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TESTING MILK
AND ITS PRODUCTS

FARRINGTON AND WOLL

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TESTING MILK AND ITS PRODUCTS.

A MANUAL FOR DAIRY STUDENTS, CREAMERY AND CHEESE-
FACTORY OPERATORS AND DAIRY FARMERS.

BY

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With Illustrations.

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BY E. H. FARRINGTON AND F. W. WOLL

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PREFACE.

The present volume is intended for the use of dairy students, creamery and cheese-factory operators, practical dairymen, and others interested in the testing or analysis of milk and its products. The subject has been largely treated in a popular manner; accuracy and clearness of statement, and systematic arrangement of the subject matter has, however, been constantly kept in mind. The aim has been to make the presentation intelligible to students with no further training than a common-school education, but their work will naturally be greatly lightened by the aid and guidance of an able teacher.

Complete directions for making tests of milk and other dairy products are given; the difficulties which the beginner may meet with, are considered in detail, and suggestions offered for avoiding them. It is expected that a factory operator or practical dairyman, by exercising ordinary common sense and care, can obtain a sufficient knowledge of the subject through a study of the various chapters of this book to make tests of milk, cream, etc., even if he has had no previous experience in this line.

For the benefit of advanced dairy students who are somewhat familiar with chemistry and chemical operations, Chapter XIV has been added giving detailed instruction for the complete chemical analysis of milk and other dairy products. The detection of preservatives and of artificial butter or filled cheese has also been treated in this connection.

As the subject of milk testing is intimately connected with the payment for the milk delivered at butter- and cheese factories, and with factory dividends, a chapter has been devoted to a discussion of the various systems of factory book-keeping, and tables

greatly facilitating the work of the factory secretary or book keeper have been prepared and are included in the *Appendix*.

Acknowledgment is due to the following parties for the use of electrotypes, viz: Vermont Farm Machine Co., Bellows Falls, Vt.; Cornish, Curtis and Greene Mfg. Co., Fort Atkinson, Wis.; Elgin Mfg. Co., Elgin, Ill.; F. B. Fargo & Co., Lake Mills, Wis.; DeLaval Separator Co., N. Y. City; Henry Troemner, Philadelphia, Pa.; Springer Torsion Balance Co., N. Y. City; J. H. Monrad, Winnetka, Ill.; Borden & Selleck Co., Chicago, Ill.; Dairymen's Supply Co., Philadelphia, Pa.; and the agricultural experiment stations at New Haven, Conn., and Madison, Wis.

University of Wisconsin,
Madison, Wis., Oct. 1, 1897.

E. H. FARRINGTON.
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TESTING MILK AND ITS PRODUCTS.

INTRODUCTION.

The need of a rapid, accurate and inexpensive method of determining the amount of butter fat in milk and other dairy products became more and more apparent, in this country and abroad, with the progress of the dairy industry, and especially with the growth of the factory system of butter and cheese making during the last few decades. So long as each farmer made his own butter and sold it to private customers or at the village grocery, it was not a matter of much importance to others whether the milk produced by his cows was rich or poor. But as creameries and cheese factories multiplied, and farmers in the dairy sections of our country became to a large extent patrons of one or the other of these, a system of equitable payment for the milk or cream delivered became a vital question.

1. The need of a practical milk- and cream test. The creameries in existence in this country up to within ten years were nearly all conducted on the cream-gathering plan: the different patrons set their milk, and cream gatherers hauled the cream to the creamery, usually twice or three times a week, where the mixed lots of cream were then ripened and churned. The patrons were paid per *inch* of cream furnished; a creamery inch is a quantity of cream which fills a can twelve inches in diameter, one inch high, or 113 cubic inches. This quantity of cream is sup-

posed to make a pound of butter, but cream from different sources, or even from the same sources at different times, varies greatly in butter-producing capacity, as will be shown under the subject of cream testing (140*). The system of paying for the number of creamery inches delivered could not therefore long give satisfaction.

The proposition to take out a small portion, a pint or half a pint of the cream furnished by each patron, and determine the amount of butter which these samples would make on being churned in so-called test churns, found but a very limited acceptance, on account of the labor involved and the difficulty of producing a first-class article of all the small batches of butter thus obtained.

2. The introduction of the so-called *oil test churn* (187) in creameries, which followed the creamery inch system, marked a decided step in advance, and it soon came into general use in cream-gathering districts. In this test, glass tubes of about $\frac{5}{8}$ inch internal diameter and nine inches long, are filled with cream to a depth of 5 inches, and the cream churned; the tubes are then placed in hot water, and the column of melted butter formed at the top is read off by means of a scale showing the number of pounds of butter per creamery inch corresponding to different depths of melted butter. While the oil test is capable of showing the difference between good and poor cream, it can not, according to investigations conducted at the Wisconsin experiment station, make strictly accurate distinctions between different grades of good and of poor cream. As a result, perfect justice can not be done to different patrons of creameries where payments for cream delivered are made on the basis of this test.

* Refers to paragraph number.

3. In cheese factories, and since the introduction of the centrifugal cream separator, in separator creameries, the problem of just payment for the milk furnished by different patrons was no less perplexing than in case of gathered-cream factories. By the pooling system generally adopted, each patron received payment in proportion to the number of pounds of milk delivered, irrespective of its quality. Patrons delivering rich milk naturally will not be satisfied with this system when they find out the quality of their milk as compared with that of their neighbors. The temptation to fraudulently increase the amount of milk delivered, by watering, or to lower its quality by skimming, will furthermore prove too strong for some patrons; the fact that it was difficult to prove any fraud committed, from lack of a reliable and practical method of milk analysis, rendered this pooling system still more objectionable.

4. As another instance in which the need of a simple test for determining the fat content of different kinds of milk was strongly felt may be mentioned the case of private dairymen and breeders of dairy cattle, who desired to follow up the butter-producing capacities of the individual cows in their herds. The only manner in which this could be done, was by the cumbersome method of trial churnings: by saving the milk of the cow to be tested, for a day or a week, and churning separately the cream obtained. This requires a large amount of work when a number of cows are to be tested, and can not therefore be done except in comparatively few cases, with cows of great excellence, or by farmers having plenty of hired help.

5. **Introduction of milk tests.** The first method which fulfilled all reasonable demands of a practical and

reliable milk and cream test was the Babcock test, invented by Dr. S. M. Babcock, chemist to the Wisconsin experiment station; a description of the test was first published in July, 1890, as bulletin No. 24 of Wisconsin experiment station, entitled: *A new method for the estimation of fat in milk, especially adapted to creameries and cheese factories.* This test which is now known and adopted in all parts of the world where dairying is an important industry, was not, however, the first method proposed for this purpose which could be successfully operated outside of chemical laboratories. It was preceded by a number of different methods, the first one published in this country being Short's method, invented by Mr. F. G. Short, and described in bulletin No. 16 of Wisconsin experiment station in July, 1888.

6. Short's test. In this ingenious method, a certain quantity of milk (20 cc.*) was boiled with an alkali solution, and afterwards with a mixture of sulfuric and acetic acids; a layer of insoluble fatty acids separated on top of the liquid, and was brought into the graduated neck of the test bottles by addition of hot water; the reading gave the per cent. of fat in the sample of milk tested.

Short's method did not find very wide application, both because it was rather lengthy and its manipulations somewhat difficult for non-chemists, and because several other methods were published shortly after it had been given to the public.

7. Other milk tests. Of these may be mentioned, besides the Babcock test, already spoken of, the Failyer and Willard method,† Parson's method,‡ Cochran's test,§

* See 44, footnote.

† Kansas experiment station report, 1888, p. 149.

‡ N. H. experiment station report, 1888, p. 69.

§ Journal of Anal. Chem., III (1889), p. 331.

the Patrick or Iowa station test,* and the Beimling (Leffmann and Beam) test.† Of foreign methods published at about the same time, or previously, the lactocrite,‡ Liebermann's method,|| the Schmid,§ Thörner,¶ and Røese-Gottlieb** methods may be noted.

8. All these tests were similar in principle, the solids not fat of the milk being in all cases dissolved by the action of one or more chemicals, and the fat either measured as such in a narrow graduated tube, or brought into solution with ether, gasoline, etc., and a portion thereof weighed on evaporation of the solvent. While this principle is an old one, having been employed in chemical laboratories for many years past, the adaptation of it to practical conditions, and the details as to apparatus and chemicals used were of course new and different in each case. The American tests given were adopted to a limited extent within the states in which they originated, and even outside of them, as in case of the Short, Patrick and Beimling methods. The Babcock test soon, however, nearly everywhere replaced the different methods mentioned, and during the past five or six years it has been in practically exclusive use in creameries and cheese factories in this country where payments are made on basis of the quality of the milk delivered, as well as in

* Ia. exp. sta., bull. No. 8, February, 1890; Iowa Homestead, June 14, 1889.

† Vermont exp. sta., bull. No. 21, September, 1890. For description of these and other volumetric methods of milk analysis, see Wiley, *Agricultural Analysis*, Vol. III, p. 490, et seq; Wing, *Milk and its Products*, p. 33, et seq; and Snyder, *Chemistry of Dairying*, pp. 112-113.

‡ *Analyst*, 1887, p. 6.

|| *Fresenius' Zeitschr.* 22, 383.

§ *Ibid.* 27, 464.

¶ *Chem. Centralbl.*, 1892, 429.

** *Landw. Vers. Stat.*, 40. 1.

the routine work in experiment station laboratories, and among milk inspectors and private dairymen. .

9. The Babcock test. An examination of the causes of the present general adoption of the Babcock test will show the strong points of the test, and the requirements made of a practical milk test. The main causes why this test has replaced all competitors are doubtless to be sought in its simplicity and its cheapness: Its manipulations are few and easily learned, and it is cheap, both in first cost and as regards running expenses.

The test is speedy, and accurate within one or two-tenths of one per cent.*

Only one chemical is used, and no training in or knowledge of chemistry is required on part of the operator.

The percentages of fat in the samples tested are shown directly from the readings of the fat column, without reference to a scale or table.

Only a small quantity of milk is used (about two-thirds of an ounce, 17.6 cc.)

The apparatus is easily kept in order, and the chances of accidents in operating the test, with properly made machines, are very slight indeed.

A small and a large number of samples may furthermore be tested with equal facility at the same time, up to the capacity of the tester.

The results obtained may be easily verified by renewed tests in the same or another machine.

The test bottles when charged with the samples of milk

* For a summary of comparative analyses made by the Babcock test and gravimetric analysis up to 1892, see Hoard's Dairyman, Oct. 7, 1892, p. 2560; also Schrott, *Milchzeitung*, 1896, p. 183, et seq.

or other dairy products may be left for months, if desired, before the test is completed, and correct results still be obtained.

The completed tests will keep indefinitely in the bottles, so that the results may be verified at any future time, if desired.

Sour milk may be analyzed with perfect assurance of accurate results, provided it can be properly sampled.

The test is finally applicable, besides to full milk, to cream, skim milk, butter milk, whey, condensed milk and (if a small scale for weighing out the sample is available) to cheese.

10. With all these advantages, the Babcock milk test is not in every respect an ideal test. The handling of the very corrosive sulfuric acid requires constant care and attention; the speed of the tester, the strength of the acid, the temperature of the milk to be tested, and other points, always require watching, lest the results obtained be too low, or otherwise unsatisfactory. The test is, however, for general purposes, in the opinion of the writers, the very best at our disposal, and in the hands of careful intelligent operators, will easily give most satisfactory results.

11. Foreign methods. In European countries three practical milk and cream tests, besides the Babcock test, are in use at the present time, viz: *Gerber's acid-butyrometer*, *De Laval's butyrometer*, and *Fjord's centrifugal cream test*.*

Of these, the last test given has never been introduced into this country, to our knowledge, and the former two, only on a small scale.

* The Lister-Babcock milk test advertised in English papers and known as such in England, is the regular Babcock test, to which the English manufacturers have prefixed their name.

12. The Gerber method * (fig. 1) is essentially the old Beimling method worked out independently by the Swiss

FIG. 1. The Gerber acid-butyrometer.

chemist, Dr. N. Gerber. In this test sulfuric acid of the same strength is used as in the Babcock test, and a small quantity of amyl alcohol is added. The amyl alcohol facilitates the separation of the fat, but introduces a source of error which may become serious, and especially so, where the results obtained with a new lot of amyl alcohol

can not be compared with gravimetric analysis or with tests made with amyl alcohol known to give correct results.

13. In the De Laval butyrometer (fig. 2) the same acid is used as in the Babcock test, but the tubes employed, and the manipulations of the method differ materially from this test; a smaller sample of milk is taken (only 2 cc.) and a correspondingly small quantity of acid used. The results obtained are correct. Where a large number of milk samples are tested every day, as is the case, for instance, in European milk control stations, the butyrometer may be preferable to the Babcock test; but it requires more skill of the operator and is more difficult to work satisfactorily in case of milk which cannot be easily sampled, as sour, lopped, or partially churned milk. The machines placed on

* Gerber, Die Praktische Milch-Pruefung.

the market both by Dr. Gerber and the De Laval Company are more expensive than the Babcock testers sold in this country; the De Laval test requires a high speed, 5-6000

FIG. 2. De Laval's butyrometer.

revolutions per minute, and therefore places greater demands for solidity in the machine than does the Babcock test.

14. Fjord's centrifugal cream tester* (fig. 3) is extensively used in Denmark and is mentioned in this connection

FIG. 3. Fjord's centrifugal cream tester.

as it furnishes a fairly reliable method for comparing the quality of different lots of milk. The method was published in 1878, by the late N. J. Fjord, director of the state experiment station in Copenhagen, through whose exertions and on

* State Danish experiment station, Copenhagen, sixth and ninth reports, 1885-7.

whose authority it was generally introduced into Danish creameries in the middle of the eighties. No chemicals are added in this test, the milk being simply placed in glass tubes, seven inches long and about 2-3 of an inch in diameter, and whirled for twenty minutes at a rate of 2000 revolutions per minute at 55° C. (131° F.) The reading of the cream layer thus obtained gives the per cent. of cream, and not of butter fat, in the sample tested. 192 samples of milk can be tested simultaneously. Within the limits of normal Danish herd milk, the results obtained correspond to the percents of fat present in the samples, one per cent. of cream being equal to about 0.7 per cent. of fat; outside of these limits the test is, however, unreliable, especially in case of very rich milk and strippers' milk. Only sweet milk can be tested by this method. The recent introduction of milk tests proper into Denmark, like the Gerber, Babcock and De Laval tests, will, however, in all probability in time force the Fjord cream test out of Danish creameries, for similar reasons that relegated to obscurity the gravity cream tests (creamometers.)

Before going over to the main part of the present work, the discussion of the Babcock milk test, a brief description of the chemistry of milk and its products is given, so that the student may understand what are the components of dairy products, and the relation of these to each other. Only such points as have a direct bearing on the subject of milk testing and the use of milk tests in butter and cheese factories or private dairies will be treated in this chapter, and the reader is referred to standard works on dairying for further information in regard to the composition of dairy products.

CHAPTER I.

COMPOSITION OF MILK AND ITS PRODUCTS.

15. Milk is composed of the following substances: *water, fat, casein, albumen, milk sugar and ash*. A few other substances are present in small quantities, but are of no practical importance and will not be considered here. The components of the milk less the water are known, collectively, as *milk solids*, or *total solids*, and the total solids less the fat, i. e. casein, albumen, milk sugar, and ash, are often spoken of as *solids not fat*, or the *non-fatty milk solids*. The *milk serum* includes all components of the milk less the fat; the *serum solids* are therefore another name for the solids not fat; when given, they are, however, generally calculated to per cent. of milk serum, not of milk. If, e. g., a sample of milk contains 9 per cent. of solids not fat, and 3 per cent. of fat, the milk serum will make up 97 per cent. of the milk, and the serum solids, $\frac{9}{97} = 9.28$ per cent. of the milk serum.

16. **Water.** The amount of water contained in milk ranges from 80 to 90 per cent. Normal cows' milk will not as a rule contain more than 88 per cent. of water, nor less than 84 per cent. In states where there are laws regulating the sale of milk, as is the case in eighteen states in the Union (see *Appendix*), the maximum limit for water in milk in all instances but one (South Carolina) is 88 per cent.; the state mentioned allows 88.5 per cent. of water in milk offered

for sale within her borders. The effect of fraudulently increasing the water content of milk by watering is considered under *Adulteration of Milk*.

17. Fat. The fat in milk is not in solution, but suspended as very minute globules, which form an emulsion with the milk serum; the globules are present in immense numbers, viz: on the average about one hundred million in a single drop of milk; a quart of milk will contain about two thousand billions of fat globules, a number written with thirteen ciphers. The size of the globules in the milk from the same cows varies according to the stage of the period of lactation, the globules being largest at the beginning of the lactation period, and gradually decreasing in size with its progress. Different breeds of cows have fat globules of different average sizes; the Channel Island cows are thus noted for the relatively large fat globules of their milk, while the Lowland breeds, the Ayrshire, and other breeds have uniformly smaller globules. The diameter of average sized fat globules in fresh milkers is about 0.004 millimeter, or one-six thousandth of an inch; that is, it takes about six thousand such globules placed side by side to cover one inch in length. The globules in any sample of milk vary greatly in size; the largest globules are recovered in the cream when the milk is set, or run through a cream separator, and the smallest ones remain in the skim milk; properly skimmed separator skim milk will contain only a small number of very minute fat globules.

Milk fat is composed of so-called glycerides of the fatty acids, i. e. compounds of the latter with glycerine; some of the fatty acids are insoluble in water, viz: palmitic, stearic, and oleic acids, while others are soluble and volatile, the

chief ones among the latter being butyric, caprylic, and caproic acids. The glycerides of the insoluble fatty acids make up about 92 per cent. of the pure milk fat, and about 8 per cent. of the glycerides of volatile fatty acids are therefore found in natural milk- (and butter-) fat. The distinction between natural and artificial butter lies mainly in this point, since artificial butter (butterine, oleomargarine) as well as other solid animal fats contain only a very small quantity of volatile fatty acids. The glycerides of the volatile fatty acids are unstable compounds, easily decomposed through the action of bacteria or light; the volatile fatty acids thus set free, mainly butyric acid, are the cause of the unpleasant odor met with in rancid butter.

The per cent. of fat in cows' milk is generally between three and six per cent. American milk contains on the average toward four per cent. of fat. The milk from single cows in perfect health will occasionally go below or above the limits given, but the mixed milk from a whole herd rarely falls outside of these limits. The legal standard for fat in milk in most states of the Union is 3 per cent.; Rhode Island allows milk containing 2.5 per cent. of fat to be sold as pure, while Georgia and Minnesota require it to contain 3.5 per cent., and Massachusetts 3.7 per cent. (in the months of May and June; see *Appendix*.)

18. Casein and albumen. These belong to the so-called *nitrogenous* substances, distinguished from the other components of the milk by the fact that they contain the element nitrogen. Another name is albuminoids or protein compounds. Casein is precipitated by rennet in the presence of soluble calcium salts, and by dilute acids and certain chemicals; albumen is not acted upon by these

agents, but is coagulated by heat, a temperature of 170° F. being sufficient to effect a perfect coagulation. The casein, with fat and water, form the main components of most kinds of cheese; in the manufacture of cheddar and most other solid cheeses, casein is coagulated by rennet, and the curd thus formed holds fat and whey mechanically, the latter containing in solution small quantities of non-fatty milk solids. The albumen goes into the whey, and in some countries is also made into cheese by evaporating the whey under constant stirring; usually whole milk of cows or goats is added and incorporated into such cheese (*primost, goat cheese*).

Casein is present in milk partly in solution, in the same way as milk sugar, soluble ash-materials and albumen, and partly in suspension, in an extremely fine colloidal condition, mixed or combined with insoluble calcium phosphates. The casein and calcium phosphates in suspension in milk may be retained on a filter made of porous clay (so-called *Chamberland filters*).

About 80 per cent. of the nitrogenous compounds of normal cows' milk are made up of casein; the rest is largely albumen. If the amount of casein in milk be determined by precipitation with rennet or dilute acids, and the albumen by boiling the filtrate from the casein precipitate, it will be found that the sum of these two compounds does not make up the total quantity of nitrogenous constituents in the milk. The small remaining portion (about five per cent. of the total nitrogenous constituents) is called by various authors, globulin, albumose, hemi-albumose, nuclein, proteose, etc. The nitrogenous constituents of milk are very unstable compounds, and their study presents many and great difficulties; as a result we find that no two scien-

tists who have made a special study of these compounds agree as to their properties, aside from those of casein and albumen, or their relation to the nitrogenous substances found elsewhere in the animal body. For our purpose we may, however, consider the nitrogen compounds of milk as made up of casein and albumen, and the term *casein and albumen* used in this book is meant to include the total nitrogenous constituents of milk, as obtained by multiplying the total nitrogen content of the milk by 6.25.*

The quantity of casein in normal cows' milk will vary from 2 to 3.5 per cent., and of albumen from .5 to .8 per cent. The total content of casein and albumen will range between 2.5 and 4.2 per cent., the average being about 3.5 per cent. Milk with a low fat content will contain more casein and albumen, than fat, while the reverse is generally true in case of milk containing more than 3.5 per cent. of fat.

19. Milk sugar or lactose belongs to the group of organic compounds known as *carbohydrates*. It is a commercial product manufactured from whey, and is obtained in this process as pale white crystals, of less sweet taste, and less soluble in water than ordinary sugar (cane sugar, sucrose). About 70 per cent. of the solids in the whey, and 33 per cent. of the milk solids, are composed of milk sugar.

When milk is left standing for some time, viz: from one to several days, according to the temperature of the surrounding medium, it will turn sour, and soon become thick and loppered. This change in the composition and the appearance of the milk is brought about through the action of

* The factor 6.25 is generally used for obtaining the casein and albumen from the total nitrogen in the milk, although 6.37 would be more correct, since these substances, according to our best authorities, contain on the average 15.7 per cent. of nitrogen.

acid-forming bacteria on the milk sugar; these are present in ordinary milk in immense numbers, and under favorable conditions of temperature multiply rapidly, feeding on the milk sugar as they grow, and decomposing it into lactic acid. When this change alone occurs, there is not necessarily a loss in the nutritive value of the milk, since the milk sugar breaks up directly into lactic acid; this is shown by the following chemical formula:

Ordinarily the souring of milk is, however, more complicated, and other organic bodies, like butyric acid, alcohol, etc., and gases like carbonic acid and hydrogen are formed, resulting in a loss in the feeding value of the milk. While sour milk may therefore contain a somewhat smaller proportion of food elements than sweet milk, the feeding of it to farm animals, especially pigs, will generally produce better results than is obtained in feeding similar milk in a sweet condition. The cause of this may lie in the stimulating effect of the lactic acid of the sour milk on the appetites of the animals, or in its aiding digestion by increasing the acidity of the stomach juices.

That the souring of milk is due to the activities of bacteria present therein is shown clearly by the fact that steril milk, i. e., milk in which all germ life has been killed, will remain sweet for any length of time when kept free from infection.

The amount of milk sugar found in normal cows' milk varies from 3 to 6 per cent., the average content being about

* One molecule of milk sugar is composed of 12 atoms of carbon (C), 22 atoms of hydrogen (H), 11 atoms of oxygen (O), and one molecule of water (H₂O). In the same way, the lactic acid molecule consists of 3 atoms of carbon, 6 atoms of hydrogen, and 3 atoms of oxygen.

5 per cent.; in sour milk this content will be decreased to toward 4 per cent.

20. Ash. The ash or mineral substances of milk are largely composed of chlorids and phosphates of sodium, potassium, magnesium and calcium; iron oxid, and sulfuric and citric acids are also present in small quantities among the normal mineral milk constituents. The amounts of the different bases and acids found in milk ash have been determined by a number of chemists; the average figures obtained are given in the following table, calculated per 100 parts of milk (containing .75 per cent. of ash) and per 100 parts of milk ash.

Mineral Components of Milk.

	<i>In per cent. of Milk.</i>	<i>In per cent. of Ash.</i>
Potassium oxid (K_2O).....	.19 per ct.	25.64 per ct.
Sodium oxid (Na_2O).....	.09	12.45
Lime (CaO).....	.18	24.58
Magnesia (MgO).....	.02	3.09
Iron oxid (Fe_2O_3).....	.002	.34
Phosphoric anhydrid (P_2O_5).....	.16	21.24
Chlorin (Cl).....	.12	16.34
	<hr/>	<hr/>
	.762 per ct.	103.68 per ct.
Less oxygen, corresponding to chlorin.....	.012	3.68
	<hr/>	<hr/>
	.75 per ct.	100.00 per ct.

The combinations in which the preceding bases and acids are contained in the milk are not known with certainty; the following scheme is, however, given on the best authority and is believed to be substantially correct.

Percentage Composition of Milk Ash (Søeldner).

Sodium chlorid (common salt).....	10.62 per ct.
Potassium chlorid.....	9 16
Mono-potassium phosphate.....	12.77
Di-potassium phosphate.....	9.22
Potassium citrate.....	5.47
Di-magnesium phosphate.....	3.71
Magnesium citrate.....	4.05
Di-calcium phosphate.....	7.42
Tri-calcium phosphate.....	8.90
Calcium citrate.....	23.55
Lime combined with casein.....	5.13
	<hr/> 100.00

According to the same author, 36 to 56 per cent. of the phosphoric acid found in milk, and from 53 to 72 per cent. of the lime, are present in suspension in the milk, as di- and tri-calcium phosphates, and may be filtered out by means of Chamberland filters (18), or by long continued centrifuging (Babcock *.) The rest of the ash constituents are dissolved in the milk serum.

The ash content of normal cows' milk varies but little, as a rule only between .6 and .8 per cent., with an average of .7 per cent. Milk with a high fat content generally contains about .8 per cent. of ash; strippers' milk always has a high ash content, at times even exceeding one per cent. Ordinarily, the mineral constituents of milk are, however, the components least liable to variations.

21. Other components. Besides the milk constituents enumerated and described in the preceding pages, normal milk contains a number of substances which are only present in small quantities and have only scientific interest, such

* Wisconsin experiment station, twelfth report, p. 93.

as the milk gases (carbonic acid, oxygen, nitrogen), citric acid, lecithin, cholesterin, urea, hypoxanthin, lactochrome, etc.

The percentage composition of cows' milk will be seen from the tables given in the *Appendix*. Tables are also given showing the average composition of milk products, like skim milk, butter milk, whey, cream, butter, cheese and condensed milk.

22. Colostrum milk. The liquid secreted directly after parturition is known as colostrum milk or biestings. It is a thick, yellowish, viscous liquid; its high content of albumen and ash is characteristic, and also its low content of milk sugar. Owing to the large quantity of albumen which colostrum contains it will coagulate on being heated to boiling. The secretion of the udder gradually changes from colostrum to normal milk in the course of four to five days; the milk is considered fit for direct consumption, or for the manufacture of cheese and butter when it does not coagulate on boiling, and is of normal appearance as regards color, taste, and other properties. For composition of colostrum milk, see *Appendix*.

CHAPTER II.

SAMPLING MILK.

23. The butter fat in milk is not in solution, like sugar dissolved in water, but the minute fat globules or drops, in which form it occurs, are held in suspension in the milk serum (17). Being lighter than the serum, the fat globules have a tendency to rise to the surface of the milk. If, therefore, a sample of milk is left undisturbed for even a short time, the upper layer will contain more fat than the lower portion. This fact should always be borne in mind when milk is sampled. The rapidity with which fat rises in milk can be easily demonstrated by leaving a quantity of sweet milk undisturbed in a cylinder or milk can for a few minutes, and testing separately the top, middle and bottom layer of this milk.

EXPERIMENT. Fill the cylinder used for making the lactometer test (100) with milk, thoroughly mixed by pouring; measure a pipetteful of milk immediately into test bottle A. Allow the milk in the cylinder to remain undisturbed for ten minutes, and then measure a pipetteful of milk from the top of that in the cylinder, into test bottle B. Next pour out most of the milk from the cylinder, and measure into test bottle C, a pipetteful of the last portion of the milk in the cylinder.

After completing the tests of A, B, and C, in the usual manner (32), record the results of each test in the note book.

24. The amount of mixing necessary to evenly distribute the constituents of milk throughout its mass, can also be

demonstrated by adding a few drops of cheese color to a quart of milk. The yellow streaks through the milk will be noticed until it has been poured several times from one vessel to another, when the milk will have a uniform pale yellow color. Stirring with a stick or a dipper will not produce an even mixture so quickly or so completely as pouring the milk a few times from one vessel to another, and in sampling milk for testing it should always be mixed by pouring just before the milk is measured into the bottle; if several tests are made of a sample, the milk should be poured before each sampling.

25. Partially churned milk. A second difficulty sometimes met with in sampling whole milk arises from the fact that a part of the butter fat may be separated in the form of small butter granules by too zealous mixing, or by reckless shaking in preparing the sample for testing. This will happen most readily in case of milk from fresh cows, or with milk containing exceptionally large fat globules. When some of the butter granules are thus churned out, they very quickly rise to the surface of the milk after pouring, and cannot again be incorporated in the milk by simple mixing; it is, therefore, impossible to obtain a fair sample of such milk for testing, without taking special measures which will be explained in the following. The granules of butter may be so small as to pass into the pipette with the milk, and the quantity measured thus contain a fair proportion of them, but they will be found sticking to the inside of the pipette when this is emptied, and so fail to be carried into the test bottle with the milk.

A similar partial churning of the milk will sometimes take place in the transportation cans. When such milk is received

at the factory, the butter granules are caught by the strainer cloth through which the milk is poured, and thus lost both to the factory and to the farmer. This separated fat cannot be put into the cream, or added to the granular butter, without running the risk of making mottled butter, and it will not enter into the sample of milk taken for testing purposes.

When milk samples are sent in small bottles by mail or express, or carried to the place of testing, they very often arrive with lumps of butter floating in the milk or sticking to the glass. This churning of the milk can be easily prevented by filling the bottle or the can completely with milk. If there is no space left for the milk in which to splash around, the fat will not be churned out in transit.

26. Approximately accurate results may generally be obtained with a partially churned sample of milk, if a teaspoonful of ether is added to it. After adding the ether, cork the bottle and shake it until the lumps of butter are dissolved in the ether. This ether solution of the butter will mix with the milk, and from the mixture a uniform sample may generally be taken without difficulty. The dilution of milk by the ether introduces an error in the testing, and only the smallest quantity of ether necessary to dissolve the lumps of butter should be used. If desired, a definite quantity of ether, say 5 or 10 per cent. of the volume of the sample of milk to be tested, may be added; in such cases the result of the test must be increased by the per cent. of ether added.

EXAMPLE. To a 4 oz. sample (120 cc.) of partially churned milk, 5 per cent., or 6 cc., of common ether are added: the mixture gives an average test of 4.2 per cent. The test must be increased by $\frac{5}{100} \times 4.2 = .21$, and the original milk, therefore contained $4.2 + .21 = 4.41$ per cent. of fat.

Instead of adding ether to partially churned samples, it has been suggested to warm the milk to 110° F. for a sufficiently long time to melt the butter granules; the sample is now shaken vigorously until a uniform mixture of milk and melted butter is obtained, and a pipetteful then drawn from the sample.

27. Sampling sour milk. When milk becomes sour, the casein is coagulated and the mechanical condition of the milk thereby changed so as to render a proper sampling very difficult. The butter fat is not, however, changed in the process of souring; this has been shown by one of us in a series of tests which were measured from one sample of sweet milk into six test bottles. A test of the milk in one of these test bottles was made every month for six months, and approximately the same amount of fat was obtained in the tests throughout the series, as was found originally in the milk when tested in a sweet condition.* If the milk is in condition to be sampled, the souring of it does not therefore interfere with its being tested by the Babcock test, or with the accuracy of the results obtained.

In order to facilitate the sampling of sour or loppered milk, some chemical is added which will re-dissolve the coagulated casein and produce a uniform mixture, that can be readily measured with a pipette. Any alkali (powdered potash or soda, or liquid ammonia) will produce this effect. Only a very small quantity of powdered alkali is necessary for this purpose. The complete action of the alkali on sour milk requires a little time, and the operator should not try to hasten the solution by adding too much alkali. An ex-

*See Hoard's Dairyman, April 8, 1892. The same holds true for cream, as shown by Winton, (U. S. Dept. Agr., Div. of Chemistry, bull. 43, p. 112.)

cess of alkali will often cause such a violent action of the sulfuric acid on the milk to which the acid is added, (on account of the heat generated or the presence of carbonates in the alkali) that the mixture will spurt out of the neck of the test bottle, when it is shaken in mixing the milk and the acid. When powdered alkali is added to the milk, it should be allowed to stand for a while, with frequent stirring, until the curd is all dissolved, and an even translucent liquid is obtained. Such milk may become dark colored by the action of the alkali, but this color does not interfere with the accuracy of the test.

Instead of powdered soda or potash, these substances dissolved in water (soda or potash lye), or strong ammonia water, may be used for the purpose of dissolving the coagulated casein in a sample of sour milk. In this case, a definite proportion of alkali solution must, however, be taken, 5 per cent. of the volume of milk being usually sufficient, and the results obtained are increased accordingly. (See example cited on p. 22).

28. Sampling frozen milk. When milk freezes, it separates into two distinct portions: Milk crystals, largely made up of water, with a small admixture of fat and other solids, and a liquid portion, containing nearly all the solids of the milk. In sampling frozen milk it is therefore essential that *both* the liquid and the frozen part be warmed and mixed thoroughly on the disappearance of the crystals, by pouring gently back and forth from one vessel into another; the sample is then taken and the test proceeded with in the ordinary manner (32).

CHAPTER III.

THE BABCOCK TEST.

29. The Babcock test is founded on the fact that strong sulfuric acid will dissolve all non-fatty solid constituents of

FIG. 4. The first Babcock tester made.

of fat contained in the sample tested.

milk and other dairy products, and will set free the fat. This will separate on standing, but to effect a speedy and complete separation, the bottles holding the mixture of milk and acid are placed in a centrifugal machine — a so-called *tester*, and whirled for five minutes; hot water is then added so as to bring the liquid fat into the graduated neck of the test bottles, and after a repeated whirling, the length of the column of fat is read off, showing the per cent.

Sulfuric acid is preferable to other strong mineral acids for the purpose mentioned, on account of its affinity for water; when mixed with milk, the mixture heats greatly, thus keeping the fat liquid without the application of artificial heat, and rendering possible a distinct reading of the column of fat brought into the neck of the test bottles.

30. So far as is known, any kind of milk can be tested by the Babcock test. Breed, period of lactation, quality or age of the milk is of no importance in using this method, so long as a fair sample of the milk can be secured. Samples of milk or other dairy products, rich in solids, require a little more effort to perfect a thorough mixture with the acid than thin milk or other dairy products low in solids, like whey, which may be readily mixed with the acid.

A—DIRECTIONS FOR MAKING THE TEST.

31. The various steps in the manipulation of the Babcock test are discussed in the following pages; attention is drawn to the difficulties which the beginner and others may meet with in working the test, and the necessary precautions to be observed in order to obtain accurate and satisfactory results are explained in detail. The effort has been to treat the subject exhaustively, and from a practical point of view, so that persons as yet unfamiliar with the test may turn to the pages of this book for help in any difficulties which they may encounter in their work in this line.

32. Sampling. The sample to be tested is first mixed by pouring the milk from one vessel to another two or three times so that every portion thereof will contain a uniform amount of butter fat. The measuring pipette which has a capacity of 17.6 cubic centimeters, (see fig. 6), is filled with the milk immediately after the mixing is completed, by

sucking the milk into it until this rises a little above the mark around the stem of the pipette; the forefinger is then quickly placed over the end of the pipette before the milk runs down below the mark. By loosening a little the pressure of the

FIG 5. Babcock milk test bottle.

finger on the end of the pipette, the milk is now allowed to run down until it just reaches the mark on the stem; the quantity of milk contained in the pipette will then, if this is correctly made, be exactly 17.6 cc. The finger should be dry in measuring out the milk so that the delivery of milk may be checked by gentle pressure on the upper end of the pipette.

The point of the pipette is now placed in the neck of a Babcock test bottle (fig. 5) and the milk is allowed to flow slowly down the inside of the neck. Care must be taken that none of the milk measured out is lost in this transfer. The portion of the milk remaining in the point of the pipette is blown into the test bottle.

The best and safest manner of holding the bottle and the pipette in this transfer is shown in fig. 7. Fig. 8 shows a position which should be avoided, since by holding

FIG. 6.
17.6 cc. pipette.

the bottle in this way, there is a danger that some of the milk may completely fill the neck of the bottle, and as a result, flow over the top of the neck.

FIG. 7. The right way of emptying pipette into test bottle.

33. Adding acid. The acid cylinder, (fig. 9), holding 17.5 cc., is then filled to the mark with sulfuric acid of a specific gravity of 1.82–1.83. This amount of acid is carefully poured into the test bottle containing the milk. In adding the acid, the test bottle is conveniently held at an

angle, (see fig. 7), so that the acid will follow the wall of the bottle and not run in a small stream into the center of the milk. By pouring the acid into the middle of the neck of the test bottle, there is also a danger of completely filling this with acid, in which case the plug of acid formed will be pushed over the edge of the neck by the expansion of the air in the bottle, and may be spilled on the hands of the operator.

The milk and the acid in the test bottle should be in two distinct layers, without any black portion of partially mixed liquids between them. Such

FIG. 8. The wrong way of emptying pipette into test bottle.

followed by an indistinct separation of the fat in the final reading. The cause of this is possibly that a partial mixture of acid and milk before the acid is diluted with the water of the milk may bring about too strong an action of the acid on the milk, and the fat in this small portion may

be slightly charred by the strong acid. The appearance of black flocculent matter in or below the column of fat which

FIG. 9. 17.5 cc.
acid cylinder.

generally results, in either case renders a correct measurement of fat difficult, and at times even impossible; if the black specks occur in the fat column itself, the readings are apt to be too high; if below it, the difficulty comes in deciding where the column of fat begins.

34. Mixing milk and acid. After adding the acid, this is carefully mixed with the milk by giving the test bottle a rotary motion. In doing this, care should be taken that none of the liquid spurts into the neck of the test bottle. When once begun, the mixing should be continued until completed; a partial and interrupted mixing of the liquids will often cause more or less black material to separate with the fat when the test is finished. Clots of curd which separate at first by the action of the acid on the milk, must be entirely dissolved by persistent and careful shaking of the bottle. Beginners sometimes fail to mix thoroughly the milk and the acid in the test bottle. As the acid is much heavier than the milk, a thin layer of it is apt to be left unnoticed at the bottom of the bottle, unless this is vigorously shaken toward the end of the operation.

The mixture becomes hot by the action of the acid on the water in the milk and turns dark colored, owing to the effect of the strong sulfuric acid on the nitrogenous constituents and the sugar of the milk.

Colostrum milk, or milk from fresh cows will form a violet colored mixture with the acid, owing to the action of

the latter on the albumen present in considerable quantities in such milk (22).

When milk samples are preserved by means of potassium bichromate (172), and so much of this material has been added that the milk has a dark yellow or reddish color, the mixture of milk and acid will turn greenish black, and a complete solution is rendered extremely difficult on account of the toughening effect of the bichromate on the precipitated casein. An indistinct separation of the fat is also sometimes obtained in such samples, but this difficulty can generally be overcome by using a little less than the regular quantity of acid.

35. Whirling bottles. After the milk and the acid have been completely mixed, the test bottle is at once placed in the centrifugal machine or tester and whirled for four to five minutes at a speed of 600 to 1,200 revolutions per minute, the proper speed being determined by the diameter of the tester (57). It is not absolutely necessary to whirl the test bottles in the centrifuge as soon as the milk and the acid are mixed; they may be left in this condition for any reasonable length of time (24 hours, if necessary) without the test being spoiled. If left until the mixture becomes cold, the bottles should, however, be placed in warm water (of about 160° F.) for about 15 minutes before whirling.

Four minutes at full speed is usually sufficient for the first whirling of the test bottles in the centrifuge; this will bring the fat to the surface of the liquid in the body of the bottle.

36. Adding water. Hot water is now added by means of a pipette, or some special device, until the bottles are filled up to the beginning of the neck. The bottles are

whirled again at full speed for one minute, and hot water added a second time, until the lower part of the column of fat comes within the scale on the neck of the test bottle, preferably to the 1 or 2 per cent. mark, so as to allow for the sinking of the column of fat, owing to the gradual cooling of the contents of the bottle. By dropping the water directly on the fat in the second filling, the column of fat will be washed free from light flocculent matter, which might otherwise be entangled therein and render the reading uncertain or even too high. A final whirling for one minute completes the separation of the fat.

37. Measuring the fat. The amount of fat in the neck of the bottle is measured by the scale or graduations on the neck. Each division of the scale represents two-tenths of one per cent. of fat, and the space which the fat occupies shows the per cent. of butter fat contained in the sample tested.

The fat obtained should form a clear yellowish liquid distinctly separated from the acid solution beneath it. There should be no black or white sediment in or below the column of fat, and no bubbles or foam on its surface. The bottles should be kept warm until the readings are made, so that the column of fat will have a sharply defined upper and lower meniscus.

The fat is measured from the lower line of separation between the fat and the water, to the top of the fat column, at the point *b*, shown in the figure 10, the reading being thus taken from *a* to *b*, and not to *c* or to *d*. Comparative gravimetric analyses have shown that the readings obtained in this manner give correct results. While the lower line of the fat column is nearly straight, the upper one is curved,

and errors in the reading of the column are therefore easily made, unless the preceding rule is observed.

FIG. 10. Measuring the column of fat in a Babcock test bottle.

The readings should be made when the fat has a temperature of about 140° F., although the results obtained will not be appreciably affected if the temperature falls below 120°. The fat separated in the Babcock test solidifies at about 100° F. No readings should be attempted if the fat is partly solidified, as it is impossible to get an accurate reading in this case.*

A pair of dividers will be found convenient for measuring the fat, and the liability of error in reading is decreased by their use. The points of the dividers are placed at the upper and lower limits of the fat column (from *a* to *b* in fig. 10). The dividers

are now lowered, one point being placed at the zero mark of the scale, and the mark at which the other point touches the scale will then show the per cent. of fat in the sample tested.

* The effect of differences in the temperature of the fat on the readings obtained will be seen from the following: If 110 and 150° F. be taken as the extreme temperatures, at which readings are made, this difference of 40° F. (22.3° C) would make a difference in the volume of the fat column obtained in case of 10 per cent. milk, of $.00064 \times 2 \times 22.3 = .028544$ cc. or .14 per cent., .00064 being the expansion coefficient of pure butter fat per degree Centigrade between 50 and 100° C. (*Zune, Analyse des Beurres*, I, 87), and 2, the volume of the fat in cc. contained in 17.6 cc. of 10 per cent. milk. On 5 per cent. milk this extreme difference would therefore be about .07 per cent., or considerably less than one-tenth of one per cent.

B.—DISCUSSION OF THE DETAILS OF THE BABCOCK TEST.

38. Although the manipulations of the Babcock test are few and comparatively simple, various difficulties may be met with in using it, particularly in the hands of beginners.

The main points that have to be observed as to apparatus and testing materials in order to obtain correct and satisfactory results by this test will now be considered, and such suggestions and help offered, as has been found desirable from an extensive experience with a great variety of milk samples, apparatus, and accessories.

1.—GLASSWARE.

