TO THE MEMORY

of

MY FATHER

This Volume is Dedicated

CONDENSED MILK and MILK POWDER

SECOND EDITION

REVISED AND ENLARGED

PREPARED FOR THE USE OF

Milk Condenseries, Dairy Students and Pure Food Departments

By

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PREFACE

This book treats of the various phases of the condensed milk and powdered milk industry. It discusses every step in the process of manufacture, following the milk from the farmer's door to the finished product in the pantry of the consumer. The processes of condensing and desiccating milk, skim milk, buttermilk and whey are given special attention and the defects of the product, their causes and prevention are explained in detail.

The inception of this publication is the result of innumerable and persistent calls for definite and reliable information on the subject of condensed milk and milk powder, from manufacturers in this country and in foreign lands; from parties contemplating embarking in the business; from national and state experiment stations which are oftentimes called upon to investigate condensed milk defects; from dairy schools desiring to give instruction on the subject; from national and state pure food departments, seeking information concerning the possibilities and limitations of manufacture, in their efforts to formulate and enforce standards and laws; and from commercial chemists in need of reliable methods of analyses of these special dairy products.

The information contained in this volume represents the author's experience, covering a period of twelve years, in the practical manufacture of condensed milk, as expert advisor to milk condensing concerns in the United States, Canada and Australia, and as visitor of condensed milk and milk powder factories in this country and in Europe.

It is the author's hope that the information contained herein may serve as a guide to manufacturers, investigators, teachers and food authorities, alike; that it may assist in a better understanding and wider dissemination of the principles, phenomena and facts involved in the processes of manufacture; and that it may lift the obstructing veil of unnecessary secrecy which has hovered over these industries since their beginning, curtailing their development and depriving them of much of the light of advanced science to which they are justly entitled and which they need for their greatest development for the lasting benefit of the producer, manufacturer and consumer alike.

O. F. Hunziker.

Purdue University, March, 1914.

PREFACE FOR SECOND EDITION

Since the issuance of the First Edition of this treatise many changes have taken place in the various phases of the Condensed Milk Industry. Old processes have been modified and improved, new processes have been invented, the equipment used for manufacture has undergone changes, new tests have been devised for the determination of the composition of the finished products and the entire status of the industry has yielded to an unexpected, unforeseen and important evolution.

Of the most outstanding new features in this edition may be mentioned the chapters on the Continuous Concentrator, the Standardization of Condensed Milk and Milk Powder, Malted Milk, the Mojonnier Test, Bacteriological Analyses. Important additions have also been made to the chapters on History of the Industry, Volume of Output, Markets, Exports, Imports, Cost of Manufacture and the various processes of manufacture of Condensed Milk, Condensed Buttermilk and Milk Powder.

In preparing the Second Edition, the author has endeavored to completely revise the old edition, incorporating in the revised edition the many changes which the tooth of time has wrought and to bring this treatise in all its important phases up-to-date.

O. F. Hunziker.

Chicago, Ill., July, 1918.

CONTENTS

PART I

CONDENSED MILK

Chapter I

Chapter II

Chapter III

PART II

MANUFACTURE OF SWEETENED CONDENSED MILK

Chapter IV

Chapter V

Chapter VI

Chapter VII

PART III

MANUFACTURE OF UNSWEETENED CONDENSED MILK

EVAPORATED MILK

Chapter VIII

Chapter IX

Chapter X

Chapter XI

Chapter XII

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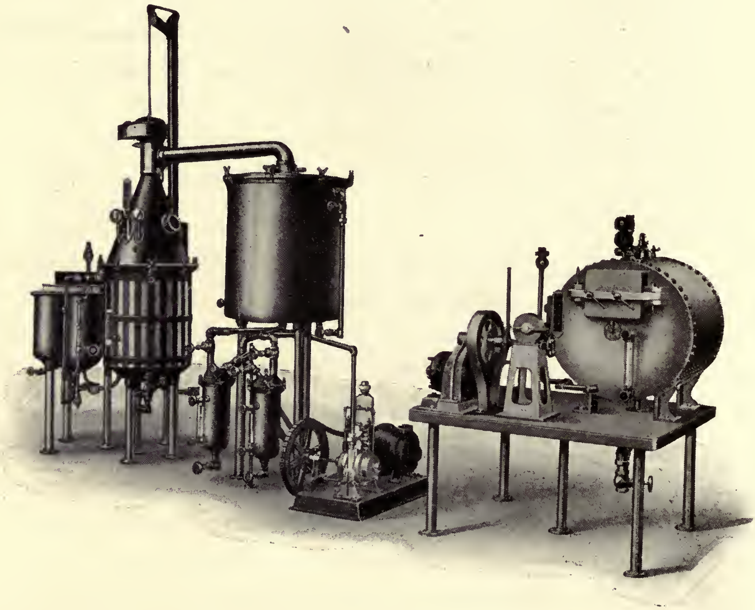
Complete Milk Condensing Unit

for

Dairy Schools
and Experimental Laboratories



The dairy school is the manufactory of dairy knowledge, the clearing house of dairy thought, and the distributory of the dairy gospel.

PART I.

CONDENSED MILK

CHAPTER I.

DEFINITION

Condensed milk is cow's fresh milk from which a considerable portion of the water has been evaporated and to which sucrose may or may not have been added.

There are chiefly two classes of condensed milk, namely, sweetened and unsweetened. Both reach the market in hermetically sealed tin cans intended for direct consumption, and in bulk, intended for bakers, confectioners and ice cream manufacturers.

A portion of the condensed milk on the market is made from the chief by-products of milk, skim milk and buttermilk. Condensed skim milk supplies the same markets as condensed whole milk sold in bulk. Condensed buttermilk furnishes a valuable chicken feed. It has, also, been recommended for medicinal purposes.

HISTORY AND DEVELOPMENT OF INDUSTRY

Invention of Process.—Condensed milk is the child of the nineteenth century. Its origin does not date back far, and its innovation and rapid development stand in sharp contrast to those of the manufacture of butter and cheese, industries to which reference is made in the Old Testament[1] and the evolution of which has been very gradual. Notwithstanding the newness of this product, its manufacture has assumed such proportions that today it occupies a prominent place among the leading branches of dairy manufactures.

The condensed milk industry was introduced at about the same time as the factory system of the butter and cheese industry; although, for many years before the invention of a successful process of condensing milk, methods had been sought to preserve milk.

[1] Book of Genesis, C. 18, V. 8: "And he took butter and milk and the calf he had dressed and set it before them."

Book of Job, C. 10, V. 10. "Hast thou not poured me out like milk and curdled me like cheese."

The American, Gail Borden, the inventor of the manufacture of condensed milk, is said to have experimented some ten years before he finally decided that a semi-fluid state, produced by evaporation in vacuo, was the best form of preservation. He first applied for a patent in 1853, but it was not until three years later that the Patent Office appreciated the originality and value of his

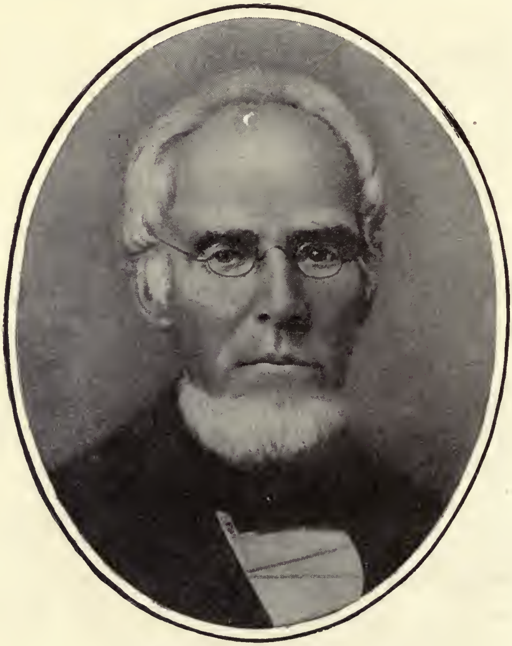


Fig. 2. Gail Borden

claim sufficiently to grant him a patent. In August, 1856, he was awarded a patent on his process both by the United States and by England.

In his application Mr. Borden says:[1]

"I am aware that sugar, and various extracts, have been and are now concentrated in vacuo under a low degree of heat, to prevent discoloration or burning. I do not claim concentrating milk in a vacuum pan for such a purpose, my object being to exclude the air from the beginning of the process to the end, to prevent incipient decomposition. This is important and I claim the discovery."

