per cent is lost in the iron calcium precipitate. Accordingly the total average recovery of vanadium, including that from the sodium uranate, has been a little less than 30 per cent of that present in the ore. The recovery of vanadium has barely covered the expense incident thereto.

SODIUM NITRATE—By using nitric acid for neutralization throughout the process, a large proportion of the nitric acid used both for the solution of the original ore and for the neutralization of the alkaline solutions is recovered in the form of sodium nitrate. During the months of May, June, and July, for which full figures are available, the average recovery was 87.5 per cent (minimum 84.87 and maximum 90.4). This high recovery has of course greatly decreased the expense of the nitric acid used in the operations as a nitric acid plant was built to work up the recovered nitrate. During May, June, and July, 1915, the expenditure for nitric acid was only 2.411 cents per lb. of 100 per cent acid.

RADIUM—When an element exists in an ore in the proportion of 1 part to 200,000,000, its extraction and recovery present difficulties not ordinarily encountered in metallurgy. A recovery of 60 to 70 per cent, or even 50 per cent might, under such conditions, appear to be satisfactory. A much larger recovery than 70 per cent is undoubtedly exceptional. The unusually high recovery of 90 per cent and over of the radium present gives the nitric acid method its real value.

COST DATA

In figuring the total costs of the first 4,258 mgs. of radium element produced, the uranium and vanadium products may be either included or excluded. By subtracting the actual costs connected with the production of the uranium and vanadium compounds from the total cost, a close approximation of the cost of radium, provided the uranium and vanadium were not recovered, will be obtained, but such a figure will not be exact, as under the changed conditions various factors would enter in, the effects of which can only be estimated. On this basis the average cost of 1 gram of radium element, including the more expensive early treatment, is as follows:

COST OF RADIUM PRODUCTION TO AUG. 1, 1915

Operating costs to Aug. 1:	
Total expenditures.....	\$129,907.42
Construction and equipment.....	52,453.60
	<hr/>
Cost of ore treated.....	\$ 77,453.82
Amortization of plant and equipment at 20 per cent per annum.....	69,767.99
Cost of U. S. Bureau of Mines cooperation (plant dept.)..	9,065.90
Cost of refining 2611.44 mgs. radium element (est.)....	13,628.38
	<hr/>
	5,353.00
	<hr/>
	\$175,269.09
Less costs in connection with the production of the uranium and vanadium compounds.....	19,947.00
	<hr/>
TOTAL COST OF 4,258 MGS. RADIUM ELEMENT.....	\$155,322.09

As already stated, refining losses have almost certainly been less than 2 per cent and probably less than 1 per cent. In order, however, to be on the safe side, an allowance of 3 per cent is made for such losses; 4,258 mgs. less 3 per cent is 4,131 mgs., which represents the radium fully recovered as high-grade salts. The average cost of 1 gram of radium element has therefore been \$37,599. It should be remembered that this

cost included the proportionally much higher operating costs of the smaller experimental plant and that the first 2 grams of radium extracted cost considerably more per gram than the last 3 grams; also there have been extracted 31,650 lbs. of uranium oxide and 11,528 lbs. of vanadium oxide. This material has all been contracted for and in part delivered. The returns from its sale will considerably more than cover the cost of its production, and this profit, together with other credits, will ultimately lower by several thousand dollars the cost per gram of radium.

As the price of ore is variable, the question will naturally arise as to the influence of the price of ore on the figures given above. A simple calculation will show at once that the cost of extracting radium, exclusive of the cost of the ore, has been \$20,710 per gram. The ore included in the figure of \$69,767.99 cited for the cost of ore used in the investigation herein outlined was partly purchased before the war and partly mined by the National Radium Institute at Long Park, Col. As 723.97 tons were used, the average cost was \$96.36 per ton. If the ore had cost \$120 per ton, the cost of radium would have been \$41,742 per gram, and for every additional amount of \$20 per ton above these figures the cost of radium would increase approximately \$4,000 per gram.

