CREAMERY BUTTER-MAKING

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Creamery Class - Michigan Dairy School.

Creamery Butter Making

BY

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PREFACE.

The author's experience in teaching creamery students has demonstrated to him the need of a suitable reference book to be used in conjunction with the lectures on creamery butter making. An attempt to supply this need has resulted in the preparation of this work, which embodies the results of a long experience both as a practical butter maker and as a teacher of creamery management.

Special emphasis has been laid upon starters, pasteurized butter making, methods of creamery construction, and creamery mechanics, subjects which have usually been treated only in a very elementary way in similar publications that have appeared heretofore.

The historical side of the various phases of butter making has in the main been omitted, not because it was deemed uninteresting, but for fear of making this volume too bulky.

With the appended glossary explaining all unavoidable technical terms, this treatise is offered to the public as a suitable hand-book for the student as well as for the butter maker who cannot attend a dairy school.

JOHN MICHELS.

Michigan Agricultural College,
March, 1904.

INTRODUCTION.

The "rule of thumb" butter making days are gone by. No one at the present time can hold any important position in the profession of butter making unless thoroughly grounded in the principles that underlie it. It is true many obscure problems yet remain to be solved, but by the aid of the bacteriologist and chemist butter making has now been fairly placed upon a scientific basis.

Bacteriology has shed no less light upon the various processes involved in the manufacture of butter than it has upon the nature and causes of the diseases with which mankind is afflicted. The souring of milk, the ripening of cream, the causes of the various taints common to milk and cream are now quite thoroughly understood. Along with this understanding have come many radical changes in the handling of milk and cream and their manufacture into butter as well as in the handling of butter itself.

The best butter makers at the present time are the men who are the most diligent students of bacteria and their relation to butter making processes. Above their doors is written in emblazoned letters "Cleanliness is next to Godliness." For cleanliness is the foundation of success in butter making.

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CREAMERY BUTTER MAKING.

CHAPTER I.

MILK.

Milk, in a broad sense, may be defined as the normal secretion of the mammary glands of animals that suckle their young. It is the only food found in Nature containing all the elements necessary to sustain life. Moreover it contains these elements in the proper proportions and in easily digestible and assimilable form.

Designed by Nature to nourish the young, milk was originally used entirely for this purpose and secreted only a short time after parturition. For many centuries, however, it has been used as an important part of the human dietary and cows at the present time yield milk almost incessantly. Because of its nutritive qualities its use as a dietetic is rapidly increasing.

Physical Properties. Milk is a whitish opaque fluid possessing a sweetish taste and a faint odor suggestive of cow's breath. It has an amphoteric reaction, that is,

Weigh can showing gate opener.

it is both acid and alkaline. This double reaction is due largely to acid and alkaline salts and possibly to small quantities of organic acids.

Milk has an average normal specific gravity of 1.032, with extremes rarely exceeding 1.029 and 1.033. After standing a few moments it loses its homogenous character. Evidence of this we have in the "rising of the cream." This is due to the fact that milk is not a perfect solution but an *emulsion*. All of the fat, the larger portion of the casein, and part of the ash are in suspension.

In consistency milk is slightly more viscous than water, the viscosity increasing with the decrease in temperature. It is also exceedingly sensitive to odors, possessing great absorption properties. This teaches the necessity of placing milk in clean pure surroundings.

Chemical Composition. The composition of milk is very complex and variable, as will be seen from the following figures:

Average Composition of Normal Milk. A compilation of figures from various American Experiment Stations.

Water	87.1%
Butter fat	3.9%
Casein	2.9%
Albumen	.5%
Sugar	4.9%
Ash	.7%
Fibrin	Trace.
Galactase	Trace.
	<hr/>
	100.0%

The great variations in the composition of milk are shown by the figures from Koenig, given below:

	<i>Maximum.</i>	<i>Minimum.</i>
Water	90.69	80.32
Fat	6.47	1.67
Casein	4.23	1.79
Albumen	1.44	.25
Sugar	6.03	2.11
Ash	1.21	.35

These figures represent quite accurately the maximum and minimum composition of milk except that the maximum for fat is too low. The author has known cows to yield milk testing 7.6% fat, and records show tests even higher than this.

BUTTER FAT.

This is the most valuable as well as the most variable constituent of milk. It constitutes about 83% of butter and is an indispensable constituent of the many kinds of whole milk cheese now found upon the market. It also measures the commercial value of milk and cream, and is used as an index of the value of milk for butter and cheese production.

Physical Properties. Butter fat is suspended in milk in the form of extremely small globules numbering about 100,000,000 per drop of milk. These globules vary considerably in size in any given sample, some being five times as large as others. The size of the globules is affected mostly by the period of lactation. As a rule the size decreases and the number increases with the advance of the period. In strippers' milk the globules are sometimes so small as to render an efficient separation of the cream and the churning of same impossible.

The size of the fat globules also varies with different breeds. In the Jersey breed the diameter of the globule

is one eight-thousandth of an inch, in the Holstein one twelve-thousandth, while the average for all breeds is about one ten-thousandth.

Night's milk usually has smaller globules than morning's. The size of the globules also decreases with the age of the cow.

The density or specific gravity of butter fat at 100° F. is .91 and is quite constant. Its melting point varies between wide limits, the average being 92° F.

Composition of Butter Fat. According to Richmond, butter fat has the following composition:

Butyrin	3.85	} Soluble or volatile.
Caproin	3.60	
Caprylin	.55	
Caprin	1.90	} Insoluble or non-volatile.
Laurin	7.40	
Myristin	20.20	
Palmitin	25.70	
Stearin	1.80	
Olein, etc.....	35.00	

This shows butter fat to be composed of no less than nine distinct fats, which are formed by the union of glycerine with the corresponding fatty acids. Thus, butyrin is a compound of glycerine and butyric acid; palmitin, a compound of glycerine and palmitic acid, etc. The most important of these acids are palmitic, oleic, and butyric.

Palmitic acid is insoluble, melts at 144° F., and forms (with stearic acid) the basis of hard fats.

Oleic acid is insoluble, melts at 57° F., and forms the basis of soft fats.

Butyric acid is soluble and is a liquid which solidifies at -2° F. and melts again at 28° F.

Insoluble Fats. A study of these fats is essential in elucidating the variability of the churning temperature of cream. As a rule this is largely determined by the relative amounts of hard and soft fats present in butter fat. Other conditions the same, the harder the fat the higher the churning temperature. Scarcely any two milks contain exactly the same relative amounts of hard and soft fats, and it is for this reason that the churning temperature is such a variable one.

The relative amounts of hard and soft fats are influenced by:

1. Breeds.
2. Feeds.
3. Period of lactation.
4. Individuality of cows.

The butter fat of Jerseys is harder than that of Holsteins and, therefore, requires a relatively high churning temperature, the difference being about six degrees.

Feeds have an important influence upon the character of the butter fat. Cotton seed meal and bran, for example, materially increase the percentage of hard fats. Gluten feeds and linseed meal, on the other hand, produce a soft butter fat.

With the advance of the period of lactation the percentage of hard fat increases. This chemical change, together with the physical change which butter fat undergoes, makes churning difficult in the late period of lactation.

The individuality of the cow also to a great extent influences the character of the butter fat. It is inherent

in some cows to produce a soft butter fat in others to produce a hard butter fat, even in cows of the same breed.

Soluble Fats. The soluble or volatile fats, of which butyrin is the most important, give milk and sweet cream butter their characteristic flavors. Butyrin is found only in butter fat and distinguishes this from all vegetable and other animal fats.

The percentage of soluble fats decreases with the period of lactation, also with the feeding of dry feeds and those rich in protein. Succulent feeds and those rich in carbohydrates, according to experiments made in Holland and elsewhere, increase the percentage of soluble fats. This may partly account for the superiority of the flavor of June butter.

It may be proper, also, to discuss under volatile or soluble fats those abnormal flavors that are imparted to milk, cream, and butter by weeds like garlic and wild onions, and by various feeds such as beet tops, rape, partially spoiled silage, etc. These flavors are undoubtedly due to abnormal volatile fats.

Cows should never be fed strong flavored feeds shortly before milking. When this is done the odors are sure to be transmitted to the milk and the products therefrom. When, however, feeds of this kind are fed shortly after milking no bad effects will be noticed at the next milking.

Albumenoids. These are nitrogenous compounds which give milk its high dietetic value. Casein, albumen, globulin, and nuclein form the albumenoids of milk, the casein and albumen being by far the most important.

Casein. This is a white colloidal substance, possessing neither taste nor smell. It is the most important tissue-forming constituent of milk and forms the basis of an almost endless variety of cheese.

The larger portion of the casein is suspended in milk in an extremely finely divided amorphous condition. It is intimately associated with the insoluble calcium phosphate of milk and possibly held in chemical combination with this. Its study presents many difficulties, which leaves its exact composition still undetermined.

Casein is easily precipitated by means of rennet extract and dilute acids, but the resulting precipitates are not identically the same. It is not coagulated by heat.

Albumen. In composition albumen very closely resembles casein, differing from this only in not containing sulphur. It is soluble and unaffected by rennet, which causes most of it to pass into the whey in the manufacture of cheese. It is coagulated at a temperature of 170° F. It is in their behavior toward heat and rennet that casein and albumen radically differ.

Milk Sugar. This sugar, commonly called lactose, has the same chemical composition as cane sugar, differing from it chiefly in possessing only a faint sweetish taste. It readily changes into lactic acid when acted upon by the lactic acid bacteria. This causes the ordinary phenomenon of milk souring. The maximum amount of acid in milk rarely exceeds .9%, the germs usually being checked or killed before this amount is formed. There is therefore always a large portion of the sugar left in sour milk. All of the milk sugar is in solution.

Ash. Most of the ash of milk exists in solution. It is composed of lime, magnesia, potash, soda, phosphoric acid, chlorine, and iron, the soluble lime being the most important constituent. It is upon this that the action of rennet extract is dependent. For when milk is heated to high temperatures the soluble lime is rendered insoluble and rennet will no longer curdle milk. It seems also that

the viscosity of milk and cream is largely due to soluble lime salts. Cream heated to high temperatures loses its viscosity to such an extent that it can not be made to "whip." Treatment with soluble lime restores its original viscosity. The ash is the least variable constituent of milk.

Colostrum Milk. This is the first milk drawn after parturition. It is characterized by its peculiar odor, yellow color, broken down cells, and high content of albumen which gives it its viscous, slimy appearance and causes it to coagulate on application of heat.

According to Eugling the average composition of colostrum milk is as follows:

Water	71.69%
Fat	3.37
Casein	4.83
Albumen	15.85
Sugar	2.48
Ash	1.78

The secretion of colostrum milk is of very short duration. Usually within four or five days after calving it assumes all the properties of normal milk. In some cases, however, it does not become normal till the sixth or even the tenth day, depending largely upon the condition of the animal.

A good criterion in the detection of colostrum milk is its peculiar color, odor, and slimy appearance. The disappearance of these characteristics determines its fitness for butter production.

Milk Secretion. Just how all of the different constituents of milk are secreted is not yet definitely understood. But it is known that the secretion takes

place in the udder of the cow, and principally during the process of milking. Further, the entire process of milk elaboration seems to be under the control of the nervous system of the cow. This accounts for the changes in flow and richness of milk whenever cows are subjected to abnormal treatment. It is well known that a change of milkers, the use of rough language, or the abuse of cows with dogs and milk stools, seriously affects the production of milk and butter fat. It is therefore of the greatest practical importance to milk producers to treat cows as gently as possible, especially during the process of milking.

How Secreted. The source from which the milk constituents are elaborated is the blood. It must not be supposed, however, that all the different constituents already exist in the blood in the form in which we find them in milk, for the blood is practically free from fat, casein, and milk sugar. These substances must then be formed in the cells of the udder from material supplied them by the blood. Thus there are in the udder cells that have the power of secreting fat in a manner similar to that by which the gastric juice is secreted in the stomach. Similarly, the formation of lactose is the result of the action of another set of cells whose function is to produce lactose. It is believed that the casein is formed from the albumen through the activity of certain other cells. The water, albumen, and soluble ash probably pass directly from the blood into the milk ducts by the process known as osmosis.

Variations in the Quality of Milk. Milk from different sources may vary considerably in composition, particularly in the percentage of butter fat. Even the

milk from the same cow may vary a great deal in composition. The causes of these variations may be assigned to two sets of conditions: I.—Those natural to the cow. II.—Those of an artificial nature.

I. QUALITY OF MILK AS AFFECTED BY NATURAL CONDITIONS.

1. The composition of the milk of all cows undergoes a change with the advance of the period of lactation. During the first five months the composition remains practically the same. After this, however, the milk becomes gradually richer until the cow “dries up.” The following figures from Van Slyke illustrate this change:

<i>Month of lactation.</i>	<i>Per cent of fat in milk.</i>
1.....	4.54
2.....	4.33
3.....	4.28
4.....	4.39
5.....	4.38
6.....	4.53
7.....	4.56
8.....	4.66
9.....	4.79
10.....	5.00

It will be noticed from these figures that the milk actually decreases somewhat in richness during the first three months of the period. But just before the cow dries up, it may test as high as 8%.

2. The quality of milk also differs with different breeds. Yet breed differences are less marked than those of the individual cows of any particular breed.

Some breeds produce rich milk, others relatively poor

milk. The following data obtained at the New Jersey Experiment Station illustrates these differences:

Breed.	Total Solids.	Fat.	Milk Sugar.	Proteids.	Ash.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Ayshire.....	12.70	3.68	4.84	3.48	.69
Guernsey	14.48	5.02	4.80	3.92	.75
Holstein	12.12	3.51	4.69	3.28	.64
Jersey.....	14.34	4.78	4.85	3.96	.75

3. Extremes in the composition of milk are usually to be ascribed to the individuality or "make up" of the cow. It is inherent in some cows to produce rich milk, in others to produce poor milk. In other words, Nature has made every cow to produce milk of a given richness, which can not be perceptibly changed except by careful selection and breeding for a number of generations.

II. QUALITY OF MILK AS AFFECTED BY ARTIFICIAL CONDITIONS.

1. When cows are only partially milked they yield poorer milk than when milked clean. This is largely explained by the fact that the first drawn milk is always poorer in fat than that drawn last. Fore milk may test as low as .8%, while the strippings sometimes test as high as 14%.

2. Fast milking increases both the quality and the quantity of the milk. It is for this reason that fast milkers are so much preferred to slow ones.

3. The richness of milk is also influenced by the length of time that elapses between the milkings. In general, the shorter the time between the milkings the richer the milk. This, no doubt, in a large measure accounts for the differences we often find in the richness of morning's and night's milk. Sometimes the morning's milk is the richer, at other times the evening's, depending largely upon the time of day the cows are milked. Milk can not, however, be permanently enriched by milking three times in stead of twice a day.

4. Unusual excitement of any kind reduces the quality of milk. The person who abuses cows by dogs, milk stools, or boisterousness, pays dearly for it in a reduction of both the quality and the quantity of milk produced.

5. Starvation also seriously affects both the quality and the quantity of milk. It has been repeatedly shown, in this country and in Europe, that under-feeding to any great extent results in the production of milk poor in fat.

6. Sudden changes of feed may slightly affect the richness of milk, but only temporarily.

So long as cows are fed a full ration, it is not possible to change the richness of milk permanently, no matter what the character of feed composing the ration.

7. Irregularities of feeding and milking, exposure to heat, cold, rain, and flies, tend to reduce both the quantity and the quality of milk produced.

CHAPTER II.

THE BABCOCK TEST.

This is a cheap and simple device for determining the percentage of fat in milk, cream, skim-milk, buttermilk, whey, and cheese. It was invented in 1890 by Dr. S. M. Babcock, of the Wisconsin Agricultural Experiment Station, and ranks among the leading agricultural inventions of modern times. The chief uses of the Babcock test may be mentioned as follows:

1. It has made possible the payment for milk according to its quality.
2. It has enabled butter and cheese makers to detect undue losses in the process of manufacture.
3. It has made possible the grading up of dairy herds by locating the poor cows.
4. It has, in a large measure, done away with the practice of watering and skimming milk.

Principle of the Babcock Test. The separation of the butter fat from milk with the Babcock test is made possible:

1. By the difference between the specific gravity of butter fat and milk serum.
2. By the centrifugal force generated in the tester.
3. By burning the solids not fat with a strong acid.

Sample for a Test. Whatever the sample to be tested, always eighteen grams are used for a test. In testing cream and cheese, the sample is weighed. For testing milk, skim-milk, buttermilk, and whey, weighing requires

too much time. Indeed, with these substances weighing is not necessary as sufficiently accurate samples are ob-

Fig. 1.—Babcock tester.

tained by measuring which is the method universally employed. In making a Babcock test it is of the greatest importance to secure a uniform sample of the substance to be tested.

Apparatus. This consists essentially of the following parts: A, Babcock tester; B, milk bottle; C, cream bottle; D, skim-milk bottle; E, pipette or milk measure; F, acid measures; G, cream scales; H, mixing cans; I, dividers.

A. Babcock Tester. This machine, shown in Fig. 1, consists of a revolving wheel placed in a horizontal position and provided with swinging pockets for the bottles. This wheel is rotated by means of a steam turbine wheel in the bottom or at the top of the tester. When the tester stops the pockets hang down allowing the bottles to stand up. As the wheel begins rotating the pockets move out causing the bottles to assume a horizontal position. Both wheels are enclosed in a cast iron frame provided with a cover.

B. Milk Bottle. This has a neck graduated to ten large divisions, each of which reads one per cent. Each large division is subdivided into five smaller ones, making each subdivision read .2%. The contents of the neck from the zero mark to the 10% mark is equivalent to two cubic centimeters. Since the Babcock test does not give the percentage of fat by volume but by weight, the 10% scale on the neck of the bottle will, therefore, hold 1.8 grams of fat. In other words, if the scale were filled with water it would hold two grams; but fat being only .9 as heavy, 2 cubic centimeters of it would weigh nine-tenths of two grams or 1.8 grams. This is exactly 10% of 18 grams, the weight of the sample used for testing. A milk bottle is shown in Fig. 2.

C. Cream Bottles. These are graduated from 30% to 55%. A 30% bottle is shown in Fig. 3. Since cream usually tests more than 30%, the sample must be divided when the 30% bottles are used.

Fig. 2.—Milk bottle.

Fig. 3.—Cream bottle.

Fig. 4.—Skim-milk bottle.

D. Skim-milk Bottle. This bottle, shown in Fig. 4, is provided with a double neck, a large one to admit the milk, and a smaller graduated neck for fat reading. The entire scale reads one-half per cent. Being divided into ten subdivisions each subdivision reads .05%. The same bottle is also used for testing buttermilk.

Fig. 5.—Pi-
pette.

Fig. 6.—
Acid meas-
ure.

Fig. 7 —
Acid meas-
ure.

E. Pipette. This holds 17.6 c.c., as shown in Fig. 5. Since about .1 c.c. of milk will adhere to the inside of the pipette it is expected to deliver only 17.5 c.c., which is equivalent to 18 grams of normal milk.

F. Acid Measures. In making a Babcock test equal quantities, by volume, of acid and milk are used. The acid measure, shown in Fig. 6, holds 17.5 c.c. of acid, the amount needed for one test. The one shown in Fig. 7 is divided into six divisions, each of which holds 17.5 c.c. or one charge of acid. Where

many tests are made a graduate of this kind saves time in filling, but should be made to hold twenty-five charges.

H. A cream scales commonly used is illustrated in Fig. 8.

Acid. The acid used in the test is commercial sul-

Fig. 8.—Cream scales.

phuric acid having a specific gravity of 1.82 to 1.83. When the specific gravity of the acid falls below 1.82 the milk solids are not properly burned and particles of curd may appear in the fat. On the other hand, an acid with a specific gravity above 1.83 has a tendency to blacken or char the fat.

The sulphuric acid, besides burning the solids not fat, facilitates the separation of the fat by raising the specific gravity of the medium in which it floats.

Sulphuric acid must be kept in glass bottles provided with glass stoppers. Exposure to the air materially weakens it.

Making a Babcock Test. The different steps are indicated as follows:

1. Thoroughly mix the sample.
2. Immediately after mixing insert the pipette into the milk and suck until the milk has gone above the mark on the pipette, then quickly place the fore finger over the

Fig. 9. — Showing manner of emptying pipette.

top and allow the milk to run down to the mark by slowly relieving the pressure of the finger.

3. Empty the milk into the bottle in the manner shown in Fig. 9.

4. Add the acid in the same manner in which the milk was emptied into the bottle.

5. Mix the acid with the milk by giving the bottle a slow rotary motion.

6. Allow mixture to stand a few minutes.

7. Shake or mix again and then place the bottle in the tester.

8. Run tester four minutes at the proper speed.

9. Add moderately hot water until contents come to the neck of the bottle.

10. Whirl one minute.

11. Add moderately hot water until contents of the bottle reach about the 8% mark.

12. Whirl one minute.

13. Leave tester open a few minutes.

14. Read test.

How to Read the Test. At the top of the fat column is usually quite a pronounced meniscus as shown in Fig. 10. A less pronounced one is found at the bottom of the column. The fat should be read from the extremes of the fat column, 1 to 3, not from 2 to 4, when its temperature is about 140° F. Too high a temperature gives too high

Fig. 10.—Fat column showing meniscuses.

a reading, because of the expanded condition of the fat, while too low a temperature gives an uncertain reading.

Fig. 11.—Waste acid jar.

Fig. 12.—Milk bottle tester.

Precautions in Making a Test. 1. Be sure you have a fair sample.

2. The temperature of the milk should be about 60 or 70 degrees.

3. Always mix twice after acid has been added.

4. Be sure your tester runs at the right speed.

5. Use nothing but clean, soft water in filling the bottles.

6. Be sure the tester does not jar.

7. Be sure the acid is of the right strength.

8. Mix as soon as acid is added to milk.

9. Do not allow the bottles to become cold before reading the test.

10. Read the test twice to insure a correct reading.

The water added to the test bottles after they have been whirled should be clean and pure. Water containing much lime seriously affects the test. Such water may be used, however, when first treated with a few drops of sulphuric acid.

As stated before, skim-milk, buttermilk, and cream are tested in the same way as milk, with the exception that the cream sample is weighed not measured.

Cleaning Test Bottles. As soon as the test is read, the bottle should be emptied into an earthen jar (covered with a perforated board) by shaking it up and down so as to remove the white sediment. (Fig. 11.) It is now rinsed with one-third pipetteful of cleaning solution, which is made by dissolving about an ounce of potassium bichromate in one pint of sulphuric acid. Next run test bottle brush once up and down the neck of the bottle and finally rinse with hot water.

Testing or Calibrating Milk Bottles. Fill the bottle to the zero mark with water, or preferably wood alcohol to which a little coloring matter has been added. Immerse the lower section of the tester, shown in Fig. 12, in the contents of the bottle. If the bottle is correct, the contents will rise to the 5% mark. Next immerse both sections of the tester which will bring the contents to the 10% mark if the bottle is correctly calibrated.

It has been learned that the volume of the graduated part of the neck is 2 c.c. Each section of the tester is made to displace 1 c.c. when immersed in the liquid, hence the two sections will just fill the scale if the latter is correct.

Calculating Speed of Tester. The speed at which a tester must be run is dependent upon the diameter of the wheel carrying the bottles. The larger this wheel the fewer the revolutions it must make per minute to effect a complete separation of the fat.

In the following table by Farrington and Woll the necessary speed per given diameter is calculated:

<i>Diameter of wheel in inches.</i>	<i>No. of revolutions of wheel per minute.</i>
10.....	1,074
12.....	980
14.....	909
16.....	848
18.....	800
20.....	759
22.....	724
24.....	693

General Pointers. Black fat is caused by

1. Too strong acid.
2. Too much acid.
3. Too high a temperature of the acid or the milk.
4. Not mixing soon enough.
5. Dropping the acid through the milk.

Foam on top of fat is caused by hard water, and can be prevented by adding a few drops of sulphuric acid to the water.

Unclean or cloudy fat is caused by

1. Insufficient mixing.
2. Too low speed of tester.
3. Too low temperature.
4. Too weak acid.

Curd particles in fat are caused by

1. Too weak acid.
2. Not enough acid.
3. Too low temperature.

CHAPTER III.

I. THE LACTOMETER AND ITS USE.

This instrument, shown in Fig. 13, is used to determine the specific gravity of milk. The stem has two scales upon it, a thermometer scale at the upper end and a lactometer scale at the lower. The latter scale reads from fifteen to forty, being divided into twenty-five divisions, each of which reads one *lactometer degree*. The lower end of the instrument consists of two bulbs: an upper one containing the mercury for the thermometer scale, and a lower and larger one weighted with shot or mercury which serves to immerse and to keep in an upright position the large oblong bulb or float below the stem.

Making the Test. In making a lactometer test the sample of milk is carefully mixed and placed in the lactometer cylinder. (Fig. 14.) The lactometer is now carefully lowered into it and enough milk is added to the cylinder to fill it brim full. Now place your eye in a horizontal position with the surface of the liquid and read down as far as the liquid will permit. The reading thus obtained is the correct lactometer reading, provided the temperature as indicated by the thermometer scale is 60°

Corrections for Temperature. Lactometers are standardized at a temperature of 60° F.; but, since it is difficult to have a sample always at this temperature, corrections may be made for temperatures ranging from 50° to 70° . As the temperature rises the liquid expands and the specific gravity decreases. This decrease amounts to

one-tenth of a lactometer degree for every degree of temperature above 60. A decrease in temperature would result in a corresponding increase in the specific gravity. For every degree below 60, therefore, we subtract one-tenth degree from, and for every degree above 60 we

Fig. 13.
Lactom-
eter.

Fig. 14.—Lactom-
eter cylinder.

add one-tenth degree to, the lactometer reading. Examples:

1. Lactometer reading is 32.5 at a temperature of 55. Corrected reading is 32.5 less .5, equals 32.
2. Lactometer reading is 31.7 at a temperature of 63. Corrected reading is 31.7 plus .3, equals 32.

Interpretation of Lactometer Reading. In the chapter on milk we learned that normal milk has an average

specific gravity of 1.032. This means that a tank that holds just 1,000 pounds of water would hold 1,032 pounds of milk. On the lactometer scale the 1.0 is omitted. A reading of 32, expressed in terms of specific gravity, would therefore read 1.032.

Precautions in Making a Lactometer Test. 1. A lactometer test should not be made until three or four hours after the milk leaves the udder of the cow. The reason for this is that milk, immediately after it is drawn, holds mechanically mixed with it air and probably other gases, which tends to give too low a reading.

2. The sample must be thoroughly mixed. If a layer of cream is allowed to form at the surface, the consequence is that the hollow oblong bulb will float in partially skimmed milk and give too high a reading.

3. A dirty lactometer is certain to give a false reading. A lactometer should be washed in luke warm (not hot) water to which a little soda or other alkali has been added, and then rinsed off with clean water and wiped.

II. MILK SOLIDS.

The solids of milk include everything but the water. If a sample of milk be kept at the boiling temperature until all the water is evaporated, the dry, solid residue that remains constitutes the solids of milk. It is convenient to divide the solids into two classes, one including all the fat, the other all the solids which are not fat. In referring, therefore, to the different solids of milk, we speak of the "fat" and the "solids not fat" which, together, constitute the "total solids." The amount of each of these different solids present in milk is easily seen from the composition of milk. Thus, besides water, milk contains:

3.9%	fat	} = 9% = solids not fat.
2.9%	casein	
0.5%	albumen	
4.9%	sugar	
0.7%	ash	

Total 12.9% = total solids.

Relationship of Fat and Solids not Fat. In normal milk a fairly definite relationship exists between the fat and the solids not fat. For example, milk rich in fat is likewise rich in solids not fat. On the other hand, milk poor in fat is also poor in solids not fat. As a general rule, an increase in the solids not fat always accompanies an increase in the percentage of fat. The increase is, however, not quite proportionate, the fat increasing the more rapidly.

Since the casein represents the most valuable constituent of the solids not fat, the following ratio between this substance and the fat very well illustrates the relationship that exists between the fat and solids not fat in milk:

<i>According to Van Slyke.</i>	
<i>Per cent fat.</i>	<i>Per cent casein.</i>
3.00	2.10
3.25	2.20
3.50	2.30
3.75	2.40
4.00	2.50
4.25	2.60
4.50	2.70

Specific Gravity as Affected by Richness of Milk. The richness of milk seems to have but a very slight effect on its specific gravity. Usually a four per cent milk shows a slightly higher reading than a three per

cent milk, but the specific gravity of a four per cent milk is practically the same as that of a four and one-half per cent milk. From what has been said about the relationship of the fat and solids not fat in milks of different richness, it is quite natural that the specific gravity of such milks should vary but little. If the fat alone were increased, the lactometer reading would naturally be depressed. But since the solids not fat increase in nearly the same proportion as the fat, the depression caused by the latter is compensated for by the former.

Calculation of Milk Solids. The milk solids are calculated from the fat and the lactometer reading of milk. This is done by means of the following formula worked out at the Wisconsin Agricultural Experiment Station:

Formula for solids not fat equals one-fourth L R plus one-fifth F, in which L stands for lactometer, R for reading, and F for fat. Expressed in another way, *the solids not fat are obtained by adding one-fifth of the fat to one-fourth of the lactometer reading.* The total solids are obtained by adding the fat to the solids not fat. Examples:

1. To calculate solids not fat when the milk shows a lactometer reading of 31.6 and fat reading of 3.5. Substituting these figures for the letters in the formula, one-fourth L R plus one-fifth F, we get:

$\left(\frac{31.6}{4} \text{ plus } \frac{3.5}{5}\right)$ equals (7.9 plus .7) equals 8.6 equals solids not fat.

2. The total solids in the above sample are obtained by adding the fat and solids not fat. Thus: 8.6 plus 3.5 equals 12.1 equals total solids.

III. DETECTION OF MILK ADULTERATION—WATERING AND SKIMMING.

A knowledge of the methods of detecting watering and skimming of milk is in many cases of considerable value to butter makers, even when the milk is bought on the fat basis. Where the milk is bought irrespective of its fat content, such a knowledge is simply indispensable for the welfare of the creamery.

In normal milk ranging in fat from 3% to 5%, it is not difficult to detect a moderate amount of watering and skimming. We speak of *normal* milk because this means the milk from a full milking and excludes colostrum milk, milk from diseased cows and those far advanced in lactation. Normal milk cannot be expected when cows are either only partially milked, diseased, or very far advanced in lactation.

The accuracy of determining the amount of watering and skimming becomes greater in proportion as the sample represents more cows. For example, no sample of milk from a herd consisting of six or more cows has been known to average below 3% fat. For this reason any sample of milk testing below 3%, when taken from a herd, is to be looked upon with suspicion. On the other hand there are records of individual cows that show tests as low as 1.7% and as high as 8%. It is owing to these extreme variations in the composition of milk from individual cows, that small amounts of adulteration cannot be estimated with the same degree of accuracy in such milk as in herd milk.

Detection of Adulteration. The general procedure in determining whether milk has been watered or skimmed, or both, is as follows:

1. Determine the percentage of fat in the sample under consideration.
2. Determine its specific gravity.
3. From the fat and specific gravity calculate the solids not fat and total solids.
4. Compare the results obtained with the average specific gravity, per cent of fat, solids not fat, and total solids given for normal cows' milk, or compare with the legal State Standard.
5. In drawing conclusions remember that
 - a. Fat is lighter than water.
 - b. Milk is heavier than water.
 - c. Skimming increases the lactometer reading.
 - d. Skimming slightly increases solids not fat.
 - e. Skimming decreases fat and total solids.
 - f. Watering decreases fat, solids not fat, lactometer reading, and total solids.
 - g. Watering and skimming decrease fat (materially), solids not fat, and total solids.
 - h. The solids not fat are less variable than the fat.
 - i. Skimming and watering may give a normal lactometer reading.

From i it is seen that a normal lactometer reading is possible when milk is skimmed and watered in the right proportions. A lactometer reading without a Babcock test is therefore worthless.

For herd milk a lactometer reading above 33.5 is positive evidence of skimming when accompanied with a low percentage of fat. Herd milk showing a lactometer reading below 28 is considered watered.