[1] "A Brief Sketch of Gail Borden" by S. L. Goodale, Secretary Maine State Board of Agriculture, 1872.—Courtesy of Borden's Condensed Milk Company.

The claim, United States Patent, August, 1856, is in the following words:

> "Producing concentrated sweet milk by evaporation *in vacuo,* substantially as set forth,—the same having no sugar or other foreign matter mixed with it."

Since the introduction of the process of milk condensing, invented and patented by Borden, numerous modifications of the process, as well as entirely different processes, have been invented in this country and abroad. The most characteristic among these are: *condensation by refrigeration, by centrifugal force, by boiling under atmospheric pressure, by passing hot air through milk, etc.* Most of these new processes have not proved commercially satisfactory, with the result that the principle of the process, originally invented by Gail Borden, and which consists of condensing the milk in vacuo to a semi-fluid liquid, is still made use of in the manufacture of the great bulk of condensed milk produced, both in this country and abroad.

While the claim of the patent granted Gail Borden was that of "producing concentrated sweet milk by evaporation *in vacuo* without the admixture of sugar or other foreign matter," records show that Gail Borden manufactured sweetened condensed milk, sold under the famous Eagle Brand label as early as 1856. The first advertisement by Borden of unsweetened condensed milk was recorded in Leslie's Weekly, May 22, 1858. It reads as follows:

> "BORDEN'S CONDENSED MILK. Prepared in Litchfield County, Conn., is the only milk ever concentrated without the admixture of sugar or some other substance and remaining easily soluble in water. It is simply Fresh Country Milk, from which the water is nearly all evaporated, and nothing added. The Committee of the Academy of Medicine recommend it as 'an article, that, for purity, durability and economy, is hitherto unequalled in the annals of the milk trade.'
>
> "One quart, by the addition of water, makes two and a half quarts,—equal of cream, five quarts rich milk and seven quarts good milk.
>
> "For sale at 173 Canal Street, or delivered at dwellings in New York or Brooklyn at 25 cents per quart."

Development of Industry.— The beginning was small, the process crude and the product imperfect. Not until the strenuous years of the war of Secession did the value and usefulness of con-

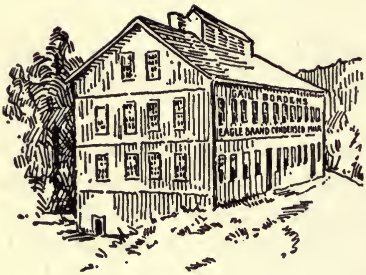


Fig 3.

The first condensed milk factory in America, Wolcottville, Conn.

densed milk as a commodity become fully recognized. During the Civil War there was a great demand for this product and from that time on the industry grew with great rapidity.

The first factory was operated by Gail Borden in Wolcottville, Litchfield county, Connecticut, in the summer of 1856, but disappointed in not obtaining means, nothing was accomplished. A second attempt was made at Burrville, five miles distant, in 1857, by a company consisting of the owners of the patent. A small quantity of milk was here successfully condensed and its introduction into New York began. Although admitted by all to be superior to any before made, it was slow in meeting with sales proportional in magnitude to the expenses incurred. Yielding to the monetary revulsion of that year the company suspended operations, leaving Mr. Borden liable for bills drawn, on which he was sued.

It was not until February, 1858, when Mr. Borden (with the other owners of the patent) associated himself with Jeremiah Milbank, Esq., who advanced money to revive the business, that he could be said to enjoy adequate means to develop his invention and at which time the New York Condensed Milk Company was formed. Abandoning Burrville, the new company established work on a more extensive scale in Wassaic, Duchess county, New York, in 1860. In 1865, extensive works were erected at Elgin, Illinois. Borden's Condensed Milk factories today number upwards of fifty, extending from Maine to Washington State as well as into Canada. The New York Condensed Milk Company was incorporated in New Jersey in 1860 and in New York in 1870. This company was succeeded by Borden's Condensed Milk Company which was incorporated in New Jersey in 1899.

In the sixties of the last century, the Anglo-Swiss Condensed Milk Company was organized in Switzerland under the leadership of Charles A. Page, then United States Consul at Zurich, Switzerland, and his brother George H. Page, and with the assistance of

Swiss and English capital. The first factory of that company was built and operated in 1866 at Cham, Lake Zug, Switzerland, under the direction of George H. Page, who was its president until 1898, when he died.

This company prospered and grew rapidly in Europe. In the eighties of the last century it invaded the United States, where it built and operated several large factories in New York, Wisconsin and Illinois. The American factories were managed by David Page and William B. Page, brothers of George H. Page. In 1902 the Anglo-Swiss Condensed Milk Company sold its entire American

Morey Condensery, North Prairie, Wis.

interests, factories and business, to Borden's Condensed Milk Company. In 1904 the Anglo-Swiss Condensed Milk Company consolidated with Henry Nestle, of Vevey, Lake Geneva, Switzerland, another successful manufacturer of condensed milk. The company which is now known as the Nestle-Cham Condensed Milk Company, is operating some twenty large condensed milk factories in European countries, with headquarters at Cham, Switzerland.

Up to the early eighties of the last century, sweetened condensed milk was the only condensed milk that was put on the market and sold in hermetically sealed cans, while unsweetened condensed milk was manufactured and sold open, largely direct to the consumer, in a similar way as market milk. The purity and keeping quality of this unsweetened condensed milk, however, were greatly superior to market milk.

Early in 1885 the Helvetia Milk Condensing Company was organized at Highland, Illinois. This company confined its efforts exclusively to the manufacture of evaporated milk (unsweetened condensed milk, sterilized by heat and sold in hermetically sealed cans). While, for several years before the organization of this company, the possibilities of producing a sterile unsweetened condensed milk were essayed in laboratory investigations by scientists, and while simultaneously with the commencement of operations of this company, several other companies also experimented on this form of condensed milk, the Helvetia Milk Condensing Company was the first organization that succeeded in producing a marketable unsweetened condensed milk that was sterile and would keep indefinitely.

Fig. 5. John B. Meyenberg

The rudiments of the process of evaporated, sterilized milk were introduced by Mr. John B. Meyenberg, a native of Switzerland, who formerly was operator in the mother plant of the Anglo-Swiss Condensed Milk Co. at Cham, Switzerland. Mr. Meyenberg, being a man with an inventive turn of mind, experimented on the evaporation and sterilization of milk, during the years 1880 to 1883. As the result of these experiments he decided that it was possible to preserve milk, without the aid of sugar. Migrating to this country, he applied for, and was granted a patent on his idea of preserving milk by sterilization, by the United States Government in 1884 (Patent No. 308,422), and again in 1887 (Patent No. 358,213). Mr. Meyenberg was also granted patent rights (Patent No. 308,421) on apparatus for preserving milk.

Attracted to Highland, Illinois, by reason of its large Swiss population, on the representations of Mr. A. J. Pagan, a leading Highland citizen, who brought Mr. Meyenberg to Highland and introduced him to the community, Mr. Meyenberg associated himself with Mr. John Wildi, then a merchant of Highland, who at once took a leading part in the organization of the Helvetia Milk Condensing Co., early in the year 1885. Mr. Meyenberg served as the technical manager for the first year, after which he severed his connections with this company and became engaged in the promotion of other evaporated milk factories in the middle west, and on the Pacific Coast. Mr. Meyenberg died in 1914.

During the first year of its existence, operations of the Helvetia Milk Condensing Company were suspended a number of times, both on account of difficulties encountered in the technique of successful manufacture and also for financial reasons. In an endeavor to place the company on a technically and commercially successful basis, the board of directors took charge of the work with Mr. Louis Latzer as technical manager, and the first half of the second year was mostly devoted to experimental work. During the third year, interruptions in the operations were only slight and after that the company operated continuously and successfully until the panic of 1893, which marked the last suspension of business and which was due to the strained commercial conditions that prevailed throughout the country.

The first board of directors of this company was composed of Dr. Knoebel, John Wildi, George Roth, Fred Kaeser and Louis Latzer, with Dr. Knoebel as president and Mr. Wildi as secretary and treasurer, and business manager. In 1888 Mr. Latzer became president, which position he is holding to the present day. In 1907 Mr. Wildi severed his connection and organized the John Wildi Evaporated Milk Co. with headquarters in Columbus, Ohio. Mr. Wildi died in 1910.