39. Test bottles. When 17.6 cc., or 18 grams of milk, are measured into the Babcock test bottle, the scale on the neck of the bottles shows directly the percent of fat found in the milk. The scale is graduated from 0 to 10 per cent. 10 per cent. of 18 grams is 1.8 grams. As the specific gravity of pure butter fat (i. e. its weight compared with that of an equal quantity of pure water) at the temperature at which the readings are made (about 120° F.), is 0.9, 1.8 grams of fat will occupy a volume of $\frac{1.8}{.9} = 2$ cubic centimeters. The space between the 0 and 10 per cent. marks on the necks of the test bottles must therefore hold 2 cc., if correctly made. The scale is divided into 10 equal parts, each part representing one per cent., and each of these are again sub-divided into five equal parts. Each one of the latter divisions therefore represents two-tenths of one per cent. of fat when 17.6 cc. of milk is measured out. The small divisions are sufficiently far apart in most Babcock test bottles to make possible the estimation of one-tenth of one per cent. of fat in the samples tested.

The figures and lines of the measuring scale become indistinct by use; the black color may be restored by rubbing a soft lead pencil over the scale, or by the use of a piece of burnt cork after the scale has been rubbed with a little tallow. On wiping the necks with a cloth, or a piece of paper, the black color will show in the etchings of the glass, making these plainly visible.

40. The test bottles should have a capacity of about 50 cc., or less than two ounces; they should be made of well-annealed glass that will stand sudden changes of temperature without breaking, and should be sufficiently heavy to withstand the maximum centrifugal force to which they are likely to be subjected in making tests. This force may not on the average be very far from 30.65 lbs. (see 57) or the pressure exerted in whirling the bottles filled with milk and acid, in a centrifugal machine of 18 inches diameter, at a speed of 800 revolutions per minute.

Special forms of test bottles used in testing cream and skim milk are described under the heads of cream- and skim milk testing.

41. Marking test bottles. Test bottles can now be bought with a small band or portion of their neck or body ground or "frosted," for numbering the bottles with a lead pencil. Bottles without this ground label can be roughened at any convenient spot by using a wet fine file to rub off the smooth surface of the glass. There is this objection to the latter method that unless carefully done, it is apt to weaken the bottles so that they will easily break, and to both methods, that the lead pencil marks made on such ground labels are easily erased during the test, unless the bottles are carefully handled. Small strips of tin or copper with a

number stamped thereon are sometimes attached as a collar around the necks of the bottles. They are, however, easily lost, especially when the top of the bottle is slightly broken, or at any rate, are soon corroded so that the numbers can only be seen with difficulty.

The best and most permanent label for test bottles is made by scratching a number with a marking diamond into the glass directly above the scale on the neck of the bottles. In ordering an outfit, or test bottles alone, the operator may specify that the bottles are to be marked 1 to 24, or as many as are bought, and the dealer will then put the numbers on with a marking diamond. A careful record should be kept of the number of the bottle into which each particular sample of milk is measured. Mistakes are often made when the operator trusts to his memory for locating the different bottles tested at the same time.

42. Cleaning test bottles. The fat in the neck of the test bottles must be liquid when these are cleaned. The bottle should be shaken in emptying the acid, in order to remove the white residue of sulfate of lime, etc., from the bottom; if the acid is allowed to drain out of the bottle without this being shaken during the emptying, this residue will be found to stick very tenaciously to the bottom in the subsequent cleaning with water.

A convenient method of emptying the test bottles is shown in the illustration (fig. 11). After reading the fat, the bottles are taken from the tester and placed, neck down, in the $\frac{1}{2}$ inch holes of the board cover of a five-gallon stoneware jar. An occasional shaking while the liquid is running from the bottles will rinse off the precipitate of sulfate of lime. A thorough rinsing with boiling hot water by means

of an apparatus, devised by one of us* (see fig. 12) is generally sufficient to remove all grease and dirt, as well as

FIG. 11. Waste acid jar.

acid solution, from the inside of the bottles. When the bottles have been rinsed, they are placed in an inverted position to drain, on a galvanized iron rack, as shown in fig. 13, where they are kept until needed. The

outside of the bottles should occasionally be wiped clean and dry.

43. The amount of unseen fat that clings to glassware is generally not sufficient to be noticed in the results obtained in testing whole milk, but it plays an important part in testing samples of separator skim milk. It may be readily noticed by making a blank test with clean water in bottles which have been used for testing ordinary milk, and have been cleaned by simply draining the contents and rinsing once or twice with hot water; at the conclusion of the test the operator will often find that a few drops of fat — sometimes enough to condemn a separator — will collect in the neck of the bottles, although the water tested has not been near a separator.

Boiling hot water will generally clean the grease from glassware for a time, but all test bottles should, in addition,

* Farrington.

be given an occasional bath in some weak alkali, or other grease-dissolving solution. Persons doing considerable milk testing will find it of advantage to provide themselves with a small copper tank, which can be filled with a weak alkali-solution (figs. 14 and 15). After having been rinsed

FIG. 12. Apparatus for cleaning test bottles. *A*, apparatus in position; the water flows from the reservoir through the iron pipe *b* into the inverted test bottle *d* through the brass tube *c*, screwed into the iron pipe. *B* shows construction of the rubber support on which the top of the test bottle rests; *f*, draining sink.

with hot water, the test bottles are placed in the hot solution kept in the tank, where they may be left completely covered with the liquid. If the tank is provided with a small

faucet at the bottom, the liquid can be drawn off when the test bottles are wanted. A tablespoonful of *Savogran* to about two gallons of water will make a very satisfactory cleaning solution; *sal soda*, *Gold Dust*, *Lewis lye* or *Babbitt's potash* are equally efficient. The cleansing properties of solutions of any of these substances are increased by warming the liquid. The test bottles must be rinsed twice with hot water after they are taken from this bath.

FIG. 13. Draining-rack for test bottles.

The black stains that sometimes stick to the inside of test bottles after prolonged use, can be removed with a little muriatic acid.

44. Pipette. The difference in the weights of various samples of normal milk generally falls within comparatively narrow limits: if a given quantity of water weighs 1 pound, the same quantity of the usual grades of normal milk will weigh from 1.029 to 1.033 pounds, or on the average 1.03 lbs. 18 grams* of water measures 18 cc.; 18 grams of

* Cubic centimeters (abbreviated: cc.) are the standard used for measuring volume in the metric system, similar to the quart or pint measure in our ordinary system of measures. 1 quart is equal to a little more than 1000 cubic centimeters. In the same way, grams represent weight, like pounds and ounces. 1 cc. of water at 4° Centigrade weighs 1 gram. 1000 grams (= 1 kilogram) is equal to 2.2 lbs. Avoir. (See *Appendix, for Comparisons of Metric and Customary Weights and Measures*).

milk will therefore take up a smaller volume (measure less) than 18 cc., viz: 18 divided by 1.03, which is very nearly

FIG. 14. Tank for cleaning test bottles.

For convenience in measuring the milk, the shape of the pipette is of importance. The mark on the stem should be two inches or more from the upper end of the pipette. The lower part should be small enough to fit loosely into the neck of the test bottle, and not contracted to a fine hole at the point; the point should be large enough to allow a quick emptying of the pipette. (Fig. 16).

45. *Fool pipettes.* Soon after the Babcock test began to be generally used at creameries as a means of paying for the milk, a creamery supply house put

17.5. This is the quantity of milk taken in the Babcock test. A certain amount of milk will adhere to the walls of the pipette when it is emptied, and this thin film has been found to weigh about one-tenth of a gram; consequently 17.6 cc. has been adopted as the capacity of the pipette used for delivering 18 grams of milk.

FIG. 16. Pipette points—

A, proper construction; B, undesirable construction.

on the market a 20 cc. milk-measuring pipette, which was claimed to show the exact *butter* value of milk, instead of its content of butter *fat*, as in the case in using the ordinary 17.6 cc. pipette. A 20 cc. pipette will deliver 2.4 cc., or 13.6 per cent. more milk than a 17.6 cc. pipette, and it follows that the results obtained by measuring out milk for Babcock tests with these pipettes will be about 13.6 per cent. too high. In considering the subject of *Overrun* it is noted that the excess of butter yield over the amount of fat contained in a certain quantity of milk will range from about 10 to 15 per cent., or on the average 12-13 per cent. The 20 cc. pipettes may, therefore, give approxi-

FIG. 15. Rack for holding test bottles in tank shown in fig. 14.

mately the yield of butter obtained from a quantity of milk, but as will be seen, this yield is variable, according to the skill of the butter maker, and according to conditions beyond his control, and cannot therefore be used as a standard in the same manner as the fat content of the milk. Similar 22 cc. pipettes were also sent out. These pipettes created a great deal of confusion during the short time they were on the market, and were popularly termed "fool pipettes," as the tests obtained by them did not give, what they professed to do, an accurate and definite measure of the butter-producing qualities of different lots of milk. It is not known that any of these pipettes are on the market at the present time.

46. Acid measures. A 17.5 cc. glass cylinder for measuring the acid is generally included in the outfit, when a Babcock tester is bought. This cylinder answers every purpose if only occasional tests are made; the acid is poured into the cylinder from the acid bottle, as needed, or a quantity of acid sufficient for the number of test bottles to be whirled at a time, is poured into a small glass beaker, provided with a lip, or into a porcelain pitcher; these may be more easily handled than the heavy acid bottle, and the acid measure is then filled from such a vessel.

Where a considerable number of tests are made regularly, the acid can be measured into the test bottles faster and with less danger of spilling, by using some one of the many devices proposed for this purpose. There is some objection to nearly all of these appliances, automatic pipettes, burettes, etc., although they will often give good satisfaction for a time while new. Sulfuric acid is so corrosive, and operators as a rule take such poor care of such apparatus, that it is a very difficult matter to design a form which will remain in good working order for any length of time. Automatic pipettes attached to acid bottles or reservoirs, to prove satisfactory, must be made entirely of glass, and strong, of simple construction, tightly closed and quickly operated.

47. The *Swedish Acid Bottle* answers these requirements better than any other device for this purpose known to the writers at the present time. Its use is easily understood (see fig. 17); it gives good satisfaction if the hole in the glass stop cock through which the acid passes has a diameter of at least one-eighth of an inch, as is generally the case. We have used or inspected some half a dozen other devices, which have been placed on the market by various dealers

for delivering the acid, but cannot recommend them for use in factories, or outside of chemical laboratories.

48. Instead of measuring out the acid, Bartlett* recently suggested adding it directly to the milk in the test bottles, till the mixture rises to a mark on the body of the bottle at the point where this will hold 37.5 cc., i. e., the total volume of milk and acid (74). This method of adding the acid is in the line of simplicity and may in time become generally adopted. The marks should, however, be put on by the manufacturers, as the operator in attempting to do so will be apt to weaken or break the bottles.

FIG. 17. Swedish acid bottle; the side-tube is made to hold 17.5 cc. of acid.

Calibration of glassware. 1.—**TEST BOTTLES.** The Babcock milk test bottles are so constructed that the scale or graduation of the neck measures a volume of 2 cubic centimeters, between the zero and the 10 per cent. marks (39). The correctness of the graduation may be easily ascertained by one of the following methods:

49. **Calibration with mercury.** 27.18 grams of metallic mercury are weighed into the perfectly clean and dry test bottle; since the specific gravity of mercury is 13.59, double this quantity will occupy a volume of exactly 2 cubic centimeters (44*). The neck of the test bottle is then closed with a small smooth and soft cork, or a wad of absorbent cotton, cut off square at one end, the stopper being pressed down to the first line of the graduation. The bottle is now

* Maine experiment station, bull. No. 31.

inverted so that the mercury will run into its neck. If the total space included between the 0 and 10 marks is just filled with the two cubic centimeters of mercury, the graduation is correct. Bottles, the whole length of the scale of which vary more than two-tenths of one per cent., are inaccurate, and should not be used.

The mercury may be conveniently transferred from one test bottle to another, by means of a thin rubber tube which is slipped over the end of the necks of both bottles, and one weighing of mercury will thus suffice for a number of calibrations. In transferring the mercury, care must be taken that none of it is lost, and that small drops of mercury are not left sticking to the walls of the bottle emptied. A sharp tap on the bottle with a lead pencil will help to remove minute drops of mercury from the inside of it. Unless the bottles to be calibrated are thoroughly cleaned and dry, it is impossible to transfer all the mercury from one bottle to another.

After several calibrations have been made, the mercury should be weighed again in order to make certain that none has been lost by the various manipulations. The scale, fig. 28, shown in (84) is sufficiently delicate for making these weighings.

50. *Cleaning mercury.* Even with the best of care, mercury used for calibration of glassware will gradually become dirty so that it will not flow freely over a clean surface of glass. It may be cleaned from mechanical impurities, dust, films of grease, water, etc., by filtration through heavy filter paper. This is folded the usual way, placed in an ordinary glass funnel and its point perforated with a couple of pin holes. The mercury will pass through in fine streams, leaving the impurities on the filter paper. Mercury may be

freed from foreign metals, zinc, lead, etc., sometimes noticed as a grayish, thin film on its surface, by leaving it in contact with common nitric acid for a number of hours; the mercury is best placed in a shallow porcelain or granite ware dish and the nitric acid poured over it, the dish being covered to keep out dust. The acid solution is then carefully poured off and the mercury washed with water; the latter is in turn poured off, and the last traces of water absorbed by means of heavy clean filter paper.

The mercury to be used for calibration of glassware should be kept in a strong bottle, closed by an ordinary stopper. In handling mercury, care must be taken not to spill any portion of it; finger-rings should be removed when calibrations with mercury are to be made.

Mercury forms the most satisfactory and accurate material for calibration of test bottles, on account of its heavy weight and the ease with which it may be manipulated. Equally correct results may, however, with proper care be obtained by using one of the following methods:

Calibration with water. This may be done by means of a delicate pipette or burette, or by weighing in a somewhat similar manner, as explained in case of calibration with mercury.

51. a, *Measuring the water.* Fill the test bottle with water to the zero mark of the scale; remove any surplus water and dry the inside of the neck with a piece of filter paper or clean blotting paper; then measure into the bottle 2 cc. of water from an accurate pipette or a burette, divided to $\frac{1}{10}$ of a cubic centimeter. If the graduation is correct, 2 cc. will fill the neck exactly to the 10 per cent. mark of the scale.

52. b, *Weighing the water.* Fill the bottle with water to the zero mark of the scale and remove any surplus water in the neck, as before. Weigh the bottle with the water contained therein. Now fill the neck with water to the 10 per cent. mark, and weigh again. The difference between these weights should be 2 grams.

In all cases when calibrations are to be made, the test bottles, or other glassware to be calibrated, must be thoroughly cleaned with strong sulfuric acid, or soda lye, and washed repeatedly with pure water, and dried. Glassware is not clean unless water will run freely over its surface, without leaving any adhering drops.

53. *Intermediate divisions.* The space between 0 and 10 on the scale of the Babcock test bottle is divided into 50 divisions, each five of which, as previously shown (39) representing 1 per cent. Since these intermediate divisions are generally made with a dividing machine, they are as a rule correct, but it has happened that the divisions have been inaccurately placed, although the space between 0 and 10 was correct. The accuracy of the intermediate divisions can be ascertained by sliding along the scale a strip of paper upon which has been marked the space occupied by one per cent., and compare the space with those of each per cent. on the scale.

54. 2.—*PIPETTE AND ACID CYLINDER.* The pipette and the acid cylinder used in the Babcock test may be calibrated by any of the methods already given. Sufficiently accurate results are obtained by weighing the quantity of water which each of these pieces of apparatus will hold, viz: 17.6 grams and 17.5 grams, respectively. The necessity of previous thorough cleaning of the glassware is evident from

what has been said in the preceding. The pipette and the acid measure may be weighed empty and then again when filled with pure water to the mark, or the measureful of water may be emptied into a small weighed vessel, and this weighed a second time. In either case the weight of the water contained in the pipette or the acid measure is obtained by difference.*

Calibrations of the acid cylinder are generally not called for, except as a laboratory exercise, since small variations in the amount of acid measured out do not affect the accuracy of the test.

2.—CENTRIFUGAL MACHINES.

55. The capacity of the testing machine to be selected should be governed by the number of tests which are likely to be made at one time. For factory purposes a twenty-five to thirty bottle tester is generally large enough, even if toward a hundred samples of milk are to be tested at a time. The operator can use his time more economically in running a machine of this size than one holding fifty or sixty bottles; the work of filling or cleaning the bottles and measuring the fat can be done while the centrifuge is running if a double supply of bottles are at hand. Large testers require more power than smaller ones, and when sixty tests are completed, many of the bottles will cool, and the fat column crystalize, before the operator has time to read them, unless special precautions are taken for keeping the bottles warm.

* 1 cubic centimeter of distilled water weighs 1 gram, when weighed in a vacuum at the temperature of the maximum density of water (4° C); for the purposes of calibration of glassware used in the Babcock test, sufficiently accurate results are, however, obtained by weighing the water in the air and at a low room temperature (60° F.)

56. The tester should be securely fastened to a solid foundation and set so that the revolving wheel is level. The latter must be carefully balanced in order that the tester may run smoothly at full speed when empty. A machine that trembles and shakes when in motion is neither satisfactory nor safe, and the results obtained are apt to be too low. High-standing machines are more apt to cause trouble in this respect than low machines, and should therefore be subjected to a severe test before they are accepted.

If all the sockets are not filled with bottles when a test is to be made, the bottles must be placed diametrically opposite one another so that the machine will be balanced when run. The bearings should be kept cleaned and oiled with as much care as the bearings of a cream separator.

The cover of the machine should always be kept on while the bottles are whirled, and should not be removed until the machine stops; the cover should be tight-fitting and may be fastened with hooks soldered on the side of the machine; test bottles have sometimes been broken while the machine has been running at full speed, and every possible precaution should be taken to protect the operator from any danger from spilled acid or broken glass.

57. Speed required for the complete separation of the fat. There is a definite relation between the diameter of the Babcock testers and the speed required for a perfect separation of the fat. In the preliminary work with the Babcock test the inventor found that with the machine used, the wheel of which had a diameter of eighteen inches, it was necessary to turn the crank, so as to give the test bottles seven to eight hundred revolutions per minute, in order to effect a maximum separation of fat; later work has

shown that this speed is ample. Taking therefore this as a standard, the centrifugal force to which the contents of the test bottles are subjected when supported on an eighteen inch wheel and turned 800 revolutions per minute, can be calculated as follows :

The centrifugal force, F , acting on the bottles is expressed by the formula

$$F = \frac{w \cdot v^2}{32.2r} \quad . \quad . \quad . \quad . \quad . \quad (I)$$

in which w = the weight of the bottle with contents, in pounds ;
 v = the velocity, in feet per second, and r = the radius of the wheel, in feet.

When the wheel is turned 800 times a minute, a bottle supported on its rim will travel $2\pi r \times \frac{800}{60} = 2 \times 3.1415 \times \frac{9}{12} \times \frac{800}{60} = 62.83$ feet per second. The weight of a bottle, with milk and acid, is very near 3 ounces, or $\frac{3}{16}$ of a pound. Substituting these values for v and w , gives

$$F = \frac{\frac{3}{16} \times 62.83^2}{32.2 \times \frac{9}{12}} = 30.65 \text{ lbs.}$$

The bottles are therefore, under conditions given, subjected to a pressure of 30.65 lbs. In order to calculate the speed required for obtaining this force in case of machines of other diameters, the value of v in formula (I) is found from

$$v = \sqrt{\frac{32.2 F \times r}{w}} \quad . \quad . \quad . \quad (II)$$

Substituting the values for F and w ,

$$v = \sqrt{\frac{32.2 \times 30.65 r}{\frac{3}{16}}} = \sqrt{5264r}$$

In this equation the values $r = 5, 6, 7, \dots 12$ inches are substituted in each case ($\frac{5}{12}, \frac{6}{12}, \frac{7}{12}, \dots \frac{12}{12}$ feet), and the velocity in feet per second then found at which the bottles are whirled when placed in wheels of diameters 10 to 24 inches, and subjected in each case to a centrifugal force of 30.65 lbs. As the number of

revolutions per minute = $\frac{60 v}{2 \pi r}$, v being as before the velo-

city in feet per second, and r the radius of the wheel, the speed at which the wheel must be turned, is found by substituting for v the values obtained in the preceding calculations in case of wheels of different diameters. The results of these calculations are given in the following table:

<i>Diameter of wheel, d.</i>	<i>Velocity in feet per second, v.</i>	<i>Number of revolutions of wheel, per minute,</i>
10	46.84	1074
12	51.31	980
14	55.43	909
16	59.26	848
18	62.84	800
20	66.24	759
22	69.47	724
24	72.56	693

These figures show that a tester, for instance, 25 inches in diameter, requires less than 700 revolutions per minute for a perfect separation of the fat in Babcock bottles, while a ten-inch tester must have a speed of nearly 1100 revolutions, in order to obtain the same result.

58. To find the number of turns of the handle corresponding to the number of revolutions made by the wheel, the handle is given one full turn, and the number of times which a certain point or part of the wheel revolves, is noted. If the wheel has a diameter of 20 inches, and revolves 12 times for one turn of the handle, the latter should be turned $7\frac{5}{12}=63$ (see table), or about once every second, in order to effect a maximum separation of fat. By counting the number of revolutions, watch in hand, and consulting the preceding table, the operator will soon note the speed which must be maintained in case of his particular machine. It is vitally important that the required speed is always kept up; if through carelessness, worn-out or dry bearings, slipping belts, etc., the speed is slackened, the result will come too

low; it may be a few tenths, or even more than one percent. Care as to this point is so much the more essential as the results obtained by too slow whirling may seem to be all right, a clear separation of fat being often obtained even when the fat is not completely separated.

59. Ascertaining the necessary speed of testers. In buying a tester the operator should first of all satisfy himself at what speed the machine must be run to give correct results; the preceding table will serve as a guide on this point. He should measure out a dozen tests of the same sample of milk, and whirl half the number at the speed required for machines of the diameter of his tester. Whirl the other half at a somewhat higher speed. If the averages of the two sets of determinations are the same, within the probable error of the test (say, less than one-tenth of one percent.) the first whirling was sufficient, as it is believed will generally be the case. If the second set of determinations come higher than the first set, the first whirling was too slow, and a new series of tests of the same sample of milk should be made to ascertain that the second whirling was ample.

This method will test not only the speed required with the particular machine at hand, but will also serve to indicate the correctness of the calibration of the bottles. A large number of tests of the same sample of milk made as directed (pouring the milk once or twice previous to taking out a pipetteful for each test) should not vary more than three-tenths of one percent. at the outside, and in the hands of a skilled operator will come within two-tenths of one percent. If greater discrepancies occur, the test bottles giving too high or too low results should be further examined, and calibrated according to the directions already given (49).

60. Hand testers. When only a few tests are made at a time, and at irregular intervals, as in case of dairymen who test single cows in their herds, a small hand tester answers every purpose. These may be had in sizes from two to twelve bottles. In selecting a particular make of tester the dairymen has the choice of a large number of different kinds of machines. It is a source of regret that most of the machines placed on the market for this purpose in the past have been so cheaply and poorly constructed as to prove very unsatisfactory after having been in use for a time. The sharp competition between manufacturers of dairy supplies, and the clamor of dairymen for something cheap,

fully account for this condition of affairs. This applies especially to the many machines made with belts or friction application of power. The main objection to these machines is the uncertainty of the speed obtained, when they have

FIG. 18. "No-tin" test.

been in use for some time, and the belt or friction appliance begins to slip. Hand testers made with cog gear wheels are more to be depended on for giving the necessary speed than belt or friction machines; they are generally noisy, but the bottles are always whirled at the speed which the number of turns made by the crank would indicate.

The "No-tin" test (see fig. 18) is, in the opinion of the authors, worthy of special mention among the hand testers made at the present time; it is a six-bottle geared machine, durable of construction, and runs smoothly and without noise.

61. Power testers. For factory purposes, steam turbine machines (fig. 19) are most satisfactory when well made and well cared for. They should always be provided with a speed indicator and steam gauge, both for the purpose of knowing that sufficient speed is attained, and also to prevent what may be serious accidents from a general smash-up, if the turbine "runs wild" by turning on too much steam. The revolving wheel of the tester should be made of wrought or malleable iron, or of wire, so that it will not

FIG. 19. Type of Babcock steam turbine testers.

be broken by the centrifugal force, thus avoiding serious accidents. The swinging pockets which hold the test bottles in some machines, should be so made that the

bottles will not strike the center of the revolving frame when in a horizontal position. Tests have often been lost by the end of the neck catching at the center, the bottles thus failing to take an upright position when the whirling stops.

3.—SULFURIC ACID.

62. The sulfuric acid to be used in the Babcock test should have a specific gravity of 1.82–1.83.* The commercial oil of vitriol which can be bought for about 2 cents a pound in carboy lots, is commonly used. One pound of acid is sufficient for fifteen tests. The acid should be kept in stoppered glass bottles, preferably glass or rubber stoppered ones, since a cork stopper is soon dissolved by the acid and rendered useless. If the bottle is left uncorked, the acid will absorb moisture from the air and will after a time become too weak for use in this test. Lead is the only common metal which is not dissolved by strong sulfuric acid; where considerable milk testing is done, it is therefore desirable to provide a table covered with sheet lead on which the acid may be handled.

63. The acid dissolves iron, tin, wood and cloth, and burns the skin. If acid is accidentally spilled, plenty of water should be used at once to wash it off. Ashes, potash, soda, and ammonia neutralize the action of the acid, and a weak solution of any one of these alkalies can be used after the acid has been washed off with water. The red color caused by the action of the acid on clothing can be removed by wetting the spot with weak ammonia water; the ammonia must, however, be applied while the stain is fresh, and is in its turn washed off with water.

64. **Testing the strength of the acid.** The strength of the acid can be easily tested by the use of such a balance as shown in fig. 27 (84). A *dry* test bottle is weighed, and

* A specific gravity of 1.82 means that any given volume of the acid weighs 1.82 times as much as the same volume of water at the same temperature (see also under *Lactometer*, 94).

then filled with acid exactly to the zero mark, or to any other particular line of the scale. It is then again weighed accurately; the difference between these two weights will give the weight of the acid in the bottle. Next empty the bottle and rinse it thoroughly with water (until the water has no longer an acid taste); fill the bottle with water to the same line as before and weigh; the difference between this weight and that of the empty bottle gives the weight of the same volume of water as that of the acid weighed. Divide the weight of the acid by the weight of the water; the quotient gives the specific gravity of the acid. If this is between 1.82 and 1.83, the strength of the acid is correct. The outside of the test bottle should always be wiped dry before the liquids are weighed in it. Unless great care is taken in measuring out the acid and the water, and in weighing both these and the test bottle, the results obtained will not be trustworthy.

65. Too strong acid can sometimes be successfully used by taking less than the required amount of each test, e. g. about 15 cc. Operators are warned against reducing the strength of the acid by adding water to it, as accidents are very apt to occur when this is done. A too strong acid can, if desired, be weakened by simply leaving the bottle which holds it, uncorked for a time; or by pouring the acid into a bottle containing a small quantity of water; in the latter case, the first portions of acid should be added carefully, a little at a time, shaking the bottle after each addition, so as not to cause it to break from the great heat evolved in mixing the acid and the water. *Never dilute acid by pouring water into it.*

66. If the acid is too weak, correct results may sometimes be obtained by using more than the specified quantity,

say 20 cc. If a good test is not obtained with this quantity of acid, a new lot must be secured, as its specific gravity in such a case must be below 1.82. The observing operator will soon be able to judge of the strength of the acid by its action on milk in mixing the two liquids in the Babcock test bottles; it is indeed remarkable what slight differences in the specific gravity of the acid will make themselves apparent in working the test, as regards the rapidity with which both the curdled milk is dissolved, and the mixture of acid and milk turns black.

67. The relation between the strength of sulfuric acid and its specific gravity will be seen from the following table:

Strength of Sulfuric Acid (Lunge and Isler, 1890).

<i>Sulfuric Acid</i> (H_2SO_4).	<i>Specific Gravity</i> (15° C, water 4° C).
97 per cent.	1.841
96 "	1.840
95 "	1.839
94 "	1.837
93 "	1.834
92 "	1.830
91 "	1.825
90 "	1.820
89 "	1.815
88 "	1.808

It will be noticed that the sulfuric acid to be used in the Babcock test should contain 90 to 92 per cent. of acid (H_2SO_4); slightly weaker or stronger acid than this may, as previously stated, be used by adjusting the quantity of acid taken for each test to the strength of the acid, but successful tests cannot be made with acid weaker than 89 per cent., or stronger than 95 per cent.

68. **The Swedish acid tester** (fig. 20) is a small hydrometer, intended to show whether the acid to be used in the Babcock test is of the correct strength. We have examined a number of these testers, and have found them practically useless for the purpose intended. The reason for this lies in insufficient sensitiveness in the instrument; while the testers examined were found to sink to the line marked *Correct* on the scale, when lowered into sulfuric acid of a specific gravity of 1.83, they would sink to a point much nearer the same mark when lowered into either too strong or too weak acid, than to the lines marked *Too strong* or *Too weak*, respectively.

FIG. 20.
Swedish

acid tester. grams; the diameter of the stem is 6 mm., and the distance between the 1.82 and 1.84 marks on the scale is 15.5 mm.; these limits may be taken to represent too weak and too strong acid, respectively. Comparing now this hydrometer with the Swedish tester, the weight of the former would make it ten times as sensitive as the latter, if the size of the stem was the same in either case; as it is, the tester has the advantage in point of thinness of stem (see 94), as the volumes of the same lengths of stem in the two instruments are as the square of their diameters, i. e., as 25:36. This means that the Swedish testers are only $\frac{36}{10 \times 25} = \frac{1}{7}$ as sensitive as the hydrometer, or a difference on the scale of the latter amounting to 15.5 mm. (see

above), would represent only 2.2 mm., on the scale of the Swedish tester. The line marked *Too strong* must therefore be only 1.1 mm. ($\frac{1}{23}$ of an inch) below the *Correct* line; and that marked *Too weak* the same distance above the line. But this is too small a distance to be differentiated by persons unfamiliar with the use of delicate hydrometers, especially since the meniscus of the liquid formed around the stem of the tester renders an accurate reading somewhat difficult.

The Swedish acid tester can be made more delicate by changes in one or two directions: by making the bulb larger, thus necessitating an increase in weight, or by making the stem thinner. By way of comparison it may be stated that the hydrometers used for determining the specific gravity of the ether-fat solution in Soxhlet's areometric method of milk analysis have a stem only 2 mm. in diameter, and the distance of the scale between .765 and .745 is 70 mm., or $2\frac{3}{4}$ inches.

Even if these testers are changed as suggested, their practicability still remains an open question. The action of sulfuric acid of different strength is very characteristic (66), and in the hands of experienced operators, is as delicate an index to the strength of the acid as can be desired, making rather unnecessary a separate instrument for ascertaining the correctness of the strength of the acid used in milk testing.

69. The color of the fat column an index to the strength of the acid used. The strength of the acid is indicated to a certain extent by the color of the fat which separates in the neck of the test bottle when milk is tested. If the directions given for making the test are carefully followed, the fat separated out will be of a golden yellow color. If the fat is light colored or whitish, it generally indicates that the acid is too weak, and a dark colored fat, with a layer of black material beneath it, shows that the acid is too strong.

The strength of the acid used in the test is not sufficient at ordinary temperatures of testing to appreciably dissolve

the fat, but a variation in the strength of the acid or in the temperature of the milk influences the intensity of the action of the acid on the fat, as shown in the color of the fat obtained.

The following experiment shows the relation between the strength of the acid, the temperature of the milk, and the color of the fat.

First:—From a sample of milk measure the usual quantity for testing into each of three bottles, A, B and C. Place A in *ice* water, and C in *warm* water, leaving bottle B at the *ordinary* temperature. After the bottles have been left for twenty minutes under these conditions, add the normal quantity of acid to each and proceed with the test in the ordinary manner.

Second:—Measure some of the same milk into three other bottles, D, E and F. Into test bottle D pour the usual amount of rather weak acid; add the same amount of acid of normal strength (1.82-1.93) to bottle E, and add 17.5 cc. of a still stronger acid, (concentrated sulfuric acid, sp. gr. 1.84) in test bottle F; complete these tests in the usual way.

On the completion of the preceding six tests the operator will notice that the fat in the necks of test bottles A (*cold milk*) and D (*weak acid*) is much lighter colored than that in C (*warm milk*) and F (*strong acid*), and that the color of the fat in B (*normal temperature*) and E (*normal acid*) is somewhere between that of these two series.

70. Influence of temperature on the separation of fat. The intensity of the action of the sulfuric acid on the milk is influenced by the temperature of either liquid; the higher the temperature, the more intense will be the action of the acid on the solids of the milk. It may be noticed that acid from the same carboy will act differently on milk in summer than in winter time, if the acid and the milk are not brought to the same temperature before testing during

both seasons, by cooling or heating, respectively. The temperature of the liquids may be as low as 40° F. in winter and as high as 80° F. in summer. This difference of forty degrees will often have considerable influence on the clearness of the fat separated, showing white curdy substances, and a light colored fat in winter, and black flocculent specks, with a dark colored column of fat in summer. Both these defects can be avoided when the acid is of the proper strength, by bringing the temperature of the milk and the acid to about 70° F. before the milk is tested.

The operator should be particularly cautious against overheating either milk or acid; so intense an action may be caused thereby as to force the hot acid out of the neck of the test bottle when it is added to the milk, thus spoiling the test and possibly causing an accident.

4.—WATER TO BE USED IN THE BABCOCK TEST.

71. Rain water, condensed steam, or soft water should be used for the purpose of bringing the fat into the neck of the test bottles. The surface of the fat column will then usually be clear and distinct. The foam or bubbles that sometimes obscure the upper line (meniscus) of the fat, making the point indistinct from which to measure it, is generally caused by the action of the acid on the carbonates in hard water. The carbonic acid gas liberated from hard water by the sulfuric acid is more or less held by the viscid fat and produces a layer of foam on its surface. If clean soft water cannot be obtained for this purpose, hard water may be used by adding a few drops of sulfuric acid to the water before it is heated, thus causing the carbonic acid to be driven out of it. By simply boiling, most hard waters will be rendered soft, and adapted to use in the Babcock

test, as the carbonates which cause this foaming are thereby precipitated.

If the test has been completed, and a layer of foam appears over the fat, it may be removed by adding a drop or two of alcohol which will destroy the foam. If this is done, the fat column should be read as rapidly as possible after the alcohol is added, and before the latter unites with the fat and increases its volume.

FIG. 21. The Russian test.

72. Reservoir for water. When only a few tests are made at one time, the hot water can be added with the 17.6 cc. pipette. If many tests are made, the water is more con-

veniently and quickly filled into the test bottles by drawing it from a small copper reservoir or tin pail suspended over the testing machine.* The flow of water through a rubber tube connected with the reservoir, is regulated by means of a pinch cock. The water must be hot when added to the test bottles so as to keep the fat in a melted condition until the readings are taken.

The use of zinc or steel oilers, or perfection oil cans has been suggested, as a handy and rapid method of adding hot water to the test bottles.

5.—MODIFICATIONS OF THE BABCOCK TEST.

73. The Russian milk test. The same chemical and mechanical principles applied in the regular Babcock test,

are used in the Russian milk test, except that in this case the machine in which the bottles are whirled, and the bottles themselves, are so constructed that the latter can be filled with hot water while the machine is running at full speed, thus saving time and trouble incident to the stopping of the tester and filling the bottles by means of a pipette. The milk-measuring pipette (fig. 22) and the acid measure used in the Russian test are one-half the ordinary size, and the test bottles are made in two pieces, with a detachable narrow graduated stem (see fig. 23). The machine is substantially made of cast iron; it is provided with a very satisfactory speed indicator which shows at any time the number of revolutions at which the bottles are being turned.

FIG. 22. Pipette used in the Russian test.

The accompanying illustrations show the appa-

* Ordinary tinware rusts very soon when water is left standing in it, and copper reservoirs are therefore more economical.

ratus used in the Russian test. In our experience with this machine there seemed to be a tendency toward too low results.

74. Bartlett's modification. Bartlett* proposed a modification of the method of procedure in the Babcock

FIG. 23. Test bottles used in the Russian test.

test, which aims to simplify the manipulations. 20 cc. of acid are added, instead of 17.5 cc., and the bottles filled with the milk-acid mixture are left standing for not less than five minutes and then filled to within the scale, with hot water; the bottles are then whirled for five minutes at the regular rate (48).

In the experience of the authors the modification cannot always be depended upon to give satisfactory results. It was tried by each of the one hundred students in the Wisconsin Dairy School during 1896-'97; while some of these operators obtained a clear separation of fat, and results that compared favorably with those made by the regular Babcock test, others failed to obtain correct results with the method as modified. It is not known that the modification has proved superior to, or taken the place of the regular Babcock test to any extent.

* Maine experiment station, bull. No. 31, (S. S.)

CHAPTER IV.

CREAM TESTING.

75. Cream may be tested by the Babcock test in the same manner as milk, and the results obtained are accurate

FIG. 24. Students testing dairy products.

when the necessary care has been taken in sampling the cream and in measuring the fat. The composition of cream varies greatly according to the process of creaming, temperature of milk during the creaming, quality and composition of the milk to be creamed, etc. The cream usually met with in the creameries or on the market will contain from

15 to 30 per cent. of fat; during late years the practice in many creameries has been to churn a very rich cream, containing from 30 to 40 per cent. of fat. Such cream is, however, rarely met with, and cream containing 25 per cent. of fat may be considered of average composition for a good quality of cream.* If 18 grams of such cream is measured into an ordinary Babcock test bottle, it follows that there will be $18 \times .25 = 4.5$ grams (or $\frac{4.5}{.9} = 5$ cc.) of pure butter fat in the bottle. It is shown, however, (p. 34), that the space from 0 to 10 in the neck of these bottles holds exactly 2 cc. The neck of the milk test bottles will not therefore be large enough to show the per cent. of fat in a sample of cream if 18 grams are taken for testing, so that less cream must be measured out, or special forms of test bottles used (79).

76. Errors of measuring cream. Several factors tend to render inaccurate the measuring of cream for the Babcock test, and in exact work, it is recommended to weigh the amount taken for a test. If a 17.6 cc. pipette is used for measuring the cream, it will not deliver 18 grams of cream, as it will of milk, for the following reasons:

1. The specific gravity of cream is lower than that of milk; if a certain quantity of milk weighs 1030 lbs., the same quantity of cream will weigh from 1020 lbs. to below 1000 lbs., the weight being determined by the richness of the cream; the more fat the cream contains, the less a certain quantity of it, e. g., a gallon, will weigh.†

2. Cream is thicker (more viscous) than milk at the same temperatures, and more of it will adhere to the sides of the measuring pipette than in case of milk. This is of special importance in testing very rich or sour cream.

* For average quality of cream furnished at five Connecticut creameries see (194).

† For specific quantity of cream of different richness, see table on p. 66.

3. In case of separator cream, more or less air will become incorporated with the cream during the process of separation. In the ripening of cream, fermentation gases are developed and held in the cream in the same way as bread dough holds the gases generated by the yeast. In either case the weight of a certain measure of cream is diminished.

77. As an illustration of the effect of the preceding factors on the amount of cream measured out by a Babcock 17.6 cc. pipette, the following weighings of separator cream are given. The cream was in all cases fresh from the separator; it was weighed as delivered by the pipette into a Winton cream bottle (81), and the test proceeded with at once. The specific gravity of the cream measured out was determined by means of a picnometer. The data given are in all cases averages of several determinations; the samples of cream have been grouped according to their average fat contents.*

Weight of cream delivered by a 17.6 cc. pipette.

<i>Per ct. of fat in cream</i>	<i>Specific gravity (17.5° C.)</i>	<i>Weight of cream delivered, grams</i>
10	1.023	17.9
15	1.012	17.7
20	1.008	17.3
25	1.002	17.2
30	.996	17.0
35	.980	16.4
40	.966	16.3
45	.950	16.2
50	.947	15.8

The data given in the table show plainly the variations in the specific gravity of cream of different richness and the

* For influence of condition of cream on the amount measured out with a 17.6 cc. pipette, see also Bartlett, Maine exp. sta., bull. 31 (s. s.)

error of making tests of cream by measuring it with a 17.6 cc. pipette; if the cream to be sampled is fresh separator cream, testing over 30 per cent., less than 17.0 grams of cream will be delivered into the test bottle, and the results of the reading will be at least one-eighteenth too low, or about 1.4 per cent. on a 25 per cent. cream. If the cream is sour, the error will of course be still greater.

78. Avoiding errors of measuring cream. The preceding table shows that a 17.6 cc. pipette in case of cream containing less than 25 per cent. of fat, and fresh from the separator, will deliver only about 17.2 grams of cream; it is therefore evident that the pipette to deliver cream for the Babcock test must be made larger than the 17.6 cc. pipette used in testing milk. Quite satisfactory results may be obtained in testing such cream, by using a 18 cc. measuring pipette; to avoid the expense and trouble of using two different pipettes, one for milk and one for cream, a pipette with two marks on the stem, at 17.6 cc. and at 18 cc., has been placed on the market, the former mark being used when milk is tested, and the latter for cream.

In testing cream by the Babcock test, one of two methods may be followed:

First, one of the special forms of cream test bottles which have been devised is used; or,

Second, only sufficient cream to be tested in a regular Babcock milk test bottle is taken for a sample.

79. Cream test bottles. Three special forms of bottles have been devised for testing samples of cream by the Babcock test; two of these were suggested by Bartlett of Maine,* in 1892; one with a long detachable neck designed

* Maine experiment station, bulletins 3 and 4 (second series).

FIG. 25. The bulb-necked cream test bottle.

for testing very rich cream (up to 35 per cent. fat), and the other with a neck widened into a bulb in the middle so as to allow a large quantity of fat to be measured. The former kind of cream bottle has, so far as is known to the writers, found but a limited distribution; the neck is too long to be used in the ordinary centrifugal machines, and is not attached until the base portion, containing the cream, acid and first filling with water, has been whirled. This cream bottle is more difficult to handle and cannot be considered as practical as either of the two other forms of bottles devised for testing cream.

80. *The bulb-necked cream bottles*, (fig. 25), allow the testing of cream containing 23 or 25 per cent. of fat, the usual quantity of cream (18 grams) being measured out. The neck is graduated from 0 to 23 per cent., and in some cases to 25 per cent., the graduation extending both below and above the bulb. This is sometimes an inconvenience, as the water must be added carefully so that the lower end of the column of fat will always come below the bulb, in the graduated part of the neck, and not in the bulb itself. Especially in case of beginners, tests are often lost when this bottle is first used, for the reason given,

until the operator learns to add the proper amount of hot

water to float the fat to some point within the scale. It is recommended to fill these bottles with the first portion of hot water to just above the bulb, so that one can see how much water to add the second time in order to bring the fat within the scale.

Each division of the scale on these cream bottles represents two-tenths of one per cent. of fat, as in case of the milk test bottles.

81. *The Winton cream bottle.* The cream test bottle devised by Winton,* (fig. 26), has a neck of the usual length, and sufficiently wide to measure 30 per cent. of fat. The scale of the neck is divided into one-half percents, but readings of a quarter of a percent can easily be estimated. Determinations of fat in cream accurate to a quarter of a percent are sufficiently exact for most commercial purposes, e. g., in creameries, and this form of cream bottle will be found very convenient in making tests of composite samples of cream.

FIG. 26. The Winton cream bottle.

82. Use of milk test bottle. Cream may be tested by emptying a 17.6 cc. pipetteful of the sample into two or more test bottles, dividing the amount about equally between the bottles, and filling the pipette with water once or twice, which is then in turn divided about equally between the test bottles; the

* Connecticut experiment station (New Haven), bull. No. 117; report 1894, p. 224.

per cent of fat in the cream is found by adding the readings obtained in each of the bottles. This method does away with the error incident to the adhesion of cream to the side of the pipette, but not that due to the low specific gravity of the cream, and the results obtained will therefore be somewhat too low. The dilution of the cream with water in the test bottles not only makes it possible to bring into the bottle all the cream measured out, but also insures a clear test. If ordinary cream is mixed with the usual quantity of sulfuric acid used in the Babcock test, a dark-colored fat will generally be obtained, while the cream diluted with an equal or twice its volume of water, when mixed with the ordinary amount of acid, will give a light yellow, clear column of fat, which will allow of a very distinct and sharp reading.

