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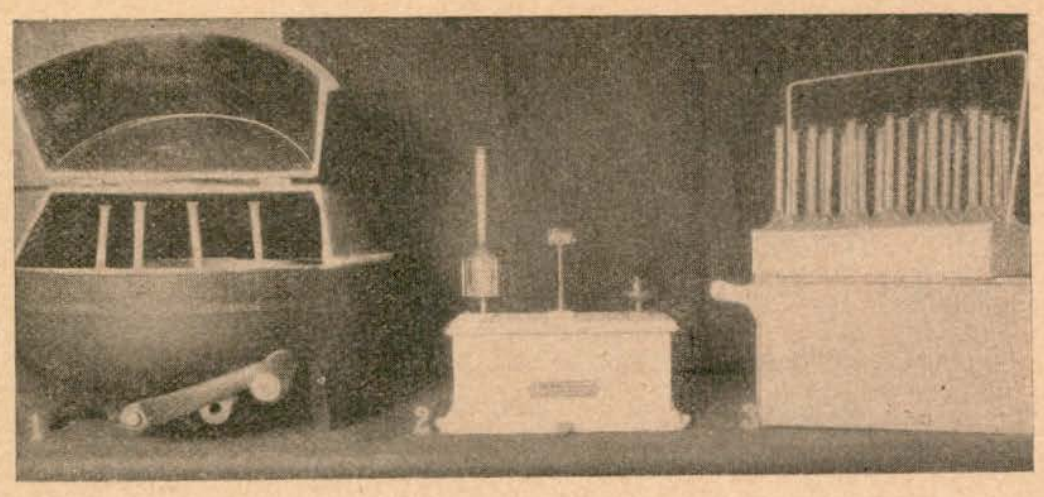

THE UNIVERSITY OF NEBRASKA
COLLEGE OF AGRICULTURE
EXPERIMENT STATION
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Babcock Testing — Principles and Uses

L. K. CROWE and H. P. DAVIS
Dairy Husbandry

The manufacturing of dairy products on a commercial scale began about the middle of the nineteenth century and was greatly stimulated by the development of the centrifugal cream separator in the late eighties. The invention of the Babcock test in the early nineties overcame some of the difficulties that had developed in paying for milk upon its butterfat content, since it was early recognized that milk varied widely in that respect. A number of practical methods had been developed by dairy manufacturing plants to determine the butterfat in the milk. Among these were:

1. The creamery inch system in which a sample of each patron's milk was placed in a glass tube and after setting, the depth of the cream layer was measured. This was far from satisfactory since it took much time, and milk that contained a large percentage of small fat globules gave an inaccurate cream layer.
2. The trial churning in which a small sample of each patron's milk was churned and the butter weighed. Great care was necessary in this method to have the conditions alike in order to keep the moisture content of the butter the same for all samples.
3. The oil test churn in which a small sample of each patron's cream was churned, after which the butter was melted and measured. If the churning was not complete this method developed inaccuracies. This and the previous methods were slow and bothersome.

As the result of much experimentation by the agricultural experiment stations, a number of tests were devised, of which that devised by Dr. S. M. Babcock * proved to be the simplest, least costly, most accurate for practical purposes, and most rapid in operation.

The economic importance of the Babcock test was threefold:

1. It revolutionized the dairy industry by putting it upon a business basis.

2. It hastened and made possible the rapid development of the factory system of dairy products manufacture.

3. It provided a rapid and accurate method of selecting individual cows upon their ability to produce butterfat and thus was a stimulus to better breeding.

* Dr. S. M. Babcock was chief chemist at the Wisconsin Agricultural Experiment Station. The test was patented and given free to the world in 1890.

BABCOCK TEST

Essentially this method of determining the percentage of butterfat in certain dairy products consists in transferring a definite weight of the product to be tested into a specially constructed and graduated test bottle. Sulphuric acid is then added and mixed with the material in the test bottle. The bottles are then centrifuged or whirled three times in succession, at a definite speed and for a definite time. Hot water is added to the contents of the bottle after the first two whirlings. After the last whirling the percentage of fat is read directly with a pair of dividers.

PRINCIPLES INVOLVED

The Babcock test is based on the principles: That an acid will curdle and then dissolve or digest the curd in milk, thus freeing the butterfat; that heat which is developed from the action of the acid upon the water and milk solids melts the butterfat; that difference in the weight or specific gravity tends to cause the separation of liquids; and that the application of centrifugal force (whirling) hastens the separation of the fat from the other constituents of the milk.

Milk fat or butterfat has a specific gravity (compared with water which equals 1.00) of .93 while whole milk has a specific gravity of about 1.032. This means that one cubic centimeter of butterfat would weigh .93 gram and 1 cubic centimeter of milk would weigh 1.032 grams. One gallon of water weighs 8.34 lbs., therefore, 8.34 x 1.032 equal 8.60 lbs., the weight of a gallon of whole milk. The globules of butterfat in milk, being lighter than the surrounding fluid, will tend to rise but are retarded by the interference of the other milk solids. Commercial sulphuric acid (H_2SO_4) first curdles and then digests the proteins in the milk. This frees the fat, and since heat is generated by the action of sulphuric acid and water, the fat is melted and tends to rise to the top. The sulphuric acid being heavier than the milk serum increases the specific gravity of the mixture, thus making it easier for the fat to rise. In whirling, the test bottle is in a horizontal position with the bottom to the outside. Whirling produces centrifugal force which causes the heavier material to go to the bottom of the test bottle and in consequence forces the lighter fat to the top.

The Babcock test is based upon the use of a definite weight of milk or cream in the test bottle. In the case of cream, 9 grams are weighed directly into the test bottle which is graduated to read direct. When testing milk the 17.6 c.c. pipette is used for measuring the milk into the test bottle.

This pipette delivers 17.5 c.c. of milk (.1 c.c. of milk sticks to the inside of the pipette). With milk of an average specific gravity of 1.032 the 17.5 c.c. will weigh 18.06 grams (ordinarily figured 18 grams). The milk test bottle reads direct in percentage of fat with this amount.

