

A STUDY OF THE INFLUENCE OF TEMPERATURE ON WHEAT  
TEMPERING

by

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## INTRODUCTION

Tempering is the process of conditioning wheat by the adding or removing of water, for the purpose of toughening the germ and bran; also making the endosperm or floury portion of the berry more friable. Another way to define tempering would be the changing of wheat into such a physical condition that the separation of the bran from the endosperm is facilitated, and whereby so far as is possible the baking quality of the resulting flour shall be improved.

Since the two principal objects in tempering are to bring the wheat into a suitable condition for mechanical treatment in the mill, and to improve the baking qualities of the flour, the results of good milling, as influenced by tempering, may be seen and judged more easily than those associated with the flour quality. It is also evident if the first object of tempering is not achieved, the baking quality of the flour will suffer indirectly; for the presence of bran powder in the flour, as an example, lowers the general quality of the flour. The color of the flour being poor, and due to the harmful enzymes introduced along with the bran, the baking value of the flour is seriously depreciated. Hence the miller should remember that in tempering there are two objects, and in order to achieve excellence in the one he should see that the other does not

suffer.

The problem of tempering developed when Turkey wheat was first grown on the western plains, where the dry weather during the ripening period produced a hard vitreous kernel. This made it impossible to separate the floury portion from the bran and germ, so as to produce as white a flour as was produced from soft wheat.

In the United States we think of tempering as adding water to the wheat, while in some of the foreign countries it is necessary to reduce the moisture content of the grain before milling. It is generally accepted among millers that wheat with approximately 15 per cent of moisture is the best for grinding. Slight variations must be made due to the physical texture of the grain and fluctuation in relative humidity during milling.

Automatic devices have been invented to add the water to the wheat before putting it in tempering bins; where it stands from six to seventy-two hours. For mills of 1000 to 6000 barrels daily capacity the longer time necessitates enormous bin space to hold the wheat during tempering. The loss may also be considerable if the mill breaks down so the wheat cannot be milled for several days, since heating may occur due to excess moisture.

In many mills wheat heaters are used during the cold weather to heat the wheat before tempering, and some use

these heaters the year round. Since the chemical constituency and the physical properties of the bran, germ, and endosperm are so different, wheat may be conditioned to a certain extent by the use of heat alone. As the temperature of the wheat is increased the physical texture of the wheat is changed, the endosperm becomes softer, while the germ and bran become less friable. These changes help to accomplish the requirements of tempering.

Temperature also influences the rate of movement of the water molecules. The higher temperature not only speeds the action of these molecules, but increases the distance between them, which will increase the rate at which water will penetrate the grain.

In 1928 a device called a temperator was patented by the General Mill Equipment Company, in which the wheat is heated in the process of tempering. Experiments have been conducted with the apparatus, and it is claimed that wheat can be tempered with it in thirty minutes. If it is possible to temper wheat in that length of time, it will mean a great economic saving both in time and building space. It will also eliminate the uncertainties in tempering wheat to suit the weather conditions of to-day, and then finding them changed at the actual time of milling.

In a survey of tempering practice in the different mills, a letter was mailed from the college to 144 mills. Eighty-eight of these mills answered this letter, some omitting the answers to part of the questions. Seventy-six of these mills ground hard wheat and 34 were using heat in connection with tempering, 7 of the 34 used heat the entire year while 27 used heat only during cold weather, which shows that using heat is considered by some practical, although they may not be using it to the best economical advantage.

The experiments reported in this thesis are divided into three groups: water penetration, work on the experimental mill, and work on the large mill. The former mill is non-automatic, and the sample milled is five pounds or less. The large mill is the long system mill of 60 barrels capacity.

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#### REVIEW OF LITERATURE

In reviewing current literature in milling magazines, we find that most statements are based upon the conclusions which the authors have made from rather casual observations. As a rule, no data is offered to substantiate the statements made. The knowledge of the best conditions for tempering is still fragmentary, as far as scientifically conducted investigations are concerned.

Amos (1920) states that conditioning of wheat is the process of lining up various wheats in a mixture to the same degree of hardness, toughness and yellowness, so that

each individual grain shall stand the same breaking down on the rolls, with approximately the same results; in large bran flakes, small percentage of break flour, and plenty of good bright semolina and middlings. There shall be no bran powder (due to brittle skins and too small percentage of water) and no pasty juicy bran, stained flour and lost flour in the offals (due to too great a percentage of water.)

Tagus (1920) states that in tempering wheat at 5°, 20°, and 40°C., for the periods of 24, 48, and 72 hours. At the temperature of 5°C. the length of tempering period appeared to have very little influence on either the physical characteristics or the chemical composition of the flour.

When the wheat was tempered at 20°C., a small but definite chemical change took place. The hydrogen-ion concentration was increased, as shown by the lower  $P_H$  figure. The total acidity, the water soluble phosphorus and the titrable nitrogen were also higher. Both the yield and the milling qualities were better than when the wheat was tempered at 5°C. The time of tempering appeared to be a factor in the chemical changes, but had very little if any relation to the physical characteristics.

The chemical changes were still more pronounced when the wheat was tempered at 40°C. The physical changes,

however, appeared to be detrimental to the milling qualities of the grain.

Simon (1923) states that the four direct results of good conditioning are:

1. To toughen the bran and to prevent bran powder being formed.
2. To secure the easiest separation of the bran from the endosperm.
3. To render easy the subsequent breaking down of the endosperm.
4. To get accurate and easy sifting on the dressing machines.

He also states that owing to the risk of damage, the bulk of the wheat ought not to be heated to a temperature higher than 49°C. as otherwise some individual grains might reach 60°C. at which temperature rapid and far-reaching changes may occur which may be very harmful.

In order to get quick and effective conditioning or tempering of the wheat so that it grinds nicely on the rolls the wheat ought to be heated to not less than 43°C.

Dunham (1925) states that with the knowledge of how the endosperm of the wheat berry is built up, the function of the hollow hairs and the structural resistance of the skins to prevent the entrance of moisture to the endosperm except through the hollow hairs-- for the entrance by the

placenta is closed and sealed by the two hairy valves (the valve however can be displaced by friction in the cleaning department of the mill) that water can enter only through the hair of the grain. It is at once apparent how washing, drying, and chilling the grain are simply carrying out a natural law by going one step forward in developing the wheat in the mill as well as making the grain more uniform and improving the resultant flour.

Lawellen (1927) states that their observations lead them to state that the ideal temperature of a finished flour at the agitators is between  $21^{\circ}$  and  $27^{\circ}\text{C}$ . That below  $21^{\circ}\text{C}$  the miller cannot get the proper dress, clean up, or yield, and that too much of the feed is included in the flour. That above  $27^{\circ}\text{C}$ , the flour is too hot in that mold growth may start, chemical and enzymatic changes will be started which will result in rancidity, increased acidity and deterioration of gluten.

Kent-Jones (1927) experimented with wheat dampened to a moisture content of 17-18 per cent placing it in enclosed rectangular tin slots about one inch in width, and these were put in a water bath which was kept at the desired temperature for a definite time. In this way dampened Manitoba wheat was heated at  $32^{\circ}\text{C}$ . for periods of 30 minutes to 24 hours. No substantial difference was found

between the wheats heated for 30 minutes to 24 hours.

The experiment was repeated at 43°C. and again it was found that no chemical change apparently occurred under the conditions of the experiment at that temperature for as long as 24 hours. In no case were the baking qualities affected.

In heating the dampened wheat at 57°C. it was found that no chemical or physical changes were apparent. It must be remembered that the whole of the wheat would not be at that temperature all the time. The outside portions soon acquired a temperature 1 or 2° below that of the bath, but the center portions took some time to reach the maximum temperature.

In continuing the heating at 57°C. for six hours it was found that slight chemical changes took place, but very little change could be observed in the baking test. When the heating was continued for 24 hours, however, a definite change occurred which was indicated by the baking test, the strength of the flour being improved. In a few hours the flour developed a disagreeable sour odor.

Samples then were heated to 71°C. for 1½ to 2 hours and then cooled before adding the tempering water. The wheat appeared to be unchanged, but later when it was conditioned and ground into flour, the flour was found to have increased strength.

As the protein of most wheats appears to be in an insufficient degree of coagulation or aggregation, it can be greatly improved by a subsequent heat coagulation, before undergoing the process of milling.