The early development and the vicissitudes through which this pioneer company in the evaporated milk business passed are most instructively expressed by its president, Mr. Latzer:

"Very little of the product turned out the first two years would now pass as standard goods. About the third year, after more knowledge of the physical and chemical properties of milk and after the introduction of the practice of fractional sterilization, had solved the keeping properties and had improved the physical condition of the product, we felt that the industry had come to stay. After we had gained more knowledge and experience, and a lower standard of the product was adopted by the industry, the practice of fractional sterilization was abandoned for economic reasons.

"The commercial part of the business also had its trials and tribulations in introducing a new and comparatively inferior product of comparatively high cost, and to overcome the prejudices of both the trade and the medical profession.

"The problem thus confronting the company was to improve the product, decrease its cost and improve selling methods at the least possible cost."

At first this unsweetened condensed milk, of relatively thin consistency and pregnant with the cooked flavor resulting from its exposure to high sterilizing temperatures, failed to appeal to the public, who had become accustomed to the use of the sweet, thick and semi-fluid sweetened condensed. But of late years the demand for, and the manufacture of this product, evaporated milk, has increased rapidly, until today, in this country, its output by far exceeds that of sweetened condensed milk.

Originally this unsweetened sterilized condensed milk was labeled and sold under the name of "Evaporated Cream." The Federal Food & Drugs Act of 1906 caused the name "Evaporated Cream" to be changed to "Evaporated Milk."

A further important step in the development of the manufacture of condensed milk occurred with the introduction of the Continuous Concentrator, which machine was developed by the By-Products Recovery Co., of Toledo, Ohio. This company was organized in 1913 and their machine and process are covered by numerous United States patents. The principle upon which the Continuous Concentrator is constructed and operates is as follows:

"To rapidly move a film in layer formation within a cylinder having a heated surface, having means for escaping vapors and means for keeping the surface bright and clean, circumferentially and from the point of inlet to the point of outlet."

The Continuous Concentrator in its present improved form has reached a state of perfection that renders this machine applicable for the commercial manufacture of the diverse forms of condensed milk and milk by-products.

The simplicity and economy of the equipment involved, the simplicity and rapidity of the process and the fact that no water is required for condensing the escaping vapors, are decided advantages over the condensation in vacuo. Already the demand for these concentrators among condenseries and ice cream factories is very great. This process lends itself admirably to the establishment and operation of small local condenseries and milk shipping stations where milk is condensed and then shipped for packing and sterilization to concentration plants.

In this country, as well as in Canada and Europe, the condensed milk industry grew rapidly. Every succeeding decade marked the organization of new companies and the erection of new factories until today, there are milk condensing factories in nearly every civilized country within the dairy belt.

ANNUAL OUTPUT OF CONDENSED MILK IN THE UNITED STATES 1899-1917, INCLUSIVE

Years	Total condensed milk	Sweetened condensed Milk	Unsweetened condensed Milk
1899—			
Pounds[1]	186,921,787	(5)	(5)
Dollars[1]	11,888,792	(5)	(5)
1904—			
Pounds[1]	308,485,182	198,355,189	110,129,993
Dollars[1]	20,149,282	13,478,376	6,670,906
1909—			
Pounds[1]	494,796,544	214,518,310	280,278,234
Dollars[1]	33,563,129	17,345,278	16,217,851
1914—			
Pounds[2]	883,112,901	(5)	(5)
Dollars[3]	58,011,677	(5)	(5)
1917—			
Pounds[2]	975,000,000	(5)	(5)
Dollars[4]	106,000,000	(5)	(5)

[1] United States Census Report for 1910.
[2] United States Dairy Division, by Correspondence.
[3] Value estimated at $3.40 per case.
[4] Value estimated at $5.50 per case.
[5] Not reported separately.

The above figures serve to emphasize the rapid growth which the condensed milk industry has enjoyed during the last decade. The total output of condensed milk in 1917 was 975,000,000 pounds, estimated at a value of $106,000,000.00. Calculating the ratio of concentration at 2.5 to 1, this output represents the utilization of 2,437,000,000 pounds of fluid milk for the condensed milk industry. The total production of fluid milk in the United States in 1917 was 84,611,350,000 pounds, of which 2.9 per cent were manufactured into condensed milk.

The above figures largely represent canned condensed milk only. Within recent years, the manufacture of condensed milk sold in bulk, especially to the ice cream trade, has increased enormously. If this bulk condensed milk were included in the above figures, the amount shown for the total output would be materially augmented.

A new and unprecedented impetus was given the condensed milk industry in America by the advent of the World War. The concentration of the product, its wholesomeness and high food value, the serviceableness of its package and its great keeping quality render it indispensable as a food for the army and navy as well as for the civilian population of the warring nations in its dire need for food. In this great crisis in which the food supply of the nations of the earth is playing a most important role, condensed milk has proved its worth and the demand for this commodity has increased to tremendous proportions. This demand has been readily responded to by the industry on the American continent and has resulted in a vast increase of the output of condensed milk and in the erection of many new and large factories within the short span of the war.

In 1899, there were in operation in this country about fifty factories manufacturing condensed milk, distributed over fourteen different states, New York and Illinois leading the list by over 50 per cent. In 1904, the Government estimated the total number of condenseries in operation at eighty-seven. In 1914, there were in the United States over two hundred milk condensing factories, distributed over twenty-three different states, as shown on the following page:

DISTRIBUTION OF MILK CONDENSING FACTORIES IN UNITED STATES IN 1914

States	Number of Factories
Arizona	1
California	7
Colorado	1
Illinois	39
Indiana	9
Iowa	3
Kansas	4
Kentucky	1
Maine	1
Maryland	3
Massachusetts	1
Michigan	12
Missouri	2
New Jersey	6
New York	54
North Dakota	1
Ohio	19
Oregon	6
Pennsylvania	20
Utah	6
Vermont	4
Washington	14
Wisconsin	26
Total 23	240

The above distribution of milk condenseries has undergone considerable change since the beginning of the war. In many states new factories have been erected and in numerous instances creameries and cheese factories have been converted into condenseries. In the State of Wisconsin alone the number of condenseries has risen from 26 in 1914 to 52 in 1918.

Other countries in which the condensed milk industry has made rapid progress are: Canada, Australia, New Zealand, Switzerland, Germany, England, Ireland, Holland, Sweden, Norway, Austria, Russia, Japan and India.

CHAPTER II.

ESSENTIALS OF SUITABLE LOCATIONS FOR MILK CONDENSING FACTORIES

Unlike the establishment of creameries and cheese factories, the building of condenseries and the installing of the necessary machinery involve the investment of large capital. There is need of a substantial building and of expensive machinery. The supplies are numerous and must be purchased in larger quantities before the returns from the sale of the manufactured product are available. It is estimated that it takes from three to six months before the condensed milk reaches the consumer. This holds true especially in the case of canned goods. The fixed expenses also are comparatively heavy, and do not materially change with a decrease or increase in the milk supply.

All of these facts emphasize the importance of locating the factory in a territory most suitable for economic manufacture, to guard against heavy loss which would naturally result in localities unfavorable to the industry.

The chief factors to be considered in this connection are:

Milk supply
Water supply
Transportation facilities.
Other conditions.

Milk Supply.—A large supply of milk with possibilities for extending the milk supply territory is the first essential. The condensery must have milk to do business. The locality in which it is located must be adapted for the production of large quantities of milk; it must be a dairy country where reasonably large herds are kept. Other things being equal, the larger the milk supply, the lower the cost of manufacture. Where the milk supply drops below fifteen thousand pounds of milk daily, profitable manufacture becomes difficult. Territories of gathered cream creameries are usually not very desirable. The farmers generally have small herds and are not inclined to haul their milk daily. They prefer to take their cream to the creamery once or twice per week, or whenever it is convenient for them to do so. Again, they appreciate the feeding value of the skim milk and depend on the skim milk to raise their young stock and pigs. When they take their milk to the condensery, there is no skim milk nor buttermilk left for feeding purposes.

The presence of whole milk creameries and cheese factories renders a locality most attractive for the establishment of milk condenseries. The farmers usually have reasonably large herds, they are accustomed to take reasonable care of their milk and to haul it to the factory daily, and the condensery prices are generally high enough above the creamery or cheese factory prices to induce the farmers to patronize the condensing factory.

