sectional sifters. The mill is equipped with metal dust collectors which are exhausted into a cloth dust collector located on the purifier floor. This returns the moist air of the dust system to the mill. In addition the mill has a Carrier air conditioner with air outlet on the roll and purifier floors.

For this work a car of wheat, mixed and blended to correspond to commercial mill mixes, was purchased from a Salina mill. The protein of the wheat was 13.25 per cent and the moisture content was 11.0 per cent. In conducting these experiments approximately 5000 pounds of wheat was ground for each test. This corresponds to about eight hours of running time for the mill. The roll floor was held as near 70°F. as possible, and an effort was made to keep the relative humidity in the neighborhood of 50 per cent. Thermometers were placed on the roll floor, the purifier floor, and in the texas. They were also placed in the feeder boxes of each roll, in the spouts just under the rolls, in the spout leading from the tempering bin, and in the flour spout over the packer.

Very accurate data were taken on the amount of wheat used for each test and the weight of the total products. Three times during each test all the temperatures and the relative humidity on each floor were recorded. At the same time these data were secured, samples for moisture determinations were taken of the stocks above each roll and of each of the finished products. Several times during the day samples of the stock from the different break rolls were weighed and sifted so that the extraction of each roll was kept as nearly constant as possible. The moisture content of the wheat was varied from 14.5 to 18 per cent in the different tests, and some of the relative humidities were below 50 per cent, and one or two as high as 60 per cent. These two variations gave opportunity for comparison of the effect of the initial moisture content of the wheat and the effect of humidity on the amount of evaporation.

Due to the vast extent of the data obtained it was not deemed advisable to present all the figures; therefore, six tables were compiled which give representative results. The tables are in pairs. In each pair there is one table for the moisture drop and one for the temperature rise for each set of conditions.

The moisture drop was determined, in each case by the difference between the initial moisture content of the wheat and the moisture content of the sample of the stock above the different rolls and of the finished products.

The temperature rise was determined by the difference between the temperature over the roll and the temperature under the roll. The thermometers were read to the nearest tenth of a degree.

The first two tables (Table VI and VII) represent data taken from a series of seven lots of wheat each tempered for 16 hours. The temperature of the tempering water was 150°F. This gives a series of results with no variable factors excepting those of operation and the moisture content of the wheat.

The figures in Table VI seem to show a very definite trend of the temperature rise on the different rolls. In the breaks the highest temperature is on the first, next the third, followed by the fourth, and the lowest on the second. This would indicate that most of the work of the break system was done on the first and third breaks. In the reduction system the highest temperature rise is on the sizings with the first middlings a close second, and first tailings third. There are three causes for these high temperature rises in the reduction grinding. On the sizings rolls there is a large volume of stock, and on the first middlings there is also a large volume of stock from which a large extraction is made. In the first tailings there is a large proportion of chip stock which calls for closer grinding in order to flatten it so that it can be scalped off.

The figures for moisture of the break stocks given in Table VII seem to vary. There is in some cases a small loss, and in others a gain in moisture. This variation of the moisture in the break stock is probably due both to the humidity of the air in the spouts and machines of the break system, and to the large amount of surface exposed by the bran to the high moisture content of the air. In the reduction system there seems to be a gradual loss in moisture from the sizings and first middlings to the fifth middlings. The exception is the first tailings which seem to act as the break stocks in holding the moisture.

In the experiments furnishing the data reported in Tables VIII and IX the temperature of the tempering water was held constant (120°F.) and the length of temper was 4, 8, 16 and 48 hours respectively. This introduced a controlled variable, namely, the length of temper. The length of temper seemed to have no effect either on the moisture loss or on the temperature rise of the stocks from the different rolls.

In the experiments whose data are recorded in Tables X and XI the length of temper was held constant (48 hours) and the temperature of the tempering water was 180°F., 150°F., 120°F., and 60°F. respectively. This introduced the temperature of the tempering water as a controlled variable. The temperature of the tempering water did not seem to affect the general trend of either moisture losses or temperature rises to any extent.

A study of these tables seems to show that neither the length of the tempering time nor the temperature of the tempering water has any consistent effect on the amount of evaporation. However, the results seem to show a direct relation between the moisture content of the wheat and the evaporation in the various stocks. Also there seemed to be a direct relationship between the relative humidity and the amount of evaporation.

Table VI Temperature rise in degrees Fahrenheit.