U. S. BUREAU OF MINES, WASHINGTON

A METHOD FOR THE DETERMINATION OF THE STRENGTH AND BAKING QUALITIES OF WHEAT FLOUR

By C. H. BAILEY

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It is quite generally recognized that some form of practical test is necessary in determining the baking quality of wheat flour. Chemical analyses are of value, but the relation between composition and quality is not perfectly understood despite the great amount of research which is directed toward the solution of this problem. It is also probable that if infallible chemical tests were announced which would serve to indicate the relative baking value of flour, they would be too numerous, and require too much time and technical skill to make their use possible on the extended scale necessary in the flour trade. In other words, there are so many factors involved in the chemistry of baking strength, and the determination of all of these would, in most instances, be so difficult that actual baking tests would probably be resorted to in the majority of cases where rapid and voluminous work must be disposed of. For these reasons the development of methods for conducting careful and accurate measurements of flour quality in a practical way are justifiable and necessary.

In developing practical flour tests, a comprehension of the purposes for which the flour is to be used, and of the manner in which it is ordinarily treated in trade practices, are essential. At the present time flours of good baking "strength," color, absorption, flavor and odor are in greatest demand by the bread-making trade. The term "strength" has been used rather loosely at times, although the definition of Humphries

and Biffin¹ has been quite generally adopted. They state that "a strong wheat is one which yields flour capable of making large, well-piled loaves." The rather general terms in which this is stated render it difficult of interpretation at times. The writer has preferred to state it in somewhat more definite, though necessarily technical terms, as follows: *the strength of flour is determined by the ratio between the rate of production of CO₂ in, and the rate of loss of CO₂ from, the fermenting mass of dough.* The defense of this definition, and the application of the principles involved will be made the subject of another paper. The general truth of the assertion will be apparent to those familiar with the production of yeast-leavened bread. Assuming the accuracy of this definition of flour strength, it is evident that some practical, and at the same time accurate, means of determining the extent of production, and retention of carbon dioxide is desirable. This is what is commonly attempted in baking tests in which the dough is allowed to expand to the maximum before being placed in the oven. In such tests the volume of the loaf thus produced is taken as an expression of the relative strength of the flour. In other cases, in which the dough is not raised to such an extent, the texture of the crumb—the "well-piled" condition referred to in the definition of Humphries and Biffin—is used as indicating the strength, in connection with the volume of the loaf. Such tests are of considerable value and are widely used, but certain criticisms may be made of each of them which indicate the desirability of more accurate methods.

CRITICISMS OF THE USUAL METHODS

In the case of the expansion of dough to the maximum before baking, the element of judgment enters in to a considerable extent. If the dough be placed in the oven too soon its expansion will be arrested by the inactivation of the yeast and its enzymes, and the fixation of the dough which constitutes the most important phenomenon of baking. The resulting loaf will not be as large as it might have been had it raised longer in the dough stage. If on the other hand the dough stands too long, it will fall in the oven and not only will the volume of bread be reduced, but the texture of the crumb will be impaired as well. The gas pockets will be large and uneven, and the crumb will lack that soft, velvety feeling characteristic of the "well-piled" loaf. It will render the judging of color more difficult as well, owing to the increased expanse and depth of shadow cast by the walls of the large gas pockets.

These criticisms do not apply to those methods in which the masses of dough are placed in the oven as soon as they have expanded to a fixed and uniform volume. In following such methods the expansion in the oven, known to the baker as the "spring" of the dough, and the texture of the crumb of the baked loaf, are taken as indications of the strength of the flour. The element of judgment enters into the scoring of crumb texture, however, and the relative differences between the various flour samples compared may not

be apparent from the reports of the tests. This is particularly true when it is desired that the test serve as a basis for indicating the proportions in which several different flours may be blended to produce a mixture of a certain standard.