Territories in close proximity of large consuming centers, though dairying may have reached a high state of development, are not desirable, owing to the continuous and growing demand for fresh milk. Competition of this kind means high prices, which no business tactics are capable of modifying.

Water Supply.—The value to the milk condensing plant of a generous and never-failing supply of clean, cool water cannot be overestimated. The folly of erecting condenseries without first ascertaining the water supply has in some instances compelled milk condensing companies to abandon new plants, merely because of lack of water.

In addition to the water used in the boilers and for washing purposes, large amounts of water are necessary for condensing and for cooling the condensed milk. It is estimated that the condensation of one pound of fresh milk requires about three gallons of water.

The water must be pure. In spite of all precautions, it will come in contact, more or less, with the milk. Though all apparatus and utensils holding and conveying milk and condensed milk may be thoroughly steamed after rinsing with water, there are untold channels through which the milk may become contaminated with polluted water. Frequently, while the milk is condensing, the vacuum pump accidentally stops. If the processor fails to immediately shut off the water supplying the condenser, water will pour back from the condenser into the milk in the vacuum pan. In the case of filthy, polluted water, the entire batch may be ruined. Again, the pan is usually rinsed between batches and, if the water used is unclean, it will contaminate the milk of the succeeding batch.

Finally, when the heavy 40-quart cans filled with condensed milk are set into the cooling tank, water frequently splashes over into the cans. Here again the quality of the condensed milk is jeopardized, unless the water used is pure.

The water must be cold. The colder the water the more satisfactory is the operation of the vacuum pan. If the temperature of the water used in the condenser rises much above 65 degrees F., the process of condensing becomes difficult. Cold water is essential, also, for the prompt and proper cooling of the condensed milk.

Transportation Facilities.—It is essential that the factory have access to one or more railway lines.

While, for reasons discussed under "Milk Supply," it is not advisable to erect a factory in too close proximity to large consuming or railway centers, it is equally undesirable to choose a condensery site where transportation facilities are poor.

Where access to one railroad only can be had, the factory is at the mercy of that road. Experience has shown that monopoly of transportation usually means a low standard of efficiency of service and high freight rates.[1] On the other hand, competition involves a struggle for the survival of the fittest, and it offers the public all the inducements that business ingenuity and enterprise can produce. Where two or more transportation companies are after the business of the same manufacturing concern, they will generally leave nothing undone in the way of accommodations and low rates to please the manufacturer. The result is that the manufacturer enjoys the advantages of efficient service, good accommodations and reasonable freight rates.[1]

This is a factor which the condensery cannot afford to overlook, as the freight charges are a very conspicuous item in the expense account of the milk condensing business. A part of the fresh milk may have to be shipped to the factory by rail, all the finished product must leave the factory by rail and the condensery is dependent on the railway for its raw materials and supplies, such as sugar, tinplate, solder, box shooks, barrels, labels, oil, rosin, gasoline, coal, etc. Prompt and efficient transportation is essential.

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[1] The matter of freight rates is now largely regulated by the Federal Department of Transportation.

Undue delays may cause the condensery serious inconvenience and loss, and may result in the cancelling of important orders.

Other Conditions.—The removal of the sewage of the factory is important. It may be possible for the factory to connect with the town or city sewer, in which case the problem is easily solved. Where this is not possible, a site along a creek, river, pond or lake may offer effective means to take care of the condensery sewage. Where no such natural depository is available, the elevation of the site should be sufficient to carry off the sewage far enough from the factory to insure the plant against foul odors and unsanitary conditions. In the absence of all of these avenues for the disposal of the sewage, a properly laid-out system of septic tanks with efficient filter beds may serve the purpose.

Where possible, it is advisable to take advantage of hillsides, affording natural means to arrange and operate the factory on the gravity plan.

BUILDING AND EQUIPMENT

Material of Construction.—Since the establishment of a milk condensing factory involves the investment of considerable capital, those willing to invest must have faith in the permanency of the business. For a permanent business, a building substantially constructed is the most economical. Most of the factories belonging to the most reputable concerns are built very substantially. However, there are in this country condensing factories in the construction of which cheapness was the governing factor. Many of these cheap factories are the work of unscrupulous promoters, whose ambition it is to convince men of wealth or farmnig communities of the "enormous" profits possible in the manufacture of condensed milk, and to induce them to invest large sums of money in the condensed milk industry. By skillful manipulation these promoters frequently secure "fat rake-offs" on every purchase of machinery and on every contract of labor, occasionally on every sale of the product. Their victims pay exorbitant prices for a first class building and most up-to-date equipment, and often receive a shack barely strong enough to stand up under its own weight, and equipment of inadequate capacity.

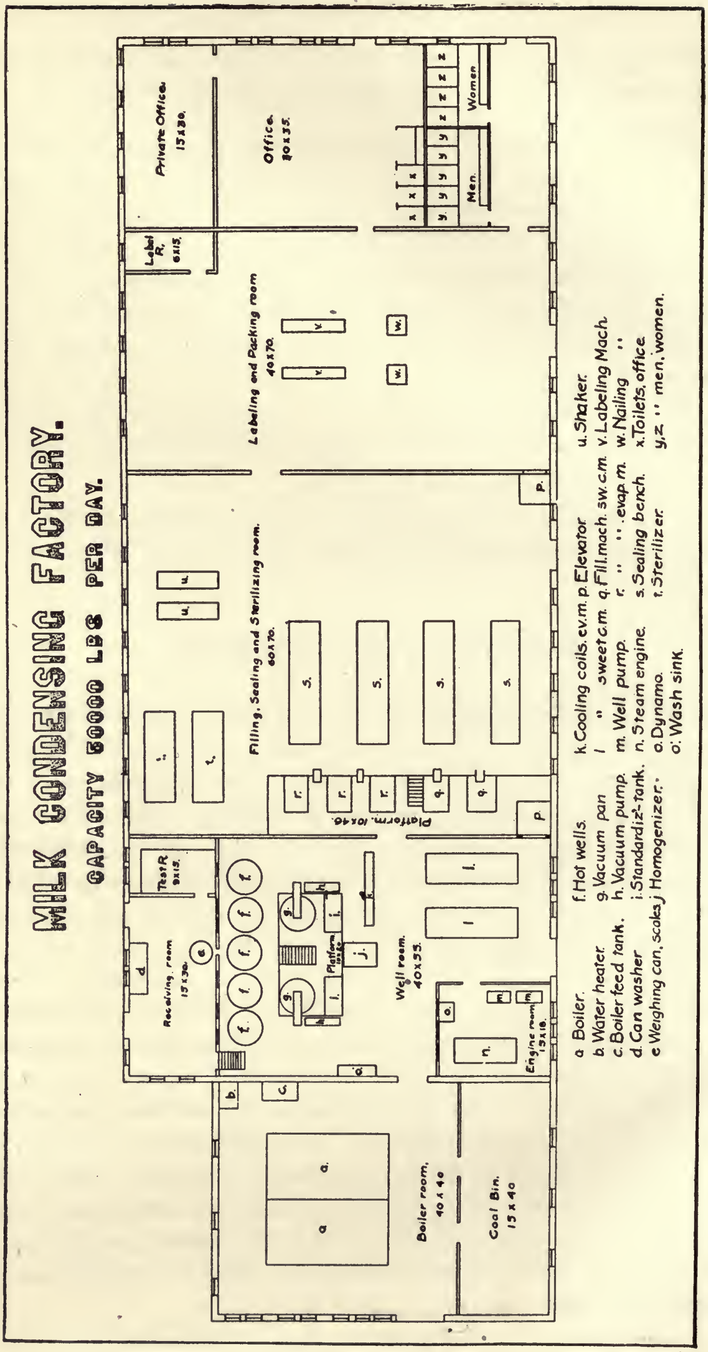

Fig. 6. This factory is arranged and equipped for the manufacture of sweetened condensed milk and evaporated milk

It is beyond the realm of this volume to furnish detailed specifications and plans for the construction of condensed milk factories. Such information would be of comparatively little value, as such details must of necessity vary with locality, capacity of prospective plant, type of equipment, system of operation and preferences of individual owners. Such details are best decided on and worked out for each individual factory separately and when needed. There are a few fundamental principles, however, which apply to all factories and to which attention may be briefly called here.