Examples of milk adulteration in which only herd milk is considered are given as follows:

1. Suspected sample shows: Normal milk shows:

Lactometer reading.....	32	Lactometer reading.....	32
Fat	2.5	Fat	3.9
Solids not fat.....	8.5	Solids not fat.....	8.78
Total solids.....	11.0	Total solids.....	12.68

Conclusion: Sample is watered and skimmed because
(a) lactometer reading is normal and fat low; (b) solids
not fat are nearly normal and total solids low.

2. Suspected sample shows:

Lactometer reading	33.2
Fat	3.1
Solids not fat.....	8.92
Total solids	12.02

Conclusion: Sample is skimmed because lactometer
reading is high and fat low.

3. Suspected sample shows:

Lactometer reading shows.....	29
Fat	3.4
Solids not fat.....	7.93
Total solids	11.33

Conclusion: Sample is watered because everything
is much below normal, which is to be expected in the case
of watered milk.

CHAPTER IV.

BACTERIA AND MILK FERMENTATIONS.

A thorough knowledge of bacteria and their action forms the basis of success in butter making. Indeed the man who is lacking such knowledge is making butter in the dark; his is chance work. Much attention will therefore be given to the study of these organisms in this work.

I. BACTERIA.

The term bacteria is applied to the smallest of living plants, which can be seen only under the highest powers of the microscope. Each bacterium is made up of a single cell. These plants are so small that it would require 30,000 of them laid side by side to measure an inch. Their presence is almost universal, being found in the air, water, and soil; in cold, hot, and temperate climates; and in living and dead as well as inorganic matter.

Bacteria grow with marvelous rapidity. A single bacterium is capable of reproducing itself a million times in twenty-four hours. They reproduce either by a simple division of the mother cell, thus producing two new cells, or by spore formation in which case the contents of the mother cell are formed into a round mass called a spore. These spores have the power of withstanding unfavorable conditions to a remarkable extent, some being able to endure a temperature of 212° F. for several hours.

Most bacteria require for best growth a moist, warm, and nutritious medium such as is furnished by milk, in

which an exceedingly varied and active life is possible.

In nature and in many of the arts and industries, bacteria are of the greatest utility, if not indispensable. They play a most important part in the disintegration of vegetable and animal matter, resolving compounds into their elemental constituents in which form they can again be built up and used as plant food. In the art of butter and cheese making bacteria are indispensable. The tobacco, tanning, and a host of other industries cannot flourish without them.

II. MILK FERMENTATIONS.

Definition. In defining fermentation processes, Conn says that, "In general, they are progressive chemical changes taking place under the influence of certain organic substances which are present in very small quantity in the fermenting mass."

With few exceptions, milk fermentations are the result of the growth and multiplication of various classes of bacteria. The souring of milk illustrates a typical fermentation, which is caused by the action of lactic acid bacteria upon the milk sugar breaking it up into lactic acid. Here the chemical change is conversion of sugar into lactic acid.

The most common fermentations of milk are the following:

Milk Fermentations	{	Normal.....	{	Lactic.
			{	Curdling and Digesting.
			{	Butyric.
	{	Abnormal...	{	Bitter.
			{	Slimy or Ropy.
			{	Gassy.
			{	Toxic.
			{	Chromogenic.

NORMAL FERMENTATIONS.

We speak of normal fermentations because milk always contains certain classes of bacteria even when drawn and kept under cleanly conditions. These fermentations will be discussed in the following pages.

I. LACTIC FERMENTATION.

This is the most common and by far the most important fermentation of milk. Indeed it is indispensable in the manufacture of butter of the highest quality. The germ causing this fermentation is called *Lactici Acidi*. It is non-spore bearing and has its optimum growth temperature between 90° and 98° F. At 40° its growth ceases. Exposed to a temperature of 140° for fifteen minutes it is killed.

The souring of milk and cream, as already mentioned, is due to the action of the lactic acid bacteria upon the milk sugar changing it into lactic acid. Acid is therefore always produced at the expense of milk sugar. But the sugar is never all converted into acid because the production of acid is limited. When the acidity reaches about .9% the lactic acid bacteria are either checked or killed and the production of acid ceases. Owing to the universal presence of these bacteria it is almost impossible to secure milk free from them.

Under cleanly conditions the lactic acid type of bacteria always predominates in milk. When, however, milk is drawn under uncleanly conditions the lactic organisms may be outnumbered by other species of bacteria which give rise to the numerous taints often met with in milk.

Contradictory as it may seem, the lactic acid bacteria are alike friend and foe to the butter maker. Creamery

patrons are expected to have milk as free as possible from these germs so that it may arrive at the creamery in a sweet condition. They are therefore expected to thoroughly cool and care for it, not alone to suppress the action of the lactic acid bacteria but also that of the abnormal species that might have gained access to the milk.

While the acid bacteria are objectionable in milk, in cream made into butter they are indispensable. The highly desirable aroma in butter is the result of the growth of these organisms in the process of cream ripening. There are a number of different species of bacteria that have the power of producing lactic acid.

2. CURDLING AND DIGESTING FERMENTATION.

In point of numbers this class of bacteria ranks perhaps next to the lactic acid type. Indeed it is very difficult to obtain milk that does not contain them. It is not often, however, that their presence is noticeable owing to their inability to thrive in an acid medium.

According to bacteriologists most of these bacteria secrete two enzymes, one of which has the power of curdling milk, the other of digesting it. The former has the power of rennet, the latter of trypsin. "As a rule," says Russell, "any organism that possesses the digestive power, first causes a coagulation of the casein in a manner comparable to rennet."

It is only occasionally when the lactic acid organisms are in a great minority, or when for some reason their action has been suppressed, that this class of bacteria manifests itself by curdling milk while sweet. The curd thus formed differs from that produced by lactic acid in being soft and slimy.

Most of the curdling and digesting bacteria are spore bearing and can thus withstand unfavorable conditions better than the lactic acid bacteria. For this reason milk that has been heated sufficiently to kill the lactic acid bacteria, will often undergo the undesirable changes attributable to the digesting and curdling organisms.

3. BUTYRIC FERMENTATION.

It was mentioned that many bacteria have the power of producing lactic acid but that the true lactic acid fermentation is probably caused by a single species. So it is with the butyric acid bacteria. While a number of different organisms are known to produce this acid, Conn is of the opinion that the common butyric fermentation of milk and cream is due to a single species belonging to the anaerobic type.

The butyric acid produced by these organisms is the chief cause of rancid flavors in cream and butter. These bacteria are widely distributed in nature, being particularly abundant in filth. They are almost universally present in milk, from which they are hard to eradicate on account of their resistant spores. It is on account of these spores and their ability to grow in the absence of oxygen that the butyric fermentation is often found in ordinary sterilized milk from which the air has been excluded.

This class of bacteria has great significance in cream ripening and in the keeping quality of butter. In the ripening of cream the desirable flavor develops with the increase of acidity until the latter has reached .6%. When the development of acid goes beyond this, the flavor is no longer of the desirable kind but turns rancid as a result of the development of the butyric fermentation.

The butyric fermentation is rarely noticeable during the early stage of cream ripening and its subsequent development in a highly acid cream is explained by Russell as being "probably due, not so much to the presence of lactic acid, as to the absence of dissolved oxygen, which at this stage has been used up by the lactic acid organisms."

Butter that is apparently good in quality when freshly made, will usually turn rancid when kept at ordinary temperatures a short time. The quickness with which this change comes is dependent largely upon the amount of acid present in cream at the time of churning. Butter made from cream in which the maximum amount of acid consistent with good flavor has been developed, usually possesses poor keeping quality. This seems to indicate that at least part of the rancidity that develops in butter after it is made is due to the butyric acid bacteria, while light and air, doubtless, also contribute much to this end.

ABNORMAL FERMENTATIONS.

No trouble needs to be anticipated from these fermentations so long as cleanliness prevails in the dairy. The bacteria that belong to this class are usually associated with filth, and dairies that become infested with them show a lack of cleanliness in the care and handling of the milk. Since milk is frequently infected with one or another of these abnormal fermentations a brief discussion will be given of the most important.

I. BITTER FERMENTATION.

Bitter milk and cream are quite common and there are several ways in which this bitterness is imparted: it may

be due to strippers' milk and to certain classes of feeds and weeds, but most frequently to bacteria. This class of bacteria has not yet been studied very thoroughly but we know a great deal about it in a practical way. In milk and cream in which the action of the lactic acid germs has been suppressed by low temperatures, bitterness due to the development of the bitter fermentation is almost certain to be noticeable. When the temperature is such as to cause a rapid development of the lactic fermentation, the bitter fermentation is rarely, if ever, present. It is quite evident from this that the bitter organisms are capable of growing at much lower temperatures than the lactic and that so long as the latter are rapidly growing the bitter fermentation is held in check.

This teaches us that it is not safe to ripen cream below 60° F. The author has found that cream quickly ripened and then held at a temperature of 45° for twenty-four hours would show no tendency toward bitterness, while the same cream held sweet at 45° for twenty-four hours and then ripened would develop a bitter flavor. This indicates that the lactic acid is unfavorable to the development of the bitter fermentation.

The bitter germs produce spores capable of resisting the boiling temperature. This accounts for the bitter taste that often develops in boiled milk.

2. SLIMY OR ROPY FERMENTATION.

This is not a common fermentation and rarely causes trouble where cleanliness is practiced in the dairy. The bacteria that produce it are usually found in impure water, dust, and dung. These germs are antagonistic to

the lactic organisms and for this reason milk infected with them sours with great difficulty.

The action of this class of bacteria is to increase the viscosity of milk, which in mild cases simply assumes a slimy appearance. In extreme cases, however, the milk develops into a ropy consistency, permitting it to be strung out in threads several feet long.

Slimy or ropy milk cannot be creamed and is therefore worthless in the manufacture of butter. Such milk should not be confused with gargety milk which is stringy when drawn from the cow. The bacteria belonging to this class are easily destroyed as they do not form spores.

3. GASSY FERMENTATION.

This is an exceedingly troublesome fermentation in cheese making and is also the cause of much poor flavored butter. The gas germs are very abundant during the warm summer months but are scarcely noticeable in winter. Like the bitter germs, they are antagonistic to the lactic acid bacteria and do not grow during the rapid development of the latter. They are found most abundantly in the barn, particularly in dung.

4. TOXIC FERMENTATIONS.

Toxic or poisonous products are occasionally developed in milk as a result of bacterial activity. They are most commonly found in milk that has been kept for some time at low temperature.

5. CHROMOGENIC FERMENTATIONS.

Bacteria belonging to this class have the power of imparting to milk various colors. The most common of

these is blue. It is, however, not often met with in dairy practice since the color usually does not appear until the milk is several days old. The specific organism that causes blue milk has been known for more than half a century and is called cyanogenous. Another color that rarely turns up in dairy practice is produced by a germ known as prodigiosis, causing milk to turn red. Other colors are produced such as yellow, green, and black, but these are of very rare occurrence.

Fig. 15.—Composite test jar.

CHAPTER V.

COMPOSITE SAMPLING.

Where milk is bought on the fat basis, it is essential that it be sampled daily as it arrives at the creamery. It is not practicable, however, to make daily tests of the samples because this would involve too much work. Each patron is therefore provided with a pint jar to which samples of his milk are added daily for one or two weeks, the sample thus secured being called a *composite* sample. A test of this composite sample represents the average percentage of butter fat in the milk for the period during which the sample was gathered.

Careful experiments have shown that quite as accurate results can be obtained with the composite method of testing as is possible by daily tests, besides saving a great deal of work. This has led to its universal adoption wherever milk is bought by the Babcock test.

All composite jars should be carefully labeled by placing numbers upon them. These numbers should be written in large indelible figures as exhibited by the composite jar shown in Fig. 15. Shelves are provided in the intake upon which the jars are arranged in regular consecutive order. Numbers corresponding to those on the jars are placed on the milk sheet opposite the names of the patrons which should be arranged alphabetically.

Taking the Samples. Whatever the method of sampling, all milk should be sampled immediately after it enters the weigh can, not, as is frequently the case, after it is weighed.

Most of the sampling is done by either of two methods: (1) by means of a half ounce dipper, shown in Fig. 16, or (2) by means of long narrow tubes, one of which is shown in Fig. 17.

The dipper furnishes a simple and easy means of sampling milk. Where the milk is thoroughly mixed, and the variations in quantity from day to day are slight, the dipper method of sampling is accurate.

The other method of sampling is illustrated by the Scovell sampler (Fig. 17). The main tube of the sampler is open at both ends, the lower of which closely fits into a cap provided with three elliptical openings. As the sampler is lowered into the milk the latter rushes through the openings filling the tube to the height of the milk in the can. When the cap strikes the bottom of the can the tube slides over the openings, thus permitting the sample to be withdrawn and emptied into the composite jar.

This sampler has the advantage of always taking an aliquot portion of the milk, and furnishing an accurate sample when the sampling is somewhat delayed, because it takes as much milk from the top as it does from the bottom of the can.

The Equity sampler designed by Kolarik, works on the same principle as the Scovell and has proven very satisfactory.

Preservatives. Milk cannot be satisfactorily tested after it has loppered owing to thhe difficulty of securing an accurate sample. This makes it necessary to add some preservative to the composite samples to keep them sweet.

The best preservatives for this purpose are corrosive sublimate, formalin, and bichromate of potash. All of these are poisons and care must be taken to place them

Fig. 16.—Milk
sampler.

Fig. 17.—
Scovell
sampling
tube.

where children, and others unfamiliar with their poisonous properties, can not have access to them.

The bichromate of potash and corrosive sublimate can be purchased in tablet form, each tablet containing enough preservative to keep a pint of milk sweet for about two

weeks. The tablets color the milk so that there can be no mistake about its unfitness for consumption.

When colorless preservatives are used, like ordinary formalin and corrosive sublimate, a little analine dye should be added to prevent mistaking the identity of milk treated with these preservatives.

During the warm summer time the bichromate of potash is not as satisfactory as either of the other two preservatives mentioned, because of its comparative weakness and liability to interfere with the test when too much of it is used. When the bichromate is used in the ordinary solid form not more than a piece the size of a pea should be used, otherwise a good, clear test is not possible.

For spring, fall, and winter use, however, bichromate of potash is excelled by no other preservative, either in cheapness, or safety and convenience in handling.

Care of Composite Samples. It is a duty which the butter maker owes his patrons to keep the sample jars carefully locked up when not in use so as to prevent the possibility of anyone's tampering with them. This will serve the additional purpose of excluding the light from the samples, for they will keep but a short time when exposed to light and heat.

When the sample jars are permitted to stand a few days without shaking, the cream which rises will dry and harden, especially that in contact with the sides of the jar, so that it becomes difficult to secure a fair sample on testing day without special treatment of the sample. This is prevented by giving the jar a rotary motion every time a sample of milk is added.

It is important, too, that the covers of the jars fit tight, otherwise evaporation takes place, resulting in an increased test. In several instances the author has ob-

served that the butter maker (?) did not cover the jars at all! Can we wonder why patrons complain so frequently about the testing? Where the jars are kept uncovered for several weeks the cream is in a condition in which it can not be reincorporated with the milk and the Babcock test in this case becomes truly a snare and delusion.

Should the samples show any dried or churned cream on testing day, the sample jars must be placed in water at a temperature of 110° F. for five or ten minutes to allow the cream or butter to melt. When this is done the sample for the test bottle must be taken instantly after mixing, as the melted fat separates very quickly.

Frequency of Testing. It must not be supposed that if enough preservative can be added to the sample jars to keep the milk sweet for a month or longer that it is just as well to make monthly tests as weekly. Far from it. Even if the milk does remain sweet, the tendency of the cream to churn and become dried and crusty is in-itself sufficient protest against monthly testing. It is rare, indeed, that samples that have been kept for a month or longer can be sampled satisfactorily without warming them in a water bath, which means a great deal of extra work.

The best tests are secured when the samples are tested weekly or at most every two weeks. When the tests are made weekly it rarely becomes necessary to warm the samples if they have been properly cared for. Then, too, if an error is made anywhere in the testing, there are three other tests for the month that help to minimize it. It is not strange at all that a sample jar should break occasionally. If the jar should contain a whole month's milk the patron is deprived of his test for

that month. On the weekly basis of testing there would still be three tests to fall back on.

Supervision of Test. To relieve the butter maker from any suspicion of unfairness or carelessness in the testing of the composite samples, one or two of the patrons should be present at each testing. When one of the patrons thus witnesses the details of the testing and is furnished with a copy of the test, the butter maker is practically exempt from the suspicions that usually rest upon him, no matter how honest or careful a man he may be.

Duplicate Set of Jars. Where the testing is not under the supervision of one of the patrons, some butter makers have adopted the scheme of providing a double set of sample jars. After the test is made the jars, instead of being emptied, are set aside for a week, so that any one who has any complaint to offer on the test may call on the buttermaker for a retest, another set of sample jars being used in the meantime.

CHAPTER VI.

CREAMING.

Definition. Milk upon standing soon separates into two portions, one called cream, the other skim-milk. This process of separation is known as *creaming*, and is due to the difference in the specific gravity of the fat and the milk serum. The fat being light and insoluble, rises, carrying with it the other constituents in about the same proportion in which they are found in milk. The fat together with these other constituents forms the *cream*. After the cream has been skimmed off, there remains a more or less fat-free watery portion called *skim-milk*.

Processes of Creaming. The processes by which milk is creamed may be divided into two general classes: (1) that in which milk is placed in shallow pans or long narrow cans and allowed to set for about twenty-four hours, a process known as natural or gravity creaming; (2) that in which gravity is aided by subjecting the milk to centrifugal force, a process known as centrifugal creaming. The centrifugal force has the effect of increasing the force of gravity many thousands of times, thus causing an almost instantaneous creaming. This force is generated in the cream separator.

Before the days of the centrifugal cream separator, creameries either bought the milk and creamed it at the creamery by the gravity process, or bought and gathered the cream that had been creamed at the farms by the same process. The method of cream gathering is still extensively employed by creameries; indeed in many sections

of the country this practice is actually growing. Cream thus gathered is, however, largely the product of the cream separator, only a small portion being still creamed by the gravity process. The discussion on creaming will therefore be confined to the centrifugal process.

CREAM SEPARATORS.

History. The cream separator had its beginning in 1864 when Prandtl, of Munich, creamed milk by means of two cylindrical buckets revolving upon a spindle. In 1874 Lefeldt constructed a separator with a revolving drum similar to the later hollow bowl separators. This drum had a speed of 800 revolutions per minute. But it lacked an arrangement permitting a continuous discharge of cream and skim-milk, so that the separator had to be stopped at regular intervals when the cream was skimmed off, the skim-milk removed, and the bowl refilled for the next separation.

It was not until 1879 that real separators appeared upon the market. During this year two machines were perfected which permitted continuous cream and skim-milk discharges. One was known as the Danish Weston, invented in Denmark, the other the De Laval, invented in Sweden. Both of these separators were hollow bowl machines.

Other separators soon followed but no decided improvement was made until 1891, when the De Laval separator, shown in Fig. 18, appeared with a series of discs inside the bowl which had the effect of separating the milk in thin layers, thus increasing both the efficiency and the capacity of the separator. Since then various bowl devices have been invented by numerous separator manufacturers.

In 1896 a hollow bowl separator was again placed upon the market, this time by the Sharples Company. This separator had a long, narrow, suspended bowl, revolving about 24,000 times per minute, in which the efficiency of skimming was greater than that in the old hollow bowl style of separators.

Fig. 18.—De Laval cream separator.

Fig. 19.—Sharples cream separator.

In 1902 this company introduced another separator with a bowl of about the same construction but filled with a core made up of numerous sections which allowed the speed to be reduced to 14,000 revolutions per minute. This is a turbine separator a cut of which is shown in Fig. 19.

Numerous other power separators have been in use for many years, chief among which may be mentioned the United States and Reid.

Hand separators first appeared on the market in 1886. They are extensively used on dairy farms at the present time and are rapidly replacing the gravity methods of creaming.

In 1887 a machine appeared on the market which extracted the butter directly from sweet milk. This machine was called butter extractor. The butter made with the extractor was inferior in quality and the machine has practically gone out of existence.

Choice of Separator. In choosing a cream separator we should be guided by three things: 1. Efficiency of skimming; 2. Power required to operate; 3. Its durability.

I. EFFICIENCY OF SKIMMING.

Under favorable conditions a separator should not leave more than .05% fat in the skim-milk by the Babcock test. There are a number of conditions that affect the efficiency of skimming and these must be duly considered in making a separator test. The following are some of these conditions:

- A. Speed of bowl.
- B. Steadiness of motion.
- C. Temperature of milk.
- D. Manner of heating milk.
- E. Amount of milk skimmed per hour.
- F. Acidity of milk.
- G. Viscosity of milk.
- H. Richness of cream.
- I. Stage of lactation. (Stripper's milk.)

A. The greater the speed the more efficient the creaming, other conditions the same. It is important to see

that the separator runs at full speed during the separating process. The speed indicator should always be applied before turning on the milk and several times during the run. Loose belts, pulleys slipping on the shaft, and low steam pressure will reduce the speed of the separator.

B. A separator should run as smoothly as a top. The slightest trembling will increase the loss of fat in the skim-milk. Trembling of bowl may be caused by any of the following conditions: (1) loose bearings, (2) separator out of plum, (3) dirty oil or dirty bearings, (4) unstable foundation, or (5) unbalanced bowl.

C. The best skimming is not possible with any separator when the temperature falls below 60° F. A temperature of 85° F. is the most satisfactory for ordinary skimming. Under some conditions the cleanest skimming is obtained at temperatures above 100° F. The reason milk separates better at the higher temperatures is that the viscosity is reduced.

D. Sudden heating tends to increase the loss of fat in skim-milk in ordinary skimming. The reason for this is that the fat heats more slowly than the milk serum which diminishes the difference between their densities. When, for example, milk is suddenly heated from near the freezing temperature to 85° F. by applying live steam, the loss of fat in the skim-milk may be four times as great as it is under favorable conditions. If, instead of suddenly heating the milk to 85°, it is heated to 160° or above, then no extra loss of fat occurs. Hence the advantage of separating milk at pasteurizing temperature during the winter.

E. Unduly crowding a separator increases the loss of fat in the skim-milk. On the other hand, a marked underfeeding is apt to lead to the same result.

F. The higher the acidity of milk the poorer the creaming. With sour milk the loss of fat in the skim-milk becomes very great. This emphasizes the importance of having the milk delivered to the creamery in a sweet condition.

G. Sometimes large numbers of undesirable (slimy) bacteria find entrance into milk and materially increase its viscosity. This results in very unsatisfactory creaming. Low temperatures also increase the viscosity of milk which accounts for the poor skimming at these temperatures.

H. Most of the standard makes of separators will do satisfactory work when delivering cream of a richness of 50%. A richer cream is liable to result in a richer skim-milk. The reason for this is that in rich cream the skim-milk is taken close to the cream line where the skim-milk is richest.

I. Owing to the very small size of the fat globules in stripper's milk, such milk is more difficult to cream than that produced in the early period of lactation.

2. POWER REQUIRED TO OPERATE.

This is a matter of importance as a heavy running machine will add much to the running expenses of the creamery. Such a machine will not only require more fuel but will increase the wear of belts and machinery.

3. DURABILITY.

Cream separators are expensive machines and due regard should be given to their wearing qualities. They should be made of the best material, possess good workmanship, and have as few wearable parts as possible.

SEPARATING TEMPERATURE.

During the summer time, when milk is fresh and requires little heating, a separating temperature of 70° F. gives good results. In the late fall and during the winter, when milk is received cold and often two days old, it is necessary to raise the temperature of the milk to 85° before separating. When milk is received in a partly frozen condition or when permeated with bad odors, a separating temperature of 140° to 170° is preferred. Whenever such high temperatures are employed it is necessary to cool the cream immediately after it leaves the separator to a temperature of 70° or lower.

RICHIENESS OF CREAM.

How Regulated. The richness of cream is usually regulated by means of a cream screw in the separator bowl. When a rich cream is desired the opening in the screw is turned toward the center of the bowl, and for a thin cream it is turned away from the center.

In some machines the richness of cream is regulated by the rate of separation. With all separators the more milk separated per hour and the lower the speed the thinner the cream. Too low a speed always results in a rich skim-milk and poor cream.

Temperatures between 60° and 90° have little effect on the richness of cream. When, however, the temperature is raised to 140° or above, the cream becomes thinner.

Advantages of Rich Cream. These may be summed up as follows:

1. Permits the use of more starter.
2. Contains fewer objectionable bacteria.

3. Can be churned at a lower temperature.
4. Occupies less space.
5. There is less cream to cool.

Where a large amount of starter is to be added to the cream it is necessary to separate a rich cream so that the starter will not bring it below the churning richness.

Fig. 20. —Curtis milk heater.

In case milk is tainted it is desirable to separate a very heavy cream so as to get rid of as much milk serum as possible. In this way we get rid of most of the taint, which develops in the milk serum. The cream is then reduced to churning richness with starter, or partly with starter and partly with fine flavored milk.

The fat globules in a rich cream are close together which permits churning at a comparatively low temperature. The chief advantage gained in this is the greater exhaustiveness of churning.

MILK HEATERS.

There are to be found upon the market two general classes of milk heaters: Those which admit the steam directly to the milk called direct heaters, and those in which the steam enters a jacket surrounding the milk known as indirect heaters.

Direct Heaters. These are practically nothing more than an expansion in the feed pipe in which the steam

Fig. 21.—Twentieth Century milk heater.

enters the milk. They are permissible only when first class steam is available and when milk is to be heated through a short range of temperature. But even under these conditions indirect heaters are always preferred.

The two main objections to the direct heaters are: (1) the liability of contaminating the milk with impure steam, and (2) the effect of the sudden heating upon the loss of fat in the skim-milk which may be quite considerable when the milk is heated through a long range of temperature.

Indirect Heaters. Figs. 20 and 21 illustrate this type of heaters. In the Curtis heater the milk circulates in a

thin sheet between an inner removable cylinder and the inner wall of the steam jacket, thus heating it gradually as it passes from one end to the other. In the Twentieth

Fig. 22.—Reid pasteurizer.

Fig. 23.—Bair cream cooler.

Century heater the steam passes inside a series of discs. These discs are in motion during the heating and force the milk into the separator. Another type of indirect heater is the Reid pasteurizer shown in Fig. 22. This machine not only heats the milk but elevates it, thus dispensing with the use of a milk pump.

CREAM COOLERS.

With the modern cream ripeners described in Chapter VII no special cream cooler is necessary since the cooling is very quickly done in the ripener.

With open vats placed on the same floor with the separators the most practical cooler is that belonging to the Bair type, which is illustrated in Fig. 23. This cooler is from six to eight feet long, about one foot wide, and three inches deep. The top of the cream vat need therefore not be more than four inches lower than the cream spout of the separator. The circulation of the water is indicated by the arrows, the water entering the cooler at the point at which the cream leaves it. The surface over which the cream flows is slightly corrugated, thus increasing the amount of cooling surface. This cooler will cool cream within ten degrees of the temperature of the water when separated at ordinary temperatures.

CHAPTER VII.

CREAM RIPENING.

This chapter will be discussed under three heads :

- Part I. Theory and Methods of Cream Ripening.
- Part II. The Control of the Ripening Process.
- Part III. Cream Acid Tests.

PART I.—THEORY AND METHODS OF CREAM RIPENING.

Cream ripening is a process of fermentation in which the lactic acid organisms play the chief role. In every-day language, cream ripening means the souring of the cream. So important is this process that the success or failure of the butter maker is largely determined by his ability to exercise the proper control over it. In common creamery practice the time consumed in the ripening of cream varies from six to twenty-four hours and includes all the changes which the cream undergoes from the time it leaves the separator to the time it enters the churn.

Object. The ripening of cream has for its prime object the development of flavor and aroma in butter, two qualities usually expressed by the word flavor. In addition to this, cream ripening has several minor purposes, namely: (1) renders cream more easily churnable; (2) obviates difficulties from frothing or foaming in churning; (3) permits a higher churning temperature; (4) increases the keeping quality of butter.

Flavor. This, so far as known at the present time,

is the result of the development of the lactic fermentation. If other fermentations aid in the production of this important quality of butter, they must be looked upon as secondary. In practice the degree or intensity of flavor is easily controlled by governing the formation of lactic acid. That is, the flavor develops gradually with the increase in the acidity of the cream. Sweet cream butter for example is almost entirely devoid of flavor, while cream with an average richness possesses the maximum amount of good flavor possible when the acidity has reached .6%.

From this it might appear that all of the flavor is inherent in the lactic acid itself. But this is not the case. The souring of milk free from fat does not produce the flavor found in sour cream, though the acid is the same in both cases. The view held by Duclaux is perhaps the most satisfactory in explaining the origin of the flavor produced in cream ripening. He maintains that since some caproic and butyric acids always exist in a free state in butter, the flavor may be the result of the formation of caproic and butyric ethers from these acids.

The formation of such ether compounds in cream would doubtless be due to the presence of lactic acid. And it can not be denied that the lactic acid itself figures as one of the components of butter flavor.

Churnability. Practical experience shows that sour cream is more easily churnable than sweet cream. This is explained by the fact that the development of acid in cream tends to diminish its viscosity. The concussion produced in churning causes the little microscopic fat globules to flow together and coalesce, ultimately forming the small granules of butter visible in the churn. A high viscosity impedes the movement of these globules. It is

evident, therefore, that anything that reduces the viscosity of cream, will facilitate the churning.

As a rule, too, the greater the churnability of cream the smaller the loss of fat in the buttermilk.

Frothing. Experience shows that ripened cream is less subject to frothing or foaming than unripened. This is probably due to the reduced viscosity of ripened cream and the consequent greater churnability of same.

Temperature. Sour cream can be churned at higher temperatures than sweet cream with less loss of fat in the buttermilk. This is of great practical importance since it would be difficult, if not impossible, for most creameries to get low enough temperatures for the successful churning of sweet cream. Indeed, many creameries fail to get a low enough churning temperature for ripened cream.

Keeping Quality. It has been found that butter with the best keeping quality is obtained from well ripened cream. It is true, however, that butter made from cream that has been ripened a little too far will possess very poor keeping quality. An acidity of .5% should be placed as the limit when good keeping quality is desired.

METHODS OF CREAM RIPENING.

There are three ways in which cream is ripened at the present time:

1. By the unaided development of the lactic fermentation called *natural ripening*.
2. By first destroying the bulk of the bacteria in cream by heat and then inoculating same with cultures of lactic acid bacteria. This method is known as *pasteurized cream ripening*.

3. By the aided development of the lactic fermentation called *starter ripening*.

I. NATURAL RIPENING.

By this is meant the natural souring of the cream. In this method no attempt is made to repress the abnormal fermentations or to assist in the development of the lactic. From the chapter on Milk Fermentations we have learned that milk normally contains a number of different kinds of germs, frequently as many as a dozen or more. Naturally, therefore, where this method of ripening is practiced, a number of fermentations must go on simultaneously and the flavor of the butter is impaired to the extent to which the abnormal fermentations have developed. If the cream is clean and uncontaminated the lactic fermentation greatly predominates and the resulting flavor is good. If, on the other hand, the cream happens to contain many bad germs the probability is that the abnormal ferments will predominate and the flavor of the butter will be badly "off."

Where cream is therefore allowed to take its own course in ripening the quality of the butter is a great uncertainty. This method, though still practiced by many butter makers, is to be condemned as obsolete and unsatisfactory.

2. PASTEURIZED CREAM RIPENING.

Theoretically and practically the ideal way of making butter is to pasteurize the cream, a process which consists in heating cream momentarily to a temperature of 160° to 185° F. and then quickly cooling to 60° F. In this manner most of the bacteria in the cream are destroyed. After this treatment the cream is heavily inoculated with the lactic acid bacteria, and the lactic fermentation is given

a favorable temperature for development. When cream is treated in this way the lactic fermentation is practically the only one present and a butter with the desirable flavor and aroma is the result. It is the only way in which a uniform quality of butter can be secured from day to day.

This system of cream ripening is almost universally followed in Denmark, whose butter is recognized in all the world's markets as possessing qualities of superior excellence. The method is also gradually gaining favor in America and its general adoption can only be a matter of time. In the chapter on Cream Pasteurization this method is discussed in detail.

3. STARTER RIPENING.

This method of ripening consists in adding "starters," or carefully selected sour milk, to the cream after it leaves the separator. A full discussion of starters will be found in the following chapter.