ADVANTAGES OF THE USUAL METHODS

These tests have certain commendable features, however, and it was with a view toward eliminating the objectionable features of each, while including the desirable ones, that this study was undertaken. First of all the value of the determination of the volume occupied by a dough raised to the maximum must be recognized. While doughs are not usually so raised in either commercial or household practices, it seems to be well established that those flours from which doughs can be produced in which gas production and gas retention are so related as to yield large volumes per unit of weight when tested, will make the most satisfactory bread when treated in the ordinary manner. This is particularly true if the bread is to be baked in pans with relatively high sides, such as are commonly employed in making white bread in the United States. The support afforded by the high sides prevents part of the difficulty experienced by Scottish and English bakers in controlling the shape of their round "cottage" loaves which are baked in shallow pans. Moreover, those doughs which raise well, as evidenced by this test of maximum expansion, will usually stand more rough treatment in the process of fermentation and baking than will weaker, less elastic doughs. The development of a method for the determination of the rate and extent of expansion was accordingly undertaken.

GENERAL PRINCIPLES OF THE PROPOSED METHOD

The expansion of an ordinary dough in a graduated cylinder is often employed by flour chemists. This necessitates careful watching, however, in order that the greatest volume occupied by the mass may be noted before it falls. If the observer finds it necessary to leave his post for a few moments, the dough may have collapsed and fallen during his absence, and the record is thus lost. An apparatus was accordingly designed which would automatically measure the extent of expansion. In its design the simplest means commensurate with the requisite accuracy were aimed at. A cylinder was constructed which would hold a dough made from 150 grams of a strong flour if expanded to the maximum by the method followed. It was 7 cm. in diameter at the bottom, tapering to 9 cm. in diameter at a height of 8.2 cm. and continuing at this diameter to a total height of 23.8 cm. A disk was suspended in the cylinder and attached by a cord to a counterpoise weight, the cord being passed over a light-running pulley. This pulley was fastened to the top of a board, the face of which was provided with the calibrated scale shown in Fig. 2. The disk, while resting lightly on the surface of the dough, exerted no pressure because of the counterpoise. To the cord was attached a device provided with a needle which moves along the face of the scale and shows the extent of expansion. A circle of heavy linen paper was

¹ A. E. Humphries and R. H. Biffin, "The Improvement of English Wheat," *Jour. Agr. Sci.*, 2 (1907), 1-16 (note p. 4).

inserted between the top of the dough and the disk so that the latter did not stick, and it was accordingly left at the highest point which it reached during the course of the expansion. The relation of the several parts of this device, which has been termed the expansimeter, is shown in cross-section in Fig. 1.

In arranging the position of the needle on the cord which passes across the calibrated scale, due allowance was made for the curved form of the surface of the dough. This was done by allowing a mass of dough to expand in a glass cylinder of the same diameter, and measuring the segment of the circle described

FIG. 1

FIG. 2

by the dough surface. The volume of this dome-shaped mass was then calculated and the needle attached to the cord at the proper point.

It was recognized that such an expansion test would serve to show only one factor in the determination of flour quality, *viz.*, the expansibility of the dough. Other items such as color and appearance of the crust and crumb of the baked loaf, and its odor, flavor, etc., are important. To afford a test of these, a dough was made from 450 grams of flour, and at the close of the initial fermentation period it was divided into two portions, one of which was twice the weight of the other, and accordingly represented 300 grams of flour. It was raised and baked in a black iron baking pan, and the cooled loaf on cutting was scored for color and texture, and the flavor and odor noted.

DETAILED DESCRIPTION OF THE METHOD

A straight dough was employed which was prepared much as are similar white-bread doughs made in many commercial bakeries. The formula was as follows:

Flour	Yeast	Salt	Sugar	Water
450 g.	5.5 g.	6.75 g.	11.25 g.	Sufficient

No lard was used, since preliminary tests had shown

that the relative quality of the loaves was not altered when it was included.