Floors, Walls and Ceilings.— Stone, brick, concrete, concrete-steel, according to availability, are satisfactory materials of which to construct a condensery. Intersecting walls or partitions are best constructed of similar material. If constructed of wood, they should rest on concrete, brick or stone, built up at least two feet from the floor, or the lower two feet of which partitions should be wainscoated with an approved quality of cement plaster.

All floors of the main building should be of cement, great care being taken that the foundation of these floors be of uniformly hard material, thoroughly tamped and avoiding soft spots. The concrete bed should be at least four inches in depth, consisting of one part of cement, two parts of sand and four parts of gravel. The sand should be sharp building sand and the gravel should be washed pebbles, ranging in size from one-half to one inch. The top dressing should be not less than one inch thick, consisting of one part of cement and one and one-half parts of sharp building sand. It should be carried up on the walls and partitions at least two inches, forming a sanitary cove. After finishing, the floors should be allowed to harden for at least two weeks. This will greatly prolong their life. It is advisable to use some cement hardener such as Master Builders' cement, or Lapidolith, etc., which will help to make these floors more nearly wear-, water-, dust- and crack-proof. It is difficult to keep the condensery in sanitary condition and to protect the product against contamination, unless the floors of the factory are and stay free from cracks and holes.

Ventilation.— A proper and effective system of ventilation is another very important and too often entirely neglected factor in the planning of the condensed milk factory. This applies to all parts of the plant where work is being done, but it is especially essential in rooms where free steam escapes. The ventilating system should be adequate to afford ready and quick escape of steam, to remove foul air and to facilitate the regulation of temperature. Unless free steam does promptly find an exit from the factory rooms, it condenses on the walls and ceilings, making them sweat profusely, causing corrosion of the walls and ceiling, deterioration of motors and other similar equipment, and molding of supplies; this is especially the case during the winter months. The removal of foul air and the control of the temperature of the air are essential for the comfort, health and efficiency of the employes.

The system of ventilation that will accomplish efficient ventilation will of necessity vary with the type of plant and arrangement of equipment. Gravity ventilation, such as is represented by the King system is, under average conditions, inadequate to produce satisfactory results in factories, like milk condenseries, where there is bound to be much escape of free steam. The exchange of air is not rapid enough to remove the steam before it condenses on the walls and ceilings, especially in cold weather. It is, therefore, advisable to provide for some form of forced ventilation. Under certain conditions of construction an air flue connecting with the smoke stack may furnish all the ventilation needed.[1] Under many other conditions, however, it is necessary to hood that equipment from which free steam escapes in large volume, such as can washers, and can sterilizers, hot wells, etc., and to draw the steam away through ducts of adequate size by one or more motor fans located in the outside wall or ceiling.

Drainage.—All floors of the manufacturing rooms should slope to facilitate rapid drainage. A fall of one-eighth inch per foot is usually sufficient. Large water-sealed floor drains should be sufficiently numerous and well placed in all rooms to rapidly carry off water. The surface of these floor drains should be about one-half inch below that of the adjoining floor, so as to catch the water readily. In the larger rooms open drain-ditches in the cement floor, six to eight inches wide and covered with perforated iron plates, are preferable to bell-traps. They may be placed along the walls or elsewhere. They should be not more than forty feet apart and have a fall of one-eighth inch to the foot, with the floor sloping toward them. It is generally most convenient to have all the drain pipes enter into one large sewer pipe not less than ten inches in diameter,

[1] In this case there should be an inner and outer stack with an air space between which connects with the air flue.

for a condensery receiving about fifty thousand pounds of milk daily, which should dispose of all the factory sewerage. It is advisable to place the main sewer pipe outside the building and to have it terminate in a "clean-out." This will afford more ready access in case the sewer is stopped up.

General Plan of Factory.—Most of the condensing factories are either one- or two-story buildings. In the case of two-story buildings the first floor is usually devoted to the boiler and engine rooms, vat room, well room, filling, sealing and packing rooms. On the second floor are installed the pan room, store room for sugar and box shooks, the tinshop and possibly the offices. A basement is sometimes provided and used for the storing of condensed milk.

Fig. 6 illustrates a floor plan of a milk condensing factory with a capacity of fifty thousand pounds of milk daily. All operating rooms are located on one floor. The arrangement of machinery permits of the handling of the milk on the gravity plan or with pumps, according to the topography of the site and the elevation of the rooms. The receiving room floor and the platform which accommodates the vacuum pans, should be seven to eight feet above the main floor. In order to take care of storage of water, sugar, tin cans, barrels and box shooks, there should be a second floor over the well room and the filling, sealing and sterilizing room. The ceiling of these rooms should be not less than sixteen feet above the floor.

The rooms are so arranged as to necessitate the minimum expenditure of machinery, conveyors and labor. All work rooms open on the railway switch, and the storage room is accessible by two elevators. The well room, where most of the steam is needed, is next to the boiler room, so as to minimize condensation in the steam pipes. If the main steam pipes are properly insulated, this arrangement should furnish the vacuum pans with dry steam. The floor in the boiler room should be two feet below the main floor, in order to give additional fall for the condensation water from jacket and coils of the vacuum pans to the boiler feed tank.

The partition between the receiving room and testing room is equipped with a cabinet, opening on both sides so that the sample bottles can be placed on the shelves in the receiving room and taken off the shelves in the test room.

From the weigh cans on the receiving platform the milk runs direct into the hot wells, which are sufficient in number to conveniently divide the milk into batches and to heat the milk with the least possible delay. The capacity of the vacuum pumps is augmented by their close proximity to the vacuum pans and the hot-wells and by the fact that the water supply tanks are overhead. The space to be evacuated is confined very largely to the vacuum pan only, the milk has to be lifted by the vacuum pump but a few feet and the water runs into the condenser by gravity.

From the well room the condensed milk is transferred to the tanks on the platform over the filling machines. The evaporated milk is pumped from the cooling coils through the wall and the sweetened condensed milk is raised to the platform in ten-gallon cans on the elevator, or is forced by a piston pump into the tanks feeding the filling machines. The sealing benches are equipped with self-heating soldering coppers. In the place of the soldering benches and hand coppers, automatic sealing machines may be installed. The sterilizers and shakers are conveniently placed to take care of the sealed evaporated milk. The tin cans for the sealing room and the box shooks for the packing room are brought down from the storage room overhead on the elevator. The labeling and packing room, equipped with the labeling and box nailing machines, provides for considerable storage of the finished product. Additional storage at a moderate and uniform temperature might be provided for by a basement under the packing room. A label stock room furnishes satisfactory storage for the labels.

In case the factory manufactures its own tin cans, a tinshop, equipped with the necessary machinery (see list of machinery and equipment) should be located in as close and convenient proximity to the filling and sealing room as possible. A suitable place is directly opposite the filling room with the railway track separating the latter from the tinshop. The tinshop should have two outside doors, opening out on the track, and its machinery should be so arranged that the tin plate can be unloaded from the car at one door, is moved back through the machinery and appears again in the form of finished cans at the other door, directly opposite the filling room and ready for the reception of the condensed milk. Instead of erecting a separate building for the tinshop, the latter may also be conveniently installed in the second story directly over the filling room.

Where natural gas and gas from municipal corporations is not available, one or more gasoline gas generators should be installed. These gas generators contain inflammable material and should, therefore, be located at a reasonable distance from the main building.

List of Equipment.—The following is a list of the principal machinery and equipment needed in an up-to-date condensery with a capacity of fifty thousand pounds of milk daily:

BOILER ROOM

Boilers with a total capacity of 400 H. P.
1 boiler feed tank.
1 boiler feed pump.
1 boiler water heater.

ENGINE ROOM[1]

1 40 H. P. engine.
2 well pumps, 150 gallons per minute each.
1 80 light dynamo.
Pipe and thread-cutting tools, anvil and forge.

RECEIVING ROOM

2 1000-pound weigh cans, "low down" style.
2 6-beam milk scales.
1 can-washing machine with steam and water jets and air blower for drying the cans.
1 milk sample bottle rack.

WELL ROOM

6 5000-pound capacity jacketed kettles with revolving agitators and superheating device.
1 6-foot vacuum pan.
1 7-foot vacuum pan.
2 vacuum pumps.
2 500-gallon standardizing vats.
1 6-cylinder homogenizer.
1 internal tube cooler, capacity 5000 to 8000 pounds per hour, for cooling evaporated milk.