In America this is at present the most popular method of cream ripening. While it does not, and can not, give the uniformly good results obtained by pasteurizing the cream, it is far superior to natural or unaided ripening.

When we have a substance which contains many kinds of bacteria, there naturally follows a struggle for existence and the fittest of the species will predominate.

We always have a number of different types of bacteria in cream, both desirable and undesirable. The latter can be held in check by making the conditions as favorable as possible for the former. Fortunately, when milk is properly cared for the lactic acid germs always predominate. But where milk is received at the creamery from 30 to 200 patrons, undesirable germs are frequently present in such large numbers as to seriously endanger

the growth of the lactic acid bacteria. However, when a large amount of starter containing only lactic acid germs is added to the cream from such milk these organisms are certain to predominate.

The best results with the starter method are secured when the milk is received at the creamery in a sweet condition and when a large amount of starter is used. Generally when milk is received in a sweet condition, especially during the summer months, it indicates that it has been thoroughly cooled and that the germs are present only in small numbers. When the cream from such milk is heavily inoculated with lactic acid germs by adding a starter, the development of the lactic fermentation is so rapid as to either check or entirely suppress the action of undesirable bacteria that may be present in the cream.

PART II.—THE CONTROL OF THE RIPENING PROCESS.

In Part I an attempt was made to convey some idea as to our present theory and methods of cream ripening. We learned that the highly desirable flavor and aroma of butter are produced by the development of the lactic fermentation. In the following discussion we shall take up the means of controlling this fermentation and treat of the more mechanical side of cream ripening. This will include: 1. The time the starter should be added to the cream; 2. The amount of starter to be added; 3. The ripening temperature; 4. Time in ripening; 5. Agitation of cream during ripening; 6. Means of controlling temperature.

1. The value of a starter in cream ripening has already been made evident in the discussion of the theory of cream ripening. To secure the maximum effect of a starter it should be added to the cream vat soon after the separation

of the milk has begun but not until the cream has reached a temperature of 70° F. The cream thus coming in contact with the starter as it leaves the separator insures a vigorous development of the starter germs, so that by the time the separation is completed, the starter fermentation is almost certain to predominate, especially when a large amount of starter is used.

2. The maximum amount of starter that may be consistently used is one pound to two pounds of cream. A larger amount than this would be liable to result in too thin a cream. Experience teaches us that the maximum richness of cream permissible in clean skimming under average conditions is 50%. Adding one pound of starter to two pounds of such cream would give us a 33 1-3 % cream, the ideal richness for churning. But this amount of starter is rarely permissible on account of the poor facilities for controlling the temperature of the cream.

3. Since the lactic acid bacteria develop best at a temperature of 90° to 98° F. it would seem desirable to ripen cream at these temperatures. But this is not practicable because of the unfavorable effect of high temperatures on the body of the cream and the butter. Good butter can be produced, however, under a wide range of ripening temperatures. The limits may be placed at 60° and 80° . Temperatures below 60° are too unfavorable for the development of the lactic acid bacteria. Any check upon the growth of these germs increases the chances for the development of other kinds of bacteria. But it may be added that when cream has reached an acidity of .4% or more, the ripening may be finished at a temperature between 55° and 60° with good results. In general practice a temperature between 60° and 70° gives

the best results. This means that the main portion of the ripening is done at this temperature. The ripening is always finished at temperatures lower than this.

4. As a rule quick ripening gives better results than slow. The reason for this is evident. Quick ripening means a rapid development of the lactic fermentation and, therefore, a relatively slow development of other fermentations. Practical experience shows us that the growth of the undesirable germs is slow in proportion as that of the lactic is rapid. For instance, when we attempt to ripen cream at 55° F., a temperature unfavorable for the growth of the lactic acid bacteria, a more or less bitter flavor is always the result. This is so because the bitter germs develop better at low temperatures than the lactic acid bacteria.

The main portion of the ripening should be done in about six hours. After this the temperature should be gradually reduced to a point at which the cream will not overripen before churning.

5. It is very essential in cream ripening to agitate the cream frequently to insure uniform ripening. When cream remains undisturbed for some time the fat rises in the same way that it does in milk, though in a less marked degree. The result is that the upper layers are richer than the lower and will sour less rapidly, since the action of the lactic acid germs is greater in thin than in rich cream.

This uneven ripening leads to a poor bodied cream. Instead of being smooth and glossy, it will appear coarse and curdy when poured from a dipper. The importance of stirring frequently during ripening should therefore not be underestimated.

6. The subject of cream cooling is a very important

one and will be discussed under the head of cream ripeners.

CREAM RIPENERS.

Fig. 24.—Boyd cream ripener.

During the summer months much butter of inferior quality is made by overripening the cream and churning at too high a temperature. This is due chiefly to a lack of proper cooling facilities. With the open cream vats the control of temperature is a difficult thing. For-

tunately these vats are being replaced by the more modern cream ripeners of which the Farrington and the Boyd are

Fig. 25.—Farrington cream ripener

types. These ripeners possess two important advantages over the open vats, namely: first, they permit a more rapid cooling by agitating the water and cream while cooling; second, they maintain a more uniform temperature because of tight fitting covers and better all round construction.

With the Boyd ripener, shown in Fig. 24, the cooling is done by running cold water through a series of tinned-iron pipes which are inserted in the cream and kept moving to and fro by means of power attachment. The cooling in the Farrington vat is accomplished by circulating cold water in a jacket surrounding the cream. The vat is of cylindrical shape and is rotated by power during cooling. The Farrington ripener and air compressor for forcing the cream into the churn are shown in Figs. 25 and 26.

Since these ripeners are so constructed as to render the addition of ice to the water in them impossible, they can not be considered complete without an ice water attachment. In Fig. 27 an ice water tank may be seen attached to the Boyd ripener. Ice water may be circulated in the same way with the Farrington ripener.

Tank A contains ice water which is kept circulating through the ripener by means of pump B. By using the water over and over again, only a very small quantity

Fig. 26.—Air compressor.

of ice is required in cooling cream to the desired temperature. When the great cooling power of ice is once fully understood it is easy to see what a great amount of cooling a small quantity of ice will do. One pound of ice in melting will give out 140 times as much cold as

Fig. 27.—Showing method of circulating ice water through ripener.

one pound of water raised from 32° to 33° F. In other words, the cooling power of ice is 140 times as great as that of water.

To get at the amount of ice necessary in cooling cream with ice a series of tests was made with a 400 gallon Farrington ripener, which was carried out as follows: As soon as about thirty-five gallons of cream was separated, the ripener was set in motion and a continuous stream of cold water kept flowing through it until all the cream was separated. Further cooling was then delayed for three or four hours when the ripener was again started and iced water allowed to circulate through it by means of a common rotary pump. The results thus secured are set forth in the following table:

Results obtained with a 400 gallon Farrington Cream Ripener.

COOLING WITH ICED WATER.

Gallons cream.	Initial temperature of cream.	Initial temperature of water.	Final temperature of cream.	Final temperature of water.	Amount of ice used, lbs.	Time run.	Temperature of cream in morning.	Temperature of water in morning.
260.....	64°	58°	53°	53°	100	45 min.	57°	60°
260.....	58°	58°	54°	53°	94	45 "	58°	62°
260.....	64°	58°	54°	53°	105	35 "	58°	62°
260.....	61°	58°	55°	54°	140	45 "	57°	60°
280.....	59°	60°	52°	48°	110	35 "	58°	61°
260.....	60°	58°	55°	52°	120	40 "		
260.....	59°	60°	53°	53°	100	40 "	58°	62°
260.....	58°	60°	55°	53°	70	30 "		
260.....	66°	58°	55°	53°	100	45 "	59°	60°
260.....	58°	59°	52°	50°	80	30 "	58°	58°
260.....	58°	58°	53°	51°	75	30 "	59°	60°
260.....	62°	58°	54°	52°	100	40 "	58°	59°

Attention is called to the large amount of cream cooled in these experiments. The 260 gallons of cream represented about 20,000 pounds of milk. Moreover, it must be remembered that the maximum cooling efficiency is not possible with the ripener more than half full as was the case in these experiments.

The temperature of the cream and water in the morning is given to show to what extent the ripener is capable of holding temperature. The nights during these tests were moderately warm.

With uniced water a low temperature is not possible. One warm day the ripener was run during the entire forenoon and the larger portion of the afternoon, and yet, after all this run, the temperature of the cream was still 56°, and this in spite of the fact that the water was pumped directly from the well into the ripener. In no case was a temperature lower than this obtained with

the uniced water, which had a temperature of 51° to 52° as it entered the ripener.

When we compare the quick cooling with iced water and the slow and inadequate cooling with uniced water, it is easily seen that the saving in fuel and wear and tear of machinery will more than cover the cost of the ice. Moreover, quick cooling has a very important advantage in cream ripening. It permits the use of a large amount of starter which is not possible where good cooling facilities are not at hand. Using iced water makes it possible to have cream with the same degree of acidity 365 days in the year, and it is believed that the general use of the improved cream ripeners with ice water attachments will result in a great improvement in both the quality and uniformity of butter and do away with the dangerous practice of adding ice directly to the cream.

DANGER OF ADDING ICE TO CREAM.

Adding ice to the cream is a pernicious practice, both because of its tendency to lower the quality of the butter and of the danger of infecting it with disease producing germs. This is so because most of the ice used is more or less contaminated with filth and various kinds of germs. Moreover, a good bodied cream cannot be obtained where it becomes excessively diluted with ice water.

Butter makers generally realize these facts but are often forced into the practice of adding ice to the cream because proper cooling facilities are not available. One of the contestants in our Educational Butter Scoring Test writes as follows: "The ice we have been using comes from a mill pond, a very filthy hole. I did not use it in the cream until July when I was obliged to in order

to get the cream cold enough. I am satisfied that is one reason my butter has such a poor flavor." Compare his scores for May and June when no ice was used in the cream, with those for July and August when ice was added. Score for May, $92\frac{1}{2}$; score for June, 94; score for July, 87; score for August, 88.

PART III. ACID TESTS FOR MILK AND CREAM.

Butter makers who have had years of experience and who rank high in the profession of butter making, do not find it safe to rely upon their noses in determining the ripeness of cream for churning. They use in daily practice tests by which it is possible to determine the actual amount of acid present. The method of using these tests is based upon the simplest form of titration.

Titration. This consists in *neutralizing* an *acid* with an *alkali* in the presence of an *indicator* which determines when the point of neutrality has been reached.

Acids and alkalies are substances that have entirely opposite chemical properties. The acid in milk gives it its sour taste, and for our purpose, illustrates very well what we mean by an acid. Ordinary lime may be used to illustrate what we mean by an alkali.

When lime is added to sour milk the acid unites with the lime forming a neutral substance which is neither alkaline nor acid. If we keep on adding lime to the milk we reach a point at which all the acid has combined with the lime. This is called the point of *neutrality*. The moment this point is passed is made visible to the eye by means of the indicator (phenolphthalein) which is colorless in the presence of an acid but pink in the presence of an alkali. One drop of alkali added to milk after the acid has been neutralized will turn it pink.

In the tests used for milk and cream the alkali used is sodium hydroxide. This is made up of a definite strength so that the amount of acid can be calculated from the amount of alkali used.

Kinds of Tests. There are two tests in general use at the present time: one devised by Prof. Manns and known as the Manns' Test; the other devised by Prof. Farrington and known as Farrington's Alkaline Tablet Test.

Fig. 28.—Manns' acid test apparatus.

MANNS' TEST.

The apparatus used in this test is illustrated in Fig. 28. It consists of a 50 c.c. burette, a 50 c.c. pipette, a small funnel, and a glass beaker with stirring rod. The alkali (not shown in the figure) can be bought ready made in gallon bottles and is labeled "neutralizer." This alkali or neutralizer is made by dissolving

four grams of sodium hydroxide in enough water to make one liter solution. The solution thus formed is called a one-tenth normal solution, each cubic centimeter of which contains .004 of a gram of sodium hydroxide which will neutralize .009 of a gram of lactic acid.

Making the Test. Measure 50 c.c. of cream with the pipette into the beaker, then with the same pipette add 50 c.c. of water. Now add five or six drops of indicator. Next fill the burette to the zero mark with the neutralizer

and slowly run this from the burette into the cream, shaking the beaker after each addition of alkali. With the first few additions of alkali the pinkish color produced quickly disappears. But when the point of neutrality approaches, the color disappears very slowly and the neutralizer must be added drop by drop only. The moment the cream remains pink indicates that the acid has all been neutralized. The number of cubic centimeters of alkali added to the cream is then noted, and from this the percentage of acid is calculated according to the following formula:

$$\text{Per cent acid} = \frac{\text{No. c.c. alkali} \times .009}{\text{No. c.c. cream}} \times 100.$$

Example: What is the percentage of acidity when 30 c.c. of alkali are required to neutralize 50 c.c. of cream?

$$\frac{30 \times .009}{50} \times 100 = .54\%.$$

From the formula it is evident that any amount of cream may be used for a test. But more accurate results are obtained by using 50 c.c. than less. Where this amount of cream is always used the formula may be considerably simplified.

Thus, by dividing the numerator and denominator by 50, the expression $\left(\frac{\text{No. c.c. alkali} \times .009}{50} \times 100 \right)$ becomes $(\text{No. c.c. alkali} \times .009 \times 2)$ or $(\text{No. c.c. alkali} \times .018)$. The acidity in the problem above would therefore equal $30 \times .018 = .54\%$.

FARRINGTON'S ALKALINE TABLET TEST.

In the Farrington test the same alkali is used as in Manns', but in a dry tablet form in which it is more

easily handled than in the liquid form. Each tablet contains enough alkali to neutralize .034 gram of lactic acid.

Apparatus Used for the Test. This is shown in Fig. 29 and consists of a porcelain cup, one 17.6 c.c. pipette, and a 100 c.c. rubber-stoppered graduated glass cylinder.

Fig. 29.—Farrington acid test apparatus.

Making the Solution. The solution is made in the graduated cylinder by dissolving 5 tablets in enough water to make 97 c.c. solution. When the tablets are dissolved, which takes from six to twelve hours, the solution should be well shaken and is then ready for use. The solution of the tablets may be hastened by placing the graduate in a reclining position as shown in the cut.

Making the Test. With the pipette add 17.6 c.c. of cream to the cup, then with the same pipette add an equal amount of water. Now slowly add of the tablet solution,

rotating the cup after each addition. As soon as a permanent pink color appears, the graduate is read and the number of c.c. solution used will indicate the number of hundredths of one per cent of acid in the cream. Thus, if it required 50 c.c. of the tablet solution to neutralize the cream then the amount of acid would be .50%. From this it will be seen that with the Farrington test no calculation of any kind is necessary.

TESTING THE ACIDITY OF MILK.

The acidity of milk may be determined in the same way as that of cream, except that the milk need not be diluted with water before adding the alkali.

A Rapid Acid Test for Milk. Where milk is pasteurized it is often desirable to determine approximately the acidity of each lot as it arrives at the creamery. It has been found that milk that contains more than .2% acid cannot be satisfactorily pasteurized. Farrington and Woll have devised the following rapid method for testing the acidity of milk that is to be pasteurized:

Prepare a tablet solution by adding two tablets for each ounce of water. When the tablets have dissolved, take the solution into the intake. Now, as each lot is dumped into the weigh can a sample of milk is taken with a No. 10 brass cartridge shell and emptied into a teacup. With another, or the same, No. 10 shell add a measure of tablet solution to the cup. Mix the alkali and milk by giving the contents of the cup a rotary motion. If the milk remains white it contains more than .2% acid; if it is colored, there is less than .2% acid present.

Where the tablet solution is prepared as above care must be taken to secure equal quantities of milk and solution for the test.

PRECAUTIONS IN MAKING ACID TESTS.

1. Always thoroughly mix the cream or milk before taking a sample for a test.
2. Prepare the tablet solution and dilute the cream with water as nearly neutral as possible. Soft water is better than hard.
3. Keep the tablets dry and well bottled.
4. Keep the Manns neutralizer and the Farrington tablet solution carefully stoppered with a rubber stopper, as exposure to the air will weaken the solutions by absorbing carbonic acid.
5. With the Farrington tablets it is best to prepare a new solution every day.
6. Make the tests where there is plenty of light so that the first appearance of a permanent pink color can readily be noticed.

RELATION OF RICHNESS AND ACIDITY IN CREAM.

In practice we find that the ripening is slower in rich than in poor cream. The reason for this is that the acid develops in the milk serum, which really should be used as the basis in measuring the degree of acidity, if this were possible.

In a cream testing 25% we find that more acid must be developed to get the desired effects in cream ripening than is necessary in a 35% cream. This is so because in the 25 % cream we have the acid distributed through 75% milk serum, while in the 35% cream it is distributed through only 65% milk serum.

If both the above creams show an acidity of .5%, this means that in the poor cream the .5 pound of acid is distributed through 75 pounds of serum, while in the rich

cream it is distributed through only 65 pounds of serum, hence the latter must have the greater intensity of acidity. This may be graphically shown as follows:

Poor cream.	Rich cream.
25% fat.	35% fat.
75% serum. .5% acid.	65% serum. .5% acid.

In the illustrations above it is seen that the acid in the rich cream is distributed through less space than in the poor, hence the degree of acidity must be higher in the rich cream.

We find in practice where the same results are to be expected from the ripening process, a 25% cream must show about .6% acidity, while a 35% cream, about .5%.

In bulletin No. 24 of the Washington Experiment Station, Prof. Spillman gives a table showing the required acidity for cream of different richness.

CHAPTER VIII.

STARTERS.

The value of carefully selected cultures of lactic acid producing bacteria in cream ripening was first demonstrated by Dr. Storch, of Copenhagen, a little less than a decade and a half ago. Since then the use of these cultures has spread so rapidly that few successful creameries can be found at the present time in which they are not used.

Definition. *Starter* is the general term applied to cultures of lactic acid organisms, whether they have been selected artificially in a laboratory, or at creameries by picking out lots of milk that seem to contain these organisms to the exclusion of others. A good starter may be defined as a clean flavored batch of sour milk or sour skim-milk.

The word starter derives its name from the fact that a starter is used to "start" or assist the development of the lactic fermentation in cream ripening.

Object of Starters. Cream ordinarily contains many kinds of bacteria—good, bad, and indifferent—and to insure the predominance of the lactic acid type in the ripening process it is necessary to reinforce the bacteria of this type already existing in the cream by adding large quantities of them in a pure form, that is, unmixed with undesirable species.

The bacterial or plant life of cream may be aptly compared with the plant life of a garden. In both we find plants of a desirable and undesirable character. The

weeds of the garden correspond to the bad fermentations of cream. If the weeds get the start of the cultivated vegetables, the growth of the latter will be checked or suppressed. So with the bacterial fermentations of cream. When the lactic acid bacteria predominate, other fermentations will be checked or crowded out. The use of a liberal amount of starter nearly always insures a majority of good bacteria and the larger this majority the better the product.

Classification of Starters. The following is a classification of the various starters in use at the present time:

Starters.	Natural.....	{ Sour skim-milk.... }	{ Desirable.
		{ Sour milk..... }	
		{ Sour cream..... }	{ Undesirable.
		{ Buttermilk..... }	
	Commercial (American)...	{ O. Douglas Cultures (Boston, Mass.).. }	{ 1. Boston Butter Culture 2. Lactic Acid Culture. 3. Duplex Culture.
		{ S. C. Keith Jr., (Charlesto'n, Mass.) }	
		{ Elov Erricsen (Mankato, Minn.). Hansen's Lactic Ferment (Little Falls, N. Y.) and a few others.	

NATURAL STARTERS.

Sour Milk and Skim-milk. Natural starters are those obtained by allowing milk, skim-milk, or possibly cream, to sour in the ordinary way.

The earlier methods of using natural starters consisted in selecting milk or skim-milk from the patrons who furnished the best milk at the creamery, and allowing this to sour by holding it over till the following day. While good milk could be selected in this way, the method of souring it was very unsatisfactory. On warm days the milk might oversour, while on cooler days it would be

found comparatively sweet unless a good deal of attention was given to keeping the temperature where it would sour in the proper length of time. This method of starter making is rapidly falling into disuse.

The most satisfactory natural starters are selected and prepared in the following manner: Secure, say, one quart of milk from each of half a dozen healthy cows not far advanced in lactation, and fed on good feed. Before drawing the milk, brush the flanks and udders of the cows and then moisten them with water or, preferably, coat thinly with vasaline to prevent dislodgement of dust. Then, after rejecting the first few streams, draw the milk into sterilized quart jars provided with narrow necks. Now allow the milk to sour, uncovered, in a clean, pure atmosphere at a temperature between 65° and 90° F. When loppered pour off the top and introduce the sample with the best flavor into fifty pounds of sterilized skim-milk and ripen at a temperature at which it will sour in twenty-four hours (about 65° F.).

A starter thus selected can be propagated for a month or more by daily inoculating newly sterilized or pasteurized milk with a small amount of the old or mother starter. Usually three or four pounds of the mother starter added to one hundred pounds of pasteurized skim-milk will sour it in twenty-four hours at a temperature of 65° F. Under certain conditions of weather this amount may possibly have to be modified a little, for it is well known that on hot sultry days milk will sour more quickly at a given temperature than on cooler days. The best rule to follow is to use enough of the mother starter to sour the milk in twenty-four hours at a temperature of 65° F.

Buttermilk and Sour Cream. If the cream has a good flavor, a portion of this, or the buttermilk from it,

may be used as a starter. But in the case of unpasteurized cream, even though the flavor is good, there are always present some undesirable germs which will multiply in each successive batch of cream or buttermilk used as a starter, so that after a week's use the flavor may actually be bad. Where cream is slightly off flavored and a portion of this, or the buttermilk from it, is used as a starter, it will readily be seen that the taint will not only be transmitted but will multiply in the cream from day to day. The use of either cream or buttermilk as a starter is therefore never to be recommended.

COMMERCIAL STARTERS.

Commercial starters may consist of a single species of lactic acid organisms, but usually they are made up of a mixture of several species. These starters are prepared in laboratories where the utmost precautions are taken to keep them free from undesirable germs. The methods by which the good bacteria are separated from the bad are quite complicated and of too little practical value to permit a discussion of them here. Suffice it to say that such separation is possible only with the skilled bacteriologist.

Keith and Douglas each manufacture three different cultures which are put upon the market in liquid form, the liquid usually being bouillon, or beef extract, treated with milk sugar. The development of the germs in this medium is very rapid and the cultures should therefore not be used later than ten days after they are sent out from the manufacturer unless they are kept at low temperatures. The reason for this is that the rapid growth of the bacteria will quickly result in vast numbers of them,

which, together with their by-products, is fatal to their development.

The chief difference in the three cultures prepared by these men lies in the intensity of acid produced. The "lactic" is the most vigorous, and the "Boston" the least vigorous acid producing culture, while the "duplex" seems to take an intermediate position. Sometimes, however, it is difficult to distinguish between these cultures.

Erricson's culture has only recently been placed upon the market but is already popular. It is sent out in the form of a liquid which appears to consist of sterilized milk to which some sugar has been added.

Hansen's lactic ferment is put up in the form of a powder which consists chiefly of sterilized milk with possibly slight additions of casein and starch. In this dry powdery medium the germs remain in a dormant condition. When held a long time in this condition their vitality seems to become impaired.

Preparation. Most of the commercial cultures are sent out in one ounce bottles which are hermetically sealed. The method of making starters from them is the same for all whether they are obtained in the liquid or in the dry form.

In making the first batch of commercial starter, the entire contents of the bottle is put into a quart of skim-milk, sterilized by keeping it at a temperature of 200° F. for two hours, and then cooling to 80° which temperature should be maintained until the starter has thickened. A new starter is now prepared by introducing the quart of starter into fifty pounds of skim-milk, pasteurized by keeping it at a temperature of 170° to 185° for thirty minutes and then cooling to 65° F. All subsequent starters are prepared in the same way except that the amount of

mother starter for inoculation must be reduced a little for a few days because the germs become more vigorous after they have propagated several days.

In preparing the first starter from a bottle of culture it is necessary to have the skim-milk *sterile*. For if any spores should remain, the slow souring would give them a chance to develop which might spoil the starter. Moreover, the cooked flavor imparted by the prolonged heating at high temperatures does not matter in the first starter as this should never be used to ripen cream. The first and second starters prepared from a new culture seldom have the good flavor produced in subsequent starters. The cause of this in all probability is the inactive condition of the germs and the peculiar flavor of the medium in which they are sent out.

In the starters prepared later the destruction of the spores is not so essential as the lactic acid germs are then in a vigorously growing condition which renders the spores practically harmless. At any rate the harm done by them would be less than that caused by the sterilizing process. When milk is pasteurized at 170° to 185° F. for thirty minutes the vegetative germs are destroyed and but little cooked flavor is noticeable.

NATURAL VERSUS COMMERCIAL STARTERS.

Experimental tests have shown that equally good results can be secured with commercial and natural starters. It is believed, however, that the average butter maker can get the best results with commercial starters. Too few are good judges of milk and for this reason are not always capable of selecting the best for natural starters. Standard commercial cultures can be relied upon as giving uniformly good results.

From what has been said of the methods of preparing starters it must have been noticed that they are essentially the same for both the natural and the commercial, the chief difference being in the original ferment, which in the case of the natural starter consists of a quart of selected milk allowed to sour naturally, while in the commercial it consists of a bottle of culture prepared in a laboratory.

USING A STARTER EVERY OTHER DAY.

During the winter when milk is received every other day at creameries the ordinary method of preparing starters daily is, of course, out of question. There are two ways, however, in which starters may be carried along during this time. One way is to keep the starter an extra twenty-four hours by holding it at a temperature below 50° after it has soured. The other and more satisfactory way is to prepare a small starter on the day the milk is separated; and, in addition, to pasteurize, but not inoculate, the amount of skim-milk needed for the regular starter. This milk is repasteurized the following day and then inoculated from the small starter prepared the day previous.

The object in repasteurizing the milk is to destroy the spores that have developed into the vegetative state.

HOW TO SELECT MILK FOR STARTERS.

It is poor practice to select starter milk promiscuously. The sweetest and best flavored milk should be obtained for the preparation of starters. Where possible the best plan is to select the morning's milk of one of the earliest patrons at the creamery and separate this first. In case

the best milk is received toward the middle or close of the run, it should be carried into the creamery and separated by itself so as to secure the skim-milk without contamination from other milk of inferior flavor.

It must not be supposed that any milk may be made into a first-class starter by thorough pasteurization and inoculation with good cultures of bacteria. The best starters are possible only with the best milk.

WHOLE MILK STARTERS.

Where whole milk is used for making starters the cream should always be skimmed off before using the starter. Indeed it is good practice to skim off the top of any starter before using as the surface is liable to become contaminated from exposure to the air.

ACIDITY OF STARTERS.

It has already been stated that a starter is at its best immediately after it has thickened when it usually shows about .7% acid. It must not be supposed, however, that all starters are at their best when they show this amount of acid, because different starters thicken with different degrees of acidity. Nor must it be supposed that a starter that tends to sour very quickly is better than one that sours slowly. Marshall, of the Michigan Agricultural College, has recently found that when certain alkali producing bacteria are associated with the lactic acid organisms the milk sours more quickly than when the alkali bacteria are not present. These alkali producing bacteria, while they hasten the souring, produce an undesirable flavor. This probably explains why starters that have a tendency to sour very rapidly are often inferior to those

that sour less rapidly. Usually, too, starters after they have been propagated for some time, become intensely acid producing, which is probably due to contamination with the peculiar alkali producing bacteria.

RENEWAL OF STARTERS.

Under average creamery conditions it is policy to renew the starter at least once a month by purchasing a new bottle of culture. It will be found that after the starter has been propagated for two or three weeks bad germs will begin to manifest themselves as a result of imperfect-pasteurization, contamination from the air, or from over-ripening, so that its original good flavor may be seriously impaired at the end of one month's use. It is only where the utmost precautions are taken in pasteurizing the milk and ripening the starter, that it is possible to propagate a starter for many weeks and still maintain a good flavor.

VALUE OF CARRYING SEVERAL STARTERS.

There is always some possibility of losing a starter by overripening or by accidental contamination which would deprive the butter maker of the use of a starter for several days. To insure against this, butter makers should practice carrying a few extra ones in quart cans. This has the additional advantage of offering some choice. The best is, of course, always selected for regular use. The milk for the small starters should be sterilized rather than pasteurized.

This practice of carrying several starters is strongly recommended.

STARTER CANS.

The most difficult thing in connection with starters is to get them just ripe when ready to use. A starter has its best flavor right after it has thickened. When it begins

Fig. 30.—Haugdahl starter can.

to show whey it indicates that the ripening has gone too far and should not then be used in the cream. The strong and curdy flavors found in butter are often directly attributable to overripened starters.

It becomes evident that to secure the proper acidity in the starter from day to day cans or vats must be used in which it is possible to obtain perfect control of temperature. The improved Haugdahl starter can, shown in Fig. 30, answers the purpose very satisfactorily. This can is

portable and provided with a double jacket between which steam, hot water, cold water, or ice water may be circulated as the case may demand. It is also provided with an agitator which is operated by power.

POINTERS ON STARTERS.

1. Starters give best results when added to cream immediately after they have thickened.

2. An overripe starter produces somewhat the same effect in butter as overripened cream. Curdy flavors are usually the result of such starters.

3. To prevent overripening, starter cans or starter vats must be used in which the temperature can be kept under perfect control.

4. Skim-milk furnishes the best medium for starters, since this has undergone the cleansing action of the separator and is free from fat, which hampers the growth of lactic acid bacteria.

5. Agitate and uncover the milk while heating to insure a uniform temperature and to permit undesirable odors to escape.

6. Always dip the thermometer in hot water before inserting it in pasteurized milk. The pasteurizing process becomes a delusion when dirty thermometers are used for observing temperatures.

7. Always use a sterilized can for making a new starter.

8. Keep the starter can loosely covered after the milk has been heated to prevent germs from the air getting into it.

9. Stir the starter occasionally the first five hours after inoculation to insure uniform ripening.

10. Never disturb the starter after it has begun thickening until ready to use.

11. When a new bottle of commercial culture is used, the first two starters from it should not be used in cream as the flavor is usually inferior on account of the slow growth of the bacteria and the undesirable flavor imparted by the medium in which the cultures are sent out. A commercial starter is usually at its best after it has been propagated a week.

12. Always sterilize the neck of a new bottle of culture before emptying the contents into sterilized skim-milk.

CHAPTER IX.

CHURNING.

Theory. Under the physical properties of butter fat it was mentioned that this fat existed in milk in the form of extremely minute globules, numbering about 100,000,000 per drop of milk. In rich cream this number is increased at least a dozen times owing to the concentration of the fat globules during the separation of the milk.

So long as milk and cream remain undisturbed, the fat remains in this finely divided state without any tendency whatever to flow together. This tendency of the globules to remain separate was formerly ascribed to the supposed presence of a membrane around each globule. Later researches, however, have proven the falsity of this theory and we know now that this condition of the fat is due to the surface tension of the globules and to the dense layer of casein that surrounds them.

Any disturbance great enough to cause the globules to break through this caseous layer and overcome their surface tension will cause them to unite or coalesce, a process which we call *churning*. In the churning of cream this process of coalescing continues until the fat globules have united into masses visible in the churn as butter granules.

CONDITIONS THAT INFLUENCE CHURNING.

There are a number of conditions that have an important bearing upon the process of churning. These may be enumerated as follows:

1. Temperature.
2. Character of butter fat.
3. Acidity of cream.
4. Richness of cream.
5. Amount of cream in churn.
6. Speed of churn.
7. Abnormal fermentations.

1. Temperature. To have the microscopic globules unite in churning they must have a certain degree of softness or fluidity which is greater the higher the temperature. Hence the higher the temperature, within certain limits, the quicker the churning. To secure the best results the temperature must be such as to churn the cream in from thirty to forty-five minutes. This is brought about in different creams at quite different temperatures.

The temperature at which cream must be churned is determined primarily by the character of the butter fat and partly also by the acidity and richness of the cream.