The number of bottles to be used for testing a sample of cream by this method must be regulated by the richness of the cream. If a sample probably contains 20 per cent. or more, one pipetteful should be divided nearly equally between three milk test bottles, and two-thirds of a pipetteful of water is added to each bottle. If the cream contains less than 20 per cent. of fat, it will only be necessary to use two milk test bottles, dividing the pipetteful between these, and adding one-half of a pipetteful of water to each bottle.

By using cream test bottles (79), more accurate tests may be obtained, in case of cream containing as much as 25 per cent. of fat, by dividing one pipetteful between two bottles, rinsing half a pipette of water into each one, than by adding all the cream to one bottle, without rinsing the pipette, for reasons apparent from what has been said in the preceding.

83. Use of 5 cc. pipette. When the cream is in good condition for sampling, satisfactory results can be obtained by the use of a 5 cc. pipette; 5 cc. of cream are measured into a milk test bottle, and two pipettefuls of water are added. In this way all the cream in the pipette is easily rinsed into the test bottle. The readings multiplied by $\frac{18}{5} = 3.6$ will give the per cent. of fat in the cream. If the specific gravity of the cream tested varies appreciably from 1, corrections should be made accordingly; e. g., if the specific gravity is 1.02, the factor should read $\frac{18}{5 \times 1.02} = 3.63$; if .95, $\frac{18}{5 \times .95} = 3.79$, etc.

84. Weighing the cream. For the reasons already given, it is always to be preferred to weigh the cream into the test bottles when accurate tests are required. When a small delicate balance is used, this can be done quite rapidly. Either of the scales shown in the accompanying illustration (figs. 27 and 28), will be found useful and sufficiently accurate for this purpose; a small scale of this kind is also

FIG. 27. Scale used for weighing cream, cheese, etc., in the Babcock test.

FIG. 28. Torsion balance used for weighing cream, cheese, etc., in the Babcock test.

convenient and helpful in testing cheese, butter and condensed milk, and in determining the strength of sulfuric acid, and the accuracy of test bottles and pipettes (q. v.). In testing cream by weight, the test bottle is first weighed empty,

and again when 5 to 10 cc. of cream have been measured into it; the difference between the two weights gives the weight of cream taken for the test. If the cream contains less than 30 per cent. of fat, the regular milk test bottle can be used for testing the cream, if not much more than 5 grams are weighed out; if more cream is taken, or if this is richer than 30 per cent., it is advisable to use the bulb-necked cream bottle.

The operator should be careful in weighing the cream not to spill it on the outside of the test bottle, as the balance does not discriminate between cream inside and outside of the bottle. Sufficient water is added to the bottle to make the total volume about 15 cc. The usual quantity of acid (17.5 cc.) is then added, and the test completed in the ordinary manner. The reading of the amount of fat in the neck of the test bottle in this case does not show the correct per cent. of fat in the cream, because less than 18 grams were weighed out. The per cent. of fat in the cream tested is obtained by multiplying the reading by 18, and dividing the product by the weight of the cream taken.

Example: Weight of cream tested, 5.2 grams; reading of columns of fat ¹)4.8, ²)4.7, average 4.75; per cent. of fat in the cream $\frac{4.75 \times 18}{5.2} = 16.44$.

The weighing of cream and the reading of the fat column must be made very carefully; a division of one-tenth on the neck of the test bottle has a value of over three-tenths of one per cent. of fat when 5 grams of cream are tested, and six-tenths of one per cent. if only 3 grams of cream are weighed out. The reading is rendered more accurate and certain if a number of tests of a sample are made, at least two or three, and the results averaged.

The accompanying illustration, (fig. 29), shows the proper method of reading the fat column in cream tests; readings are made from *a* to *b*, not to *d* or to *c*.

85. No special precautions other than those required in testing milk have been found necessary in testing cream, except that it is sometimes advisable not to whirl the test bottles in the centrifuge at once after mixing, but to let the cream-acid mixture stand for a while, until it turns dark colored. At first, the mixture of cream and acid is much lighter colored than that of milk and acid, owing to the smaller amount of solids not fat contained in the cream.

FIG. 29. Measuring the fat column in the neck of a cream bottle. Readings should be made from *a* to *b*, not to *d* or to *c*.

The liquid beneath the fat in a completed test of cream is sometimes milky, and the fat appears white and cloudy, making an exact reading difficult. Such defects can usually be overcome by placing the test bottles in hot water for about 15 minutes previous to the whirling, or by allowing the fat to crystallize (which is done by cooling the bottles in ice water or cold water after the last whirling) and remelting it by placing the bottles in hot water.

CHAPTER V.

BABCOCK TEST FOR OTHER MILK PRODUCTS.

86. Skim milk, butter milk, and whey. Each division on the scale of the neck of the regular Babcock test bottle represents two-tenths of one per cent. (39). When a sample of skim milk or butter milk containing less than this per cent. of fat, is tested, the estimated amount is expressed by different operators as one-tenth, a trace, one-tenth trace, or one to five hundredths of one per cent. Gravimetric chemical analyses of skim milk have shown that samples which give only a few small drops of fat floating on the water in the neck of the test bottle, or adhering to the side of the neck, generally contain one-tenth of one per cent. of fat, and often more. Samples of skim milk containing less than one-tenth of a per cent. of fat are very rare, and it is doubtful whether a sample of separator skim milk representing a full run of, say 5000 lbs. of milk has ever shown less than five-hundredths of one per cent. of fat. Under ordinary factory conditions, few separators will deliver skim milk containing under one-tenth of one per cent. of fat, when the sample is taken from a whole day's run. This must be considered a most satisfactory separation.*

87. The reason why the Babcock test fails to show all the fat present in skim milk must be sought in one or two

* For comparative analyses of separator skim milk by the gravimetric method and by the Babcock test, see bull. 52, Wis. exp. station.

causes: a trace of fat may be dissolved in the sulfuric acid, or owing to the minuteness of the fat globules of such milk they may not be brought together in the neck of the bottles at the speed used with Babcock test. If a drop of the dark liquid obtained in a Babcock bottle from a test of whole milk, be placed on a slide under the microscope, it will be seen that a fair number of very minute fat globules are found in the liquid. These globules are not brought into the column of fat in the neck of the bottle by the centrifugal force exerted in the Babcock test; the loss of the fat contained in these fine globules is compensated for, in the testing of whole milk, by a liberal reading of the column of fat separated out, the reading being taken from the lower meniscus of the fat to the top of the upper one (see p. 32); in some separator skim milk, on the other hand, not enough fat remains to completely fill the neck, and the apparent result of the reading must therefore be increased by from five-hundredths to one-tenth of one per cent.

It follows from what has been said that tests of skim milk showing no fat in the neck of the test bottles on completion of the test, generally indicate inefficient work of the centrifugal tester, or the operator, or both. The test should be repeated in such cases, using more acid and whirling for full four minutes.

In order to bring as much fat as possible into the neck of the bottles, in testing skim milk, it is advisable to add somewhat more acid than when whole milk is tested, viz: about 20 cc., and to whirl the bottles at full speed for four to five minutes. The readings must be taken as soon as the whirling is completed, as owing to the contraction of the liquid by cooling, the fat is otherwise spread over the inside of

the neck of the test bottle as a film of grease which cannot be measured by the scale.

88. *The double-necked test bottle*, (fig. 30), suggested by one of us,* is made especially for measuring small quantities of fat and gives most satisfactory results in testing skim milk and butter milk. Each division of the scale in these bottles represents five-hundredths of one per cent., and the marks are so far apart that the small fat column can be easily estimated to single hundredths of one per cent. In the first forms, now not in common use, the neck was graduated to hundredths of one per cent.

FIG. 30. The double-necked skim milk bottle, (sometimes called the Ohlsson or B. & W. bottle).

The value of the divisions of the scale on the double-necked test bottles has been discussed of late in dairy papers, and various opinions have been expressed whether they show one-tenth or one-twentieth (.05) of one per cent. of fat. By calibration with mercury the value of the divisions will be found to be .05 or one-twentieth of one per cent., but, as shown above, the results obtained in using the bottles for thin separator skim milk come .05 to .1 per cent. too low, so that, practically speaking, each division may be taken to show one-tenth of one per cent., if the column of fat obtained fills only one or two divisions of the scale.

The double-necked bottle is very convenient for the testing of separator skim milk, thin butter milk and whey. The milk, acid, and water are added to the bottle

* Farrington, and constructed by Mr. J. J. Nussbaumer, of Illinois.

through the large side-tube; the mixing of milk and acid, and the addition of hot water, must be done with great care so that none of the contents are forced into the fine measuring tube and lost. When the fat is in the lower end of the measuring tube, it can be forced up into the scale by pressing tightly with the finger on the top of the side tube.

This test bottle is more fragile and expensive than the ordinary Babcock bottles, and unless carefully handled, will not prove a good investment; the bottle has recently been made of heavier glass and this form is to be highly recommended.

89. *The double-sized skim milk bottle* is of no particular value. It is difficult to obtain a thorough mixture of the milk and the acid in these bottles, and the tests invariably come too low, more so than in case of the regular Babcock bottles, or the double-necked skim milk bottles.

90. The testing of *butter milk* or *whey* by the Babcock test offers no special difficulties, and what has been said in regard to tests of separator skim milk is equally true in case of these by-products. Whey contains only a small quantity of solids not fat (less than 7 per cent), and the mixing with acid, and the solution of the whey solids therein, is therefore readily accomplished; the acid solution is of a light reddish color, turning black but very slowly.

91. **Cheese.** Cheese can be easily tested by the Babcock test if a small scale (fig. 27-8) is at hand for weighing the sample; the results obtained will furnish accurate information as to the amount of fat in the cheese, provided good judgment and exactness is used in sampling and weighing. The following method of sampling the cheese is recommended:*

* U. S. Dept. of Agriculture, Chemical Division, bull. No. 46, p. 37.

“Where the cheese can be cut, a narrow wedge reaching from the edge to the center of the cheese will more nearly represent the average composition of the cheese than any other sample. This may be cut quite fine, with care to avoid evaporation of water, and the portion for analysis taken from the mixed mass. When the sample is taken with a cheese trier, a plug taken perpendicular to the surface, one-third of the distance from the edge to the center of the cheese, should more nearly represent the average composition than any other. The plug should either reach entirely through or only half through the cheese.

“For inspection purposes the rind may be rejected, but for investigations, where the absolute quantity of fat in the cheese is required, the rind should be included in the sample. It is well, when admissible, to take two or three plugs on different sides of the cheese and after splitting them lengthwise with a sharp knife, take portions of each for the test.”

92. When a satisfactory sample of the cheese has been obtained, about 5 grams are weighed into a milk test bottle, or a larger quantity may be used with a cream test bottle. The test bottle is first weighed empty, and again after the pieces of cheese have been added. About 15 cc. of hot water is added to the cheese in the test bottle, and this is shaken occasionally until the cheese softens and forms a creamy emulsion with the water. A few drops of strong ammonia will aid in this mixing and disintegration, the process being hastened by placing the test bottles in hot water. When all lumps of cheese have disappeared in the liquid, the test bottles are cooled to about 70° F., acid is added, and the test completed in the ordinary manner.

The per cent. of fat in the cheese is obtained by multiplying the reading of the fat column by 18 and dividing the product by the weight of cheese added to the test bottle. The weighing of the cheese and the reading of the fat must be done with great care, since any error introduced is more than trebled in calculating the per cent. of fat in the cheese.

93. Condensed milk. The per cent. of fat in condensed milk can be obtained by weighing about 8 grams into a test bottle and proceeding in exactly the same way as given under testing of cheese. It is not necessary to add ammonia or to warm the condensed milk in the test bottles, since the solution of this in water is readily effected without any outside agency. Enough water should be added to make the total volume of liquid in the bottles about 17.6 cc.

If a scale is not available for weighing the sample, fairly accurate results may be obtained by diluting the condensed milk with water (1:1), and completing the test in the ordinary manner. When this is done, the results must be corrected for the dilution which the sample received.

CHAPTER VI.

THE LACTOMETER AND ITS APPLICATION.

94. The Quevenne lactometer. This instrument, (see fig. 31), consists of a hollow glass cylinder weighted down by means of mercury or fine shot so as to float in milk in an upright position, and provided with a narrow stem at its upper end, inside of which is found a graduated paper scale. In the better forms, like the Quevenne lactometer shown in the figure, a thermometer is melted into the cylinder, with its bulb at the lower end of the lactometer, and its stem rising above the lactometer scale.

The lactometer is used for the determination of the specific gravity of milk. The term *specific gravity*, means the weight of a certain volume of a solid or a liquid substance compared with the weight of the same volume of water at 4° C (39.2° Fahr.); for gases the standard of comparison is air or hydrogen. If the milk which a can will hold, weighs exactly 103.2 lbs., this can will hold a smaller weight of water, say, 100 lbs., as milk is heavier than water; the specific gravity of this milk will then be $\frac{103.2}{100} = 1.032$.

95. The lactometer enables us to determine rapidly the relative weight of milk and water. Its application rests on well-known laws of physics: When a body floats in a liquid, the weight of the amount of liquid which it replaces, is equal to the weight of the body. It will sink further into a light liquid than into a heavy one, because a larger vol-

FIG. 31. Quevenne lactometer floating in milk in a tin cylinder (100).

ume of the former will be required to equal the weight of the body. A lactometer will therefore sink deeper into milk of a low specific gravity than into milk of a high specific gravity.

The scale of the Quevenne lactometer is marked at 15 and 40, and divided into 25 equal parts, with figures at each five divisions of the scale. The single divisions are called *degrees*. The 15 degree mark is placed at the point to which the lactometer will sink when lowered into a liquid of a specific gravity of 1.015, and the 40 degree mark, at the point to which it will sink when placed in a liquid of a specific gravity of 1.040. The specific gravity therefore is changed to lactometer degrees by multiplying by 1000 and subtracting 1000 from the product.

Example: Given, specific gravity 1.0345; corresponding lactometer degree, $1.0345 \times 1000 - 1000 = 34.5$.

96. Influence of temperature.

Like most liquids, milk will expand on being warmed, and the same volume will therefore weigh less when warmed than before; that is, its specific gravity will be decreased. It follows then that a lactometer is only correct for the temperature at which it is standardized. If

a lactometer sinks to the 32 mark in a sample of milk of a temperature of 60° F., it will sink below this mark if the temperature of the milk is 50° F., and will not sink so far down as 32, if the temperature is 70° F. Lactometers in the market at present are generally standardized at 60° F., and to show the correct specific gravity, the milk to be tested should first be warmed (or cooled, as the case may be) to exactly 60° F. As this is a somewhat slow process, tables have been constructed for correcting the results for errors due to differences in temperature (see *Appendix*).

97. As the fat content of a sample of milk has a marked influence on its specific gravity at different temperatures, the coefficient of expansion of fat differing greatly from that of the milk serum, the table cannot give absolutely accurate corrections for all kinds of milk, whether rich or poor. But the errors introduced by the use of one table for any kind of whole milk within a comparatively small range of temperature, like ten degrees above or below 60°, are too small to have any importance outside of exact scientific work, and in such, the specific gravity is always determined by means of a pycnometer, or a specific gravity bottle, at the temperature at which the calibration has been made. In taking the specific gravity of a sample of milk by means of a lactometer, the milk is always warmed or cooled so that its temperature does not vary ten degrees either way from 60° F.

98. The temperature correction table for whole milk, given in the *Appendix* shows that if, e. g., the specific gravity of a sample of milk taken at 68° F. was found to be 1.034, its specific gravity would be 1.0352 if the milk was cooled down to 60°. If the specific gravity given was found at a temperature of 50°, the correct specific gravity of the milk would be 1.033.

In practical work in factories or at the farm, sufficiently accurate temperature corrections may generally be made by adding .1 to the lactometer reading for each degree above 60° F., and by subtracting .1 for each degree below 60°; e. g., if the reading at 64° is 29.5, it will be about $29.5 + .4 = 29.9$ at 60° F.; and 34.0 at 52° F. will be about $34.0 - .8 = 33.2$ at 60° F. By reference to the table in the *Appendix*, we find it to be 33.0 in either case.

The scale of the thermometer in the lactometer should be placed *above* the lactometer scale so that the temperature may be read without taking the lactometer out of the milk; this will give more correct results, will facilitate the reading and save time.

99. N. Y. Board of Health lactometer. In the East, and among city milk inspectors generally, the so-called New York Board of Health lactometer is often used. This does not give the specific gravity of the milk directly, as is the case with the Quevenne lactometer, but the scale is divided into 120 equal parts, known as *Board of Health degrees*, the mark 100 being placed at the point to which the lactometer sinks when lowered into milk of a specific gravity of 1.029 (at 60° F.); this is considered the lowest limit for specific gravity of normal cow's milk. The zero-mark on the scale shows the point to which the lactometer will sink in water; the distance between these two marks is divided into 100 equal parts, and the scale is continued below the 100 mark to 120. As 100° on the Board of Health lactometer corresponds to 29° on the Quevenne lactometer, the zero mark showing in either case a specific gravity of 1, the degrees on the former lactometer may easily be changed into Quevenne lactometer degrees by multiplying by .29. To further aid in this

transposition, a table is given in the *Appendix*, showing the readings of the two scales, between 60° and 120° on the Board of Health lactometer.

100. Reading the lactometer. For determining the specific gravity of milk in factories or private dairies, tin cylinders, $1\frac{1}{2}$ inches in diameter, and 10 inches high, with a base about 4 inches in diameter, are recommended, (see fig. 31); another form of specific gravity cylinders, in use in chemical laboratories, is shown in fig. 32. The cylinder is

FIG. 32.
Specific
gravity
cylinder.

filled with milk of a temperature ranging between 50° and 70° F. to within an inch of the top, and the lactometer is slowly lowered therein until it floats; it is left in the milk for about half a minute before the lactometer- and the thermometer readings are taken, both to allow the escape of air which has been mixed with the milk in pouring it preparatory to the specific gravity determination, and to allow the thermometer to adjust itself to the temperature of the milk. The lactometer should not be left in the milk much more than a minute before the reading is taken, as cream will very soon begin to rise on the milk, and the reading, if taken later, will be too high, as the bulb of the lactometer will be floating in partially skimmed milk. In reading the lactometer degree, the mark on the scale plainly visible through the upper portion of the surface meniscus of the milk should be noted. Owing to surface tension the milk in immediate contact with the lactometer stem will rise above the level of the surface in the cylinder, and this must be taken into consideration in reading the degrees. There is no need of reading closer than one-half of a lactometer degree in the practical work of a factory or dairy.

101. Time of taking lactometer readings. The specific gravity of milk should not be determined until six to twelve hours after the milk has been drawn from the udder, as too low results are otherwise obtained.* The cause of this phenomenon is not definitely understood; it may lay in the escape of the gases in the milk, or in changes in the mechanical condition of the nitrogenous components of the milk, (most likely of the casein), occurring on standing. The results obtained after twelve hours will as a rule come about one degree higher than when the milk is cooled down directly after milking, and its specific gravity then determined.

CALCULATION OF MILK SOLIDS.

102. A number of chemists have prepared formulas for the calculation of milk solids when the fat content and the specific gravity (lactometer reading) of the milk are known. By careful work with milk tester and lactometer it is possible by means of these formulas to determine the composition of samples of milk with considerable accuracy outside of, as well as in, chemical laboratories. As the complete formulas given by various chemists (Behrend and Morgen, Clausnitzer and Mayer, Fleischmann, Hehner and Richmond, Richmond, Babcock,)[†] are very involved, and require rather lengthy calculations, tables facilitating the figuring have been prepared. The formulas in use at the present time, in this country or abroad, are those proposed by Fleischmann, Hehner and Richmond, and Babcock. Babcock's formula forms the foundation of the tables for solids not fat given in the *Appendix*, as it is generally taught in American dairy schools.

* Bulletin No. 43, Chem. Div., U. S. Dept. of Agriculture, p. 191.

† Agricultural Science, vol. III, p. 139.

By the use of these tables the percent of solids not fat corresponding to lactometer readings from 26 to 36, and to fat contents from 2 to 6 percent may be found. The formula, as amended in 1895, is as follows,* S being specific gravity, and f the percent of fat in the milk.

$$\text{Solids not fat} = \left(\frac{100 S - S f}{100 - 1.0753 S f} - 1 \right) (100 - f) 2.5$$

103. The derivation of this formula is as explained in the following:

Milk is considered a mechanical mixture of butter fat and milk serum, the latter being an aqueous solution (or in part semi-solution) of all the solid components of the milk, except the fat. If f therefore designate the percent. of fat in a sample of milk, then

$$100 - f = \text{per cent. serum in the milk.}$$

Let furthermore the specific gravity of the serum be called x , and the increase in specific gravity of the milk caused by one per cent. of serum solids $= a$. The difference between the specific gravity of milk serum and that of water is nearly directly proportional to the amount of serum solids present, and the per cent. of serum solids will therefore be obtained if this difference be divided by the constant factor a , representing the increase in specific gravity caused by one per cent. serum solids. If this per cent. be multiplied by the per cent. of serum in the milk, and the product divided by 100, the result will give the per cent. solids not fat in the milk, viz.:

$$\text{Per cent. solids not fat} = \frac{x-1}{a} \times \frac{100-f}{100} \quad (I)$$

To find the value of x in terms of S , the specific gravity, and f , the fat of the milk, it is necessary to determine the value of a from a large number of analyses.

The volume of a substance in cc. is equal to its weight in grams divided by its specific gravity; therefore

$$\text{Volume in cc. of 100 grams of milk} = \frac{100}{S}$$

* Wisconsin experiment station, twelfth report, p. 120.

Volume in cc. of serum in 100 grams of milk $= \frac{100 - f}{x}$

The specific gravity of pure butter fat being .93, therefore

Volume in cc. of fat in 100 grams of milk $= \frac{f}{.93} = 1.0753 f$

Since milk is made up of fat and serum, we have

$$\frac{100}{S} = \frac{100 - f}{x} + 1.0753 f$$

By solving this equation we find that

$$x = \frac{100 S - Sf}{100 - 1.0753 Sf} \quad (II)$$

To obtain the value a , the last equation is solved for a large number of analyses of different kinds of milk. 1 is subtracted from the average value obtained for x (equation II) and the difference is divided by the per cent. of serum solids. Such calculations have shown that the value of a with normal cow's milk will come very near .004; substituting therefore this value and that of x (equation II) in equation I, and reducing, we have

$$\text{Solids not fat} = \left(\frac{100 S - Sf}{100 - 1.0753 Sf} - 1 \right) (100 - f) 2.5$$

104. The tables made up from this formula, giving the percentages of solids not fat corresponding to certain percents of fat and lactometer readings, are given in the *Appendix*. A careful examination of the same discloses the fact that the percent of solids not fat increases uniformly at the rate of .25 percent for each lactometer degree, and .02 percent for each percent of fat. This relation is expressed by the following simple formulas:

$$\text{Solids not fat} = \frac{1}{4} L \times .2 f$$

$$\text{Total solids} = \frac{1}{4} L \times 1.2 f,$$

L being the lactometer reading at 60° F. (specific gravity $\times 1000 - 1000$), and f the percent of fat in the milk.

Rule: a , To find the percent of solids not fat in milk, add two-tenths of the percent of fat to one-fourth of the lactometer reading, and

b, *To find percent of total solids in milk, add one and two-tenths times the percent of fat to one-fourth of the lactometer reading.*

These formulas and rules are easily remembered, and can be quickly applied without the use of tables. The results obtained by using them do not differ more than .04 percent from those of the complete formula for milks containing up to 6 percent of fat, and may be safely relied upon in practical work.

ADULTERATION OF MILK.

105. The problem of determining whether or not a sample of milk is adulterated, becomes an important one in the work of milk inspectors, and dairy and food chemists. Managers of creameries and cheese factories are also sometimes interested in ascertaining possible adulterations in case of some patron's milk, although at present, since the general introduction of the Babcock test in factories, and the payment for the milk on basis of the amount of butter fat delivered, the temptation to water or skim the milk has been largely removed. In the city milk trade, especially in our larger cities, watered or skimmed milk is still frequently met with, in spite of the vigilance of their milk inspectors or the officers of the city boards of health.

When the origin of a suspected sample of milk is known, a second sample should always be taken on the premises by, or in the presence of, the inspector, and the composition of the two samples compared. If the suspected sample is considerably lower in fat content, than the second, so-called control-sample, with a normal percent of solids not fat, it is skimmed; if the solids not fat are below normal, it is watered; and if both these percentages are abnormally low, the sample is most likely both watered and skimmed.

106. In order to determine whether or not a sample of milk is skimmed, or watered, or both skimmed and watered, the percents of fat and of solids not fat in the sample must be ascertained, and if a control-sample can be secured, these determinations for both samples compared. The proper latitude to be allowed for the natural variation in the composition of milk differs according to the origin of the milk; in case of milk from single cows, the variations in fat content from day to day may exceed one percent, although under ordinary conditions the percent of fat in most cows' milk will not vary that much. The content of solids not fat is more constant, and rarely exceeds one-half of a percent from day to day with single cows. Cows in heat or sick cows may give milk differing considerably in composition from normal milk.*

107. Mixed herd milk is of comparatively uniform composition on consecutive days, and as most milk offered for sale or delivered to factories is of this kind, the task of the milk inspector is made considerably easier and more certain on this account. Daily variations in herd milk beyond one percent of fat, and one-half percent of solids not fat, are suspicious and may be taken as fairly conclusive evidence of adulteration. This is especially true in case the control-sample shows a comparatively low content of fat or solids not fat.

108. Where a control-sample cannot be taken, the legal standards for fat or solids in milk, in force in the various states, are used as a basis for calculating the extent of adulteration of a sample of milk. A list of legal standards for milk in this country and abroad is given in the *Appendix*. These standards determine the limits below which the milk

* Blyth, *Foods, their Composition and Analysis*, London, 1882, p. 246 et seq.

offered for sale must not fall within the respective states. Legally it matters not whether a sample of milk offered for sale has been skimmed or watered by the dealer or by the cow; in the latter case, the cows producing the milk are of a breed or strain that has been bred persistently for quantity of milk, without regard to its quality. In most states the legal standards for the fat content of milk is 3 per cent., and for solids not fat, 9 or 9.5 per cent. There are, however, cows that normally will produce milk containing only 2.5 to 2.8 per cent. of fat, and less than 8.5 per cent. solids not fat. Such milk cannot therefore be legally sold in most states in the Union, and the farmer offering such milk for sale, even if he does not know the composition of the milk produced by his cows, is as liable to prosecution as if he had directly watered the milk. By mixing the milk of several cows, the chances are that the mixed milk will contain more fat and solids not fat, than called for by the legal standard; if such should not be the case, cows producing richer milk must be added to the herd so as to raise the quality of the herd milk up to the legal standard.

109. Calculation of extent of adulteration.* In the following formulas, the percents found in the control-samples, if such are at hand, are always substituted for the legal standards.

a. *Skimming*.—1. If a sample of milk has been skimmed, the following formula will give the number of pounds of fat abstracted from 100 lbs. of milk:

Fat abstracted = $(x) = \text{legal standard for fat} - f$, . (I)
f being the percent of fat in the suspected sample.

2. The following formula will give the percent of fat ab-

* Woll, Handbook for Farmers and Dairymen, New York, 1897, pp. 267-8.

stracted, calculated on the total quantity of fat, originally found in the milk;

$$x = 100 - \frac{f \times 100}{\text{legal standard for fat}} \quad . \quad . \quad . \quad (II)$$

b. *Watering*.—1. If a sample is watered, the calculations are most conveniently based on the percentage of solids not fat in the milk.

$$\text{Percent. of foreign ("extraneous") water in adulterated milk} = 100 - \frac{S \times 100}{\text{leg. stand. for solids not fat}} \quad \text{. . . . (III)}$$

S being the percent. of solids not fat in the suspected sample.

*Example:—*A sample of milk contains 7.5 percent. solids not fat; if the legal standard for solids not fat is 9 percent., $100 - \frac{7.5 \times 100}{9} = 16.7$, shows the percent. of extraneous water in the milk.

2. Watering of milk may also be expressed in per cent. of water *added to the original milk*, by formula IV:

$$\text{Percent. water added to original milk} \\ = (x) = \frac{100 \times \text{leg. stand. for sol. not fat}}{S} - 100 \quad . \quad . \quad (IV)$$

In the example given above, $\frac{100 \times 9}{7.5} - 100 = 12$ percent. of water was added to the original milk.

c, *Watering and skimming*.—If a sample has been both watered and skimmed, the extent of watering is ascertained by means of formula (III) or (IV), and the fat abstracted found according to the following formula:

$$\text{Percent. fat abstracted} = \frac{\text{leg. stand. for sol. not fat}}{S} \times f. (V)$$

111. The following method given by Wallace* is claimed to detect one part of coloring matter in 100,000 of milk.

About 30 cc. of milk are coagulated with a few drops of acetic acid by the aid of heat. The coloring matter of annatto being insoluble in acids, is precipitated with the casein. The coagulated mass is separated from the whey by straining through a coarse cotton cloth, and the excess of liquid pressed out. The casein is placed in a mortar and rubbed with ether. The ether is then poured into a separatory funnel and about 10 cc. of a dilute soda solution (1 : 100) are added. After thorough shaking, the funnel is set aside to allow the liquids to separate. The lower layer which consists of soda solution in which the annatto is dissolved is drawn off into a porcellain dish, and in it are placed two discs of filter-paper, and the liquid is greatly evaporated. If annatto is present, the discs will be dyed orange to buff color. One of the well-washed discs is moistened with a dilute sodium carbonate solution to fix the color; the other is touched with a drop of stannous chlorid, and becomes instantly changed in color to a rich pink. "This test may be used in any condition of the milk, and with as small a quantity as 10 cc."

It is not known that other methods of adulterating milk than those mentioned are practiced at the present time.

For methods of detection of preservatives in milk, see Chapter X.

* N. J. Dairy Commissioner Report, 1896, p. 36.

CHAPTER VII.

TESTING THE ACIDITY OF MILK AND CREAM.

112. Cause of acidity in milk. Very soon after milk is drawn from the udder, it will be found to have an acid reaction, when phenolphthalein is used as an indicator.* The acidity in fresh milk is not due to the presence of free organic acids in the milk, like lactic or citric acid, but to acid phosphates, and possibly also in part to free carbonic acid gas in the milk, and to the acid reaction of casein. Even in case of so-called sweet milk, nearly fresh from the cow, a certain amount of acidity, viz: on the average .07 percent. is therefore found. When the milk is received at the factory it will rarely test less than .10 percent. of acid, calculated as lactic acid; some patrons bring milk day after day that does not test over .15 percent. of acid; others bring milk that tests from .20 to .25 percent., and some lots, although very rarely, will test as high as .3 of one percent. of acid. It has been found that milk will not usually smell or taste sour, or "turned," until it contains .3 to .35 percent. of acid.

113. The acidity in excess of that found normally in milk as drawn from the udder, is due to other causes than those described, viz: the presence of acid milk-components. Bacteriological examinations of milk from various sources

* Freshly drawn milk shows an *amphoteric* reaction to litmus, i. e., it colors blue litmus paper red, and red litmus paper blue.

and of different age have shown that there is a direct relation between the bacteria found in normal milk, and its acidity; the larger the number of bacteria per unit of milk, the higher the acidity of the milk. The increase in the acidity of milk on standing is caused by the breaking-down of milk sugar into lactic acid through the influence of acid-forming bacteria. Since the bacteria get into the milk through lack of cleanliness during the milking, and careless handling of the milk after the milking, this being kept under conditions that favor the multiplication of the bacteria contained therein, it follows that an acidity test of fresh milk give a very accurate measure of the care bestowed in handling the milk; such a test will show which patrons take good care of their milk and those who do not wash their cans clean, or their hands and the udders of the cows before milking, and have dirty ways generally in milking and caring for the milk. The acidity test will always be high in case of milk kept for more than a day (Monday milk) or delivered after a warm sultry day or night. The bacteria have had a chance to multiply enormously in such milk, even if it be kept cooled down to 40°–50° F., and as a result considerable quantities of lactic acid have been formed. The determination of the acidity of fresh milk is explained in detail below (128).

114. Methods of testing acidity. Methods of measuring the acidity or alkalinity of liquids by means of certain chemicals giving characteristic color reactions in the presence of acid or alkaline solutions (so-called *volumetric* methods of analysis) have been in use for many years in chemical laboratories. They were applied to milk as early as 1872 by Soxhlet,* and the method worked out by Soxhlet and

* Jour. f. prakt. Chemie, 1872, p. 6, 19.

Henkel has since been in general use by European chemists. They measured out 50 cc. of milk to which was added 2 cc. of a 2 percent alcoholic solution of phenolphthalein, and this was titrated with a one-fourth normal soda solution * (see below). In this country, Dr. A. G. Manns,† in 1890, published the results of work done in the line of testing the acidity of milk and cream, and the method of procedure and apparatus proposed by him has become known under the name of *Manns' test*, and has been advertised as such by dealers in dairy supplies.

115. Manns' test. The acid in milk or cream is measured by using an alkali solution of a strength, together with an indicator, which shows by a change of color in the milk when all its acid has been neutralized. Any of the alkalies, soda, potash, ammonia, lime or barium can be used for making the standard solution, but it requires the skill and apparatus of a chemist to prepare it of the proper strength. A one-tenth normal solution ‡ of caustic soda is the alkali solution used most frequently in determining the acidity of milk, and is the solution labeled *Neutralizer of Manns' test*.

* Fleischmann, Lehrb. d. Milchwirtschaft, p. 23.

† Illinois experiment station, bulletin No. 9.

‡ A *normal solution* of a chemical is known by the chemist as a solution containing as many grams of the chemical in a liter (1000 cc.) as the figure representing its molecular weight. Caustic soda is made up of an atom each of sodium (Na), oxygen (O), and hydrogen (H); its molecular weight is therefore

A normal soda solution then is made by dissolving 40 grams of soda in water, making up the volume to 1000 cc.; a one-tenth normal solution will contain one-tenth of this amount of soda, or 4 gr. dissolved in one liter. One cubic centimeter of the latter solution will contain .004 grams of soda, and will neutralize .009 grams of lactic acid. The formula for lactic acid is $\text{C}_3\text{H}_6\text{O}_3$ (see p. 16) and its molecular weight therefore $3 \times 12 + 6 \times 1 + 3 \times 16 = 90$. A one-tenth normal solution therefore contains 9 grams per liter, and .009 grams per cubic centimeter.

The indicator used for this purpose is *phenolphthalein*, a yellowish light powder; its compounds with alkalis are red, in weak alkaline solutions, pink colored; while its acid compounds are colorless. The phenolphthalein solution used is prepared by dissolving 10 grams in 300 cc. of 90 percent. alcohol (Mohr).

116. In testing the acidity of either milk or cream it is necessary to measure out with exactness the quantity of liquid to be tested; Manns recommended using a 50 cc. pipette. This amount of milk or cream is measured into a clean tin, porcelain or glass cup, a few drops of the phenolphthalein solution are added, and the "Neutralizer" (or alkali solution) is cautiously dropped in from a burette, the point at which the solution stands before it is drawn out being noted. By constant stirring during this operation it will be noticed that the pink color formed by the addition of even a drop of alkali solution will at first entirely disappear, but as more and more of the acid in the sample becomes neutralized, the color will disappear more slowly, until finally a point is reached when the pink color remains permanent for a time. No more alkali should be added after the first appearance of a permanent and uniform pink color in the sample. This color will fade and gradually disappear again on standing, owing to the effect of the carbonic acid of the air, to which acid, phenolphthalein is very sensitive. The amount of the alkali solution used for the test is then obtained from the reading on the scale of the burette, and this shows the degree of acidity in the sample. The per cent. of acid in the sample is calculated by multiplying by .009 the number of cc. of alkali solution used, and dividing the product by the number of cc. of the sample tested, the quotient being multiplied by 100.

$$\text{Percent acidity} = \frac{\text{c. c. alkali} \times .009}{\text{c. c. sample tested}} \times 100$$

If 50 cc. of cream required 32 cc. of alkali solution to produce a permanent pink color, the percent of acid in the cream would be $\frac{32 \times .009}{50} \times 100 = .58$ percent. A part of this calculation may be saved by using a factor for multiplying the number of cc. of alkali added in each test. This factor is obtained by dividing .009 (the number of grams of lactic acid neutralized by one cc. of alkali solution) by the number of cc. of sample tested, and multiplying the quotient by 100. If a 50 cc. pipette is used for measuring the sample to be tested, the factor will be $(.009 \div 50) \times 100 = .018$; if a 25 cc. pipette is used, the factor will be $(.009 \div 25) \times 100 = .036$; and if a 20 cc. pipette is used, $(.009 \div 20) \times 100 = .045$ will be the factor to be applied in calculating the percent of acidity, the number of cc. of alkali used being in all cases multiplied by the particular factor corresponding to the volume of the sample tested.

117. A table showing the percent of acid corresponding to different quantities of alkali solution for a given quantity of milk or cream can be easily prepared by the use of the factors given, and the necessity of calculating the result in percent thus saved. If a 50 cc. pipette is used for measuring out milk or cream, the table will thus be as follows:

<i>CC. alkali solution used</i>	<i>Corresponding acidity</i>	<i>CC. alkali solution used</i>	<i>Corresponding acidity</i>
1 cc	.018 per cent.	6 cc	.108 per cent.
2 cc	.036 "	7 cc	.126 "
3 cc	.054 "	8 cc	.144 "
4 cc	.072 "	9 cc	.162 "
5 cc	.090 "	10 cc	.180 "

With a little practice the operator will easily be able to determine the acidity of different portions of the same milk or cream to within 1 cc. of alkali solution ($= .02$ per cent. of acid, when a 50 cc. sample is taken).

118. Manns's testing outfit. The apparatus (see fig. 33) and chemicals needed for testing the acidity of milk or cream by the so-called Manns' test include 1 gal. one-tenth normal alkali solution; 4 oz. of an alcoholic solution of phenolphthalein, one 50 cc. glass burette with stop-cock, one burette stand, and a pipette for measuring out the sample. This outfit will make about 100 tests and is sold for \$5.00.*

119. The alkaline tablet test. Solid alkaline tablets were proposed by Farrington in 1894, as a substitute for the liquid used in Manns' test.† It was found possible to mix a solid alkali and coloring matter, and compress the mixture into a small tablet, which would contain an exact amount of alkali. The advantage of the tablets lies in the fact that they will keep far better than a standard alkali

FIG. 33. Apparatus used in Manns' test.

* *Devarda's acidimeter* (Milchzeitung, 1896, p. 785) is built on the same principle as Manns' test; one-tenth soda solution is added to 100 cc. of milk in a glass-stoppered graduated flask, 2 cc. of a 4 per cent. phenolphthalein solution being used as an indicator. The graduations on the neck of the flask give the "degrees acidity" directly.

† Illinois experiment station, bulletin No. 32.

solution, and they can be easily and safely sent by mail; they also require less apparatus and are considerably cheaper than standard alkali solutions; 1000 of these tablets, costing \$2.00, will make about 400 tests.* Similar alkaline tablets were placed on the market in Europe at about the same time, viz: Stokes' *Acidity Pellets* in 1893, and Eichler's *Sæurepillen* (acid-pills) in 1895.†

Two methods of using the tablets have been proposed, one, for the titration (determination of acidity) of ripening cream, in the manufacture of sour-cream butter; and the other, for determining the approximate acidity of different lots of apparently sweet milk or cream.

120. Determination of acidity in sour cream.

The method is equally applicable for the determination of the acidity of sour cream, sour milk and butter milk, but is most frequently employed in testing the acidity of ripening cream, to examine whether or not the ripening process has reached the proper stage for churning the cream. The apparatus used (see fig. 34) are as follows:

1 Babcock 17.6 cc. pipette.

100 cc. graduated cylinders; it is well to provide two or three of these, although only one is strictly necessary.

1 white cup.

121. Preparation of the solution. The tablet solution used during the past two years was prepared by dissolving five tablets in 50 cc. of water; with 20 cc. of cream each cubic centimeter of this solution represents .017 percent of acidity (lactic acid) in the sample tested. The amount of acid in a given sample was then obtained by multiplying

* The tablets are sold by dealers in dairy supplies.

† *Milchzeitung*, 1895, pp. 513-16.

the number of cubic centimeters of the tablet solution used by .017.

122. According to a suggestion recently made* the strength of the solution has been changed in such a manner that the percentages of acidity are indicated directly by the number of cubic centimeter of tablet solution used in each test. The solution may be made up in two ways, viz: by use of a 20 cc. or a 17.6 cc. pipette.

FIG. 34. Apparatus used for determining the acidity of cream or milk.

a. *Use of 20 cc. pipette.* When a 20 cc. pipette is used for measuring the sample to be tested, the tablet solution is prepared by dissolving one tablet for every 17 cc. of water; for five tablets 85 cc. of water are therefore taken. When made in this way, each cubic centimeter of solution repre-

* By Mr. C. L. Fitch, of Hoard's Creameries, (Hoard's Dairyman, Sept. 3, 1897).

sents .01 percent of acid in the sample tested, 20 cc. of cream being taken; the number of cubic centimeters required to produce a pink color in the sample tested as read off directly from the graduations of the cylinder used for making the tablet solution gives the percent of acid in the sample, 10 cc. being equal to .10 percent acid, 32 cc. to .32 percent, 65 cc. to .65 percent, etc.

b. *Use of 17.6 cc. pipette.* The 17.6 cc. milk pipette of the Babcock test may be used for measuring the sample for acidity testing, and the results read directly from the graduated cylinder, if the tablet solution is prepared by taking one tablet for every 19.5 cc. of water; five tablets are therefore dissolved in 97 cc. of water.

123. As cream during its ripening process should generally have from .5 to .6 percent of acid, before it is ready to churn, a 50 cc. cylinderful of tablet solution of this strength will not be sufficient to make a test of cream containing over .5 percent of acid, although it is enough for testing the cream up to this point during the ripening process. The acid-testing outfit should therefore contain a 100 cc. graduated cylinder, instead of one of 50 cc. capacity, so that cream of any amount of acidity up to one percent can be tested. A tablet solution of the strength given has not only the advantage over the solution previously recommended* (5 tablets to 50 cc. of water) of showing the percent of acidity directly, without tables or calculations, but being weaker, the unavoidable errors of determination are decreased by its use.

Equally accurate results may be obtained by using solutions made up according to method *a* or method *b*, explained

* Ill. exp. sta., bull. 32; Wis. exp. sta., bull. 52.

in the preceding. The latter method (17.6 cc. cream, 5 tablets per 97 cc. of water) has, however, the advantage in point of economy of apparatus, since a 17.6 cc. pipette is found in creameries and dairies with the Babcock test outfit and is therefore most likely already available for use in testing the acidity of cream. This method is therefore considered preferable and referred to as

124. The standard solution. The preparation of this solution is as follows: Five tablets are added to the 100 cc. cylinder which is filled to the 97 cc. mark with clean soft water, tightly corked, shaken and laid on its side, as the tablets will dissolve more quickly when the cylinder is placed in this position than when left in an upright position with the tablets at the bottom. Several cylinders containing the tablet solution may be prepared; as soon as one is emptied, tablets and water are again added, and the cylinder is corked and placed in a horizontal position. In this way fresh solutions ready for testing are always at hand. The cylinder is kept tightly corked, while the tablets are dissolving, so that none of the liquid is lost by the shaking. It is well to put the tablets in the cylinder with water at night; the solution will then be ready for use in the morning. Excepting a flocculent residue of inert matter, "settlings," which will not dissolve, the tablets must all disappear in the solution before this is used. The strength of the tablet solution does not change perceptibly by standing for twenty-four hours; but a change takes place in solutions more than a day old. The solid tablets will not change if kept dry. The only precaution necessary is to use a fresh solution when acidity tests are made.