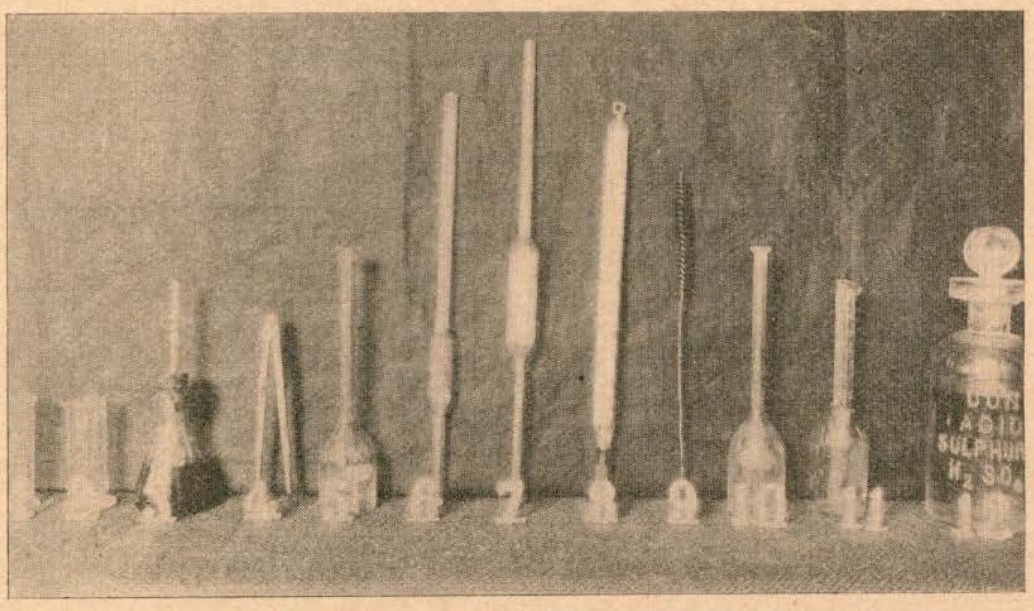

FIG. 1.—Babcock Testing Equipment. 1. 9 c.c. acid measure. 2. 17.5 c.c. acid measure. 3. Glymol. 4. Dividers. 5. 9 gram 50 per cent test bottle. 6. 9 c.c. pipette. 7. 17.6 c.c. pipette. 8. Floating dairy thermometer. 9. Test bottle brush. 10. 10 per cent milk test bottle. 11. Double-necked skim-milk test bottle. 12. Sulphuric acid.

EQUIPMENT FOR BABCOCK TESTING

MILK TESTING EQUIPMENT

1. Centrifuge or Babcock Tester—hand, steam, or electric, in which tests are whirled. (See Frontispiece.)
2. Sample jars—any size, 4 ounce size with tight covers are very convenient.
3. Milk test bottles *—either 8 per cent or 10 per cent graduation.
4. Milk pipette *—17.6 c.c. capacity for measuring milk.
5. Acid measure or dipper—17.5 c.c. capacity for measuring acid.
6. Thermometer—floating dairy type, with Fahrenheit graduation to 220°.
7. Dividers—for measuring the fat column.
8. Sulphuric acid (commercial grade) specific gravity 1.82 to 1.83.
9. Water bath—a vessel that will hold hot water in which all test bottles are placed to be tempered before reading.

* See Nebraska Standard—Dairy Law, Bul. No. 3, State of Nebraska, Department of Agriculture.

10. Washing powder—any commercial alkali powder for cleaning glassware.
11. Test bottle brush—a small wire handled brush for cleaning bottles and pipettes.

ADDITIONAL EQUIPMENT REQUIRED FOR TESTING CREAM

1. Cream test bottles *—9 gram 50 per cent graduation.
2. Cream test balance or scales *—a balance or scale sensitive to 25 milligrams (.25 grams) 1 bottle type. (See Frontispiece.)
3. Weight *—a 9 gram weight tested as accurate.
4. Pipette—a 9 c.c. pipette may be used for convenience but must be used with scales.
5. Acid measure or dipper—9 c.c. capacity.
6. Glymol—"red reader"—to eliminate meniscus or curved surface at top of fat column.

ADDITIONAL EQUIPMENT REQUIRED FOR TESTING SKIM MILK, BUTTERMILK, AND WHEY

1. Skim milk test bottles—double necked.

SAMPLING MILK OR CREAM

The accuracy of testing depends to a great extent upon the care used in sampling. The sample must be uniform in composition and representative of the material from which it has been taken. Careful testing will not correct inaccuracies in sampling. It is impossible to be too careful in sampling.

MILK

To sample the milk of a cow, pour the complete milking from one vessel to another at least 3 times. Then dip out a sample for testing—not less than 4 ounces, cover tightly to prevent evaporation, and set in a cool place. Milk should not be tested until at least one hour after milking because of the air incorporated during milking. If milk has stood long enough for the cream to rise, it should be poured back and forth at least 6 times instead of 3 times. In pouring do not agitate unduly so as to cause churning. Milk can be tested satisfactorily only when sweet.

CREAM

Cream is thicker, more viscous and consequently more difficult to sample accurately than milk. It should be poured or thoroly stirred after which the sample should be taken with a recognized cream sampler (slotted openings in the side thruout the entire length of the tube). It is difficult to obtain an accurate sample of cream by means of a dipper.

* See Nebraska Standard — Dairy Law, Bul. No. 3, State of Nebraska, Department of Agriculture.

ABNORMAL MILK AND CREAM

Sour Milk.—An accurate sample of curdled milk is difficult to obtain. Pour back and forth until thoroly mixed, then take sample as with sweet milk.

Sour Cream.—Thoro mixing of sour cream is not difficult because cream does not contain as much curd as milk. Accurate samples depend only upon thoro mixing. If properly sampled, cream will test the same whether sweet or sour.

Churned Milk or Cream.—If particles of butter appear on the surface of milk or cream the vessel containing either should be placed in a bath of water at a temperature of 105°-115° F. (Fahrenheit). When the butter particles have melted, the milk or cream should be poured back and forth several times from one vessel to another and sampled immediately. Even then such a sample may be inaccurate.

Frozen Milk or Cream.—When milk or cream freezes, ice starts to form at the outer edge next to the container. This ice is very largely water, the other constituents being more concentrated in the soft mushy core in the center of the container. An accurate sample cannot be taken from the frozen material. To thaw, place in a water bath at 70° F. or in a room at that temperature until melted, then mix well and sample as usual.