Rule for Churning Temperature. A good rule to follow with regard to temperature is this: When the cream enters the churn with a richness of 30 to 35 per cent and an acidity of .5 to .6 per cent, the temperature should be such that the cream will churn in from thirty to forty-five minutes. This will insure an exhaustive churning and leave the butter in a condition in which it can be handled without injuring its texture. Moreover, the buttermilk can then be easily removed so that when a plug is taken with a trier the day after it is churned the brine on it will be perfectly clear.

2. Character of Butter Fat. The fat globules in cream from different sources and at different times have the proper fluidity to unite at quite different temperatures.

This is so because of the differences in the relative amount of "soft" and "hard" fats of which butter fat is composed. When the hard fats largely predominate the butter fat will of course have a high melting point. Such fat may be quite hard at a temperature of 60° while a butter fat of a low melting point would be comparatively soft at this temperature. For a study of the conditions that influence the hardness of butter fat the reader is referred to the discussion of the "insoluble fats" treated in the chapter on milk.

3. Acidity of Cream. This has a marked influence on the churning process. Sour or ripened cream churns with much greater ease than sweet cream because the acid renders it less viscous. The ease with which the fat globules travel in cream becomes greater the less the viscosity. Ripe cream will therefore always churn more quickly than sweet cream. Ripe cream also permits of a higher churning temperature than sweet which is of great practical importance where it is difficult to secure low churning temperatures.

4. Richness of Cream. It may naturally be inferred that the closer the fat globules are together the more quickly they will unite with the same amount of concussion. In rich cream the globules are very close together which renders it more easily churnable than thin cream. The former can therefore be churned in the same length of time at a lower temperature than the latter.

The ideal richness lies between 30% and 35%. A cream much richer than this will stick to the sides of the churn which reduces the amount of concussion. The addition of water to the churn will overcome this stickiness and cause the butter to come in a reasonable length of

time. It is better, however, to avoid an excessive richness when an exhaustive churning is to be expected.

5. Amount of Cream in Churn. The best and quickest churning is secured when the churn is one-third full. With more or less cream than this the amount of concussion is reduced and the length of time in churning correspondingly increased.

6. Speed of Churn. The speed of the churn should be such as to produce the greatest possible agitation or concussion of the cream. Too high or too low a speed reduces the amount of concussion. The proper speed for each particular churn must be determined by experiment.

7. Abnormal Fermentations. The slimy or ropy fermentation sometimes causes trouble in churning by rendering the cream excessively viscous. Cream from single herds may become so viscous as to render churning impossible. At creameries where milk is received from many herds very little trouble is experienced from these fermentations.

CHURNS.

A churn is a machine in which the cream is made to slide or drop, or is in some way agitated to bring about the union of the fat globules, which changes the liquid fat into a solid. For many years the factory churns had assumed the form of a box or barrel free from any inside fixtures. Such churns were revolved by power and did very satisfactory work. But it was necessary to transfer the butter, after it was churned, to a worker upon which it was worked.

This transfer from one piece of apparatus to another was obviated by the invention of "combined" churns and

Fig. 31.—Victor combined churn and butter worker.

workers (Figs. 31 and 32) placed upon the market a little more than a decade ago. These are provided with rollers inside, which remain stationary during churning, but can be made to revolve when it is desired to work the butter.

The combined churns have to a great extent replaced the old box and barrel styles because of the many advantages they possess over the latter. The principal advantages may be stated as follows:

Fig. 32.—Disbrow combined churn and butter worker.

1. They occupy less space.
2. Require less belting and fewer pulleys.
3. The churn can be kept closed while working which keeps the warm air and flies out during the summer.
4. The butter can be made with considerably less labor.

A few disadvantages might be mentioned such as the greater original cost and the greater difficulty of cleaning and salting. But with proper care the butter may be evenly salted and the churns kept clean.

CHURNING OPERATIONS.

Preparing the Churn. Before adding the cream, the churn should be scalded with hot water and then thoroughly rinsed with cold water. This will “freshen”

the churn and fill the pores of the wood with water so that the cream and butter will not stick.

Straining Cream. All cream should be carefully strained into the churn. This removes the possibility of white specks in butter which usually consist of curd or dried particles of cream.

Adding the Color. The amount of color to be added depends upon the kind of cream, the season of the year, and the market demands.

Jersey or Guernsey cream requires much less color than Holstein because it contains more natural color.

During the summer when the cows are feeding on pastures the amount of color needed may be less than half that required in the winter when the cows are feeding on dry feed.

Different markets demand different shades of color. The butter must therefore be colored to suit the market to which it is shipped.

In the winter time about one ounce of color is required per one hundred pounds of butter. During the summer less than one-half ounce is usually sufficient.

In case the color is not added to the cream (through an oversight) it may be added to the butter at the time of working by thoroughly mixing it with the salt. When the colored salt has been evenly distributed through the butter the color will also be uniform throughout.

Kinds of Color. There are two classes of butter color found upon the market. One is a vegetable color having its origin in the annatta and other plants, the other is a mineral color, a product of coal tar. Both are entirely satisfactory so far as they impart to butter a desirable color. But from a sanitary standpoint the vegetable color

seems to be preferred though the odor due to the vegetable oils has been objected to by butter experts.

Gas in Churn. During the first five minutes of churning the vent of the churn should be opened occasionally to relieve the pressure developed inside. This pressure according to Babcock "is chiefly due to the air within becoming saturated with moisture and not to gas set free from the cream."

Size of Granules. Butter should be churned until the granules are about half the size of a pea. When larger than this it is more difficult to remove the buttermilk and distribute the salt. When smaller, some of the fine grains are liable to pass out with the buttermilk, and the percentage of water in the butter is reduced. When the granules have reached the right size, cold water should be added to the churn to cause the butter to float. Salt will answer the same purpose. The churn is now given two or three revolutions and the buttermilk drawn off.

Washing Butter. One washing in which as much water is used as there was cream is usually sufficient. When butter churns very soft two washings may be advantageous. Too much washing is dangerous, however, as it removes the delicate flavor of the butter.

Too much emphasis cannot be laid upon the importance of using clean, pure water for washing. Experiments conducted at the Iowa station and elsewhere have shown that impure water seriously affects the flavor of butter. When the water is not perfectly pure it should be filtered or pasteurized.

SALTING.

It is needless to say that nothing but the best grades of salt should be used in butter. This means salt readily

soluble in water and free from impurities. If there is much foreign matter in salt, it will leave a turbid appearance and a slight sediment when dissolved in a tumbler of clear water.

Rate of Salt. The rate at which butter should be salted, other conditions the same, is dependent upon market demands. Some markets like Boston require much salt in butter while some buyers in the New York market require scarcely any. The butter maker must cater to the markets with regard to the amount of salt to use as he does with regard to color.

The rate of salt used does not necessarily determine the amount contained in butter. For instance it is perfectly possible under certain conditions to get a higher percentage of salt in butter by salting at the rate of one ounce per pound than is possible under other conditions by salting at the rate of one and a half ounces. This means that under some conditions of salting more salt is lost than under others.

The amount of salt retained in butter is dependent upon:

1. Amount of drainage before salting.
2. Fineness of butter granules.
3. Amount of butter in churn.

1. When the butter is salted before the wash water has had time to drain away, any extra amount of water remaining will wash out an extra amount of salt. It is good practice, however, to use a little extra salt and drain less before adding it as the salt will dissolve better under these conditions.

2. Small butter granules require more salt than large ones. The reason for this may be stated as follows: The surface of every butter granule is covered with a thin

film of water, and since the total surface of a pound of small granules is greater than that of a pound of larger ones, the amount of water retained on them is greater. Small granules have therefore the same effect as insufficient drainage, namely, washing out more salt.

3. Relatively less salt will stick to the churn in large churnings than in small, consequently less will be lost.

Standard Rate. The average amount of salt used in butter made in the combined churns comes close to one and a half ounces per pound of butter. But the rate demanded by different commission men may vary from no salt to two and a half ounces per pound of butter.

With the combined churns great care must be exercised to get the salt evenly distributed from one end of the churn to the other as it can not redistribute itself in the working.

Brine Salting. This consists in dissolving the salt in water and adding it to the butter in the form of a brine. This will usually insure an even distribution with less working since the salt is already dissolved. Where butter containing a high percentage of salt is demanded the method of brine salting is not practical, because it limits the amount that can be incorporated in butter.

Where there is difficulty in securing an even distribution of the salt without excessive working, an oversaturated brine may be used to advantage. Salt added to butter in this form very quickly dissolves and a butter with any degree of salt is possible.

But it is believed that where butter is drained little and a somewhat higher rate of salt is used, dry salting will never require overworking and will insure greater uniformity than is possible with brine salting.

Object of Salting. Salt adds flavor to butter and

materially increases its keeping quality. Very high salting, however, has a tendency to detract from the fine delicate aroma of butter while at the same time it tends to cover up slight defects in the flavor. As a rule a butter maker will find it to his advantage to be able to salt his butter rather high.

Salt an Absorbent. Salt very readily absorbs odors and must therefore be kept in clean, dry places where the air is pure. Too frequently it is stored in musty, damp store rooms where it will not only lump, but become impregnated with bad odors which seriously impair the quality of the butter.

WORKING BUTTER.

The chief object in working butter is to evenly incorporate the salt. To accomplish this end with the least amount of working it is necessary to work butter twice.

After the wash water has sufficiently drained away, the salt is carefully distributed over the butter and the churn revolved a few times with the rollers stationary. This will aid in mixing the salt and butter. The rollers are now set in gear and the butter worked about two minutes to fairly incorporate the salt. After this it is allowed to stand not less than half an hour to allow the salt to dissolve when the working may be finished.

How Much to Work. Butter is worked enough when the salt has been evenly distributed. Just when this point has been reached can not always be told from the appearance of the butter immediately after working. But after four or six hours standing the appearance of white streaks or mottles indicates that the butter has not been sufficiently worked. The rule to follow is to work the butter just enough to prevent the appearance of mottles

after standing about six hours. Just how much working this requires every butter maker must determine for himself, by experiment, for the reason that there are a number of conditions that influence the length of time that butter needs to be worked in a combined churn. These conditions are:

1. Amount of butter in the churn.
2. Temperature of the butter.
3. Time between workings.
4. Size of granules.
5. Solubility of salt.

1. When there is a moderately large amount of butter in the churn the working can be accomplished with fewer revolutions than with a small amount. Satisfactory working can not be secured, however, when the capacity of the churn is overtaxed.

2. Hard, cold butter is difficult to work because the particles will not knead together properly.

3. A moderately long time between workings allows the salt to dissolve and diffuse through the butter and hence reduces the amount of working.

4. Coarse or overchurned butter needs a great deal of working because of the greater difficulty of distributing the salt.

5. A salt that does not readily dissolve requires excessive working and is therefore productive of overworked butter. With such salt the brine method of salting is undoubtedly preferable.

DIFFICULT CHURNING.

The causes of trouble in churning may be enumerated as follows: (1) thin cream, (2) low temperature, (3) sweet cream, (4) high viscosity of cream, (5) churn too full, (6) too high or too low speed of churn, (7) colostrum milk, (8) advanced period of lactation, and (9) abnormally rich cream.

Foaming. This is usually due to churning a thin cream at too low a temperature, or to a high viscosity of the cream. When caused by these conditions foaming can usually be overcome by adding warm water to the churn. Foaming may also be caused by having the churn too full, in which case the cream should be divided and two churnings made instead of one.

CLEANING CHURNS.

After the butter has been removed, the churn should be washed, first with moderately hot water, next with boiling hot water containing a little alkali, and finally with hot water. If the final rinsing is done with cold water the churn dries too slowly, which is apt to give it a musty smell.

This daily washing should be supplemented once a week with a washing with lime water, which is prepared as follows: Gradually slake half a bushel of freshly burned lime by adding water to it at short intervals until about 150 pounds of water has been added. Stir the mixture once every half hour for several hours, after which allow it to remain undisturbed for about ten hours. This permits the undissolved material to settle. The clear liquid is now poured off and added to the churn, which is

slowly revolved for at least half an hour so that the lime water may thoroughly penetrate the pores of the wood.

Nothing is equal to the cleansing action of well prepared lime water and its frequent use will prevent the peculiar churn odor that is bound to develop in churns not so treated.

The outside of the churn should be thoroughly cleaned with moderately hot water containing a small amount of alkali.

CHAPTER X.

PACKING AND MARKETING BUTTER.

Butter is usually in the best condition for packing immediately after the second working. It can then be packed solidly into the packages without the vigorous ramming necessary when the butter becomes too cold. When allowed to stand in the churn some time after working during the warm summer days, the butter will usually get too soft for satisfactory packing.

There is a great variety of packages in which butter may be packed for the markets. These may be conveniently divided into two groups: (1) those used for home trade, and (2) those designed for export trade.

Home Trade Packages. The bulk of the butter for home trade is packed in ash and spruce tubs, the former holding 20, 30, and 60 pounds, while the latter are made in 10, 20, 30, and 50 pound sizes.

Before adding the butter, the tubs must be thoroughly scrubbed inside and outside, the hoops carefully set, and then soaked in hot water for about half an hour. After this they are steamed for three minutes and then allowed to soak in cold water not less than four hours. The sides and bottom of the tubs are next lined with parchment paper which has been soaked in strong brine for twenty-four hours.

The wet liners are easily placed in the tubs by allowing them to project an inch and turning this over the edge.

The tubs are now weighed and the butter packed into

them directly from the churn, adding about five pounds at a time and firmly packing it with a wooden packer made for this purpose. The butter should be packed solid so that when stripped of its package on the retailer's counter no open spaces will appear in it.

When ash tubs are used they are packed brim full and trimmed off level with the tub by running a string across the top. The tubs are then weighed and the weights marked on the outside, allowing not less than half a pound for shrinkage for a sixty pound tub. A cheese cloth circle is next placed over the top and an oversaturated brine is pasted upon this. After careful cleaning place the covers on the tubs and fasten them with not less than three butter tub fasteners.

With spruce tubs the method of packing is the same with the exception that most markets require an even number of pounds in a tub, as 30 or 50 pounds. The tubs are, therefore, trimmed down till the required weight, plus half a pound for shrinkage, is reached. Some markets do not require the spruce tubs to be lined but it is always better to do so.

Prints. Considerable quantities of butter made in creameries are put up in one pound oblong blocks called *prints*. Where many of these prints are made a printer like that shown in Fig. 33 is most serviceable. This makes twenty-five prints at a time.

The prints are carefully wrapped in parchment paper which has been soaked in strong brine for twenty-four hours, and then packed in cheap wood boxes which usually hold about fifty of them. These boxes should be held not less than one day in a refrigerator before they are shipped. Print butter is growing in popularity.

There are various other packages in which butter is

packed, such as five pound crocks, gem fibre paper boxes lined with parchment and holding 2, 3, 4, 5, and 10 pounds, and the wooden bail boxes holding from 5 to 10 pounds. Most of these packages are used for local trade.

Fig. 33.—Butter printer.

Foreign Trade Packages. For export trade butter is preferably packed in cubical spruce boxes lined with paraffin and holding 56 pounds. These boxes are prepared by rinsing them with cold brine and then lining with double thickness of parchment paper which has been soaked in strong brine. The boxes are now weighed and carefully packed, after which they are trimmed down to a weight of 57 pounds, which allows one pound for shrinkage. Finish the packing by placing a double thick-

ness of parchment paper over the top and upon this over-saturated brine.

Butter shipped to tropical countries is packed in tin cans which are hermetically sealed.

MARKETING BUTTER.

The producer of any commodity is always confronted with the problem of finding the best markets for his product. Indeed his success is measured more or less by his ability in handling this end of the business.

Butter makers lose thousands and thousands of dollars every year because they do not fully understand how to manage the sale of their product. They fall into the clutches of men without credit or credentials who offer big prices but no returns. Swindlers are always on the lookout for victims and every year many butter makers are entrapped by them. To the one who is just beginning to seek a market for his butter the following course of procedure is recommended.

1. Find the names of three or more leading reputable butter firms in the leading butter markets by inquiring of men from whom trustworthy information may be expected.

2. Divide a day's standard make among these butter firms and instruct each to send you statement as to the price they can give you net (f. o. b.) at your station for regular shipments, the price to be based on quotations of some leading market. Inform them further that you are ready and willing to comply with their demands as to color, package, and salt, in future shipments.

3. Ship your butter to the firm that offers you the best price, but do not deal with this firm exclusively. A tub

should occasionally be sent to a new and reliable firm with a view to securing better prices.

4. Remember, however, that it requires time to establish a good trade for butter. Frequent changes from one firm to another are therefore undesirable.

5. Do not sell butter on commission, but ask for prices f. o. b. your station, based on some market quotation like New York.

6. Demand that payment shall be made for each shipment of butter within two weeks after it is sent out.

7. Never send a firm a third shipment until the first has been paid for.

8. Butter that is not up to the standard should be marked and the firm properly instructed regarding its disposition. An attempt to crowd in an inferior shipment may cost you your regular trade.

9. Do not feel hurt when criticisms come regarding defects in your butter but seek to overcome them.

10. Always allow one-half pound of butter for shrinkage on fifty and sixty pound tubs. If this allowance proves inadequate it indicates that the tubs have not been properly soaked or that the "house" is cutting you on weights.

11. Never contract butter for more than a year at a time.

CHAPTER XL

CALCULATING DIVIDENDS.

1. Whole Milk. It is customary to pay for milk at creameries once a month. Such payment is called the monthly dividend. The method by which this dividend is calculated depends, of course, on the basis upon which the milk is bought. Fortunately the large majority of creameries now pay for it according to the butter fat content. Milk so paid for is spoken of as being bought by the "Babcock test" or on the "fat basis." Since it makes butter in proportion to the amount of fat it contains, the Babcock test or fat basis is manifestly the only just way of buying milk at creameries. This method will be discussed in detail.

CALCULATING DIVIDENDS ON A FAT BASIS.

The different steps in this calculation are indicated as follows:

1. Find the total pounds of milk delivered by each patron for the month.
2. Find each patron's average percentage of butter fat for the month by averaging up the number of tests.
3. Multiply each patron's total milk for the month by the average percentage of butter fat it contains, the product will be the total pounds of butter fat delivered.
4. Add together all butter fat delivered by the patrons for the month, the sum will be the total butter fat.
5. Determine the total gross receipts for the month by multiplying each sale of butter by the price received

per pound; the sum obtained by adding all the sales will be the total gross receipts.

6. Calculate the amount charged to cover running expenses by multiplying the total pounds of butter by the price charged for making.

7. Subtract the sum charged to cover running expenses from the total gross receipts, the difference will be the net money due patrons.

8. The total net money divided by the total pounds of butter fat will give the average price per pound of butter fat.

9. Each patron's share of the monthly dividend is now found by multiplying his total butter fat by the average price per pound of butter fat obtained in 8.

To make the above steps perfectly clear let us calculate a monthly dividend at a creamery in which A, B, and C are the patrons.

		<i>Milk Pounds.</i>		
	<i>Date.</i>	A	B	C
1.	August 1.....	260	150	312
	August 2.....	255	151	300
	August 3.....	261	145	305
				
	August 31.....	240	162	301
		<hr/>	<hr/>	<hr/>
	Total.....	8,091	4,650	9,405

		<i>Per cent of butter fat.</i>		
	<i>Date.</i>	A	B	C
2.	August 7.....	3.3	4.2	3.6
	August 15.....	3.4	4.3	3.6
	August 23.....	3.4	4.2	3.7
	August 31.....	3.3	4.0	3.6
		<hr/>	<hr/>	<hr/>
		4 13.4	4 16.7	4 14.5
	Average test....	3.35	4.17	3.62

					4.
		<i>Total milk.</i>	<i>Ave. test.</i>		<i>Total butter fat.</i>
3.	A	8,091	×	3.35	= 271.05 lbs.
	B	4,650	×	4.17	= 193.91 lbs.
	C	9,405	×	3.62	= 340.46 lbs.
					<hr/>
Total butter fat at Creamery					= 805.42 lbs.

Sales of butter.

5.	205 lbs. at 23 cts.	= \$47.15
	240 lbs. at 23.5 cts.	= 56.40
	214 lbs. at 24 cts.	= 51.36
	269 lbs. at 24 cts.	= 64.56
		<hr/>

Total... 928 Total..... \$219.47

6. Total pounds of butter = 928.
Price charged for making = 3 cts. per pound.
 $928 \times .03 = \$27.84$ = Amount charged to cover running expenses.
7. $\$219.47 - \$27.84 = \$191.63$ = Net money due patrons.
8. $\$191.63 \div 805.42 = \$.2379$ = Average price per pound butter fat.
9. $271.05 \times \$.2379 = \64.48 = A's money.
 $193.91 \times .2379 = 46.13$ = B's money.
 $340.46 \times .2379 = 81.00$ = C's money.

OVERRUN.

In a well conducted creamery the total pounds of butter is always greater than the total pounds of butter fat. The excess is called the "overrun."

In the above problem 805.42 pounds of butter fat made 928 pounds of butter.

$$928.00 - 805.42 = 122.58 = \text{No. pounds overrun.}$$

$$122.58 \div 805.42 = 15.2 = \text{Per cent overrun.}$$

MONTHLY STATEMENT.

When the monthly payments are made each patron is presented with an envelope upon which is printed his individual account with the creamery and also the entire transactions of the creamery. A check on the nearest bank, or the money, is placed in the envelope and handed to the patron on "pay day." Below is shown such a monthly statement:

The preceding pages show the correct method of calculating the dividend at creameries. The author has learned from experience, however, that it is often difficult to make clear to patrons how the price per pound of butter fat is obtained. Frequently also competing creameries are inclined to cut a little on the test to increase the price per pound of butter fat. Where trouble from these sources is experienced dividends may be apportioned on the plan indicated on the following monthly statement:

In this method the net price per pound of butter is used instead of the price per pound of butter fat. The method involves a little more work as each patron's overrun in pounds must be calculated separately. For clearness, however, we believe no other method surpasses this.

The price of butter net to the patrons is obtained by subtracting the price charged for making from the average price for which the butter has sold. This average price is found by dividing the total gross receipts by the total pounds of butter at the creamery, thus:

Sales of butter.

205 lbs. at 23 cts.	=	\$47.15
240 lbs. at 23½ cts.	=	56.40
214 lbs. at 24 cts.	=	51.36
269 lbs. at 24 cts.	=	64.56
<hr/>		
Total.. 928	Total.....	\$219.47

$\$219.47 \div 928 = \$.2365 =$ Average price for which butter was sold. $\$.2365$ less three cents for making $= \$.2065 =$ price of butter net patrons. The butter fat plus overrun multiplied by the net price gives each patron's portion of the dividend.

II. Whole Milk and Cream. Where both whole milk and cream are received at the creamery, the calculation of dividends for cream patrons differs from that for whole milk patrons in one point; namely, in increasing each cream patron's total butter fat by 2%. The reason for this is that the cream patrons are credited with the butter fat found in the cream, while the whole milk patrons are credited with all the butter fat found in the milk, which is about 2% more than would be found in the cream from the same milk, 2% of the butter fat being lost in the skim-milk. To illustrate:

A delivers 6,500 pounds of milk testing 4.0%.

B delivers 600 pounds of cream testing 30%.

A's total fat = $6,500 \times .04 = 260$ pounds.

B's total fat = $600 \times .30 = 180$ pounds.

To increase B's fat by 2%, we multiply 180 by 1.02 which equals 183.6.

In making the dividend, therefore, A is paid for 260 pounds of butter fat and B for 183.6 pounds.

THE TWO PER CENT—HOW CALCULATED.

In a well conducted creamery the average loss of fat in the skim-milk should not be more than .078%. Dividing this figure by the average percentage of fat in milk, 3.9, we get .02. So that in the separating process .02 pound of fat is lost in the skim-milk for every pound of fat present in the milk.

From the above calculation it will be seen that the cream factor (2%) would necessarily vary with the efficiency of skimming and the average test of the milk. To determine what this shall be for any particular creamery divide the average loss of fat in the skim-milk by the average test of the milk at the creamery.

CHAPTER XII.

THEORETICAL OVERRUN.

For the purpose of instructing patrons with regard to the percentage of overrun the following calculation is submitted which incidentally involves the calculation of the amount of skim-milk and buttermilk to be returned from 100 pounds of milk, a calculation with which every butter maker should be familiar.

1. To calculate the amount of skim-milk per 100 pounds of milk.

Rule: Divide the per cent of fat in milk by the per cent of fat in cream and multiply the result by 100; the product subtracted from 100 will be the number pounds of skim-milk.

Example: How much skim-milk is obtained from 100 pounds of 4% milk when the separator delivers a 40% cream?

$$4 \div 40 = .10, .10 \times 100 = 10, 100 - 10 = 90 = \\ \text{No. lbs. skim-milk.}$$

COROLLARIES. (1) The richer the milk and the poorer the cream the less skim-milk.

(2.) The poorer the milk and the richer the cream the more skim-milk.

To allow for variations in richness of cream and small overweights at the creamery, 3 should be subtracted from the calculated amount of skim-milk. Thus in the problem above, the skim-milk should be distributed on the basis of 87 instead of 90 pounds per 100 pounds of milk as calculated.

2. To calculate the amount of buttermilk per 100 pounds of milk.

Rule: This is approximately found by increasing the pounds of butter fat in the cream by one-sixth and subtracting the result from the total pounds of cream.

Example: How much buttermilk from 100 pounds of 4% milk yielding 10 pounds of cream testing 40%?

$$\begin{aligned} 10 \times .40 &= 4.0 = \text{lbs. of butter fat.} \\ 4 \times 1 \frac{1}{6} &= 4.66, \quad 10 - 4.66 = 5.34 = \text{No. lbs.} \\ &\quad \text{buttermilk.} \end{aligned}$$

OVERRUN. The method of calculating the *actual* overrun at creameries has already been discussed in Chapter XI. With the following known conditions the *theoretical* overrun can be calculated with a fair degree of accuracy:

- (1) Average per cent of fat in butter.
- (2) Loss of fat in skim-milk.
- (3) Loss of fat in buttermilk.

Problem: 100 pounds of milk testing 4% yields cream testing 40%. Test of skim-milk is .05%, that of buttermilk .15%. Per cent of fat in butter is 84. Calculate butter and overrun.

By applying the rules for calculating skim-milk and buttermilk we find that there will be 90 pounds of skim-milk and 5.34 pounds buttermilk.

$$\begin{aligned} .90 \times .05 &= .045 = \text{lb. fat in skim-milk.} \\ .0534 \times .15 &= .008 = \text{lb. fat in buttermilk.} \\ \hline \text{Total loss} &= .053 \\ 4 - .053 &= 3.947 = \text{fat made into butter.} \\ 3.947 \div .84 &= 4.70 = \text{lbs. butter made.} \\ 4.70 - 4 &= .70 = \text{overrun in lbs.} \\ .7 \div 4 \times 100 &= 17.5 = \text{overrun in per cent.} \end{aligned}$$

CHAPTER XIII.

DISTRIBUTION OF SKIM-MILK AND BUTTERMILK.

In recent years much attention has been given to the problem of skim-milk distribution at creameries. The old way of weighing on a common pair of scales is too slow and tedious. Efforts to improve upon this method of weighing have resulted in bringing upon the market various kinds of automatic weighing and measuring devices such as our skim-milk weighers and check pumps. With the skim-milk weigher the patron drops into the machine a check corresponding to the amount of milk delivered, and the amount of skim-milk called for by the check is weighed or measured out automatically. In the case of the check pump the operation is somewhat different. A check is dropped into the pump and, instead of flowing out, the amount of skim-milk called for by the check is pumped out.

Some of these skim-milk weighers are giving good satisfaction when properly handled. But at least fifty per cent of the creameries are still adhering to the old methods of weighing on a common platform scales which, though tedious, is still perhaps the most accurate method.

Attention is here called to an automatic valve closing arrangement, shown in Fig. 34, which reduces the labor of weighing on a platform scales at least fifty per cent. A is a common pair of scales, B an ordinary receiving can with a two inch valve instead of a faucet, and C a device which closes the inlet valve, D, when the proper amount of skim-milk has run into the can.

It will be seen that one end of the rod, C, is attached to

the beam rod of the scales, while upon the other rests the handle which opens and closes the skim-milk valve. When the beam rises the connection is broken and the weight of the handle closes the valve. This makes it an automatic valve. Without this device the closing of the valve at the right time requires a good deal of watching which consumes too much time.

A skim-milk table like that shown below should be posted in a conspicuous place so that no time needs to be wasted in calculating each patron's skim-milk.

SKIM-MILK TABLE—85 POUNDS PER 100
POUNDS MILK.

Milk.	Skim-milk.	Milk.	Skim-milk.	Milk.	Skim-milk.	Milk.	Skim-milk.
10	8	110	93	210	178	310	263
20	17	120	102	220	187	320	272
30	25	130	110	230	195	330	280
40	34	140	119	240	204	340	289
50	42	150	127	250	212	350	297
60	51	160	136	260	221	360	306
70	59	170	144	270	229	370	314
80	68	180	153	280	238	380	323
90	76	190	161	290	246	390	331
100	85	200	170	300	255	400	340

With the automatic valve it is possible for the man who weighs in the milk also to weigh out the skim-milk with little additional work. The device is unpatented and costs not more than one dollar. Attached to an ordinary plat-

Fig. 34.—Apparatus for distributing skim-milk and buttermilk.

form scales, it furnishes with them an ideal skim-milk weigher which is cheap, simple, accurate, and needs no repairs.

BUTTERMILK DISTRIBUTION.

To insure a just distribution of buttermilk at creameries it is necessary to either weigh or measure it out to the patrons. The long cylindrical can, X, shown at the left

in Fig. 34, illustrates a very convenient and satisfactory measuring device. The measuring is done by means of a long hollow shaft, N, which consists of two boards between which a pointer, M, is made to slide. Attached to the pointer is a string which passes over pulleys, O and P, and ends in the buttermilk can where it is attached to a wooden disc floating on top of the buttermilk. As the buttermilk flows into the can the disc rises, causing the pointer to sink in the shaft. Marks on the shaft indicate the number of pailfuls measured out.

CHAPTER XIV.

BUTTER JUDGING.

Expert butter judges, like great musicians, are "born" not "made." A good musician must be born with a good ear, a good butter judge with a good nose. Most people, however, can become fair musicians with proper training, and the same may be said of butter judges.

By repeated judging and comparing of different samples of butter one will soon become able to make fair discriminations. The important point to learn is to know an ideal butter when you see it. A butter maker can not expect to reach or even approach an ideal butter unless he has the ideal fixed in mind.

One can learn much about butter judging by daily examining his own make. But to become expert, he must be able to compare his score with that of recognized experts. Dairy conventions and butter scoring tests offer excellent opportunities for such comparison.

BASIS FOR JUDGING.

Butter is judged commercially on the basis of 45 points for flavor, 25 for texture, 15 for color, 10 for salt, and 5 for package, total 100.

Flavor. Strictly speaking flavor means taste. But the use of the term flavor in butter judging usually includes both taste and aroma, the emphasis resting on the latter. Aroma is the odor noticeable when a sample of butter is held close to the nose, hence frequently called "nose" aroma.

It is difficult to describe an ideal butter flavor. It may, perhaps, be likened to the flavor of clean, uncontaminated, well ripened cream, that is, it should be rich and creamy.

Texture. This includes three distinct things: (1) grain, (2) body, and (3) brine.

An ideal grain is indicated by a somewhat granular appearance when a piece of butter is broken, an appearance quite similar to that of the broken ends of a steel rod.

Body refers to the consistency of butter. In other words, it refers to its degree of firmness or its ability to "set up" well at ordinary temperatures.

Brine refers to the amount and character of the water in butter. It should be as clear as water and not present in such quantities as to run off the trier.

Color. The essential thing in color is to have it uniform. It should have a little deeper shade than that produced by June pasturage. Artificial coloring is therefore necessary.

Salt. As with color, the essential thing with salt is to have it evenly worked through the butter and none of it should remain undissolved.

Package. Butter should be well packed and the top covered with cheese cloth and saturated brine. The package should be neat and clean and in no way mutilated.

BUTTER SCORE CARDS.

The score card contains the "score" or judgment as given by the judge. In commercial judging of butter a score card is used which is quite similar to the one given below.

BUTTER SCORE CARD.