These ingredients were thoroughly mixed in the small motor-propelled mixing machine illustrated on page 14 of Minnesota Experiment Station Bulletin No. 131.¹ Machine mixing was preferred to hand mixing because it had been found that more uniform results could be obtained in this manner. Moreover, it was not necessary to determine the water-absorbing capacity of the flour first, since this could be done to the best possible advantage during the course of the mixing. The salt and sugar were added in solution in 200 cc. of water. A stock solution consisting of somewhat more than sufficient salt and sugar for the day's work, with water in the proper proportions, was made up and aliquots taken for each test. It had been determined that a solution of 6.75 grams of salt and 11.25 grams of sugar in 200 cc. of water occupied a volume of 208.5 cc., and this quantity was used in each case. A stock yeast suspension was also made up in the proportions of 1 gram of yeast to 1.786 cc. of water (usually 50 grams of yeast were suspended in 89.5 cc. of water): 15 cc. of this suspension, after thorough mixing, were added to the salt-sugar solution from a volumetric pipette. That quantity of yeast suspension represented 5.5 grams of yeast and a trifle more than 9.8 cc. of water, since 5.5 grams of yeast in a water suspension displace 5.17 cc. The mixture of yeast, salt, sugar, and water was placed in the mixing machine together with the flour, and additional water added during the course of the mixing until the dough attained the proper consistency. The quantity of this additional water was noted on the record sheet. A table was arranged showing in parallel columns this added water, and the total water used reduced to terms of cubic centimeters per 100 grams of flour, in which manner these data were reported.

It is recognized that the proportions of yeast and sugar employed in these tests were much less than are commonly used in commercial flour testing. This was partly because the use of such large quantities of yeast and yeast food, with the resulting abnormally large and rather coarse-textured loaf of bread, had been criticized by practical bakers. While their objections were not well founded in every particular, our experience with the formula and method proposed has shown it to give as satisfactory results as the use of such formulae as are used in commercial flour laboratories. The crumb of the resulting bread resembled closely the appearance and flavor of baker's and household bread of good quality; it was a palatable product when made from good flour.

The dough was mixed in the machine until the slow blade of the latter had made 200 revolutions. It was then removed from the machine and placed in a half-gallon stoneware jar. This was covered and set in an electrically heated and controlled thermostat or fermentation cabinet. The temperature was maintained at 28° C. (82.4° F.), which is about the temperature at which the fermentation is conducted

¹ C. H. Bailey, "Minnesota Wheat Investigations: Series I, Milling and Baking Tests, Crop of 1911," *Minn. Exp. Sta. Bull.*, 131, 1913.

in most large bakeries. The length of the fermentation period was varied somewhat, being reduced by as much as 30 minutes in the case of doughs made from weak flours. Strong flour doughs were allowed to ferment 150 minutes before being broken down, followed by successive light kneadings at the end of 60, 45, and 15 minutes. The total time from kneading to molding the loaf was thus 270 minutes or $4\frac{1}{2}$ hours. At the end of the last 15-minute interval the dough was removed from the jar and kneaded vigorously on a board. The entire quantity was weighed and divided as previously mentioned into two portions representing $\frac{2}{3}$, or 300 grams of flour, and $\frac{1}{3}$ or 150 grams of flour, respectively. The former was placed in a lightly greased baking pan, the latter in the expansimeter cylinder similarly greased.

The black iron baking pans employed were similar to those used in many flour-mill control laboratories in the United States. They are 14 cm. deep, 7.5×14 cm. at the bottom, and 9×16.5 cm. at the top. While some other form of pan might be satisfactory, this style was preferred because on cutting the loaf lengthwise a large area of cross-section was afforded for scoring the color and texture. Tall, round pans would do the same but on trying them it was found that the crumb texture was impaired over the lower part of the area because of the pressure of the tall mass of dough. Ordinary bakers' pans were not found desirable, as so large a surface area was not afforded on longitudinal sectioning the loaves baked in them.