Swenson (1928) states that carefully controlled use of heat on fully matured, but new wheat, will bring about an improvement in the baking qualities. However, if the degree of temperature is too high, or if the period of heating is too long, marked damage may result.

When heating takes place under uncontrolled conditions such as happens when wheat is cut immature, serious damage may result. The same will apply to wheat cut too wet but fully mature. Controlled heating will improve immature wheat when the degree of temperature is not too high or the period of heating too long.

McCormick (1930) states that he found very little difference if any in the influence of the length of tempering at ordinary temperatures of around 25 to 30°C. upon the process of milling or upon the resultant flour as determined by the baking methods.

## RATE OF WATER PENETRATION IN WHEAT DURING TEMPERING

In a survey which was conducted by the Milling Department it was found that in commercial practice the extremes in time of tempering are from 3 hours to 72 hours. If the water gets to the center of the wheat kernel and is uniformly distributed in a short length of time, why the many hours of tempering? The object of this investigation was to learn how soon the tempering water becomes evenly distributed throughout the endosperm.

In analyzing the water penetration in wheat during tempering, it may be well to define the words adsorb and absorb, before going too far in this discussion. The definition may help to avoid confusion of the two terms since they are spelled and sound so similar. These definitions are taken from the New Century dictionary: Adsorb means to gather on the surface of the molecules in a condensed layer, while absorb means to take up by chemical or molecular action. According to these definitions, absorption takes place when the water penetrates the wheat kernel, and may take place under the following conditions: When the wheat is immersed or dipped in water, and when water is added as in tempering, that is, when a small amount of water is added to the wheat and thoroughly mixed. Water is also absorbed when wheat is exposed to air of a high humidity.

### Absorption when Wheat is Immersed in Water

To determine the rate of absorption when wheat is totally submerged in water for varying lengths of time and in water of different temperatures, a definite amount of wheat was immersed in the water at a controlled temperature for a given length of time. Then it was placed in specially made cups with screens on the bottoms. These cups were then placed in a centrifuge and the surface water thrown off by centrifugal force. The centrifuge used was an ordinary Babcock cream tester. It was turned at a given rate and for the same length of time in every determination.

In order to eliminate error from evaporation in these experiments, two cups were centrifuged at a time, then weighed before starting to centrifuge the next two. A uniform lot of hard wheat was used. By this method it is believed that very comparative data was obtained. In a preliminary trial, four samples were treated alike in order to determine if comparable results could be obtained. The figures in Table I give the variation which occurred in this series of tests, and shows the limits of accuracy for the figures obtained in the trials which are reported in this thesis.

Table I Variations in the amounts of water absorbed under similar conditions.

Time of soaking	Grams of water absorbed by 100 gm. of wheat at room temperature.	Maximum difference	Average	Maximum deviation from average.	Probable error	Ratio D/P.E.
10 minutes	6.88 : 6.7	6.84 : 6.78	.16	6.80	.065	.667 : .09
30 minutes	10.44 : 10.86	10.22 : 10.42	.22	10.38	.115	.667 : .17
40 minutes	12.54 : 11.82	11.96 : 11.88	.72	12.07	.465	.667 : .70
16 hours	46.56 : 46.14	46.52 : 46.40	.42	46.40	.265	.667 : .39

The greatest difference between the maximum and minimum in these single trials was .72 gm., and the least .16 gm. or the variation was less than one gram of the amount of water absorbed by the wheat. However, one must determine if these errors are significant, or if more trials are necessary in order to obtain sufficient accuracy. In order to make this clear it will be necessary to find the deviation from the average, and also its ratio to the probable error. The largest deviation from the average of each four trials was .465 gm., and for the ten minutes it was .065 gm., which is very small. The ratio of deviation to probable error should be less than three if an experiment does not need more trials for reliable information. To determine the probable error, it is first necessary to calculate the standard deviation of the point binomial using the formula  $S = \sqrt{npq}$ , where  $S$  is the standard deviation of the point binomial,  $n$  is the number of trials and  $p$  is the probability of accuracy, while  $q$  is the probability of inaccuracy.

The probability of a complete set of compound events may be illustrated by tossing up a coin. The probability that heads will turn up during a number of trials will be a fifty-fifty chance -- or  $p$  and  $q$  each will be equal to .5. The same is true with experimental work. One has a fifty-fifty chance of accuracy on each test.

Now since the probable error is equal to .6745 times the standard deviation of the point binomial, the probable error is equal to  $.6745 \sqrt{.5 \times .5n}$  or  $.3375 \sqrt{n}$ . Substituting  $1/3$  for  $.3375$ , we have the probable error equal to  $1/3\sqrt{n}$ . The probable error then equals  $1/3\sqrt{4}$  or  $.667$ , while the largest deviation from the average is the difference from the average and the trial farthest away from the average. The ratio of deviation to probable error is found by dividing the deviation by its probable error. This ratio of the deviation from the mean to its probable error is less than one in all cases, as shown in the last column of Table I. In fact, the largest ratio is  $.7$  for the 40 minutes of soaking the grain, which indicates very good experimental results. Consequently, the data obtained under these experimental conditions may be considered reliable.

This data shows that in ten minutes at room temperatures, the wheat had taken up 6.8 per cent of its original weight in water. In thirty minutes it had gained 10.33 per cent of its original weight. This is not three times the amount absorbed in ten minutes, but is an average of .17 of one per cent per minute after the first ten minutes. We notice that in the next ten minutes it gains in a similar ratio, but as the time increased the amount of water absorbed decreased in proportion. In other words, wheat immersed in

water absorbs it rapidly at first, thereafter as the length of time increases the amount of water absorbed gradually decreases, that is, as the wheat becomes filled with water, the rate of absorption diminishes. At the end of fifteen hours it had gained 46.46 per cent of its original weight, or nearly all the water possible for it to hold.

Tests were also made to ascertain the influence that temperature has upon the rate of water penetration. Experiments were conducted, heating and cooling wheat and water to given temperatures before immersing the wheat in the water. The following temperatures were used: 6°, 27°, 40°, 60°, and 80°C. Time of immersion was varied at the lower temperatures from just dipping the wheat into the water to soaking it for 48 hours. For the higher temperatures it was not soaked over such long periods, but in all cases the wheat was heated or cooled to temperature of the water before submerging. The length of time for immersion recorded was from the time the wheat was submerged until it was taken from the water bath. The cups holding the wheat were then immediately placed in the centrifuge and whirled. The figures in Table II are the averages from four determinations.

The instant dipping trial was done to determine the amount of water that would cling to the grain. Just how much of this entered the interior of the grain is impossible to say, but the samples showed over four per cent gain in

Table II Effect of temperature in water penetration

Duration of immersion in water.	Grams of water absorbed per 100 gm. of wheat.						D./p.l.
	Temperatures						
	5°C.	27°C.	40°C.	60°C.	80°C.	Mean	Largeest deviation
Instant dipping:	4.1	4.5	3.4	4.1	4.1	4.04	.64
10 seconds	4.1	5.1	4.6	4.4	4.7	4.68	.58
20 seconds	4.6	5.6	5.0	4.5	5.3	5.0	.6
40 seconds	5.4	6.5	5.1	4.9	5.6	5.5	1.0
1 minute	5.5	7.3	7.4	5.7	6.8	6.54	1.04
2 minutes	5.6	7.7	8.4	7.2	9.0	7.68	1.98
5 minutes	5.7	8.9	10.0	10.0	14.1	9.54	4.56
10 minutes	6.2	9.9	11.7	14.7	22.1		
20 minutes	6.9	12.0	15.7	20.5	33.7		
40 minutes	9.1	14.3	19.9	29.5	45.7		
90 minutes	10.6	18.6	28.6	46.8			
2 hours	18.5	21.1	32.2	40.7			
3 hours	14.3	24.4	36.6				
4 hours	15.4	29.6	40.7				
6 hours	20.1	33.8	45.5				
8 hours	23.5	38.4	49.1				
18 hours	24.7	43.5					
24 hours	27.8	50.4					
48 hours	35.8						

weight. The 10 seconds immersion shows only a slight increase in gain of water over the instant dipping, although the average for the various temperatures is one-half per cent greater. No material increase is noted at the higher temperatures for the short periods of time, which indicates that temperature effect is very small on the amount of water absorbed when the time is short. If we apply the ratio of the deviation from the mean to the probable error in the analysis and comparison of this data we find that the temperature does not enter into the results until the grain has soaked more than 2 minutes. Our comparison of the deviation from the mean to the probable error is only .86 for instant dipping, but at 2 minutes soaking its ratio is 2.66; at 5 minutes soaking it is 6.12. This shows that after 2 minutes soaking there is a marked difference in the effect of temperature upon the rate of absorption of water by the grain. Since the ratio will increase with the time of soaking it was not calculated for the rest of the data.