Name _____

Sample.	No.	1	2	3					
Flavor - -	45	40	38	36					
Texture	25	23	23	23					
Color - - -	15	15	14	14					
Salt - - -	10	10	10	9					
Package - -	5	5	5	5					
Total - -	100								
		93	90	87					

Date _____ Judge _____

In such scoring no attempt is made to point out the particular defects any further than to indicate the number of points for each sample. The total number of points determines the class to which the butter belongs. Thus in the score card above, sample No. 1 grades as "extras," sample No. 2 as "firsts," and sample No. 3 as "seconds."

At dairy conventions and in educational butter scoring tests the object in judging is not so much to determine the score of the butter as to point out as nearly as possible the causes of any defects and to suggest remedies for overcoming them. The score card used in this case is shown on the next page.

BUTTER SCORE CARD

No. _____

	Perfect.	1st Scoring Date.....	2d Scoring. Date.....	
Flavor.....	45			{ Curdy. Light. Rancid. Fishy. Feverish. Oily. Weedy. Stable. Unclean.
Texture.....	25			{ Poor grain. Cloudy brine. Weak body. Too much brine.
Color.....	15			{ Mottles. White specks. Too high. Too light.
Salt.....	10			{ Too much salt. (Undissolved.) Poor salt. Lacks salt.
Package.....	5			{ Dirty. Poorly packed. Poorly nailed. Poorly lined.
Total.....	100			

Remarks :

Judges {

Date.....

A brief discussion of the defects indicated on this score card is given below:

FLAVOR.

Curdy flavor is caused by overripened starters or adding starters to cream while the latter is at too high a temperature.

Light flavor is generally due to churning cream too sweet. It may be due also to too much washing and to the character of the feed. It is well known that good succulent June pasturage produces a higher flavored butter than average dry winter feed.

Rancid flavor is due chiefly to overripened cream. The age of the milk, cream, and butter is also frequently the cause of rancidity. Good butter exposed to light and air at ordinary temperatures turns rancid in a very short time.

Feverish flavor is noticeable principally in the spring of the year when cows are turned out on pastures and is, no doubt, due in most cases to the sudden change from dry feed to luxuriant pasturage. It is possible that this feverish or grassy odor is due partly to the grass itself and partly to a feverish condition of the cow caused by the sudden change of feed. We find that any feverish condition of the cow will manifest itself in the milk and the products therefrom.

Oily flavor may be caused by churning and working butter at too high a temperature, or by keeping the milk and cream at high temperatures. Bacteriologists claim that certain species of bacteria have the power of imparting an oily flavor to butter.

Weedy flavors are caused by cows feeding on weeds.

Leeks or wild onions are frequently the cause of very serious trouble when cows have free access to them.

Fishy flavor has been shown to be due to certain species of bacteria and possibly to enzymes. By inoculating good cream with cultures of these germs the fishy flavor may be produced at will. This flavor has also been ascribed to poor salt.

Stable flavor is caused by lack of cleanliness in milking, and by keeping milk too long in, or near, a dirty stable.

Unclean flavors are caused by dirty pails, strainers, and cans, filthy creamery conditions, and general uncleanness in the care and handling of milk.

TEXTURE.

Poor grain is caused by overworking and overchurning; also by too high temperatures in churning and working.

Weak body is usually caused by employing too high temperatures in the entire process of manufacture, including the ripening of the cream. These high temperatures usually result in overripened cream, overchurned butter and consequently butter with too high a water content. The character of the butter fat also influences the body of the butter.

Too much brine is caused chiefly by underworking and by churning to small granules.

Cloudy brine is caused by churning at too high a temperature and also by granulating too coarse. Insufficient washing has a tendency to produce a cloudy brine.

COLOR.

Mottles are discolorations in butter caused by the uneven distribution of salt. Those portions of the butter

that contain the most salt will have the deepest color because of the attraction of salt for color. Mottles can always be removed from butter by working, but frequently the conditions are such as to require overworking to secure this end. The following are conditions that favor mottles:

Fig. 35.—
Butter
trier.

1. Coarse uneven grained salt.
2. Carelessly adding the salt to the churn.
3. Butter too cold for working.
4. Using too cold or too warm wash water.

White specks are due either to curd particles in cream caused by overripening and lack of stirring during ripening, or to dried and hardened cream.

SALT.

Undissolved salt may be due to three things:

1. Poor salt.
2. Too much draining before salting.
3. Salting the butter at too low a temperature.

SAMPLE FOR SCORING.

In judging butter only a small sample is necessary which is secured by inserting a "trier" (Fig. 35) into the butter and giving it a whole turn, after which the plug of butter may be removed.

CHAPTER XV.

LOCATION AND CONSTRUCTION OF CREAMERIES.

The creamery industry has had a marvelous growth during the past decade and at no time in its history has it been in a more healthy, flourishing condition than it is at the present time. This growth has been the result of a gradual change in agricultural methods, necessitated chiefly by the need of conserving the fertility of lands now under cultivation. As our lands become older, an agricultural practice that will have for one of its objects the preservation or restoration of soil fertility, must grow more and more imperative. We have, therefore, much assurance that the creamery industry will flourish in the future as it has in the past, and that the creamery has come to stay as a permanent institution. The same care and attention should therefore be given to the location and construction of creameries that is now given to our schools, churches, and other institutions.

CREAMERY LOCATION.

In deciding upon the location of a creamery, we should carefully consider the following points: (1) the number of cows in the community; (2) the slope necessary to insure good drainage; (3) the center of the milk producing territory; and (4) the supply of pure water.

(1.) Before building a creamery we must first ascertain the number of cows available for its support. There should be an assurance of not less than 400 cows in a

radius of five miles of the creamery to start with. Too frequently creamery "promoters" are the cause of creamery failures because the creamery has been placed in a territory containing too few cows.

(2.) The ground upon which the creamery stands should slope at least one foot in ten. This amount of slope is necessary for two reasons: (a) to secure sufficient drainage, and (b) to permit the construction of a creamery with an ideal interior and exterior arrangement, such as will do away with extra can lifting, and extra pumps and piping.

(3.) Locations far removed from railroad stations are undesirable. It makes transportation to and from the station too expensive. Besides, during the summer the butter is liable to get too warm before it reaches a refrigerator car.

(4.) Pure water is absolutely indispensable to the success of a creamery. Experiments have abundantly demonstrated that butter washed with impure water will be inferior in flavor and particularly poor in keeping quality.

CREAMERY CONSTRUCTION.

The following cuts illustrate a creamery constructed of brick with galvanized iron roof, making a creamery that may be considered fire proof. These plans have been drawn up with special reference to: I. Sanitation; II. Saving of labor; III. Durability; IV. Cost. In the construction of all creameries attention must be directed to these four points.

Fig. 36.—Ground plan.

1. Skim-milk can.	11. Wash sink.
2. Receiving can.	12. Ice water pump.
3. Buttermilk can.	13. Ice water tank.
4. Test table.	14. Buttermilk pump.
5. Tester.	15. Ventilator.
6. Office desk.	16. Intermediates.
7. Bath tub.	17. Blower or ventilating fan.
8. Skim-milk pump.	18. Butter printer.
9. Skim-milk can.	19. Wash sink.
10. Rack for apparatus.	

Fig. 37.—Longitudinal section.

Fig. 38.—Rear view

Fig. 39.—Front view.

Fig. 40—Side view.

Fig. 41.—Side view.

I. SANITATION.

In a place where human food is manufactured sanitation should be of first importance. But unfortunately in too many creameries this is made an entirely secondary issue.

Creamery sanitation brings into consideration (1) the disposal of sewage; (2) the construction of floors and walls; (3) facilities for cleaning; (4) the construction and placing of pipes and machinery; (5) methods of ventilation; and (6) the bath room.

1. Sewage. The disposal of waste or sewage from creameries is often a serious problem, especially with those creameries that cannot discharge their sewage into flowing water. The best means at our disposal at the present time is the method of sewage purification. This consists essentially of a septic tank, or germ incubator,

Fig. 42.—Septic tank.

in which the waste is oxidized or decomposed by the action of bacteria. This scheme is illustrated in Fig. 42.

The tank, A and B, is divided by a water-tight partition which extends to within six inches of the top, making in reality a double tank. It is located in the ground below the frost line and may be constructed of brick, stone, or cement, with capacity sufficient to hold all of one day's waste in division A. Here the larger portion of the organic matter is oxidized or decomposed by the action of bacteria. When the next day's waste begins to flow into the tank, the partially decomposed sewage flows through the discharge pipe into tank B, where the purification is completed by further oxidation.

The discharge pipe at E withdraws the liquid from near the bottom when the water rises above the elbow, M, leaving the sediment and flocculent material undisturbed, to be further decomposed by the continued action of the bacteria. The object is to hold the coarse undissolved material in tank A, and for this reason this tank is also divided by a partition, the coarse material being mostly held in the first section.

The tank should be built air tight, except in two places, C and D. At C is an air inlet, consisting of a goose-neck pipe, which renders the vent or air outlet at D more effective. This vent consists of a long shaft extending beyond the top of the creamery, thus carrying off the foul gases caused by the decomposition of the material within the tank.

The liquid from tank B should be conducted away by means of 6-inch drain tile laid underground. This liquid will not give rise to bad odors after undergoing the process of purification herein explained.

Creameries that have a scanty water supply use the water from the cream vats for the boiler. But where there is an abundant supply, the water used for cooling is run into the sewer.

The water pipe, xy, is connected with the starter can and cream ripeners which makes it possible to conduct all water used for cooling directly into the drain at K. This water requires no purification and, if conducted through the septic tank, would necessitate one of too large dimensions. Moreover the large amount of cold water needed for cooling starter and cream would cool the contents of the tank too much for a rapid decomposition of the organic matter within.

Where the soil permits the drain may be emptied into a

network of tile laid a suitable distance below the surface. The arrangement of tile is shown in G.

For an ordinary creamery a tank eight feet square and four feet deep will be large enough, provided the water used for cooling is not run into it.

2. Floors and Walls. Wood floors because of their porous nature and tendency to rot should never be placed in creameries. They are not sanitary. Well constructed cement floors are durable and easy to clean and are recommended for all creameries. Frequently objections are raised against cement floors because of their dampness. This tendency to dampness can easily be overcome by constructing the floor on a cobble stone and cinder foundation underlaid with drain tile.

The inside wall of a brick building should be finished partly with cement and partly with matched lumber or paint. From the floor to a height of at least four feet, the wall should be finished with good cement. The rest is finished either with good building paper and matched lumber nailed on 2 in. x 4 in. studding, or by simply painting the walls. Plaster finish is undesirable because of its tendency to crack and drop off, due to moisture and jar of the machinery. The junction of wall and floor should be well filled in with cement to permit easy cleaning.

3. Facilities for Cleaning. Ample facilities should be provided for steaming and scalding with hot water. Every sink should be provided with a suitable steam jet. A tank providing hot water should be located in the boiler room and elevated so that hot water can be conducted to the churn, butter printer, and vats. Butter ladles, packers, and printers cannot be satisfactorily steamed and should therefore receive liberal treatment

with hot water. A few coils of piping in the bottom of the hot water tank through which the exhaust steam from the engine can be conducted will furnish all the hot water necessary. This tank should be covered and provided with a vent to permit the escape of steam during excessive heating of the water within.

4. Creamery Machinery. In selecting creamery machinery, we should be largely guided by the ease with which it can be cleaned. A piece of machinery that cannot be properly cleaned is a positive damage to the creamery. Only tinned ironed pipes should be used for conducting milk, and these should be in sections not longer than four feet. Rubber hose should never be used for this purpose. The machinery should be located so as to require the least possible amount of piping. Extra piping means extra cleaning and consequently more work. The seams, corners, and sharp angles in all cans, vats, and conductors should be flushed with solder.

5. Ventilation. Hitherto this subject has received little or no attention whatever from creamery builders. The influence of foul, moist air upon the quality of the butter and the general health of the butter maker is too little appreciated. We hear much about that "peculiar creamery odor" which is simply another expression for the foul, moist, stifling air that prevails in a great many of our creameries. Almost daily we learn of butter makers who are forced into retirement or compelled to take up other lines of work because of lung trouble, rheumatism, or general ill health. Unsanitary creamery conditions are held accountable.

Ventilating shafts, extending from the creamery room to the top of the building where they end in cupolas, are serviceable but inadequate for the best ventilation. The

most effective ventilator with which the author is acquainted is installed in the Michigan Dairy School. This ventilator consists of a galvanized iron pipe fifteen inches in diameter which is suspended from the ceiling. The pipe starts from the middle of the creamery room, where it is expanded into a cowl five feet in diameter, and is placed right up against the ceiling. It ends in a fan or blower four feet in diameter which is located in the boiler room. Here the blower connects with a chimney extending from the floor through the roof of the building. The fan is so run that it will suck the air from the creamery room into the ventilating pipe whence it is discharged into the chimney. With a speed of two hundred revolutions per minute the air of an ordinary creamery room can be changed six to eight times per hour. Less than one horse power is required to run the fan.

Sucking the air out of the room will, of course, necessitate an inlet of air from the outside. A two-inch screen under a few windows will answer this purpose very well.

The cost of pipes and blower will not exceed \$125, an amount that should be no consideration where the health of the butter maker and the quality of the butter are at stake. This ventilator is shown in Fig. 36.

6. Bath Room. Some, no doubt, will look upon a bath room as a novelty and luxury rather than as a necessary adjunct to the creamery. But where everything needs to be kept so scrupulously clean, it must be important for the butter maker and his assistants to keep themselves clean also. The sweaty smell of the butter maker can certainly have no favorable effect upon his produce, so sensitive to all odors, nor upon his own precious health. A light daily bath after the work is done can not fail to add much to the comfort and health of the

butter maker and his helpers. The bath room will add to the sanitary aspect of the whole creamery and will teach the patrons an object lesson in personal cleanliness in the care and handling of their milk.

II. SAVING OF LABOR.

There are two general plans upon which creameries have been constructed in the past. One is known as the gravity plan, the other as the one floor plan. In the gravity plan the milk flows by gravity from the intake to the separator, thus dispensing with the use of a milk pump. It necessitates, however, two floors on a different level; one for the receiving vat, the other, five feet lower, for separators and cream vats. In the one floor plan all vats and machinery stand on one floor, the milk being forced into the separators by means of a pump.

The chief objection to the gravity plan is that it necessitates the climbing of high steps, which makes going from one floor to the other difficult and tiresome. Yet, five years ago, such steps were preferable to the unsanitary milk pumps then in use for elevating the milk into the separators. With the vanishing of the old uncleanable milk pumps and with the advent of the air pumps for forcing cream into the churn, vanish the chief objections that have always been raised against the one floor creamery. Our present sanitary milk pumps can be cleaned as readily and thoroughly as our milk and cream vats. Moreover our combined milk heaters and milk pumps constructed on the principle of the Reid pasteurizer are practically vats which can be cleaned without the slightest difficulty. Then, too, with our modern cream vats, the air pumps permit the raising of the cream into the churn by means of power. But even if this were not

possible it would still be easier to put the cream into the churn by hand than climb steps many times a day, which is not only tiresome but requires time. The one floor plan is, therefore, much to be preferred to the gravity plan, because of the greater convenience it affords. Fig. 37 shows a section through a creamery constructed upon the one floor plan. In drawing these plans the item of labor saving has been constantly kept in mind. Particular attention is called to the following points:

1. Creamery dimensions.
2. Intake.
3. Intake, testing room, and office.
4. Machinery.
5. Location of refrigerator and ice house.

1. Creamery Dimensions. These should be such as not to crowd the machinery, nor to leave a great deal of unnecessary space. Where the machinery and vats are placed too close together they cannot be conveniently cleaned and attended to. On the other hand, too much space means extra steps, extra pipes and conductors, and added cost to the creamery, to say nothing of the additional cleaning.

2. Intake. Nowhere in the creamery can so much labor be economized as in the intake when properly constructed. The author can state from years of experience at the intake, handling from 10,000 to 15,000 pounds of milk daily, that the work in a poor intake is by far the hardest that falls to the lot of the butter maker. Where cans weighing from 100 to 200 pounds have to be raised one or two feet to get them from the wagon onto the platform, and then three feet more to get them emptied into the weigh can, the amount of work necessary in

weighing in 15,000 pounds of milk is easily imagined. Intakes of this type are numerous.

On the other hand, an intake that dispenses with all this can lifting offers comparatively easy work. Fig. 37 illustrates such an intake. The top of the wagon box is on the level with the platform. The can, after reaching the platform is dumped without practically any lifting. When ten gallon cans are used (and these are always preferred) and a moderately strong boy draws the milk, the butter maker need not step upon the platform at all. He smells of every can before it is dumped, weighs and samples the milk, and distributes the skim-milk and buttermilk. Any creamery that is located where there is a moderate slope can have an intake like that here referred to with the little extra cost of the platform.

3. Intake, Testing Room, and Office. Instead of having the testing room in some corner remote from the intake, these two rooms should adjoin, with a door opening from one into the other. This facilitates carrying the composite bottles to the testing room. Here the record of the last test made should be conspicuously posted so that those patrons who choose may "drop in" and compare their tests with others of the creamery. The office is naturally placed next to the testing room so that all tests as soon as made can at once be placed upon record in the office. The testing room, office, and bath room are on the same floor with the separators, vats, etc.

4. Machinery. All machinery shown in Fig. 36 is so placed as to require the least amount of pipes and conductors for conveying the milk, cream, and skim-milk into their proper places. In many creameries this is a matter almost entirely overlooked. Pipes are very difficult to keep clean and should therefore be used as sparingly as

possible. Wherever permissible open conductors should be used in preference to pipes. The cream should be run through an open conductor from the ripener to the churn. When the air pump is used the end into which the cream is pumped should be closed about two feet to prevent the cream from spattering out.

Particular attention is called to the combined heater and milk pump. Where a heater like the Reid pasteurizer is used no pump is required to elevate or force the milk into the separators. Such a machine will elevate the milk to practically any height desired. It is easily cleaned, seldom out of repair, heats the milk evenly and gradually, and requires no over-flow for milk as is the case with milk pumps. It is true, however, that the original cost of such a machine is somewhat greater than that of a separate heater and pump, but the ease in cleaning and the saving in repairs, floor space, and pipes more than compensate for this extra cost.

In addition to serving as an ordinary heater and pump, such a pasteurizer may serve another and most important purpose, namely, that of a milk pasteurizer. Indeed, it is to be recommended that the milk be heated to the pasteurizing temperature before entering the separators whenever weedy or nearly frozen milk is received at the creamery. Our experience has shown that running milk through the separator at temperatures between 160° and 180° F has three distinct advantages:

- a. Increases the efficiency of skimming.
- b. Eliminates weedy flavors
- c. Destroys bacteria.

a. Efficiency of Skimming. During the past two winters careful tests were made at our dairv school to

determine the effect of sudden heating of cold milk on the loss of fat in the skim-milk. It is well known that the exhaustiveness of skimming with any separator is greatly influenced by the manner in which the milk is heated. In general very sudden heating has the effect of diminishing the difference in the specific gravity between the fat and milk serum, consequently rendering the separation of the fat from the milk more difficult.

In our experiments we found that in many instances where the milk was received in a partly frozen condition and suddenly heated to a separating temperature of 80° to 85° F., the loss of fat in the skim-milk was from .08% to .12%. When, however, such milk was suddenly heated to a temperature of 160° F. or above the loss of fat in the skim-milk was from .02% to .03%.

b. Eliminating Weedy Flavors. In our experience nothing has been found so effective in eliminating bad odors from milk as the separation of same at high temperatures. High temperatures in themselves have a tendency to evolve from milk undesirable odors so frequently present, especially during the weedy season. When the high temperature is assisted by the whirling motion to which milk is subjected in a cream separator, the power of eliminating odors is increased. This can readily be proved by carefully examining the air or gases that issue from the cream and skim-milk spouts.

c. Destroys Bacteria. Pasteurizers are placed upon the market as bacteria destroyers. In our experiments with the Reid machine no bacteriological tests were made. Repeated scoring of the butter showed, however, that when ordinary milk was used the quality was improved from two to four points by pasteurizing.

Bacteriological tests with the Reid pasteurizer are re-

ported in the 15th Annual Report of the Wisconsin Experiment Station. In two samples of milk reported the bacterial content per cubic centimeter was as follows:

Unpasteurized	9,095,000
Pasteurized	661,000
Unpasteurized	9,780,000
Pasteurized	600,000

From these results it will be seen that the efficiency of the Reid pasteurizer as a germ destroyer is very marked.

One objection that has always been raised against separating milk at the pasteurizing temperature is that it will quickly clog the separator. While this is undoubtedly true with very ripe milk, our results with a De Laval separator have shown that little or no trouble is experienced from clogging when the milk does not contain over .2% acidity.

A word with regard to the steam engine. It has been the custom heretofore to place the engine in the same room with the boiler. This is undesirable because of the coal and flue dust settling in the bearings of the engine. The engine should be placed in the creamery room and as near as possible to the boiler. If all steam packings are properly attended to and the exhaust steam from the cylinder properly conducted away, the engine will not give rise to any "oil smell" that would be objectionable in a creamery.

5. Location of Refrigerator and Ice House. It is a great mistake to have the ice house detached from the creamery. Where this is the case much unnecessary labor has to be performed in filling the refrigerator. The ice house and refrigerator should adjoin with only a well built wall between them.

III. DURABILITY.

The best and most permanent creameries are constructed of brick. They are the most sanitary, and cheapest in the long run. The original cost may be somewhat greater than that of a frame building but the insurance and repairs are considerably less. A brick creamery with galvanized iron roof, cement floors, and the walls partly of cement, is practically fire proof. Fires occur too frequently in creameries to permit their construction without regard to protection against fire. Indeed scarcely a week passes but that from one to three creameries are burned to the ground. In Denmark, the great butter producing country, the creameries are nearly all constructed of brick.

A good solid cement or stone foundation also adds much to the durability of a creamery building.

IV. COST OF THE CREAMERY BUILDING ILLUSTRATED IN

FIGS. 36 TO 41.

(Capacity 20,000 pounds.)

Cost of foundation.....	\$100.00
No. brick 83,050 at \$6.00 per M.....	498.30
Laying brick, 42 days at \$3.00 per day....	126.00
60 bbls. cement at \$2.00, for floor.....	120.00
Cost of laying floor.....	20.00
Cost of cinders and cobble stones for floor foundation	20.00
2,640 sq. ft. corrugated iron roofing at \$3.00 per 100 sq. ft.....	79.20
Cost of laying roofing.....	26.40
5,630 sq. ft. siding at \$20.00 per M.....	112.60
Labor	50.00
1,815 sq. ft. ceiling at \$20.00 per M.....	36.30
Labor	20.00
1,920 sq. ft. sheeting at \$14.00 per M.....	26.88
1,920 sq. ft. P. & B. 3-ply water and acid proof paper at \$12.00 per M.....	23.04
Labor	15.00
1,322 ft. 2 in. x 4 in. studding; 2,408 ft. 2 in. x 8 in. joists; 2,388 ft. 2 in. x 6 in. rafters; at \$17.00 per M.....	104.00
Labor	30.00
Septic tank and drain.....	25.00
Total.....	<hr/> \$1,432.64

No doors and windows are considered here, as the material above mentioned was calculated on solid walls with no openings. The cost of doors and windows will not be more than that of so much solid wall; the total cost here given may, therefore, be considered the complete cost of the building.

COST OF CREAMERY MACHINERY.

25 H. P. boiler.....	\$325.00
15 H. P. engine.....	200.00
2 separators	900.00
400 gal. cream ripener.....	300.00
Receiving vat	45.00
Skim-milk weighing outfit.....	75.00
Intake scales	18.00
Salt and butter scales.....	5.00
Receiving can	8.00
Starter vat	20.00
Skim-milk pump	10.00
Buttermilk pump	10.00
Rotary water pump.....	10.00
600 gal. churn and worker.....	250.00
Butter printer	25.00
Blower and ventilator.....	125.00
Shafting	35.00
Babcock tester	25.00
Bath tub	5.00
Pipes and conductors.....	40.00
Skim-milk tank	15.00
Buttermilk tank	10.00
Hot water tank.....	15.00
Cold water tank.....	15.00
Milk heater and pump	100.00
Belts and pulleys.....	70.00
Cream scales.....	10.00
Pails, butter ladles, dippers, etc.....	20.00
Wash sinks and rack for utensils.....	10.00
Ice water tank.....	5.00
Office desk.....	10.00
Soldering outfit.....	6.00
Tool chest and tools.....	50.00
Testing tables and glassware.....	10.00
Cost of putting up machinery.....	100.00
Skim-milk pasteurizer.....	25.00

Total..... \$2,902.00

The total cost of creamery building and machinery as shown by the foregoing figures is \$4,334.00. This represents the cost of a model brick creamery with a capacity of 20,000 pounds of milk daily. A creamery with half this capacity would cost about three-fourths this amount or \$3,250.50.

In the foregoing discussion on creamery equipment nothing has been said about cream pasteurizers and cream coolers. While it can not be expected that in a few years all creameries will make pasteurized butter, yet this method is daily gaining favor and is to be recommended. Creameries that intend to make pasteurized butter should, therefore, add not less than \$125 to the cost of the equipment to allow for a pasteurizer and cream cooler.

REFRIGERATOR.

Instead of placing the ice at the end or sides of the refrigerator as is ordinarily done, it is much more desirable to place it overhead. With ice so placed it is possible to secure a much drier and cooler air. This method of refrigerating is illustrated in Fig. 43.

From the cross section it will be noticed that 2 in. by 4 in. studding are placed across the entire width of the refrigerator. These studding are only one inch apart, and are laid from the rear to within two feet of the front of the refrigerator. The ice chamber is constructed on top of the studding. Below the chamber is a very shallow tin pan which catches the drip from the melting ice and conducts it into the sewer. This pan is supported by means of three 2 in. by 4 in. studding running the full length of the ice chamber. Both ends of the studding are provided with hooks by means of which the pan is readily attached to, and detached from, the ice chamber.

This method of attaching is necessary because the tin pan will need to be taken down occasionally for cleaning.

Fig. 43.—Sections through refrigerator.

Where the refrigerator is built in one corner of the ice house, as shown in Fig. 36, it should be filled with the ice farthest away from it. This gives the refrigerator the benefit of the cold produced by the ice surrounding it.

The floor and walls of the refrigerator should be finished with good cement and the ceiling lined with galvanized iron.

THE ICE HOUSE.

A creamery should preferably face north and south so that the ice house may occupy the north end where it will be least affected by the heat of the sun.

Good drainage is another matter of importance in the construction of an ice house. This can be secured with any kind of soil by laying an eight inch foundation of cobble stones and gravel, and on top of this six inches of cinders, the whole underlaid with drain tile. The floor of the ice house is constructed upon this foundation. For this purpose cheap lumber in the form of planks should be used, leaving enough space between the planks to permit a ready escape of the water from the melting ice.

The walls of the ice house should be so constructed as to insure good insulation. The brick wall that forms the outside of the ice house should have 2 in. by 4 in. studding built into it on the inside, upon which good building paper is tacked and this covered with good ceiling lumber.

The wall between the creamery room and the ice house should have the following construction: For uprights use 2 in. by 6 in. studdings placed 14 inches apart. Cover the outside and inside of the studding with cheap sheeting, filling the six inch space with cinders, sawdust, or tan bark. Now finish the outside as follows: (1) tack good building paper on the sheeting; (2) nail 1 in. by 2 in. strips on the paper; (3) tack paper on strips; (4) cover with matched lumber. Finish the inside wall in the same way. This will give two thicknesses of paper and a one inch dead air space on either side of the six inch space filled in. The paper used should be the best water and acid proof paper obtainable. Common building paper will not prove satisfactory.

The walls of the refrigerator are built in the same way except that the inside is finished with cement as already mentioned.

CREAMERY ROOF.

It matters not whether the creamery is constructed of wood or brick, a shingle roof is undesirable because of the danger from fire. Twenty-six gage galvanized iron, when properly laid, will make a cheap and very durable roof. The roofing should be laid with standing seams to allow for expansion and contraction of the material. To protect the under side of the roof from moisture and corroding gases it is desirable to lay the galvanized iron on common building paper.

Slate makes the neatest and most durable roof but it is rather expensive.

HEATING OF CREAMERY.

Creameries should be heated with steam, not with stoves. Either the exhaust steam from the engine or steam taken directly from the boiler may be used for this purpose. The heating pipes should be so arranged that either may be used when desired.

Where the exhaust steam is used to heat water for the boiler and for washing, it may be best to heat the building with steam taken directly from the boiler.

A very satisfactory method of piping is the following: Run one and a half inch pipes from the boiler to within two feet of the floor, and close to the walls, of the creamery room. The pipes should pass all around the creamery room and end in a steam trap which discharges the condensed steam into a hot well located near the

injector, so that the hot water may readily be drawn into the boiler. The heating pipes must all slope towards this well. Where the boiler floor is lower than the creamery floor an oil barrel sawed in two may be made to serve the purpose of a hot well.

A *reducing* valve should be placed near the boiler so that any amount of pressure may be carried in the heating pipes. With a good valve of this kind a pressure as low as one pound may be carried when the boiler pressure varies from twenty to fifty pounds.

The cost of steam trap and reducing valve should not exceed \$15.

CHAPTER XVI.

CREAMERY MECHANICS.

THE STEAM BOILER.

There are three principal types of boilers in use at the present time: (1) water tube boilers; (2) internally fired, or marine, boilers; and (3) fire tube boilers.

In the water tube boiler the water circulates through tubes which receive the heat directly from the furnace. These tubes communicate with an iron cylinder, placed directly over them; which serves the purpose of a steam reservoir. Boilers of this type are rapidly gaining favor as economical steam generators. They occupy somewhat more space, however, than the other types of boilers.

In the marine boiler, the firing is done in the shell, the entire fire box being surrounded by water. The return heat passes through a series of tubes which nearly surround the upper half of the fire box. The entire boiler consists of a round iron cylinder supported on short legs. It is heavily covered with asbestos which dispenses with the brick work necessary with the fire tube boilers.

The marine boiler is neat and attractive and has grown much in popularity in recent years. As its name implies this type of boiler has been mostly used on the sea, but is now to be seen nearly everywhere in power plants.

The common form of creamery boiler belongs to the fire tube kind. Fig. 44 illustrates this boiler partly laid in brick. The grates, or iron bars, upon which the fire is placed are seen in the front half of the brick work. The

Fig. 44.—Firetube boiler.

heat and smoke pass along the underside of the boiler toward the rear and return through the fire tubes. To prevent radiation of heat the brick work must be built up to cover the entire boiler. The fire box must be constructed of the best fire brick.

Fig. 45.—Glass gauge.

Fig. 46.—Gauge cocks.

The various boiler accessories will be described in the following paragraphs.

Glass Gauge. This is a glass tube attached to the side of the boiler to indicate the height of the water in it. The gauge is represented in Fig. 45. It is so attached that its lowest point is about two inches above the highest part of the fire line of the boiler, its entire length being usually about fifteen inches. The cock at the bottom is used to blow out the sediment that is liable to block the opening between it and the boiler. When this occurs the gauge becomes a false indicator. Frequent blowing out is therefore necessary. The cock next to the blow out admits the water from the boiler. The cock above this admits the steam. When the glass breaks shut off the water first, then the steam. Always have a few extra glasses on hand so that the broken one can be immediately replaced. Owing to its tendency to clog, the gauge can

not always be relied upon, hence the use of water cocks placed next to the glass gauge.

Water Gauge Cocks. Fig. 46 shows the attachments of these cocks. The water level should be kept as near as possible to the middle cock. It should never go below the lower cock, nor above the upper. These cocks should be opened many times during the day and so long as steam issues from the upper and water from the lower cock, the water level is all right.

Steam Gauge. This shows the number of pounds of steam pressure per square inch on the boiler by means of a pointer moving around a dial. Below the dial is a loop which contains water to prevent injury to the gauge from the hot steam. The steam gauge is liable to get out of order and will then fail to show the true pressure. Such a condition is indicated by the safety valve.

Safety Valve. This is placed on top of the steam chamber and permits the escape of steam when the steam pressure reaches the danger limit. It is an indispensable boiler attachment as without it the boiler would be a dangerous thing. There are two kinds of safety valves, the "pop" and "ball and lever" types. The former is considered the more desirable because it is not so easily tampered with. Both can be set to blow off at different pressures.

Water Feed Apparatus. There are two ways of feeding water into a boiler, namely, with injectors and with pumps.