COMPOSITE SAMPLING

A sample composed of proportionate quantities by weight of different lots of milk or cream is called a composite. A composite sample of milk is most readily and accurately taken with a pipette graduated to .5 c.c. (one-half c.c.) with a total graduation of not less than 25 c.c. For example, in testing the milk from an individual cow, a considerable saving of labor is made by composite sampling, that is, the testing of a composite sample of the different milkings for the day. Since the several milkings may differ in quantity as well as in percentage of butterfat, proportional samples should be taken from each. The number of c.c. taken per pound of milk depends upon the total quantity represented by the composite. There should be not less than 100 c.c. in the completed composite sample. For each pound of milk, use a number of c.c. large enough to insure a composite of at least 100 c.c. Suppose a cow is producing about 40 pounds of milk a day in 2 milkings. On the day the samples were taken, she produced 16 pounds in the morning and 22 pounds in the evening. Take 3 c.c. of milk for each pound of milk produced, $16 \times 3 = 48$ c.c. from the morning milk; and $22 \times 3 = 66$ c.c. from the evening milk or a total of 114 c.c. for the day. Mix

together and the 114 c.c. represents a composite of the milk of the cow for one day.

Since cream will not drain clean from a pipette the composite sampling of cream is advised only when the lots of cream are in containers of equal diameter, in which case a sample may be taken by means of a cream sampler.

If composite samples are to be kept for any length of time some preservative should be added. Bichloride of mercury (corrosive sublimate) may be obtained from creamery supply houses in tablet form and is usually the most convenient preservative for common use. Directions for the use of these tablets are on the container. Other preservatives are potassium dichromate and formalin (40 per cent formaldehyde). In using the former, which is a powder, add just enough to give the milk a lemon-yellow color. One cubic centimeter of formalin to a pint of milk will usually be sufficient. Each time milk is added to the composite sample it should be thoroly stirred or mixed. A glass jar for keeping composite samples should have a wide mouth and a tight fitting cover or stopper. When using a preservative that does not color the milk, some coloring matter should be added to indicate that the milk is unfit for food. All the milk preservatives mentioned are poisonous.

BABCOCK TEST FOR MILK

PREPARING THE SAMPLE

Milk samples for testing should be at a temperature of between 60° and 70° F. as determined by a thermometer. They may be warmed or cooled by means of a water bath. When warming a sample, the water bath should not have a temperature above 85° F. to prevent melting the fat. After having reached the proper temperature the sample should be poured slowly from one container to another at least 6 times to insure thoro mixing. Rapid pouring will incorporate air bubbles, making the succeeding measurement inaccurate. Care should be taken that no cream is left upon the lid or sides of the sample jar.

MEASURING THE SAMPLE

Immediately after mixing, insert the tip of a 17.6 c.c. pipette into the prepared sample of milk holding it with the thumb and second finger of the right hand and then draw in the milk by suction with the lips placed at the upper end until the pipette is filled well above the graduation mark on the stem. Quickly p'ace the dry fleshy pad of the first finger of the right hand tightly over the upper end of the pipette.

Holding the pipette perpendicular and with the graduation on the level with the eye release the pressure slightly on finger applied to the upper end of the pipette allowing the milk to run back into the sample until the surface of the milk is level with the graduation, disregarding the upper edges of the meniscus (the curved surface at the top of the milk column). Insert the tip of pipette into the milk test bottle and allow the milk to run out. If the neck is too small to allow the pipette stem to be inserted, the milk test bottle should be held at an angle to allow air to escape and to prevent splashing of milk. Blow the last drop of milk from the pipette. To insure accuracy, all tests should be run in duplicate.

FIG. 2.—Two methods of transferring the milk to test bottle.

ADDING ACID

Measure 17.5 c.c. of commercial sulphuric acid (specific gravity 1.82-1.83) into an acid measure or dipper. The acid should be at a temperature between 60° and 70° F. Holding the test bottle at an angle of 45 degrees, rotate it between the fingers, and pour in the acid very slowly. This will wash all the milk out of the neck of the bottle, and what is more important, will prevent the charring of the curd and the danger of the acid spurting out of the neck of the bottle. Variations in the temperature or strength of the acid will necessitate the use of a slightly greater or smaller quantity. It is advisable, therefore, to add the last third of the acid in three portions shaking after each addition with an even rotary motion. Acid should be added until the mixture after shaking and upon standing for a minute has a chocolate brown color. In mixing milk and acid, rotate the test bottle slowly until all the curd has been dissolved, always keeping the mouth of the bottle pointed away from yourself and others to prevent any possibility of injury from spurting acid. Sulphuric acid is very corrosive in action, will burn the flesh and will destroy cloth, wood, etc. Plenty of water and alkali washing powder will stop the action of sulphuric acid. First apply water in

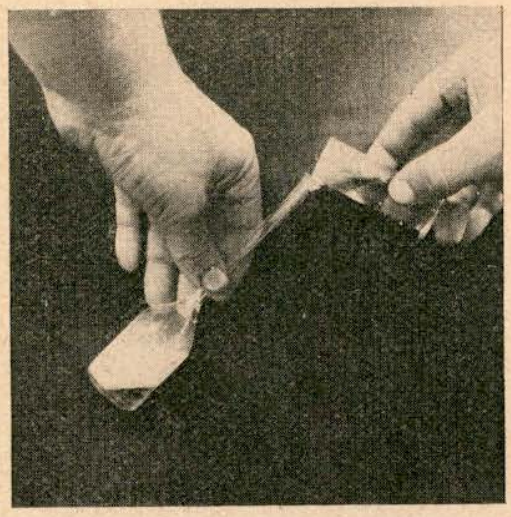

FIG. 3.—Adding sulphuric acid with the 17.5 c.c. acid measure.

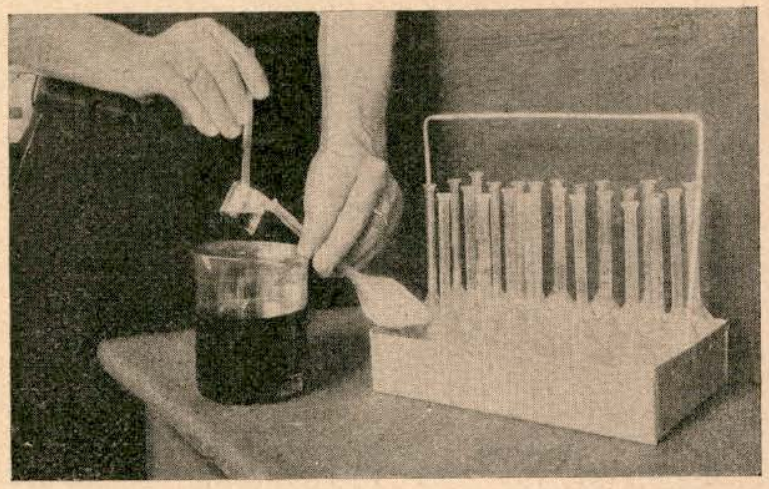

FIG. 4.—Adding sulphuric acid with the 17.5 c.c. acid dipper, also bottle rack for 24 bottles.