Table II also shows that the wheat absorbed 5.6 gm. of water in 2 minutes at 60°C., while at 80°C. 9 gm. was absorbed, or 3.4 gm. more, due to the higher temperature. The wheat at 80°C. absorbed its maximum amount of water in 40 minutes; at 60°C. it took 2 hours; at 40°C 8 hours; while at 27°C. (a little above average room temperature) it took 24 hours, and at 6°C. the maximum was not reached in

48 hours. This shows that heat plays an important part in the rate at which water will penetrate the wheat, at least when the amount of water is large. The surface tension of the water is reduced by warming and thus it will penetrate much more rapidly. For example, place a few drops of cold water on a board, then put an equal amount of warm or hot water on the same board, and note how much more readily the warm or hot water soaks into the board. The same is true of wheat, as shown in this experiment.

Some people believe that wheat is surrounded by a non-permeable membrane, but if it were, as is the case of white clover seed, it would not absorb water. Because white clover seed does not germinate readily, it was thought by some people that the seed was poor, but it was found that the slow germination was due to the non-permeable membrane which covers the grain. After scarifying the seed nearly all of it would germinate. Wheat does not need to be scarified to enable moisture to come into contact with the endosperm, as water can be absorbed very readily through the bran coat, germination taking place in twenty-four to forty-eight hours time if there is sufficient moisture and the temperature is suitable.

### Coating Wheat with Shellac to Determine where the Water Enters the Berry

An experiment was conducted to find out if water enters the wheat kernel more easily at one place than another. Head samples of Kanred wheat were obtained. Each grain was picked from the head separately so that the bran coat, or any non-permeable membrane, that might surround the kernels would not be scratched. This wheat was divided into four lots, one used as a check sample; one shellacked on the germ; one on the brush end, and one on the back of the grain. In each case approximately equal parts of the wheat surface was covered. After the shellac had dried, each sample was weighed and then placed between wet layers of muslin which was first soaked in water, then wrung to remove excess moisture. This wheat was removed for weighing at the following intervals: 1, 2, 4, 6, and 24 hours. As soon as taken from the wet muslin the kernels were placed between blotters to remove surface water, then they were weighed, and placed again between the wet cloth. Water was added at intervals to the cloths in order to keep the moisture uniform during the experiment. Table III shows the per cent gain in these samples for the various periods of time.

Table III Water penetration through different parts of bran coat showing the per cent gain.

Sample	Hours				
	1	2	4	6	24
Check	5.8	8.5	13.8	18.4	40.0
Shellac on brush	6.3	9.3	14.1	20.8	37.8
Shellac on back	4.3	6.9	10.5	14.1	32.0
Shellac on germ	4.1	6.2	9.3	12.6	29.7

At one hour of soaking the wheat treated with shellac on the brush absorbed 6.3 per cent moisture, while the check sample absorbed only 5.8 per cent. The grain treated with shellac on the germ absorbed 4.1 per cent, and that treated on the back gained 4.3 per cent. The fact that the absorption in the kernels whose brush ends were covered with shellac was as great as the check sample which was without shellac on any part, shows that very little if any absorption took place through the brush end. This statement will not hold for kernels which have been threshed or scoured. The kernels shellacked on germ or back absorbed less water than those shellacked on brush end. In fact very little difference is noticed in the samples shellacked on germ or on the back. The theory advanced by some

people that water enters only through the germ does not hold in the face of these figures, and it must be admitted that water enters the grain throughout the whole bran coat. The non absorption through the brush end in hand plucked kernels is probably due to the film of air held by the fine wheat hairs, or to the increased resistance due to the excess friction.

#### Rate of Water Absorption in Tempering Wheat.

Water is added to wheat in tempering for two reasons: to make the bran coat tougher, and to mellow the endosperm. These will be considered in this experiment. The experiments already given show that the water enters the wheat kernel rather rapidly, and the rate is increased by higher temperatures. In tempering, the water is applied in a manner altogether different from that of immersing the wheat in water as used in the above experiments. Although the fundamental principles in regard to absorption are similar, whether it enters as rapidly in the process of tempering is a question to be answered. Also we need to determine if all that is necessary in tempering is merely distributing the water through the berry. While the amount of water is comparatively small, yet the absorption may be just as complete. Whether more of this water is absorbed by the bran than by the endosperm must also be determined,

also how much of this water is lost during the tempering process.

Presumably a certain amount of absorption of a chemical nature takes place during the process of tempering. This may help change the physical texture of the endosperm. This part of the problem is not considered in this paper. Such absorption would have an effect on the colloidal behavior of the flour and on the baking qualities.

The rate of absorption in tempering for various periods may be determined by adding a definite amount of water to a weighed quantity of wheat of known moisture content, and determining the moisture in the cracked wheat, bran, and various sized middlings.

For this experiment a uniform lot of Turkey wheat of a known moisture content was used. It was first cleaned on a small experimental separator, then scoured on a small Bureka experimental scourer. For each test 600 gm. of wheat was placed in each of three half gallon Mason jars. Enough water was added to bring the moisture content up to 16.75 per cent as determined by drying at 130°C. for one hour and 15 minutes, which gives approximately 1.25 per cent more moisture than by the Brown Duvel method. Therefore by common methods the wheat had 15.5 per cent moisture which is considered optimum. The periods of tempering were 1, 2, 4, 8, 16, and 24 hours, and the time

of tempering was so regulated that the wheat could be ground at the expiration of the period set for each sample. This experiment was conducted during the winter months when a relatively low temperature could be maintained with a humidity of about 60 per cent. The evaporation is not as great under these conditions as it is at higher temperatures, even with higher humidities.

Five hundred grams of the tempered wheat was used for milling, and the rest for moisture determination on each sample of wheat milled. The wheat was first passed through the break rolls set at .028 inches apart, which corresponds to our first break, and then immediately passed through the rolls at .006 inches apart, corresponding to our third break grinding. Then the sample was sifted immediately, taking less than 5 minutes from the time grinding was started until sifting was completed. This insured only a small loss in weight due to evaporation of moisture. There was also a possibility of a small mechanical loss. The following stack of sieves were used during sifting: 24 wire, 80 G.G. and 70 G.G. The stocks as well as the wheat were weighed on a balance sensitive to 0.1 gm.

For room temperatures the Mason jars were kept in the milling room. For the higher temperature the jars were put in a specially made box with a thermostatic control, and

for tempering at 6°C. the samples were kept in the large refrigerating room of the Dairy department. The wheat was adjusted to these temperatures before the tempering water was added, and kept at that temperature during the entire tempering period. However, the milling was done at room temperature which varied between 14° and 17°C.

In performing experiments of this nature it is difficult to control or distinguish between the losses from evaporation and those due to the mechanical operation. The total loss during the milling and sifting operations can be obtained by adding the weights of the different stocks and subtracting the sum from the weight of the original wheat ground, which was 500 gm. Table IV shows an example of the experimental data obtained for each tempering period.

From all the data obtained as shown in Table IV the averages of the three trials were computed in each case, and Tables V and VI give the averages. The figures in Table V show the weight of the products obtained in the process of grinding these samples, the length of tempering period, the temperature of tempering, temperature and relative humidity of the room in which the samples were ground; also the gain or loss during grinding and weighing.

Table IV A sample of the experimental data obtained for each tempering period.

Tempering time one hour. Temperature 18° C.  
 Weight of wheat 600 gm. Water added 20 cc.  
 Relative humidity 61.

Weight of wheat after tempering.

a. 620 gm.

b. 620 gm.

c. 620 gm.