[1] In case municipally generated electricity is available, there is no need of a Dynamo and much of the equipment may be supplied with direct drive by motors. This would obviate the installation of a steam engine.

2 36-can cooling vats with cans, cross bars and paddles, complete, or

2 5000-lbs. circular cooling vats with vertical coils for cooling sweetened condensed milk.

1 wash tank.

1 elevator.

1 sugar chute.

1 2-beam platform scale.

1 truck.

FILLING, SEALING AND STERILIZING ROOM

4 200-gallon condensed and evaporated milk vats.

2 filling machines for sweetened condensed milk.

2 filling machines for evaporated milk.

4 soldering benches, 5x20 feet, with 10 self-heating soldering coppers each, or

1 or more sealing machines with can-testing baths, the number depending on type and capacity of machine used.

2000 wooden trays holding 24 16-ounce cans each.

2 sterilizers, capacity 75 to 100 cases each, complete with iron trays.

1 double shaker.

2 trucks.

LABELING AND PACKING ROOM

2 labeling machines.

2 nailing machines.

2 trucks.

TESTING ROOM

2 24-bottle Babcock testers, with one gross of standard milk test bottles and accessories, complete.

Equipment for chemical and bacteriological analyses of milk, milk products and sugar.

OFFICES

Usual equipment.

TOILET ROOMS

Usual equipment.

OVERHEAD STORAGE ROOM

1 50-000-gallon water tank. This tank is preferably located outside of factory.
1 4-beam platform scale for sugar.

ADDITIONAL EQUIPMENT

1 gasoline gas generator (complete), needed in absence of access to natural gas or municipal gas.
1 15-ton ammonia compressor. with ammonia and brine pipe lines, circulating pump and brine tank.
2 15,000-lbs. jacketed circular tanks for refrigeration of stored evaporated milk.

TIN SHOP

Needed in case cans are manufactured at the factory.
2 squaring shears.
2 body cutting machines.
2 lock seamers.
6 presses.
2 crimping machines.
2 soldering floats.
1 can tester with vacuum pump.
1 can wiper.
1 lathe with tools.
1 gasoline gas generator, complete.
1 25 H. P. engine or motor.
200 can crates.

Economic Arrangement of Machinery.—In the arrangement and connection of the machinery, economy of manufacture and sanitation of the product should receive serious consideration. The machinery should be so arranged as to reduce to the minimum the space, pumps, pipes and conveyors needed. Pumps, conveyors, pipes and fittings are expensive, and the space saved by judicious arrangement of the stationary machinery may be used to advantage for other purposes.

Human muscle is the most expensive form of motive power. Wherever muscle can be replaced by machinery and where, by intelligent arrangement of the machinery, unnecessary steps and handling can be avoided, the cost of manufacture is reduced.

The matter of insulation of ammonia, brine, steam and water pipes is an important item as related to the economy of fuel. For proper and economical insulation the following types of pipe covering are recommended:

Ammonia and Brine Lines.—

1st layer of tarred felt.
2nd layer of 1″ thick hair felt.
3rd layer of tarred felt.
4th layer of 1″ thick hair felt.
5th layer of tarred felt.
6th layer of wove-felt paper.
7th layer of 8-oz. canvas jacket, sewed on.
8th layer of sizing and one coat of lead and oil paint.

Each layer of hair felt must be securely wound with twine. Each layer of all material should be coated with hot asphalt, applied while hot, excepting layers, 6, 7 and 8.

Special seals must be made at all flanges and fittings, and such flanges and fittings must be insulated independently. This arrangement will prevent damage to adjoining coverings, should fittings spring leaks.

Before applying pitch or asphalt, the necessary precautions must be taken to have the pipes thoroughly dry and the asphalt or pitch must be hot.

Steam Lines.—Air cell asbestos covering, or covering of equal insulating and lasting quality, one inch thick on pipes, and fittings to be built up of asbestos cement to a corresponding thickness; smoothly finished and neatly canvassed, with metal bands at 18″ intervals. Before putting on the metal bands the covering should receive two coats of asbestos cold water paint.

Cold Water Lines.—Covering of wool felt, tar paper lined, sectional, one inch thick on pipes; fittings to be built up to a corresponding thickness with one inch hair felt, the entire line should be neatly finished with a graded mixture of Portland cement and asbestos cement, and canvas-jacketed and equipped with metal bands at 18″ intervals. Before putting on the metal bands, the covering should receive two coats of asbestos cold water paint.

Sanitary Arrangement of Machinery.— Milk pumps, milk pipes, milk troughs and other milk conveyors are, at best, enemies of sanitation. They should be avoided wherever possible. The gravity system of conveying milk should be used in preference to the pumping system. Milk pipes should be short and accessible; all vats should be of sanitary construction; wooden jackets should not be tolerated; all seams in the vats and kettles should be well flushed with solder; milk pumps should be brass lined; all milk pipes should be of black iron pipe made smooth on the inside by sand-blasting, or of galvanized iron or copper, heavily tinned over on the inside; long lines of milk pipes should be equipped with unions at short distances; crosses or sanitary couplings should be used in place of elbows, in order to render all sections of the milk pipes easily accessible to flue brushes.

Chapter III.

MILK SUPPLY

Basis of Buying Milk.— The prices which the condensery pays the patrons are not usually governed by any board of trade. They do not even necessarily follow the quotations of the butter and cheese market. They are generally announced from three to six months in advance. They average, in most cases, from twenty to fifty cents higher per hundred pounds of milk than those paid by the creameries and cheese factories.

The milk condenseries, as a whole, have been slow in adopting the butterfat content of milk as their basis for payment. Even up to a few years ago most condenseries were paying for the milk on the one hundred weight basis and some factories were still clinging to the mediaeval custom of buying milk by the quart, using the yardstick for remnant cans. Other factories paid a stated price per hundred weight for all milk testing say 4 per cent fat and over and made corresponding reductions for milk containing less than 4 per cent fat. Still others paid a premium for milk testing above 4 per cent fat. A few concerns only bought milk on the straight butterfat basis.

As far as the condensery is concerned it is entirely feasible to pay for all milk strictly on the butter fat basis. Milk rich in fat, and therefore rich in solids, yields more condensed milk than milk poor in fat. To pay by the hundred weight, regardless of quality is a practice which discriminates in favor of breeds of low-testing milk and against breeds of high-testing milk. This practice has, in fact, had the result that in the milk supply territory of these condenseries the breeds and individuals of cows producing low-testing milk were encouraged and developed until they largely predominated, at the expense of breeds of cows producing high-testing milk. This situation in turn was responsible for the popular, though erroneous impression, that milk from the Holstein, Ayrshire and Brown Swiss breeds is better suited for milk condensing purposes than milk from the Channel Island breeds.

Within the last half decade, during which the condensed milk industry has experienced so great a development, the great majority of condenseries have abandoned their old way of paying for milk by volume, or weight only. Many condensing concerns are now buying their milk on the straight butter fat basis and nearly all of the other condenseries pay for their milk on the basis of a standard fat content, penalizing the farmer by lower prices for milk that falls below a specified per cent of fat, and giving him a bonus for milk in which the per cent of fat is over the standard figure specified.

The great bulk of the milk supply reaches the condensery by wagon or by motor truck. Usually part of the cost of transportation is borne by the factory and part by the farmer. Shipments by rail are rare, the uncertainty of rail transportation, with its frequent delays, jeopardizes the quality of the milk. Payments for the milk are generally made monthly.

Quality.—The quality of the fresh milk is the first and most important factor to be considered. The milk condensing factory, ignoring this fact and accepting milk from unsanitary dairies and careless dairymen, is bound to pay the penalty for such neglect sooner or later.

Polluted milk and milk that has not been cooled promptly and to a reasonably low temperature on the farm, may pass through the process successfully, if it is not too sour. The condensed milk made from it, though, is inferior in flavor and keeping quality, and usually shows signs of deterioration and decay before it reaches the consumer. The risk of handling such milk is very great; it may result in total loss to the manufacturer. The trouble may and often does begin before the process is completed. Unclean, abnormal, or partly fermented milk, when subjected to the process, is prone to curdle and whey off; the condensed milk becomes lumpy and shows other defects. This is especially true where superheating is practiced and where evaporated milk is made.