Injector. This important boiler accessory, illustrated in Fig. 47, is attached to the side of the boiler. It utilizes the steam directly from the boiler for forcing water into it against a pressure as great as that which sends it forth. The principle which makes this possible may be stated

Fig. 47.- Injector.

as follows: Steam issuing from a boiler under 70 pounds pressure has a velocity of 1,700 feet per second. When steam with this high velocity strikes the combining tube A, it produces suction which in turn induces a flow of water. As soon as the water enters the combining tube it is given motion by the high velocity of the steam,

which immediately condenses and moves with the water into the boiler at a comparatively low velocity. The energy, therefore, by which steam can force water into the boiler against its own pressure is the latent heat resulting from the condensation of the steam in the combining tube.

From this it must be evident that the efficiency of the injector is dependent upon the completeness with which the steam condenses. This is clearly proved by every day practical experience. When, for instance, the feed water is too hot, the steam pressure too high, or the steam is wet, the injector fails to work properly because the steam does not sufficiently condense when it strikes the feed water.

Starting the Injector. This is done by opening the supply water valve one or two turns, then the steam valve wide. If steam issues from the overflow admit a little more water; if water overflows admit less.

Care of Injector. An injector will become coated with sediment or scale the same as the boiler and must, therefore, be frequently cleaned. This is best done by immersing it in a solution of one part muriatic acid and ten parts water. Allow to remain in this solution until the scale becomes soft enough to permit washing out. A clean injector rarely causes trouble but if trouble does occur it may be due to: (1) low steam pressure; (2) too hot water; (3) leaks in pipes and injector; (4) clogging of water pipe; (5) wet steam; (6) poor working condition of check and overflow valves; (7) clogging of feed pipe where it enters the boiler.

The injector is commonly used to feed water into the boiler because it is cheap and simple, and occupies little space.

Pumps. There are two kinds: (1) those run with

steam directly, and (2) those run by the engine. The latter is the more economical and handles hot water with less trouble. It has one disadvantage, however, and that is it does not work unless the engine is running. With good pumps, especially those run by the engine, good work may be expected when the feed water has been heated to 200° F. with the exhaust steam from the engine. With the injector such high temperatures are not permissible, hence the greater economy of the pump. The great saving of fuel by feeding water hot into the boiler is illustrated by experiments made by Jacobus which show that with a direct acting pump 12.1% fuel is saved by heating the feed water from 60° to 200° before pumping it into the boiler. With injectors the feed water used usually has a temperature of about 60° F.

STEAM.

Water is practically a non-conductor of heat. This means that it cannot conduct its heat to its neighboring particles. When, therefore, heat is applied to the bottom of a vessel containing water, the particles at the bottom do not communicate their heat to the particles next above them, but expand and rise, cool ones taking their places. This gives rise to convection currents which tend to equalize the temperature of the water in the vessel. When the water has reached a uniform temperature of 212° F. the particles begin to fly off at the surface in the form of vapor, and this we call *steam*. To generate steam in a boiler, then, it is necessary to impart to the water in it a considerable amount of heat, which is produced by burning fuel in the fire box.

FIRING OF BOILER.

The immense amount of heat stored in wood and coal is rendered effective in the boiler by burning (combustion). To understand how to fire a boiler intelligently we must first learn what the process of burning consists of.

Process of Burning. Anything will burn when the temperature has been raised high enough to cause the oxygen of the air to unite with it. Thus, in "striking" a match the temperature is raised high enough by the friction produced to cause the match to burn. The burning match will produce heat enough to ignite the kindling, which in turn, produces the necessary heat to ignite the wood or coal in the fire box of the boiler. Burning may, therefore, be defined as the union of the oxygen of the air with the fuel. In burning a pound of coal or wood a definite amount of air must be admitted to furnish the necessary oxygen for complete combustion. When oxygen is lacking part of the fuel passes out of the chimney unburned in the form of gases. If, on the other hand, too much air is admitted the excess simply passes through the chimney, absorbing heat as it passes through the boiler. The problem of firing becomes, therefore, a difficult one.

Burning Coal and Wood. When hard coal is burned the fire should be thin. A thickness of three to four inches on the grates gives very satisfactory results. For best results with soft coal a thickness of six to seven inches is recommended. Whenever fresh coal is added it should be placed near the front and the hot coals pushed back.

In case wood is burned the fire box should be kept well filled, care being necessary to keep every part of the grate well covered.

GENERAL POINTERS ON FIRING.

1. Boilers newly set should not be fired within two or three weeks after setting and then the firing should be very gradual for several days to allow the masonry to harden without cracking.

2. Never fire a boiler before determining the water level by trying the water gauge cocks. You can not entirely rely upon glass gauges, floats, and water alarms.

3. When starting the fire, open the upper water gauge cock and do not close it until steam begins to issue from it. This permits the escape of confined air.

4. Kindle the fire on a thin layer of coal to protect the grate bars.

5. Always examine the safety valve before starting a fire.

6. When starting the fire all drafts should be open.

7. The firing should be gradual until all parts of the boiler have been heated.

8. Never allow any part of the grate bars to become uncovered during firing.

9. Frequently clean the ash pit to prevent overheating of grates from the hot cinders underneath.

10. The coals upon the grates should not be larger than a man's fist.

11. Remember that firing up a boiler rapidly is apt to cause leaks.

12. Remember that too little water in the boiler causes leaks and explosions.

13. Remember that soot and ashes on heating surfaces always waste fuel.

14. When fire is drawn close dampers, and doors of furnace and ash pit.

15. Never open or close valves when the water is too low in the boiler, but immediately bank the fire with ashes or earth. Opening the safety valve at such a time will throw the water from the heated surfaces, resulting in overheating and possibly in explosions.

16. Use the poker as little as possible in firing.

17. Keep the grate bars free from "clinkers."

18. When the steam pressure goes too high, start the pump, open the doors of the furnace and close the ash pit.

19. A steady and even fire saves fuel.

GENERAL CARE OF BOILER.

1. Always close the steam and water valves of the glass gauge when you leave the building for half an hour or more.

2. Water gauges should frequently be blown out and cleaned.

3. Keep the exterior of the boiler dry. Moisture will corrode and weaken it.

4. The boiler should be blown off under low pressure every two or three days.

5. A boiler that is not used for some time should be emptied and dried. If this cannot readily be done, fill it full of water to which a little soda has been added.

6. Frequently examine the safety valve to see that it is in good working order.

7. Do not empty boiler while brick work is very hot.

8. Never pump cold water into a hot boiler. Leaks and explosions may be the result.

9. Leaky gauges, cocks, valves, and flues should be repaired at once.

10. Do not fail to examine the pressure gauge frequently.

11. It is good policy to have two means of feeding a boiler. The pump or injector may get out of order and cause delay and danger.

12. Feed pumps and injectors need frequent cleaning to keep them in good working order.

13. Look out for air leaks. If air is admitted anywhere except through the grates serious waste may result. Such leaks are to be looked for in broken doors and poor brick work.

14. Flues should be cleaned often, especially if soft coal is burned. This will prevent over heating of metal, at the same time save fuel.

15. Do not allow filth to accumulate around the boiler or boiler room.

16. Keep all the bright work about the boiler "shiny."

17. Do not fail to empty the boiler every week or two and refill with fresh water.

18. Have your steam gauge tested at least twice a year.

BOILER INCRUSTATION.

In all boilers after a period of use, there is deposited upon the parts below the water level a scale or sediment known as boiler incrustation.

Cause of Scale. The formation of scale is due to the impurities contained in the feed water. When impure water is fed into the boiler the impurity first manifests itself in the form of scum on top of the boiling water. The heavier particles of the scum slowly unite and sink to the bottom where they first appear as mud. By continued exposure to high temperature, this mud gradually

forms into a hard impervious scale which usually consists largely of lime.

Objection to Scale. 1. The excessive formation of boiler scale is the immediate cause of most boiler explosions. The scale acts as a non-conductor of heat, so that in cases where the capacity of the boiler is severely taxed, the metal becomes overheated, thus materially weakening it. The scale is, therefore, not only dangerous, but by overheating the metal, also materially shortens the life of the boiler. 2. Another most serious objection to scale is its wastefulness of fuel. This becomes evident when we note that the heat before reaching the water must first be conducted through a non-conducting layer of incrustation.

Prevention of Scale. Since nearly all water used for boilers is more or less impure, it is evident that to prevent scale, boilers must receive frequent cleaning. How often this needs to be done is, of course, dependent upon the amount and character of the impurity in the water. Boilers are kept clean in three different ways: (1) by blowing off at low pressure, (2) by cleaning through man hole, and (3) by using boiler compounds.

(1.) By blowing the boiler off at low pressure most of the mud will be blown out. But care must be taken that the pressure is not above ten pounds and that there is no more fire in the fire box, otherwise the mud, instead of flowing out with the water, will bake on and form scale.

(2.) A good way of removing mud is to allow the boiler to cool off and then run a rubber hose through the man hole. By working the hose and forcing water through it the sediment can be removed.

(3.) Boiler compounds are used to keep boilers free

from scale. The kind of compound to be used is determined by the character of the impurities of the water. Most creameries use well water for the boiler and the chief impurity in this is lime. The best compound for water of this kind is soda. Well water contains the lime in widely different proportions. In order, therefore, to ascertain the proportion of soda to feed water the following method is recommended by Hawkins:

“1. Add one sixteenth part of an ounce of soda to a gallon of the feed water and boil it. 2. When the sediment thrown down by the boiling has settled to the bottom of the kettle, pour the clear water off and add one-half drachm of soda to this. Now, if the water remains clear, the soda which was put in has removed the lime. But if it becomes muddy, the second addition of soda is necessary.” In this way the amount of soda to be added to the feed water can be calculated with sufficient accuracy.

Tan bark is very efficient in removing boiler scale but may injure the iron.

Kerosene answers the same purpose but renders the steam unfit for use in the creamery.

When the water is salt or acid, a piece of metallic zinc occasionally placed in the boiler will prevent corrosion. Water of this kind can usually be told by its corrosive effect on copper and brass. Acid water can also be detected with blue litmus paper, which it turns red.

WET AND DRY STEAM.

Wet Steam. This is steam holding in suspension extremely small particles of water which are thrown off from the water surface while steam is generating. The following are the causes of wet steam:

1. Impure water in the boiler.
2. Too much water in the boiler.
3. Too little evaporating surface for the amount of steam used. This is one of the chief objections to upright and too small boilers.
4. Violent agitation of the water in the boiler caused by too rapid a generation of steam.

Wet steam causes "priming" and is wasteful of heat.

Dry Steam. This is saturated steam holding no water mechanically in suspension. High steam pressure and a large steam space above the water level are conducive to dry steam.

HORSE POWER OF BOILERS.

A horse power of a steam boiler is thirty pounds of feed water at a temperature of 100° F. converted into steam in one hour at 70 pounds gauge pressure.

The horse power of a boiler may be approximately calculated by dividing the total square feet of heating surface in the shell, heads, and tubes, by fifteen.

SMOKE STACK.

It is difficult to state the exact size of a smoke stack for a given boiler because conditions vary so much. It is evident that it must be longer for a boiler placed at the foot of a hill than for the same boiler placed on top of the hill.

A smoke stack for a 25 H. P. boiler should be about one foot square inside and from 30 to 40 feet high and built of brick. A small smoke stack which affords inadequate draught is wasteful of fuel and gives rise to much trouble in firing.

THE STEAM ENGINE.

The engine may be defined as a machine which converts heat into mechanical power. This heat is obtained

Fig. 48.—Steam engine.

in the form of steam under pressure from the burning fuel in the boiler. A common form of creamery engine is illustrated in Fig. 48.

Engine Foundation. The engine to run smoothly must be placed upon a solid foundation constructed of hard burned brick laid in cement. Where the ground is soft and loose the brick work must be built upon a foundation of coarse stones laid in cement.

Fig. 49.—Steam cylinder and valve chest.

PARTS OF THE ENGINE.

Steam Cylinder and Valve Chest. These are the vital parts of the engine. A section through the cylinder and valve chest is shown in Fig. 49. A represents the cylinder part, B the valve chest.

Parts of A: 1, cylinder heads; 2, bore of cylinder; 3, counter bore; 4, flanges; 5, stuffing box; 6, gland.

Parts of B: 7 and 7', steam ports; 8, exhaust port;

9, valve stem gland; 10, valve stem stuffing box; 11, valve chest cover; 12, steam inlet; 13, slide valve.

Working of Piston. The arrows in the preceding cut show the course which the steam takes in the valve chest and cylinder. As the steam enters at port 7¹ the piston is

Fig. 50.—Piston and ring.

pushed back and the exhaust steam escapes through port 7. The slide valve 13 gradually moves forward while the piston moves back so that both ports will be closed when the piston has traveled about four-fifths of the distance of the cylinder. There is, however, enough energy stored in the fly wheel or drive pulley to carry the piston beyond the dead center when steam will enter the cylinder through port 7, causing the piston to move forward while the exhaust steam escapes through port 7¹. When the piston has traveled about four-fifths of the distance of the cylinder both ports are again closed, so that at every revolution of the crank the dead center is passed twice.

Fig. 50 shows the piston and piston ring.

The piston must fit the cylinder tight enough to prevent leakage of steam, yet not so tight as to cause undue

friction. A good way to find out whether a piston leaks steam is to put the engine on the dead center on the crank end. Then take off the cylinder cover on the head end and admit steam back of the piston. If the piston leaks, steam may be seen escaping between the packing ring and the wall of the cylinder.

Fig. 51.—Connecting rod end.

Crosshead. This connects the piston rod and connecting rod and serves to guide the former so as to have it move in a straight line.

Connecting Rod. This forms the connection between the crosshead and crank. The crank end of the rod is shown in Fig. 51. 1 represents the crank pin key; 2, crank brasses, and 3, burr that fixes the crank pin key.

Crank. This rotates the shaft of the engine and permits the change of rectilinear into circular motion.

Eccentric. This forms a sort of crank which, as its name implies, does not turn around a true center. It opens and closes the steam ports in the valve chest by means of the eccentric rod which forms the connection between it and the slide valve.

Setting the Slide Valve. The slide valve should be

so set on the valve stem that its edges will pass each steam port an equal amount during a full revolution of the engine. If not so set, the valve should be moved, by loosening the nuts on the valve stem, until the correct position is reached.

The next thing to do is to place the engine on its true center with the outward stroke. Now turn the eccentric upon the shaft in the direction in which the engine is to run until the valve has uncovered the port sufficiently for the required *lead*, which should be about one-sixteenth of an inch.

Governor. This device governs or regulates the speed of the engine by controlling the inlet of steam in to the cylinder.

There are two kinds of governors: one is known as the automatic cut-off which consists of centrifugal weights placed in the fly wheel, which vary the point of cut-off by revolving the governor eccentric upon the shaft. With governors of this kind the steam is entirely cut off when the speed gets too high, while with the other form of governor the steam is throttled. The "throttle" or "ball" governor is more common on creamery engines than the automatic cut-off. Fig. 52 illustrates the working of the ball governor. The important parts are: 1, governor balls; 2, pulley; 3, stem; 4, valve discs; 5, stuffing box; and 6, valve seats. As the speed of the engine increases the balls are thrown farther out and the valve discs come nearer the valve seats, thus throttling or reducing the amount of steam that enters the cylinder.

The automatic cut-off is considered the more economical of the two governors though it is somewhat more difficult to regulate. Most engines now made are of the automatic cut-off type.

Fig. 52.—Governor.

Lubricator. This device serves to supply oil to the cylinder. There are various forms of lubricators one of which is illustrated in Fig. 53. The working of this lubricator may readily be understood by following the course of the steam as indicated by the arrows.

The steam condenses in the small pipe, enters the bottom of the oil cup where the condensed steam displaces an equal quantity of oil, which, being lighter than water, is forced up and overflows into a pipe placed inside the lubricator whence it may be seen to escape in drops through the glass tube. From here it passes with the steam into the cylinder.

Fig. 53.—Lubricator.

Pipes and Piping. The main pipe is that which conducts the steam from the boiler to the engine. This pipe should be well covered with non-conductor to prevent loss of heat.

A very efficient and inexpensive pipe covering is made by mixing wood sawdust and common starch, using them in the proportion to form a thick paste. Such a paste will adhere perfectly to wrought or cast iron pipes when absolutely free from grease. A thickness of one inch is sufficient.

The *exhaust steam* pipe carries away the steam after it has been used in the cylinder. To make the best use of the heat that remains in exhaust steam, this pipe should first be carried through a water tank located in the

boiler room, thence outside the building. The exhaust steam will be ample to heat all the water needed for washing as well as that used for the boiler. A great deal of fuel can be saved in a creamery by properly utilizing the exhaust steam. A drip cock will have to be placed at the bottom turn of the exhaust pipe to permit draining it.

When the engine is placed in the creamery proper, it is very essential to have cylinder drain pipes to carry away the water and partially condensed steam that is found in the cylinder when the engine is started.

In piping avoid turns as much as possible and provide exhaust pipes of ample size.

CARE AND MANAGEMENT OF ENGINE.

1. It is essential to have all parts of the engine well oiled, using nothing but the best oil.

2. Keep the engine clean. The shiny parts should be brightened at least once a day.

3. Keep the engine well "keyed up." At both ends of the connecting rod are keys, one of which is shown in Fig. 51. The purpose of these keys is to keep the brass boxes tight enough to prevent undue play. The "keying" consists in loosening the burrs next to the key and then tapping the latter lightly until the unnecessary play is taken up. Care must be taken, however, not to get the brasses too tight or a hot box will be the result. "Pounding" is usually caused by not having the keys properly set. It is also caused by wet steam and water in the cylinder.

4. Keep stuffing boxes carefully packed to prevent leakage of steam. The packing should be treated with graphite or good cylinder oil and packed firmly around

the rod, but it must not be too tight, otherwise power is lost in friction. If the rod has become scored or rusty, smooth it with emery cloth before packing.

5. The packing rings in the piston should be kept in good repair. The clicking noise sometimes heard in cylinders is due either to the packing ring wiping over the edge of the counter bore or to its being too narrow for the groove in which it is placed. A ring is needed that fits this groove properly. If the packing ring is too small for the cylinder bore it should be set out by peneing or by tightening the setting out bolts.

6. When gumminess is noticeable in any of the bearings, remove same with benzine and use a purer oil.

7. When the engine "races" look for the trouble in the governor.

8. Thoroughly drain cylinder when not in use. This *must* be done in the winter to prevent freezing.

HORSE POWER OF ENGINE.

The horse power of an engine is calculated from the following formula:

$$\text{H. P.} = \frac{p \times l \times a \times n}{33,000} \text{ in which}$$

P = Mean effective steam pressure.

l = length of stroke in feet.

a = area of piston in square inches.

n = number of strokes per minute.

H. P. = Horse power.

33,000 = Number of foot-pounds.

A foot-pound is one pound raised through one foot of space.

Length of stroke = twice the length of crank.

No. of strokes per min. = twice the number of revolutions.

$$\text{Area of piston} = \frac{\pi d^2}{4}.$$

Example :

$$P = 40 \text{ lbs.}$$

$$l = 2 \text{ ft.}$$

$$a = 20 \text{ sq. inches.}$$

$$n = 400.$$

$$40 \times 2 \times 20 \times 400 = 640,000$$

$$640,000 \div 33,000 = 19.4 = \text{H. P.}$$

CALCULATING SIZE AND SPEED OF PULLEYS.

In creameries where new shafting and new machinery are being put up, it is important to know how to determine the required speed of the shafting as well as the speed and size of the pulleys. This calculation is not difficult when we remember the following rule:

The speed varies inversely with the diameter of the pulley. Thus, with the same speed of the engine, the speed of the main shaft becomes less as the diameter of the pulley on that shaft is increased.

It must be remembered, also, that in a creamery where the churn and separators are run directly from the main shaft, the speed of this shaft must be fixed at from 175 to 200 revolutions per minute in order to permit the use of suitable sized pulleys.

We usually speak of two kinds of pulleys: the *drive* pulley and the *driven* pulley. Where the engine drives the main shaft the pulley on the engine is called the drive pulley and that on the main shaft the driven pulley. When we refer to the main shaft driving the intermediate, then the pulley on the main shaft becomes the driver and that on the intermediate the driven pulley.

In creameries there are two problems that present themselves with respect to pulleys: one is to find the speed of

the pulley when the diameter is given; the other is to find the diameter when the speed is given.

1. To find the speed of a driven pulley: Multiply the diameter of the driver by its speed and divide the product by the diameter of the driven pulley.

Fig. 54.—Belting from engine to separator.

Example: Diameter of engine pulley, 20 inches; speed of engine, 200 revolutions per minute; diameter of driven pulley, 25 inches.

$$20 \times 200 \div 25 = 160 = \text{No. rev. per min. of driven pulley.}$$

2. To find diameter of driven pulley: Multiply the diameter of driver by its speed and divide the product by the required speed of driven pulley.

Example: Diameter of engine pulley, 20 inches; speed of engine, 200 revolutions per minute; speed of driven pulley, 200 revolutions per minute.

$$20 \times 200 \div 200 = 20 = \text{diameter of driven pulley.}$$

Let us calculate the size and speed of pulleys necessary to run a separator 6,000 revolutions per minute when the following conditions are known: Size of drive pulley on engine, 16 inches; size of separator pulley, 3 inches; size of large pulley on intermediate, 18 inches; size of small pulley on intermediate, 5 inches; speed of shaft, 180 revolutions per minute.

The known conditions given here are indicated in the diagram above by figures, the unknown by x (Fig. 54).

The calculation in this problem begins at the separator, where both the speed and diameter of the pulley are known, and ends with the determination of the speed of the engine.

1. Determine the speed of the intermediate which has a large pulley at one end and a small one at the other. Applying the foregoing rules, the speed of intermediate is equal to:

$$6000 \times 3 \div 18 = 1000 \text{ rev. per min.}$$

2. Determine diameter of pulley on main shaft. This is equal to:

$$1000 \times 5 \div 180 = 27.7 \text{ inches.}$$

3. Determine speed of drive pulley on engine. This is equal to:

$$180 \times 27.7 \div 16 = 312 \text{ rev. per min.}$$

With most engines a great range of speed is possible by regulating the governor. It is better, however, to have the drive pulley of such size as to keep the speed under 300 revolutions per minute.

FRICTION: ITS ADVANTAGE AND DISADVANTAGE.

The resistance produced by one body sliding over another is called friction. No matter how smooth a surface may appear it always contains irregularities (molecular) which are not unlike the teeth of a saw, though so small as to render them invisible to the naked eye. Whenever, then, two surfaces are put together they interlock and when made to slide over each other produce friction.

Friction as Applied to Belts. Practical application of friction is made in transmitting power by means of belts. Without friction such transmission would be impossible. The highest efficiency of belts is obtained where there is no slipping or stretching, conditions made possible by observing the following points:

1. Use only good leather belting.
2. Avoid too slack or too tight belts.
3. Run belts with the hair side next to the pulley.
4. Cover face of pulley with belting and have the hair side out.
5. Keep belts dry and flexible.

Size of Belting. A two-ply belt may be subjected to an effective tension of 40 pounds per inch of width without straining it. In determining, therefore, the width of a belt for a given horse power the effective tension of the belt must be considered. Further, since a fast running belt is capable of transmitting a greater horse power per given width than a slow running belt, the speed of the belt must also be considered. Hence the following formula:

$$\text{Width of belt} = \frac{\text{No. H. P.} \times 33,000}{\pi D \times \text{No. rev.} \times 40}$$

In which

H. P. = Horse power.

33,000 = Number of foot-pounds in one H. P.

No. rev. = Number of revolutions of drive pulley
per minute.

40 = Effective tension.

$\pi = 3.1416$.

D. = Diameter of drive pulley in feet.

Example: What width of two-ply belting is required with a drive pulley fourteen inches in diameter, making three hundred revolutions per minute and developing ten horse power?

Applying our formula we have:

$$\text{Width} = \frac{10 \times 33,000}{3.1416 \times 14 \times 300 \times 40} = 7.5 \text{ inches.}$$

Lacing Belts. In lacing belts care must be taken never to cross the lacing on the side of belt next to the pulley, nor to have more than a double thickness of lacing. The ends of the belt should be cut off squarely so as to have them come together at all points. Holes are punched in a line one inch from the cut edges with the outer ones within half an inch of the edge of the belt. They should be just large enough to permit double lacing. The lacing is best begun at the middle of the belt, care being taken to have the smooth side of the lace on the side of the belt that runs on the pulley. The ends are fastened either by running them through small holes punched in line with the lace holes, or by cutting a small slit in the middle of one end, then cutting into the edge and toward the end of the other, which is run through the slit just beyond the cut edge.

Rubber belts are not as desirable for creamery use as leather belts.

Adjustment of Shafts. To avoid straining a belt the shafts must be parallel. This means that where the intermediate and engine are hitched to the same shaft the latter must be placed in position first. The engine and intermediate are then lined up so as to have their shafts run parallel with the main shaft. When the shafts are parallel the pulleys are easily adjusted so as to have the belts run on the middle of the pulley.

Lubricants or Oils. These slippery substances act in a two-fold way in minimizing the friction between sliding surfaces: (1) by filling up the inequalities of the sliding surfaces, thus preventing interlocking; (2) by allowing oil to slide on oil instead of one solid surface upon another.

The best oils are those that are entirely free from any tendency to gumminess and it is economy to use only such. Indeed in fast running machinery no other oils are permissible.

Consistency of Oils. This is determined by the use to which the oil is put. In fast running machinery where there is little pressure on the bearings, as, for example in a cream separator, very thin oil is most serviceable. The reasons for this are (1) that only a very thin layer of oil is required in the bearings of such machinery, and (2) that there is some friction produced in one layer of oil sliding upon another, and the thinner the oil the less will be the friction produced in this way.

The crank shaft of an engine, which runs at a comparatively low speed and is subjected to more or less pressure, requires a rather heavy oil for best service.

Hot Bearings. These are most frequently caused by

using an insufficient amount, or the wrong kind, of oil. Hot bearings are also frequently caused by dirt, slipping belts, too tight belts, and too tight bearings.

TOOLS, PACKING, AND STEAM FITTINGS.

A creamery contains a great deal of machinery and

Fig. 55.—Pipe cutter.

Fig. 56.—Stock and die.

piping. The need of an ample supply of tools, packing, and steam fittings is therefore evident.

Tools. These consist mainly of pipe cutter, two pipe tongs, vise, stock and dies, alligator wrench, a pair of gas pliers, hammer, punch, and screw driver. Fig. 55 shows pipe cutter; Fig. 56, stock and dies; Fig. 57, alligator wrench; Fig. 58, vise; and Fig. 59, pipe wrench.

Packing. All steam stuffing boxes should be packed with asbestos which has been treated with a mixture of oil and graphite.

Fig. 57.—Adjustable alligator wrench.

Pipe joints, such as unions, should be fitted with rainbow gaskets to which a little graphite or chalk is added to prevent their sticking to the joints. Pipes that must be frequently taken apart should have ground joints. These will do away with the use of gaskets which are troublesome in such cases.

Steam Fittings. Extra fittings for one-half to two inch pipes should always be on hand. The necessary fittings are elbows, nipples, bushings, tees (Ts), plugs, lock nuts, couplings, reducing couplings, and unions.

Fig. 58—Vise.

Fig. 59.—Pipe wrench.

When using right and left nipples, that is, nipples with a right thread at one end and left thread at the other, screw each end separately into the pipe which it is to fit and count the number of threads covered. If, for example, four right threads are covered and six left threads,

then cover two left threads before joining with the other end. In this way the two ends turn tight at the same time, which is necessary to prevent leaking.

Fig. 60.—Globe valve.

VALVES.

The subject of valves is an important one and deserves much attention. Usually the ordinary creamery contains from twenty-five to fifty valves. It is, therefore, not surprising to find steam and

water leaks in a creamery building. To replace a valve as soon as it begins leaking is too expensive. The proper thing to do is to repair it. In the following paragraphs a brief discussion will be given of the kinds of valves and the methods of repairing them.

Globe Valve. This valve, shown in Fig. 60, takes its name from its globular form. It is preferably so placed as to allow the pressure of the steam to come under the valve.

Check Valve. This is placed between the boiler and the feed pipe to prevent the return of water and steam.

Gate Valve. As its name implies, this is a valve closed by a gate.

Throttle Valve. This is the valve that admits the steam to the engine.

Stop or Gas Valve. This is opened by giving it a half turn. It is commonly used on receiving vats, and on milk and skim-milk pipes.

Rotary Valve. This is illustrated by the stop cocks used on the boiler.

Ball Valve. This is an automatic valve illustrated by the float that regulates the feed of the separator.

Parts of a Globe Valve. These are: (1) chamber; (2) seat; (3) stem; (4) stuffing box; (5) disc; and (6) handle. The chamber is the place where the valve operates. The disc is attached to the stem and closes the valve by turning it onto the seat.

Repairing of Globe Valves. There are three parts in a valve that may cause it to leak: (1) the seat, (2) the disc, and (3) the stem. In valves like the Huxley where the seat and disc are replaceable, extras should always be kept on hand so that either may be replaced when leaking. In valves like the Jenkins where only the disc is replaceable a "reseater" should be at hand whereby the seat of the valve can be made to fit tight again. A reseater for valves from one-half to one and one-half inches in diameter can be bought for twenty-five dollars, and creameries that use valves in which the seat is not removable should be provided with one.

The valve discs are made of various materials, but, for ordinary steam pressure, brass and "composition" discs are giving the best satisfaction.

The stuffing box of the valve is packed with asbestos to which a mixture of oil and graphite is first added. This packing will prevent the stem from leaking. The burr of the stuffing box must be tightened from time to time when it shows signs of leaking.

Fig. 61.—Intersecting planes.

Fig. 62.—An aid to lining up shafts.

In case of water valves the stuffing boxes are best packed with oiled candle wicking.

LINING UP SHAFTING.

Fasten a heavily chalked string along the ceiling parallel to the direction the shafting is to take. Snap the string, and a white mark will indicate the position of the

shafting in a plane at right angles to the floor. This plane is indicated by the line *ab* in Fig. 61. Next determine the position of the shafting in a plane parallel to the floor, indicated by the line *cd*. This is done as follows: Loosely fasten the hangers along the white chalk line and properly fasten the shafting. Now hang on the shafting, at intervals of three feet, pieces of board like that shown in Fig. 62. The upper end is rounded to fit over the shaft, while the lower end is perforated as indicated by the dot. These pieces of board must be carefully cut so that the distance *P* is the same in all. If the holes at the lower ends are all in line the shafting is properly lined up. If not, the shaft needs readjusting.

CHAPTER XVII

PASTEURIZATION AS APPLIED TO BUTTER MAKING.

The process known as pasteurization derives its name from the eminent French bacteriologist Pasteur. It consists in heating and cooling in a manner which will destroy the vegetative or actively growing bacteria. Milk or cream is also considered pasteurized when only the bulk of the vegetative bacteria is destroyed.

Beginning of Cream Pasteurization. About fourteen years ago Storch, the noted Danish scientist, succeeded in isolating from milk the bacteria that are needed in successfully ripening cream. Cultures of these bacteria were prepared and propagated in his laboratory and placed upon the market for cream ripening. It became evident to Storch, however, that the best results could not be expected when these cultures were added to cream that was already teeming with various species of bacteria. This led him to the idea of preparing a clean field for his cultures by destroying the germs that already existed in the cream by pasteurizing it. After this treatment the cream was inoculated with the desirable germs that he had isolated and propagated for this purpose. The result of this practice was that it became possible to produce butter which not only possessed a very fine flavor but which was characterized by its extreme uniformity and good keeping quality.

Storch soon succeeded in introducing this method of butter making into Danish creameries which has done

much toward making Denmark the most noted butter-producing country in the world. Practically all butter produced in that country at the present time is made from pasteurized cream.

Pasteurized Butter in America. The growth of the system of pasteurized butter making has been slow in America up to within recent years. That pasteurized butter possesses merits over unpasteurized has, however, long since been demonstrated by American agricultural colleges and private investigators. It remained, nevertheless, for our practical butter makers to place the merits of this system beyond a possible doubt. During the past two years most of the important prizes awarded to butter makers have gone to makers of pasteurized butter. M. Sondergaard and John Sollie, two champion butter makers of the United States, are the firmest advocates of pasteurization. Creameries all over the country are now turning their attention to pasteurization and the general adoption of the system in America can only be a matter of time. The Continental Creamery Co. of Topeka, Kansas, one of the largest creameries in the world, is now making butter exclusively from pasteurized cream.