125. Making the test. The cream to be tested is thoroughly mixed, and 17.6 cc. is measured into the cup. The

pipette is rinsed once with water, and the rinsings added to the cream in the cup. A few cc. of the tablet solution prepared as given above are now poured from the cylinder into the cream, and mixed thoroughly with it by giving the cup a gentle rotary motion. The tablet solution is added in small quantities until a permanent pink color appears in the sample. The number of cc. of tablet solution which have been used to color the cream is now found from the scale of the cylinder.

In comparing the results of one test with another, the same shade of color should always be adopted. The most delicate point is the first change to a uniform pink color which the sample shows when the acid contained therein has just been neutralized. This shade of color is easily recognized with a little practice. The pink color is not permanent unless a large excess of alkaline solution has been added, on account of the influence of the carbonic acid of the air (116), and the operator should not therefore be lead to believe by the reappearance of the white color after a time, that the point of neutralization was not already reached when the first uniform shade of pink was observed.

126. Acidity of cream. 17.6 cc. of sweet cream is generally neutralized by 15-20 cc. of this tablet solution, representing from .15 to .20 percent. of acid. A mild sour cream is colored by 35 cc. tablet solution, and a sour cream ready for churning, by about 50 cc. tablet solution. As the cream ripens, its acidity increases. The rate of ripening depends largely on the temperature at which the cream is kept. Cream containing .5 to .6 per cent. of acid will make such butter as our American market demands at the present time. Cream showing an acid test of .55 per cent. may not

be too sour, but .65 per cent. of acid is very near, if not on the danger line, since such cream is likely to make strong flavored, almost rancid butter. Each lot of cream should be tested as soon as it is ready for ripening, and the result of the test will show whether the cream should be warmed or cooled in order to have it ready for churning at the time desired. Later tests will show the rate at which the ripening is progressing, and the time when the cream has reached the proper acidity for churning.

127. Spillman's cylinder. The graduated cylinder, shown in fig. 35, was devised by Prof. Spillman of Washington experiment station, for use in testing the acidity of milk and cream with Farrington's alkaline tablets. The following directions are given * for making tests with this piece of apparatus.

FIG. 35. Spillman's cylinder, used in determining the acidity of cream or milk.

"All that is needed in addition to the acid test graduate shown in the accompanying illustration is a common prescription bottle of six or eight ounce capacity, and a package of Farrington's alkaline tablets. Fill the bottle with water and add one tablet for each ounce of water in the bottle. Shake the bottle frequently to aid in dissolving the tablets.

"*Making the test.* In making the test, the acid test graduate is filled to the zero mark with the milk or cream to be tested. The tablet solution is then added, a little at a time, and the graduate shaken after each addition, in order to thoroughly mix the milk and the tablet solution. In shaking the

* Washington experiment station, bulletin No. 24.

graduate, give it a rotary motion to prevent spilling any of the liquid. Continue adding the tablet solution until a permanent pink color can be detected in the milk. The level of the liquid in the graduate, measured by the scale on the graduate, will then be the percent. of acidity of the milk. It is best to stand the graduate on a piece of white paper, so that the first pink coloration of the milk may be easily detected."

128. Rapid estimation of the acidity of apparently sweet milk or cream. a, Milk. The alkaline tablet method offers a ready means of estimating the acidity of fresh milk or cream that is still apparently sweet. The selection of the best kinds of milk is especially important in pasteurizing milk or cream. Investigations have shown that milk which gives the highest acid test contains, as a rule, a larger number of bacteria and spores, not destroyed by pasteurization, than does milk giving a low acid test; the acidity test may therefore be used to advantage for the purpose of selecting milk best adapted for pasteurization, as well as such as is to be retailed or used in the manufacture of high-grade butter and cheese.

In distinguishing milk fit for pasteurization purposes from that which is doubtful, an arbitrary standard of two-tenths of one percent of acid may be taken as the upper limit for milk of the former kind. The apparatus used in making this test is shown in the accompanying illustration, (fig. 36), and consists of a white tea cup; either a four, six or eight ounce bottle, and a No. 10 brass cartridge shell, or a similar measure. A solution of the tablets in water is first prepared, one tablet being always added for each ounce of water: four tablets in a four ounce bottle; six, in a six

ounce bottle, etc., the amount of tablet solution prepared depending on the number of tests to be made at one time. The bottle is filled up to its neck with clean soft water, and the solution prepared in the manner previously given (124). The manner of operating the test is as follows:

FIG. 36. Apparatus used for rapid estimation of the acidity of apparently sweet milk or cream.

129. Operating the test. As each lot of milk is brought to the creamery in the morning and poured into the weigh car, it is weighed, and the cartridge-shell dipper filled with the milk; this is then poured into the white cup. The same or another No. 10 shell is now filled twice with the tablet solution, and emptied into the milk in the cup. Instead of dipping twice with one measure or a No. 10 shell, a tin measure can be made holding as much as two No. 10 shells. The liquids are then mixed in the cup by giving this a quick rotary motion. The color of the mixture is now

noticed. If the milk remains white it contains more than two-tenths of one percent of acid, and should not be used for pasteurization. If it is colored after having been thoroughly mixed with two measures of tablet solution, it contains less than this amount of acid and may be safely used, as far as acidity goes, for pasteurization or any other purpose for which it is necessary to have thoroughly sweet milk. The shade of color obtained will vary with different lots of milk; the sweetest milk will be most highly colored, but a milk retaining even a faint pink color with two measures of tablet solution to one measure of milk contains less than .2 percent acid.

By proceeding in the manner described, the man at the factory weigh can is able to test the acidity of the milk delivered nearly as quickly as he can weigh the milk; and according to the results of the test he will send the milk to the general delivery vat, or to the pasteurization vat, as the weighing can may be provided with two conductor spouts.

130. *Size of measure necessary.* It is not necessary to use a No. 10 shell for a measure in working the preceding method; one of any convenient size that can be filled accurately and quickly, will answer the purpose equally well, if a measure of the same size is used for both the sample and the tablet solution. When this is done, each measureful of tablet solution made up as directed, will represent one-tenth percent of acid in the sample tested.

131. b, **Cream.** Cream can be tested in the way already described for testing the acidity of fresh milk, by adding to one measureful of cream in the cup, as many measures of tablet solution as are necessary to change the color of the cream when the two liquids are thoroughly mixed. If one

measure of tablet solution colors one measure of cream, this contains less than .1 percent acid; if five measures of tablet solution are required, the cream contains about .5 percent acid, etc. By proceeding in the manner described, the operator can estimate the acidity to within .05 per cent. of acid, if half measures of tablet solution used are observed. The results thus obtained are sufficiently delicate for all practical purposes.

132. Detecting preservaline* in milk. The tablet solution furnishes a simple method of detecting preservaline in milk. The application of the alkaline tablets for this purpose was first discussed in bulletin No. 52 of Wisconsin experiment station. The acidity of the milk is increased by the addition of preservaline, but neither the odor nor taste of the milk is affected thereby. By adding to sweet milk the amount of preservaline which the manufacturers claim will keep it sweet for 36 hours, its acidity may be increased to .35 per cent., in a sample of milk which before adding the preservaline tested perhaps only .15 per cent. acid.

As before stated, unadulterated milk will usually smell or taste sour, or "turned", when it contains .30-.35 per cent. acid; milk testing as high as this limit, which neither smells nor tastes sour in any way, is therefore in all probability adulterated with preservaline or some other preparation containing boracic acid, or a similar compound.

133. "Alkaline Tabs." These are not alkaline tablets, but a substitute which was put on the market by a New York firm. The outfit furnished consisted of four packages of paper discs made of filter paper, each of about the size of an old-style copper cent; two packages of square paper; one glass of about 10 cc. capacity, and one small

* Preservaline is the trade name of an antiseptic extensively advertized for preserving milk and cream. It consists essentially of boracic acid and borax, the use of which in milk and other dairy products offered for sale, is prohibited by law in many states.

glass bottle. The directions stated that each paper disc represented .1 per cent. acidity when added to the small glassful of milk or cream, with two of the square papers, the whole to be well shaken in the long glass bottle. The acidity of the sample of milk or cream was claimed to be measured by counting the number of round papers required to produce a pink color in the sample tested.

An investigation of the reliability of these "Tabs" soon disclosed the fact that they were entirely inaccurate, and that no dependence could therefore be put on the results obtained by their use. A report of the comparative work done in testing the acidity of milk or cream by a one-tenth normal alkali solution and these "Alkaline Tabs" was published in the dairy press in 1895, to which reference is here made as to the details of the results obtained.*

* Hoard's Dairyman, Sept. 6, 1895.

FIG. 37. Students operating the Wisconsin curd test.

CHAPTER VIII.

TESTING THE PURITY OF MILK.

134. The Wisconsin curd test. Cheese makers are often troubled with so-called floating or gassy curds which produce cheese defective in flavor and texture. These faults are usually caused by some particular lot of milk containing

impurities that cannot be detected by ordinary means of inspection. The Wisconsin curd test is used to detect the source of these defects and thus enable the cheese maker to exclude the milk from the particular farm or cow to which the trouble is traced. This test is similar in principle to tests that have for many years past been in use in cheese-making districts in Europe, notably in Switzerland,* but was worked out independently at the Wisconsin Dairy School in 1895 and has become generally known as the Wisconsin curd test from the description of it in the report of Wis. experiment station for 1895.† The method of operating this test is as follows (see fig. 37).

135. *Method of making the test.* Pint glass jars, thoroughly cleaned and sterilized with live steam, are provided; they are plainly numbered or tagged, one jar being provided for each lot of milk to be tested. The jars are filled about two-thirds full with the milk from the various sources (it is not necessary to take any exact quantity); they are then placed in a tank or vat containing water, which is heated until the milk in the jars has a temperature of 98° F. The thermometer used must not be transferred from one sample to another, unless special precautions are taken, for fear of contaminating the pure lots of milk by impure ones.

When the milk has reached a temperature of 98°, add to each sample, 10 drops of rennet extract, and mix by giving the jar a rotary motion. The milk is thus curdled, and the curd allowed to stand for about twenty minutes until it is firm. It is then cut fine with a case knife, and after settling, the whey is poured off. The best tests are made when the separation of the whey is most complete. By allowing the

* Herz, *Unters. d. Kuhmilch*, Berlin, 1889, p. 87.

† Twelfth report, p. 148.

samples to stand for a short time, more whey can be poured off, and the curd thereby rendered firmer. The water around the jars is kept at a temperature of 98° , the vat is covered, and the curds allowed to ferment in the sample jars for six to twelve hours.

During this time the impurities in any particular sample will cause gases to be developed in the curds so that by examining the same carefully, by smelling of them, and cutting them with a sharp knife, those having a bad flavor or a spongy or in any way abnormal texture may be easily detected, and the lot of milk from which it was made, thereby picked out.

136. By proceeding in the same way with the milk from the different cows in a herd, the mixed milk of which produced abnormal curds, the source of contamination in the herd may be located. Very often the trouble will be found to come from the cows' drinking foul stagnant water or from fermenting matter in the stable. In the former case the pond or marsh must be fenced off, or the cows kept away from it in other ways; in the latter, a thorough cleaning and disinfection of the premises are required. If the milk of a single cow is the source of contamination, it must be kept by itself, until the milk is again normal; under such conditions the milk from the healthy cows may of course safely be sent to the factory.

137. The fermentation test. The Gerber fermentation test (see fig. 38) furnishes a convenient method for discovering the cause of abnormal fermentations which show themselves in tainted, pin-hole, gassy, or floating curds, and is also useful in examining the purity of different lots of milk. The test consists of a tin tank which can be heated

by means of a small lamp, and into which a rack fits, holding a certain number of cylindrical glass tubes; these are all numbered and provided with a mark and a tin cover. In making the test, the tubes are filled to the mark with milk, the number of each tube being recorded in a note book, opposite the name of the particular patron whose milk was placed therein. The tubes in the rack are put in the tank, which is two-thirds full of water; the temperature of the

FIG. 38. The Gerber fermentation test.

water is kept at 104–106° F. for six hours, when the rack is taken out, the tubes gently shaken, and the appearance of the milk, its odor, taste, etc., carefully noted in each case.

The tubes are then again heated in the tank at the same temperature as before, for another six hours, when observations are once more taken of the appearance of the milk in each tube. The tainted milk may then easily be discovered by the abnormal coagulation of the sample.

According to Gerber,* good and properly handled milk should not coagulate in less than twelve hours, when kept under the conditions described, nor show anything abnormal when coagulated. Milk from sick cows and from cows in heat, or with diseased udders will always coagulate in less than twelve hours. If the milk does not curdle inside of a day or two, it should be tested for preservatives (240).

* Die praktische Milch-Pruefung; Woll, Handbook f. Farmers and Dairymen, pp. 253-5.

CHAPTER IX.

TESTING MILK ON THE FARM.

139. Variations in milk of single cows. The variations in the tests of milk of single cows from milking to milking, or from day to day, are greater than many cow-owners suspect. There seems to be no uniformity in this variation, except that the quality of the milk produced generally improves with the progress of the period of lactation; even this may not be noticeable, however, except when the averages of a number of tests made at different stages during the lactation period are compared with each other. When a cow gives her maximum quantity of milk, shortly after calving, the quality of her milk is generally poorer (by one percent of fat, or less) than when she is drying off. Strippers' milk is therefore as a rule richer in fat than the milk of fresh cows.

140. By testing separately every milking of a number of cows through their whole periods of lactation, the results obtained have seemed to warrant the following conclusions in regard to the variations in the tests of the milk from single cows, and it is believed that these conclusions allow of generalization.*

1. Some cows' milk tests about the same at every milking. Such cows generally give a uniform quantity of milk from day to day.

* Illinois experiment station, bulletin 24.

2. Other cows give milk that varies in an unexplainable way from one milking to another. Neither the morning nor the evening milking is always the richer, and even if the interval between the two milkings is exactly the same, the quality as well as the quantity of milk produced will vary considerably. Such cows are mostly of a nervous, excitable temperament, and are easily affected by changes in feed, drink, or surrounding conditions.

3. The milk of a sick cow, or of a cow in heat, generally tests higher than when the cow is in a normal condition; the milk yield generally decreases under such condition; marked exceptions to this rule have, however, been observed.

4. Starved or underfed cows may give milk testing higher than when the cows are properly nourished, probably on account of an accompanying feverish condition of the animal. The milk is, however, more generally of an abnormally low fat content, which may be readily increased to the normal percent of fat in the milk by liberal feeding.

5. Fat is the most variable constituent of milk, while the solids not fat vary within comparatively narrow limits. The summary of analysis of 2400 American samples of milk calculated by Cooke* shows that while the percentage of fat varies from 3.07 to 6.00 percent, or nearly three percent, that of casein and albumen varies only from 2.92 to 4.30 percent, or less than one and one-half percent, and the milk sugar and ash content increases but little (about .69 percent), as the milk grows richer, within the range given.

6. A test of only one milking may give a very erroneous impression of the average quality of a certain cow's milk. A composite sample (see below) taken from two or more

* Woll, Handbook for Farmers and Dairymen, p. 195.

successive milkings will more nearly represent the quality of the milk which a cow produces at the time of the sampling.

141. The variations that may occur in testing the milk of single cows, are illustrated by the following figures obtained in an experiment made at the Illinois experiment station,* in which the milk of each of six cows was weighed and analyzed daily during the whole periods of lactation. Among the cows were pure-bred Jerseys, Shorthorns, and Holsteins, the cows being from 3 to 8 years of age, and varying in weight from 850 to 1350 lbs. During a period of two months of the year, the cows were fed a heavy grain ration consisting of 12 lbs. of corn and cob meal, 6 lbs. of wheat bran, and 6 lbs. of linseed meal, per day per head. This course of feeding was tried for the purpose of increasing, if possible, the richness of the milk. The influence of this heavy grain feed, as well as that of the first pasture grass feed, on the quality and the quantity of the milk produced is shown in the following table which gives the complete average data for one of the cows (No. 3). The records of the other cows are given in the publication referred to; they were similar to the one here given, in so far as variations in quality are concerned.

* Bulletin No. 24.

Average results obtained in weighing and testing a cow's milk daily during one period of lactation.

MONTH.	Live weight, lbs.	Daily milk yield.			Tests of one day's milk.			Yield of fat per day.		
		Average lbs.	Highest lbs.	Lowest lbs.	Average per ct.	Highest per ct.	Lowest per ct.	Average lbs.	Highest lbs.	Lowest lbs.
December.....	920	12.1	16.0	10.0	3.8	4.9	3.0	.46	.60	.34
January.....	927	16.0	17.7	14.0	3.7	4.6	2.7	.59	.76	.44
February.....	1035	16.1	17.7	13.5	3.6	5.8	3.2	.58	.84	.51
March.....	1047	14.3	16.0	12.5	3.8	4.7	3.4	.54	.61	.50
April.....	1054	13.8	16.5	11.5	4.0	5.8	3.0	.55	.72	.46
May.....	1079	14.5	17.2	10.0	3.8	4.6	3.4	.55	.70	.44
June.....	1105	12.1	14.0	9.2	3.9	4.6	3.2	.47	.57	.35
July.....	1180	9.3	12.2	6.0	4.2	6.2	2.8	.39	.60	.27
August.....	1130	6.4	9.3	3.5	4.7	7.9	2.9	.30	.50	.16

142. The average test of this cow's milk for her whole period of lactation was 3.8 per cent. of fat (i. e. the total quantity of fat produced $\div$ total milk yield, $\times 100$) ; the milk of the cow twice during this time tested as high as 5.8 per cent., and once as low as 2.7 per cent., while tests of 3.0 and 4.6 per cent. were obtained a number of times. The average weight of milk produced per day by the cow was 14 lbs.; this multiplied by her average test, 3.8, shows that she produced on the average .53 lbs., or about one-half a pound of butter fat per day during her lactation period. If, however, her butter-producing capacity had been judged by the test of her milk for one day only, this test might have been made either on the day when her milk tested 5.8 per cent., or when it was as low as 2.7 per cent. Both of these tests were made in midwinter when the cow gave about 16 lbs. of milk a day. Multiplying this quantity by 5.8 gives .93 lbs. of fat, and by 2.7 gives .43 lbs. of fat. Either result might show the butter fat produced by the cow on certain days, but neither gives a correct record of her actual average daily performance for this lactation period.

A sufficient number and variety of tests of the milk of many cows have been made to prove that there is no definite regularity in the daily variations in the richness of the milk of single cows. The only change in the quality of milk common to all cows is, as stated, the natural increase in fat content as the cows are drying off, and even in this case the improvement in the quality of the milk sometimes does not occur until the milk yield has dwindled down very materially.

143. Causes of variations in fat content. The quality of a cow's milk is as a rule decidedly influenced by the following conditions:

Rough treatment.

Exposure to rain or rough weather.

Change of feed.

Change of milkers.

Rapidity of milking.

Length of interval between milkings.

Unusual excitement or sickness.

144. Disturbances like those enumerated frequently increase the richness of the milk for one, and sometimes for several milkings, but a decrease in quality follows during the reaction or the gradual return to normal conditions, and taken as a whole, there is a considerable falling off in the total production of milk and butter fat by the cow, on account of the nervous excitement which she has gone through. Aside from changes due to well-definable causes, like those given above, the quality of some cow's milk will often change very considerably without any apparent cause. The dairyman who is in the habit of making tests of the milk of his individual cows at regular intervals, will have abundant material for study in the results obtained, and he will soon

be able to tell from the tests made, if these are continued for several days, whether or not the cows are in a normal healthy condition, or have been subjected to excitement or abuse in any way.

145. Number of tests required during a period of lactation in testing cows. The daily records of the six cows referred to on p. 118 give data for comparing their total production of milk and butter fat during one period of lactation, as found from the daily weights and tests of their milk, with the total amount calculated from weights and tests made at intervals of 7, 10, 15 or 30 days. The averages of all results obtained with each of the six cows show that weighing and testing the milk of a cow every seventh day, gave 98 per cent. of the total milk and butter fat, which according to her daily record was the total product. Tests made once in two weeks gave 97.6 per cent. of the total milk, and 98.5 per cent. of the total butter fat, and tests made once a month, or only ten times during the period of lactation, gave 96.4 per cent. of the total milk, and 97 per cent. of the total production of butter fat.

146. The record of one of the cows will show how these calculations are made: It was found from the daily weights and tests that cow No. 1, in one lactation period of 307 days, gave 5,044 lbs. of milk which contained 254 lbs. of butter fat. Selecting every thirtieth day of her record as testing day, the total production of milk and fat is shown to be as follows:

Production of milk and butter fat per day.

Testing day.	Weight of milk.	Test of milk.	Yield of butter fat.
	lbs.	per cent.	lbs.
Nov. 4.....	20.5	4.7	.96
Dec. 4.....	18.7	4.6	.86
Jan. 3.....	17.7	4.9	.86
Feb. 2.....	20.0	4.5	.90
Mar. 3.....	18.2	4.7	.86
April 2.....	19.5	4.4	.81
May 2.....	17.7	4.8	.85
June 1.....	13.1	5.5	.72
July 1... ..	12.2	6.2	.76
July 31.....	3.2	7.2	.23
Total,	159.7 lbs.	.....	7.81 lbs.
Average per day.	15.97 lbs.	4.89	.78 lbs.

The average daily production of the cow, according to the figures given in the preceding table, was nearly 16 lbs. of milk, containing .78 lbs. of butter fat. Multiplying these figures by 307, the number of days during which the cow was milked, gives 4903 lbs. of milk and 240 lbs. of fat. This is 141 lbs. of milk and 14 lbs. of fat less than the total weights of milk and butter fat, as found by the daily weights and tests, or 2.8 and 5.5 percent less, for milk and fat production, respectively. This is, however, calculated from only ten single weights and tests, while it required over 600 weighings and 300 tests of the milk to obtain the exact amount.

Similar calculations from the records of the other cows gave fully as close results, showing that quite satisfactory records of the total production of milk and butter of a cow may be obtained by making correct weighings and tests of her full day's milk once every thirty days.

147. When to test a cow. The Vermont experiment station for several years made a special study of the question when a cow should be tested in order to give a correct idea of the whole year's performance, when only one or two tests are to be made during the lactation period.* The results obtained may be briefly summarized as follows:

a. *As to quality of milk produced.* If two tests of each cow's milk are to be made during the same lactation period, it is recommended to take composite samples at the intervals given below.

First sample.

Second sample.

For spring cows, 6 weeks after calving,	6½-7½ mos. after calving
summer " 8 " " "	6 -7 mos. "
fall " 8-10 " " "	5½-7 mos. "

If only one test is to be made, approximately correct results may be obtained by testing the milk during the sixth month from calving, in case of spring cows; during the third to fifth month in case of summer calving cows, and during the fifth to seventh month for fall calving cows.

In all cases composite samples of the milk for at least four days should be taken (162). "The test of a single sample, drawn from a single milking or day, will not of necessity, or indeed, usually, give trustworthy results."

This method of obtaining the average composition of the milk produced during a lactation period is naturally more correct in case of mixed herd milk, than when single cows are tested.

b. *As to quantity of milk produced.* The milk may be weighed for four days in the middle of the month, and the entire month's yield obtained with considerable accuracy (barring sickness and drying off), by multiplying the sum by

* Sixth report, 1892, p. 106; Ninth report, 1895, p. 176.

7, $7\frac{1}{2}$ or $7\frac{3}{4}$, according to the number of days in the different months. The weighing is most readily done by means of a spring balance, the hand of which is set back so that the empty pail brings it to zero (fig. 39). If several pails are to be used, they should first be made to weigh the same by putting a little

FIG. 39. Milk scale.

FIG. 40. Automatic milk scale for weighing and registering the milk of individual cows.

solder on the lighter pails. Milk scales which weigh and automatically register the yield of milk from twenty cows have recently been placed on the market (see fig. 40); the pail is hung on the hook, and by pressing the button showing the number of the particular cow, the weight is recorded on the milk sheet.

148. H. B. Gurler, the well-known Illinois dairyman, suggests* a method of determining the total production of a cow during one lactation period from the test of her milk for one week only. This plan is, however, only recommended to those who cannot or do not care to take the necessary time to make a more reliable test.

The test should be made after the cow has been in milk for about three months. It is necessary that the cow should be producing a normal quantity and quality of milk at the time when the test is made; if, e. g., a cow is fresh March 1, and tested June 1, she is probably on good pasture feed, and produces more milk and butter fat than at any previous or subsequent time. She should, therefore, be tested either before she is put on pasture or after the luxuriance of the pasture is gone. Mr. Gurler suggests that the milk be weighed for a week, and a composite sample taken of the milkings. At the end of this time it may be found that the cow gave 154 lbs. of milk during the week, and the composite sample tested 4.3 percent fat; the cow, therefore, produced 6.6 lbs. of butter fat during the week, or on the average, .94 lbs. per day. This average yield is now multiplied by 252, the number of days in 8.4 months, and a yield of 237 lbs. of butter fat is obtained. This will very nearly represent the total production of fat by the cow during the whole period of lactation.

It is assumed in this calculation that the cow gives milk more than 8.4 months, and that what is produced beyond this time will bring the production during the last 2.4 months up to the same average per month as in the first six months.

* American Dairying, p. 18.

149. Record of tests. Where tests of the single cows in a herd are made regularly, a complete record should be kept in a note book arranged in about the manner shown on the following blank.

RECORD OF TESTS OF COWS.

MONTH....., 189....

Date.	Name of cow.	Pounds of milk.	No. of test bottle.	Percent. of butter fat	Yield of butter fat pounds.	Remarks.
.....						

150. Sampling milk of single cows. In sampling the milk of single cows, all the milk obtained at the milking must be thoroughly mixed, by pouring it from one vessel to another for a few times, or stirring it thoroughly by means of a dipper moved up and down, as well as horizontally in the pail or can in which it is held; the sample for testing purposes is then taken at once. A correct sample of a cow's milk cannot be obtained by milking directly into a small bottle from one teat, or by filling the bottle with a little milk from each teat, or by taking some of the first, middle, and last milk drawn from the udder. Such samples cannot possibly represent the quality of the milk of one entire milking, since there is almost as much difference between the first and the last portions of a milking, as between skim milk and cream.* Lack of care in taking a fair sample is the cause of many surprising results obtained in testing milk of single cows.

151. When a cow is to be tested, she should be milked dry the last milking previous to the day when the test is to

* Woll, Handbook for Farmers and Dairymen, p. 194; Agricultural Science, 6, pp. 540-42.

be made. The entire quantity of milk obtained at each milking is mixed and sampled separately. On account of the variations in the composition of the milk, a number of tests of successive milkings must be made. As this involves considerable labor, the plan of taking composite samples is preferable; the method of composite sampling and testing is explained in detail under the second subdivision of Chapter X (162); suffice it here to say that the method followed in case of single cows' or herd milk, is to take about an ounce of the thoroughly mixed milk of each milking; this is placed in a pint or quart fruit jar containing a small quantity of some preservative, preferably about one-half a gram of powdered potassium bi-chromate. If a number of composite samples of the milk of single cows are taken, each jar should be labeled with the number or name of the particular cows. Composite tests are generally taken for four days or for a week. If continued for a week, the jars will contain at the end of this time a mixture of the milk of fourteen milkings. The composite sample is then carefully mixed by pouring it gently a few times from one jar to another, and is tested in the ordinary manner. The result of this test shows the average quality of the milk produced by the cow during the time the milk was sampled.

152. As the amount^{*} as well as the quality of the milk produced by single cows vary somewhat from day to day, and from milking to milking, it is quite important in testing single cows, especially when the test includes only a few days, to take a proportionate part (an aliquot) of each milking for the composite test sample. This is easily done by means of a Scovell sampling tube, the use of which is explained in another place (166).

153. Size of the testing sample. Four ounces is a sufficient quantity for a sample of milk if it is desired to determine its percent of fat only; if the milk is to be tested with a lactometer, when adulteration is suspected, as much as a pint is needed for a sample. If this sample of milk is put into a bottle and carried or sent away from the farm to be tested, the bottle should be completely filled with milk, to prevent a partial churning of butter in the sample during transportation (25).

154. Variations in herd milk. While considerable variations in the quality of milk of single cows are often met with, a mixture of the milk of several cows, or of a whole herd, is comparatively uniform from day to day; the individual differences tend to balance one another so that variations when they do occur, are less marked than in case of milk of single cows. There are, however, at times marked variations also in the test of herd milk on successive days; the following figures from the dairy tests conducted at the World's Columbian Exposition in Chicago in 1893 will show the correctness of this statement. The test included twenty-five cows each of the Jersey and the Guernsey breeds, and twenty-four of the Shorthorn breed.

Tests of herd milk on successive days.

Date.	Jersey.	Guernsey.	Shorthorn.
July 16, 1893.....	4.8 percent.	4.6 percent.	3.8 percent.
July 17, 1893.....	5.0 "	4.5 "	3.8 "
July 18, 1893.....	4.7 "	4.4 "	3.8 "
July 19, 1893.....	4.6 "	4.6 "	3.7 "
July 20, 1893.....	5.0 "	4.5 "	3.8 "

On July 17, 1893, the mixed milk of the Jersey cows tested two-tenths of one percent higher than on the preceding day; the Guernsey herd milk tested one-tenth of one percent lower, while the Shorthorn milk did not change in composition; comparing the tests on July 19 and 20, we find that the Jersey and Shorthorn milk tested four-tenths and one-tenth of one percent higher, respectively, on the latter day than on the former, and the Guernsey milk tested one-tenth of one percent lower.

155. Ranges in variations of herd milk. According to Fleischmann,* herd milk on single days may vary from the average values for the year, as follows, expressed in percent of the latter:

The specific gravity (expressed in degrees) may go above or below the yearly average by more than 10 percent.

The percent of fat content may go above or below the yearly average by more than 30 percent.

The percent of total solids may go above or below the yearly average by more than 14 percent.

The percent of solids not fat may go above or below the yearly average by more than 10 percent.

To illustrate, if the average test of a herd during a whole period of lactation is 4.0 percent, the test on a single day may exceed $4.0 + \frac{3}{10}\% \times 4.0 = 5.2$, or may go below 2.8 percent, (viz. $4.0 - \frac{3}{10}\% \times 4.0$); if the average specific gravity is 1.031 (lactometer degrees 31),† the specific gravity of the milk on a single day may vary between 1.0279 and 1.0341 ($31 + \frac{1}{10}\% \times 31 = 34.1$; $31 - \frac{1}{10}\% \times 31 = 27.9$).

* Book of the Dairy, p. 32.

† See page 81.

156. Influence of heavy grain feeding on the quality of milk. If cows are not starved or underfed, an increase in the feeding ration will not materially change the richness of the milk produced, as has been shown by careful feeding experiments, conducted under a great variety of conditions and in many countries. Cows that are fairly well fed will almost invariably give more milk when their rations are increased, but the milk will remain of about the same quality after the first few days are passed as before this time, provided the cows are in good health and under normal conditions. Any change in the feed of cows will usually bring about an *immediate* change in the fat content of the milk, as a rule increasing it to some extent, but in a couple of days when the cows have been accustomed to their new feed, the fat content of the milk will again return to its normal amount.

157. The records of the cows included in the feeding experiment at the Illinois station, to which reference has been made on p. 118, furnish illustrations as to the effect of heavy feeding on the quality of milk. The feed as well as the milk of the cows were weighed each day of the experiment; during the month of December each cow was fed a daily ration consisting of 10 lbs. of timothy hay, 20 lbs. of corn silage and 2 lbs. of oil meal; the table on p. 119 shows that cow No. 3 produced on this feed, on the average, 12.1 lbs. of milk, testing 3.8 percent of fat. In January the grain feed was gradually increased until the ration consisted of 12 lbs. of timothy hay, 8 lbs. of corn and cob meal, 4 lbs. of wheat bran, and 4 lbs. of oil meal. All cows gained in milk on this feed; cow No. 3 thus gave an average of 4 lbs. more milk per day in January than December, but the average test of her milk was 3.7 percent, or one-tenth of one percent

lower than during the preceding month. The heavy grain feeding was continued through February and March, when it reached 12 lbs. of timothy hay, 12 lbs. of corn and cob meal, 6 lbs. of wheat bran and 6 lbs. of oil meal per day. The records show that the flow of milk kept up to 16 lbs. per day in February, in case of this cow, but fell to 14 lbs. in March and April, the average test of the milk being, in February, 3.6; in March 3.8, and in April, 4.0 percent. The milk was, therefore, somewhat richer in April than in December, but not more so than is found normally, owing to the progress of the period of lactation.

158. Influence of pasture on the quality of milk.

On May 1, the cows were given luxuriant pasture feed and no grain; a slight increase in the average amount of milk produced per day followed, with a reduction in the test, this being 3.8 percent,—the same as in December.

During all these changes of feed, there was, therefore, not much change in the richness of the milk, while the flow of milk was increased by the heavy grain feeding for several months, as well as by the change from grain feeding in the barn to pasture feed with no grain.*

159. The increase in the amount of butter produced by a cow, which has often been observed as a result of a change in feed, doubtless as a rule, comes from the fact that more, but not richer milk is produced. The quality of milk which a cow produces is as natural to her as is the color of her hair, and is not materially changed by any special system of normal feeding.†

*For further data on this point, see Cornell (N. Y.) exp. sta., bulletins 13, 22, 36 and 49; N. D. exp. sta., bull. 16; Kansas exp. sta., report 1888; Hoard's *Dairyman*, 1896, pp. 924-5.

†On this point almost endless discussions have in recent years taken place in the agricultural press of this and foreign countries, and the subject has been under

160. Method of improving the quality of milk. The quality of the milk produced by a herd can generally be improved by selection and breeding, i. e., by disposing of the cows giving poor milk, say below 3 percent of fat, and by breeding to pure-bred or high-grade bulls of a strain that is known to produce rich milk. This method cannot work wonders in a day, or even in a year, but it is the only certain way which we have to improve the quality of the milk produced by our cows.

It may be well in this connection to call attention to the fact that the quality of the milk which a cow produces is only one side of the question; the quantity is another, and equally important one. Much dissatisfaction and grumbling about low tests among patrons of creameries and cheese factories would be stopped if this fact was more generally borne in mind. A cow giving 3 percent milk should not be condemned because her milk does not test 5 percent; she may give twice as much milk per day as a 5 percent cow, and will therefore produce considerably more butter fat.

debate at nearly every gathering of farmers where feeding problems have been considered. Many farmers are firm in their belief that butter fat can be "fed into" the milk of a cow, and would take exception to the conclusion drawn in the preceding. The results of careful investigations by our best dairy authorities point conclusively, however, in the direction stated, and the evidence on this point is overwhelmingly against the opinion that the fat content of the milk can be materially and for any length of time increased by changes in the system of feeding. The most conclusive evidence in this line is perhaps the Danish co-operative cow feeding experiments, conducted during the past ten years, with over 2,000 cows in all. The conclusion arrived at by the director of the Copenhagen experiment station, under whose supervision and direction the experiments have been conducted has been stated over and over again in the published reports of the station: that the changes of feed made in the different lots of cows included in the experiments have had practically no influence on the chemical composition (the fat content) of the milk produced. In these experiments grain feeds have been fed against roots, against oil cake, and against wheat bran or shorts; grain and oil cakes have furthermore been fed against roots, and roots have been given as an additional feed to the standard rations tried,—in all cases with the same negative results as far as changes in the fat contents of the milk produced are concerned,

The point whether or not a cow is a persistent milker is also of primary importance; a production of 300 lbs. of butter fat during a whole period of lactation is a rather high dairy standard, but one reached by many herds, even as the average for all mature cows in the herd. Dairymen should remember that a high production of butter fat in the course of the whole period of lactation is of more importance than a very high test.

CHAPTER X.

COMPOSITE SAMPLES OF MILK.

161. Shortly after milk testing had been introduced to some extent in creameries and cheese factories, it was suggested by Patrick, then of Iowa experiment station,* that a great saving in labor, without a coincident diminution in the accuracy of the results, could be obtained by mixing the daily samples of milk from one source, and testing this mixture, instead of each sample contributing thereto. Such a mixture is called a composite sample. The usual methods of taking such samples at creameries and cheese factories during the past few years have been as follows:

162. **Methods of taking composite samples.** a. *Use of tin dipper.* Either pint or quart Mason fruit jars, or milk bottles provided with a cover, are used for receiving the daily samples. One of these jars is supplied for each patron of the factory and is labeled with his name or number. A small quantity of preservative (bi-chromate of potash, bichlorid of mercury, etc., (see 172) is added to each jar; these are placed on shelves, or somewhere within easy reach of the operator inspecting and weighing the milk as it is received at the factory. When all the milk delivered by a patron is poured into the weighing can and weighed, a small portion thereof, usually about an ounce, is put into the jar labeled with the name or number of the patron. The samples

* Bulletin No. 9, May 1890.

are conveniently taken by means of a small tin dipper holding about an ounce. This sampling is continued for a certain number of days, a week, ten days, or sometimes two weeks, a portion of each patron's milk being added to his particular jar every time he delivered milk. Each of these composite samples are then tested; this test takes the place of separate daily tests, and gives accurate information regarding the average quality of the milk delivered by each patron during the period of sampling. The weight of butter fat which each patron brought to the factory in his milk during this time, is obtained by multiplying the total weight of milk delivered during the sampling period by the test of the composite sample.

163. This method of taking composite samples has been proved to be practically correct. It is absolutely correct only when the same weight of milk is delivered daily by the particular patron. If this is not the case, the size of the various small samples should bear a definite relation to the milk delivered; one-sixteen hundredth, or one-two thousandth of the amount of milk furnished should, for instance, be taken for the composite sample from each lot of milk. This can easily be done by means of special sampling devices (see 165). As the quantities of the milk delivered from day to day by each patron vary but little, perhaps not exceeding 10 percent of the milk delivered, the error introduced by taking a uniform sample, e. g., an ounce of milk, each time is, however, too small to be worth considering in factory work, and the method of composite sampling described is generally adopted in separator creameries, and in cheese factories, where the payment of the milk is based on its quality.

164. By this method of composite sampling each lot of rich, medium or thin milk receives credit for the amount of butter fat which it contains, and complications that might arise from testing only one day's milk at irregular intervals are avoided. In order to obtain reliable results by composite sampling it is essential that each lot of milk sampled shall be sweet and in good condition, containing no lumps of curdled milk or small butter granules churned out. The milk is of course always evenly mixed before the sample is taken.

165. b. *Drip sample.* Composite samples are sometimes taken at creameries and cheese factories by collecting the milk that drips through a small hole or tube placed in the conductor spout through which the milk runs from the weighing can to the receiving vat or tank. A small portion of the drip is then each day placed in the composite sample jar, or the quantity of drip obtained is regulated so that all of it may be taken. In the latter case the quantity of milk delivered will enter into the composite sampling as well as its quality, and the sample from, say 1000 lbs. of milk will be twice as large as the sample from 500 lbs. of milk.

Where it is desired to vary the size of the sub-samples, according to the quantity of milk delivered from day to day, it is necessary to adopt the method of collecting drip samples, just explained, or to make use of special sampling devices, like the "milk thief," a Scovell sampling tube, etc. The principle of both these tubes is the same, and it will be sufficient to describe here only one.

166. c. *The Scovell sampling tube.** This convenient device for sampling milk (fig. 41), consists of a drawn copper

* Kentucky experiment station, 8th report, pp. xxvi-xxxii.

or brass tube, one-half to one inch in diameter; it is open at both ends, the lower end sliding snugly in a cap provided with three elliptical openings at the side, through which the milk is admitted. The milk to be sampled is poured into a cylindrical pail, or the factory weighing can, and the tube, with the cap set so that the apertures are left open, is lowered into the milk until it touches the bottom of the can. The tube will be filled instantly to the level of the milk in the can, and is then pushed down, thereby closing the apertures of the cap and confining within the tube a column of milk representing exactly the quality of the milk in the can, and forming an aliquot part thereof. The milk in the sampling tube is then emptied into the composite sample jar by turning the tube upside down.

FIG. 41.
Scovell milk
sampling tube.

167. If the diameter of the sampling pail used is 8 inches, and that of the sampling tube $\frac{1}{2}$ inch (these dimensions will be found convenient in sampling milk from single cows), then the quantity of milk secured in the tube will always stand in the ratio to that of the milk in the pail, of $(\frac{1}{2})^2$ to 8^2 ,* that is, very nearly 1:256; no matter how much or how little milk there is in the pail, the sample will represent $\frac{1}{256}$ part of the milk. For composite sampling of the milk of single cows, this proposition will prove about right; if more milk is wanted for a sub-sample, the milk to be

* The contents of a cylinder are represented by the formula $\pi r^2 h$, r being the radius of the cylinder, and h its height. The relation between two cylinders of the same height, the radii of which are R and r , is, therefore, as $\pi R^2 h$ to $\pi r^2 h$, or as R^2 to r^2 .

sampled may be poured into a can of smaller diameter. If the mixed milk from a number of cows is to be sampled, a wider sampling can is used. By adjusting the diameters of the tube and the can, any desired proportion of milk can be obtained in the sample.

For factory sampling, with a 26-inch weighing can, a tube three-quarters of an inch in diameter will be found of proper dimensions.

168. The sampling tube will furnish a correct sample of the milk in the can, even if this has been left standing for some time; it is better, however, to take out the sample soon after the milk has been poured into the can, as the possible error of cream adhering to the side of the sampling tube is then avoided.

169. The accuracy of the sampling of milk by means of the Scovell tube was proved beyond dispute in the breed tests conducted at the World's Columbian Exposition in 1893, in which tests this method of sampling the milk produced by the single cows, and the different herds was adopted.* The data obtained in these breed tests also furnish abundant material proving the accuracy of the Babcock test.

In using any one of these tubes, the size of the sample is regulated by the amount of milk in the sampling can, as the milk always rises to the same height in the tube as in the can. In all cases *cylindrical* sampling cans must be used.

170. **Composite sampling with a "one-third sample pipette."** Milk is sometimes sampled directly from the weighing can into the Babcock test bottle by means of a

* Kentucky experiment station, 8th report, pp. xxx-xxxI. Another form of a milk sampling tube in use at the Iowa experiment station is described and illustrated by Mr. Eckles, in *Breeder's Gazette*, May 19, 1897.

pipette holding 5.87 cc, which is one-third the size of the regular pipette. This quantity is measured into the test bottle from three successive lots of milk, and the test then made in the ordinary manner. In this way one test shows the average composition of the milk delivered during three successive days, or deliveries. When this method is adopted, as many test bottles are provided as there are patrons; there is no need of using any preservatives for the milk in this case. Fig. 42 shows a convenient rack for holding the test bottles used in composite sampling with a "one-third sample pipette."

Accurate results can be obtained by this method of sampling, if care is taken in measuring out the milk, and if it is not frozen or contains lumps of cream. It is doubtful if the method has any advantage over the usual method of

FIG. 42. Test bottle rack for use in creameries and cheese factories.

composite sampling. If milk is delivered daily and each lot is sampled with the one-third pipette, twice or three times the number of tests are required as when composite samples are taken and tested once every week, or every ten days. This method furthermore takes

more time in the daily sampling than the latter, as the

quantity of milk must be measured out accurately each time. If the test bottle is accidentally broken, or some milk spilled, the opportunity of ascertaining the fat content of the milk delivered during the three days is lost; if a similar accident should occur in testing composite samples collected in jars, another test can readily be made.