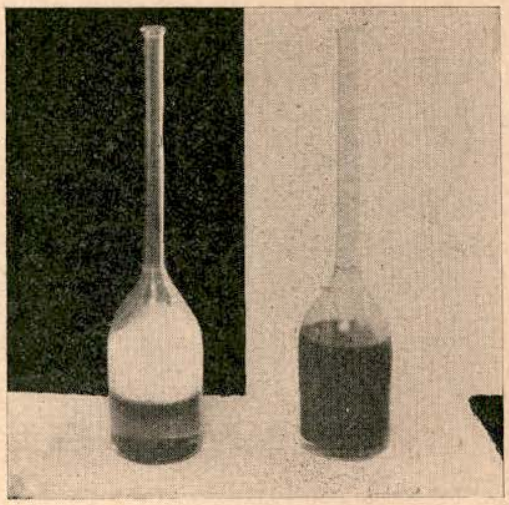

FIG. 5.—Left-hand bottle—Immediately after acid has been added. Right-hand bottle—After mixing milk and acid.

large amounts, then apply water in which the washing powder has been dissolved or apply dry washing powder.

CENTRIFUGING (Whirling)

First Time.—After the addition of the acid, place the test bottles in the centrifuge or Babcock tester. Always place the bottles opposite each other so that the revolving disc carrying the buckets or pockets for the bottles will be balanced. Use a bottle filled with water to balance in the case of an uneven number of bottles. In centrifuges with double pockets, use the outside pockets if both are not filled. Revolve the bottles at the proper speed, as indicated on the machine, for 5 minutes after that speed has been attained. Stop the centrifuge gradually to prevent the breaking of bottles. Always be sure that the centrifuge or tester is level, securely fastened to a firm foundation to prevent vibration and is well oiled, clean, and free from foreign material.

After stopping the tester, add water at a temperature of not less than 180° F. until the bottle is filled to within one-fourth to one-half inch of the base of the neck. It is impossible to have this water too hot. Soft or distilled water is preferable because sulphuric acid often forms gas bubbles in its action on lime salts in hard water, which collect at the surface of the fat column making it difficult to read. A pipette or a small glass nozzle attached to a container by means of a rubber hose may be used to add hot water.

Second Time.—Centrifuge (whirl) the test bottles for 3 minutes at the proper speed after which add water at not less than 180° F. until the lower extremity of the fat column is well above the zero mark of the graduation or scale on the neck of the test bottle. Add water carefully to prevent overflowing, and if using a pipette, do not let the tip reach the fat column.

Third Time.—Centrifuge (whirl) the test bottles at the proper speed for one minute, then place the test bottles in the water bath whose temperature is between 135°-140° F. for 5 minutes, after which time they may be read. Any vessel of sufficient depth to hold enough water to immerse all but the upper one-half inch of the top of the neck of the test bottle can be used as a water bath. A frame of metal with compartments for individual bottles is a great convenience. Tests may be read directly from a steam tester or heated tester providing the temperature of the air within the tester is between 135°-140° F.

READING THE TESTS

Remove only one bottle from the water bath at a time. Hold the bottle in the hand with the fat column perpendicular

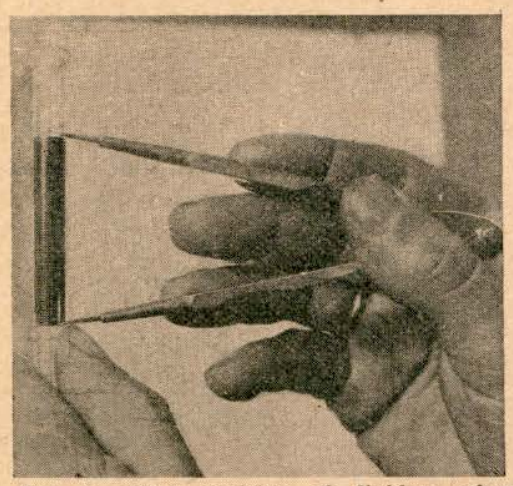

FIG. 6.—First position of dividers when reading the whole milk test.

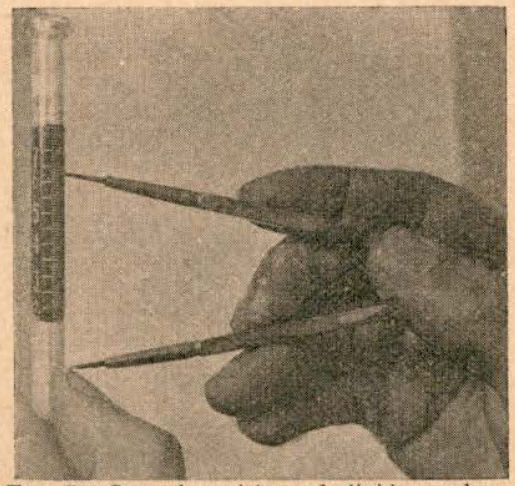

FIG. 7.—Second position of dividers when reading the whole milk test. This sample tested 6.3 per cent of butterfat.

and on a level with the eye. With the other hand place one point of a pair of dividers on the lowest point of the curve or meniscus at the bottom of the fat column, and the other point at the highest point of the fat column, or where the extreme upper edge of the fat comes in contact with the neck of the bottle. The curved surfaces at the top and bottom of the fat column are called the menisci (plural of meniscus). Hold the dividers without changing the distance between the points and place one point on the zero mark of the scale of the test bottle and take the reading on the scale as indicated by the other point. Always read to the nearest mark or graduation on the scale. The scale on the milk test bottle is marked in percentage of butterfat, being graduated to 8 or 10 per cent in tenths of one per cent.

If the test bottle is held toward the light the extremities of the fat column may be seen distinctly. Readings should be made rapidly as the temperature of the fat column will change, causing an incorrect reading. The dividers should be tight enough at the joint so they will hold any position in which they are placed, but they should move freely. Duplicate tests should check within 1/10 of one per cent.

EMPTYING THE TEST BOTTLES

Empty the bottles into a stone or glass jar or on ashes. The acid in the test bottles should be carefully handled as it will attack wood, iron, steel, tin and most metals except brass and lead. The test bottles are easier to clean if vigorously shaken during emptying in order to dislodge the white (calcium sulphate) sediment in the bottom of the bottle and then washed while still hot.