The dough in the pan was allowed to expand in a thermostat at a temperature of 34°C . (93.2°F .) until that portion in the expansimeter cylinder occupied a volume of 710 cc. This was $3\frac{1}{2}$ times the volume of the unfermented dough, and about 3 times the volume of the dough when placed in the pan. It was then placed in an electric oven which had previously been heated to 200°C ., and baked at that temperature until well browned. The time of baking was about 45 minutes. An effort was made to keep the air in the oven as nearly saturated as possible by the introduction of water vapor. This is a factor of considerable importance if it is desired to insure the greatest possible expansion or "spring" in the oven.

The smaller portion of dough, representing 150 grams of flour, was molded and placed in the round cylinder shown in Fig. 1, care being taken to exclude all air bubbles from below and around the mass. A small circle of paper was placed on the top of the dough, and the cylinder set in the proper location in the thermostat, which was maintained at 32°C . The disk was lowered into position, after which this apparatus required no further attention until the dough had fallen, when the maximum expansion which it had attained was read on the scale.

RECORDING THE RESULTS OF THE TEST

The expansion of the dough in the cylinder was stated in terms of the increase in volume in cubic centimeters, rather than the total volume of the fermented dough. The initial volume of a dough made from 150 grams of flour was found to be 203 cc. A scale (Fig. 2) was accordingly prepared for use with

the cylinders, on the left side of which the increase in volume due to retention of carbon dioxide was shown, while the right side of the same scale showed the total volume occupied by the mass. This means of expressing expansibility was preferred because the difference between flours is evidenced even more strikingly than it would be by a statement of the total volume. Thus two flours, the first of which occupied a maximum total volume of 600 cc., and the second of 720 cc., on this basis showed differences of only 20 per cent, while as a matter of fact the second sample had actually expanded over 30 per cent more than the first. Since it is this expansion, due to the production and retention of carbon dioxide, with which we are concerned, the expression of the results in that manner which best served to accentuate the relative differences seemed to be desirable.

The baked loaf was cooled, and the volume in cubic centimeters determined by displacement in flax seed. The apparatus used for this purpose is illustrated on page 16 of Bulletin No. 131.¹ It was then cut lengthwise and the crumb scored for color and texture. The lightest shades of color were scored the highest, a score of 100 being given to those loaves having the shade of color possessed by the crumb of loaves baked from the average Minneapolis mill patents. The completed record contains 6 items: (1) the maximum expansion of the dough in the cylinder; (2) the volume of the baked loaf; (3) absorption of water in making the dough, stated in terms of cc. of water at 28°C . per 100 grams of flour; (4) color of crumb; (5) crumb texture; and (6) remarks concerning the flavor and odor. If the latter was not out of the ordinary it was merely recorded as normal; if musty, sour, or otherwise abnormal a brief notation was made concerning its character. It is believed that such a record contains all of the data necessary to a satisfactory evaluation of the flours which are to be compared.

A control baking should be included in each day's work. The dough is made preferably from a strong patent flour which has aged for about 8 weeks before using it for this purpose. The change from day to day is less great in a flour aged to this extent and it may be discarded and another control employed after 6 or 8 weeks' time. The new control should always be tested at least twice in comparison with the old before the latter is discarded. It is only by referring all results back to the control that the results of such empirical tests made on different days can be compared. This is particularly true with regard to the volume of loaf, and the dough expansion in the cylinder. Thus, when the volume and expansion of the control fall below the average, the similar data for all the other samples in that series must be increased in the proper proportion. The control flour need not be regarded as a "standard," but may simply serve as a check on the quality and activity of the yeast, and other conditions.