171. Accuracy of the described methods of sampling. An experiment made at the Wisconsin Dairy School may here be cited, showing that concordant results will be obtained by the use of the drip sampling method and the Scovell tube. Two composite samples were taken from fifty different lots of milk, amounting to about 6000 lbs. in the aggregate. One sample was taken of the drip from a hole in the conductor spout through which the milk passed from the weighing can; the other was taken in the weighing can by means of a Scovell sampling tube. The following percentages of fat were found in each of these samples:

	<i>Babcock test.</i>	<i>Gravimetric analysis.</i>
Drip composite sample.....	4.0 percent.	4.04 percent.
Scovell tube composite sample..	4.0 "	4.06 "

PRESERVATIVES FOR COMPOSITE SAMPLES.

When milk is kept for any length of time under ordinary conditions, it will soon turn sour and become lopered, and further decomposition shortly sets in, which renders the sampling of the milk both difficult and unsatisfactory (19). The changes which occur are due to the formation of lactic acid through the action of bacteria on milk sugar; the acid in turn coagulates the casein of the milk, but does not destroy or attack the butter fat (27). The period during which milk will remain in an apparently sweet, or fresh condition varies, with the temperature at which it is kept,

and with the cleanliness of the milk, from less than a day to a week or more; milk will not generally remain sweet longer than two days at the outside, at ordinary summer or room temperature.

In order to preserve composite samples of milk in a proper condition for testing, some chemical which will check or prevent the fermentation of the milk must be added to it. A number of substances have been proposed for this purpose.

172. Bi-chromate of potash. Of these, bi-chromate of potash is to be preferred, in the opinion of the authors, on account of its relative harmlessness, its cheapness and efficiency. The bi-chromate method for preserving samples of milk was proposed by Mr. J. A. Alen, city chemist of Gothenburg, Sweden, in 1892,* and has been generally adopted in dairy regions in this country and abroad. While not perfectly harmless, the bi-chromate is not a violent poison like other chemicals proposed for this purpose, and no accidents are liable to result from its use; at least none have been known to the writers to occur during the years that it has been used in creameries or dairies as a preserving agent.

173. The quantity of bi-chromate necessary for preserving half a pint to a pint of milk for a period of one or two weeks is about one-half gram (nearly 8 grains). As there are about 900 half-grams in a pound, this quantity will suffice for nine weeks for a creamery having one hundred patrons, if tests are made once a week, or for three months (90 days), if tests are made every ten days.

According to Winton and Ogden,† a .22-inch pistol cart-

* Biedermann's Centralblatt, 1892, p. 549.

† Connecticut experiment station report 1884, p. 222.

ridge shell cut to $\frac{1}{2}$ inch long, or a .32-inch calibre shell cut to $\frac{1}{4}$ inch long will hold, when loosely filled, enough of powdered bi-chromate to preserve $\frac{1}{2}$ pint, a .32-inch calibre shell cut to $\frac{1}{2}$ inch long will hold enough to preserve one pint. These shells may be conveniently handled by soldering on to them a piece of stiff wire to serve as a handle. The amount of bi-chromate placed in each composite sample jar would fill about half the space representing one percent in the neck of the Babcock milk test bottle.

174. The first portions of milk added to the composite sample jars containing the specified amount of bi-chromate will be colored almost red, but as more milk is added, day by day, its color will become lighter yellow. The complete sample should have a light straw color; such samples are most easily mixed with acid when tested. If more bi-chromate is used, the solution of the casein in the acid is rendered difficult and calls for more persistent shaking. Bi-chromate can be bought at drug stores or from dairy supply dealers at about 30 cents a pound, and will cost about 25 cents a pound at wholesale. Powdered bi-chromate of potash should be ordered, and not crystals, as the latter dissolve only slowly in the milk. Farrington's bi-chromate tablets contain the correct quantity of preservative for a quart sample, and will be found convenient; price per 1,000 tablets, \$2.00.

175. Other preservatives for composite samples. Among other substances recommended for use in butter or cheese factories as milk preservatives for composite samples are boracic acid compounds, formalin, chloroform, carbon bisulfid,* copper-ammonium sulfate, sodium fluorid, ammonia-

* Delaware experiment station, eighth report, 1896, which also see for trials with a large number of different preservatives.

glycerin (sp. gr. 1.031), and mixtures containing mercuric chlorid (corrosive sublimate) with anilin color (rosanilin).^{*} The coloring matter in the latter compounds is added to give a rose color to the sample preserved, thus showing that the milk is not fit for consumption; the bi-chromate giving naturally a yellow color to the milk, renders the addition of any special coloring matter unnecessary.

None of the substances mentioned are as cheap as bi-chromate or more effective for the purpose for which they are used, when milk is to be kept not to exceed two or three weeks. The compounds containing corrosive sublimate are violent poisons, and must always be handled with the greatest care, lest they get into the hands of children or persons unfamiliar with their poisonous properties; they will preserve the milk longer than bi-chromate when applied in sufficient quantities, but for factory use the latter is amply effective, and has, as already stated, the advantage in several other respects.

176. Care of composite samples. The composite sample jars should be kept covered to prevent loss by evaporation, and in a cool place. They should be kept in the dark, in a special closed closet, or at least out of direct sunlight; the chromic acid formed by the reducing influence of light on chromate solutions produces a leathery cream which is very difficultly dissolved in sulfuric acid.

A coating of white shellac will protect the labels of the composite sample jars so that they may be used for a long time, allowing the jars to be washed and cleaned after each period of testing. The shellac is applied after the names of the patrons have been written on the labels, and these have

^{*} Iowa experiment station, bulletins 9, 11, 32.

been put on the jars. Gummed labels, $1 \times 2\frac{1}{2}$ in., answer this purpose well.

In keeping the milk from day to day, care should be taken that the cream forming on the milk does not stick to the sides of the jars in patches above the level of the milk. Unless the daily handling of the jars, and the addition of fresh portions of milk, be done with sufficient care, the cream will become lumpy, and will dry on the sides of the jars. In some cases it is nearly impossible to evenly distribute this dried cream through the entire sample so as to make the composite sample a true representative of the different lots of milk from which it has been taken.

177. Every time a new portion of milk is added to the jar it should be given a gentle horizontal rotary motion, thereby mixing the cream already formed in the jar with the milk, and rinsing off the cream sticking to its side. This manipulation also prevents the surface of the milk from becoming covered with a layer of partially dried leathery cream.

Composite samples having patches of dried cream on the inside of the jar are the result of carelessness or ignorance on the part of the operator. If a little careful attention is given to the daily handling of the composite samples, the cream which is formed in the jars can be evenly mixed again with the milk without difficulty.

178. Fallacy of averaging percentages. A composite sample of milk should represent the average quality of the various lots of milk of which it is made up. This will invariably be true if a definite aliquot portion or fraction of the different lots of milk is taken. If the weights of, say ten different lots of milk are added together, and the sum divided by ten, the quotient will represent the average

weight per lot of milk, but the average obtained in this way of the tests of the different lots, may not be the correct average test of the entire quantity of milk. The accuracy of such an average figure would depend on the uniformity in the composition and weights of the ten lots of milk. When there is no uniformity, the weights of the different lots of milk as well as their tests, must be considered. An average of a number of weights can be calculated directly, but not average percentages. The following example illustrates the difference between the arithmetical average of a number of single tests, and the true average test of the various lots.

Methods of calculating average percentages.

I. Milk varying in weights and tests.				II. Milk of uniform weights and tests.			
Lot.	Weight of milk.	Test of milk.	Weight of fat.	Lot.	Weight of milk.	Test of milk.	Weight of fat.
	lbs.	per ct.	lbs.		lbs.	per ct.	lbs.
I.....	120	3.5	4.2	I.....	250	4.2	10.5
II.....	570	5.0	28.5	II.....	225	4.0	9.0
III.....	360	5.2	18.7	III.....	240	4.3	10.3
IV.....	55	3.0	1.6	IV.....	238	4.1	9.7
V.....	82	4.0	3.2	V.....	234	4.4	10.3
Total.....	1187	.....	56.2	Total.....	1187	.....	49.8
Average.....	237	4.14	11.24	Average.....	237	4.20	10.0
True av'ge test..	.....	4.73*	.....	True av'ge test.....	.....	4.22†	.....

$$* \frac{56.2 \times 100}{1187} = 4.73.$$

$$† \frac{49.8 \times 100}{1187} = 4.22.$$

179. The figures given in the table show that when the different lots of milk vary in test and weight, as in the first case, the correct average test of the 1187 lbs. of milk is not found by dividing the sum of these tests by five, which would give 4.14 percent; but the percentage which 56.2 (the total amount of fat in the mixed milk, in lbs.) is of 1187

(the total amount of milk, in lbs.) is 4.73, and this is the correct average test of the mixed milk made up of the five different lots.

In the second case, the variations in both the weights of the different lots of milk, and their tests, are comparatively small, and both methods of calculation give therefore practically the same average test; but also in this case, the correct average test is found by dividing the total amount of fat by the total quantity of milk, making 4.22 percent, instead of 4.20 percent, which is the arithmetical mean of the five tests, the quantities of milk in the various lots do not enter into the calculation of the latter.*

180. The second example represents more nearly than the first one the actual conditions met with at creameries and cheese factories. As a rule the mixed milk from a herd of cows does not vary more in total weight or tests, within a short period of time like one to two weeks, than the figures given in this example. On account of this fact, samples taken, for instance, with a small dipper may give perfectly satisfactory results to all parties. If the different lots of milk varied in weight and test from day to day, as shown in the first case, it would be necessary to use a "milk thief" or a Scovell sampling tube for taking the composite samples, as the size of the samples taken would then represent an exact aliquot portion of each lot of milk (166).

181. A patron's dilemma. The following incident which occurred at the Wisconsin Dairy School creamery during the past winter, will further explain the difficulties met with in calculating the average tests of various lots of milk.

* In the experiment given on p. 122, the arithmetical mean of the tests given is 5.15 percent, while the true average fat content of the milk is 4.89 percent.

The weekly composite sample of the milk supplied by a patron of the creamery from his herd of 21 cows tested 4.0 percent. One day the farmer brought to the creamery a sample of the morning's milk from each of his cows, and had them tested; after adding the single tests together, and dividing the sum by 21, he obtained an average figure of 5.1 percent of fat. From this he concluded that the average test of the milk from his cows ought to be 5.1, instead of 4.0, and naturally asked for an explanation.

182. The first thing done was to show him that while 5.1 was the correct average of the figures representing the tests of his twenty-one cows, it was not a correct average test of the mixed milk of all his cows, as he had not considered in calculating this average, the quantities of milk yielded by each cow; the following illustration was used:

Cow No. 1, yield 25 lbs. of milk, test 3.6 percent, = 0.9 lbs. of butter fat.		
Cow No. 2, yield 6 lbs. of milk, test 5.0 percent, = 0.3 lbs. of butter fat.		
Total.....	31 lbs.	
	2) <u>8.6</u>	<u>1.2</u> lbs.
		4.3 percent.

The two cows gave 31 lbs. of milk containing 1.2 lbs. of fat; the test of the mixed milk would therefore not be 4.3 percent ($\frac{3.6 + 5.0}{2}$), but $\frac{1.2 \times 100}{31} = 3.87$ percent. If the fat in the mixed milk was calculated by the average figure 4.3 percent, 1.33 lbs. of fat would be obtained, i. e., .13 lbs. more than the cows produced.

In order to further demonstrate the actual composition of the mixed milk of the twenty-one cows, the milk of each cow was weighed and tested at each of the two milkings of one day. The weights and tests showed that the cows produced the following total number of pounds of milk and fat:

Morning milking, 113.3 lbs. of milk, containing 5.17 lbs. of fat.

Night milking, 130.9 lbs. of milk, containing 4.98 lbs. of fat.

The morning milk contained $\frac{5.17 \times 100}{113.3} = 4.56$ percent of fat, and the night milk $\frac{4.98 \times 100}{130.9} = 3.80$ percent of fat.

The average of 21 tests of morning milk was 4.8 percent, and of 21 tests of night milk, 3.8 percent. The sum of the morning and night milkings gave: milk 244.2 lbs. fat 10.15 lbs. The mixed morning and night milk, therefore, contained $\frac{10.15 \times 100}{244.2} = 4.1$ percent of fat. This is the true average test of the morning and night milkings of these twenty-one cows, as found by weighing and testing separately the milk of each cow at both milkings.

183. The total milk was strained into a large can at the farm, both in the morning and in the evening. A sample of the mixed milk was taken in each case with a long-handled dipper as soon as the milkings were finished. When the cans of milk were delivered at the creamery, a sample of each was taken with a Scovell sampling tube. The tests of these four samples are given below, together with the results from the individual tests.

	<i>Morning milk.</i>	<i>Night milk.</i>
Sample taken at the farm, with dipper..	4.4 percent.	3.8 percent.
Sample taken at creamery, with Scovell		
tube	4.5 percent.	3.7 percent.
Calculated from weights and tests of		
milk from each cow.....	4.5 percent.	3.8 percent.

The figures given show that practically uniform tests were obtained by the different methods of sampling.

The sum of the weights of the milk from the different cows was as follows:

	Morning milk.	Night milk.	Daily milk.
Total milk produced.....	113.3 lbs.	130.9 lbs.	244.2 lbs.
Milk in samples.....	12.3 lbs.	8.9 lbs.	21.2 lbs.
Milk for family use	2.5 lbs.	.....	2.5 lbs.
	<hr/>	<hr/>	<hr/>
Milk taken to creamery.....	98.5 lbs.	122.0 lbs.	220.5 lbs.

It has already been shown from the weights and tests of each cow's milk that the herd milk contained 4.1 percent of fat. Multiplying the total milk delivered at the creamery, 220.5 lbs., by 4.1 gives 9.04 lbs. of fat. The morning and night milkings, which were weighed and tested separately, contained the following quantities of butter fat.

Morning milk.....	98.5 lbs. $\times$ test 4.5 = 4.43 lbs. of butter fat.
Night milk.....	122.0 lbs. $\times$ test 3.8 = 4.63 lbs. of butter fat.
	<hr/>
Total.....	220.5 lbs. 9.06 lbs.

By weighing, sampling and testing separately the morning and night milkings of twenty-one cows, deducting the weight of milk in the samples, and what was taken out for family use, it was found that 9.04 lbs. of butter fat was sent to the creamery. The weights and tests of this same milk when delivered at the creamery, gave 9.06 lbs. of butter fat.

184. This example furnishes an excellent illustration of the accuracy of the Babcock test, and of the closeness of results which may be obtained at creameries when proper care is taken in weighing, sampling and testing the milk. Similar demonstrations may be made by any factory operator, and with equally satisfactory results, provided that the work is carefully done.

CHAPTER XI.

CREAM TESTING AT CREAM-GATHERING
CREAMERIES.

185. The cream delivered at gathered cream factories is now in many localities tested by the Babcock test, and this has been adopted as a basis of paying for the cream in the same manner as milk is paid for at separator creameries. It has been found to be more satisfactory to both cream buyer and seller, than either the oil test churn or the space (or gauge) systems which have been used for this purpose in the past.

The details of the application of the Babcock test to the practical work at cream-gathering creameries have been carefully investigated by Winton and Ogden in Connecticut,* Bartlett in Maine,† and Lindsey in Massachusetts;‡ and we also owe to the labors of these chemists much information concerning the present workings of other systems of paying for the cream delivered at creameries.

186. The space system. Numerous tests have shown that one *space* or *gauge* of cream does not contain a definite, uniform amount of fat. In over 100 comparisons made by Winton it was found that one space of cream $\frac{2}{3}$ contained

* Conn. experiment station, (New Haven) bull. No. 108 and 119; report 1894, pp. 214-244.

† Maine experiment station, bull. 3 and 4 (S. S.).

‡ Hatch experiment station, report 1894, pp. 92-103; 1895, pp. 67-70.

$\frac{2}{3}$ The *space* is the volume of a cylinder, $8\frac{1}{2}$ inches in diameter and $\frac{1\frac{9}{16}}{4}$ of an inch high. The number of spaces in each can of milk is read off before skimming by means of a scale marked on a strip of glass in the side of the can. (Conn. exp. sta., bull. No. 119).

from .072 to .170 lbs. of butter fat, or on the average, .13 lbs., and the number of spaces required to make one pound of butter varied from 5.01 to 11.72. It is also claimed that in the winter season when the cream is gathered at long intervals, as once a week, it is necessary for the buyer to accept the seller's statement of the record of the number of cream spaces which he furnishes, since the cream cannot be left in

FIG. 43. The oil test churn.

the creaming cans for so long a time. These objections to the space system apply only to the method of paying for the cream, and not the manner in which the cream is obtained.

187. The oil-test churn. As stated in the introduction, the *oil-test churn* (fig. 43), has been used quite extensively among gathered cream factories; this system is based on the

number of creamery inches of cream which the various patrons deliver to the factory; one inch of cream contains 113 cubic inches (i. e., a layer of cream one inch deep in a 12-inch pail; two inches in an 8-inch pail contains 100.531 cubic inches, two inches in an $8\frac{3}{8}$ -inch pail 110.18 cubic inches, and two inches in an $8\frac{1}{2}$ -inch pail 113.490 cubic inches). The driver pours the patron's cream into his 12-inch gathering pail, and with his rule measures and records the depth of the cream in the can in inches and tenths of an inch. The cream is then stirred thoroughly with a ladle or a stout dipper, and a sample is taken by filling a test tube from the oil test churn outfit, to the graduation mark by means of a small conical dipper provided with a lip. A driver's case contains either two or three "cards," holding fifteen test tubes each. The tubes as filled are placed in the case, and the corresponding number is in each instance recorded in front of the patron's name together with the number of inches of cream furnished by him.

On the arrival at the creamery the tin cards holding the tubes are placed in a vessel filled with water of the temperature wanted for churning (say, 60° in summer, and 65 to 70° in winter). When ready for churning they are placed in the oil-test churn, the cover of the churn put on, and the samples churned into butter. On the completion of the churning, the cards are transferred to water of 175–190° Fahr., where they are left for at least ten minutes to melt the butter and "cook the butter milk into a curd." The oil will now be seen mixed all through the mass. The test tubes are then re-tempered to churning temperature and churned again, by which process the curd is broken into fine particles, which, when the butter is re-melted, will settle to the bottom. The butter is melted after the second churning

by placing the tubes in water at 150–175° F., allowing them to remain therein for at least twenty minutes. If a clear separation of oil does not take place, the sample must sometimes be churned three or four times until a good separation is obtained. A clear separation of the fat in oil test churn tubes is often helped by adding a little sulfuric acid to them.

The length of the column of liquid butter fat thus separated is determined by means of a special rule for measuring the butter oil; this shows the number of pounds and tenths of a pound of butter which an inch of cream will make; the first tenth of a pound on the rule is divided into five equal parts, so that measurements may be made to two-hundredths of a pound. The melted fat is measured with the rule, by raising the tin card holding the bottles, to about the height of the eye; the reading is recorded on the driver's tablet under *Test per inch*, opposite the number of the particular patron. The test per inch multiplied by the inches and tenths of an inch of cream supplied will give the butter yield in pounds, with which the patron will be credited on the books of the creamery.

188. The objection to this system of ascertaining the quality of cream delivered by different patrons lies in the fact that it determines the churnable fat, and not the total fat of the cream; the amount of the former obtained is dependent on many conditions beyond the control of the patron, viz: the acidity and the temperature of the cream, the size of the churn or churning vessel, etc. The same reasons which caused the churn to be replaced by methods of determining the total fat of the milk, in the testing of cows among dairymen and breeders, have gradually brought about the abandonment of the oil test in creameries, and the adoption of the Babcock test in its place.

189. The Babcock test for cream. Both the space system and the oil test churn used for estimating the quality of cream at creameries have now largely been replaced by the Babcock test in the more progressive creameries in this country, and composite samples of cream are collected and tested in a similar manner as is done with milk at separator creameries and cheese factories.

A very satisfactory method of arrangements for working the Babcock test, which is in use in many Eastern creameries, is described by Winton and Ogden in the Connecticut report, previously referred to. The cream gatherer who collects the cream in large cream cans is supplied with a spring balance (1, see fig. 44), pail for sampling and weighing the cream (2), sampling tube (3), and sample bottles (5). At each patron's farm he takes from his wagon the sampling pail and tube, the scales, and one small collecting bottle. He should find in the dairy of the patron the cans of perfectly sweet cream, kept at a temperature of 40° to 50° F., and protected from dirt and bad odors. Either sour or frozen cream must be rejected. The patron's number should be painted in some conspicuous place near the cream cans in his dairy house. The gatherer hangs the scale on a hook near the cream to be collected; the scale should be so made that the hand of the dial will stand at zero when the empty pail is hung on it. The cream is then poured at least twice from one can to another in order to mix it thoroughly.*

* The necessity of care in mixing the cream is shown by the following illustration given by the authors referred to:

Percent of fat in cream which stood for 24 hours.

	Surface.	Bottom.	Sample drawn with sampling tube
Not mixed.....	28.0	5.0	19.25
Poured once.....	23.75	22.0	22.50
Poured twice .....	.....	.....	22.25

FIG. 44. Outfit for cream testing by the Babcock test at gathered cream factories.

190. When properly mixed, the cream is poured into the weighing pail, and is weighed and sampled. The authors give the following description of the cream sampling tube used, and directions for sampling and weighing the cream.

"Sampling Tube.—This tube, devised by Mr. Ogden, is of stout brass, about $\frac{1}{32}$ of an inch thick, and a few inches longer than the weighing pail which is used with it. On the upper end, a small brass stop-cock of the same bore is fastened. It should be nickel plated inside and out, to keep the metal smooth and free from corrosion. These tubes may be obtained from less than $\frac{3}{16}$ to over $\frac{1}{4}$ inch bore. The greater the diameter of the weighing pail, the wider should be the bore of the tube. For use with pails 8 inches in diameter, a $\frac{3}{16}$ inch bore sampling tube will serve the purpose, but when the pail has a diameter of 9 or more inches, a tube with a bore of $\frac{1}{4}$ inch or more should be used. It must be borne in mind that doubling the diameter of the pail, or of the sampling tube, increases the capacity fourfold.

The tube when not in use should be kept in an upright position to permit draining.

"Sampling and Weighing.—Lower the sampling tube *with the cock open*, to the bottom of the weighing pail which holds the mixed cream. When it is filled, raise it out of the liquid and allow it to drain for a few seconds. By this means the tube is rinsed with the cream to be sampled and any traces of cream adhering to the tube from previous use are removed. With the cock still open, slowly lower the sampling tube to the bottom of the cream pail. After allowing a moment for the cream to rise in the tube to the same height as in the pail, close the cock and raise the sampler carefully out of the cream. As long as the cock is closed, the cream in the tube will not flow out, unless the tube is strongly jarred. Allow the cream adhering to the outside of the tube to drain off for a few seconds, then put the lower end into the 1 to 1½ oz. wide-mouth glass collecting bottle which bears the patron's number on its cork, and open the cock. The cream will then flow out of the sampler into the bottle, which is afterwards securely corked and put into the cream-gatherer's case. Immediately weigh the cream in the cream pail to the quarter or half pound, as may be judged expedient, and record the weight.

"If the patron has more than one pailful, repeat with each pailful the operation of sampling and weighing, putting all the sam-

ples in one and the same bottle. *Weigh all cream collected, in one and the same sampling pail and draw a sample from each separate portion weighed."*

191. After sampling and weighing each patron's cream it is poured into the driver's large can, and the sample bottles are carried in a case to the creamery where the contents of each are poured into the composite sample jar of the particular patron. The accompanying illustration (fig. 45) shows an arrangement for keeping the composite sample jars in the testing room of the creamery.

192. The samples of cream in the small bottles, besides furnishing the means of testing the richness of the cream,

FIG. 45. Case for holding composite sample bottles at creamery.

give the creamery owner or manager an opportunity to inspect the flavor of each lot of cream, and the condition in which it has been kept by the various patrons. Potassium bi-chromate is placed in the composite sample jars, and these are cared for and tested in the same manner as composite samples of milk (176).

193. The collecting bottles should be cleaned with cold, and afterwards with hot water, as soon as they are emptied, and before a film of cream dries on them. When washed and dried, these bottles are placed in the cases, ready for the next collecting trip. There can be no confusion of bottles since the corks and not the bottles are marked with the numbers of the respective patrons.

194. When cream is bought by this system of testing composite samples, the patrons are paid for the number of butter fat contained in their cream, in exactly the same way as milk is paid for at separator creameries. It makes no difference how thick or how thin the cream may be, or how much skim milk is left in the cream when brought to the factory. Eighty pounds of cream containing 15 percent of fat will bring no more or less than 48 pounds of cream testing 25 percent; in either case 12 pounds of pure butter fat is delivered, which will make the same amount of butter in both cases, viz: toward 14 lbs., and both patrons should therefore receive the same amount of money.

There is a small difference in the value of the two lots of cream to the creamery owner or the butter maker, in favor of the richer cream, both because its smaller bulk makes the transportation and handling expenses lighter, and because slightly less butter fat will be lost in the butter milk, a smaller quantity of this being obtained from the richer cream. But it is doubtful if the differences thus occurring

are of sufficient importance to be noticed under ordinary creamery conditions; the example selected presents an extreme case of variation in the fat content of cream. A trial of this system at five Connecticut creameries, supplied mostly with Cooley cream, by over 175 patrons, showed that the average composition of the cream from the different patrons varied only from 16.9 to 19.8 percent fat. The cream of some patrons on certain days contained only 9.5 percent of fat, and other patrons at times had as high a test as 30 percent., but these great differences were largely evened up when the average quality of the cream delivered during a period of time, like a month or more, was considered.

195. Smaller differences in the composition of cream will, however, always occur, even if the same system of setting the milk, like the cold deep-setting process, is used, and the water is kept at the same temperature at all times. This is due to differences in the composition of the milk and its creaming quality; whether largely from fresh cows or from late milkers; whether kept standing for a time before being set or submerged in the creamer immediately after milking and straining; diameter of creaming cans, etc. Bartlett states* that the percentage of fat in the cream from the same cows may be increased ten percent or more by keeping the water at 70° instead of at 40° F. The higher temperature will give the richer cream, but the separation will not be so complete, since a richer skim milk is obtained from the milk set at the higher temperature. Separator cream is not materially influenced by the conditions mentioned, as the separator can be regulated to deliver cream of nearly uniform richness from all kinds of sweet milk.

* Maine experiment station, bulletin No. 3 (S. S.).

CHAPTER XII.

CALCULATION OF BUTTER AND CHEESE YIELD.

A.—CALCULATION OF YIELD OF BUTTER.

196. Butter fat test and yield of butter. The Babcock test shows the amount of pure butter fat contained in a sample of milk or other dairy products. The butter obtained by churning cream or milk contains, in addition to pure butter fat, a certain amount of water, salt and curd. While an accurate milk test gives the total quantity of butter fat which there is in the sample of milk or cream tested, the churn cannot be depended upon either to leave the same amount of butter fat in the butter milk or to include the same amount of water, salt and curd in the butter at each churning.

If a quantity of milk, say 3000 lbs., be thoroughly mixed in a vat, and then divided into half a dozen equal portions, a Babcock test of the different lots will show the same percentage of butter fat in each portion. If, on the other hand, each of these lots be skimmed, and the cream ripened in different vats and churned separately, the same weight of butter from each lot of 500 lbs. of milk will not be obtained, even by the most expert butter maker, or if all the operations of skimming, cream ripening, churning, salting and butter-working were made as nearly uniform as possible. Careful operators can handle the milk and cream so that very nearly the same proportion of the fat contained in the

milk is recovered in the butter in different churnings, but since the water in butter is held mechanically, and is not chemically combined with it, the amount retained by the butter is quite variable in different churnings, especially since the laws governing the retention of water in butter are but imperfectly understood.

197. Variations in the composition of butter. As an illustration of the variability of butter in its composition, the analyses of the butter made in the breed tests at the World's Fair in 1893, may here be cited; the butter was in all cases made by as nearly identical methods and under as uniform conditions as could possibly be obtained by the skilled operators having this work in charge; the average composition of 350 samples of this butter, with upper and lower limits, was as shown in the following table.

Composition of samples of butter, World's Fair, 1893.

	Water.	Fat.	Curd.	Salt and ash.	Sum of water, curd, salt and ash.
	Percent.	Percent.	Percent.	Percent.	Percent.
Average of 350 analyses.....	11.57	84.70	.95	2.78	15.30
Lower and upper limits.....	8.63-15.00	76.53-88.26	.50-2.14	1.01-8.58	.....

Analyses of fifty samples of creamery butter taken from the tubs ready for market at as many Wisconsin creameries, in 1896, indicated that no two of them were exactly alike in composition, but varied within the limits given below.*

* Wisconsin experiment station, bull. 56.

Summary of analyses of Wisconsin creamery butter.

	Water.	Butter fat.	Curd.	Salt and ash.	Sum of water, salt and curd.
	Percent.	Percent.	Percent.	Percent.	Percent.
Highest.....	17.03	87.50	2.45	4.73	22.95
Lowest.....	9.18	77.07	0.36	1.30	12.50
Average.....	12.77	83.08	1.28	2.87	16.92

The preceding analyses show the composition of butter made at one place where every possible effort was taken to produce a uniform product, and of butter made at fifty different creameries, where there was more or less variation in the different operations of manufacture, and in the appliances and machinery used. The majority of the samples of butter analyzed were, in either case, naturally of, or very near, the average composition given, but since there is such wide variations in the composition of the butter made by the uniform methods adopted in the World's Fair breed tests, butter of a more uniform composition cannot be expected from the thousands of different creameries and private dairies which supply the general market with butter.

The analyses of the fifty samples of creamery butter, given above, show that the content of the butter fat varied from 77 to over 87 percent, and according to the average of the analyses, 83 pounds of butter fat was contained in, or made, 100 lbs. of butter. There was, therefore, in this case produced 20.5 percent more butter than there was butter fat, since

83:100 :: 100 : x; therefore

$$x = \frac{100 \times 100}{83} = 120.5.$$

198. "Overrun" of churn over test. The yield of butter is not, however, as a rule compared with the amount of butter fat contained in the butter, but with the total butter fat of the whole milk from which it was made. This "increase of the churn over the test" is what is generally called the *overrun* in creameries.

The overrun obtained in different creameries, or even in the same creameries at different times, will be found to vary considerably. When the milk is accurately tested, and the butter well worked, this overrun will vary from 10 to 16 per cent; that is, if a quantity of milk contains exactly 100 lbs. of butter fat, as found by the Babcock test or any other accurate method of milk testing, from 110 to 116 lbs. of butter ready for market may be made from it.

Variations will occur in the speed of the separator, in the conduct of the ripening and the churning processes, and in the condition of the butter when the churn is stopped, even under the very best of care and attention to details; and absolutely uniform losses of fat in skim milk and butter milk, or the same water content of the butter cannot, therefore, be expected.

199. Factors influencing the overrun. The overrun is influenced by two factors: the losses of butter fat sustained in separating the milk and churning the cream, and the gain due to the admixture of water, salt, etc., in the manufacture of butter. Considering first the losses of fat in skim milk and butter milk, the separator usually, when run at normal capacity, will leave the same percent of fat in skim milk, whether rich or poor milk is skimmed; an exception to this may be found in separating rich milk having large fat globules, or milk from fresh milkers, in either of

which cases the large size of the fat globules occasions a more complete separation of fat by the centrifugal force. But generally speaking, the statement holds good that the total loss of fat in separator skim milk is a factor of the quantity of milk run through the separator, rather than of its quality. It follows from this, however, that the *relative* losses of fat in skim milk will vary to some extent according to the quality of the milk separated. Selecting two extremes in the quality of milk, 2.5 and 6.0 percent of fat, there will be found, say .2 percent of fat in the skim milk from either lot, provided the separator is not unduly crowded, and the separation is conducted under normal conditions in either case. But .2 percent fat makes 8 percent of the total fat in the poor milk ($\frac{.2 \times 100}{2.5} = 8$), and only 3 percent of that in the rich milk. It takes 4000 lbs. of the 2.5 percent milk to furnish 100 lbs. of fat, and only 1666 lbs. of the 6 percent milk; in skimming the poor milk, a loss of .2 percent of fat is sustained in the skim milk from 4000 lbs. of milk, while in the rich milk a similar loss is sustained in the skim milk from only 1666 lbs. of milk.

The example gives an extreme case, and one not likely to be met with in practice. The range in the richness of the milk delivered by different patrons at the factory is usually within one-half a percent of fat. In such cases the proportion of fat lost in skimming does not vary much, e. g., in case of milks containing 3.5 and 4.0 percent of fat, and variations in the overrun occurring when the proper care in skimming, ripening and churning is taken, are due, therefore, primarily to differences in the water content of the butter made (197).

200. The losses from very poor, very rich and average milk, as received at creameries and cheese factories, can be traced from the following statement; this gives the quantities of fat lost in handling milk of four grades, viz: 2.5, 3.5, 4.0 and 6.0 percent, in case of each grade calculated to a standard of 100 lbs. of fat in the milk.

To supply 100 lbs. of fat would require the following amounts of the different grades of milk:

4000 lbs. of milk testing 2.5 percent will contain 100 lbs. of fat.									
2857	"	"	"	3.5	"	"	"	100	"
2500	"	"	"	4.0	"	"	"	100	"
1666	"	"	"	6.0	"	"	"	100	"

Assuming that the skim milk contains .2 percent of fat and makes up 80 percent of the whole milk, and that the butter milk tests .3 percent, and forms 20 percent of the whole milk, the butter fat record of the quantities of different grades of milk containing 100 lbs. of fat will appear as follows:

Fat available for butter in different grades of milk.

Grade of milk.	Whole milk.	Skim milk.	Butter milk.	Total loss.	Fat available for butter.
				lb.	Percent.
2.5 percent.....	4000 lb. 2.5 per ct.	3200 lb. .2 per ct.	800 lb. .3 per ct.		
Fat.....	100 lb.	6.4 lb.	2.4 lb.	8.8	91.2
3.5 percent.....	2857 lb. 3.5 per ct.	2285 lb. .2 per ct.	572 lb. .3 per ct.		
Fat.....	100 lb.	4.6 lb.	1.7 lb.	6.3	93.7
4.0 percent.....	2500 lb. 4 per ct.	2000 lb. .2 per ct.	500 lb. .3 per ct.		
Fat.....	100 lb.	4.0 lb.	1.5 lb.	5.5	94.5
6.0 percent.	1666 $\frac{2}{3}$ lb. 6 per ct.	1333 lb. .2 per ct.	333 lb. .3 per ct.		
Fat.....	100 lb.	2.6 lb.	1.0 lb.	3.6	96.4

The table shows that with 2.5 percent milk, there is a loss of 6.4 lbs. of fat in the skim milk and 2.4 lbs. of fat in the butter milk for every 100 lbs. of fat in the whole milk, or a total loss of 8.8 lbs. from these sources. In case of 6 percent milk these losses are 2.6 lbs. and 1.0 lbs. for skim milk and butter milk, respectively; a total loss of 3.6 lbs., or 5.2 lbs. less than the losses with the very poor milk. This difference in the losses between 3.5 percent and 4.0 percent milk shrink to only .8 pound of fat when a quantity of milk containing 100 lbs. of fat is handled in both cases.

The overrun from each of the four grades of milk can be calculated to butter containing a certain percent of fat. The fat content of butter varies greatly, as has been shown (197); assuming it to be 83 percent, on the average, the quantity of butter obtained from the 100 lbs. of fat, or rather from the portion thereof which is available for butter, in each case would be as follows :

							<i>Butter cont.</i>
							<i>Available fat. 83 prct. fat.</i>
100 lbs. of fat from	4000 lbs. of	2.5 pr ct. milk,	91.2 lbs.	=	109.6 lbs.		
100 " " "	2857 " 3.5 " "		93.7 " "	=	112.9 lbs.		
100 " " "	2500 " 4.0 " "		94.5 " "	=	113.8 lbs.		
100 " " "	1666 " 6.0 " "		96.4 " "	=	116.1 lbs.		

The overrun in each case would be:

For 2.5 percent milk = $109.6 - 100 = 9.6$ percent.

3.5 " " = $112.9 - 100 = 12.9$ "

4.0 " " = $113.8 - 100 = 13.8$ "

6.0 " " = $116.1 - 100 = 16.1$ "

All butter makers should obtain more butter from a certain quantity of milk than the Babcock test shows it to contain butter fat, but it is impossible to know exactly how much butter fat is lost in the skim milk and the butter milk, unless these products are tested, and how much water, salt and curd the butter will contain.

201. Calculation of overrun. The overrun is calculated by subtracting the amount of butter fat contained in a certain quantity of milk, from the amount of butter made from it, and finding the percent which this difference is of the amount of butter fat in the milk.

Example. 8000 lbs. of milk is received at the creamery on a certain day; the average test of the milk is 3.8 percent. 340 lbs. of butter was made from this milk, as shown by the weights of the packed tubs. By a simple multiplication we find that the milk contained $8000 \times .038 = 304$ lbs. of butter fat. The difference between the weight of butter and butter fat, is, therefore, 36 lbs.; 36 is $\frac{36 \times 100}{304} = 11.8$ percent of the quantity of butter fat in the milk; that is, the overrun for the day considered was 11.8 percent.

The formula for the *overrun* is as follows:

$$X = \frac{(b-f) 100}{f}$$

b and *f* designating the quantities of butter and butter fat, respectively, made from or contained in a certain quantity of milk. In the preceding example, the calculation would be as follows: $\frac{(340-304) 100}{304} = 11.8$ percent.

202. Conversion factor for butter fat. A committee of the Association of American Agricultural Colleges and Experiment Stations reported at the ninth annual convention of the Association that "in the ninety-day Columbian Dairy Test, 96.67 percent of the fat in the whole milk was recovered in the butter. This butter on the average contained 82.37 percent butter fat; in other words, 117.3 pounds of butter were made from each 100 pounds of butter fat in the whole milk.* The exact conversion factor would be 1.173.

* When 82.37 lbs. of butter fat will make 100 lbs. of butter, how much butter will 96.67 lbs. of butter fat make? $82.37:96.67::100:x$, $x = 117.3$.

As this is an awkward number to use, and as $1\frac{1}{6}$ is so nearly the same . . . it has seemed best to recommend that the latter be used as the conversion factor."

A resolution was adopted by this association recommending that the approximate equivalent of butter be computed by multiplying the amount of butter fat by $1\frac{1}{6}$.

These figures represent more than ordinary care in testing, skimming and churning, and probably the minimum loss of fat in the manufacturing processes. The increase of churn over test represented by one-sixth, or 16 percent, therefore may be taken as a maximum "overrun." Butter makers who report overruns of 16-20 percent do not show their expertness in butter making by such high figures, but their lack of accuracy in testing, or carelessness in working the butter; a large overrun may be obtained both by reading the test too low, and by leaving an excess of water in the butter through insufficient working or other causes.

203. Butter yield from milk of different richness.

a. *Use of butter chart.* The approximate yield of butter from milk of different richness is shown in table IX in the *Appendix*. This table is founded on ordinary creamery experience and will be found to come near to actual every-day conditions of creameries where modern methods are followed in the handling of the milk and its products. The table has been prepared in the following manner:

It is assumed that the average loss of fat in the skim milk is .20 percent, and that 85 lbs. of skim milk is obtained from each 100 lbs. of whole milk; to this loss of fat is added that taking place in the butter milk; about 10 lbs. of butter milk is obtained per 100 lbs. of whole milk, testing on the average .30 percent.

If f designate the fat in 100 lbs. of milk, then the fat recovered in the butter from 100 lbs. of milk will be

$$f - \left(\frac{85}{100} \times .20 + \frac{10}{100} \times .30 \right) = f - .20$$

There is, on the other hand, an increase in weight in the butter made, owing the admixture of non-fatty components therein, principally water and salt. Butter packed and ready for the market will contain in the neighborhood of 84 percent of fat (197), so that the fat recovered in the butter must be increased by $\frac{100}{84} = 1.19$. If B therefore designate the yield of butter from 100 lbs. of milk, the following formula will express the relation between yield and fat content, provided there are no other factors entering into the problem, viz:

$$B = (f - .20) 1.19$$

Certain mechanical losses are, however, unavoidable in the creamery, as in all other factory operations, viz: milk and cream remaining in vats and separators, butter sticking to the walls of the churn, etc. These losses have been found to average about 3 percent of the total fat in the milk handled, under normal conditions and under good management (202); we therefore deduct this percent from the preceding value for B , and have:

$$B = (f - .20) 1.16$$

204. Table IX in the *Appendix*, founded on this formula, may be used to determine the number of pounds which the milk delivered by the various patrons within the limits of 3 and 5.3 percent will be likely to make. It presupposes good and careful work at the separator, churn and butter worker, and will generally under such conditions show yields of butter varying but little from those actually obtained. It may also be conveniently used by the butter maker or

the manager to check the work in the creamery; the average test of the milk received during a certain period is found by dividing the total butter fat received by the total milk, multiplying by 100; the amount of butter which the total milk of this average fat content will make according to the table, is then compared with the actual churn yield.

Example. A creamery receives 200,000 lbs. of milk during a month; the milk of each patron is tested and the fat contained therein calculated. The sum of these amounts of fat may be 7583 lbs.; the average test of the milk is then 3.79 percent. According to table IX, 10,000 lbs. of milk, testing 3.8, will make 421.2 lbs. of butter, and 200,000 lbs., therefore, 8424 lbs. of butter. The total quantity of butter made during the month should not vary appreciably from this figure.

205. b. *Use of overrun table.* The table referred to above gives a definite calculated butter yield for each grade of milk, according to the average creamery conditions. As it may be found that this table will either give uniformly too low or too high results, table X in *Appendix* is included, by means of which the butter yield corresponding to overruns from 10-20 percent may be ascertained in a similar way as above described.

The total yield of butter is divided by the total number of pounds of fat delivered; the quotient will give the amount of butter made from one pound of fat, and this figure multiplied by the fat delivered by each patron shows the pounds of butter to be credited to each patron. To use the table, find in the upper horizontal line the number corresponding most nearly to the number of pounds of butter from one pound of fat. The vertical column in which this falls gives the pounds of butter from 100 lbs. of milk containing the percents of fat given in the outside columns (Babcock *).

* Woll, Handbook for Farmers and Dairymen, p. 273.

B.—CALCULATION OF YIELD OF CHEESE.

206. a. From fat. The appropriate yield of green cheddar cheese from 100 lbs. of milk may be found by multiplying the percent of fat in the milk by 2.7; if f designate the percent of fat in the milk, the formula will, therefore, be:

$$\text{Yield of cheese} = 2.7 f \quad . \quad . \quad . \quad . \quad . \quad (I)$$

The factor 2.7 will only hold good as the average of a large number of cases. In extensive investigations during three consecutive years, Van Slyke * found that the number of pounds of green cheese obtained for each pound of fat in the milk varied from 2.51 to 3.06, the average figures for the three years 1892-'94, incl., being 2.73, 2.71, and 2.72 lbs., respectively. The richer kinds of milk will produce cheese richer in fat, and will yield a relatively a larger quantity of cheese, pound for pound, than poor milk, for the reason that an increase in the fat content of milk is accompanied by an increase in the other cheese-producing solids of the milk.† The preceding formula would not, therefore, be correct for small lots of either rich or poor milk, but only for milk of average composition, and for large quantities of normal factory milk. For cured cheese the factor will be somewhat lower, viz: about 2.6, on the average.