CLEANING GLASSWARE

Test bottles and sample bottles should be rinsed out in warm water. They should then be filled with a solution of hot water in which is dissolved an alkali washing powder. Soap and soap powders are undesirable. Shake the test bottles vigorously, and clean the inside of the necks with a small brush. Then empty and rinse thoroly with clean hot water. If this method is ineffective, add a little sulphuric acid, shake thoroly, then empty and rinse with clean water. A pipette should be rinsed out with water immediately after measuring the milk and then cleaned with the other glassware.

BABCOCK TEST FOR CREAM

WEIGHING THE SAMPLE

The sample of cream for testing should be prepared the same as with milk except that greater care should be taken in mixing to insure uniform composition. The same volume of cream may vary much in weight due to difference in percentage of butterfat. For that reason, cream must be weighed instead of measured as is the case with milk. The greater the percentage of butterfat, the lighter will be a given volume of cream.* Besides this, sour cream and cream fresh from the separator sometimes contain air or gas bubbles that increase the inaccuracy of a measured sample. The thickness or viscosity of cream which makes it stick to a pipette is the final reason for weighing instead of measuring cream.

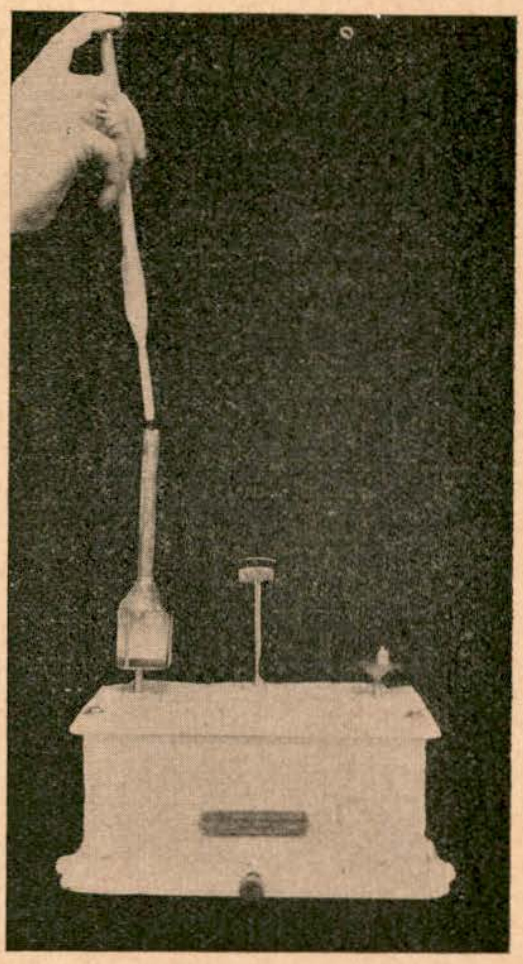

FIG. 8.—Using the 9 c.c. pipette to transfer cream from the sample bottle to the cream test bottle previously balanced on the scale.

For weighing the cream sample different types of balances or scales may be used. In a common type the test bottle is placed on the left hand pan of the balance and balanced by means of an adjusting screw on the right hand end of the cream test scale. It is properly balanced if the pointer when swinging

* See weight and specific gravity table for milk and cream on page 27.

free rests either exactly on the center mark of the graduated scale or swings an equal distance to either side of this mark. A 9 gram weight is then placed on the right hand pan of the cream test scale. With a 9 c.c. or other pipette transfer enough cream to the test bottle so that the pointer again rests exactly on the center of the graduated scale or swings an equal distance to either side of this mark. Add the last bit of cream slowly, drop by drop. If too much cream is added to the cream test bottle it may be removed by pouring it from the test bottle, inverting the test bottle on the finger and removing the cream that sticks to the finger, or by inserting a stick or pencil into the neck of the test bottle and removing the cream that adheres to it.

After the cream test scale is once balanced it must not be moved until the desired amount of cream is weighed into the test bottle. Each bottle must be balanced separately on the test scale as they are not of equal weight. If cream is spilled on the test scale pan it must be removed before the final weight is taken. To insure accuracy all tests should be run in duplicate and should check within one-half of one per cent.

ADDING THE ACID

Measure out 9 c.c. of commercial sulphuric acid (specific gravity 1.82-1.83), which should be at a temperature between 60° and 70° F., into the acid measure or dipper, and add this acid to the cream in the test bottle, holding the test bottle neck at an angle to prevent the acid from charring the curd and spurting out the bottle neck. Add enough acid to produce a chocolate brown color when thoroly mixed with the cream. Then add 10 to 15 c.c. of water at a temperature of at least 180° F. to retard the action of the acid; since cream contains a higher percentage of fat and a lower percentage of other solids and water than does whole milk, the acid is more liable to cause charring.

The test bottles are centrifuged for the same length of time and water added in the same way as in the milk test.

READING THE TESTS

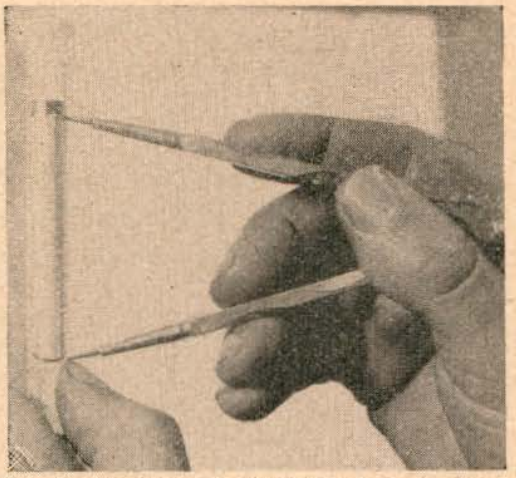

FIG. 9.—Position of dividers when reading the completed cream test after adding glymol.

The completed tests are read from a water bath at a temperature of between 135° and 140° as in milk testing. In the case of cream, glymol or red reader is usually added to the upper surface after which the fat column is measured from its lower extremity to the juncture or union of the glymol and fat at the top of the column. The graduated scale on the cream test bottle is marked in percentage of butterfat from 0 to 50, the smallest graduation being one-half of one per cent (.005). After reading, the test bottles are emptied and cleaned the same as milk test bottles.

BABCOCK TEST FOR SKIM MILK AND BUTTERMILK

The same procedure is followed in testing skim milk as in testing whole milk, with certain exceptions. Double necked test bottles having a large filling neck and a small graduated neck are used because of the small amount of fat contained in skim milk.