Milk that has received the best of care on the farm may be detrimental to the interests of the condensery, if it comes from cows less than thirty days before their parturition, or from fresh cows within the first seven days after calving, or from cows otherwise in abnormal condition. Such milk is often abnormal in its chemical properties, and, when subjected to high temperatures, undergoes changes that make its manufacture into a marketable condensed milk difficult.

Control of Quality—Every well managed milk condensing factory plays the part of an educator in the production of sanitary milk. The condensery usually issues a set of rules, setting forth specifically the conditions under which the milk coming to the factory shall, or shall not be produced. Copies of these rules, which are generally a part of the contract, are placed in the hands of all patrons. The condensery employs one or more dairy inspectors whose business it is to see that the rules are rigidly enforced. These rules cover, in general, the following principal points:

1. COWS.—The milk must come from healthy cows. Milk from cows that are diseased, or that have a diseased udder, or that are otherwise in poor physical condition, will be rejected.

2. FEED AND WATER.—Do not feed weeds, roots, or other feed stuffs possessing strong and obnoxious odors, such as onions, garlic, turnips, cabbage, wet distillery slops, decayed, musty or sour silage, or other fermented feed. (Some condenseries prohibit the use of all silage. This restriction betrays prejudice and ignorance on the part of the management concerning the great value and absolute harmlessness of good silage as a dairy feed. It is an injury to the dairy interests of the country. Corn silage or other silage, in good condition, and fed in reasonable quantities, does in no way injure the milk for condensing purposes.) The cows must be supplied with clean, fresh water.

3. LACTATION PERIOD.—Reject all milk from cows less than thirty days before, and of the first seven days after calving.

4. MILKERS AND MILKING.—Milk with clean, dry hands into clean utensils and remove the milk to the milk room immediately after drawn.

5. STRAINING.—Strain the milk in the milk room through a fine wire mesh strainer (80 to 100 meshes to the inch). Do not use cloth strainers.

6. COOLING.—Cool the milk to 60 degrees F. or below and keep it at that temperature until it reaches the factory. Do not mix the warm morning's milk with the cold night's milk; cool the morning's milk before mixing, or send it to the factory in separate cans.

7. CARE OF UTENSILS.—Rinse with cold water, wash with warm water and washing powder, and rinse with boiling water all milk utensils thoroughly after use; keep them in a clean place between milkings. Do not store the milk on the farm in cans that have not been washed by the factory.

8. STABLES.—Whitewash the stable twice every year and remove manure daily. (Some condenseries furnish spray pumps for applying whitewash.)

Inspection of Milk at the Condensery.—At the condensery the milk is subjected to rigid inspection by a man who is, or should be, an expert on milk inspection; every can is examined. Warm milk and milk that is tainted, or smells slightly sour should be rejected.

INSPECTION OF MILK BY SENSE OF SMELL AND TASTE.—In most cases the milk is inspected with reference to odor. The inspector quickly raises the cover of each can to his nostrils. The odor in the cover is typical of that in the can. If it is "off," the can is rejected. An experienced man on the platform can, by the use of this method, tell with much accuracy, whether the milk should pass or not.

INSPECTION OF MILK ACCORDING TO ITS TEMPERATURE.—The temperature is also noted. This need not be done with the thermometer in each case. By placing his hand on the body of the can, or by noting the warmth of the air and odor in the cover immediately after removing it, or by the presence or absence of small particles of butter floating on the surface of the milk, the inspector can readily tell if the milk has or has not been properly cooled. A correct thermometer should always be on the platform for guidance.

Inspection of Milk by the Use of Acid Tests.—Since the degree of acidity, or the sweetness of the milk, is one of the chief factors that determines its fitness for condensing purposes, tests that rapidly and accurately determine the per cent of lactic acid in the fresh milk, are of great service.

Some concerns have adopted a definite acid standard of milk, rejecting all milk containing more than the maximum per cent of acid of their standard, and they test every can of milk received with an acid test. This method insures sweet milk in the factory, provided that the alkaline solutions used are correct. This work involves considerable expense, however, and unless the solution is carefully prepared and made up fresh often, its use may yield misleading results. Again, when the acid test is performed on the milk of each can, the acceptance or rejection of the milk depends altogether on the per cent of acid it contains. Although milk may be otherwise unfit for use, it will pass, as long as it is low in acidity. Experience has shown that, while it is necessary for the condensery to decide on a maximum acidity of milk above which all milk be rejected, the nose and the palate of the experienced inspector are better criterions than the acid test alone, as to the fitness of milk for condensing. Acid tests are valuable in the case of uncertainty and suspicion as to the quality of any given can of milk. All milk containing .2 per cent lactic acid or more is dangerous for condensing purposes and should be rejected.

Acid Test for Daily Use, Where Each Can of Milk is Tested.—Stock Solution.—Weigh out two hundred grams of sodium hydrate C. P. and add distilled water to make up one liter. Keep tightly stoppered.

Solution for Daily Use.—Mix 4 c.c. of stock solution with 991 c.c. of distilled water, and add 5 c.c. of phenolphthalein indicator. The indicator is prepared as follows: dissolve one gram of dry phenolphthalein in 100 c.c. of 50 per cent alcohol. Each cubic centimeter of the prepared alkaline solution neutralizes .01 per cent lactic acid, 20 c.c. of the prepared solution, therefore, neutralize .2 per cent lactic acid, when a 17.6 c.c. pipette is used for measuring out the milk.

Making the Test.—With the Babcock pipette, measure 17.6 c.c. into a white cup. With a small dipper, holding exactly 20 c.c., pour 20 c.c. of the prepared solution into the cup; stir or shake. If the mixture remains faintly pink, it contains less than .2 per cent acid and will pass; if it turns white, it contains more than .2 per cent acid and should be rejected.

The stock solution should be standardized by a chemist. The prepared solution should be made up daily. Both solutions should be kept in glass bottles, tightly corked. The bottle containing the stock solution should be glass-stoppered.

Acid Test for Use on Suspicious Cans Only.—The Farrington Alkaline Tablet Test. Use an eight ounce, wide-mouth bottle, place in it sixteen Farrington alkaline tablets, add eight ounces of distilled water or rain water, or any pure water relatively free from carbonates. Stopper tightly and let stand for six hours, or until the tablets are completely dissolved. This solution neutralizes .2 per cent of lactic acid in equal parts of milk.

Making the Test.—Use small dippers of the same size for milk and for test solution. Pour into a white cup one dipperful of milk and one dipperful of solution. If the mixture turns white, it contains more than .2 per cent lactic acid and should be rejected. If it remains pink, the milk contains less than .2 per cent acid.

THE BOILING TEST.—Inspection by Heating. The heating to the boiling point of samples of suspicious milk furnishes a most reliable means to determine the fitness of such milk for condensing. In many instances milk may satisfactorily pass the other tests and yet it may not be in condition to stand the heat to which it will be subjected in the process. If it curdles, when boiled, it is obviously unfit for use. This test shows more than the acid test above. By its use the operator is able to detect milk otherwise abnormal, such as milk containing colostrum, etc., or the proteids of which are unstable for other reasons.

Making the test.—The boiling test is simple and can be manipulated rapidly. A sample of the questionable milk is taken into a small dipper. The dipper is held up against a steam jet turned down into the milk. Direct steam is turned into the milk until it comes to a boil. If flakes or specks of curd cling to the sides of the dipper, the milk is unfit for use.

An alcohol lamp ar gas burner on the platform may be used for heating the sample. In this case a few cubic centimeters of the milk are discharged with an ordinary pipette into an ordinary test tube, such as are in common use in the chemical laboratory and can be obtained from the drug store. The tube is held over the flame and the milk comes to a boil in less than a minute. If the milk is in good condition the sides of the glass tube remain perfectly clear. If it curdles upon heating, the sides of the tube show fine specks of the curd. The appearance of these specks condemns the milk.

Fig. 7.
The sediment tester

THE SEDIMENT TEST.—This test shows the relative amount of dirt present in milk. One-half pint of milk is passed through a small circle of absorbent cotton and the amount of mechanical impurities present in the milk is indicated by the color of the cotton after filtration. In order to hasten the filtration, the milk is forced through the filter under slight pressure. this is accomplished by a rubber bulb attachment to the apparatus, as shown in the accompanying Fig. 7.