207. b. From solids not fat and fat. If the percentages of solids not fat and of fat in the milk are known, the following formula by Babcock will give close results:

$$\text{Yield of green cheese} = 1.58 \left(\frac{s}{3} + .91 f \right) \quad . \quad . \quad (II)$$

* N. Y. experiment station, (Geneva), bulletins No. 65 and 82.

† Investigations as to the relation between the quality of the milk and the yield of cheese have been conducted by a number of experiment stations; the following references give the main contributions published on this point: N. Y. (Geneva) exp. sta., reports 10-13, incl.; Wis. exp. sta., reports 11 and 12; Ont. Agr. College, reports 1894-'96, incl.; Minn. exp. sta., reports 1892-'94, incl.; Iowa exp. sta., bull. 21.

s being the percent of solids not fat in the milk, and f the percent of fat.

The derivation of this formula is as given below.*

Cheese is made up of water, fat and casein, with small quantities of other milk solids, and also salt and a little cheese color added in the process of manufacture. The green cheese as taken from the press, will contain in the neighborhood of 37 percent of water.† The total quantity of solids other than fat in the cheese has been found equal to one-third of the solids not fat in the milk from which the cheese is made. The fat contained in the cheese is that found in the milk less the fat lost in the process of manufacture, i. e., in the whey and the drippings. In the manufacture of cheddar cheese very nearly 9 percent of the fat in the milk is lost; a little less than 9 percent has been found in case of very rich milks, and a trifle more with poor milks, but this may be considered a correct average figure. The quantity of cheddar cheese made from 100 lbs. of milk will therefore be found by adding one-third of the percent of solids not fat in the milk to 91 percent of the fat, and multiplying the sum by $\frac{100}{83}$, or 1.58. The formula then is

Yield of green cheddar cheese

$$\text{from 100 lbs. of milk} = 1.58 \left(\frac{s}{3} + 91 f. \right)$$

The solids not fat can be readily ascertained from the lactometer reading and the percent of fat, as shown on p. 87, by means of table V, given in the *Appendix*.

Table XI in the *Appendix* gives the yield of cheese from 100 lbs. of milk containing from 2.5 to 6.0 percent fat, the lactometer readings of which range between 26 and 36. By means of this table cheese makers can calculate very closely the yields of cheese which certain quantities of milk will make; as it takes into consideration the non-fatty solids as

* Wisconsin experiment station, twelfth report, p. 105.

† N. Y. (Geneva) experiment station, twelfth report, p. 485.

well as the fat of the milk, the results obtained by the use of this formula will be more correct than those found by means of formula (I). The uncertain element in the formula lies in the factor 1.58, which, as shown above, is based on an average water content of 37 percent in the green cheese. This may, however, be changed to suit any particular case, e. g., 35 percent ($\frac{100}{35} = 1.54$), 40 percent ($\frac{100}{40} = 1.67$) etc. The average percentages of water in green cheese found by Van Slyke in his investigations referred to above, were for the years 1892-'94, respectively, 36.41, 37.05 and 36.70 percent.

208. c. From casein and fat. If the percentages of casein and fat in the milk are known, the yield of cheese may be calculated by the following formula, also prepared by Dr. Babcock:

$$\text{Yield of cheese} = 1.1 f + 2.5 \text{ casein} \quad . \quad . \quad . \quad . \quad (III)$$

This formula will give fairly correct results, but no more so than formula (II); it is wholly empirical.

CHAPTER XIII.

CALCULATING DIVIDENDS.

A.—CALCULATING DIVIDENDS AT CREAMERIES.

209. The simplest method of calculating dividends at creameries is to find the weight of butter fat in pounds delivered to the creamery by each patron for a certain length of time, and then multiply this amount by the price per pound of fat. Farmers are usually paid once a month for their milk at the factory. Each lot of milk is weighed, when delivered at the creamery, and a small quantity thereof is saved for the composite sample, as previously explained under composite tests (134). Some creameries test these samples at the end of each week, and others after collecting them for ten days or two weeks. If the four weekly composite samples of a patron's milk tested 3.8, 4.0, 3.9, 4.1 percent., these four tests are added together, and the sum divided by 4; the result, 3.75 percent, is used as the average test of this milk. By multiplying the total number of pounds of milk delivered by this patron, by his average test, the total weight in pounds of butter fat delivered to the factory during the month is obtained. This weight of fat is then multiplied by the price to be paid by the creamery per pound of butter fat; the product shows the amount of money due this patron for the milk delivered during the time samples were taken.

210. Price per pound of butter fat. The method of obtaining the price to be paid for one pound of butter

fat varies somewhat in different creameries, on account of the various ways of paying for the cost of manufacturing the butter. The method to be followed is generally determined by agreement between the manufacturer and the milk producers, in case of proprietary creameries, or between the shareholders, in co-operative creameries. The following methods of paying for the cost of manufacture are at the present time met with in American creameries:

211. I. Proprietary creameries. a. When the creamery is owned by some one person or company, the owner or owners agree to make the butter for 3 or 4 cents a pound; the difference between the total receipts of the factory and the amount due the owner is then divided between the different parties, according to the amount of butter fat contained in the milk delivered by them.

In the majority of cases, the price charged for making butter is now 4 cents a pound; $3\frac{3}{4}$ and $3\frac{1}{2}$ cents are sometimes charged. The larger the amount of milk received at a factory, the lower will naturally be the cost of manufacturing the butter.*

b. The proprietor of the creamery sometimes agrees to pay a certain price for 100 lbs. of milk delivered, according to its fat content, the price of milk containing 4 percent of butter fat being the standard. This price may change during the different seasons of the year by mutual agreement.

c. A creamery owner may offer to pay 1 to 2 cents, usually $1\frac{1}{2}$ cents, below the average market price of butter, for each pound of butter fat received in the milk.

212. II. Co-operative creameries. In this case, where the creameries is owned by the patrons, one of the stockholders.

* Wisconsin experiment station, bull. 56, p. 26.

who is elected secretary attends to the details of running the factory and selling the product. His accounts show the amount of money received each month for the butter and other products sold, and the expenses of running the factory during this time. The expenses are subtracted from the receipts, and the balance is divided among the patrons, each one receiving his proportionate share according to the amounts of butter fat delivered in each case (as shown by the total weight and the average tests of the milk delivered during this time).

In nearly all cases, the farmers receive about eighty pounds of skim milk for each hundred pounds of whole milk they deliver to the factory, in addition to the amount received for the milk, calculated according to one or the other of the preceding methods.

213. Illustrations of calculations of dividends. In order to illustrate the details of calculating dividends, or the amount to be paid each patron for the milk supplied each month, when payments are made by each of the four systems given, it will be assumed that a creamery receives 5000 pounds of milk daily for thirty days, and makes 6650 lbs. of butter from the 150,000 lbs. of milk received during this time. The average test of this milk may be found by multiplying the total weight of milk delivered by each patron by his average test, and dividing the sum of these products by the total weight of milk received at the creamery, (in the example given, by 150,000) the quotient being multiplied by 100. Such calculations may show that, e. g., 5700 lbs. of butter fat have been received in all in the milk delivered by the different patrons; this multiplied by 100, and divided by 150,000 gives 3.8 as the average test, or the

average amount of butter fat in each 100 lbs. of milk received during the month.

So far, the method of calculation is common for all different systems of payment given above; the manner of procedure now differs according to the agreement made between owner and patrons, or between the shareholders, in case of co-operative creameries.

214. I a. If the *net* returns for the 6650 lbs. of butter sold during the month were \$1197, and the creamery is to receive 4 cents per pound of butter as the cost of manufacture, etc., the amount due the creamery is $6650 \times .04 = \$266$, and the patrons would receive $\$1197 - \$266 = \$931$. This sum, \$931, is to be paid to the patrons for the 5700 lbs. of butter fat, which, as shown above, was the weight of fat contained in the 150,000 lbs. of milk delivered during the month. The price of one pound of butter fat is then easily found: $\$931 \div 5700 = 16\frac{1}{3}$ cents. This price is then paid to all patrons for each pound of butter fat delivered in their milk during the month. The monthly milk record of three patrons may, e. g., be as given in the following table:

PATRON.	FIRST WEEK		SECOND WEEK		THIRD WEEK		FOURTH WEEK		Total Milk lbs.	Average Test per cent.
	Milk lbs.	Test per ct.	Milk lbs.	Test per ct.	Milk lbs.	Test per ct.	Milk lbs.	Test per ct.		
No. 1.....	3500	3.6	3000	3.5	3600	3.65	3450	3.45	13,550	3.55
" 2.....	700	3.8	665	3.8	720	3.6	750	3.7	2,825	3.73
" 3.....	2480	4.2	2000	3.8	1850	4.0	1500	3.6	7,830	3.9

Multiplying each patron's total milk by his average test gives the number of pounds of butter fat in his milk, and this figure multiplied by $.16\frac{1}{3}$ shows the money due for his milk, as given below.

PATRON.	Total milk lbs.	Average test, per cent.	Butter fat, lbs.	Price of fat per lbs., cents	Amounts due.
No. 1.....	13,550	3.55	481.0	$16\frac{1}{3}$	\$78.56
" 2.....	2,825	3.7	104.5	$16\frac{1}{3}$	16.75
" 3.....	7,830	3.9	305.4	$16\frac{1}{3}$	48.96

215. b. When the proprietor of a creamery agrees to pay a certain price for 100 lbs. of 4 percent. milk, the receipts for butter sold and the price per pound of butter do not enter into the calculation of the amount due each patron for his milk; but the weight and the test of each patron's milk are just as important as before. If it is agreed to pay 66 cents per 100 lbs. of 4 percent milk (i. e. milk containing 4 percent of butter fat), the price of one pound of butter fat will be $66 \div 4 = 16\frac{1}{2}$ cents, and the amount due each patron is found by multiplying the total weight of butter fat in his milk by this price. To facilitate this calculation, so-called *Relative Value Tables* have been constructed, the use of which is explained in the following (221).

216. c. If a creamery agrees to pay for butter fat, say $1\frac{1}{2}$ cents per pound below the average market price obtained for butter each month, the price of one pound of butter fat is found by averaging the market quotations and subtracting $1\frac{1}{2}$ cents therefrom. If the four weekly market prices were $17\frac{1}{2}$, 17, $16\frac{1}{2}$ and 19 cents, the average of these would be $17\frac{1}{2}$ cents, and this less $1\frac{1}{2}$ cents gives 16 cents as the price per pound of fat to be paid to the patrons; this price is then used in calculating the dividend as in case of method I a.

Patron No.	Total milk lbs.	Average test, per cent.	Butter fat, lbs.	Price of fat. per lb., cents.	Amounts due.
1	13,550	3.55	481.0	16	\$76.96
2	2,825	3.7	104.5	16	16.72
3	7,830	3.9	305.4	16	48.86

217. II. If the creamery is owned by the farmers, the running expenses for a month are subtracted from the net returns received for the butter, and the amount left is divided by the total number of pounds of butter fat delivered during the month, to get the price to be paid per pound of butter fat. This price is used for paying each patron for his milk according to the amount of fat contained therein, as already explained under *Proprietary Creameries* (214).

The monthly running expenses of a co-operative creamery generally includes such items as the wages of the butter maker (and manager or secretary, if these officers are salaried), labor (hauling, helper, etc.), cost of butter packages, coal or wood, salt and other supplies, freight and commission on the butter sold, repairs and insurance on buildings, etc. A certain amount is also paid into a *sinking fund*, which represents the depreciation of the property, wear and tear of building and machinery, bad debts, etc. These items are added together, and their sum subtracted from the gross receipts for the butter sold during the month.

218. Assuming the receipts for the butter sold during the month to be \$1197, and the running expenses of the factory \$285, the amount to be divided among the patrons is \$912, the quantity of butter fat received was 5700 lbs., and the price per pound of butter fat will therefore be 16 cents. The account will then stand as follows:

Patron No.	Total milk lbs.	Average test, per cent.	Butter fat, lbs.	Price per lb. of butter fat, cents	Amounts due.
1	13,550	3.55	481.0	16	\$76.96
2	2,825	3.7	104.5	16	16.72
3	7,830	3.9	305.4	16	48.86

219. Other systems of payment. Besides these four systems of payment, there are various other agreements made between manufacturer and producer, but with them all the one important computation of the price to be paid per pound of butter fat is the basis of calculating the factory dividends, when milk is paid for by the Babcock test.

220. *Paying for butter delivered.* In some instances patrons desire to receive pay for the quantity of butter which the milk delivered by them will make. This can be ascertained quite accurately from the total receipts and the total weight of both butter fat and butter. The total money to be paid for butter (the net receipts) are divided by the number of pounds of butter sold, to get the price to be paid per pound of butter; the total yield of butter divided by the total amount of butter fat delivered in the milk, gives the amount of butter corresponding to one pound of butter fat, and the pounds of fat delivered by each patron is then multiplied by this figure. This method requires more figuring, than those given in the preceding, and the dividends are no more accurate, in fact, less so, than when calculations are based on the price per pound of fat.

221. Relative value tables. These tables give many of the multiplications used in computing the amount due for various weights of milk testing from 3 to 6 per cent. of fat. They can be easily constructed by any one as soon as the price of one pound of fat is determined in each case. If the price to be paid per pound of fat is, say, 15 cents, the value of each 100 lbs. of milk of different quality is found by multiplying its test by 15. If the average tests of the different patrons' milk vary from 3 to 5 percent, the relative value table would be as follows:

$3.0 \times 15 = 45\text{c.}$	per 100 lbs.	$3.6 \times 15 = 54\text{c.}$	per 100 lbs.
$3.1 \times 15 = 46.5\text{c.}$	"	$3.7 \times 15 = 55.5\text{c.}$	"
$3.2 \times 15 = 48\text{c.}$	"	$3.8 \times 15 = 57\text{c.}$	"
$3.3 \times 15 = 49.5\text{c.}$	"	$3.9 \times 15 = 58.5\text{c.}$	"
$3.4 \times 15 = 51\text{c.}$	"	$4.0 \times 15 = 60\text{c.}$	"
$3.5 \times 15 = 52.5\text{c.}$	"	etc.	

Continuing this multiplication, or adding the multiplier each time, in the same way for each tenth of a percent. up to 5 percent. of fat, gives a table that can be used for calculating the amount due per 100 lbs. of milk, at this price per pound, and the weight of milk delivered by each patron is multiplied by the price per 100 lbs. of milk shown in the table opposite the figure representing his test.

Example. A patron supplies 2470 lbs. of milk testing 3.2 percent of fat; price per pound of fat 15 cents; he should then receive $24.70 \times 48\text{c.} = \11.85 , (see above table). Another patron delivering 3850 lbs. of milk testing 3.8 percent, will receive, at the same price per pound of fat, $38.50 \times 57\text{c.} = \21.94 .

The relative value tables in the *Appendix* give the price per 100 lbs. of milk testing between 3 and 6 percent fat, when the price of three percent milk varies from 30 to 90c. per 100 lbs. In using the tables, first find the figure showing the price which it has been determined to pay for 100 lbs. of milk of a certain quality, say 3 or 4 percent milk; the figures in the same vertical column then give the price to be paid per 100 lbs. of milk testing between 3 and 6 percent.

Example 1. It has been decided to pay 90 cents per 100 lbs. of 4 percent milk. The figure 90 is then sought in the table in the same line as 4.00 percent, and the vertical column in which it is found, gives the price per 100 lbs. of 3 to 6 percent milk. 3.8 percent milk is thus worth 85 cents per 100 lbs., and 4.5 percent milk, \$1.01, under the conditions given. The prices of other qualities of milk are found in the same way.

Example 2. In the example referred to under Illustrations of Calculating Creamery Dividends (I b, 215), the figures for the patrons No. 1, 2, and 3, would be as follows:

PATRON NO.	Milk delivered lbs.	Average test.	Price per 100 lbs. of milk, cents.	Amounts due.
1.....	13550	3.55	58.5	\$79.26
2.....	2325	3.7	61.	17.23
3.....	7830	3.9	64.	50.11

B.— CALCULATING DIVIDENDS AT CHEESE FACTORIES.

222. The amount of cheese made from a certain quantity of milk depends, as before shown (206), in a large measure on the richness of the milk in butter fat. Rich milk will give more chesse per hundred weight than poor milk, and the increased yields will be nearly, but not entirely, proportional to the fat contents of the different kinds of milk. Since the quality of the cheese produced from rich milk is better than that of cheese made from thin milk, and will demand a higher price, it follows that no injustice is done by rating the value of milk for cheese production by its fat content. This subject has been discussed frequently during late years in experiment station publications and in the dairy press (see 206). Among others, Babcock has shown that the price of cheese stands in a direct relation to its fat content.* Prof. Robertson, the Dairy Commissioner of Canada, is authority for the statement that the quality of the cheese made from milk containing 3.0 to 4.0 percent of fat was increased in value by one-eighth of a cent for every two-tenths of a percent of fat in the milk,† a figure which is fully corroborated by Dr. Babcock's results. The injustice

* Wisconsin exp. station, 11th report, p. 134.

† Hoard's Dairyman, March 29, 1895.

of the "pooling system," by which all kinds of milk receive the same price, is evident from the preceding; if the milk of a certain patron is richer than that of others, it will make a higher grade of cheese, and more of it, per hundred weight, and hence should be paid a higher price.

Payment on the basis of the fat content of milk is, therefore, the most equitable method of valuing milk for cheese making, and in case of patrons of cheese factories as with creamery patrons, dividends should be calculated from the results obtained by testing the milk delivered. The testing may be conveniently arranged by the method of composite sampling, in the same way as already described for creameries (162).

223. Calculation of dividends. As with creameries the first thing to be ascertained is the price to be paid per pound of butter fat. The factory records should show the number of pounds of cheese made from the total milk delivered to the factory during a certain time, generally one month, and the money received for this cheese. The cost of making cheese and all other expenses that should be paid for out of the money received for the cheese are deducted from the total receipts, and the difference is divided among the patrons in proportion to the amounts of butter fat delivered in the milk.

The weights of the milk delivered, and the tests of the composite samples furnish data for calculating the quantities of butter fat to be credited to each patron. The money to be paid to the patrons is then divided by the total weight of butter fat delivered to the factory, and the price of one pound of fat thus obtained. The money due each patron is now found by multiplying the total number of pounds of butter fat in his milk by this price per pound.

The illustrations already given for calculating patrons' dividends at creameries according to the various methods, will serve equally well to show the manner in which dividends are calculated at a cheese factory. For the sake of clearness an example is given that applies directly to cheese factories.

224. Illustrations of calculation of dividends. It may be assumed that 15,000 lbs. of green cheese is made from 150,000 lbs. of milk delivered to a factory in a month; according to the weighings and the tests made, the milk contained 5700 lbs. of butter fat. If the cheese sold at an average price of $7\frac{1}{2}$ cents a pound, the gross receipts would be \$1,125.00. The amount to be deducted from the gross receipts will depend on the agreement made between the factory operator and the patrons, in case of proprietary cheese factories, or between the shareholders and the maker, when the factory is run on the co-operative plan. As before we shall consider these systems separately.

225. I. Proprietary cheese factories. The owner of the factory generally agrees to make the cheese for a certain price per pound, and to pay the patrons what is left after deducting this conclusion. If the price agreed on is $1\frac{1}{2}$ cents per pound of green cheese, this would amount to \$225, in the example given. Subtracting this sum from the gross receipts, \$1,125, leaves \$900, which is to be paid the patrons. The total amount of butter delivered by the patrons was 5700 lbs.; hence the price of one pound of butter fat will be $900 \div 5700 = .1577$, or 15.8 cents. Taking the figures for the three patrons already mentioned under creamery dividends, we then have:

Patron.	Total milk, lbs.	Average test, percent.	Butter fat. lbs.	Price per lb. of fat.	Amounts due.
No. 1.....	13,550	3.55	481.0	15.8c.	\$76.00
No. 2.....	2,825	3.7	104.5	15.8c.	16.57
No. 3.....	7,830	3.9	305.4	15.8c.	48.25

206. II. *Co-operative cheese factories.* The method of payment at co-operative cheese factories is nearly the same as that already given, except that a certain sum representing the expenses is subtracted from the gross receipts for the cheese, and the balance is divided among the patrons according to the amounts of butter fat furnished by each, in the same manner as in the above case, after the price of a pound of fat has been obtained.

The price per 100 lbs. of milk can be calculated in the the same way as at creameries, by multiplying the test of each lot by the price per pound of fat.

CHAPTER XIV.

CHEMICAL ANALYSIS OF MILK AND ITS PRODUCTS

227. An outline of the methods followed in determining quantitatively the components of milk and its products is given in the following, for the guidance of advanced dairy students. This work cannot be done outside of a fairly well-equipped chemical laboratory, or by persons who have not been accustomed to handling delicate chemical apparatus and glassware, analytical balances, etc., and who have not a knowledge of at least the elements of chemistry and chemical reactions.

A.—MILK.

208. In a complete milk analysis, the specific gravity of the milk is determined, and the following milk components, water, fat, casein and albumen, milk sugar, and ash. The methods of analysis described in the following are those used in the chemical laboratory of the Wisconsin experiment station, which in the main are the same as those adopted by the Association of Official Agricultural Chemists, and in use with but slight modifications in the chemical laboratories of all American experiment stations and schools.*

229. a. Specific gravity is determined by means of a picnometer or specific gravity bottle, since more accurate

* The methods of analysis adopted by the Asso. of Official Agr'l Chemists are published annually by the chemical division of the U. S. Department of Agriculture; see Bull. No. 46, Washington, 1895, edited by Harvey W. Wiley, secretary, pp. 84.

results will thus be reached than by using an ordinary Quevenne lactometer. A thermometer is ground into the neck of the specific gravity bottle so as to form a stopper, and the bottle is provided with a glass-stoppered side tube to furnish an exit for liquids on expanding. A specific gravity bottle holding 100 grams of water is preferably used. The empty and scrupulously cleaned bottle is first weighed on a chemical balance. The bottle is then filled with recently-boiled distilled water of a temperature below 60° F. (15.5° C.); the thermometer is inserted, and the bottle is warmed slightly by immersing it for a moment in tepid water and left standing until the thermometer shows 60° F.; the opening of the side tube is then wiped off and closed with the stopper, and the water on the outside of the bottle and in the groove between its neck and the thermometer wiped off with filter paper or a clean handkerchief, when the bottle is again weighed. The weight being recorded, the bottle is emptied and dried in a water oven, or, if sufficient milk is at hand, the bottle is repeatedly rinsed with the milk, the specific gravity of which is to be determined. It is then filled with milk in a similar manner as in case of water; the temperature of the milk should be slightly below 60° F., and is gradually brought up to this degree after the bottle has been filled, proceeding in the same manner as before with water; the weight of the bottle and milk is then taken.

The weights of water and of milk contained in the specific gravity bottle are found by subtracting the weight of the empty bottle from the second and third weight, respectively, and the specific gravity of the milk then found by dividing the weight of the milk by that of the water.

Example: Weight of sp. gr. bottle + water...146.9113 grams.
 Weight of sp. gr. bottle empty..... 46.9423 “

Weight of water..... 99.9690 grams.

Weight of sp. gr. bottle + milk.....149.8718 grams.

Weight of sp. gr. bottle empty..... 46.9423 “

Weight of milk.....102.9285 grams.

$$\text{Sp. gr. of milk} = \frac{102.9285}{99.969} = 1.0296$$

230. If a plain picnometer without a thermometer attached, is available, the method of procedure is similar to that described, with the difference that the temperature of the water and of the milk must be brought to 60° F., before the picnometer is filled, or the picnometer filled with either liquid is placed in water in a small beaker, which is very slowly warmed to 60° F. and kept at this temperature for some time so as to allow the liquid in the picnometer to reach the temperature desired; the temperature of the water in the beaker is ascertained by means of an accurate chemical thermometer. The perforated stopper is then wiped off, the picnometer is taken out of the water, wiped and weighed. It is necessary to weigh very quickly if the room temperature is much above 60° F., as in such cases the expanding liquid will flow on to the balance pan, with a resultant loss in weight from evaporation.

The weights of specific gravity bottle or picnometer, empty and filled with water, need only be determined a couple of times, and the averages of these weighings used in subsequent determinations.

231. b. Water. The milk is weighed into a perforated copper tube filled with prepared dry asbestos. The tubes are made from perforated sheet copper, with holes about

.7 mm. in diameter and about .7 mm. apart; they are 60 mm. long, 20 mm. in diameter and closed at the bottom. The asbestos is prepared from clean fibrous asbestos, which is ignited in a muffle oven, treated with dilute HCl (1 : 3) and then with distilled water till all acid is washed out; it is then torn in loose layers and dried at a low temperature in an air bath; when dry it can be easily shredded in fine strings and is placed in a wide-mouth, glass-stoppered bottle.

About 2 grams of asbestos are placed in each tube, packing it rather loosely; the tube is then weighed, a small narrow beaker being inverted over it on the scale pan. 5 cc. of milk are then dropped on to the asbestos from a 5 cc. fixed pipette, the beaker again placed over the tube, and the weight of the 5 cc. of milk delivered + copper tube taken. The weight of the milk is obtained by difference. The tubes are now placed in a steam oven and heated to 100° C. until they no longer decrease in weight, which ordinarily will take about three hours. Place in dessiccator until cold, and weigh; the difference between the weight of the tube + milk and this last weight gives the water contained in the milk, which is then calculated in percent of the quantity of milk weighed out.

Example. Weight of tube + breaker + milk.....29.3004 grams.

Weight of tube + beaker.....24.1772 “

Milk weighed out..... 5.1232 grams.

Weight of tube + beaker + milk.....29.3004 grams.

Weight of tube + beaker + milk, dry..24.9257 “

Weight of water 4.3747 grams.

$$\text{Percent of water in milk} = \frac{4.3747 \times 100}{5.1232} = 85.39 \text{ percent.}$$

Note. The percent of total solids in milk is often given, instead of that of water; this may be readily obtained by

subtracting the weight of the empty tube from that of the tube filled with milk solids, and finding the percent of the milk weighed out which this difference makes. In the above example, the weight of milk solids thus is $24.9257 - 24.1772 = .7485$ grams, and the percent. of total in the milk $= 14.61$ percent.

232. *Alternate method.* 5 cc of milk are measured out on a weighed flat porcellain dish (50–60 mm. in diameter; porcellain crucible covers will answer the purpose better than any other vessel on the market, provided the handle be broken off or ground off level on an emory wheel); this is weighed rapidly; two or three drops of 30 percent acetic acid are added, and the dish is dried in a steam oven at 100°C until no further loss in weight is obtained. After cooling in desiccator, the weight of the milk solids is obtained, and by calculation as before, the percent of water or total solids in the milk.

233. c. **Fat.** The dried tubes from the water determination are placed in Caldwell extractors and connected with weighed, numbered glass flasks (capacity, 2–3 oz.); the extractors are attached to upright Liebig condensers and the tubes extracted with pure ether, free from water, alcohol or acid, until all fat is dissolved; 4–5 hours' extraction is sufficient; in case of samples of skim milk it is well to continue the extraction for 6 hours. The ether is then distilled off and recovered, and the flasks dried in a copper oven until constant weight; after cooling they are weighed, and the amount of fat contained in the quantity of milk originally weighed into the tubes is thus ascertained, and the percent. present in the milk calculated.

<i>Example:</i> Weight of flask + fat.....	15.8039 grams.
Weight of flask.....	15.5171 “
Weight of fat.....	.2868 grams.
Milk weighed out.....	5.1232 grams.
Per cent. of fat in milk =	$\frac{.2868 \times 100}{5.1232} = 5.58$ percent.

234. Casein and albumen. The sum of these components is generally determined by the Kjeldahl method.* 5 cc. of milk are measured carefully into a flat-bottom 800 cc. Jena flask, 20 cc. of concentrated sulfuric acid (C. P., sp. gr., 1.84) are added, and .7 gram of mercuric oxid (or its equivalent in metallic mercury); the mixture is then heated over direct flame until it is straw colored or perfectly white; a few crystals of potassium permanganate are now added till the color of the liquid remains green. All the nitrogen in the milk has now been converted into the form of ammonium sulfate. After cooling, 200 cc. of distilled water, free from ammonia, are added, 20 cc. of a solution of potassium sulfid (containing 40 grams sulfid per liter), and a fraction of a gram of powdered zink. A small quantity of semi-normal HCl solution, more than sufficient to neutralize the ammonia obtained in the oxidation of the milk, is now carefully measured out from a delicate burette (divided in $\frac{1}{20}$ cc.) into an Erlenmeyer flask, and the flask connected with a distillation apparatus. At the other end, the Jena flask containing the watery solution of the ammonium sulfate is connected, after adding 50 cc. of a concentrated soda solution (1 pound “pure potash” dissolved in 500 cc. of distilled water, and allowed to settle); the contents of the Jena flasks are now heated to boiling, and the distillation is

* Fresenius' Zeitschrift, p. 22, 366; U. S. Dept. Agr., Chem. Div., bull. 43.

continued for 40 minutes to an hour, until all the ammonia has been distilled over.

The excess of acid in the Erlenmeyer receiving flask is then accurately titrated back by means of a tenth-normal standard ammonia solution, using a cochineal solution * as an indicator. From the amount of acid used, the percent of nitrogen, and from it, the percent of casein and albumen in the milk is obtained by multiplying by 6.25.† The amount of nitrogen contained in the chemicals used is determined by blank experiments, and deducted from the nitrogen obtained as described.

Example: The weight of 5 cc. of milk (as obtained in determining the water in milk, see *a.*) was 5.1465 grams. 5 cc. of standard HCl are added in the receiver, and 1.55 cc. of $\frac{N}{10}$ alkali solution are used in titrating back the excess of acid. 1.55 cc. of $\frac{N}{10}$ alkali = $\frac{1.55}{5} = .51$ cc. $\frac{N}{2}$ acid solution; the ammonia distilled over therefore neutralized $5 - .51 = 4.49$ cc. acid. By blank trials it was found that the reagents used furnish an equivalent of .02 cc. acid in the distillate; this quantity subtracted from the acid-equivalent of the nitrogen of the milk leaves 4.47 cc. 1 cc. semi-normal HCl. solution corresponds to 7 milligrams or .007 grams of nitrogen; 4.47 cc. $\frac{N}{2}$ HCl. therefore represents .03129 grams of nitrogen. This quantity of nitrogen was obtained from the 5.1465 grams of milk measured out; the milk therefore contains $\frac{.03129 \times 100}{5.1465} = .608$ percent of nitrogen, and $.608 \times 6.25 = 3.80$ percent of casein and albumen.

235. *Casein and albumen* may be determined separately by Van Slyke's method: ‡ 10 grams of milk are weighed out

* Sutton, Volumetric Analysis, 4th edition, p. 81.

† The factor 6.30 or 6.37 is more correct for the albumenoids of milk, but has not yet been generally adopted.

‡ Bulletin No. 43, p. 189, Chem. Division, U. S. Dept. of Agriculture.

and diluted with about 90 cc. of water at 40°–42° C. 15 cc. of a 10 percent acetic acid solution are then added; the mixture is well stirred with a glass rod and the precipitate allowed to settle for 3–5 minutes. The whey is decanted through a filter and the precipitate washed two or three times with cold water. The nitrogen is determined in the filter paper and its contents by the Kjeldahl method; blank determinations with the regular quantities of chemicals and the filter paper used are made, and the nitrogen found therein deducted. The percent of nitrogen obtained multiplied by 6.25 gives the percent of casein in the milk.

236. *Albumen* is determined in the filtrate from the casein precipitate; the filtrate is placed on a water bath and heated to boiling temperature of water for ten to fifteen minutes. The washed precipitate is then treated by the Kjeldahl method for the determination of nitrogen; the amount of nitrogen multiplied by 6.25 gives the amount of albumen in the milk. The difference between the total nitrogenous components found by the Kjeldahl method, and the sum of the casein and the albumen, as given above, is due to the presence in milk of a third class of nitrogen compounds, called by various authors, globulin, lactopepton, nuclein, etc. (18).

237. *e. Milk sugar* is generally determined by difference, the sum of fat, casein and albumen ($\text{total N} \times 6.25$), and ash, being subtracted from the total solids. It may be determined directly by means of a polariscope, or gravimetrically by Fehling's solution; only the former method, as worked out by Wiley, * will be given here.

The specific gravity of the milk is accurately determined, and the following quantities of milk are measured out by

* *Agricultural Analysis*, iii, p. 275; *Am. Chem. Jour.*, 6, p. 289 et seq.

means of a 100 cc. pipette graduated to .2 cc. (or a 64 cc. pipette made especially for this purpose, with marks on the stem between 63.7 and 64.3 cc.), according to the specific gravities given: 1.026, 64.3 cc.; 1.028, 64.15 cc.; 1.030, 64.0 cc.; 1.032, 63.9 cc.; 1.034, 63.8 cc.; 1.036, 63.7 cc. These quantities refer to the Soleil-Ventzke half-shadow polariscopes, requiring a normal weight of 26.048 grams of sugar. The milk is measured into a small flask graduated at 100 cc. and 102.6 cc.; 30 cc. of mercuric iodid solution (prepared from 33.2 grams potassium iodid, 13.5 grams mercuric chlorid, 20 cc. glacial acetic acid and 640 cc. water) are added; the flask is filled to 102.6 cc. mark with distilled water, the contents mixed, filtered through a dry filter, and when the filtrate is perfectly clear, the solution is polarized in a 200 millimeter tube. The readings of the scale divided by 2 shows the percent of lactose (milk sugar) in the milk. Take five readings of two different portions of the filtrate, and average the results.

238. f. Ash. About 20 cc. of milk are measured into a flat bottom porcellain dish and weighed; about one-half of a cc. of 30 percent acetic acid is added, and the milk first dried on water bath, and then ignited in a muffle oven at a low red heat. Direct heat should not be applied in determining the ash of milk, since alkali chlorids are likely to be lost at the temperature to which milk solids have to be heated to ignite all organic carbon.

Example. Weight of porcellain dish + milk.....49.0907 grams.
Weight of porcellain dish.....28.3538 “

Weight of milk.....20.7369 grams.
Weight of dish + milk, after ignition..28.5037 grams.
Weight of dish.....28.3538 “

Weight of milk ash..... .1499 grams.

Percent of ash = $\frac{.1499 \times 100}{20.7369} = .72$ percent.

239. Acidity of milk. The acidity of milk is conveniently determined by means of Farrington's alkaline tablets (see p. 99), or by one-tenth normal soda solution. In the latter case, 20 cc. of milk are measured into a porcellain casserole; a few drops of an alcoholic phenolphthalein solution are added, and soda solution is dropped in slowly from a burette until the color of the milk remains uniformly pinkish on agitation. 1 cc. of $\frac{N}{10}$ alkali corresponds to .009 grams lactic acid, or to .045 percent, when 20 cc. of milk are taken, (see p. 98).

DETECTION OF PRETERTVATIVES IN MILK.

240. a. Boracic acid (*borax, borates, preservaline, etc.*) 100 cc. of milk are made alkaline with a soda or potash solution, evaporated to dryness and incinerated. The ash is dissolved in water to which a little hydrochloric acid has been added, and the solution filtered. A strip of turmeric paper moistened with the filtrate will be colored reddish brown when dried at 100° C on a watch glass.

If a little alcohol is poured over the ash to which conc. sulfuric acid has been added, and fire is set to the alcohol after a little while, it will burn with a yellowish green tint, especially noticeable if the ash is stirred with a glass rod and when the flame is about to go out.

241. The following modification of the first test given is said to prove the presence of only a thousandth of a gram of borax in a drop of milk* (.13 percent.): Place in a porcellain dish one drop of milk with two drops of strong hydrochloric acid and two drops of saturated turmeric tincture; dry this on the water bath, cool and add a drop of am-

* N. J. Dairy commissioner, report 1896, p. 37.

monia by means of a glass rod. A slaty blue color, changing to green, is produced if borax is present.*

242. b. Bi-Carbonate of soda. 100 cc. of milk to which a few drops of alcohol are added, are evaporated and carefully incinerated; the proportion of carbonic acid in the ash, as compared with that of milk of known purity, is determined. If an apparatus for the determination of carbonic acid is available, like the Scheibler apparatus, etc., the per cent. of carbonic acid per gram of ash (and quart of milk) can be easily determined. Normal milk ash contains only a small amount of carbonic acid (less than 2 per cent), presumably formed from the citric acid of the milk in the process of incineration.

The following quantitative test is easily made: To 10 cc. of milk add 10 cc. of alcohol and a little of a one-percent rosolic acid solution. Pure milk will give a brownish yellow color; milk to which soda has been added, a rose red color. A control experiment with milk of known purity should be made.

243. c. Fluorids. 100 cc. of milk are evaporated in a platinum or lead crucible, and incinerated; the ash is made strongly acid with conc. sulfuric acid. If fluorids are present, hydrofluoric acid will be generated on gentle heating, and will be apparent from its etching a watch glass placed over the crucible.

244. d. Salicylic acid (*salicylates*, etc.). 20 cc. of milk are acidulated with sulfuric acid and shaken with ether; the ether solution is evaporated, and the residue treated with alcohol and a little iron chlorid solution; a deep violet color will be obtained in the presence of salicylic acid.

* See also 132, 137.

245. e. Formaline (a forty-percent solution of *formaldehyde* in water). A solution of diphenylamin is made with water and just enough sulfuric acid to secure a proper solvent effect. The milk to be tested, or better, the distillate therefrom, is added to this solution and boiled. If formaline be present, a white flocculent precipitate is formed; if the acid used contained nitrates, a green precipitate will be formed.*

B.—SKIM-MILK, BUTTER-MILK, WHEY.

246. The analysis of these products is conducted in the same manner as in case of whole milk, and the same constituents are determined, when a complete analysis is wanted. As they generally contain only small quantities of solids, and especially of fat, it is well to weigh out a larger quantity than in case of whole milk; if possible, toward 10 grams. The acidity of some milk and butter milk must be neutralized with sodium carbonate previous to the drying and extraction, as lactic acid is soluble in ether and would thus tend to increase the ether-extract (fat) if not combined with an alkali previous to the extraction.

C.—BUTTER.

248. Sampling. A four to eight-ounce sample of butter is melted in a tightly closed fruit jar, shaken vigorously and cooled until the butter is hardened, the jar being shaken at short intervals during the cooling so as to keep the water of the butter evenly distributed in the mass.

249. a. Determination of water. Small pieces of butter (about 2 grams in all) are taken from the sample by means of a steel spatula, and placed in glass tubes, seven-

* See also Chem. News, 1896, No. 71; Milchzeitung, 1896, 491; 1897, 40, 667.

eighths of an inch in diameter and two and a half inches long, closed at the bottom by a layer of stringy asbestos, and filled two-thirds full of asbestos prepared as for milk analysis (231). The tubes are dried at 100° C. in the water oven, until no further loss in weight takes place, and are then cooled and weighed. The percent of water is determined as in case of milk analyses.

250. b. Fat. The tubes are placed in Caldwell's extractors and extracted for four hours with anhydrous ether; the ether is then distilled off, and the flasks dried in the steam bath and weighed, the increase in weight being the fat in the samples of butter weighed out.

251. c. Casein. 10 grams of butter are weighed into a small beaker provided with a lip, and treated twice with about 50 cc. of gasoline each time; the solution is filtered off, and the residue transferred to a filter and dried; its nitrogen content is then determined by the Kjeldahl method (234). The nitrogen in the filter and chemicals used is determined by blank trials and deducted. The nitrogen multiplied by 6.25 gives the casein in the butter.

252. d. Ash. 1. 10 grams of butter are weighed into a porcellain dish and treated twice with gasoline, as in preceding determination, the solution is filtered through an ash-free (quantitative) filter, and the filter when dry, is transferred to the dish. The dish is heated in an air-bath for half an hour and then placed in a muffle oven, where the contents are burnt to a light greyish ash; the dish is now cooled in a desiccator and weighed. The difference between this weight and that of the empty dish gives the amount of ash in the butter weighed out.

253. 2. About 2 grams of butter are weighed into a small porcellain dish, half filled with stringy asbestos; the dish is dried for an hour in the water oven, and the fat then set fire to with a match, the asbestos fiber serving as a wick. When the flame has gone out, the dish is placed in a muffle oven, and the residue burnt to a greyish ash. After cooling, the dish is weighed, and the percent. of ash in the butter calculated as under method *a*.

254. Complete analysis of butter in the same sample. About 2 grams of the butter are weighed into a platinum gooch, half filled with stringy asbestos, and dried in water oven at 100° C. to constant weight, cooled and weighed. The difference gives *water* in the sample. The gooch is then treated repeatedly with small portions of gasoline, suction being applied, and again dried in the water oven, cooled, and weighed; the *fat* in the sample is obtained from the difference between this and the preceding weight. The gooch is then carefully heated over direct flame until a light greyish ash is obtained; this operation is preferably done in a muffle oven to avoid possible loss of alkali chlorids. The loss in weight gives the *casein* in the sample weighed out, and the increase in the weight of the gooch over that of the empty gooch with asbestos gives the *ash* (mainly salt) of the butter. The *salt* in the ash may be dissolved out by hot water, acidulated with a drop or two of nitric acid, and the chlorin content of the solution determined by means of a standard silver nitrate solution using potassium chromate as an indicator.

DETECTION OF ARTIFICIAL BUTTER.

255. Determination of the specific gravity of the filtered butter fat serves as a good preliminary test. A number of practical methods for the detection of artificial butter have been proposed, but they are either worthless, in case of samples containing a considerable proportion of natural butter, or give satisfactory results only in the hands of experts. The Reichert-Wollny method given in detail below is the standard method the world over, and the results obtained by it are accepted in the courts.

256. Filtering the butter fat. The butter to be examined is placed in a small narrow beaker and kept at 60° C. for about two hours. The clear supernatant fat is then filtered through absorbent cotton into a 200 cc. Erlenmeyer flask, taking care that none of the milky lower portion of the contents of the beaker be poured on the filter. In sampling the butter fat, it is poured back and forth repeatedly from a small warm beaker into the flask, and the quantity wanted is then drawn off with a warm pipette.

257. Specific gravity. This is generally determined at 100° C. The method of procedure is similar to that described under milk (230). The picnometer (capacity about 25 cc.) filled with dry filtered butter fat, free from air bubbles; the fat is heated for 30 minutes in a beaker, the water in which is kept boiling. On cooling, the weight of picnometer and fat is obtained, and by calculation as usual, the specific gravity of the fat.

The specific gravity of pure natural butter fat at 100° C. ranges between .8650 and .8685, while artificial butter fat (i. e. fat from other sources than cows' milk) has a specific gravity at 100° C. of below .8610, and generally about .85.

258. Reichert-Wollny method (*Volatile Acids*). 5.75 cc. of fat are measured into a strong 250 cc. weighed saponification flask, by means of a pipette marked to deliver this amount, and the flask when cool, is weighed again. 10 cc. of 95 percent. alcohol and 2 cc. of a concentrated soda solution (1:1) are then added to the flask which is securely stoppered with a cork stopper tied down with a piece of twine. The flask is heated for an hour on the water bath, being gently rotated from time to time in order to facilitate the saponification. The flask is then uncorked, the alcohol evaporated slowly and the heating continued until the last traces of alcohol are gone.

100 cc. of recently-boiled, distilled water are now added, and the flask heated on the water bath until the soap formed is completely dissolved. When cooled to about 70° C, 40 cc. of dilute sulfuric acid (25 cc. conc. H_2SO_4 per liter) are added to the soap solution to decompose the soap into free fatty acids and glycerol. The flask is restoppered and heated until the insoluble fatty acids separated out form a clear oily layer on the surface of the acid solution of the flask. After cooling to room temperature, a few pieces of pumice stone (prepared by throwing the pieces at a white heat into distilled water and keeping them under water until used) are added, the flask connected with a glass condenser, heated slowly till boiling begins, and the contents then distilled at such a rate as will bring 110 cc. of the distillate over in as nearly thirty minutes as possible.