More acid is required for skim milk and buttermilk because of the greater percentage of solids not fat to be dissolved. If 17.5 c.c. of the available acid are required for the whole milk test, then from 19 to 20 c.c. of that acid will be required for the skim milk test.

Skim milk tests should be centrifuged 10 minutes the first time instead of 5 minutes to insure the most complete separation of the very small butterfat globules found in skim milk. The skim milk test bottles should always be placed in the centrifuge with the filling neck toward the center, so that the passage of the fat into the small graduated neck will not be obstructed by the filling tube. The reading of the test after tempering to between 135° and 140° F. may be made direct or with a pair of dividers. The graduated scale of the skim milk bottle has a range from 0 to 25/100 or 50/100 of one per cent of butterfat, the smallest graduation being 1/100 of one per cent.

It sometimes saves time in the testing of skim milk, buttermilk, or whey, if two whole-milk bottles are used together with the skim-milk bottles, since the percentage of fat in the sample may be too large to be measured in skim milk bottles.

BABCOCK TEST FOR WHEY

The Babcock test for fat in whey is the same as that for skim milk and buttermilk except that less sulphuric acid is used. If 19-20 c.c. of the available acid has been satisfactory in the skim milk test, then 8 to 12 c.c. will be sufficient for the whey test since whey has a smaller quantity of solids to dissolve than skim millk in order to liberate the fat.

Fig. 10.—1. Completed whole milk test.
2. Completed cream test.
3. Completed skim milk test.

PRECAUTIONS AND SUGGESTIONS

1. Keep sulphuric acid of the correct specific gravity tightly covered, since it will absorb moisture from the air and become weaker.
2. If too strong (too high specific gravity), sulphuric acid may be weakened by allowing it to be exposed to the air. *Do not add water* to sulphuric acid as it will splash and spatter and cause much damage.
3. Make all tests in duplicate to insure accuracy. Milk test duplicates should check within one-tenth of one

per cent; cream test duplicates to one-half of one per cent; and skim milk, buttermilk or whey duplicates to 2/100 of one per cent.

4. If foreign matter appears in the fat column or directly below it, repeat the test.
5. Glymol or red reader is a white mineral oil colored red with alkanet root so as to produce a contrast with the fat column and is used only in cream testing.
6. Take all temperatures with a thermometer. Accuracy is necessary. Don't guess.
7. Hard water may be used if first it be boiled, or if a few drops of sulphuric acid have been added to it and it has been allowed to stand for all gas to escape.
8. Sharp pointed dividers assist in accurate reading of tests.
9. If possible, centrifuge tests immediately, otherwise they must be reheated to 180° F. by placing them in a water bath for at least 10 minutes.
10. Small shot or coarse sand used with hot water and alkali will help clean dirty glassware.

DEFECTS AND REMEDIES

The perfect finished test should show a clear fat column varying from straw to golden yellow in color with upper and lower surfaces clear and distinct. A dark fat column or one that has dark specks within or directly below it may be due to any of the following causes:

Cause	Remedy
1. Acid too strong	Use less acid or the same quantity of weaker acid
2. Too much acid	Use less acid
3. Pouring acid directly into milk	Pour acid down side of bottle held at an angle
4. Uneven mixing of acid and milk	Mix milk or cream with acid with an even rotary motion
5. Acid too warm	Temper to between 60° and 70° F.
6. Milk too warm	Temper to between 60° and 70° F.
7. Failure to mix milk with acid promptly after addition of acid	Mix acid and milk immediately after the addition of the acid
8. Failure to add water before centrifuging in a cream test	Add proper quantity of water before whirling or centrifuging for first time.

A light-colored fat column or one that has light specks within or directly below it may be due to any of the following causes:

Cause	Remedy
1. Acid too weak	Use more acid or the same quantity of stronger acid
2. Too little acid	Use more acid
3. Milk too cold	Temper to between 60° and 70° F.
4. Acid too cold	Temper to between 60° and 70° F.
5. Curd not dissolved before centrifuging	Mix milk and acid thoroly before centrifuging

A milky-colored fat column in cream testing is sometimes caused by the use of either a large excess of acid or too strong acid, together with the failure to add water before centrifuging. A smaller quantity of standard acid, or the same quantity of weaker acid, together with the addition of water before centrifuging will prevent the trouble.

SUMMARY OF PROCEDURE IN BABCOCK TESTS

Always run duplicate tests

	WHOLE MILK	CREAM	SKIM MILK OR BUTTERMILK	WHEY
Test bottles to use	8% or 10% whole milk bottles *	9 gm. 50% cream bottles *	Double necked skim milk bottles	Double necked skim milk bottle
Amount of sample to use in each test bottle	Measure 17.5 c.c.	Weigh 9 gms.	Measure 17.5 c.c.	Measure 17.5 c.c.
Approximate amount of acid to use (Sp. Gr. 1.82-1.83) (60°–70° F.)	17.5 c.c.	9 c c.	19-20 c.c	8-12 c.c.
Centrifuge (whirl) first time	5 min.	Add 10–15 c.c. 180° F. water, then centrifuge 5 min.	10 min.	10 min.
Adding water, first time, 180° F. or warmer	Enough to raise the butterfat column to within about one-half inch of the base of the neck of the bottle.			
Centrifuge (whirl) second time	3 min.	3 min.	3 min.	3 min.
Adding water, second time, 180° F. or warmer	Enough to raise all of the butterfat above the zero mark of the graduated scale on the neck of the test bottle.			
Centrifuge (whirl), third time	1 min.	1 min.	1 min.	1 min.
Water bath 135–140° F.	5 min.	5 min.	5 min.	5 min.
Reading—Remove only one bottle from water bath at a time	Use dividers	Add a few drops of glymol and use dividers	Read direct or use dividers.	

* See Nebraska Standard Dairy Law, Bul. No. 3, State of Nebraska, Department of Agriculture.