Sample No.	Weight: wheat	Over 24 %	Over 50 G.G.	Over 70 G.G.	Through: 70 G.G.	Sum:	Loss
a	: 500	: 221.3	: 160.0	: 56.0	: 53.8	: 491.2	: 8.6
b	: 500	: 229.0	: 160.0	: 55.5	: 54.0	: 498.5	: 1.5
c	: 500	: 229.95	: 159.7	: 52.9	: 52.8	: 494.8	: 5.2
Average		: 226.6	: 159.9	: 54.8	: 53.5	: 494.8	: 5.2

Per cent Moisture

a	: 16.73	: 17.48	: 15.98	: 16.15	: 16.68
b	: 16.98	: 17.55	: 16.50	: 16.42	: 16.46
c	: 16.93	: 18.24	: 16.17	: 16.24	: 16.37
Average	16.88	: 17.76	: 16.15	: 16.27	: 16.50

The three temperatures at which the wheat was tempered were 6°C., 18°C. and 40°C. The mean room temperature during the grinding was 16° when grinding the wheat tempered at temperatures higher or lower than that of the room, and 18° for the wheat tempered at room temperature. The mean relative humidity was 62, 59, and 64 per cent respectively.

The loss which is shown in the last column of Table V. is very small in all cases. The mean loss for the 6°C. tempered wheat was 1.0 gm. or 0.2 per cent; for the 18°C. it was 3.1 gm. or 0.62 per cent, and for the 40°C tempered wheat it was 6.5 gm., or 1.3 per cent, or the loss increased with the temperature of the wheat during tempering as these samples were not cooled before grinding. This shows the greater part of the loss was due to evaporation, and that the mechanical losses were small.

The mean weights show that as the temperature for tempering was increased, more of the fine products were obtained and fewer of the coarse. We will consider the overs of the 50 S.S. as sizings, the overs of the 70 S.S. as coarse middlings, and the throughs of the 70 S.S. as fine middlings. The average amount of fine middlinge produced by tempering at the low temperature of 6°C was 51.2 gm.; at 18°C 56.8 gm., and at 40°C 63.2 gm. The average amount of coarse middlings produced by tempering at 6°C. was 53 gm., at 18°C. 56.3 gm., and at 40°C. it was 60.7 gm. This shows

Table V Distribution of Grinding.

Time of tempering hours.	:Temperature of room °C.	:Rela- tive humid- ity.	Grams per 100 gm. of wheat.							
			:Over 24 W.	:Over 50 G.G.	:Over 70 G.G.	:Through	:Sum	:Loss		
1	6	:	64	: 250.1	: 156.3	: 48.8	:	44.3	: 499.5	: 0.5
2	6	:	56	: 243.4	: 197.8	: 50.6	:	47.2	: 498.5	: 1.1
4	6	:	56	: 241.0	: 158.7	: 51.6	:	49.6	: 500.9	: 9 <sup>a</sup>
8	6	:	63	: 233.5	: 158.8	: 53.2	:	52.1	: 497.6	: 2.4
16	6	:	66	: 222.4	: 165.6	: 56.7	:	55.7	: 500.0	: 0.0
24	6	:	67	: 218.8	: 163.2	: 57.3	:	58.3	: 497.6	: 2.4
Mean	:	:	62	: 234.9	: 160.1	: 53.0	:	51.2	: 499.0	: 1.0
1	18	:	61	: 226.6	: 159.9	: 54.8	:	55.5	: 494.8	: 5.2
2	18	:	56	: 230.6	: 159.5	: 54.8	:	53.9	: 498.8	: 1.2
4	18	:	60	: 227.2	: 158.1	: 53.4	:	57.2	: 495.9	: 4.1
8	18	:	60	: 228.2	: 153.3	: 57.8	:	58.0	: 497.3	: 2.7
16	18	:	60	: 219.9	: 158.0	: 58.7	:	60.0	: 496.3	: 3.7
24	18	:	56	: 227.7	: 153.9	: 58.1	:	59.3	: 498.0	: 2.0
Mean	:	:	59	: 226.7	: 157.1	: 56.3	:	56.8	: 496.9	: 3.1
1	40	:	60	: 220.3	: 150.7	: 58.5	:	61.1	: 490.7	: 9.3
2	40	:	63	: 220.5	: 142.5	: 62.8	:	66.8	: 492.6	: 5.6
4	40	:	63	: 224.6	: 140.3	: 62.8	:	66.8	: 494.5	: 5.6
8	40	:	64	: 229.7	: 133.4	: 62.0	:	65.8	: 491.8	: 8.1
16	40	:	66	: 224.2	: 155.9	: 58.0	:	57.8	: 495.3	: 4.7
24	40	:	57	: 220.0	: 155.6	: 60.4	:	59.9	: 495.9	: 4.1
Mean	40	:	64	: 223.2	: 146.4	: 60.75	:	63.2	: 493.5	: 6.5

<sup>a</sup>2min.

a constant increase in coarse and fine middlings when tempering at higher temperatures. The mean amount of siftings obtained when tempering at 6°C. was 160 gm., at 18°C. 157.1 gm., and 40°C. 146.4 gm. This shows a constant decrease in siftings as the temperature was increased during tempering. The mean amount of bran and endosperm left in contact was at 6°C. 234.9 gm., at 18°C. 226.7 gm., and at 40°C. 223.2 gm. This indicates that temperature helps mellow the endosperm and toughen the bran.

The length of time used in tempering showed a marked effect at 6°C., since with the longer time of tempering more siftings, coarse and fine middlings were produced. This effect is also slightly noticeable for the wheat tempered at 18°C., but at 40°C. no differences could be detected in the weight of products. This means that the desired effect of the tempering water is produced in a much shorter time at higher temperatures.

Table VI shows the figures for the moisture content of wheat, the overs and throughs of the sieves for the different samples. These samples were taken as soon as possible after grinding and placed in air tight bottles where they were kept until the moisture tests were made. These figures are the average from each of the three samples milled. The data show that the moisture content of the

Table VI Penetration of water in wheat under various conditions of time and temperature.

Time of temper	Temperature of milling conditions.		Moisture per cents.	
	of room	of wheat	Over 500.0.	Through 70 0.0.
temper	tempering	Relative humidity	24%	70 0.0.
	C.	%		
1 hour	6	64	16.51	16.90
2 hours	6	58	16.91	16.85
4 hours	6	56	16.98	16.18
8 hours	6	63	16.94	16.17
16 hours	6	66	16.72	16.10
24 hours	6	67	16.70	16.98
Mean	6	63	16.79	16.04
1 hour	18	61	16.88	16.15
2 hours	18	56	16.91	16.13
4 hours	18	60	16.89	16.47
8 hours	18	60	17.09	16.59
16 hours	18	60	17.21	16.68
24 hours	18	56	16.74	16.59
Mean	18	59	16.85	16.53
1 hour	40	60	16.02	16.91
2 hours	40	63	16.89	16.21
4 hours	40	63	16.67	16.78
8 hours	40	64	16.51	16.65
16 hours	40	66	16.73	16.08
24 hours	40	67	16.63	16.94
Mean	40	64	16.67	16.09

wheat samples was rather uniform. They also show that in all cases the bran contained a larger per cent of moisture than the endosperm. In fact, in every case the moisture content of the bran was greater than that of the wheat. At the lowest temperature of 6°C., the moisture content of the sizings was less than that of the finer middlings. This indicates that the moisture was not evenly distributed through the interior of the grain. After two hours at 18°C. the moisture seemed to be evenly distributed throughout the endosperm, as shown by the moisture content of the sizings and coarse and fine middlings. At 40°C. a fairly uniform distribution was found at one hour, as indicated by moisture content of sizings, coarse and fine middlings.

The following conclusions may be drawn from the experiments with the rate of water penetration of wheat:

1. The wheat kernel is not enclosed in a non permeable membrane, but absorbs water freely through the entire bran surface.

2. The bran coat has a greater affinity for water than the endosperm of the wheat.

3. Temperature influences the rate at which water may enter the wheat.

4. At 18°C. or above, the water had penetrated the wheat kernel in 2 hours, and was evenly distributed throughout the endosperm.

## EXPERIMENTS ON SMALL EXPERIMENTAL MILL

The effects of temperature on wheat tempering were studied first on the small experimental mill for the economic reason that it could be attacked from many more angles at less expense. The disposal of the products manufactured did not enter into the question as they were easily blended in with other products on the large mill. The problem, influence of temperature on wheat tempering was attacked from five angles on the small mill.

The effect of temperature and length of tempering period on the distribution of grinding, as measured by the per cent of extraction done by each break roll in the process of separating the endosperm from the bran.