The distillate is mixed thoroughly and filtered through a dry filter; 100 cc. of the filtrate are poured into a 250 cc. beaker and titrated with a deci-normal barium hydrate solution, half a cubic centimeter of phenolphthalein solution being used as an indicator. A blank test is made in the

same manner as described, and the alkali solution required deducted from the results obtained with the samples analyzed. The number of cubic centimeters of barium hydrate solution used is increased by one-tenth, and the so-called *Reichert number* thus obtained.

The Reichert number for pure butter fat will ordinarily come above 24 cc.; butter fat from strippers will have a low Reichert number. Pure oleomargarine will have a Reichert number of 1–2 cc.; and mixtures of artificial and natural butters will show intermediate numbers.

D.—CHEESE.

For method of sampling, see p. 78.

259. a. Water. Five grams of cheese cut into very thin slices are weighed into a small porcellain dish filled about one-third full with freshly-ignited stringy asbestos; the dish is placed in a water oven and heated for ten hours. The loss in weight is taken to represent water.

260. b. Fat. About 5 grams of cheese are ground finely in a small porcellain mortar with about twice its weight of anhydrous copper sulfate, until the mixture is of a uniform, light blue color and the cheese evenly distributed throughout the mass. The mixture is transferred to a glass tube, of the kind used in butter analysis (249), only a larger size; a little copper sulfate is placed at the bottom of the tube, then the mixture containing the cheese, and on top of it, a little extracted absorbent cotton or ignited, stringy asbestos; the tube is placed in an extraction apparatus and extracted with anhydrous ether for 15 hours. The ether is then distilled off, the flasks dried in a water oven at 100° C, to constant weight, cooled and weighed. The method is apt to

give too low results and, therefore, not to be preferred to the Babcock test for cheese (91).

261. c. Casein (total nitrogen $\times 6.25$). About 2 grams of cheese are weighed out on a watch glass and transferred to a Jena nitrogen flask, and the nitrogen in the sample determined according to the Kjeldahl method; the percentage of nitrogen multiplied by 6.25 gives the total nitrogenous components of the cheese.

262. d. Ash. The residue from the water determination is taken for the ash; it is preferably set fire to, in the same manner as explained under determination of ash in butter (253), before it is placed in the muffle oven and incinerated. The increase in the weight above that of the empty dish + asbestos, gives the amount of ash in the sample weighed out.

263. e. Other constituents. The sum of the percentages of water, fat, casein and ash, subtracted from 100 will give the percent. of other constituents, organic acids, milk sugar, etc., in the cheese.

DETECTION OF OLEOMARGARINE CHEESE ("FILLED" CHEESE)

20 grams of cheese are extracted with ether in a Caldwell extractor or a paper extraction cartridge; the ether is distilled off, and the fat dried in the water oven until there is no further loss in weight. 5.75 cc. of the clear fat are then measured into a 250 cc. saponification flask and treated according to the Reichert-Wollny method, as already explained under *Detection of Artificial Butter* (255).

APPENDIX.

Table I. Composition of milk and its products.

	No. of analyses.	Water	Fat.	Casein and alb'men	Milk sugar.	Ash.	Authority.
		pr. ct	pr. ct.	pr. ct.	pr. ct.	pr. ct.	
Cows' milk.....	793	87.17	3.69	3.55	4.88	.71	Koenig.§
“ “		87.75	3.40	3.50	4.60	.75	Fleischmann.
“ “	900	87.40	3.75	3.10	5.10	.65	Van Slyke.
“ “	2173	86.48	4.20	3.51*	.....	‡ .71	Holland.||
“ “	120,540	87.1	4.1	.....	.....	.....	Vieth.
Colostrum milk	42	74.57	3.59	17.64†	2.67	1.56	Koenig.§
Cream.....	43	68.82	22.66	3.76	4.23	.53	“
Cream, Cooley.	203	73.90	17.60	.....	.....	.62	Holland.||
Skim milk, (gravity)	56	90.43	.87	3.26	4.74	.70	Koenig.§
Skim milk, (gravity)	354	90.52	.32	.....	.....	.....	Holland.||
Skim milk, (centrifugal)..	7	90.60	.31	3.06	5.29	.74	Koenig.§
Butter milk.....	57	90.12	1.09	4.03	4.04	.72	“
“ “	31	91.67	.27	.....	.....	.....	Holland.||
Whey	46	93.38	.32	.86	4.79	.65	Koenig.§
“ .....	.....	93.12	.27	.81	5.80	.....	Van Slyke.
Condensed milk (no sugar)....	36	58.99	12.42	11.92	14.49	2.18	Koenig.§
Condensed milk (sugar added)	64	25.61	10.35	11.79	50.06	2.19	“
Butter.....	302	13.59	84.39	.74	.50	.66	“
“ sweet cream	10	12.93	84.53	.61	.68	1.25	“
“ sour cream..	11	13.08	84.26	.81	.66	1.19	“
“ unsalted.....	78	13.73	84.82	1.36	.....	.09	“
“ World'sFair	350	11.57	84.70	.95	.....	2.78	Farrington.
“ American premium...	9	10.23	85.74	.96	.....	3.05	Morrow.
Cheese, cream..	27	36.33	40.71	18.84	1.02	3.10	Koenig.§
“ full cream.	143	38.00	30.25	25.35	1.43	4.97	“
“ cheddar, green.....	.....	36.84	33.83	23.72	5.61	.....	Van Slyke.
“ cheddar, cured.....	27	34.38	32.71	26.38	2.95	3.58	Drew.
“ Worl'sFair mammoth	1	32.06	34.43	28.00	5.51	.....	Shutt.
“ half skim..	21	39.79	23.92	29.67	1.79	4.73	Koenig.§
“ skim.....	41	46.00	11.65	34.06	3.42	4.87	“
“ centrifugal skim.....	.....	50.5	1.2	43.1	.....	5.2	Storch.

* 42 analyses. † 8 analyses. ‡ 13.60 percent albumen.

§ Mostly European samples. || Massachusetts samples.

Table II. Milk standards.

	Solids.	Fat.	Solids not fat.	Law or Ordinance of
	Percent.	Percent.	Percent.	
Maine.....	12.0	3.0	[9.0]	1893,255
New Hampshire.....	13.0			1883
Vermont.....	12.5	[3.25]	9.25	1888,108
in May and June.....	12.0	3.0	[9.0]	
Massachusetts.....	13.0	[3.7]	9.3	1886,318
in May and June.....	12.0			
skimmed milk.....			9.3	1885,252
Rhode Island.....	12.0	2.5	[9.5]	
New York.....	12.0	3.0	[9.0]	1893,338
New Jersey.....	12.0			1882,82
Pennsylvania *.....	12.5	3.0	[9.5]	1885,106
District of Columbia.....	12.0	3.0	[9.0]	
Georgia.....	12.0	3.5	[8.5]	
South Carolina.....	11.5	3.0	[8.5]	
Ohio.....	12.5	3.0	[9.5]	1889,86
Michigan†.....	12.5	3.0	[9.5]	1889,219
Wisconsin.....		3.0		1889,425
Minnesota‡.....	13.0	3.5	[9.5]	1889,247
Iowa.....		3.0		1892,50
Oregon‡.....	12.5	3.2	[9.3]	1893
Washington.....		3.0		
City of Chicago.....	12.0	3.0	[9.0]	1892
" St. Louis.....	12.0	2.8	[9.2]	
" cream.....	22.0	12.0	[10.0]	1887
" Omaha.....	12.0	3.0	[9.0]	1893
" cream.....		16.0		
" Denver.....	12.0			1893
England.....	[11.5]	2.5	9.0	
Germany §.....		2.7		

* Specific gravity, 1.029 — 1.033 at 60° F.

† Cheese, 40 percent fat in solids.

‡ Butter, 14 percent. water.

§ Specific gravity, 1.029 at 15° C.

Table III. Quevenne lactometer degrees corresponding to N. Y. Board of Health lactometer degrees.
(See p. 83).

Bd. of Health degrees.	Quevenne scale.	Bd. of Health degrees.	Quevenne scale.	Bd. of Health degrees.	Quevenne scale.
60	17.4	81	23.5	101	29.3
61	17.7	82	23.8	102	29.6
62	18.0	83	24.1	103	29.9
63	18.3	84	24.4	104	30.2
64	18.6	85	26.6	105	30.5
65	18.8	86	24.9	106	30.7
66	19.1	87	25.2	107	31.0
67	19.4	88	25.5	108	31.3
68	19.7	89	25.8	109	31.6
69	20.0	90	26.1	110	31.9
70	29.3	91	26.4	111	32.2
71	20.6	92	26.7	112	32.5
72	20.9	93	27.0	113	32.8
73	21.2	94	27.3	114	33.1
74	21.5	95	27.6	115	33.4
75	21.7	96	27.8	116	33.6
76	22.0	97	28.1	117	33.9
77	22.3	98	28.4	118	34.2
78	22.6	99	28.7	119	34.5
79	22.9	100	29.0	120	34.8
80	23.2				

Table IV. Correction table for specific gravity of milk.

Lactometer reading.	Temperature of milk (in degrees Fahrenheit).									
	51	52	53	54	55	56	57	58	59	60
20	19.3	19.4	19.4	19.5	19.6	19.7	19.8	19.9	19.9	20.0
21	20.3	20.3	20.4	20.5	20.6	20.7	20.8	20.9	20.9	21.0
22	21.3	21.3	21.4	21.5	21.6	21.7	21.8	21.9	21.9	22.0
23	22.3	22.3	22.4	22.5	22.6	22.7	22.8	22.8	22.9	23.0
24	23.3	23.3	23.4	23.5	23.6	23.6	23.7	23.8	23.9	24.0
25	24.2	24.3	24.4	24.5	24.6	24.6	24.7	24.8	24.9	25.0
26	25.2	25.2	25.3	25.4	25.5	25.6	25.7	25.8	25.9	26.0
27	26.2	26.2	26.3	26.4	26.5	26.6	26.7	26.8	26.9	27.0
28	27.1	27.2	27.3	27.4	27.5	27.6	27.7	27.8	27.9	28.0
29	28.1	28.2	28.3	28.4	28.5	28.6	28.7	28.8	28.9	29.0
30	29.1	29.1	29.2	29.3	29.4	29.6	29.7	29.8	29.9	30.0
31	30.0	30.1	30.2	30.3	30.4	30.5	30.6	30.8	30.9	31.0
32	31.0	31.1	31.2	31.3	31.4	31.5	31.6	31.7	31.9	32.0
33	31.9	32.0	32.1	32.3	32.4	32.5	32.6	32.7	32.9	33.0
34	32.9	33.0	33.1	33.2	33.3	33.5	33.6	33.7	33.9	34.0
35	33.8	33.9	34.0	34.2	34.3	34.5	34.6	34.7	34.9	35.0
	61	62	63	64	65	66	67	68	69	70
20	20.1	20.2	20.2	20.3	20.4	20.5	20.6	20.7	20.9	21.0
21	21.1	21.2	21.3	21.4	21.5	21.6	21.7	21.8	22.0	22.1
22	22.1	22.2	22.3	22.4	22.5	22.6	22.7	22.8	23.0	23.1
23	23.1	23.2	23.3	23.4	23.5	23.6	23.7	23.8	24.0	24.1
24	24.1	24.2	24.3	24.4	24.5	24.6	24.7	24.9	25.0	25.1
25	25.1	25.2	25.3	25.4	25.5	25.6	25.7	25.9	26.0	26.1
26	26.1	26.2	26.3	26.5	26.6	26.7	26.8	27.0	27.1	27.2
27	27.1	27.3	27.4	27.5	27.6	27.7	27.8	28.0	28.1	28.2
28	28.1	28.3	28.4	28.5	28.6	28.7	28.8	29.0	29.1	29.2
29	29.1	29.3	29.4	29.5	29.6	29.7	29.9	30.1	30.2	30.3
30	30.1	30.3	30.4	30.5	30.7	30.8	30.9	31.1	31.2	31.3
31	31.2	31.3	31.4	31.5	31.7	31.8	31.9	32.1	32.2	32.4
32	32.2	32.3	32.5	32.6	32.7	32.9	33.0	33.2	33.3	33.4
33	33.2	33.3	33.5	33.6	33.8	33.9	34.0	34.2	34.3	34.5
34	34.2	34.3	34.5	34.6	34.8	34.9	35.0	35.2	35.3	35.5
35	35.2	35.3	35.5	35.6	35.8	35.9	36.1	36.2	36.4	36.5

DIRECTIONS.—Bring the temperature of the milk to within 10° from 60° F. Take the reading of the lactometer and that of the temperature of the milk; find the former in the first vertical column of the table and the latter in the first horizontal row of figures; the figure where the horizontal and vertical columns meet is the corrected lactometer reading; e. g., observed, 31.0 at 67° F; corrected reading, 31.9.

Table V. Percent of solids not fat, corresponding to 0 to 6 percent. of fat, and lactometer readings of 26 to 36. (See p. 85).

Percent. of fat.	LACTOMETER READINGS AT 60° F.											Percent. of fat.
	26	27	28	29	30	31	32	33	34	35	36	
0	6.50	6.75	7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	0
0.1	6.52	6.77	7.02	7.27	7.52	7.77	8.02	8.27	8.52	8.77	9.02	0.1
0.2	6.54	6.79	7.04	7.29	7.54	7.79	8.04	8.29	8.54	8.79	9.04	0.2
0.3	6.56	6.81	7.06	7.31	7.56	7.81	8.06	8.31	8.56	8.81	9.06	0.3
0.4	6.58	6.83	7.08	7.33	7.58	7.83	8.08	8.33	8.58	8.83	9.08	0.4
0.5	6.60	6.85	7.10	7.35	7.60	7.85	8.10	8.35	8.60	8.85	9.10	0.5
0.6	6.62	6.87	7.12	7.37	7.62	7.87	8.12	8.37	8.62	8.87	9.12	0.6
0.7	6.64	6.89	7.14	7.39	7.64	7.89	8.14	8.39	8.64	8.89	9.14	0.7
0.8	6.66	6.91	7.16	7.41	7.66	7.91	8.16	8.41	8.66	8.91	9.16	0.8
0.9	6.68	6.93	7.18	7.43	7.68	7.93	8.18	8.43	8.68	8.93	9.18	0.9
1.0	6.70	6.95	7.20	7.45	7.70	7.95	8.20	8.45	8.70	8.95	9.20	1.0
1.1	6.72	6.97	7.22	7.47	7.72	7.97	8.22	8.47	8.72	8.97	9.22	1.1
1.2	6.74	6.99	7.24	7.49	7.74	7.99	8.24	8.49	8.74	8.99	9.24	1.2
1.3	6.76	7.01	7.26	7.51	7.76	8.01	8.26	8.51	8.76	9.01	9.26	1.3
1.4	6.78	7.03	7.28	7.53	7.78	8.03	8.28	8.53	8.78	9.03	9.28	1.4
1.5	6.80	7.05	7.30	7.55	7.80	8.05	8.30	8.55	8.80	9.05	9.30	1.5
1.6	6.82	7.07	7.32	7.57	7.82	8.07	8.32	8.57	8.82	9.07	9.32	1.6
1.7	6.84	7.09	7.34	7.59	7.84	8.09	8.34	8.59	8.84	9.09	9.34	1.7
1.8	6.86	7.11	7.36	7.61	7.86	8.11	8.36	8.61	8.86	9.11	9.37	1.8
1.9	6.88	7.13	7.38	7.63	7.88	8.13	8.38	8.63	8.88	9.13	9.39	1.9
2.0	6.90	7.15	7.40	7.65	7.90	8.15	8.40	8.66	8.91	9.16	9.41	2.0
2.1	6.92	7.17	7.42	7.67	7.92	8.17	8.42	8.68	8.93	9.18	9.43	2.1
2.2	6.94	7.19	7.44	7.69	7.94	8.19	8.44	8.70	8.95	9.20	9.45	2.2
2.3	6.96	7.21	7.46	7.71	7.96	8.21	8.46	8.72	8.97	9.22	9.47	2.3
2.4	6.98	7.23	7.48	7.73	7.98	8.23	8.48	8.74	8.99	9.24	9.49	2.4
2.5	7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.76	9.01	9.26	9.51	2.5
2.6	7.02	7.27	7.52	7.77	8.02	8.27	8.52	8.78	9.03	9.28	9.53	2.6
2.7	7.04	7.29	7.54	7.79	8.04	8.29	8.54	8.80	9.05	9.30	9.55	2.7
2.8	7.06	7.31	7.56	7.81	8.06	8.31	8.57	8.82	9.07	9.32	9.57	2.8
2.9	7.08	7.33	7.58	7.83	8.08	8.33	8.59	8.84	9.09	9.34	9.59	2.9

Table V. Percent. of solids not fat (*Continued*)

Percent. of fat.	LACTOMETER READINGS AT 60° F.											Percent. of fat.
	26	27	28	29	30	31	32	33	34	35	36	
3.0	7.10	7.35	7.60	7.85	8.10	8.36	8.61	8.86	9.11	9.36	9.61	3.0
3.1	7.12	7.37	7.62	7.87	8.13	8.38	8.63	8.88	9.13	9.38	9.64	3.1
3.2	7.14	7.39	7.64	7.89	8.15	8.40	8.65	8.90	9.15	9.41	9.66	3.2
3.3	7.16	7.41	7.66	7.92	8.17	8.42	8.67	8.92	9.18	9.43	9.68	3.3
3.4	7.18	7.43	7.69	7.94	8.19	8.44	8.69	8.94	9.20	9.45	9.70	3.4
3.5	7.20	7.45	7.71	7.96	8.21	8.46	8.71	8.96	9.22	9.47	9.72	3.5
3.6	7.22	7.48	7.73	7.98	8.23	8.48	8.73	8.98	9.24	9.49	9.74	3.6
3.7	7.24	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.26	9.51	9.76	3.7
3.8	7.26	7.52	7.77	8.02	8.27	8.52	8.77	9.02	9.28	9.53	9.78	3.8
3.9	7.28	7.54	7.79	8.04	8.29	8.54	8.79	9.04	9.30	9.55	9.80	3.9
4.0	7.30	7.56	7.81	8.06	8.31	8.56	8.81	9.06	9.32	9.57	9.83	4.0
4.1	7.32	7.58	7.83	8.08	8.33	8.58	8.83	9.08	9.34	9.59	9.85	4.1
4.2	7.34	7.60	7.85	8.10	8.35	8.60	8.85	9.11	9.36	9.62	9.87	4.2
4.3	7.36	7.62	7.87	8.12	8.37	8.62	8.88	9.13	9.38	9.64	9.89	4.3
4.4	7.38	7.64	7.89	8.14	8.39	8.64	8.90	9.15	9.40	9.66	9.91	4.4
4.5	7.40	7.66	7.91	8.16	8.41	8.66	8.92	9.17	9.42	9.68	9.93	4.5
4.6	7.43	7.68	7.93	8.18	8.43	8.68	8.94	9.19	9.44	9.70	9.95	4.6
4.7	7.45	7.70	7.95	8.20	8.45	8.70	8.96	9.21	9.46	9.72	9.97	4.7
4.8	7.47	7.72	7.97	8.22	8.47	8.72	8.98	9.23	9.48	9.74	9.99	4.8
4.9	7.49	7.74	7.99	8.24	8.49	8.74	9.00	9.25	9.50	9.76	10.01	4.9
5.0	7.51	7.76	8.01	8.26	8.51	8.76	9.02	9.27	9.52	9.78	10.03	5.0
5.1	7.53	7.78	8.03	8.28	8.53	8.79	9.04	9.29	9.54	9.80	10.05	5.1
5.2	7.55	7.80	8.05	8.30	8.55	8.81	9.06	9.31	9.56	9.82	10.07	5.2
5.3	7.57	7.82	8.07	8.32	8.57	8.83	9.08	9.33	9.58	9.84	10.09	5.3
5.4	7.59	7.84	8.09	8.34	8.60	8.85	9.10	9.36	9.61	9.86	10.11	5.4
5.5	7.61	7.86	8.11	8.36	8.62	8.87	9.12	9.38	9.63	9.88	10.13	5.5
5.6	7.63	7.88	8.13	8.39	8.64	8.89	9.15	9.40	9.65	9.90	10.15	5.6
5.7	7.65	7.90	8.15	8.41	8.66	8.91	9.17	9.42	9.67	9.92	10.17	5.7
5.8	7.67	7.92	8.17	8.43	8.68	8.94	9.19	9.44	9.69	9.94	10.19	5.8
5.9	7.69	7.94	8.20	8.45	8.70	8.96	9.21	9.46	9.71	9.96	10.22	5.9
6.0	7.71	7.96	8.22	8.47	8.72	8.98	9.23	9.48	9.73	9.98	10.24	6.0

Directions for Use of Tables VI, VII, and IX.

TABLE VI. Find the test of the milk in the first or last horizontal row of figures; the amounts of fat in ten thousand, thousands, hundreds, tens, and units of pounds of milk are then given in this vertical column. By adding the corresponding figures in any given quantity of milk, the total quantity of butter fat contained therein is obtained.

Example. How many pounds of fat is contained in 8925 lbs. of milk testing 3.65 percent? On p. 213, second column the test 3.65 is found, and by going downward in this column we have:

8000 lbs	292. lbs.
900 "	32.9 "
20 "	.7 "
5 "	.2 "
<hr/>	
8925 lbs. of milk.	325.8 lbs. of fat.

8925 lbs. of milk testing 3.65 percent, therefore, contains 325.8 lbs. of butter fat.

TABLE VII. The price per pound is given in the outside vertical columns, and the weight of butter fat in the upper and lower horizontal row of figures. The corresponding tens of pounds are found by moving the decimal point one place to the left; the units, by moving it two, and the tenths of a pound, by moving it three places to the left. The use of the table is, otherwise, as explained above.

Example. How much money is due for 325.8 lbs. of butter fat, at $15\frac{1}{2}$ cents per pound? In the horizontal row of figures beginning with $15\frac{1}{2}$, we find:

300 lbs	\$ 46.50
20 "	3.10
5 "	.77
.8 "	.12
<hr/>	
325.8 lbs.	\$50.49

325.8 lbs. of butter fat at $15\frac{1}{2}$ cents per pound, therefore, is worth \$50.49.

TABLE IX. Find the test of milk in the upper or lower horizontal row of figures. The amount of butter likely to be made from ten thousand, thousands, hundreds, tens, and units of pounds of milk are then given in this vertical column. The use of the table is, otherwise, as explained above in case of table VI.

Example. How much butter will 5845 lbs. of milk testing 3.8 percent be apt to make under good creamery conditions? In the column headed 3.8, we find:

5000 lbs	209.0 lbs.
800 "	33.4 "
40 "	1.7 "
5 "	.2 "
<hr/>	
5845 lbs.	244.3 lbs.

5845 lbs. of milk testing 3.8 percent of fat will make about 244.3 lbs. of butter, under conditions similar to those explained on pp. 168-69 of the present work.

Table VI. Lbs. of fat in 1 to 10,000 lbs. of milk, testing 3.0 to 5.35 percent. (See p. 211).

Test.	3.00	3.05	3.10	3.15	3.20	3.25	3.30	3.35	3.40	3.45	3.50	3.55	Test.
Milk lbs.													Milk lbs.
10,000	300	305	310	315	320	325	330	335	340	345	350	355	10,000
9,000	270	275	279	284	289	293	297	302	306	311	315	320	9,000
8,000	240	244	248	252	256	260	264	268	272	276	280	284	8,000
7,000	210	214	217	221	224	228	231	235	238	242	245	249	7,000
6,000	180	183	186	189	192	195	198	201	204	207	210	213	6,000
5,000	150	153	155	158	160	163	165	168	170	173	175	178	5,000
4,000	120	122	124	126	128	130	132	134	136	138	140	142	4,000
3,000	90.0	91.5	93.0	94.5	96.0	97.5	99.0	101	102	104	105	107	3,000
2,000	60.0	61.0	62.0	63.0	64.0	65.0	66.0	67.0	68.0	69.0	70.0	71.0	2,000
1,000	30.0	30.5	31.0	31.5	32.0	32.5	33.0	33.5	34.0	34.5	35.0	35.5	1,000
900	27.0	27.5	27.9	28.4	28.8	29.3	29.7	30.2	30.6	31.1	31.5	32.0	900
800	24.0	24.4	24.8	25.2	25.7	26.0	26.4	26.8	27.2	27.6	28.0	28.4	800
700	21.0	21.4	21.7	22.1	22.4	22.8	23.1	23.5	23.8	24.2	24.5	24.9	700
600	18.0	18.3	18.6	18.9	19.2	19.5	19.8	20.1	20.4	20.7	21.0	21.3	600
500	15.0	15.3	15.5	15.8	16.0	16.3	16.5	16.8	17.0	17.3	17.5	17.8	500
400	12.0	12.2	12.4	12.6	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.2	400
300	9.0	9.2	9.3	9.5	9.6	9.8	9.9	10.1	10.2	10.4	10.5	10.7	300
200	6.0	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7.0	7.1	200
100	3.0	3.1	3.1	3.2	3.2	3.3	3.3	3.4	3.4	3.5	3.5	3.6	100
90	2.7	2.8	2.8	2.8	2.9	2.9	3.0	3.0	3.1	3.1	3.2	3.2	90
80	2.4	2.4	2.5	2.5	2.6	2.6	2.6	2.7	2.7	2.8	2.8	2.8	80
70	2.1	2.1	2.2	2.2	2.2	2.3	2.3	2.3	2.4	2.4	2.5	2.5	70
60	1.8	1.8	1.9	1.9	1.9	2.0	2.0	2.0	2.0	2.1	2.1	2.1	60
50	1.5	1.5	1.6	1.6	1.6	1.6	1.7	1.7	1.7	1.7	1.8	1.8	50
40	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.3	1.4	1.4	1.4	1.4	40
30	.9	.9	.9	.9	1.0	1.0	1.0	1.0	1.0	1.0	1.1	1.1	30
20	.6	.6	.6	.6	.6	.7	.7	.7	.7	.7	.7	.7	20
10	.3	.3	.3	.3	.3	.3	.3	.3	.3	.3	.4	.4	10
9	.3	.3	.3	.3	.3	.3	.3	.3	.3	.3	.3	.3	9
8	.2	.2	.2	.3	.3	.3	.3	.3	.3	.3	.3	.3	8
7	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	7
6	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	6
5	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	5
4	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	4
3	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	3
2	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	2
1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1
Test.	3.00	3.05	3.10	3.15	3.20	3.25	3.30	3.35	3.40	3.45	3.50	3.55	Test.

Table VI. Lbs. of fat in 1 to 10,000 lbs. of milk (Continued)

Test.	3.60	3.65	3.70	3.75	3.80	3.85	3.90	3.95	4.00	4.05	4.10	4.15	Test.
Milk lbs.													Milk lbs.
10,000	360	365	370	375	380	385	390	395	400	405	410	415	10,000
9,000	324	329	333	338	342	347	351	356	360	365	369	374	9,000
8,000	288	292	296	300	304	308	312	316	320	324	328	332	8,000
7,000	252	256	259	263	266	270	273	277	280	284	287	291	7,000
6,000	216	219	222	225	228	231	234	237	240	243	246	249	6,000
5,000	180	183	185	188	190	193	195	198	200	203	205	208	5,000
4,000	144	146	148	150	152	154	156	158	160	162	164	166	4,000
3,000	108	110	111	113	114	116	117	119	120	122	123	125	3,000
2,000	72.0	73.0	74.0	75.0	76.0	77.0	78.0	79.0	80.0	81.0	82.0	83.0	2,000
1,000	36.0	36.5	37.0	37.5	38.0	38.5	39.0	39.5	40.0	40.5	41.0	41.5	1,000
900	32.4	32.9	33.3	33.8	34.2	34.7	35.1	35.6	36.0	36.5	36.9	37.4	900
800	28.8	29.2	29.6	30.0	30.4	30.8	31.2	31.6	32.0	32.4	32.8	33.2	800
700	25.2	25.6	25.9	26.3	26.6	27.0	27.3	27.7	28.0	28.4	28.7	29.1	700
600	21.6	21.9	22.2	22.5	22.8	23.1	23.4	23.7	24.0	24.3	24.6	24.9	600
500	18.0	18.3	18.5	18.8	19.0	19.3	19.5	19.8	20.0	20.3	20.5	20.8	500
400	14.4	14.6	14.8	15.0	15.2	15.4	15.6	15.8	16.0	16.2	16.4	16.6	400
300	10.8	11.0	11.1	11.3	11.4	11.6	11.7	11.9	12.0	12.2	12.3	12.5	300
200	7.2	7.3	7.4	7.5	7.6	7.7	7.8	7.9	8.0	8.1	8.2	8.3	200
100	3.6	3.7	3.7	3.8	3.8	3.9	3.9	4.0	4.0	4.1	4.1	4.2	100
90	3.2	3.3	3.3	3.4	3.4	3.5	3.5	3.6	3.6	3.7	3.7	3.7	90
80	2.9	2.9	3.0	3.0	3.0	3.1	3.1	3.2	3.2	3.2	3.3	3.3	80
70	2.5	2.6	2.6	2.6	2.7	2.7	2.7	2.8	2.8	2.8	2.9	2.9	70
60	2.2	2.2	2.2	2.3	2.3	2.3	2.3	2.4	2.4	2.4	2.5	2.5	60
50	1.8	1.8	1.9	1.9	1.9	1.9	2.0	2.0	2.0	2.0	2.1	2.1	50
40	1.4	1.5	1.5	1.5	1.5	1.5	1.6	1.6	1.6	1.6	1.6	1.7	40
30	1.1	1.1	1.1	1.1	1.1	1.2	1.2	1.2	1.2	1.2	1.2	1.2	30
20	.7	.7	.7	.8	.8	.8	.8	.8	.8	.8	.8	.8	20
10	.4	.4	.4	.4	.4	.4	.4	.4	.4	.4	.4	.4	10
9	.3	.3	.3	.3	.3	.3	.4	.4	.4	.4	.4	.4	9
8	.3	.3	.3	.3	.3	.3	.3	.3	.3	.3	.3	.3	8
7	.3	.3	.3	.3	.3	.3	.3	.3	.3	.3	.3	.3	7
6	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	6
5	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	5
4	.1	.1	.1	.2	.2	.2	.2	.2	.2	.2	.2	.2	4
3	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	3
2	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	2
1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1
Test.	3.60	3.65	3.70	3.75	3.80	3.85	3.90	3.95	4.00	4.05	4.10	4.15	Test.

Table VI. Lbs. of fat in 1 to 10,000 lbs. of milk (Continued)

Test.	4.20	4.25	4.30	4.35	4.40	4.45	4.50	4.55	4.60	4.65	4.70	4.75	Test.
Milk lbs.													Milk lbs.
10,000	420	425	430	435	440	445	450	455	460	465	470	475	10,000
9,000	378	383	387	392	396	401	405	410	414	419	423	428	9,000
8,000	336	340	344	348	352	356	360	364	368	372	376	380	8,000
7,000	294	298	301	305	308	312	315	319	322	326	329	333	7,000
6,000	252	255	258	261	264	267	270	273	276	279	282	285	6,000
5,000	210	213	215	218	220	223	225	228	230	233	235	238	5,000
4,000	168	170	172	174	176	178	180	182	184	186	188	190	4,000
3,000	126	128	129	131	132	134	135	137	138	140	141	143	3,000
2,000	84.0	85.0	86.0	87.0	88.0	89.0	90.0	91.0	92.0	93.0	94.0	95.0	2,000
1,000	42.0	42.5	43.0	43.5	44.0	44.5	45.0	45.5	46.0	46.5	47.0	47.5	1,000
900	37.8	38.3	38.7	39.2	39.6	40.1	40.5	41.0	41.4	41.9	42.3	42.8	900
800	33.6	34.0	34.4	34.8	35.2	35.6	36.0	36.4	36.8	37.2	37.6	38.0	800
700	29.4	29.8	30.1	30.5	30.8	31.2	31.5	31.9	32.2	32.6	32.9	33.3	700
600	25.2	25.5	25.8	26.1	26.4	26.7	27.0	27.3	27.6	27.9	28.2	28.5	600
500	21.0	21.3	21.5	21.8	22.0	22.3	22.5	22.8	23.0	23.3	23.5	23.8	500
400	16.8	17.0	17.2	17.4	17.6	17.8	18.0	18.2	18.4	18.6	18.8	19.0	400
300	12.6	12.8	12.9	13.1	13.2	13.4	13.5	13.7	13.8	14.0	14.1	14.3	300
200	8.4	8.5	8.6	8.7	8.8	8.9	9.0	9.1	9.2	9.3	9.4	9.5	200
100	4.2	4.3	4.3	4.4	4.4	4.5	4.5	4.6	4.6	4.7	4.7	4.8	100
90	3.8	3.8	3.9	3.9	4.0	4.0	4.1	4.1	4.1	4.2	4.2	4.3	90
80	3.4	3.4	3.4	3.5	3.5	3.6	3.6	3.6	3.7	3.7	3.8	3.8	80
70	2.9	3.0	3.0	3.0	3.1	3.1	3.2	3.2	3.2	3.3	3.3	3.3	70
60	2.5	2.6	2.6	2.6	2.6	2.7	2.7	2.7	2.8	2.8	2.8	2.9	60
50	2.1	2.1	2.2	2.2	2.2	2.2	2.3	2.3	2.3	2.3	2.4	2.4	50
40	1.7	1.7	1.7	1.7	1.8	1.8	1.8	1.8	1.8	1.9	1.9	1.9	40
30	1.3	1.3	1.3	1.3	1.3	1.3	1.4	1.4	1.4	1.4	1.4	1.4	30
20	.8	.9	.9	.9	.9	.9	.9	.9	.9	.9	9	1.0	20
10	.4	.4	.4	.4	.4	.4	.5	.5	.5	.5	.5	.5	10
9	.4	.4	.4	.4	.4	.4	.4	.4	.4	.4	.4	.4	9
8	.3	.3	.3	.3	.4	.4	.4	.4	.4	.4	.4	.4	8
7	.3	.3	.3	.3	.3	.3	.3	.3	.3	.3	.3	.3	7
6	.3	.3	.3	.3	.3	.3	.3	.3	.3	.3	.3	.3	6
5	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	5
4	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	4
3	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	3
2	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	2
1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1
Test.	4.20	4.25	4.30	4.35	4.40	4.45	4.50	4.55	4.60	4.65	4.70	4.75	Test.

Table VI. Lbs. of fat in 1 to 10,000 lbs. of milk (*Continued*)

Test.	4.80	4.85	4.90	4.95	5.00	5.05	5.10	5.15	5.20	5.25	5.30	5.35	Test.
Milk lbs.													Milk lbs.
10,000	480	485	490	495	500	505	510	515	520	525	530	535	10,000
9,000	432	437	441	446	450	455	459	464	468	473	477	482	9,000
8,000	384	388	392	396	400	404	408	412	416	420	422	428	8,000
7,000	336	340	343	347	350	354	357	361	364	368	371	375	7,000
6,000	288	291	294	297	300	303	306	309	312	315	318	321	6,000
5,000	240	243	245	248	250	243	255	258	260	263	265	268	5,000
4,000	192	194	196	198	200	202	204	206	208	210	212	214	4,000
3,000	144	146	147	149	150	152	153	155	156	158	159	161	3,000
2,000	96.0	97.0	98.0	99.0	100	101	102	103	104	105	106	107	2,000
1,000	48.0	48.5	49.0	49.5	50.0	50.5	51.0	51.5	52.0	52.5	53.0	53.5	1,000
900	43.2	43.7	44.1	44.6	45.0	45.5	45.7	46.4	46.8	47.3	47.7	48.2	900
800	38.4	38.8	39.2	39.6	40.0	40.4	40.8	41.2	41.6	42.0	42.4	42.8	800
700	33.6	34.0	34.3	34.7	35.0	35.4	35.7	36.1	36.4	36.8	37.1	37.5	700
600	28.8	29.1	29.4	29.7	30.0	30.3	30.6	30.9	31.2	31.5	31.8	32.1	600
500	24.0	24.3	24.5	24.8	25.0	25.3	25.5	25.8	26.0	26.3	26.5	26.8	500
400	19.2	19.4	19.6	19.8	20.0	20.2	20.4	20.6	20.8	21.0	21.2	21.4	400
300	14.4	14.6	14.7	14.9	15.0	15.2	15.3	15.5	15.6	15.8	15.9	16.1	300
200	9.6	9.7	9.8	9.9	10.0	10.1	10.2	10.3	10.4	10.5	10.6	10.7	200
100	4.8	4.9	4.9	5.0	5.0	5.1	5.1	5.2	5.2	5.3	5.3	5.4	100
90	4.3	4.4	4.4	4.5	4.5	4.5	4.6	4.6	4.7	4.7	4.8	4.8	90
80	3.8	3.9	3.9	4.0	4.0	4.0	4.1	4.1	4.2	4.2	4.2	4.3	80
70	3.4	3.4	3.4	3.5	3.5	3.5	3.6	3.6	3.6	3.7	3.7	3.7	70
60	2.9	2.9	2.9	3.0	3.0	3.0	3.1	3.1	3.1	3.2	3.2	3.2	60
50	2.4	2.4	2.5	2.5	2.5	2.5	2.6	2.6	2.6	2.6	2.7	2.7	50
40	1.9	1.9	2.0	2.0	2.0	2.0	2.0	2.1	2.1	2.1	2.1	2.1	40
30	1.4	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.6	1.6	1.6	1.6	30
20	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.1	1.1	1.1	20
10	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	.5	10
9	.4	.4	.4	.4	.5	.5	.5	.5	.5	.5	.5	.5	9
8	.4	.4	.4	.4	.4	.4	.4	.4	.4	.4	.4	.4	8
7	.3	.3	.3	.3	.4	.4	.4	.4	.4	.4	.4	.4	7
6	.3	.3	.3	.3	.3	.3	.3	.3	.3	.3	.3	.3	6
5	.2	.2	.2	.2	.3	.3	.3	.3	.3	.3	.3	.3	5
4	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	4
3	.1	.1	.1	.1	.2	.2	.2	.2	.2	.2	.2	.2	3
2	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	2
1	.....	.....	.....	.....	.1	.1	.1	.1	.1	.1	.1	.1	1
Test.	4.80	4.85	4.90	4.95	5.00	5.05	5.10	5.15	5.20	5.25	5.30	5.35	Test.

Table VII. Amount due for butter fat, in dollars and cents, at 12 to 25 cents per pound.

Price per pound, cents.	Pounds of butter fat.										Price per pound, cents.
	1, 000	900	800	700	600	500	400	300	200	100	
	\$	\$	\$	\$	\$	\$	\$	\$	\$	\$	
12	120.00	108.00	96.00	84.00	72.00	60.00	48.00	36.00	24.00	12.00	12
12 $\frac{1}{4}$	122.50	110.25	98.00	85.75	73.50	61.25	49.00	36.75	24.50	12.25	12 $\frac{1}{4}$
12 $\frac{1}{2}$	125.00	112.50	100.00	87.50	75.00	62.50	50.00	37.50	25.00	12.50	12 $\frac{1}{2}$
12 $\frac{3}{4}$	127.50	114.75	102.00	89.25	76.50	63.75	51.00	38.25	25.50	12.75	12 $\frac{3}{4}$
13	130.00	117.00	104.00	91.00	78.00	65.00	52.00	39.00	26.00	13.00	13
13 $\frac{1}{4}$	132.50	119.25	106.00	92.75	79.50	66.25	53.00	39.75	26.50	13.25	13 $\frac{1}{4}$
13 $\frac{1}{2}$	135.00	121.50	108.00	94.50	81.00	67.50	54.00	40.50	27.00	13.50	13 $\frac{1}{2}$
13 $\frac{3}{4}$	137.50	123.75	110.00	96.25	82.50	68.75	55.00	41.25	27.50	13.75	13 $\frac{3}{4}$
14	140.00	126.00	112.00	98.00	84.00	70.00	56.00	42.00	28.00	14.00	14
14 $\frac{1}{4}$	142.50	128.25	114.00	99.75	85.50	71.25	57.00	42.75	28.50	14.25	14 $\frac{1}{4}$
14 $\frac{1}{2}$	145.00	130.50	116.00	101.50	87.00	72.50	58.00	43.50	29.00	14.50	14 $\frac{1}{2}$
14 $\frac{3}{4}$	147.50	132.75	118.00	103.25	88.50	73.75	59.00	44.25	29.50	14.75	14 $\frac{3}{4}$
15	150.00	135.00	120.00	105.00	90.00	75.00	60.00	45.00	30.00	15.00	15
15 $\frac{1}{4}$	152.50	137.25	122.00	106.75	91.50	76.25	61.00	45.75	30.50	15.25	15 $\frac{1}{4}$
15 $\frac{1}{2}$	155.00	139.50	124.00	108.50	93.00	77.50	62.00	46.50	31.00	15.50	15 $\frac{1}{2}$
15 $\frac{3}{4}$	157.50	141.75	126.00	110.25	94.50	78.75	63.00	47.25	31.50	15.75	15 $\frac{3}{4}$
16	160.00	144.00	128.00	112.00	96.00	80.00	64.00	48.00	32.00	16.00	16
16 $\frac{1}{4}$	162.50	146.25	130.00	113.75	97.50	81.25	65.00	48.75	32.50	16.25	16 $\frac{1}{4}$
16 $\frac{1}{2}$	165.00	148.50	132.00	115.50	99.00	82.50	66.00	49.50	33.00	16.50	16 $\frac{1}{2}$
16 $\frac{3}{4}$	167.50	150.75	134.00	117.25	100.50	83.75	67.00	50.25	33.50	16.75	16 $\frac{3}{4}$
17	170.00	153.00	136.00	119.00	102.00	85.00	68.00	51.00	34.00	17.00	17
17 $\frac{1}{4}$	172.50	155.25	138.00	120.75	103.50	86.25	69.00	51.75	34.50	17.25	17 $\frac{1}{4}$
17 $\frac{1}{2}$	175.00	157.50	140.00	122.50	105.00	87.50	70.00	52.50	35.00	17.50	17 $\frac{1}{2}$
17 $\frac{3}{4}$	177.50	159.75	142.00	124.25	106.50	87.75	71.00	53.25	35.50	17.75	17 $\frac{3}{4}$
18	180.00	162.00	144.00	126.00	108.00	90.00	72.00	54.00	36.00	18.00	18
18 $\frac{1}{4}$	182.50	164.25	146.00	127.75	109.50	91.25	73.00	54.75	36.50	18.25	18 $\frac{1}{4}$
18 $\frac{1}{2}$	185.00	166.50	148.00	129.50	111.00	92.50	74.00	55.50	37.00	18.50	18 $\frac{1}{2}$
18 $\frac{3}{4}$	187.50	168.75	150.00	131.25	112.50	93.75	75.00	56.25	37.50	18.75	18 $\frac{3}{4}$
	1, 000	900	800	700	600	500	400	300	200	100	

Table VII. Amount due for butter fat (*Continued.*)

Price per pound, cents.	Pounds of butter fat.										Price per pound, cents.
	1,000	900	800	700	600	500	400	300	200	100	
	\$	\$	\$	\$	\$	\$	\$	\$	\$	\$	
19	190.00	171.00	152.00	133.00	114.00	95.00	76.00	57.00	38.00	19.00	19
19 $\frac{1}{4}$	192.50	173.25	154.00	134.75	115.50	96.25	77.00	57.75	38.50	19.25	19 $\frac{1}{4}$
19 $\frac{1}{2}$	195.00	175.50	156.00	136.50	117.00	97.50	78.00	58.50	39.00	19.50	19 $\frac{1}{2}$
19 $\frac{3}{4}$	197.50	177.75	158.00	138.25	118.50	98.75	79.00	59.25	39.50	19.75	19 $\frac{3}{4}$
20	200.00	180.00	160.00	140.00	120.00	100.00	80.00	60.00	40.00	20.00	20
20 $\frac{1}{4}$	202.50	182.25	162.00	141.75	121.50	101.25	81.00	60.75	40.50	20.25	20 $\frac{1}{4}$
20 $\frac{1}{2}$	205.00	184.50	164.00	143.50	123.00	102.50	82.00	61.50	41.00	20.50	20 $\frac{1}{2}$
20 $\frac{3}{4}$	207.50	186.75	166.00	145.25	124.50	103.75	83.00	62.25	41.50	20.75	20 $\frac{3}{4}$
21	210.00	189.00	168.00	147.00	126.00	105.00	84.00	63.00	42.00	21.00	21
21 $\frac{1}{4}$	212.50	191.25	170.00	148.75	127.50	106.25	85.00	63.75	42.50	21.25	21 $\frac{1}{4}$
21 $\frac{1}{2}$	215.00	193.50	172.00	150.50	129.00	107.50	86.00	64.50	43.00	21.50	21 $\frac{1}{2}$
21 $\frac{3}{4}$	217.50	195.75	174.00	152.25	130.50	108.75	87.00	65.25	43.50	21.75	21 $\frac{3}{4}$
22	220.00	198.00	176.00	154.00	132.00	110.00	88.00	66.00	44.00	22.00	22
22 $\frac{1}{4}$	222.50	200.25	178.00	155.75	133.50	111.25	89.00	66.75	44.50	22.25	22 $\frac{1}{4}$
22 $\frac{1}{2}$	225.00	202.50	180.00	157.50	135.00	112.50	90.00	67.50	45.00	22.50	22 $\frac{1}{2}$
22 $\frac{3}{4}$	227.50	204.75	182.00	159.25	136.50	113.75	91.00	68.25	45.50	22.75	22 $\frac{3}{4}$
23	230.00	207.00	184.00	161.00	138.00	115.00	92.00	69.00	46.00	23.00	23
23 $\frac{1}{4}$	232.50	209.25	186.00	162.75	139.50	116.25	93.00	69.75	46.50	23.25	23 $\frac{1}{4}$
23 $\frac{1}{2}$	235.00	211.50	188.00	164.50	141.00	117.50	94.00	70.50	47.00	23.50	23 $\frac{1}{2}$
23 $\frac{3}{4}$	237.50	213.75	190.00	166.25	142.50	118.75	95.00	71.25	47.50	23.75	23 $\frac{3}{4}$
24	240.00	216.00	192.00	168.00	144.00	120.00	96.00	72.00	48.00	24.00	24
24 $\frac{1}{4}$	242.50	218.25	194.00	169.75	145.50	121.25	97.00	72.75	48.50	24.50	24 $\frac{1}{4}$
24 $\frac{1}{2}$	245.00	220.50	196.00	171.50	147.00	122.50	98.00	73.50	49.00	24.50	24 $\frac{1}{2}$
24 $\frac{3}{4}$	247.50	222.75	198.00	173.25	148.50	123.75	99.00	74.25	49.50	24.75	24 $\frac{3}{4}$
25	250.00	225.00	200.00	175.00	150.00	125.00	100.00	75.00	50.00	25.00	25
	1,000	900	800	700	600	500	400	300	200	100	

(For directions for use, see page 211).