Date	11-12-30		12-17-30		1-7-31		1-14-31
Temperature of water.	150°F.		150°F.		150°F.		150°F.
Length of temper	16 hours		16 hours		16 hours		16 hours
Wheat	82.5	84.0	77.0	79.0	79.0	79.0	80.0
1st. Break	7.2	7.6	4.3	5.2	5.4	5.8	5.6
2nd. "	1.4	1.3	1.3	0.9	0.2	0.5	0.2
3rd. "	5.4	6.1	5.8	3.8	4.0	3.8	3.8
4th. "	4.7	4.1	4.9	2.2	1.1	0.5	0.4
Sizings	16.4	16.9	17.7	12.6	8.3	8.1	13.1
1st. Middlings	9.9	9.9	13.9	13.9	9.9	9.4	9.9
2nd. "	12.8	9.4	5.4	4.0	0.0	1.8	2.3
3rd. "	8.3	7.9	7.3	5.2	4.3	4.5	5.4
4th. "	9.2	9.0	5,9	4.3	7.6	7.9	6.8
5th "	4.3	3.6	0.9	0.4	1.3	2.2	3.6
1st. Tailings	10.4	10.8	12.6	7.6	6.8	6.8	5.8
2nd. "	2.7	4.3	2.3	2.5	0.9	0.0	1.8
Temperatures							
Flour	84.2	87.8	77.6	79.7	80.0	81.3	78.2
Roll Floor	77.0	75.0	68.0	69.0	74.0	75.0	76.0
Purifier Floor	84.2	87.2	76.8	78.5	80.6	80.6	82.4
Texas	85.8	88.7	76.8	78.2	81.4	80.6	77.0

Table VII Moisture drop in per cent.

Date	11-12-30		12-17-30		1-7-31		1-14-31
Temperature of water.	150°F.		150°F.		150°F.		150°F.
Length of temper	16 hours		16 hours		16 hours		16 hours
Wheat	14.4	14.4	16.0	14.7	17.9	17.7	17.0
1st. Break							
2nd. "	0.5	+0.4	+0.1	1.0	0.2	+0.4	0.1
3rd. "	0.0	0.6	+1.4	0.6	+0.3	0.3	0.2
4th. "	0.5	0.4	+1.6	0.6	+0.1	0.1	0.7
Sizings	0.9	1.3	1.8	1.0	1.8	1.7	1.5
1st. Middlings	0.8	1.5	2.1	1.1	1.9	2.5	1.8
2nd. "	0.8	1.8	1.8	0.9	2.8	2.6	2.7
3rd. "	1.5	1.5	2.7	1.4	3.6	3.4	2.9
4th. "	1.6	2.0	3.0	1.9	4.1	3.9	3.4
5th. "	2.7	2.7	3.9	1.4	5.3	4.5	4.4
1st. Tailings	1.3	1.7	2.3	1.3	3.0	2.4	2.7
2nd. "	2.1	2.5	3.4	2.4	4.7	4.2	4.1
Bran	0.4	1.4	1.0	1.2	0.5	0.1	1.5
Shorts	2.7	3.9	4.6	3.2	5.6	4.0	4.6
Flour	1.8	2.4	3.4	1.8	4.7	3.7	3.5
Relative Humidities							
Roll Floor	50	41	58	67	54	64	40
Purfier Floor	45	44	45	65	56	56	53
Texas	41	40	51	59	60	62	49

+ = gain in moisture.

Table VIII Temperature rise in degrees Fahrenheit.

Date	3-30-31		3-8-31		12-3-30		2-9-31	
Temperature of water.	120° F.		120°F.		120°F.		120°F.	
Length of temper	4 hours		8 hours		16 hours		48 hours	
Wheat	76.0	76.0	76.0	76.0	80.0	81.0	77.0	76.0
1st. Break	6.1	8.3	6.5	6.8	5.9	7.2	6.8	7.9
2nd. Break	2.2	0.4	0.4	0.9	4.0	3.2	2.7	2.2
3rd. "	4.0	4.5	3.6	3.8	6.5	4.3	4.5	4.3
4th. "	2.2	2.9	1.4	0.7	3.6	2.7	1.3	1.4
Sizings	10.8	11.0	9.4	10.8	16.2	18.1	9.4	10.8
1st. Middlings	6.5	7.4	10.8	11.0	9.4	13.7	11.0	9.4
2nd. "	5.6	3.6	2.5	3.4	2.7	4.5	6.7	5.0
3rd. "	4.0	5.4	7.0	5.2	9.0	8.3	5.2	6.7
4th. "	3.6	4.5	7.3	6.5	7.4	9.9	4.7	5.4
5th "	2.5	0.0	1.8	0.7	7.6	5.4	4.9	3.4
1st. Tailings	5.8	7.0	9.0	9.0	12.6	11.0	9.7	10.8
2nd. Tailings	1.8	0.4	2.9	2.2	6.0	4.5	5.4	4.3
Flour	75.2	76.8	74.3	77.9	80.6	83.2	73.4	76.1
Temperatures								
Roll Floor	67.8	68.2	71.6	70.7	70.0	76.4	72.8	72.8
Purifier Floor	76.6		74.8	78.0	69.0	82.0	73.4	75.9
Texas	81.1		76.6	81.7	71.2	80.6	73.4	76.3

Table IX Moisture drop in per cent.