Why We Should Pasteurize. It must not be forgotten that the standard of American butter is becoming higher year after year. Methods which only six years ago produced a butter that fairly suited the general market, are now obsolete and unsatisfactory. In illustration of this may be cited the practice of using butter-milk starters, or the use of no starters at all, in creamery practice. The author has closely watched the careers of several young men who, only a few years ago, had met with a fair degree of success in ripening cream with but-

termilk starters, but whose persistence in adhering to old methods has driven them out of the profession of butter making.

The rational use of starters has done much to raise the general standard of butter in America. But the finest starters added to cream already teeming with many species of good and bad bacteria, can not produce the best results. It is obvious that the best results with good starters are possible only when the bacteria in the cream are first destroyed by pasteurization so that the good germs introduced by the starter may have a clean field for development.

If nothing but clean, uncontaminated milk were delivered at our creameries, pasteurization could hold no place in our system of butter making, for such milk could not be improved by this process. But we can not hope, for many years at least, to have all milk arrive at the creameries in good, clean condition, though of course great possibilities remain for improvement in this direction. Some milk will persist in coming to the creamery too good to reject and too poor to make the best quality of butter.

Then, too, with the advent of the hand separator system in creamery butter making, pasteurization has become more imperative than ever before. Where cream of varying ages and acidity is received it is more difficult to secure uniformity and good keeping quality in butter than is the case where the milk is daily delivered to the creamery.

It is hoped that the general recognition of the merits of pasteurization will soon be followed by the adoption of this method of butter making in all of our creameries. We need to produce a butter of better keeping quality and

of greater uniformity, two qualities which American butter notably lacks.

Some of the advantages of pasteurization are well set forth by M. Mortenson in an article contributed to the Chicago Dairy Produce (p. 798, 1903). He says: "By pasteurizing the cream and adding a starter he (butter maker) secures perfect control of fermentations, and he will be enabled to make a uniform grade of butter. By pasteurization it is also possible to remove taints caused by foods consumed by the animal, also taints that have been absorbed by the milk from unfavorable surroundings. One point strongly in favor of this system is the keeping quality which pasteurized butter possesses. If we desire to compete for the foreign trade we must make pasteurized butter. A dealer in Montreal informed me that he would willingly pay one cent more for pasteurized than raw cream butter." Mortenson is one of our most successful butter makers and a champion of pasteurization.

Methods of Making Pasteurized Butter. Pasteurized butter may be made by pasteurizing either the milk or the cream. The latter method is the one generally employed at the present time.

The machines used for pasteurizing are of two kinds:

1. *Discontinuous* pasteurizers, used for pasteurizing small quantities of milk or cream, in which the heating lasts from 15 minutes to 1 hour, according as the temperature is high or low.
2. *Continuous* pasteurizers in which a constant stream of cream or milk flows through the machine and is heated only during its few moments passage from the bottom to the top of the pasteurizer.

The heating in both classes of machines is done in a jacket surrounding the milk or cream in which either

live steam or hot water is used. The latter is to be preferred, because hot water does not scorch as much as live steam.

Fig. 63.—Cream pasteurizer and cooler.

In purchasing a pasteurizer the following points should be observed: first, the ease with which the machine can be cleaned; second, the capacity, which should be large enough to avoid crowding; third, the ease and uniformity with which the cream or milk can be heated; fourth, the durability of the machine.

It is a great mistake to buy a machine of too small

capacity. Such a machine must be fed so heavily as to necessitate a thick layer of milk or cream over the heating surface which can not result in uniform heating.

Fig. 64.—Cream cooler.

Cream Pasteurization. For creameries the most popular as well as the most practical method of making pasteurized butter consists in heating cream to 185° F. in a continuous pasteurizer and then rapidly cooling it to 65° F. By this treatment the great bulk of bacteria is destroyed.

Fig. 63 illustrates a common form of pasteurizer and cream cooler. The cream flows directly from the separator into the bottom of the pasteurizer whence it is forced upward by means of revolving dashers, which finally discharge it over the cream cooler at the left.

The circulation of the water in the cooler is indicated by the arrows. A cooler consisting of 12 discs will cool the cream from two separators to within 10 degrees of the temperature of the water.

It will be noticed from the cut that the cooler is provided with a cover, but it is best to leave this off as pasteurized cream needs very thorough aeration.

A cooler like that shown in Fig. 22 will cool and aerate cream satisfactorily when made large enough. It should be at least 10 feet long and 1 foot wide. Fig. 64 illustrates another form of cream cooler which has proved very efficient.

Pasteurization will not prove successful unless the cream is *rapidly* cooled to at least 65° F. *immediately* after it leaves the pasteurizer.

During the past four years a great many experiments have been carried out at the Michigan Dairy School along pasteurizing lines, with a view of determining the advantages of making pasteurized butter.

The experiments have had for their immediate objects :
1. To study the relative merits of pasteurizing whole milk and cream ; 2. To study the extent to which pasteurization improves the quality of the butter ; 3. To study the keeping quality of pasteurized butter.

The results of these tests are briefly summarized as follows :

1. There was practically no difference in the quality of the butter produced from pasteurized whole milk and that made from pasteurized cream.

2. Where the milk was of average purity the butter from the pasteurized cream scored on an average 3 points higher than that from the unpasteurized, using 15% starter in each case.

3. When the milk was below average purity, the butter from the pasteurized cream scored from 4 to 6 points higher than that from the unpasteurized, using 15% starter in each case.

4. When the unpasteurized cream from milk below average purity was ripened without starter and the pasteurized cream from the same milk was ripened with 15% starter, the difference in the scores was from 8 to 11 points in favor of the pasteurized cream.

5. The keeping quality of the butter made from pasteurized cream was in most cases so far superior to that from the unpasteurized, that the author feels that the increased keeping quality alone should warrant the general introduction of pasteurization in our system of butter making.

Samples of the butter obtained in the above experiments were usually sent to W. H. Healey, New York City, for scoring.

A host of other careful experiments conducted in Wisconsin, Iowa, Canada, and elsewhere, have so firmly established the merits of pasteurized butter that the general introduction of the system of pasteurization can not long be delayed.

Purification of Wash Water. The matter of using clean, pure water for washing butter has hitherto not received the attention which this subject demands. There is no question that much butter is robbed of its rich, creamy flavor by too much washing with impure water. Experiments conducted at the Iowa station and elsewhere have shown that the flavor and keeping quality of butter can be improved by purifying the average wash water, either by filtering or sterilizing it.

Where pasteurized butter is made it is of the utmost

importance to use nothing but pure water for rinsing cream vats and washing butter, else pasteurization will prove a delusion.

Purifying Water by Filtration. Most people are familiar with the purifying action which water undergoes in its passage through sand, gravel, charcoal, etc. For purifying water used for washing butter, artificial filter beds constructed of such material have given excellent satisfaction.

The filter can described in bulletin No. 71 from the Iowa Experiment Station is 48 inches high, 18 inches in diameter, and constructed of 22 gage galvanized iron. Beginning at the bottom the filtering material was placed in the can in the following order: 1. 2 inches of small flint stones; 2. 22 inches of fine sand; 3. 12 inches of fine coke; 4. 9 inches of charcoal; 5. 2 inches of fine stone or coarse gravel. Two perforated plates are placed in the can, one near the bottom upon which the filtering material rests, the other on top of the fine sand. A third and concave plate is placed near the top with a hole in the center, which directs the water to the center of the filter bed.

This can has a filtering capacity of 16 gallons per hour, and it is claimed that the filter does not need to be cleaned or renewed oftener than once in four months and possibly not this often. The cost of the can is \$11.11.

Filtration offers one of the cheapest methods of purifying water and is the method generally employed by cities that are dependent upon lakes for their water supply.

Purification of Water by Heating. Water may be pasteurized in the same manner as cream. There is, however, one objection to this method of purifying water, and that is the bad effect which it has on the pasteurizer. In the course of time a distinct layer of the mineral im-

purities of the water will be deposited upon the walls of the pasteurizer in a manner similar to the formation of scale in the boiler. This mineral deposit will in time destroy the usefulness of the pasteurizer.

Fig. 65.—Showing method of sterilizing wash water for butter.

A more satisfactory method of purifying water by heating is illustrated in Fig. 65. The water is pumped from the well into the galvanized iron tank A, which is placed about 6 feet above the floor in the boiler room. This tank is tightly covered with the exception of a small vent in the cover.

The water is heated by placing a series of galvanized iron pipes in the bottom of the tank through which all, or a part, of the exhaust steam from the engine is conducted. In this way the expense of heating water will cost nothing more than a slight back pressure on the engine.

The hot water may be drawn off from this tank whenever desirable and cooled in the same manner as the cream, that is, by running it over the cream cooler B. From the cooler the water should be run into a tank, in which it can be cooled to the desired temperature by means of ice water. The water as it leaves the cooler will have a temperature of from 60 to 65 degrees, so that only enough ice will be needed to reduce the temperature about 10 degrees.

Fig. 65 also illustrates the method of heating water for the boiler and for general washing.

Cost of Pasteurizing Cream. Unfortunately definite data on the cost of pasteurizing cream are still wanting. According to Danish experiments the cost will be approximately .1 cent per pound of butter. These results seem to be confirmed by the best practical butter makers in this country who have pasteurized for several years.

The cost of pasteurizing must, however, always depend largely upon the manner in which the pasteurizing process is carried out. For example, if the water used for cooling the cream is pumped into the water supply tank for the boiler, a large portion of the heat used for pasteurizing is recovered. Further, if the proper coolers are used, ordinary well water will cool the cream to the ripening temperature without the use of ice. Some have also found it practical to use the exhaust steam from the engine for pasteurizing cream.

The care and cleaning of the pasteurizer and cooler will, of course, entail extra labor, but the labor thus involved will not materially add to the expense of pasteurizing.

Pasteurization of Gathered Cream. There is probably no problem along pasteurizing lines of greater impor-

tance at present than the pasteurization of hand separator or gathered cream. Heretofore the apparent difficulty in the way of pasteurizing this cream has been the high degree of acidity which it often reaches before delivery to the creamery.

To arrive at some definite conclusions, a series of experiments was carried out at the Michigan Dairy School under the direction of the author, in which cream with an acidity varying from .3 to .6 per cent was pasteurized in a continuous pasteurizer at a temperature of 185° F. After pasteurization, one-half was left without starter, the other half was treated with 25 per cent starter after it had reached a temperature of 65° F. Both lots were then cooled to 48° F., where they were held for ten hours and then churned. Control experiments were carried of unpasteurized cream ripened without starter. Samples of the butter made were sent to W. H. Healy of New York for scoring.

The results obtained in these experiments are summarized as follows:

1. Cream with a fat content of from 20 to 40 per cent can be pasteurized without difficulty even when the acidity reaches .6 per cent.

2. When no starter was added to the pasteurized sour cream no improvement in the flavor of the butter was noticeable.

3. When the pasteurized sour cream was treated with 25 per cent starter the flavor of the butter was improved from 2 to 4 points in every experiment.

4. Pasteurizing sour cream destroys its heavy consistency, which cannot be recovered even when ripened with 25 per cent starter. The body of the butter from this cream was perfect, however.

5. There was practically no difference in the yield of butter from the pasteurized and unpasteurized sour cream.

6. The average test of the buttermilk from the pasteurized sour cream was .07 per cent, that from the unpasteurized, .09 per cent.

7. There was a marked increase in the keeping quality of the butter made from pasteurized sour cream treated with starter.

8. The acidity of the sour cream was somewhat diminished by the pasteurizing process.

These experiments have shown that it is absolutely essential to add a heavy starter to the pasteurized sour cream even if the latter shows an acidity of .6 per cent.

CHAPTER XVIII.

CO-OPERATION.

I. Co-operative Creameries. There are two distinct classes of creameries in existence at the present time. (1) Those owned and operated by private individuals, called proprietary creameries; (2) those owned and operated by the patrons, known as co-operative creameries.

Most of the creameries built at the present time belong to the co-operative type. This is the ideal plan upon which creameries should be built and operated and it has in most cases proved successful.

Methods of Organizing Co-operative Creameries. Too frequently co-operative creameries are established by so-called "promoters," whose aim is to make money for themselves by taxing the farmers a thousand dollars or more in excess of the actual cost of the creamery.

If a community of farmers is interested in the establishment of a creamery, the following method of organizing should be pursued:

1. Let those most interested in the project make a thorough canvass of the milk producers in that community to ascertain the number of cows available. There should not be less than 400 cows to start with.

2. If the desired number of cows is available, the next step is to secure a subscription of \$4,500 by selling shares for that amount. This sum of money is necessary to build and equip a substantial fire proof creamery containing all the modern creamery machinery. Where possible it is

desirable to sell shares only to prospective creamery patrons, so that the creamery may be a truly co-operative one.

3. When the necessary funds have been subscribed, call a meeting of the shareholders to elect a president, secretary, treasurer, manager, and a board of directors which should consist of the president, secretary, treasurer, and at least three other shareholders.

4. The next step is to specify a certain time within which all subscriptions must be paid. The money is preferably turned over to a reliable banker in the form of notes bearing interest.

5. The treasurer should be authorized to draw upon the bank for the money thus deposited whenever occasion demands, but he should be required to give security for the money that comes into his hands.

6. When all subscriptions have been paid, a meeting of the board of directors should be called for the purpose of hiring a butter maker who shall not only be able to make a first class article of butter, but who shall also be competent to plan and superintend the construction of the creamery. This is a point which most co-operative creameries overlook. The result is there are dozens of creameries scattered all over the country which are faulty in both design and construction.

Before drawing up his plans it would be policy for the butter maker to visit several up-to-date creameries so as to get the latest ideas on creamery construction.

7. The creamery is paid for out of a sinking fund created by charging the patrons, in addition to the charge necessary to cover running expenses, say one cent for every pound of butter fat delivered until the creamery is paid for.

8. After the creamery is paid for, there should be an annual dividend declared to the shareholders as interest on their investment.

9. A sufficient sinking fund must be maintained to cover the annual dividend and the running expenses, by charging from two to three cents for every pound of butter fat delivered.

Management of Co-operative Creameries. Too frequently the management of co-operative creameries is placed in the hands of persons who know little or nothing about creamery matters. Perhaps more co-operative creamery failures can be traced to this cause than to any other.

The stockholders of co-operative creameries should select a manager and managing board who are familiar with the details of the business they are going to manage. Advice should freely be sought from the butter maker who in most cases is the best posted man to govern the affairs of the creamery.

2. Co-operation of Butter maker and Patron. The relationship of butter maker and patron should be one of mutual interest—a business relationship. Butter making is a business and, as such, should be governed by business principles.

The butter maker, then, besides being able to make a fine quality of butter, must be a business man, dealing as he does with farmers, bankers, merchants, mechanics, and others. He must be honest, tactful, and full of enterprise.

Too frequently self-interest figures too conspicuously in the management of creamery affairs. This can not help but result, sooner or later, in the ruination of the business.

The butter maker has, and must have, certain rights which, if rightly asserted, can not help but be productive

of much good. If used otherwise, these rights will create enmity and become a damage to the creamery. For example, a butter maker has a right to demand of his patrons good clean milk, but he can not attain his object by repeatedly sending back milk that is not right. Tactfully explaining the evils resulting from unclean milk, giving the probable cause, and manifesting a willingness to visit his premises, will accomplish very much more in reforming the patron.

Greeting the patrons with a smile and a "good morning" inspires confidence. Accuracy in sampling, weighing and testing, a clean person and clean surroundings, are things that merit more than ordinary attention.

The best way for butter makers to get along with their patrons is to help them in every way they can. They should act as educators of their patrons in their respective communities. No person has a greater opportunity for doing good in his community than the butter maker.

A few printed instructions to patrons occasionally can not fail to be productive of much good, both to the patron and to the butter maker. The following may be considered as sample instructions:

1. Get cows that are purely dairy animals. Cows that have a tendency to lay on flesh while giving milk are not the most profitable for the dairy. A milch cow should convert her food into milk, not into flesh. Such a cow you will generally find a spare, lean looking animal.

2. Do not be afraid to invest \$100 in a good sire of some good dairy breed to head your herd. See to it that this sire is a descendant of prolific milkers, and that he has good breeding qualities.

3. Feed liberally. Remember that about sixty per cent of what a cow can eat and properly assimilate is

required for her maintenance; that which is fed beyond this is utilized for the production of milk if the cow is a purely milk-producing animal. Hence the wisdom of feeding a cow to her full capacity.

4. Do not feed just one kind of feed. Variety of feeds is essential in economical feeding.

5. Feed liberally of concentrated feeds like bran and oil meal, especially during scarcity of pasturage.

6. Do not be afraid to invest \$16 in a ton of bran, for its value to you as a fertilizer alone is \$11.

7. Always milk your cows at the same time morning and evening. Regularity in milking means more milk.

8. Do not change milkers, and insist that the milkers treat the cows gently.

9. Always thoroughly cool night's milk by placing it in cold water and stirring it frequently.

10. Do not allow the calves to suckle the cows more than three days after calving.

11. Always add a few tablespoonfuls of oil meal or cooked flax seed to the skim-milk before feeding it to your calves.

12. Grow a liberal supply of clover and peas, for these produce a liberal flow of milk, at the same time enriching the soil.

13. Grow an abundance of corn and ensilo it. It may prove your most economical feed.

14. Never place your milk cans in the barn while milking for the barn odors will taint the milk.

15. Do not bed or feed your cows, or in any way disturb the barn dust, while milking.

16. Always provide your cows with a liberal supply of salt and pure water. Never allow them to drink stagnant water.

17. Bring samples of milk from the individual cows of your herd for testing. It will cost you nothing, but it may be of great value to you.

18. A sample consisting of a portion (1 oz.) of the night's and morning's milk is necessary for a test. Always thoroughly mix milk before sampling.

CHAPTER XIX.

DETECTION OF TAINTED OR IMPURE MILK.

In well regulated creameries the head butter maker will usually be found at the intake every morning carefully examining the milk as it arrives at the factory. It requires skill and training to detect and properly locate the numerous taints to which milk is heir. It also requires considerable tact to reform patrons who have been careless in the handling of their milk. The best skill available in the creamery should therefore be placed in the intake.

In the daily examination of milk, defects can usually be detected by smelling of it as soon as the cover is removed from the cans. When, however, milk arrives at the creamery at a temperature of 50° F. or below, it becomes more difficult to detect taints; indeed during the winter when milk is often received in a partly frozen condition, experts may be unable to detect faults which become quite prominent when the milk is heated to a temperature of 100° F. or above.

Frequently milk is seeded with undesirable kinds of bacteria which have not had time to develop sufficiently to manifest themselves at the time the milk is delivered to the creamery, but which later in the course of cream ripening produce undesirable flavors. It is necessary, therefore, in making a thorough examination of milk to heat it to a temperature of from 95° to 100° F. and to keep it there for some time to permit a vigorous bacterial development. Such bacterial development is best carried on in what is known as the Wisconsin Curd Test, a full description of which is given below.

WISCONSIN CURD TEST.

This test originated at the Wisconsin Dairy School. The name of the test implies that the samples of milk to be tested are curded, which is accomplished in a manner similar to that in which milk is curded for cheese making.

The Wisconsin Curd Test is frequently spoken of as "fermentation test," since the process involved consists in fermenting the milk by holding it at a temperature at which the bacterial fermentations go on most rapidly.

Apparatus. This consists of one pint cylindrical tin cans placed in a tin frame, and of a well insulated box made so that the tin frame will nicely slide into it. Added to this is a case knife, and a small pipette used to measure rennet extract.

The construction of the box and the position of the cans inside is illustrated in Fig. 66. This box consists of three-eighths inch lumber, the inside of which is lined with a quarter inch thickness of felt. Narrow strips are tacked on the felt and tin upon these, the object of the strips being to prevent conduction of heat by contact of the tin with the felt. The cover of the box is constructed in the same way and made to fit tight. This construction makes it possible to maintain a nearly constant temperature of the samples which are surrounded by water as shown in the illustration.

Making the Test. A curd or fermentation test is made at the creamery by selecting from each patron about two-thirds of a pint of milk and placing this in the tin pint cans after they have been thoroughly sterilized. Each pint can should be provided with a sterilized cover which is placed upon it as soon as the sample has been taken.

The sample cans are next placed in the insulated box provided for them. Here they are warmed by adding water at a temperature of 103° F. to the box, a temperature which should be maintained throughout the whole test.

Fig. 66.—Section through curd test.

With a sterile thermometer watch the rise in temperature until it has reached 86° F. when 10 drops of rennet extract are added to each sample and mixed with it for a few moments with a sterile case knife. This knife must be sterilized for each sample to avoid transferring bacteria from one can to another.

As soon as the milk has curdled it is sliced with the case knife to permit the separation of the whey. After the whey has been separating for half an hour, the samples should be examined for flavor, which can be told far better at this stage than is possible by smelling of the milk as it arrives at the creamery.

After the samples have all been carefully examined, the whey is poured off at intervals of from twenty to forty minutes for not less than eight hours. At the end

of this time a mass of curd will be found at the bottom of the can in which there has been a vigorous development of bacteria throughout the test.

If the sample of milk is free from taint, this curd when cut with a knife will be perfectly smooth and close. If, on the other hand, the sample contains gas germs, these in course of eight hours' development will have produced enough gas to give the curd an open spongy appearance when cut. The openings are usually small and round, hence the name "pin holes" has been applied to them indicating holes the size of a pin's head.

Whenever, therefore, milk produces a curd that answers this description it may be taken for granted that it contains **undesirable bacteria**.

Sometimes the milk may be tainted and yet produce a close textured curd, but in such cases the taint can be detected by carefully smelling of the curd.

Precautions. In making a test as above outlined two things must constantly be kept in mind: first, that to secure the desired bacterial development, the temperature of the samples must be maintained as nearly as possible at 98° F., which is accomplished by surrounding them with water at a temperature of 103°; second, that to avoid contaminating one sample with another, the knife used for mixing the rennet with the milk and cutting the curd must be sterilized for each can. The thermometer used must also be sterile.

The temperature of the samples can easily be maintained by using a well insulated box like that shown in Fig. 66. When a common tin box is used it becomes necessary to change the water in it about once every half hour.

CHAPTER XX.

CARE OF MILK AND SKIM-MILK.

No matter how skillful a butter maker may be he can not produce the highest quality of butter from milk of inferior quality. Skill may do much to improve quality but it can never make perfection out of imperfection. It should, therefore, be as much a duty of the butter maker to keep his patrons properly instructed in the care and handling of milk as it is to keep himself posted on the latest and most approved methods of making butter.

The cows should be milked in clean, well ventilated barns in which the air is kept free from dust during milking. This means that cows should not be fed or bedded about milking time. In ordinary milking a great share of the bacteria find their way into the milk through the dust that dislodges from the animal. This is easily prevented by wiping the flanks and udder of the cow with a moist cloth just before milking.

Immediately after the milk is drawn it should be removed from the barn to a clean, pure atmosphere where it is aerated and cooled by running it over a combined aerator and cooler like that shown in Fig. 67. The

Fig. 67.—Milk aerator and cooler.

barrel here shown is filled with cold water which circulates, as it flows from the barrel, between the two tin surfaces of the cooler over which the milk flows in thin sheets, thus cooling it to within five degrees of the temperature of the water.

Fig. 68.—Skim-milk pasteurizer.

The ordinary method of cooling milk in ten gallon cans by setting them in a tank of cold water is too slow. The result is that during the summer months milk frequently arrives at the creamery sour or nearly so.

All milk should be strained through absorbent cotton. A strainer consisting of a few thicknesses of cheese cloth is of little value.

Milking utensils, such as pails, cans and dippers, should be thoroughly washed and scalded after which they are placed in direct sunlight.

Pasteurization of Skim-milk. To secure the greatest feeding value of skim-milk it must be fed sweet. During the summer months skim-milk as it is ordinarily returned from creameries, keeps sweet but a short time, a fact which has compelled many a farmer to purchase a hand separator and separate the milk at the farm.

To keep the skim-milk in good feeding condition it must be pasteurized at the creamery. The cheapest and most common means by which this is done is to heat it with a heater like that shown in Fig. 68. This heater utilizes the exhaust steam from the engine and heats the skim-milk to temperatures ranging from 170° to 200° F. The skim-milk enters at one end of the heater while the steam (either live or exhaust) enters through the top near the point at which the skim-milk enters. The steam thus comes in direct contact with the skim-milk and condenses, heating it to the above temperature. One end of the pasteurizer is removable so as to permit thorough cleaning.

Objections have frequently been raised against this method of pasteurizing because of the small quantity of cylinder oil contained in the exhaust steam. Where judgment is used in oiling cylinders no trouble need be anticipated from this source as the oil can be detected only with difficulty.

Extensive inquiry into the matter of pasteurizing skim-milk has developed the fact that the *patrons* and the *calves* must be educated to the change from unpasteurized to pasteurized skim-milk, and where this has been done pasteurization has given the best of satisfaction—indeed the patrons would refuse to accept the skim-milk unpasteurized. Calves will object somewhat at first to a change from unpasteurized to pasteurized skim-milk (especially if the latter is fed at a temperature of 150° F.) but they will soon begin to like it.

A difficulty that has always been experienced in pasteurizing skim-milk is the foam that results from the heating. Various so-called “foam killers” have been placed upon

the market which have been more or less successful in obviating this trouble.

Fig. 69 illustrates a method of handling skim-milk which prevents, to a great extent the difficulty usually experienced from foam.

Fig. 69.—Skim-milk tank and pasteurizer.

The pasteurizer is placed on top of the skim-milk tank and the pasteurized skim-milk flows through a pipe which runs to within an inch or an inch and a half of the bottom of the tank. A pipe so placed will tend to destroy a portion of the foam formed in the heater. The tank is of ample size to hold the foam not thus destroyed, which, during the early summer, is quite considerable. The larger the tank the less trouble will be experienced from the foam.

CHAPTER XXI.

HANDLING AND TESTING CREAM.

The rapid introduction of hand separators among creamery patrons during the past few years has confronted many creamery operators with the problem of how this cream should be handled to make the best quality of butter from it. The practice of receiving cream instead of milk at the creamery is growing. Creameries which only a few years since were running entirely on the whole milk plan have now changed more or less to cream gathering plants. Indeed many creameries that are now being built operate entirely on the hand separator plan.

Sampling. Where the cream is delivered to the creamery in a sweet condition, *composite* samples may be taken in the same manner as with milk. Usually, however, where a great deal of hand separator cream is handled, some of it is delivered too sour for composite sampling. In this case it becomes necessary to test the cream as often as it is delivered.

Where cream of varying degrees of acidity is received, the following method of sampling and weighing is recommended: With a long-handled conical dipper thoroughly mix the cream in the can and then pour into a small glass tube enough of it for a duplicate test. Weigh the cream in the cans in which it is delivered and subtract from the gross weight the weight of the can which should be marked upon it in plain figures. The cream is now emptied into one or two receiving vats, one provided for

sweet cream, the other for that which has more or less soured.

After all the cream has been sampled and weighed, the tubes containing the samples for testing are placed in a water bath at a temperature of 120° where the cream is warmed preparatory to testing. A suitable rack, made to fit the water bath, should be provided for the cream tubes. When the cream has become sufficiently warmed in the tubes, it is poured and repoured a few times and a sample weighed out by transferring the cream to the test bottle by means of an automatic pipette like that shown in Fig. 70. This consists essentially of a pipette with a rubber bulb at one end by means of which the cream is sucked into the pipette and again forced out of it. This method of forcing permits a rapid delivery of the cream.

Testing. Accurate tests of cream can not be secured by measuring the sample into the bottle as is done in the case of milk. The reason for this is that the weight of cream varies with its richness. The richer the cream the less it weighs per unit volume. This is illustrated in the following table by Farrington and Woll:

Weight of fresh separator cream delivered by a 17.6 c.c. pipette.

Per cent of fat in cream.	Specific gravity (weighed).	Weight of cream in grams.
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

These figures plainly show that justice can not be done to patrons where cream is sampled with a 17.6 c.c. pipette. Cream is therefore always weighed on a cream balance (Fig. 7.), the amount necessary for a full sample being eighteen grams. To save time in weighing place a cream bottle on each side of the scales and balance. Then place an eighteen-gram weight on one side and pour cream into the bottle on the other side until the scales balance. Now remove the weight and pour cream into the empty bottle until the scales again balance. The same operation is repeated with the next two bottles, and so on.

Fig. 70.—Automatic pipette.

Special Cream Bottles and Tester.

Since most cream tests above 30%, a full sample of it can not be tested in a 30% bottle. Fig. 71 illustrates a cream tester which is specially designed to whirl a long-necked cream bottle graduated at 55%. At the left in the figure is shown one of these bottles. Another cream bottle graduated to 55% is shown in Fig. 72. These bottles have the advantage of permitting the use of a full sample for testing which insures a more accurate reading than is possible where only half a sample of cream is taken for a test.

With proper care, however, cream may be tested in an ordinary tester by using the 30% cream bottles. When these bottles are used only half a sample (8 grams) of cream is weighed out and a corresponding amount of acid used.

Amount of Acid. It is evident that the richer the

cream the less the amount of acid necessary for a test, for acid does not act upon the fat but spends its energy upon

Fig. 71.—Cream tester.

the serum, which becomes less the richer the cream. 14 or 15 c.c. of acid is usually sufficient for 18 grams of ordinary cream.

In case 18 grams of cream are divided between two 30% bottles and the same quantity of water is added, the full measure of acid may be used with satisfactory results.

It must be remembered that when only half a sample of cream is used for a test the fat in the neck must always be multiplied by 2 to get the correct reading.

Necessity of Grading Cream. It is a fact which can not be disputed that in most of the gathered cream factories some cream is received sweet and some more

or less sour. Hence the necessity of grading. The sour cream should be placed in a class by itself and the same with the sweet cream.

The butter maker has far better control over sweet cream than he has over sour and can therefore make a better quality of butter from it. It is, then, no more than just that the patron who takes good care of his cream and endeavors to deliver it often, should receive more for it than the man who is careless and delivers the cream only once a week. Indeed grading cream seems to be the only resource left to the butter maker to induce his patrons to deliver sweet cream.

Where it is desired to churn all the cream in the same churning, a better quality of butter is possible when the sweet cream is ripened by itself with a heavy starter and the sour cream added to this some hours previous to churning.

Adding sour cream to sweet cream is equivalent to adding so much starter of a kind not likely to produce very good results. Moreover when a fine flavored starter is added to such a mixture its influence is small compared with what it is when added to sweet cream, because acid is a hindrance to the development of the lactic acid bacteria.

Necessity of Pasteurizing. Experiments have abundantly proven that average cream, whether sweet or sour, will make a better quality of butter when pasteurized. This subject is fully discussed in the chapter on pasteurization.

Fig. 72.—55% Cream bottle.

CHAPTER XXII.

MECHANICAL REFRIGERATION.

In warm climates and in localities where ice is not obtainable or only so at a high cost, cold may be produced by artificial means known as mechanical refrigeration. This system of refrigeration is also finding its way into creameries that are able to procure ice at a moderate cost but which are seeking more satisfactory means of controlling the temperature of their cream, refrigerator, make room, etc.

Refrigerating Machines. There are four kinds of machines used for refrigerating purposes: (1) vacuum machines in which water is used as the refrigerating medium; (2) absorption machines in which a liquid of a low boiling point is used as the refrigerating medium, the vapors being absorbed by water and again separated from it by distillation; (3) compression machines which operate practically the same as the absorption machines except that the vapors in this case are compressed instead of absorbed; and (4) mixed absorption and compression machines.

Most of the machines in use at the present time belong to the compression type; the following discussion will therefore confine itself strictly to this class of machines.

Principle. The principle employed in mechanical refrigeration is the production of cold by the evaporation of liquids which have a low boiling point* like liquid ammonia, liquid carbonic acid, ether, etc.

When a liquid evaporates or changes into the gaseous state it absorbs a definite amount of heat called heat of vaporization or "latent" heat. Thus to change water from 212° F. to steam at 212° F. requires a considerable amount of heat which is apparently lost, hence the term latent (hidden) heat.