Table VIII. Relative value tables.

(For directions for use, see pp. 180-81).

Percent. fat.	PRICE OF MILK PER 100 POUNDS, IN DOLLARS AND CENTS.										
3.0	.30	.31	.33	.34	.36	.37	.39	.40	.42	.43	.45
3.1	.31	.33	.34	.36	.37	.39	.40	.42	.43	.45	.46
3.2	.32	.34	.35	.37	.38	.40	.42	.43	.45	.46	.48
3.3	.33	.35	.36	.38	.40	.41	.43	.45	.46	.48	.49
3.4	.34	.36	.37	.39	.41	.42	.44	.46	.48	.49	.51
3.5	.35	.37	.38	.40	.42	.44	.45	.47	.49	.51	.52
3.6	.36	.38	.40	.41	.43	.45	.47	.49	.50	.52	.54
3.7	.37	.39	.41	.43	.44	.46	.48	.50	.52	.54	.55
3.8	.38	.40	.42	.44	.46	.47	.49	.51	.53	.55	.57
3.9	.39	.41	.43	.45	.47	.49	.51	.53	.55	.57	.58
4.0	.40	.42	.44	.46	.48	.50	.52	.54	.56	.58	.60
4.1	.41	.43	.45	.47	.49	.51	.53	.55	.57	.59	.61
4.2	.42	.44	.46	.48	.50	.52	.55	.57	.59	.61	.63
4.3	.43	.45	.47	.49	.52	.54	.56	.58	.60	.62	.64
4.4	.44	.46	.48	.51	.53	.55	.57	.59	.62	.64	.66
4.5	.45	.47	.49	.52	.54	.56	.58	.61	.63	.65	.67
4.6	.46	.48	.51	.53	.55	.57	.60	.62	.64	.67	.69
4.7	.47	.49	.52	.54	.56	.59	.61	.63	.66	.68	.70
4.8	.48	.50	.53	.55	.58	.60	.62	.65	.67	.70	.72
4.9	.49	.51	.54	.56	.59	.61	.64	.66	.69	.71	.73
5.0	.50	.52	.55	.57	.60	.62	.65	.67	.70	.72	.75
5.1	.51	.54	.56	.59	.61	.64	.66	.69	.71	.74	.76
5.2	.52	.55	.57	.60	.62	.65	.68	.70	.73	.75	.78
5.3	.53	.56	.58	.61	.64	.66	.69	.72	.74	.77	.79
5.4	.54	.57	.59	.62	.65	.67	.70	.73	.76	.78	.81
5.5	.55	.58	.60	.63	.66	.69	.71	.74	.77	.80	.82
5.6	.56	.59	.62	.64	.67	.70	.73	.76	.78	.81	.84
5.7	.57	.60	.63	.66	.68	.71	.74	.77	.80	.83	.85
5.8	.58	.61	.64	.67	.70	.72	.75	.78	.81	.84	.87
5.9	.59	.62	.65	.68	.71	.74	.77	.80	.83	.86	.88
6.0	.60	.63	.66	.69	.72	.75	.78	.81	.84	.87	.90

Table VIII. Relative value tables (*Continued*).

Percent. fat.	PRICE OF MILK PER 100 POUNDS, IN DOLLARS AND CENTS.									
3.0	.46	.48	.49	.51	.52	.54	.55	.57	.58	.60
3.1	.48	.50	.51	.53	.54	.56	.57	.59	.60	.62
3.2	.50	.51	.53	.54	.56	.58	.59	.61	.62	.64
3.3	.51	.53	.54	.56	.58	.59	.61	.63	.64	.66
3.4	.53	.54	.56	.58	.59	.61	.63	.65	.66	.68
3.5	.54	.56	.58	.59	.61	.63	.65	.66	.68	.70
3.6	.56	.58	.59	.61	.63	.65	.67	.68	.70	.72
3.7	.57	.59	.61	.63	.65	.67	.68	.70	.72	.74
3.8	.59	.61	.63	.65	.66	.68	.70	.72	.74	.76
3.9	.60	.62	.64	.66	.68	.70	.72	.74	.76	.78
4.0	.62	.64	.66	.68	.70	.72	.74	.76	.78	.80
4.1	.64	.66	.68	.70	.72	.74	.76	.78	.80	.82
4.2	.65	.67	.69	.71	.73	.76	.78	.80	.82	.84
4.3	.67	.69	.71	.73	.75	.77	.80	.82	.84	.86
4.4	.68	.70	.73	.75	.77	.79	.81	.84	.86	.88
4.5	.70	.72	.74	.76	.79	.81	.83	.85	.88	.90
4.6	.71	.74	.76	.78	.80	.83	.85	.87	.90	.92
4.7	.73	.75	.78	.80	.82	.85	.87	.89	.92	.94
4.8	.74	.77	.79	.82	.84	.86	.89	.91	.94	.96
4.9	.76	.78	.81	.83	.86	.88	.91	.93	.96	.98
5.0	.77	.80	.82	.85	.87	.90	.92	.95	.97	1.00
5.1	.79	.82	.84	.87	.89	.92	.94	.97	.99	1.02
5.2	.81	.83	.86	.88	.91	.94	.96	.99	1.01	1.04
5.3	.83	.85	.87	.90	.93	.95	.98	1.01	1.03	1.06
5.4	.84	.86	.89	.92	.94	.97	1.00	1.03	1.05	1.08
5.5	.85	.88	.91	.93	.96	.99	1.02	1.04	1.07	1.10
5.6	.87	.90	.92	.95	.98	1.01	1.04	1.06	1.09	1.12
5.7	.88	.91	.94	.97	1.00	1.03	1.05	1.08	1.11	1.14
5.8	.90	.93	.96	.99	1.01	1.04	1.07	1.10	1.13	1.16
5.9	.91	.94	.97	1.00	1.03	1.06	1.09	1.12	1.15	1.18
6.0	.93	.96	.99	1.02	1.05	1.08	1.11	1.14	1.17	1.20

Table VIII. Relative value tables (Continued).

Percent. fat.	PRICE OF MILK PER 100 POUNDS, IN DOLLARS AND CENTS.									
3.0	.61	.63	.64	.66	.67	.69	.70	.72	.73	.75
3.1	.64	.65	.67	.68	.70	.71	.73	.74	.76	.78
3.2	.66	.67	.69	.70	.72	.74	.75	.77	.78	.80
3.3	.68	.69	.71	.73	.74	.76	.78	.79	.81	.83
3.4	.70	.71	.73	.75	.76	.78	.80	.82	.83	.85
3.5	.72	.73	.75	.77	.79	.80	.82	.84	.86	.88
3.6	.74	.76	.77	.79	.81	.83	.85	.86	.88	.90
3.7	.76	.78	.80	.81	.83	.85	.87	.89	.91	.93
3.8	.78	.80	.82	.84	.85	.87	.89	.91	.93	.95
3.9	.80	.82	.84	.86	.88	.90	.92	.94	.96	.98
4.0	.82	.84	.86	.88	.90	.92	.94	.96	.98	1.00
4.1	.84	.86	.88	.90	.92	.94	.96	.98	1.00	1.03
4.2	.86	.88	.90	.92	.94	.97	.99	1.01	1.03	1.05
4.3	.88	.90	.92	.95	.97	.99	1.01	1.03	1.05	1.08
4.4	.90	.92	.95	.97	.99	1.01	1.03	1.06	1.08	1.10
4.5	.92	.94	.97	.99	1.01	1.03	1.06	1.08	1.10	1.13
4.6	.94	.97	.99	1.01	1.03	1.06	1.08	1.10	1.13	1.15
4.7	.96	.99	1.01	1.03	1.06	1.08	1.10	1.13	1.15	1.18
4.8	.98	1.01	1.03	1.06	1.08	1.10	1.13	1.15	1.18	1.20
4.9	1.00	1.03	1.05	1.08	1.10	1.13	1.15	1.18	1.20	1.23
5.0	1.02	1.05	1.07	1.10	1.12	1.15	1.18	1.20	1.23	1.25
5.1	1.05	1.07	1.10	1.12	1.15	1.17	1.20	1.22	1.25	1.27
5.2	1.07	1.09	1.12	1.14	1.17	1.20	1.22	1.25	1.27	1.30
5.3	1.09	1.11	1.14	1.17	1.19	1.22	1.25	1.27	1.30	1.32
5.4	1.11	1.13	1.16	1.19	1.21	1.24	1.27	1.30	1.32	1.35
5.5	1.13	1.15	1.18	1.21	1.24	1.26	1.29	1.32	1.35	1.38
5.6	1.15	1.18	1.20	1.23	1.26	1.29	1.32	1.34	1.37	1.40
5.7	1.17	1.20	1.23	1.25	1.28	1.31	1.34	1.37	1.39	1.43
5.8	1.19	1.22	1.25	1.28	1.30	1.33	1.36	1.39	1.42	1.45
5.9	1.21	1.24	1.27	1.30	1.33	1.36	1.39	1.42	1.45	1.48
6.0	1.23	1.26	1.29	1.32	1.35	1.38	1.41	1.44	1.47	1.50

Table VIII. Relative value tables (*Continued*)

Percent. fat.	PRICE OF MILK PER 100 POUNDS, IN DOLLARS AND CENTS.									
3.0	.76	.78	.79	.81	.82	.84	.85	.87	.88	.90
3.1	.79	.81	.82	.84	.85	.87	.88	.90	.91	.93
3.2	.82	.83	.85	.86	.88	.90	.91	.93	.94	.96
3.3	.84	.86	.87	.89	.91	.92	.94	.96	.97	.99
3.4	.87	.88	.90	.92	.93	.95	.97	.99	1.00	1.02
3.5	.89	.91	.93	.94	.96	.98	1.00	1.01	1.03	1.05
3.6	.92	.94	.95	.97	.99	1.00	1.03	1.04	1.06	1.08
3.7	.94	.96	.98	1.00	1.02	1.03	1.05	1.07	1.09	1.11
3.8	.97	.99	1.01	1.03	1.04	1.06	1.08	1.10	1.12	1.14
3.9	.99	1.01	1.03	1.05	1.07	1.09	1.11	1.13	1.15	1.17
4.0	1.02	1.04	1.06	1.08	1.10	1.12	1.14	1.16	1.18	1.20
4.1	1.05	1.07	1.09	1.11	1.13	1.15	1.17	1.19	1.21	1.23
4.2	1.07	1.09	1.11	1.13	1.15	1.18	1.20	1.22	1.24	1.26
4.3	1.10	1.12	1.14	1.16	1.18	1.20	1.23	1.25	1.27	1.29
4.4	1.12	1.14	1.17	1.19	1.21	1.23	1.25	1.28	1.30	1.32
4.5	1.15	1.17	1.19	1.21	1.24	1.26	1.28	1.30	1.33	1.35
4.6	1.17	1.20	1.22	1.24	1.26	1.29	1.31	1.33	1.36	1.38
4.7	1.20	1.22	1.25	1.27	1.29	1.32	1.34	1.36	1.39	1.41
4.8	1.22	1.25	1.27	1.30	1.32	1.34	1.37	1.39	1.42	1.44
4.9	1.25	1.27	1.30	1.32	1.35	1.37	1.40	1.42	1.45	1.47
5.0	1.27	1.30	1.32	1.35	1.37	1.40	1.42	1.45	1.47	1.50
5.1	1.30	1.33	1.35	1.38	1.40	1.43	1.45	1.48	1.50	1.53
5.2	1.33	1.35	1.37	1.40	1.43	1.46	1.48	1.51	1.53	1.56
5.3	1.35	1.38	1.40	1.43	1.46	1.48	1.51	1.54	1.56	1.59
5.4	1.38	1.40	1.43	1.46	1.48	1.51	1.54	1.57	1.59	1.62
5.5	1.40	1.43	1.46	1.48	1.51	1.54	1.57	1.60	1.62	1.65
5.6	1.43	1.46	1.48	1.51	1.54	1.57	1.60	1.62	1.65	1.68
5.7	1.45	1.48	1.51	1.54	1.57	1.60	1.62	1.65	1.68	1.71
5.8	1.48	1.51	1.54	1.57	1.59	1.62	1.65	1.68	1.71	1.74
5.9	1.50	1.53	1.56	1.59	1.62	1.65	1.68	1.71	1.74	1.77
6.0	1.53	1.56	1.59	1.62	1.65	1.68	1.71	1.74	1.77	1.80

Table IX. Butter chart, showing calculated yield of butter (in lbs.) from 1 to 10,000 lbs. of milk, testing 3.0 to 5.3 per cent. (See directions for use, p. 211).

Test.	3.00	3.10	3.20	3.30	3.40	3.50	3.60	3.70	3.80	3.90	4.00	4.10	Test.
Milk lbs.													Milk lbs.
10,000	325	336	348	360	371	383	394	406	418	429	441	452	10,000
9,000	293	302	313	324	334	345	355	365	376	386	397	407	9,000
8,000	260	269	278	288	297	306	315	325	334	343	353	362	8,000
7,000	228	235	244	252	260	268	276	284	293	300	309	316	7,000
6,000	195	202	209	216	223	230	236	244	251	257	265	271	6,000
5,000	163	168	174	180	186	192	197	203	209	215	221	226	5,000
4,000	130	134	139	144	148	153	158	162	167	172	176	181	4,000
3,000	97.5	101	104	108	111	115	118	122	125	129	132	136	3,000
2,000	65.0	67.2	69.6	72.0	74.2	76.6	78.8	81.2	83.6	85.8	88.2	90.4	2,000
1,000	32.5	33.6	34.8	36.0	37.1	38.3	39.4	40.6	41.8	43.9	44.1	45.2	1,000
900	29.3	30.2	31.3	32.4	33.4	34.5	35.5	36.5	37.6	38.6	39.7	40.7	900
800	26.0	26.9	27.8	28.8	29.7	30.6	31.5	32.5	33.4	34.3	35.3	36.2	800
700	22.8	23.5	24.4	25.2	26.0	26.8	27.6	28.4	29.3	30.0	30.9	31.6	700
600	19.5	20.2	20.9	21.6	22.3	23.0	23.6	24.4	25.1	25.7	26.5	27.1	600
500	16.3	16.8	17.4	18.0	18.6	19.2	19.7	20.3	20.9	21.5	22.1	22.6	500
400	13.0	13.4	13.9	14.4	14.8	15.3	15.8	16.2	16.7	17.2	17.6	18.1	400
300	9.7	10.1	10.4	10.8	11.1	11.5	11.8	12.2	12.5	12.9	13.2	13.6	300
200	6.5	6.7	6.9	7.2	7.4	7.6	7.9	8.1	8.3	8.6	8.8	9.0	200
100	3.2	3.4	3.5	3.6	3.7	3.8	3.9	4.1	4.2	4.3	4.4	4.5	100
90	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.1	90
80	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.4	3.5	3.6	80
70	2.3	2.3	2.4	2.5	2.6	2.7	2.8	2.8	2.9	3.0	3.1	3.2	70
60	1.9	2.0	2.1	2.2	2.2	2.3	2.4	2.4	2.5	2.6	2.7	2.7	60
50	1.6	1.7	1.7	1.8	1.9	1.9	2.0	2.0	2.1	2.2	2.2	2.3	50
40	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.6	1.7	1.7	1.8	1.8	40
30	1.0	1.0	1.0	1.1	1.1	1.2	1.2	1.2	1.3	1.3	1.3	1.4	30
20	.6	.7	.7	.7	.7	.8	.8	.8	.8	.9	.9	.9	20
10	.3	.3	.4	.4	.4	.4	.4	.4	.4	.4	.4	.5	10
9	.3	.3	.3	.3	.3	.3	.4	.4	.4	.4	.4	.4	9
8	.3	.3	.3	.3	.3	.3	.3	.3	.3	.3	.4	.4	8
7	.2	.2	.2	.3	.3	.3	.3	.3	.3	.3	.3	.3	7
6	.2	.2	.2	.2	.2	.2	.2	.2	.3	.3	.3	.3	6
5	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	5
4	.1	.1	.1	.2	.2	.2	.2	.2	.2	.2	.2	.2	4
3	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	3
2	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	2
1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1
Test.	3.00	3.10	3.20	3.30	3.40	3.50	3.60	3.70	3.80	3.90	4.00	4.10	Test.

Table IX. Butter chart (Continued).

Test.	4.20	4.30	4.40	4.50	4.60	4.70	4.80	4.90	5.00	5.10	5.20	5.30	Test.
Milk lbs.													Milk lbs.
10,000	464	476	487	499	510	522	534	545	557	568	580	592	10,000
9,000	418	428	438	449	459	470	481	491	501	511	522	533	9,000
8,000	371	381	390	399	408	418	427	436	446	454	464	474	8,000
7,000	325	333	341	349	357	365	374	382	390	398	406	414	7,000
6,000	278	286	292	299	306	313	320	327	334	341	348	355	6,000
5,000	232	238	244	250	255	261	267	273	279	284	290	296	5,000
4,000	186	190	195	200	204	209	214	218	223	227	232	237	4,000
3,000	139	143	146	150	153	157	160	164	167	170	174	178	3,000
2,000	92.8	95.2	97.4	99.8	102	104	107	109	111	114	116	118	2,000
1,000	46.4	47.6	48.7	49.9	51.0	52.2	53.4	54.5	55.7	56.8	58.0	59.2	1,000
900	41.8	42.8	43.8	44.9	45.9	47.0	48.1	49.1	50.1	51.1	52.2	53.3	900
800	37.1	38.1	39.0	39.9	40.8	41.8	42.7	43.6	44.6	45.4	46.4	47.4	800
700	32.5	33.3	34.1	34.9	35.7	36.5	37.4	38.2	39.0	39.8	40.6	41.4	700
600	27.8	28.6	29.2	29.9	30.6	31.3	32.0	32.7	33.4	34.1	34.8	35.5	600
500	23.2	23.8	24.4	25.0	25.5	26.1	26.7	27.3	27.9	28.4	29.0	29.6	500
400	18.6	19.0	19.5	20.0	20.4	20.9	21.4	21.8	22.3	22.7	23.2	23.7	400
300	13.9	14.3	14.6	15.0	15.3	15.7	16.0	16.4	16.7	17.0	17.4	17.8	300
200	9.3	9.5	9.7	10.0	10.2	10.4	10.7	10.9	11.1	11.4	11.6	11.8	200
100	4.6	4.8	4.9	5.0	5.1	5.2	5.3	5.5	5.6	5.7	5.8	5.9	100
90	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.2	5.3	90
80	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5	4.5	4.6	4.7	80
70	3.3	3.3	3.4	3.5	3.6	3.7	3.7	3.8	3.9	4.0	4.1	4.1	70
60	2.8	2.9	2.9	3.0	3.1	3.1	3.2	3.3	3.3	3.4	3.5	3.6	60
50	2.3	2.4	2.4	2.5	2.6	2.6	2.7	2.7	2.8	2.8	2.9	3.0	50
40	1.9	1.9	2.0	2.0	2.0	2.1	2.1	2.2	2.2	2.3	2.3	2.4	40
30	1.4	1.4	1.5	1.5	1.5	1.6	1.6	1.6	1.7	1.7	1.7	1.8	30
20	.9	1.0	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.2	1.2	20
10	.5	.5	.5	.5	.5	.5	.5	.6	.6	.6	.6	.6	10
9	.4	.4	.4	.5	.5	.5	.5	.5	.5	.5	.5	.5	9
8	.4	.4	.4	.4	.4	.4	.4	.4	.5	.5	.5	.5	8
7	.3	.3	.3	.4	.4	.4	.4	.4	.4	.4	.4	.4	7
6	.3	.3	.3	.3	.3	.3	.3	.3	.3	.3	.4	.4	6
5	.2	.2	.2	.3	.3	.3	.3	.3	.3	.3	.3	.3	5
4	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	4
3	.1	.1	.2	.2	.2	.2	.2	.2	.2	.2	.2	.2	3
2	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	2
1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	1
Test.	4.20	4.30	4.40	4.50	4.60	4.70	4.80	4.90	5.00	5.10	5.20	5.30	Test.

Table X. Overrun table, showing pounds of butter from one hundred lbs. of milk. See directions for use, p. 170.

Per cent. fat.	1.10	1.11	1.12	1.13	1.14	1.15	1.16	1.17	1.18	1.19	1.20	Per cent. fat.
3.0	3.30	3.33	3.36	3.39	3.42	3.45	3.48	3.51	3.54	3.57	3.60	3.0
3.1	3.41	3.44	3.47	3.50	3.53	3.57	3.60	3.63	3.66	3.68	3.72	3.1
3.2	3.52	3.55	3.58	3.62	3.65	3.68	3.71	3.74	3.78	3.81	3.84	3.2
3.3	3.63	3.66	3.70	3.73	3.76	3.80	3.83	3.86	3.89	3.93	3.96	3.3
3.4	3.74	3.77	3.81	3.84	3.88	3.91	3.94	3.98	4.01	4.05	4.08	3.4
3.5	3.85	3.89	3.92	3.96	3.99	4.03	4.06	4.10	4.13	4.17	4.20	3.5
3.6	3.96	4.00	4.03	4.07	4.10	4.14	4.18	4.21	4.25	4.28	4.32	3.6
3.7	4.07	4.11	4.14	4.18	4.22	4.26	4.29	4.33	4.37	4.40	4.44	3.7
3.8	4.18	4.22	4.26	4.29	4.33	4.37	4.41	4.45	4.48	4.52	4.56	3.8
3.9	4.29	4.33	4.37	4.41	4.45	4.49	4.52	4.56	4.60	4.64	4.68	3.9
4.0	4.40	4.44	4.48	4.52	4.56	4.60	4.64	4.68	4.72	4.76	4.80	4.0
4.1	4.51	4.55	4.59	4.63	4.67	4.72	4.76	4.80	4.84	4.88	4.92	4.1
4.2	4.62	4.66	4.70	4.75	4.79	4.83	4.87	4.91	4.96	5.00	5.04	4.2
4.3	4.73	4.77	4.82	4.86	4.90	4.95	4.99	5.03	5.07	5.12	5.16	4.3
4.4	4.84	4.88	4.93	4.97	5.02	5.06	5.10	5.15	5.19	5.24	5.28	4.4
4.5	4.95	5.00	5.04	5.09	5.13	5.18	5.22	5.27	5.31	5.36	5.40	4.5
4.6	5.06	5.11	5.15	5.20	5.24	5.29	5.34	5.38	5.43	5.47	5.52	4.6
4.7	5.17	5.22	5.26	5.31	5.36	5.41	5.45	5.49	5.55	5.59	5.64	4.7
4.8	5.28	5.33	5.38	5.42	5.47	5.52	5.57	5.62	5.66	5.71	5.76	4.8
4.9	5.39	5.44	5.49	5.54	5.59	5.64	5.68	5.73	5.78	5.83	5.88	4.9
5.0	5.50	5.55	5.60	5.65	5.70	5.75	5.80	5.85	5.90	5.95	6.00	5.0
5.1	5.61	5.66	5.71	5.76	5.81	5.87	5.92	5.97	6.02	6.07	6.12	5.1
5.2	5.72	5.77	5.82	5.88	5.93	5.98	6.03	6.08	6.14	6.19	6.24	5.2
5.3	5.83	5.88	5.94	5.99	6.04	6.10	6.15	6.20	6.25	6.31	6.36	5.3
5.4	5.94	5.99	6.05	6.10	6.16	6.21	6.26	6.32	6.37	6.43	6.48	5.4
5.5	6.05	6.11	6.16	6.22	6.27	6.33	6.38	6.44	6.49	6.55	6.60	5.5
5.6	6.16	6.22	6.27	6.33	6.38	6.44	6.50	6.55	6.61	6.66	6.72	5.6
5.7	6.27	6.33	6.38	6.44	6.50	6.56	6.61	6.67	6.73	6.78	6.84	5.7
5.8	6.38	6.44	6.50	6.55	6.61	6.67	6.73	6.79	6.84	6.90	6.96	5.8
5.9	6.49	6.55	6.61	6.67	6.73	6.79	6.84	6.90	6.96	7.02	7.08	5.9
6.0	6.60	6.66	6.72	6.78	6.84	6.90	6.96	7.02	7.08	7.14	7.20	6.0

Table XI. Yield of cheese, corresponding to 2.5 to 6 percent of fat with lactometer readings 26 to 36. (See p. 172).

Percent of fat.	LACTOMETER DEGREES.											Percent of fat.
	26	27	28	29	30	31	32	33	34	35	36	
2.5	7.28	7.41	7.54	7.67	7.81	7.94	8.07	8.20	8.33	8.47	8.60	2.5
2.6	7.44	7.57	7.70	7.83	7.96	8.09	8.22	8.35	8.49	8.62	8.76	2.6
2.7	7.59	7.72	7.85	7.99	8.12	8.25	8.38	8.51	8.64	8.77	8.91	2.7
2.8	7.74	7.87	8.00	8.14	8.27	8.40	8.53	8.67	8.80	8.94	9.07	2.8
2.9	7.90	8.03	8.16	8.30	8.34	8.56	8.69	8.82	8.95	9.09	9.22	2.9
3.0	8.05	8.18	8.31	8.45	8.58	8.71	8.81	8.97	9.11	9.24	9.37	3.0
3.1	8.21	8.34	8.47	8.60	8.74	8.87	9.00	9.13	9.26	9.39	9.53	3.1
3.2	8.36	8.49	8.62	8.75	8.89	9.02	9.15	9.28	9.42	9.55	9.68	3.2
3.3	8.52	8.65	8.78	8.91	9.05	9.18	9.31	9.44	9.57	9.70	9.84	3.3
3.4	8.67	8.80	8.93	9.06	9.20	9.33	9.46	9.59	9.73	9.86	9.99	3.4
3.5	8.82	8.96	9.09	9.22	9.35	9.48	9.62	9.75	9.88	10.01	10.15	3.5
3.6	8.98	9.11	9.24	9.37	9.50	9.63	9.77	9.90	10.03	10.17	10.30	3.6
3.7	9.13	9.26	9.39	9.52	9.65	9.78	9.92	10.05	10.19	10.32	10.46	3.7
3.8	9.29	9.42	9.55	9.68	9.81	9.94	10.08	10.21	10.34	10.48	10.61	3.8
3.9	9.44	9.57	9.70	9.84	9.97	10.10	10.23	10.36	10.50	10.64	10.77	3.9
4.0	9.60	9.73	9.86	10.00	10.13	10.26	10.39	10.53	10.66	10.79	10.93	4.0
4.1	9.75	9.88	10.02	10.15	10.28	10.39	10.54	10.68	10.81	10.94	11.08	4.1
4.2	9.90	10.03	10.17	10.30	10.43	10.57	10.70	10.84	10.97	11.10	11.24	4.2
4.3	10.06	10.19	10.32	10.45	10.58	10.72	10.85	10.99	11.12	11.25	11.39	4.3
4.4	10.21	10.34	10.48	10.61	10.74	10.87	11.00	11.14	11.27	11.41	11.55	4.4
4.5	10.36	10.49	10.63	10.76	10.79	11.03	11.16	11.29	11.42	11.56	11.70	4.5
4.6	10.52	10.65	10.78	10.92	11.05	11.18	11.31	11.45	11.58	11.71	11.85	4.6
4.7	10.67	10.81	10.94	11.07	11.20	11.34	11.47	11.60	11.73	11.87	12.01	4.7
4.8	10.83	10.96	11.09	11.22	11.36	11.49	11.62	11.76	11.89	12.02	12.16	4.8
4.9	10.98	11.11	11.25	11.38	11.51	11.65	11.78	11.91	12.04	12.18	12.32	4.9
5.0	11.14	11.27	11.40	11.54	11.67	11.80	11.93	12.07	12.20	12.34	12.48	5.0
5.1	11.29	11.42	11.55	11.69	11.82	11.96	12.09	12.23	12.36	12.49	12.63	5.1
5.2	11.45	11.58	11.71	11.85	11.98	12.11	12.24	12.38	12.52	12.66	12.80	5.2
5.3	11.60	11.73	11.86	11.99	12.13	12.27	12.40	12.53	12.67	12.71	12.85	5.3
5.4	11.76	11.89	12.02	12.16	12.29	12.42	12.55	12.69	12.83	12.97	13.01	5.4
5.5	11.91	12.04	12.17	12.31	12.44	12.58	12.71	12.85	12.99	13.12	13.25	5.5
5.6	12.07	12.20	12.33	12.47	12.60	12.73	12.87	13.00	13.14	13.28	13.41	5.6
5.7	12.22	12.35	12.48	12.52	12.75	12.89	13.02	13.16	13.30	13.44	13.57	5.7
5.8	12.38	12.51	12.64	12.77	12.91	13.05	13.18	13.31	13.45	13.59	13.72	5.8
5.9	12.53	12.66	11.79	12.93	13.06	13.19	13.33	13.47	13.60	13.74	13.87	5.9
6.0	12.69	12.82	12.95	12.09	13.22	13.35	13.49	13.62	13.75	13.89	14.02	6.0

Table XII. Comparisons of Farenheit and centigrade (celsius) thermometer scales.

Fahren- heit.	Centi- grade.	Fahren- heit.	Centi- grade.	Fahren- heit.	Centi- grade.
+212	+100	+176	+80	+140	+60
211	99.44	175	79.44	139	59.44
210	98.89	174	78.89	138	58.89
209	98.33	173	78.33	137	58.33
208	97.78	172	77.78	136	57.78
207	97.22	171	77.22	135	57.22
206	96.67	170	76.67	134	56.67
205	96.11	169	76.11	133	56.11
204	95.55	168	75.55	132	55.55
203	95	167	75	131	55
202	94.44	166	74.44	130	54.44
201	93.89	165	73.89	129	53.89
200	93.33	164	72.83	128	53.33
199	92.78	163	72.78	127	52.78
198	92.22	162	71.22	126	52.22
197	91.67	161	71.67	125	51.67
196	91.11	160	71.11	124	51.11
195	90.55	159	70.55	123	50.55
194	90	158	70	122	50
193	89.44	157	69.44	121	49.44
192	88.89	156	68.89	120	48.89
191	88.33	155	68.33	119	48.33
190	87.78	154	67.78	118	47.78
189	87.22	153	67.22	117	47.22
188	86.67	152	66.67	116	46.67
187	86.11	151	66.11	115	46.11
186	85.55	150	65.55	114	45.55
185	85	149	65	113	45
184	84.44	148	64.44	112	44.44
183	83.89	147	63.89	111	43.89
182	83.33	146	63.33	110	43.33
181	82.78	145	62.78	109	42.78
180	82.22	144	62.22	108	42.22
179	81.67	143	61.67	107	41.67
178	81.11	142	61.11	106	41.11
177	80.55	141	60.55	105	40.55

Table XII. Comparisons of thermometer scales (*Continued*)

Fahren- heit.	Centi- grade.	Fahren- heit.	Centi- grade.	Fahren- heit.	Centi- grade.
+104	+40	+68	+20	+32	+0
103	39.44	67	19.44	31	—0.55
102	38.89	66	18.89	30	1.11
101	38.33	65	18.33	29	1.67
100	37.78	64	17.78	28	2.22
99	37.22	63	17.22	27	2.78
98	36.67	62	16.67	26	3.33
97	36.11	61	16.11	25	3.89
96	35.55	60	15.55	24	4.44
95	35	59	15	23	5
94	34.44	58	14.44	22	5.55
93	33.89	57	13.89	21	6.11
92	33.33	56	13.33	20	6.67
91	32.78	55	12.78	19	7.22
90	32.22	54	12.22	18	7.78
89	31.67	53	11.67	17	8.33
88	31.11	52	11.11	16	8.89
87	30.55	51	10.55	15	9.44
86	30	50	10	14	10
85	29.44	49	9.44	13	10.55
84	28.89	48	8.89	12	11.11
83	28.33	47	8.33	11	11.67
82	27.78	46	7.78	10	12.22
81	27.22	45	7.22	9	12.78
80	26.67	44	6.67	8	13.33
79	26.11	43	6.11	7	13.89
78	25.55	42	5.55	6	14.44
77	25	41	5	5	15.00
76	24.44	40	4.44	4	15.55
75	23.89	39	3.89	3	16.11
74	23.33	38	3.33	2	16.67
73	22.78	37	2.78	1	17.22
72	22.22	36	2.22	0	17.78
71	21.67	35	1.67	—1	18.33
70	21.11	34	1.11	2	18.89
69	20.55	33	0.55	3	19.44

To convert deg. Fahrenheit to corresponding deg. Centigrade :

Subtract 32, multiply difference by 5, and divide by 9.

Example : Which degree Centigrade corresponds to 110° F.? $110 - 32 = 78$;
 $78 \times 5 = 390$; $390 \div 9 = 43.33$.

To convert deg. Centigrade to corresponding deg. Fahrenheit :

Multiply by 9, divide product by 5, and add 32 to quotient.

Example : Which degree Fahrenheit corresponds to 95.5° C.? $95.5 \times 9 = 859.5$;
 $859.5 \div 5 = 171.9$; $171.9 + 32 = 203.6$.

Table XIII. Comparison of metric and customary weights and measures.

Customary weights and measures.	Equivalents in metric system.	Metric weights and measures.	Equivalents in customary system.
1 inch.....	2.54 centimeters.	1 meter.....	39.37 inches.
1 foot.....	.3048 meter.	1 meter.....	1.0936 yards.
1 mile.....	1.6094 kilometers.	1 kilometer.....	.6214 mile.
1 square inch.	6.452 sq. centimeters.	1 sq. centimeter.	.155 sq. inch.
1 square foot.	9.29 sq. decimeters.	1 square meter..	10.764 sq. feet.
1 square yard	.836 sq. meter.	1 square meter..	1.196 sq. yards.
1 acre.....	.4047 hectare.	1 hectare.....	2.471 acres.
1 cubic inch....	16.387 c. c.	1 c. c.....	.061 cubic inch.
1 cubic foot....	.0283 cub. meter.	1 cub. decimeter.	61.023 cubic inches.
1 cubic yard...	.765 cub. meter.	1 cub. meter.....	35.314 cub. feet.
1 bushel.....	.3525 hectoliter.	1 hectoliter.....	2.8377 bushels.
1 fluid ounce...	29.57 c. c.	1 c. c.....	.0338 fluid ounce.
1 quart.....	.9464 liter.	1 liter.....	1.0567 quarts.
1 gallon.....	3.7854 liters.	1 decaliter.....	2.6417 quarts.
1 grain.....	64.8 milligrams.	1 gram.....	15.43 grains.
1 ounce (av.)..	28.35 grams.	1 gram.....	.035274 ounce.
1 pound (av.)	.4536 kilogram.	1 kilogram.....	2.2046 pounds (av.)

SUGGESTIONS regarding the organization of co-operative creameries and cheese factories.

When the farmers of a neighborhood are considering the establishment of a creamery or cheese factory, they should first of all make an accurate canvas of the locality to ascertain the number of cows that can be depended on to supply the factory with milk. The area which may be drawn from, will vary according to the kind of factory which it is desired to operate. A successful separator creamery will need at least 400 cows within a radius of four to five miles from the proposed factory.* Small cheese factories can be operated with less milk, and gathered-cream and butter factories, generally cover a much larger territory than that mentioned.

In all cases, however, the question of the number of cows contributing to the enterprise must be fully settled before further steps are taken, since this is the vital point, and one upon which success will largely depend.

Methods of organization. The farmers should form their own organization, and not accept articles of agreement proposed by traveling agents. An agreement to supply milk from a stated number of cows should be signed by all who expect to join the association. When a sufficient number of cows has been pledged to insure the successful operation of a factory, the farmers agreeing to supply milk should meet and form an organization. This may be done according to either of the following plans which have been known to give good satisfaction.

Raising money for building and equipment.

First.— Each member will sign an agreement to pay on or before a given date for a certain number of shares or stock in the company at dollars per share; or,

Second.—An elected board of directors may be authorized to borrow a sum of money not exceeding thousand dollars on their individual responsibility, and the sum of cents, (usually five cents) per hundred pounds of milk received at the factory shall be reserved for the payment of this borrowed money.

* Bull. 56, Wisconsin experiment station.

Constitution and by-laws of co-operative associations are drawn up and signed by the prospective members of the association as soon as possible after it has been determined to form such an association. As it is impossible to include in an illustration all the articles and rules that may be found useful in each particular instance, the following suggestions in regard to some of the points to be included in the documents are given as a guide only. It may be found advisable to modify them in various ways to meet the needs of the organization to be formed.

After the constitution and by-laws have been drawn up and made plain to all the members of the association, they should be printed and copies distributed to all parties interested.

CONSTITUTION

OR

ARTICLES OF AGREEMENT OF THE ASSOCIATION.*

1. The undersigned, residents within the counties of....., state of....., hereby agree to become members of the..... co-operative association, which is formed for the purpose of manufacturing butter or cheese from whole milk.

2. The regular meetings of the association shall be held annually on the day of the month of Special meetings may be called by the president, or on written request of one-third of the members of the association, provided three days' notice of such meeting is sent to all members.

Meetings of the board of directors may be called in the same way, either by the president, or by any two members of the board of directors.

3. The members of the association, or three of the board of directors, shall constitute a quorum for the transaction of business.

4. The officers of the association shall include president, secretary, treasurer, one of whom is also elected manager, and these officers together with three other members of the association

* The following publications have been freely used in preparing this constitution and by-laws: Woll, Handbook f. Farmers and Dairymen; Minn. experiment station, bull. No. 35; Ontario Agricultural College, special bulletin, May 1897.

shall constitute the board of directors. Each of these six officers shall be elected at the annual meeting and hold office for one year, or until their successors have been elected and qualified. Any vacancies in the board of directors may be filled by the directors until the next annual meeting of the association.

5. The duties of the president shall be to preside at all meetings of the association, and perform the usual duties of such presiding officers. He shall sign all drafts and documents of any kind relating to the business of the association, and pay all money which comes into his possession by virtue of his office, to the treasurer, taking his receipt therefor. He shall call special meetings of the association whenever it is deemed necessary.

In the absence of the president, one of the board of directors shall temporarily fill the position.

6. The secretary shall attend all business meetings of the association and of the board of directors, and shall keep a careful record of the minutes of the meetings. He shall also give notices of all meetings and all appointments on committees, etc. He shall sign all papers issued, conduct the correspondence and general business of the association, and keep a correct financial account between the association and its members. He shall have charge of all property of the association, not otherwise disposed of, give bonds for the faithful performance of his duties, and receive such compensation for his services as the board of directors may determine.

7. The treasurer shall receive and give receipt for all money belonging to the association, and pay out the same upon orders signed by the president and the secretary. He shall give such bonds as the board of directors may require.

8. The board of directors shall audit the accounts of the association, invest its funds, appoint agents, and determine all compensations. They shall prescribe and enforce the rules and regulations of the factory. They shall cause to be kept a record of the weights and tests of the milk or cream received from each patron, the products sold, the running expenses, etc., and shall divide among the patrons the money due them each month. They shall

also make some provision for the withdrawal of any member from the association, and make a report in detail to the association at the annual meeting. Such report shall include the gross amount of milk handled during the year, the receipts from products sold, and all other receipts, the amount paid for milk, also for running expenses, and a complete statement of all other methods pertaining to the business association.

9. Among the rules and regulations to be enforced by the board of directors may be included some or all of the following:

a. Patrons shall furnish all the milk from all the cows promised at the organization of the association.

b. Only sweet and pure milk will be accepted at the factory, and any tainted or sour milk shall be refused.

c. The milk of each patron shall be tested at least three times a month.

d. Any patron proved to be guilty of watering, skimming or otherwise adulterating the milk sent to the factory, or by taking more than 80 pounds of skim milk or whey for every 100 pounds of whole milk delivered to the factory, shall be fined as agreed by the association.

e. A patron's premises may be inspected at any time by the board of directors, or their authorized agent, for the purpose of suggesting improvements in the methods of caring for the milk or the cows, in drainage and general cleanliness; or to secure samples of the milk of his cows for examination when it is deemed necessary.

10. Any changes or amendments to the by-laws or constitution of the association must be made in writing by the parties proposing the same, and posted prominently in a conspicuous place at the creamery at least two weeks previous to their being acted upon. Such changes to be in force must be adopted by a two-thirds vote of the stockholders.

11. In voting at any annual or special meeting of the association, the members shall be entitled to one vote for each cow supplying milk to the factory, or for each share of the stock owned by them, as agreed upon.

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