Date	3-30-31		3-[illegible]-31		12-3-31		[illegible]-9-31	
Temperature of water.	120°F.		120°F.		120°F.		120°F.	
Length of temper	4 hours		8 hours		16 hours		48 hours.	
Wheat	16.1	15.9	16.0	15.8	15.2	15.4	16.2	15.2
1st. Break								
2nd. "	0.0	+0.2	0.0	0.1	0.4	0.5	0.2	0.4
3rd. "	+0.4	+0.6	+0.6	+0.4	0.0	0.0	0.0	+0.3
4th. "	+0.3	+0.4	+0.3	+0.3	0.0	0.6	0.2	0.0
Sizings	1.2	0.7	1.0	1.0	0.2	1.7	1.5	1.1
1st. Middlings	1.6	0.9	1.2	1.4	+0.1	1.5	1.7	1.6
2nd. Middlings	1.6	1.2	1.5	1.5	1.1	1.6	1.5	1.4
3rd. "	2.1	1.7	1.9	1.2	1.4	1.3	2.5	2.2
4th. "	2.5	2.2	2.2	1.7	1.7	1.7	2.9	2.2
5th. "	3.2	3.0	3.1	2.5	2.2	2.8	2.4	3.3
1st Tailings	1.6	1.3	1.4	1.1	0.9	1.4	1.9	1.7
2nd "	3.1	2.8	2.8	2.2	2.1	2.6	3.3	3.1
Bran	0.4	0.5	0.4	+0.2	0.3	0.6	0.7	0.3
Shorts	4.0	3.5	3.8	3.2	2.7	3.2	3.6	3.2
Flour	2.6	2.3	2.7	2.3	1.9	2.2	2.7	2.2
Relative Humidities								
Roll Floor	58	58	52	51	64		55	56
Purifier Floor	46		57	52	60			
Texas	50		55	50	60			

+ = gain in moisture.

Table X Temperature rise in degrees Fahrenheit.

Date	11-26-30		2-2-31		2-9-31		2-16-31	
Temp. of water	180°F.		150°F.		120°F.		60°F.	
Length of temper	48 hours		48 hours		48 hours		48 hours	
Wheat	70.0	75.0	81.0	83.0	77.0	76.0	76.0	77.0
1st. Break	6.8	4.7	6.8	4.9	6.8	7.9	6.7	7.2
2nd. "	8.0	2.2	0.4		2.7	2.2	1.8	1.8
3rd. "	3.2	3.2	3.6	3.6	4.8	4.3	6.1	6.1
4th. "	2.1	1.4	-1.8	-1.8	1.3	1.4	3.1	2.9
Sizings	20.5	18.8	10.6	9.9	9.4	10.8	11.7	11.2
1st. Middlings	16.9	14.6	6.3	6.3	11.0	9.4	9.7	9.0
2nd. "	4.1	5.4	0.0	1.6	6.7	5.0	6.7	4.5
3rd. "	5.4	2.3	10.5	7.0	5.2	6.7	4.0	3.6
4th. "	5.4	0.9	4.9	3.2	4.7	5.4	5.6	4.5
5th. "	5.0	4.5	4.0	3.2	4.9	3.4	3.4	3.2
1st Tailings	11.0	6.8	7.8	7.2	9.7	10.8	8.7	7.2
2nd. "	3.6	1.8	2.2	1.8	5.4	4.3	2.7	3.6
Flour	69.8	67.8	79.2	82.0	75.4	76.1	75.3	79.0
Temperatures								
Roll Floor	66.0	74.0	77.0	78.0	72.8	72.8	72.0	72.8
Purifier Floor	72.0	69.5	80.0		73.4	76.0	73.3	71.8
Texas	68.0	73.5	78.5		73.4	76.0	68.4	75.2

- = a loss in temperature.

Table XI Moisture drop in per cent.