2. The effect of temperature and the length of tempering period on the amount of sizings and middlings produced.

3. The effect of temperature and the length of tempering period on the amount of break flour produced by the different breaks.

4. The effect of temperature and the length of tempering period on the ash content of the different break flours.

5. The effect of temperature and the length of tempering period on the amount of power required to separate the bran from the endosperm during the breaking process.

A lot of well-blended, hard red winter wheat of a known moisture content was used for these experiments. The wheat was cleaned and scoured before weighing out portions for each test. For each test 1000 gm. of wheat was placed in tin cans with tight lids. Enough water was added to bring the moisture content up to 15.5 per cent as determined by the Brown Duvel method. The periods of tempering were  $\frac{1}{2}$ , 1, 2, 4, 6, and 16 hours, and the time of tempering was so regulated that the wheat could be milled at the expiration of the tempering period set for each test. A relative humidity of approximately 50 per cent varying only one or two per cent, was kept during the entire experiment, and a temperature of approximately 27°C. was maintained.

For the room temperature, 27°C., the cans were kept in the milling room. For the higher temperature the cans were kept in a specially made box with a thermostatic control. The wheat was adjusted to these temperatures before the tempering water was added, and the temperature maintained constant during the entire tempering process. However, the milling was done at room temperature which varied between 25°C. and 28°C.

The samples were ground on an experimental mill equipped with a pair of 6 by 6 inch rolls, corrugated with a modified Dawson cut. A differential of  $2\frac{1}{2}$  to 1 was used for grinding, and a constant feed was maintained on these

rolls for each individual break. The mill was driven by a three horse power motor which gave ample power at all times during the tests. Since accuracy in setting the rolls was important an instrument was made which magnified the movement of the rolls sixteen times. The distance used between the rolls for the different break settings was first .028 inch, second .012 inch, third .006 inch, and fourth .002 inch. These were kept constant in all the different tests made.

The ground sample was sifted on an experimental sifter which is equipped with an automatic time regulator. The action of this sifter is similar to the action of the sifter on the large mill, and the results were comparative since all samples were sifted the same length of time, two minutes. The cloth used in each case was similar to those used on the large four break automatic mill as shown in Table VII.

Table VII Cloth used in experimental sifter.

Break 1	Break 2	Break 3	Break 4
20 Wire	20 Wire	24 Wire	18 Wire
32 "	32 "	36 "	26 "
50 G.G.	50 G.G.	54 G.G.	44 "
70 G.G.	70 G.G.	72 G.G.	70 G.G.
13 XX	12 XX	12 XX	13 XX

The overs of each sieve were weighed on a torsion balance sensitive to .01 gm., and the per cent calculated on the basis of the original sample of 1000 gm. In other words by moving the decimal point one place to the left in the weight column it will give the per cent of the original sample.

The milling of the wheat for each temperature and period of tempering was done in duplicate, and repeated when a variation indicated error in one sample or the other. The weights for the overs and break flour for the duplicate trials were averaged and the averages taken as the overs and break flour for that particular test. The ash determinations of the break flour were made on composite samples of the duplicate tests for each individual break. Table VIII is a sample of the data collected from which the following tables were made.

#### Results of Experiment

The effect of temperature and the length of tempering period on the distribution of grinding as measured by the per cent extraction done by each break roll in the process of separating the endosperm from the bran is shown in Table IX, while Table X shows the total extraction produced on each break.

Table VIII Data collected on wheat tempered at 40°C.

Moisture in wheat 13 per cent. Relative humidity 51 per  
 Moisture at rolls 15.8 per cent.

	Sieve No.	Weight of first sample	:	Weight of second sample	:	Average weight	:	Power kilowatts
1st. Break	20 W.:	772	:	777	:	774.5	:	1st. trial 180
	32 W.:	87	:	84	:	85.5	:	2nd trial 160
	50G.G.:	62	:	60	:	61.5	:	Average 170
	70G.G.:	37	:	35	:	36.0	:	
	13XX :	32	:	32	:	32.0	:	
	Flour:	6	:	4	:	5.0	:	
2nd. Break	20 W.:	365	:	340	:	352.5	:	1st. trial 80
	32 W.:	86	:	74	:	80.0	:	2nd. trial 80
	50 G.G.:	172	:	185	:	178.5	:	Average 80
	70G.G.:	66	:	83	:	75.5	:	
	12XX :	55	:	65	:	60.0	:	
	Flour:	19	:	24	:	21.5	:	
3rd. Break	24 W.:	243	:	232	:	237.5	:	1st. trial 60
	36 W.:	16	:	16	:	16.0	:	2nd. trial 50
	54G.G.:	28	:	22	:	25.0	:	Average 55
	72G.G.:	30	:	26.5	:	28.3	:	
	12XX :	35	:	32	:	32.5	:	
	Flour:	8	:	10	:	9.0	:	
4th. Break	18 W.:	165	:	145	:	155.0	:	1st. trial 40
	26 W.:	36	:	39	:	37.5	:	2nd. trial 30
	44 W.:	14	:	15	:	14.5	:	Average 35
	70G.G.:	11	:	9	:	10.0	:	
	13XX :	15	:	14	:	14.5	:	
	Flour:	2	:	2	:	2.0	:	

Table IX Per cent extraction on the different breaks.

Temperature °C.	Length of temper hours.						
	$\frac{1}{2}$	$\frac{1}{4}$	1	2	4	6	16
First Break							
27	:20.5	:20.3:20.8	:21.8	:20.0	:22.0	:22.3	
40	:22.5	:20.5:24.0	:21.0	:20.6	:20.7	:21.5	
50	:23.7	:23.5:24.5	:23.5	:23.8	:20.0	:22.3	
60	:13.3	:21.3:17.5	:15.6	:16.3	:16.0	:15.8	
Average	:20.0	:21.4:21.7	:20.3	:20.2	:19.7	:20.5	
Largest Deviation:	6.7	: 2.1: 4.2	: 4.7	: 3.9	: 3.7	: 4.7	
Second Break							
27	:38.0	:39.7:39.7	:40.0	:39.0	:38.0	:36.5	
40	:42.2	:41.3:35.0	:33.7	:36.6	:36.2	:38.7	
50	:38.0	:37.5:39.0	:36.5	:35.5	:33.8	:39.2	
60	:44.2	:34.2:36.8	:34.7	:37.5	:36.0	:40.0	
Average	:40.6	:38.2:37.6	:36.2	:37.2	:37.2	:38.6	
Largest Deviation:	3.6	: 4.0: 2.6	: 3.8	: 1.8	: 1.2	: 2.1	
Third Break							
27	:16.0	:16.0:15.3	:14.2	:17.5	:14.3	:16.0	
40	:11.5	:10.7:14.0	:16.5	:14.6	:16.5	:15.2	
50	:13.8	:13.8:11.5	:15.0	:14.1	:14.2	:12.8	
60	:16.3	:14.5:15.8	:20.8	:16.7	:19.5	:17.2	
Average	:14.4	:13.8:14.4	:16.6	:15.7	:16.1	:16.6	
Largest Deviation:	2.9	: 3.1: 2.9	: 4.2	: 1.8	: 3.4	: 2.8	
Fourth Break							
27	: 9.5	: 9.5: 9.6	: 9.3	: 9.0	:12.0	: 11.5	
40	: 8.2	: 9.5: 9.8	:10.1	:10.4	:10.0	: 9.7	
50	:11.4	:11.6:10.0	:10.5	:10.8	:10.6	:11.8	
60	:10.2	:12.3:11.0	:13.0	:11.8	:12.8	:10.8	
Average	: 9.8	:10.7:10.1	:10.7	:10.5	:11.4	:11.0	
Largest Deviation:	1.6	: 1.6: .9	: 2.3	: 1.5	: 1.4	: 1.3	

Table I Total extraction at various temperatures.

Temperature °C.	Length of temper hours						
	$\frac{1}{2}$	1	2	4	6	16	
27	84.0	85.5	85.4	85.3	85.5	86.3	86.3
40	84.4	82.0	82.8	81.5	82.2	83.4	85.1
50	86.9	86.4	85.0	85.5	84.2	83.6	86.1
60	84.0	82.5	81.1	84.1	82.5	84.5	85.8
Average	84.8	84.1	83.6	84.1	83.6	84.4	85.3
Largest Deviation	2.1	2.3	2.5	2.8	1.9	1.9	1.5

In comparing the effect of temperature on the first break extraction, Table IX shows that as the temperature was increased the per cent extraction decreased for all different lengths of temper longer than  $\frac{1}{2}$  hour. The second and third breaks do not show any direct trend, the fluctuation is within the error due to mechanical operation. For the higher temperature fourth break shows that the bran and endosperm did not separate in the former breaks as readily as at the lower temperatures.