Table I shows the results of the tests by this method of five flours of widely differing qualities. Sample A was a strong patent flour milled from hard spring wheat; B a rather weak patent milled from Washing-

¹ *Loc. cit.*

ton Bluestem; C a very weak Western Club wheat patent; D a strong First Clear milled from hard spring wheat; and E an unusually strong, hard spring wheat Second Clear. It will be noted that while the flours stand in the same order with respect to volume of loaf and maximum expansion in the expansimeter, the latter accentuates the differences much more distinctly than does the volume of the loaf. The relative texture of the loaf also serves as a check on the expansimeter test. Thus, while the loaves baked from flours B and C were practically the same in volume, the difference in texture was very striking, and paralleled the test of maximum expansion. Sample E, while strong and capable of yielding loaves of reasonably good texture, was found to be very dark in color. The same was true of D, although to a lesser extent.

TABLE I—RESULTS OF TESTS OF FIVE FLOUR SAMPLES

Sample	Maximum expansion in cylinder cc.	Volume of loaf cc.	Absorption of water per 100 g. of flour cc.	Color score	Texture
A	930	1,480	64.0	101	100
B	720	1,320	60.2	98	90
C	600	1,310	54.4	97	70
D	910	1,430	65.6	85	94
E	990	1,560	64.7	55	92

SUMMARY

The method outlined is believed to eliminate the personal equation so far as is practicable in making actual baking and expansion tests. The use of a machine for mixing, the automatic recording of maximum expansion in the cylinder, and the raising of the dough to a fixed height before baking all tend to render the element of judgment less prominent than has heretofore been the case with most methods. Automatic regulation of the temperature in the fermentation cabinet also contributes to the ease of making the tests. The use of such appliances and methods tends to render the making of baking and expansion tests less an art and more a science.

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A CHECK VALVE FOR SUCTION FLASKS

By G. P. WALTON¹

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In those determinations involving filtration through a Gooch crucible where rejection of the filtrate is permissible, it is a frequent practice to filter in sets of from ten to fifty. Often the time allowable for filtering a set is limited. This requires not only rapid filtering, but the shortest possible interval between successive filtrations. Under such conditions the frequent interruptions occasioned by the necessity for disconnecting and emptying the suction flasks are a source of no little inconvenience. To obviate this the writer has devised a form of ball check valve which may be readily fitted to any of the usual types of suction flask.

The valve shown in detail in the figure has been used in this laboratory for several months and has satisfied all requirements. It consists of a glass tube (A) having an indentation or other check for the

ball-valve; a glass ball valve with guide (D) blown from a piece of capillary tube; an inner glass tube (B); and the valve-seat (C), a short piece of smooth heavy rubber tubing with square cut ends. The parts are shown assembled and fitted to the usual form of suction flask (E). A drain tube, not shown,

completes the apparatus. It is obvious that when a Gooch crucible is placed in the holder in the top of the flask and suction applied, the ball (D) will be drawn tight against the rubber valve-seat. Upon releasing the vacuum to remove the crucible, the height of the column of filtrate in the flask will immediately cause the ball to be forced out, allowing the liquid to be completely drained off. It has been found that comparatively slight suction is sufficient to close the valve perfectly, while upon releasing the suction, a column of liquid in the flask a fraction of an inch above the valve is ample to start the outflow.

The several parts of the valve are readily made and quite durable, the rubber valve-seat lasting for several months with constant use in this laboratory.

While to have the valve made wholly of glass would appear to be advantageous, it has been found difficult to construct one in which the ball will always seat itself so as to make the ground joint air-tight, and yet not be liable to stick in the valve-seat upon releasing the vacuum.

In the form of suction-flask not provided with an outlet at the bottom, a suitable vent may be drilled using a short section of copper tube in a drill press with carborundum and water for abrasive. To adjust the valve, force the rubber (C) through the vent, moisten the inner tube (B) and push it through the rubber making a tight joint between the latter and the wall of the flask; place the ball (D) in position and force the outer tube (A) over the rubber. The rubber should project about $\frac{1}{16}$ in. beyond the end of the inner glass tube, which serves merely as a siphon and brace for the valve-seat.

A check valve of the form described has proved a great convenience and time saver when making the final filtrations in such determinations as those of crude fiber, reducing sugars, pentosans and any others wherein filtrate and washings are rejected.

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