Date	11-26-30		2-2-31		2-9-31		2-16-31	
Temperature of water.	120°F.		150°F.		120°F.		60°F.	
Length of temper	48 hours		48 hours		48 hours		48 hours	
Wheat	15.0	14.1	15.1	16.1	16.2	15.8	15.8	15.9
1st. Break								
2nd. "	0.4	0.4	0.3	+0.7	0.2	0.4	0.3	0.2
3rd. "	0.3	0.1	0.5	+0.8	0.0	+0.3	+0.1	+0.2
4th "	+0.4	0.3	0.9	0.7	0.1	0.0	+0.2	+0.2
Sizings	1.4	0.7	1.2	1.3	1.5	1.1	0.9	0.8
1st. Middlings	1.5	0.3	1.7	2.1	1.7	1.6	1.1	1.2
2nd. "	1.8	1.2	1.5	2.0	1.6	1.4	1.3	1.3
3rd. "	1.9	1.9	2.1	2.7	2.5	2.2	1.9	1.7
4th. "	2.5	2.1	2.6	3.1	2.9	2.2	2.0	2.0
5th. "	3.0	2.7	2.3	3.9	2.4	3.3	2.8	2.5
1st. Tailings	2.3	1.9	2.0	2.7	1.9	1.7	1.5	1.2
2nd. "	2.9	2.7	3.2	3.9	3.3	3.1	2.8	2.3
Bran	0.6	1.1	1.4	1.4	0.7	0.3	0.5	0.8
Shorts	4.0	3.9	3.8	4.8	3.6	3.2	3.4	3.2
Flour	2.4	1.9	2.5	3.3	2.7	2.2	1.8	2.1

Relative Humidities

Roll Floors	37	30	33		55	56	60	60
Purifier Floor	36	34	46					
Texas	34	35	53					

+ = gain in moisture.

The interpretation of such data as the above is very difficult because of the number of variable factors. Although the extraction on the breaks was held as nearly constant as possible there was no way in which the amount of grinding on the reduction rolls could be predetermined. For this reason it is difficult to say whether the temperature rise is due to the peculiar characteristics of the various stocks or whether it is due to the unavoidable variation in setting the rolls. However there seemed to be no relation between the temperature rise and the evaporation from the different stocks. In several cases there was no rise in temperature of the stock below the roll and in some cases there was actually a loss in temperature. This may have been due to the fact that the rate of evaporation in the stock was high enough to actually cool the air in the spout.

If an average is taken of the temperature rises on the different rolls in Tables VI, VIII and XI, we may obtain a view of the temperature affect of the different grindings.

Average Temperature Rise in Degrees Fahrenheit

1st. Break . . .	6.5
2nd. " . . .	1.6
3rd. " . . .	4.5
4th. " . . .	1.9
Sizings . . .	12.6
1st. Middlings	10.4
2nd. " . . .	4.5
3rd. " . . .	6.0

4th. Middlings	. .	3.9
5th. "	. .	3.2
1st. Tailings	. .	3.9
2nd. "	. .	2.9

The variation in temperature rise in the different stocks may be due to several factors. The temperature rise denotes to some extent the amount of work done by the roll. This is dependent on three things: the moisture content of the stock; the kind and amount of work done on the roll; and the character of the stock. As to whether the amount of work done to reduce any certain stock is proportional to its moisture content has not been conclusively proven. However, we do know that if we increase the extraction on the roll, or if we grind closer to flatten the bran chips, it takes more energy and consequently more heat is produced.

In some cases the moisture content of the break stocks was found to be as much as 1½ per cent higher than that of the wheat. This is no doubt due to the relative humidity in the spouts and machinery of the break system being much higher than that of the room and the branny material having a large surface adsorbs some of the moisture of the air. This same factor seemed to be operative on the first tailings stock which showed a much higher moisture content than any of the other stocks on the tail end of the mill. There was a gradual gain in the moisture drop from one reduction to the next, of .1 per cent. This seems to show that the evaporation is much higher in the finer middlings near the tail end. The moisture drop from first to second tailings was 1.2 per cent. The greatest factor influencing the loss of moisture was the initial moisture content of the wheat.

CONCLUSION

The following is apparent from the data presented.

1. The length of temper has no effect on the rate of evaporation from wheat or mill stocks.

2. The temperature of the tempering water has no effect on the rate of evaporation.

3. The rate of evaporation from stocks of high moisture content is greater than from stocks of low moisture content.

4. There seems to be no relationship between the temperature rise of the different rolls and the rate of evaporation from the stock ground by the roll.

5. There seems to be a very definite relationship in the rates of evaporation from different classes of stock. That is, the character of stock affects the rate of evaporation.

The work done in this experiment serves mostly as an introduction to the study of the problem of evaporation in the flour mill. It presents some facts and figures which may be used as a basis for further investigation. Some of the problems for future study are the effects of the relative humidity in the machinery of the break system; the relation between moisture content of the wheat and the evaporation from the different stocks; and methods of control of evaporation in different parts of the mill.

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