CAUSES OF DAILY VARIATION IN THE QUANTITY OF MILK AND PERCENTAGE OF BUTTERFAT

INDIVIDUAL COWS

An individual cow in the herd does not produce the same quantity of milk nor does her milk contain the same percentage of butterfat at each milking. Because the milk from individual cows may vary, the average percentage of butterfat in the milk of a herd may change from day to day. The accompanying figures for one cow taken from a 7-day official test illustrates such a variation:

Milking	First Day			Second Day			Third Day			Fourth Day		
	Milk *Lbs.*	Fat *Per cent*	Fat *Lbs.*	Milk *Lbs.*	Fat *Per cent*	Fat *Lbs.*	Milk *Lbs.*	Fat *Per cent*	Fat *Lbs.*	Milk *Lbs.*	Fat *Per cent*	Fat *Lbs.*
A. M.	20.3	4.5	.91	19.4	4.9	.95	21.0	4.5	.95	22.2	4.4	.98
Noon	14.4	5.1	.73	16.4	5.4	.89	18.4	4.9	.90	18.0	4.5	.81
P. M.	13.4	5.9	.79	15.6	5.1	.80	15.5	5.1	.79	16.6	4.9	.81
Midnight	15.4	4.8	.74	17.4	4.2	.73	18.1	4.9	.89	17.8	4.4	.78
Daily totals	63.5		3.17	68.8		3.37	73.0		3.53	74.6		3.38
Av. per cent fat..		5.0			4.9			4.8			4.5	

Milking	Fifth Day			Sixth Day			Seventh Day			Total Av.		Total
	Milk *Lbs.*	Fat *Per cent*	Fat *Lbs.*	Milk *Lbs.*	Fat *Per cent*	Fat *Lbs.*	Milk *Lbs.*	Fat *Per cent*	Fat *Lbs.*	Milk Fat	Fat *Per cent*	Fat *Lbs.*
A. M.	22.1	3.7	.82	24.6	4.3	1.06	24.9	4.4	1.10	154.5	4.38	6.77
Noon	19.0	4.6	.87	19.4	4.5	.87	19.0	5.0	.95	124.6	4.83	6.02
P. M.	19.0	4.6	.87	17.2	4.9	.84	17.4	4.9	.85	114.7	5.01	5.75
Midnight	18.1	4.4	.80	18.3	4.2	.77	17.9	4.8	.86	123.0	4.53	5.57
Daily totals	78.2		3.36	79.5		3.54	79.2		3.76	516.8		24.11
Av. per cent fat.		4.3			4.4			4.7			4.66	

STAGE OF LACTATION (Time from freshening)

As a cow approaches the end of her lactation or milking period, the quantity of milk produced becomes smaller and usually the percentage of butterfat increases. This is usually a gradual change and is illustrated by the following figures which represent a complete lactation period for one cow:

Month of lactation	1	2	3	4	5	6	7
Days in milk	13	30	31	30	31	31	28
Total milk, *lbs.*	637.5	2140.3	2283.3	2094.3	1943.8	1864.0	1654.7
Av. milk per day, *lbs.*	49.0	71.3	73.6	69.8	62.7	60.1	55.5
Av. fat, *per cent* *	2.77	2.77	3.23	3.06	3.42	3.42	3.37

Month of lactation	8	9	10	11	12	13
Days in milk	31	30	31	30	31	22
Total milk, *lbs.*	1801.7	1646 9	1788.0	1630.2	1431.0	901.0
Av. milk per day, *lbs.*	58.1	54.8	57.6	54.3	46.1	40.9
Av. fat, *per cent* *	3.45	3.60	3.63	3.80	4.04	3.51

* The average test of two days milk in the middle of each month.

ENVIRONMENT

The interval or time between milkings may affect the percentage of butterfat. Usually as the period is lengthened the quantity of milk at the following milking is increased and the percentage of butterfat is decreased. Shortening the interval between milkings tends to reduce the quantity of milk and increase the percentage of butterfat in the milk at the next milking.

Any change from the ordinary, as in milkers, or from hand milking to milking machines, or from one stanchion to another or from one group of cows to another; or in fact any disturbance of the ordinary routine or any special excitement due to abuse, use of dogs in driving cows, loud talking, or the presence of strangers may temporarily affect the quantity of milk and the percentage of butterfat.

WEATHER

In general, in cool or cold weather, a cow tends to produce milk containing a higher percentage of butterfat. Hot weather, especially when the atmosphere is moist, tends to lower the percentage of butterfat. Sudden changes of weather, such as cold winds, also affect the quantity of milk and the percentage of butterfat.

FEED

Early spring pasture tends to increase milk production and to decrease the percentage of butterfat. If cows are well fed, the percentage of butterfat cannot permanently be raised by the addition of any particular feed. Any change of feed may temporarily affect the quantity and percentage of butter-

fat in the milk. Cows poorly fed, when given a well balanced ration sometimes increase in milk flow and give richer milk. Well fed cows, when partially starved, give smaller quantities of milk of lower butterfat percentage.

OTHER CAUSES

Sickness or any bodily disturbance of the cow, especially a feverish condition, may affect the quantity of milk and the butterfat percentage. The percentage of butterfat may be either higher or lower due to these conditions. The period of heat or oestrum may or may not affect the quantity and quality of the milk.

CAUSES OF BUTTERFAT VARIATIONS IN SEPARATED CREAM

RICHNESS OF THE MILK

Milk from a herd of cows varies in butterfat percentage from day to day as has been explained. The cream or skim milk screws of the separator are set so as to divide the milk into a definite proportion of cream to skim milk. If, for example, the separator is adjusted to deliver 15 pounds of cream and 85 pounds of skim milk from each 100 pounds of milk separated, and the milk tested 4.5 per cent butterfat, the 15 pounds of cream would contain 4.5 pounds of butterfat or the cream would test 30 per cent ($4.5 \div 15 = .30$). If the milk tested only 4 per cent, then the 15 pounds of cream would contain 4.0 pounds of butterfat. The cream in that case would test ($4.0 \div 15 = .2666$) or 26.7 per cent. These illustrations assume no loss of butterfat in skimming.

VARIATION IN SEPARATOR SPEED

Cream separators are adjusted to skim efficiently at a certain speed. If run faster, more skim milk is run thru and consequently less cream, and the resulting cream is richer. Such operation sometimes causes clogging of the cream outlet and a consequent loss of fat in the skim milk. If operated slower than the proper speed, the proportion of cream to milk is increased and the cream contains a lower percentage of butterfat. Slow running is likely to cause incomplete skimming.

TEMPERATURE OF THE MILK

Milk should be separated at temperatures between 90° and 98° F. At those temperatures the separation is usually most complete. Cold milk causes a smaller quantity of richer cream, since the cream is heavy and viscous and does not readily flow thru the cream opening, and consequently a larger quantity of skim milk is produced.

RATE OF MILK FLOW INTO SEPARATOR BOWL

The valve on the supply tank is adjusted with the float to deliver the proper quantity of milk when the supply tank is full. When the valve is not opened completely, or when the supply tank is only partially filled, there is less pressure forcing milk into the bowl. Under such conditions, the centrifugal force in the bowl acts upon a smaller quantity of milk and consequently produces a smaller quantity of richer cream. Any condition that increases the inflow tends to decrease the richness of the cream.