The total extraction of middlings as produced by all four breaks, Table X, shows no decided trend in the amount of middlings produced as the temperature was increased or as the length of the tempering period was extended. The largest deviation from the average at any tempering period was 2.8 per cent at 40°C. tempered 2 hours.

The effect of temperature and the length of tempering period on the amount of different size middlings produced is shown in Table XI. The overs of the 32 and 36 wire was considered as siftings; the overs of the 50 and 54 grit gauge as coarse middlings; the overs of the 70 and 72 grit gauge as medium middlings; and the overs of the 12 and 13 XX silk as fine middlings. The amount of siftings and medium middlings did not vary in any direct trend but only had a slight fluctuation at 27°C. The amount of coarse middlings decreased slightly with the increased tempering period,

Table XI Influence of time and temperature on size of middlings.

Temperature C.	Length of temper hours.						
	$\frac{1}{2}$	1	2	4	6	16	
Sizings							
27	: 208	: 200	: 192	: 181	: 190	: 197	: 203
40	: 182	: 170	: 195	: 160	: 150	: 151	: 146
50	: 210	: 184	: 170	: 163	: 160	: 132	: 146
60	: 183	: 174	: 141	: 135	: 126	: 120	: 118
Coarse Middlings							
27	: 270	: 268	: 267	: 264	: 259	: 256	: 252
40	: 265	: 254	: 223	: 220	: 223	: 222	: 223
50	: 227	: 239	: 243	: 238	: 229	: 229	: 231
60	: 248	: 220	: 213	: 191	: 201	: 192	: 191
Medium Middlings							
27	: 145	: 145	: 149	: 154	: 144	: 140	: 138
40	: 150	: 147	: 140	: 150	: 157	: 157	: 173
50	: 139	: 147	: 152	: 153	: 152	: 156	: 160
60	: 148	: 144	: 157	: 145	: 155	: 165	: 162
Fine Middlings							
27	: 114	: 116	: 125	: 126	: 125	: 123	: 124
40	: 135	: 142	: 149	: 155	: 163	: 165	: 173
50	: 126	: 142	: 146	: 152	: 152	: 159	: 160
60	: 135	: 149	: 167	: 185	: 172	: 192	: 195

while the amount of fine middlings had a slight increase with the longer tempering periods. At the higher temperatures the amount of sizings and coarse middlings decreased with the temperature and longer tempering periods, while the amount of fine middlings increased with the temperature and length of tempering period. As the temperature is increased the endosperm becomes mellow in a shorter time and similar results are produced in a longer period of tempering at a lower temperature.

The effect of temperature and the length of tempering period on amount of break flour produced by the different breaks is shown in Table XII. The higher temperatures seemed to cut down the amount of break flour produced on first break. The long tempering periods produced more break flour on second and third breaks due to the mellowness of the endosperm. The amount of flour produced on fourth break followed no direct trend.

The quality of the break flours was measured by determining the ash content which is given in Table XIII. The ash content of the first break flour fluctuated so great that no comparison can be made. However, the ash content of second break flour was lower at the higher temperatures and after  $\frac{1}{2}$  hour showed no direct trend. The extreme short temper of  $\frac{1}{4}$  hour had a higher ash content than

Table XII Amount of break flour produced

Temperature °C.	Length of temper hours						
	: ½	: 1	: 1	: 2	: 4	: 6	: 16
First Break							
27	: 6.0	: 5.0	: 7.5	: 7.0	: 6.0	: 7.5	: 9.5
40	: 5.0	: 4.5	: 7.0	: 4.5	: 3.8	: 5.0	: 6.5
50	: 6.5	: 8.0	: 7.5	: 7.5	: 8.0	: 6.0	: 6.5
60	: 2.0	: 3.5	: 2.5	: 2.0	: 1.8	: 1.0	: 1.5
Average	: 4.9	: 6.3	: 6.1	: 5.3	: 5.8	: 4.9	: 6.0
Largest Deviation	: 2.9	: 2.8	: 3.6	: 3.3	: 4.0	: 3.9	: 4.5
Second Break							
27	:18.5	:18.0	:19.5	:22.0	:19.0	:20.0	:16.5
40	:21.5	:20.0	:19.0	:17.0	:22.0	:21.0	:28.4
50	:17.0	:22.5	:24.5	:23.8	:22.5	:25.5	:31.8
60	:20.5	:16.0	:20.0	:20.0	:25.0	:24.5	:36.3
Average	:19.4	:19.1	:20.8	:20.7	:22.1	:22.8	:28.3
Largest Deviation	: 2.1	: 3.4	: 1.8	: 3.1	: 3.1	: 2.8	:11.8
Third Break							
27	:13.5	:13.0	:13.5	:14.5	:12.0	:12.0	:15.0
40	: 9.0	: 8.5	:13.5	:13.8	:13.0	:17.5	:18.0
50	:13.0	:15.5	:12.0	:18.0	:16.0	:18.0	:16.3
60	:14.5	:12.5	:15.0	:25.0	:18.5	:23.5	:23.5
Average	:12.5	:12.4	:13.5	:17.8	:14.9	:17.8	:18.2
Largest Deviation	: 3.5	: 3.9	: 1.5	: 7.2	: 3.6	: 5.8	: 5.3
Fourth Break							
27	: 5.5	: 5.0	: 3.0	: 4.5	: 7.5	:10.0	: 8.0
40	: 2.0	: 3.5	: 5.5	: 4.8	: 3.8	: 3.8	: 3.5
50	: 5.0	: 5.3	: 2.5	: 3.5	: 4.8	: 5.5	: 6.5
60	: 3.5	: 5.0	: 4.0	: 5.0	: 4.5	: 5.5	: 3.5
Average	: 4.0	: 4.7	: 3.8	: 4.5	: 5.1	: 6.2	: 5.4
Largest Deviation	: 2.0	: 1.2	: 1.7	: 1.0	: 2.4	: 3.8	: 2.6

the longer tempers. Third break had the lowest ash at four hours temper in all cases except at 60°C. in which the one hour temper was the lowest for that temperature. The ash content of the fourth break flour showed no direct trends but a general fluctuation.

The effect of temperature and the length of tempering period on the amount of power in kilowatts required to separate the bran from the endosperm during the breaking process, is shown in Table XIV. The first break which breaks the grain open, required more than twice the amount of power than was used in any of the other breaks. At the higher temperatures it took nearly three times as much power as used on second break. The 1 hour temper at 27°C. required 190 kilowatts, and for the 16 hour temper 295 kilowatts; at 60°C. the 1 hour temper used 200 kilowatts, and the 16 hour temper required 335 kilowatts. On the three remaining breaks the power requirements did not show any trends. The second break required approximately 80 kilowatts; third break 60 kilowatts; fourth break 50 kilowatts.

The lower temperatures did not show any material difference in the power requirement, but the higher temperatures at longer periods of temper showed marked increased amount of power required to open the grain.

✓

Table XIII Ash in break flour.

Temperature °C.	Length of temper hours						
	$\frac{1}{2}$	$\frac{1}{2}$	1	2	4	6	16
First Break							
27	.77	.76	.70	.69	.71	.78	.74
40	.70	.67	.71	.67	.64	.66	.76
50	.66	.63	.81	.68	.72	.68	.72
60	.68	.80		.73	.71	.76	.67
Second Break							
27	.66	.64	.57	.57	.60	.61	.60
40	.60	.59	.58	.60	.54	.59	.58
50	.62	.55	.57	.56	.54	.55	.56
60	.61	.55	.55	.56	.56	.57	.56
Third Break							
27	.60	.63	.56	.59	.54	.60	.54
40	.68	.63	.62	.62	.58	.61	.66
50	.66	.62	.60	.60	.58	.63	.63
60	.64	.62	.59	.60	.62	.63	.70
Fourth Break							
27	.72	.83	.80	.79	.64	.69	.64
40	.92	.72	.76	.76	.76	.79	.88
50	.76	.87	.82	.90	.82	.79	.86
60	.83	.80	.80	.84	.80	.83	.90

Table XIV Power used in grinding, kilowatt hours.