Ether changes into its gas at a much lower temperature than water which is illustrated by its instant evaporation when poured upon the hand. The heat of the hand in this case is sufficient to cause vaporization and the sensation of cold indicates that a certain amount of heat has been abstracted from the hand in the process.

Manifestly for refrigerating purposes a liquid must be used that can be evaporated at a very low temperature; for the cold in mechanical refrigeration is produced by the evaporation of the liquid in iron pipes, the heat for the purpose being absorbed from the room in which the pipes are laid. Anhydrous ammonia has thus far proven to be the best refrigerant for ordinary refrigeration.

Anhydrous Ammonia (Refrigerant). This substance is a gas at ordinary temperatures but liquifies at 30° F. under one atmospheric pressure. In practical refrigeration the ammonia is liquified at rather high temperatures by subjecting it to pressure. The ammonia is alternately evaporated and liquified so that it may be used over and over again almost indefinitely.

Circulation of Ammonia. The cycle of operations in mechanical refrigeration is as follows: The liquid ammonia starts on its course from a *liquid receiver*, and enters the *refrigerating coils* in which it evaporates, absorbing a large amount of heat in the process. By means of a *compression pump*, operated by an engine, the ammonia vapors are forced in the *condenser coils* where the

ammonia, under pressure, is again liquified by running cold water over the coils. From the condenser coils it enters the liquid receiver, thence again on its journey through the refrigerating coils.

The intensity of refrigeration is regulated by an *expansion valve*, which is placed between the liquid receiver and the refrigerating coils. This valve may be adjusted so as to admit the desired quantity of liquid ammonia to the coils.

Systems of Refrigeration. There are two ways in which the cooling may be accomplished by mechanical refrigeration: (1) by evaporating the liquid ammonia in a series of pipes placed in the room to be refrigerated; and (2) by evaporating the liquid ammonia in a series of coils laid in a tank of brine and forcing the cold brine into coils laid in the room to be refrigerated. The former is known as the direct expansion system, the latter as the indirect expansion or brine system.

Brine System. In creameries where the machinery is run only five or six hours a day the brine system is the more satisfactory as it permits the storing of a large amount of cold in the brine, which may be drawn upon when the machinery is not running.

The brine tank is preferably located near the ceiling in the refrigerator where it will serve practically the same purpose as an overhead ice box. In addition to this, the refrigerator should contain a coil of direct expansion pipes which may be used when extra cold is desired.

Brine from the above tank may be used for cooling cream by conducting it through coils which are movable in the cream vat; it may also be conducted through stationary pipes placed in the make room for the purpose

of controlling the temperature during the warm summer months.

The brine is kept circulating by means of a *brine pump*.

Strength of Brine. The brine is usually made from common salt (sodium chloride). The stronger the brine the lower the temperature at which it will freeze. Its strength should be determined by the lowest temperature to be carried in the brine tank. The following table from Siebel shows the freezing temperature as well as the specific heat of brine of different strengths:

Percentage of salt by weight.	Pounds of salt per gallon of solution.	Freezing point (F.).	Specific heat.
1.....	0.084	30.5	.992
2.....	0.169	29.3	.984
3.....	0.256	27.8	.976
4.....	0.344	26.6	.968
6.....	0.523	23.9	.946
8.....	0.708	21.2	.919
10.....	0.897	18.7	.892
12.....	1.092	16.0	.874
15.....	1.389	12.2	.855
20.....	1.928	6.1	.829
25.....	2.488	0.5	.783
26.....	2.610	-1.1	.771

The fact that the specific heat grows less as the brine becomes stronger shows it to be wise not to have the solution stronger than necessary, because the less the specific heat the less heat a given amount of brine is able to take up.

Refrigerating Capacity. When speaking of a machine of one ton refrigerating capacity, we mean that it will produce, in the course of twenty-four hours, the amount of cold that would be given off by one ton of ice at 32° F.

melting into water at the same temperature. Its actual ice making capacity is usually about 50% less.

Size of Compressor. In a moderately well insulated creamery handling from twenty to twenty-five thousand pounds of milk daily, a four-ton compressor will be large enough. With a compressor of this size the machinery will not have to be run more than five or six hours a day. If the machinery is run longer than this a smaller compressor will do the work.

Power Required to Operate. The power required per ton of refrigeration is less the larger the machine. With a four-ton compressor the power required is from two to two and one-half horse power per ton of refrigerating capacity in twenty-four hours.

Refrigerating Pipes. The refrigerating pipes vary from one to two inches in diameter. With moderately good insulation it is estimated that by the direct expansion system one running foot of two-inch piping will keep a room of forty cubic feet content at a temperature of 32° F. With brine nearly twice this amount of piping would be necessary.

For cooling the brine in the brine tank, about 140 feet of 1¼-inch pipes are required per ton of refrigerating capacity.

Expense of Operating. When a refrigerating plant has once been installed and charged with the necessary ammonia, the principal expense connected with it will be the power required to operate the compressor. This power in a creamery is supplied by the creamery engine. The ammonia, being used over and over again, will add but a trifle to the running expenses. Nor can the water used for cooling the ammonia vapors add much to the cost of operating. It is true, however, that the refrigera-

ting plant will require some of the butter maker's time and attention, but this is probably no more than would be consumed in the handling of ice in the creamery.

Charging and Operating an Ammonia Plant. This subject is so ably discussed in *The Engineer* by H. H. Kelley that the author feels he can do no better than present the following extracts from that article.

"When about to start an ice or refrigerating plant, the first thing necessary is to see that the system is charged with the proper amount of ammonia. Before the ammonia is put in, however, all air and moisture must be removed; otherwise the efficiency of the system will be seriously interfered with. Special valves are usually provided for discharging the air, which is removed from the system by starting the compressor and pumping the air out, the operation of the gas cylinder being just the reverse of that when it is working ammonia gas. It is practically impossible to get all the air out of the entire system by this means, so that some other course must be taken to remove any remaining air after the compressor has been started at regular work. This can be accomplished by admitting the ammonia a little at a time, permitting the air to escape through a purge valve, the air being thus expelled by displacement. The cylinder containing the anhydrous ammonia is connected to the charging valve by a suitable pipe, and the valve opened. The compressor is then kept running slowly with the suction and discharge valves wide open and the expansion valve closed. When one cylinder is emptied put another in its place, being careful to close the charging valve before attempting to remove the empty cylinder, opening it when the fresh cylinder is connected up.

"From sixty to seventy-five per cent of the full charge is

sufficient to start with so that the air may have an opportunity of escaping with as little loss of ammonia as possible. An additional quantity of ammonia may then be put in each day until the full charge has been introduced. When the ammonia cylinders have been emptied and a charge of, say, seventy-five per cent of the full amount has been introduced, the charging valve is closed and the expansion valve opened. The glass gauge on the ammonia receiver will indicate the depth of ammonia. The appearance of frost on the pipe leading to the coils and the cooling of the brine in the tank will indicate that enough ammonia has been introduced to start with. It is sometimes difficult to completely empty an ammonia cylinder without first applying heat. The process of cooling being the same when the ammonia expands from the cylinder into the system as when leaving the expansion valve, a low temperature is produced and the cylinder and connections become covered with frost. When this occurs the cylinder must be slightly warmed in order to be able to get all the ammonia out of it. The ammonia cylinders, when filled, should never be subjected to rough handling and are preferably kept in a cool place free from any liability to accident. The fact that ammonia is soluble in water should be well understood by persons charging a refrigerating system, or working about the plant. One part of water will absorb about 800 parts of ammonia gas and in case of accident to the ammonia piping or machine, water should be employed to absorb the escaping gas. Persons employed about a plant of this kind should be provided with some style of respirator, the simplest form of which is a wet cloth held over the mouth and nose.

“After starting the compressor at the proper speed and adjusting the regulating valve note the temperature of

the delivery pipe, and if there is a tendency to heat open it wider, and vice versa. This valve should be carefully regulated until the temperature of the delivery pipe is practically the same as the water discharged from the ammonia condenser. With too light a charge of ammonia the delivery pipe will become heated even when the regulating valve is wide open. As a general thing when the plant is working properly the temperature of the refrigerator is about 15° lower than the brine being used, the temperature of the water discharged from the ammonia condenser will be about 15° lower than that of the condenser, the pointers on the gauges will vibrate the same distance at each stroke of the compressor and the frost on the pipes entering and leaving the refrigerator will be about the same. By placing the ear close to the expansion valve the ammonia can be heard passing through it, the sound being uniform and continuous when everything is working properly.

"When air is present the flow of ammonia will be more or less intermittent, which irregularity is generally noticeable through a change in the usual sound heard at the expansion valve. The pressure in the condenser will also be higher and the effect of the apparatus as a whole will be changed, and, of course, not so good. These changes will be quickly noticed by a person accustomed to the conditions obtaining when everything is in order and working properly.

"The removal of air is accomplished in practically the same manner as when charging the system, permitting it to escape through the purging valve a little at a time so as not to lose any more gas than is absolutely necessary.

"The presence of oil or water in the system is generally detected by shocks occurring in the compressor cylinder.

"In nearly all plants the presence of oil in the system of piping is unavoidable. The oil used for lubricating purposes, especially at the piston rod stuffing boxes, works into the cylinders and is carried with the hot gas into the ammonia piping, where it never fails to cause trouble. The method of removing the air from the system has already been referred to, but the removal of oil is accomplished by means of an oil separator. This is placed in the main pipe between the compressor and the condenser, and is of about the size of the ammonia receiver. Sometimes another oil separator is placed in the return pipe close to the compressor, which serves to eliminate any remaining oil in the warmer gas and to remove pieces of scale and other foreign matter which, if permitted to enter the compressor cylinder, would tend to destroy it in a very short time.

"The oil, which always gets into the system sooner or later and in greater or less quantity, depending upon the care exercised to avoid it, acts as an insulator and prevents the rapid transfer of heat from the ammonia to the pipe that ought to obtain, and also occupies considerable space that is required for the ammonia where the best results are to be obtained."

CHAPTER XXIII.

CREAMERY BOOK-KEEPING.

The object of book-keeping is to keep a record of business transactions, enabling the proprietor or proprietors at any time to determine the true condition of the business.

In most businesses usually one of two forms of book-keeping is followed: either double entry which makes use of three books—day book, journal, and ledger—or single entry which makes use of only two books, a day book or journal, and ledger.

The day book contains a detailed record of business transactions. Entries are made in this book as soon as the transaction occurs.

The journal contains the debits and credits arranged in convenient form for transferring to the ledger.

The ledger contains the final results.

Debits and Credits. These words are usually abbreviated Dr. and Cr. respectively. The *debits* and *credits* in any business transaction are determined by the following rule: *debit whatever costs value; credit whatever produces value.* In a journal entry the sum of the debits and the sum of the credits must be equal.

Double and Single Entry Book-keeping. While double entry is the most complete form of keeping a business record, it entails too much work for creameries, which have but a limited time to devote to keeping books.

Single entry book-keeping when properly carried out has proved very satisfactory and most creameries follow this method in a more or less modified form.

In the following pages a simple and approved method of book-keeping is presented which may be followed by any creamery whether proprietary, co-operative, or otherwise. In this method the following books and papers are made use of:

(1) Day book, (2) order book, (3) sales book, (4) cash book, (5) pay roll register, (6) ledger, (7) milk sheet, (8) milk book, (9) test book, and (10) butter slips.

Day Book. All transactions made at the creamery should be at once recorded in the day book. At the close of the day or at some convenient time the records made in the day book are transferred to the order book, sales book, or cash book, according to the transaction. The following examples illustrate the manner of making records in the day book.

January 6, 1900.

Sold to J. D. Steele & Co. on account 1,100 lbs. of butter @ 24c.....				\$264	00
Bought of Newman & Co., for cash, 1 san- itary milk pump.....	\$20	00			
5 gal. butter color @ \$1.70.....	8	50			
20 gal. separator oil @ 20c.....	4	00		32	50
Bought of H. Chandler on account 11 cords of wood @ \$3.00.....				33	00

When payment is made for goods at the time the transaction occurs the term "for cash" is used. When payment is made some time after the transaction occurs the term "on account" is used.

Order and Sales Books. All purchases and sales are recorded in the manner illustrated below :

ORDER BOOK.

Date, 1898.	Name.	Address.	Order.	Price.
March 3	Thorbin & Son.....	Chicago, Ill.....	300 butter tubs @ 30c.	\$90 00
" 7	Paul Burger.....	Thompsonville, Mich.	Tinning.....	3 00
" 16	R. S. D. & Co.....	Chicago, Ill.....	Butter printer.....	20 00
" 16	R. S. D. & Co.....	Chicago, Ill.....	1 bbl. cleaning powder	11 00
" 18	J. R. Smith & Co.....	Rushtown, Mich.....	Boiler repair.....	14 00

SALES BOOK.

Date, 1898.	Name.	Address.	No. Tubs.	Out Weight.	Their Weight.	Price.	Proceeds.	Charges.	Net Pro- ceeds.
Mar. 3	Willson & Co.....	Buffalo, N. Y.	18	900	900	\$0 20	\$180 00		\$180 00
" 10	Willson & Co.....	Buffalo, N. Y.	20	1,050	1,040	20	208 00		208 00
" 12	Nicholson & Fish..	N. Y. City....	30	1,800	1,800	21	378 00	\$3 50	374 50
18	Willson & Co.....	Buffalo, N. Y.	20	1,190	1,190	21	249 90		249 90

Cash Book. Cash book records are illustrated below :

CASH BOOK

Date. 1898.		Cash received.					
Mar. 1	*	Balance.....	From Feb.....	\$181	00		
" 10	4	Butter.....	Willson & Co.....	180	00		
" 14	4	"	Willson & Co.....	208	00		
" 20	5	"	Nicholson & Fish.....	374	50		
" 24	5	"	Willson & Son.....	249	90		
" 24	5	"	Nicholson & Fish.....	139	80		
" 28	5	"	Willson & Son.....	201	00		
" 28	5	"	J. C. R. & Co.....	10	10		
" 30	5	"	Nicholson & Fish.....	848	38	\$2,392	68

* Sales book Page.

—(monthly record).

Date, 1898.		Cash paid.					
Mar. 10	\$ 6	Butter tubs....	Thorbin & Son.....	\$90	00		
" 11	6	Tinning	Paul Burger.....	3	00		
" 18	7	Butter printer.	R. S. D. & Co.....	20	00		
" 24	7	Cleaning po'der	R. S. D. & Co.....	11	00		
" 27	7	Boiler repair...	J. R. Smith & Co.....	14	00		
" 27	7	Salary.....	John Smith.....	95	00		
" 28	7	Wood	W. Saunders	55	00		
" 29	7	Sundries.....	John Jones.....	4	35		
" 31	7	Patrons	Monthly dues.....	1,902	48		
" 31	7	Balance.....	To new account.....	197	85	\$2,392	68

\$ Order book page.

Pay Roll Register. Each patron's monthly account is recorded in the pay roll register as illustrated below :

PAY ROLL REGISTER.

Date, 1898.	Number.	Name.	Milk.	Test.	Butter fat.	Price.	Amount.	Charges.	Check.	Check No.
April 5	1	John Smith.....	7,850	3.9	306.15	\$0 20	\$61 23	\$1.48	\$59 75	123 V
" 5	2	Paul Wirth.....	4,575	4.0	183.00	20	36 60		36 60	124 V

V Means paid.

The Ledger. Where a good, permanent, and easily accessible record is desirable, the main items of all transactions should be posted under suitable heads in the ledger. Where there is liable to be a frequent change of bookkeepers the additional work involved in keeping a ledger is well justified.

In case monthly payments are made at the creamery all accounts should be closed once a month and those with different individuals should be kept separate. The following illustrates a ledger account with a butter firm in New York.

Dr.		John Johnson & Co.				Cr.	
1898.				New York City.			
Sept. 3	Balance.....	*12	\$90 40	Sept. 6	Check.....	¶14	\$80 35
" 7	Sale	12	103 38	" 18	Check.....	14	139 85
" 20	Sale	13	84 50	" 31	Balance.....	14	58 08
Oct. 1	Balance	13	58 08				

* Sales book page.

¶ Cash book page.

Below is illustrated a ledger account with a creamery supply house in Chicago:

Dr.				J. D. Murray & Co.				Cr.	
1898.								Chicago.	
Aug. 4	Check.....	*15	\$29 00	Aug. 1	Balance....	¶16		\$18 50	
" 11	Check.....	15	64 50	" 5	Order.....	16		70 38	
" 31	Balance	15	19 38	" 19	Order.....	16		24 00	
				Sept. 1	Balance....	16		19 38	

* Cash book page.

¶ Order book page.

The following illustrates a ledger record with a patron of the creamery:

Dr.				William Sampson.				Cr.	
1898.								Piketown.	
August	31	Check.....	\$61 50	August	Milk.....	\$61 50	*18		
Sept.	31	Check.....	83 92	Sept.	Milk.....	83 92	19		

* Pay roll register page.

Milk Sheet and Milk Book. Immediately after milk is weighed it is recorded upon a milk sheet placed in the intake. This sheet consists of heavy paper with the date, name, and number of the patron upon it. The names should be arranged in alphabetical order. A suitable milk sheet is illustrated in Fig. 73.

Where care is taken in recording the milk upon the milk sheet, the milk book may be dispensed with. In that case a record of the milk is preserved by filing the milk sheets after each patron's total has been transferred

to the pay roll register. In case, however, a careful daily record of the milk is to be preserved, it is better to copy the milk from the milk sheet into a milk book in which a record may be preserved for a long time.

PATRON'S NAME

1
2
3
4
5
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11
12
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15
16
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27
28
29
30
31

Fig. 73.—Milk sheet.

Test Book. A permanent record of milk tests is made in the test book. The following illustrates the method of keeping such a record:

Patron's name. 1898.	Arenz, J. P.	Blake, E. S.						
Test No.	1	2						
Date—Aug. 7.	3.8	4.3						
“ 15.	3.9	4.3						
“ 23.	3.8	4.1						

Butter Slips. It is customary with creamery patrons to take the butter for their use at the creamery and have the value of it deducted from their check. If all butter thus taken were to be recorded in the day book and from this transferred to a patron's butter book, it would involve a great deal of labor for the butter maker. Hence the use of butter slips. These are small slips of paper on which the small butter accounts are kept until the close of the month. Below is illustrated one of these slips:

BUTTER SLIP.	
DATE.....	
NAME.....	
LBS.....	Oz.....

The butter slips are all placed on file until the close of the month when each patron's total butter charged to him is found from these slips. The charge thus found is entered directly in the column marked "charge" in the pay roll register, while the slips are preserved for future reference.

APPENDIX.

Composition of Butter. According to analyses reported by various experiment stations, American butter has the following average composition:

	Per cent.
Water	13
Fat	83
Proteids	1
Salt	3

Composition of Cream. Cream contains all the constituents found in milk, though not in the same proportion. The fat may vary from 8% to 68%. As the cream grows richer in fat it becomes poorer in solids not fat. This is illustrated in the following figures by Richmond:

Total solids.	Solids not fat.	Fat.
Per cent.	Per cent.	Per cent.
32.50	6.83	25.67
37.59	6.14	31.45
50.92	5.02	45.90
55.05	4.65	50.40
57.99	4.17	53.82
68.18	3.30	64.88

The same authority also reports the following detailed analysis of a thick cream:

	Per cent.
Water	39.37
Fat	56.09
Sugar	2.29
Proteids	1.57
Ash	.38

Composition of Buttermilk. According to Vieth, buttermilk from ripened cream has the following composition:

	Per cent.
Water	90.39
Fat	.50
Milk sugar	4.06
Lactic acid	.80
Proteids	3.60
Ash	.75

Creamery buttermilk should not average above .2% fat.

Composition of Skim-milk. Richmond has found the following average composition of separator skim-milk:

	Per cent.
Water	90.50
Fat	.10
Milk sugar	4.95
Casein	3.15
Albumen	.42
Ash	.78

COMPARISON OF CENTIGRADE AND FAHRENHEIT THERMOMETER SCALES.

Thermometer.	F.	C.
Boiling point (water).....	212	100
Freezing point (water).....	32	0
Difference between boiling and freezing point.....	180	100

From the above it will be seen that one degree Centigrade is equivalent to 9-5 degrees Fahrenheit. Hence the following rules:

1. To change C. into F. reading, multiply by 9-5 and add 32.

Example: $50^{\circ}\text{C} = (50 \times \frac{9}{5}) + 32 = 112^{\circ}\text{F}.$

2. To change F. into C. reading, subtract 32 and multiply by 5-9.

Example: $182^{\circ}\text{F} = (182 - 32) \times \frac{5}{9} = 83\frac{1}{3}^{\circ}\text{C}.$

METRIC SYSTEM OF WEIGHTS AND MEASURES.

This system was devised by the French people and has very extensive application wherever accuracy in weights and measures is desired. Some of its equivalents in ordinary weights and measures are given in the following table:

Ordinary weights and measures.	Equivalents in metric system.
1 ounce (av.).....	28 35 grams.
1 quart.....	0 9464 liter.
1 gallon.....	3 7854 liters.
1 fluid ounce.....	29 57 cubic centimeters (c.c.)
1 pound (av).....	0 4536 kilogram.
1 grain.....	64 8 milligrams.
1 inch.....	2 54 centimeters.
1 foot.....	0 3048 meter.

CONSTITUTION AND BY-LAWS FOR A CO-OPERATIVE CREAM-
ERY ASSOCIATION.*

Articles of Agreement of the Association.

We the undersigned residents of the county of ,
State of , do hereby associate ourselves together
as a co-operative association under the laws of the State
of and have adopted the following constitution :

Article I.

This association shall be known as the
Association.

Article II.

The object of this association shall be the manufacture
of butter from milk and cream bought on the fat basis.

Article III.

The regular meetings of this 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 asso-
ciation, provided three days' notice of such meeting is
sent to all members.

Article IV.

The officers of this association shall be a president,
secretary, treasurer, and three trustees, who shall be
elected annually at the regular annual meeting. The

* In drawing up this constitution and by-laws, free use has been made of
Vye's Creamery Accounting and Farrington & Woll's Testing Milk and Its
Products.

president or secretary shall also act as general manager of the creamery.

Article V.

The duties of the president shall be to preside at all meetings of the association, sign all drafts and documents, and pay all money which comes into his possession by virtue of his office to the treasurer, taking his receipt therefor.

The secretary shall keep a record of all the meetings of the association and make and sign all orders upon the treasurer. He shall conduct the correspondence and general business of the association and keep a correct financial account between the association and its members.

The treasurer shall receive and receipt for all moneys belonging to the association, and pay out the same only upon orders which shall be signed by the president and the secretary. He shall give bonds in such amount as the association shall prescribe.

The president, secretary, and three trustees shall constitute a board of directors, whose duties shall be to audit the accounts of the association, invest its funds, and determine all compensations. They shall prescribe and enforce the rules and regulations of the creamery. They shall cause to be kept a record of the weights and tests of the milk and cream received from each patron, of the products sold, and of the running expenses, and shall divide among the patrons the money due them each month.

The board of directors shall cause the secretary to make, in writing, a report at the annual meeting of the association, setting forth in detail the gross milk receipts, the net receipts of products sold, and all other receipts.

the amount paid for milk and running expenses, and give a complete statement of all other matters pertaining to the business of the association. 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.

The board of directors shall borrow a sum of money not exceeding thousand dollars to be used by them solely for the purpose of building and equipping a creamery.

Article VI.

Ten members of the association, or three of the board of directors, shall constitute a quorum to transact business.

Article VII.

Each member shall be entitled to one vote only at any meeting of the association. New members may be admitted as provided by the by-laws. Members shall be permitted to withdraw only as provided by the by-laws.

Article VIII.

The constitution may be amended at any annual meeting, or at any special meeting, provided that two-thirds of all the members present vote in favor of such a change.

By-Laws of the Association.

1. The milk of each patron shall be tested not less than twice a month.
2. No milk shall be received at the creamery later than ten o'clock a. m.

3. One cent for each pound of butter fat received at the creamery shall be reserved to form a sinking fund.

4. The treasurer shall give bonds in the sum of dollars, the bond to be approved by the board of directors.

5. Patrons shall furnish all of the milk from all the cows promised at the organization of the creamery.

6. Nothing but sweet and pure milk shall be accepted at the creamery.

7. All milk received at the creamery shall be paid for on the basis of the amount of fat it contains.

8. Dividends shall be made on the twentieth day of each month.

THE WATER CONTENT OF BUTTER.

The question as to the amount of water that butter should contain has been very much discussed during the past year. There is no question that a moderate amount of water is necessary to secure the best quality. When, for example, butter contains as little as 7% water it assumes a lardy texture and does not spread well on bread.

The maximum amount of water that may safely be incorporated has as yet not been satisfactorily demonstrated. Circular No. 39 by Alvord of the U. S. Department of Agriculture shows that the best tubs of butter in the National Educational Butter Test contained between 11% and 12% of water. According to findings at the Iowa Station, a water content of 16% is as favorable to good quality as 12%. Indeed it is reported that if it were not for the law which fixes the upper limit at 16%, a water content even higher than this might be recommended.

Manifestly the more water butter contains the larger the yield from a given quantity of cream, other conditions the same. It might therefore be the part of wisdom to incorporate the maximum of water consistent with the production of the best quality of butter if it were not for the danger of going to the extreme. It seems that in this case as in others, Monrad's advice "avoid extremes" is particularly applicable.

In the following paragraphs are set forth some of the main factors that tend to increase the percentage of water in butter :

1. Churning and working butter at a moderately high temperature. The temperature must, however, not be so high as to injure the texture or cause an undue loss of fat in the buttermilk.

2. Churning butter to moderately large granules. The larger the granules the more water will be retained in the butter. But they should in no case be larger than the size of half a pea.

3. Distributing the salt with the least amount of working. The more the butter is worked the less water it will contain.

4. The less salt butter contains the higher its water content.

5. Moderately warm wash water will give a higher water content than cold.

6. Short intervals between the workings are more favorable to a high water content than long.

It has been claimed that pasteurizing reduces the percentage of water in butter. This, however, needs further proof. The author has found that the yield of butter from pasteurized and unpasteurized cream is practically the same. With the same loss of fat in the buttermilk,

this could not be expected if the water content differed to any great extent.

SKIMMING STATIONS.

In many localities where there is not sufficient milk to warrant the establishment of a creamery, skimming stations are built which separate the cream from the milk and deliver it to a creamery for churning. Hundreds of such stations are scattered throughout the country and they are serving a most useful purpose.

The main equipment of a skimming station consists of boiler, engine, separator, weigh can, scales, skim-milk weigher, receiving vat, cream vat, cream cooler, milk heater and pump, skim-milk pump, Babcock tester, ten gallon cans, skim-milk pasteurizer, skim-milk tank, water tank, and preferably a cream pasteurizer.

CLEANLINESS AND CLEANING.

There is perhaps no business in which cleanliness counts for so much as in dairying. Two reasons for this are: (1) that milk furnishes a medium in which a large number of different types of bacteria find easy development, and (2) that the bacteria which are helpful to the butter maker are found only in clean places and in a pure atmosphere, while those of an undesirable character are always associated with filth.

To keep everything thoroughly clean in a creamery is of the highest importance to the success of the butter maker, and requires considerable vigilance on his part.

Utensils like pails, dippers, cream vats, and cream coolers, should be heavily tinned and be as free as possible from seams, which afford good breeding places for bacteria. Dippers with solid handles are preferred, as leaks

in hollow dipper handles are not easily detected. Leaks are an unmitigated nuisance in a creamery. They should be guarded against as dangers of the worst character. No creamery is complete without a good soldering outfit.

Corroded or rusted tinware is sure to spoil any milk or cream that comes in contact with it. Milk delivered in rusty cans should positively be refused at the creamery.

The cleaning of milk and cream vessels is best carried out as follows: first, rinse with moderately warm water; second, scrub with moderately hot water containing some alkali; third, rinse in hot water; fourth, steam thoroughly; and fifth, expose to sunlight if possible.

Vats, printers, etc., cannot be satisfactorily steamed; they should be scalded with hot water.

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GLOSSARY.

ALBUMENOID.—Substances rich in albumen, like the white of an egg which is nearly pure albumen.

ANAEROBIC.—Living without free oxygen.

CALIBRATING.—Determining the caliber of the neck of a test bottle in order to ascertain the accuracy of the scale upon it.

CARBOHYDRATES.—Substances like starch and sugar.

CENTRIFUGAL FORCE.—That force by which a body moving in a curve tends to fly off from the axis of motion.

CHEMICAL COMPOSITION.—This refers to the elements or substances of which a body is composed.

COLLOIDAL.—Resembling glue or jelly.

CONCUSSION.—The act of shaking or agitating.

CONSTITUENTS.—The components or elements of a substance.

DEAD CENTER.—That position of the engine when the crank arm and the piston rod are in a straight line.

DIVIDERS.—An instrument used in reading tests.

EMULSION.—A mixture of oil (fat) and water containing sugar or some mucilaginous substance.

ENZYMES.—Unorganized ferments, or ferments that do not possess life.

FIBRIN.—A substance which at ordinary temperatures forms a fine network through milk which impedes the rising of the fat globules.

FOREMILK.—The first few streams of milk drawn from each teat.

GALACTASE.—An unorganized ferment in milk which digests casein.

INOCULATION.—To seed, to transplant; as to inoculate milk with lactic acid germs.

INSULATION.—The state of being protected from heat and cold by non-conducting material.

LEAD.—The amount of opening of the steam ports when the engine is on the dead center.

LOPPERED MILK.—Milk that has thickened.

MAMMARY GLAND.—The organ which secretes milk.

MEDIUM.—The substance in which bacteria live. Thus, milk furnishes an excellent *medium* for the growth of bacteria.

MENISCUS.—A body curved like a first quarter moon.

MILK SERUM.—Milk free from fat. Thus, skim-milk is nearly pure milk serum.

MIXING CANS.—Small tin cans used for mixing milk preparatory to testing.

NEUTRAL.—Possessing neither acid nor alkaline properties.

NON-CONDUCTOR.—A material which does not conduct heat or cold, or only so with great difficulty.

OSMOSIS.—The tendency in fluids to diffuse or pass through membranes.

PARTURITION.—The act of being delivered of young.

PASTEURIZATION.—The process of destroying all or most of the vegetative bacteria by the application of heat from 140° to 185° F

PERIOD OF LACTATION.—The time from calving to “drying up.”

PHYSICAL PROPERTIES.—The external characteristics of a body, like color, odor, hardness, solubility, density, form, etc.

PROPAGATE.—To continue to multiply. Thus, to *propagate* a starter means to continue multiplying the lactic

acid bacteria by daily transferring them to a new medium such as sweet pasteurized skim-milk.

PROTEIDS.—Nitrogenous substances like casein and albumen.

REDUCING VALVE.—A valve used for regulating steam pressure.

REFRIGERANT.—In mechanical refrigeration a substance whose evaporation produces cold.

RENNET.—The curdling and digesting principle of calf stomach.

SCORING.—A term used synonymously with judging.

SECRETION.—The act of separating or producing from the blood by the vital economy.

SEPTIC.—Promoting decay.

SPECIFIC GRAVITY.—The weight of one body as compared with an equal volume of some other body taken as a standard.

SPECIFIC HEAT.—The quantity of heat required to raise the temperature of a body one degree.

SOLUTION.—The state of being dissolved.

SPORE.—The resting or non-vegetative stage of certain kinds of bacteria.

STEAM TRAP.—An arrangement by which condensed steam may be taken out of heating pipes without the escape of steam.

STERILIZATION.—The process of destroying all germ life by the application of heat near 212° F.

STRIPPERS' MILK.—The milk from cows far advanced in the period of lactation.

STRIPPINGS.—The last few streams of milk drawn from each teat.

SUSPENSION.—The state of being held mechanically in a liquid, like butter fat in milk.

TRYPSIN.—The active agent in the secretion of the pancreas.

VEGETATIVE BACTERIA.—Those bacteria that are in an actively growing condition.

VISCOSITY.—The quality of being sticky; stickiness.

VOLATILE.—The state of wasting away on exposure to the atmosphere. Easily passing into vapor like ammonia.

WHOLE MILK.—Milk which has neither been watered nor skimmed.

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