ADJUSTMENT OF CREAM OR SKIM MILK SCREWS

The cream or skim milk screws regulate the proportion of skim milk to cream, and thus affect the quantity and richness of the cream. The larger the quantity of cream, the lower it will test, and the smaller the quantity of cream the richer it will be. The cream screw when turned farther toward the center of the bowl produces a smaller quantity of richer cream and when adjusted toward the outside produces a larger quantity of thinner cream. In the case of the skim milk screws, the effect is exactly opposite.

CLEANLINESS OF THE BOWL

If a separator bowl is not washed thoroly after each separation, the cream outlet may become clogged, thus causing richer cream and probably a loss of butterfat in the skim milk.

QUANTITY OF FLUSH WATER

At the completion of separation in order to prevent the waste of cream that sticks to the various parts, it is a good practice to run a quart or two of clean lukewarm water thru the separator to flush out the bowl and cream spout. As soon as the liquid flowing from the cream spout becomes watery in appearance, turn it so that the excess flush water flows into the skim milk. If the excess flush water is allowed to flow into the cream, the test will be lowered.

VIBRATION OF SEPARATOR BOWL

Any vibration of the separator bowl is likely to cause incomplete separation and a loss of butterfat in the skim milk. Vibration may be caused by an improperly balanced bowl, a bent spindle, improper adjustments, worn parts or an unsteady separator.

CAUSES OF VARIATION IN MILK AND CREAM TESTS

A true and representative sample of the total quantity of milk or cream is essential to an accurate test. This sample must be at the proper temperature and thoroly mixed at the time a portion is transferred to the test bottle. This portion must be accurately measured in the case of milk or weighed in the case of cream. Carelessness in any particular may produce inaccurate results.

The temperature at which tests are read is an important factor in their accuracy. At the time of reading, the test should be at temperatures between 135° and 140° F. A low temperature tends to lower the reading and a high temperature tends to raise the reading especially with cream tests. A few actual examples will illustrate the effect of temperatures upon the readings of the same tests:

MILK TESTS		CREAM TESTS		
Correct Temperature 135°–140° F.	Low Temperature 115° F.	Correct Temperature 135°–140° F.	Low Temperature 115° F.	High Temperature 157° F.
5.1	5.0	24.5	24.0	25.0
4.1	4.0	30.0	29.5	30.5
3.8	3.7	34.5	34.0	35.0
7.9	7.8	24.0	23.5	24.5

Tests may be read differently by different persons. This is illustrated by the following examples where four tests were made by one person and were read independently at the proper temperature by four persons.

Chemical Röse-Gottlieb *	Person No. 1	Person No. 2	Person No. 3	Person No. 4
3.58	3.6	3.6	3.4	3.5
3.57	3.6	3.6	3.6	3.5
3.96	4.1	4.1	4.0	4.0
3.96	4.0	3.9	3.8	3.9

* Approved method of the Association of Official Agricultural Chemists.

Failure to correctly read the fat column is quite common and is usually due to not having the tests level with eyes or to the curved surfaces at the top and bottom. See correct method of reading tests on page 12.

COMPOSITION OF MILK

On April 17, 1919, the Secretary of the United States Department of Agriculture issued, under the Food Inspection Decision 178, the following definition for milk:

"Milk is the whole, fresh, clean, lacteal secretion obtained by the complete milking of one or more healthy cows, properly fed and kept, excluding that obtained within fifteen days before and five days after calving, or such longer period as may be necessary to render the milk practically colostrum free."

It must not be concluded, however, that all milk is the same.

Instead, it has a widely varying composition, affected by controllable and uncontrollable conditions. The main constituents of milk and their percentage in milk of average composition are shown below:

				Per cent
Water				87.6
Milk sugar (lactose)	4.70			
Casein	2.70	Solids not fat	8.70	
Milk protein albumin	.60			
Ash (mineral matter)	.70			
Milk fat	3.70			
			Total Solids	12.4
			Total	100.0

A result of the complete analysis of milk is shown in the table on page 26.

DISTRIBUTION OF CONSTITUENTS OF MILK *

Milk

Globules .004" to .00006" diameter — Milk fats — Emulsions

Olein	33.95†	Glycerides of insoluble volatile acids	3.40	3.7	Total solids 12.35
Palmitin	40.51†				
Stearin	2.95†				
Myristin	10.44†				
Laurin	2.57†				
Butyrin	6.23†	Glycerides of soluble volatile acids	.30		
Caproin	2.32†				
Caprylin	.53†				
Caprinin	.34†				
Casein	2.60	Nitrogen containing substances	3.25		
Albumin	.60				
Globulin	trace	Solution and colloidal suspension			
Fibrin	trace				
Leoithin	.05				
Milk sugar			4.50	Solids not fat 8.65	
Citric acid			.20		

Milk Serum

Potassium oxide	.175	Ash .70 solution and colloidal suspension	
Sodium oxide	.070		
Calcium oxide	.140		
Magnesium oxide	.017		
Iron oxide	.001		
Sulphur trioxide	.027		
Phosphorus pentoxide	.170		
Chlorine	.100		
Water			87.65
		Total	100.00

* By Mojonnier and Troy, "Technical Control of Dairy Products."
† Percentage of total fat.

WEIGHT AND SPECIFIC GRAVITY TABLE FOR MILK AND CREAM

Material	Specific Gravity * at 60° F.	Weight of 17.5 c.c. in grams	Weight of one gallon in pounds
Water	1.0000	17.500	8.3389
Milk (average 4 per cent fat)	1.0320	18.060	8.6057
Skim milk (average)	1.0360	18.130	8.6391
Cream 18 per cent butter fat	1.0152	17.766	8.4656
20	1.0129	17.726	8.4465
22	1.0107	17.687	8.4281
24	1.0085	17.649	8.4097
26	1.0062	17.608	8.3906
28	1.0040	17.570	8.3722
30	1.0017	17.530	8.3531
32	0.9995	17.491	8.3347
34	0.9973	17.453	8.3164
36	0.9952	17.416	8.2989
38	0.9930	17.377	8.2805
40	0.9908	17.339	8.2622
42	0.9886	17.300	8.2438
44	0.9864	17.262	8.2255
46	0.9843	17.225	8.2080
48	0.9821	17.187	8.1896
50	.9801	17.152	8.1729
Butter fat	.9300	16.275	7.7552

* According to Hunziker — The Butter Industry, First Edition.