Temperature °C.	Length of temper hours						
	$\frac{1}{2}$	$\frac{1}{2}$	1	2	4	6	16
First Break							
27	: 175	: 170	: 190	: 200	: 210	: 200	: 220
40	: 170	: 160	: 220	: 210	: 235	: 230	: 250
50	: 190	: 245	: 210	: 230	: 275	: 265	: 295
60	: 165	: 255	: 200	: 190	: 340	: 300	: 335
Second Break							
27	: 80	: 75	: 85	: 80	: 93	: 96	: 100
40	: 80	: 70	: 60	: 75	: 70	: 65	: 80
50	: 75	: 80	: 65	: 70	: 80	: 75	: 85
60	: 70	: 70	: 95	: 65	: 80	: 80	: 90
Third Break							
27	: 55	: 50	: 60	: 55	: 60	: 60	: 66
40	: 55	: 35	: 60	: 55	: 50	: 65	: 90
50	: 65	: 70	: 40	: 60	: 57	: 55	: 65
60	: 60	: 55	: 55	: 65	: 60	: 65	: 70
Fourth Break							
27	: 55	: 60	: 55	: 50	: 60	: 70	: 56
40	: 35	: 40	: 50	: 40	: 50	: 55	: 45
50	: 75	: 80	: 50	: 65	: 75	: 58	: 75
60	: 50	: 50	: 50	: 45	: 60	: 55	: 60

## LARGE MILL EXPERIMENTS

A few tests were conducted on the large experimental mill in order to check the results obtained on the small mill for the effect of temperature during tempering in the conditioning of wheat for milling. Ten to 15 bushel samples of dark hard winter wheat were used in these tests.

In two of these tests a high quality wheat of the 1929 crop was used. This wheat graded number two dark hard winter having a moisture content of 12 per cent. Two tests were made from a blend of half 1929 wheat, and the other half a weak 1928 wheat which contained heat damaged and weevil eaten kernels. This latter wheat had 13 per cent moisture. Two tests were made on number two dark hard winter wheat bought from export grain in Galveston, Texas. The one sample was heated to 60°C. for sterilization, then both were shipped to Kansas State Agricultural College for milling.

When conducting these tests a 5 bushel sample was milled before starting the test in order to get the mill in proper working condition. The sample under observation was then milled. The length of tempering period was 3 hours in all cases eliminating this variable.

Tempering was done at three different temperatures in addition to room temperature: Sound wheat was heated to

44°C for three hours during tempering; a blend of sound wheat and damaged wheat was cooled to 12°C, and tempered for three hours at that temperature; export wheat sterilized by heating to 60°C. for five minutes was tempered at 24°C. For each of the three cases similar wheat was tempered at 24°C. or room temperature and milled for comparison.

The same system of cleaning was used in all tests: receiving separator, milling separator, Carter disc, horizontal scourer, heater (when used), and a dampener. The wheat was then placed in specially constructed tank in which the temperature could be maintained as that at the time of tempering. At the end of the tempering period it was scoured and then run through a cooler, cooling to 24°C. just before going to the break rolls. The humidity control was started two hours before starting the mill in order to have the temperature and humidity constant before grinding the preliminary sample.

The breaks and reduction rolls were set during the grinding of the preliminary sample and not changed during the experiment with the exception of a few of the reduction rolls which heated and formed rings on the rolls.

The effect of temperature on wheat during tempering was studied by the following measurements: Samples were caught under the break rolls and sifted on a Rotomatic sifter to determine the per cent extraction and size of middlings

produced as determined by the weights of the overs of the various sieves used in sifting. The power used for grinding was determined by the use of a wattmeter connected to the motor which drove the rolls. The various flour streams were caught for 10 minutes, weighed, and bottle samples taken for moisture and ash determinations. Samples of the patent and clear flour were taken for moisture and ash determinations, and baking tests were made on the patent flour for comparisons.

#### Results of Large Mill Experiments

The samples caught for sifting to determine the percent extraction and size of middlings were taken from both ends of the break roll under observation, and without allowing the sampling pan to run over as the coarse stock would roll off the pan and the fine material sift down among that already in pan. The weighing of all samples and overs of the various sieves was done on a torsion balance sensitive to one tenth of a gram. The sifting of samples on the Rotomatic sifter was done on a stack of sieves similar to that used on the large mill for each break. Two minutes time was allowed for sifting as was done in connection with the work done on the experimental mill. After each sifting the overs of each sieve and the

break flour were weighed and from these weights the per cent overs of each sieve and the break flour were determined.

In Table XV are the data obtained when sifting samples caught from the wheat that had been tempered at 44°C. In column one is shown the cloth used in sifting for each break. Column two gives the weight of the sample caught and the weight of the overs of each sieve as well as the throughs of flour cloth. Column three gives the weight of wheat necessary to produce the weight of sample caught for that individual break. Column four shows the per cent overs of the various sieves and the per cent break flour. Column five gives the per cent extraction produced on the individual breaks.

In the case of the second and subsequent breaks, the weight of the wheat required to produce the sample taken, as given in column three, is computed by dividing the weight of the sample caught by the per cent overs on the top sieve for the previous break. This gives the correct value since in each case the per cent overs is figured on the basis of the original wheat, and the overs of the top wire for one break constitute the sample which passes to the next break.

Table XVI gives the per cent extraction made by the various breaks as determined by the sifting and calculated as shown in Table XV.

Table XV Data and calculations for wheat tempered at 44°C.

	Weight: in grams	Weight: of wheat	Per cent: overs	Per cent Extraction
<b>1st. Break</b>				
Wt. of sample:	323	323	100	21.8
20 wire	252	:	78.2:	
32 wire	24	:	7.4:	
50 G.G.	23	:	7.1:	
70 G.G.	10	:	3.1:	
13 XX	10	:	3.1:	
Flour	2	:	.6:	
<b>2nd. Break</b>				
Wt. of sample:	351	424	78.2:	43.5
20 wire	147	:	34.7:	
32 wire	29	:	6.8:	
50 G.G.	80	:	18.8:	
70 G.G.	35	:	8.3:	
12 XX	30	:	7.1:	
Flour	8	:	1.9:	
<b>3rd. Break</b>				
Wt. of sample:	216	680	34.7:	14.9
24 wire	134	:	19.8:	
36 wire	16	:	2.4:	
60 G.G.	25	:	3.7:	
72 G.G.	15	:	2.2:	
12 XX	17	:	2.5:	
Flour	6	:	.6:	
<b>4th. Break</b>				
Wt. of sample:	200	1001	19.8:	4.9
18 wire	104	:	10.2:	
28 wire	32	:	3.1:	
44 wire	16	:	1.6:	
70 G.G.	31	:	3.0:	
13 XX	14	:	1.4:	
Flour	2	:	.2:	

Table XVI Per cent extraction on the various breaks.

Kind of: wheat	Tempering temperature in °C.	First: break	Second: break	Third: break	Fourth: break	Bran and shorts
Mixed :	12	:26.4	: 41.0	: 11.6	: 5.2	: 14.8
Mixed :	24	:26.0	: 35.0	: 13.7	: 5.5	: 19.8
1929 :	44	:21.8	: 43.5	: 14.9	: 4.9	: 14.0
Car :	24	:22.0	: 39.4	: 16.8	: 3.2	: 18.6
Export :	24°	:28.4	: 41.5	: 12.7	: 6.4	: 14.0
Export :	24	:25.7	: 41.7	: 11.7	: 6.5	: 14.4

\* Sterilized at 60°C.

In table XVI the first column shows the type of wheat; the second column the temperature of wheat; columns three, four, five, and six the per cent extraction on the four breaks and column seven the bran plus the shorts over the 44 wire on fourth break. The per cent extraction shows no general trend as to the amount of endosperm separated from the bran. The excess amount of bran and shorts in the two cases is thought to be an accidental variation.

The size of the middlings produce<sup>d</sup> -- determined by sifting sample is shown in Table XVII. Table XVII shows the per cent of different size middlings and sizings produced by the different samples. The per cent sizings and middlings were determined from the data tables similar to Table IV by adding the percentages of similar size products

Table XVII Per cent of different size middlings.

Kind of wheat	Tempering temperature in °C.	Sizings	Coarse middlings	Medium middlings	Fine middlings	Flour
Mixed	12	20.2	28.6	17.6	15.3	4.4
Mixed	24	16.9	24.8	19.2	15.7	5.4
1929	44	16.6	29.6	16.6	13.6	5.5
Car	24	16.2	29.6	16.0	13.1	4.6
Export	24*	23.8	32.2	13.2	11.3	4.1
Export	24	21.1	31.1	13.9	12.4	4.3

\*Sterilized at 60°C.

from the different breaks. The overs of the 38 and 36 wire on first, second and third breaks were calculated as sizings; the overs of the 50 and 60 grit gauge on first, second and third breaks as coarse middlings; the overs of the 70 and 72 grit gauge on all four breaks as medium middlings; the overs of the 12 and 13 XX on all four breaks as fine middlings; and the throughs of the 12 and 13 XX as flour. By this method the mellowness of the endosperm should be shown. The trials are so few in number that no direct comparison can be shown, but the cold wheat seemed to produce more coarse middlings than the wheat tempered at a higher temperature. In the case where the export wheat was sterilized it shows practically no difference

when compared to the wheat that had not been heated or sterilized.

The effect of the temperature on the power requirement is shown by the number of kilowatts used to grind one bushel of wheat which is shown in Table XVIII.

Table XVIII Power required to grind one bushel of wheat.

Kind of wheat	Tempering temperature		Kilowatts per bushel of wheat
Mixed	12	:	1.32
Mixed	24	:	1.23
1929	44	:	1.29
Car	24	:	1.21
Export	24 <sup>o</sup>	:	1.22
Export	24	:	1.20

<sup>o</sup> Sterilized at 60°C.

This shows that in case of the mixed wheat less power was used for the wheat tempered at room temperature than at cooler temperatures. The 1929 wheat required more power when tempered at 44°C. than at room temperature. This was also true in case of the export wheat. In explaining these two trends the cool wheat had not mellowed the endosperm, which required more power to reduce it into flour. The higher than room temperature required more power because the grain was tougher and the endosperm was slightly sticky which made it difficult to mill.

Table XIX gives the weight of the flour caught from the various flour streams. These samples were caught for 10 minute periods and the weights recorded. The amount of flour produced in 10 minutes seemed to vary considerably on the different parts of the mill, probably due to the fact that these samples were not milled on the same days. The two export samples which were milled one after the other have almost identical amounts of total flour for the 10 minute periods, but the various streams have fluctuated considerably in the different tests, which makes it impossible to form any definite conclusions from these measures. The error due to the short period of time while the samples were caught was greater than the difference due to a variation in the effect of temperature upon the amount of flour produced.

In Tables XX and XXI are presented the ash and moisture determinations of the various flour streams produced while milling these different samples. There appears to be very little difference between the samples tempered at room temperature or higher, but the sample tempered at 12°C. has less moisture in the finished products and higher ash. Both of these are undesirable. Hence, it appears that wheat tempered at 12°C. or below will produce a flour of higher ash and lower moisture content than a flour tempered at 24°C. or above.

Table XIX Weights of flour streams for ten minutes.

Flour Streams	: Mixed wheat		: 1929 wheat		: Export wheat	
	: 12°C.	: 24°C.	: 44°C.	: 24°C.	: 60°C.	: 24°C.
1st. Break	: 725	: 570	:: 312	: 470	:: 475	: 412
2nd. Break	: 950	: 700	:: 682	: 585	:: 615	: 719
3rd. Break	: 780	: 655	:: 452	: 575	:: 545	: 397
4th. Break	: 725	: 340	:: 157	: 495	:: 655	: 472
Sizings	: 1400	: 1175	:: 1332	: 1105	:: 2020	: 1635
1st. Middlings	: 3680	: 3950	:: 2702	: 3105	:: 3770	: 4787
2nd. Middlings	: 4015	: 2500	:: 4065	: 2360	:: 5055	: 3210
3rd. Middlings	: 4945	: 5630	:: 4430	: 4315	:: 6295	: 6290
4th. Middlings	: 6390	: 5070	:: 2722	: 3945	:: 4165	: 4540
5th. Middlings	: 3565	: 1450	:: 1867	: 1865	:: 2320	: 2900
1st Tailings	: 1405	: 1095	:: 980	: 1275	:: 1185	: 1030
2nd Tailings	: 3655	: 2600	:: 1710	: 1730	:: 2150	: 2450
Beel	: 2805	: 2700	:: 1502	: 2100	:: 2035	: 2389
Total	: 35240	: 28435	:: 22933	: 23935	:: 31285	: 31231

Table IX Ash in the different flour streams.

Flour Streams	Mixed wheat		1929 wheat		Expert wheat	
	12°C.	24°C.	44°C.	24°C.	60°C.	24°C.
1st. Break	.75	.56	.48	.45	.67	.72
2nd. Break	.64	.51	.40	.45	.61	.63
3rd. Break	.75	.58	.50	.46	.63	.74
4th. Break	.89	.85	.68	.64	.84	.87
Sizings	.46	.42	.34	.36	.35	.35
1st. Middlings	.43	.41	.35	.37	.35	.36
2nd. Middlings	.44	.43	.36	.37	.34	.34
3rd. Middlings	.41	.40	.32	.34	.31	.31
4th Middlings	.43	.44	.36	.36	.36	.36
6th. Middlings	.47	.44	.37	.41	.36	.41
1st. Tailings	.54	.50	.41	.42	.45	.43
2nd. Tailings	.53	.51	.43	.47	.45	.51
Reel	.70	.65	.62	.60	.66	.80
Patent	.52	.43	.35	.37	.37	.36
Clear	.84	.65	.56	.54	.63	.73

Table XXI Moisture in different flour streams.

Flour Streams	Mixed wheat		1929 wheat		Export wheat	
	12°C.	24°C.	44°C.	24°C.	60°C.	24°C.
1st. Break	14.6	15.5	14.6	15.0	13.2	13.8
2nd. Break	14.6	15.0	14.5	15.5	13.0	13.6
3rd. Break	14.7	15.5	14.6	15.3	13.0	13.5
4th. Break	14.5	14.1	14.4	14.9	12.9	13.2
Sizings	14.0	14.3	14.3	14.8	12.7	13.5
1st. Middlings	13.8	14.4	14.2	15.0	12.7	13.3
2nd. Middlings	13.6	13.8	14.0	14.5	12.5	13.3
3rd. Middlings	13.1	13.4	13.7	14.2	12.3	12.9
4th. Middlings	13.0	12.1	13.8	13.5	11.8	12.6
5th. Middlings	11.7	12.2	13.8	12.6	12.0	12.3
1st. Tailings	13.3	13.5	13.5	13.7	12.2	12.9
2nd. Tailings	11.7	12.5	13.1	13.0	11.6	12.2
Keel	11.6	12.4	13.1	13.2	12.0	12.4
Patent	11.5	13.1	13.3	13.5	12.2	13.0
Clear	11.1	12.3	13.6	13.1	12.1	12.1

Baking tests were made on the patent flour samples for the various periods using a standard baking formula which is used in making the baking test in this laboratory. The results of the tests are given in Table XXII.

Table XXII Baking results of the patent flours.

Kind of flour	Tempering temperature.	Leaf Volume	Color	Texture
Mixed wheat :	12	: 1560	: 95 dark	: 97
Mixed wheat :	24	: 1490	: 96	: 98
1929 Car :	24	: 1620	: 98	: 98
" " :	44	: 1560	: 98	: 97
Export wheat :	24	: 1600	: 97	: 98
" " :	24*	: 1590	: 98	: 97

\*Sterilized at 60°C.

The smaller leaf volume obtained from the flour from the mixed wheat was expected since the gluten of this flour was weaker, while in the other flours the variation was small.

#### CONCLUSIONS

It may be concluded from these experiments that:

1. Increased temperature accelerates the rate of water penetration in wheat.
2. No portion of the wheat kernel has the characteristics of a non-permeable membrane.

3. Milling wheat at low temperatures produces flour of higher ash content, due to pulverizing the bran.

4. High temperatures maintained for a long tempering period are detrimental because of the unfavorable changes in the physical characteristics of the grain.

5. The best temperature and period for tempering is related to the characteristics of the wheat. This is a subject for further investigation.

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