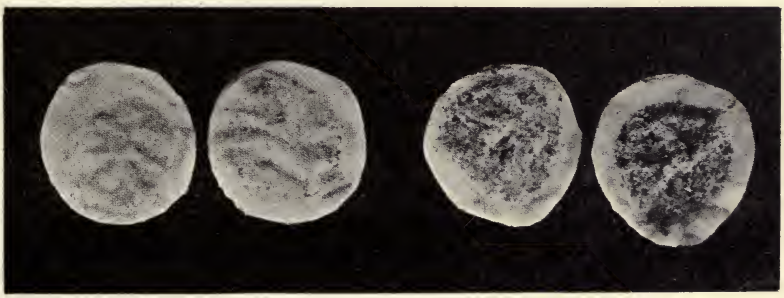

Fig. 8. Cotton Filters
Clean milk Dirty milk

If the cotton retains a white or creamy color, the milk is relatively free from filth. Milk produced under unsanitary conditions stains the cotton brown or black.

These cotton filters may be pasted on a sheet of paper similar to a milk sheet, arranged so that the circles are placed opposite the respective patron's name or number. When shown to the patrons who come to the factory, they furnish a most effective object lesson to them. When the milk reaches the factory on route wagons or by rail, cards similar to Figure 9 may be mailed to the patrons. The evidence is so conclusive that even the most obstinate patron cannot help admitting his guilt and can usually be induced to "clean up."

..................................MILK CONDENSING COMPANY

SEDIMENT CARD

NAME

ADDRESS

DATE

No.

THIS IS THE AMOUNT OF DIRT IN ONE PINT OF YOUR MILK

Fig. 9.

FERMENTATION TESTS.—These tests are of great value in the rapid determination of the kind of bacteria with which the milk from individual patrons is contaminated. Glass tubes are filled one-half full of milk from each patron. These tubes are set in a constant water bath at 100 degrees F. and the changes which milk undergoes are noted after six, twelve and twenty-four hours.

A solid curd with a clear whey indicates that lactic acid bacteria are the chief organisms and that the milk has been produced under cleanly conditions. These organisms are killed when the milk is heated in the hot wells. Such milk therefore is safe, unless it contains excessive acid, as shown by the acid test.

A curd with gas holes, or that which is torn to pieces in the tubes, shows the presence of gas-producing germs. These come largely from manure and other filth. Among these are Bacillus coli communis, the natural inhabitant of the colon of the animal, and butyric acid organisms which are spore bearers. The latter especially may give rise to serious milk defects, causing "swell heads." Patrons sending such milk should be looked after at once.

If the curd dissolves, or no curd is formed and the milk changes into a transparent liquid, it usually is contaminated by germs from the dust of hay and bedding, or polluted water. To this class of organisms belong Bacillus subtilis, Bacillus fluorescens liquifaciens, Plectridium foetidum, Bacillus putrificus, etc. Some of these are violent gas producers and most of them are spore-bearers. They are the cause of some of the most disastrous milk defects. Dairies from which such milk comes should be vigorously inspected and all milk from them should be rejected, until the patrons have learned how to furnish sanitary milk.

Milk that remains unchanged for twenty-four hours when subjected to the fermentation test, suggests that it contains some preservative. It is possible, however, for milk produced under ideally sanitary conditions to remain normal and unchanged even at these high temperatures for several days. Where milk comes to the factory in bulk as is the case in the condensery, samples showing abnormal keeping quality should be regarded with suspicion, and the respective dairies should receive immediate and thorough inspection.

TESTS FOR BUTTERFAT AND SPECIFIC GRAVITY.—In the factories where the milk is not paid for on the butter fat basis, composite samples should be taken daily, to be tested for fat and specific gravity, at regular intervals of from two to four weeks, in order to detect possible adulterations by skimming or by the addition of water. For specific directions for the Babcock test, the use of the lactometer and tests for preservatives see Chapter XXXI "Chemical Tests and Analyses of Milk and Milk Products" and Chapter XXXIII "Detection of Adulterants and Preservatives, Etc."

FACTORY SANITATION

In the previous paragraphs, special emphasis was placed on the great importance of a good quality of fresh milk. It is equally essential that the factory be kept in exemplary condition as to cleanliness and sanitation. This is necessary because of its effect on the patrons and on the wholesomeness and marketable property of the finished product.

Effect on Patrons.—It does not take the watchful eye of the intelligent patron, who daily comes to the factory, very long to learn, whether the manufacturer gives his milk as good care as he gave it on the farm. A good example set by the factory will mean much toward instilling the patron with ambition to do likewise on the farm. Shiftlessness is a contagious disease, to which the average farmer is very susceptible. It is, therefore, inconsistent for the factory to issue and enforce rules of sanitation for the dairy farmer when, within its own walls, all principles of sanitation are violated.

Effect on Wholesomeness of the Product.—Uncleanliness and filth interfere with the wholesomeness of the product. Condensed milk made in a factory ignoring sanitation, may contain certain products of decay which are poisonous to the human system. Again, it may contain germs of infectious diseases and thus become the cause of widespread epidemics of these diseases and possibly claim many victims. As a matter of common decency and of duty to the commonwealth, the condensery should pay close attention to cleanliness in all operations.

Effect on the Marketable Property of the Product.—Again, uncleanliness in the factory is bound to bring financially disastrous results. The seriousness of the disaster is greatly augmented by the fact that the consequences of neglect are usually not apparent until after the goods have reached the market. The pollution of condensed milk with impurities and filth in the factory, shortens the life of the product. Such condensed milk is of very poor keeping quality. It may reach the market and the consumer in condition that causes it to be rejected, resulting in a complete loss to the manufacturer. The manufacturer allowing such conditions to exist, is usually the last man to realize and admit that he is at fault, which renders attempts to locate and stop such defects exceedingly difficult. Furthermore, instead of helping to build up the trade and to advertise the brand, he demoralizes it.

How to Keep Factory in Sanitary Condition.—Cleanliness in the factory is absolutely essential. The milk vats should be rinsed with plenty of water and scrubbed and steamed thoroughly, as soon as possible after use. The copper kettles and vacuum pans should be rinsed, then scoured with sandpaper or emery cloth, then rinsed and steamed thoroughly. The milk pipes should be scoured by running flue brushes through, flushing them with clean water and steaming them until they are scalding hot. In the case of milk pipes of excessive length, they should be well flushed with hot alkaline water. Milk pumps should be taken apart every day and freed thoroughly from all remnants of milk. The water in the cooling tanks should be changed as often as is necessary to insure clean water in them at all times. The homogenizer should receive special attention, all its valves should be thoroughly cleaned and steamed daily. The cooling coils should be scalded before use. The filling machines for evaporated milk should be freed from all milk, rinsed and steamed thoroughly and no remnants of milk should be allowed to stick to the valves. The filling machines for sweetened condensed milk should be emptied and completely washed, at least once per week, and protected from dust and filth by covering them when not in use. The tin cans should be stored in a clean room and every precaution should be taken to guard against their defilement from dirt, dust, insects and mice. Where possible they should be sterilized before use.

All vats, kettles, milk conveyors, vacuum pans, milk pumps, and all machinery coming in contact with milk, should be flushed and steamed again in the morning, as soon as the condensery opens. The sugar chute should be kept clean, care being taken that no damp or wet sugar remains in it. Special attention should be given to the washing of the farmers' cans. After washing with brush and hot water containing some good washing powder, they should be thoroughly rinsed, then steamed until they are hot. If possible they should be dried by an air blast.

The floors and walls of the factory should be kept in sanitary condition. Accumulated rubbish should be removed and sewers and drains should be disinfected at regular intervals.

Care of Milk in the Factory Prior to Manufacture.—The problem of so handling the milk in the factory, from the time it arrives until it is heated preparatory to evaporation, is an important one, that has received much careful consideration by the foremost condensed milk men. Since bacteriological analyses have shown that, under favorable temperature conditions, the micro-organisms present in milk are capable of doubling in number once every twenty minutes, it is essential that the milk either be heated to high enough temperatures to destroy germ life, or be cooled to a temperature low enough to stop growth and multiplication, as soon as possible.

Both practices are feasible, but to heat the large volumes of milk that arrive at the factory, all within a few hours, would tax the equipment of the factory under average conditions very heavily. And unless the condensery were equipped with very large vacuum pan capacity, much of this heated milk would have to lie idle in the

Fig. 10. Glass-lined tank for cooling and holding milk before manufacture
Courtesy of The Pfaudler Company

forewarmers for hours, awaiting its turn for condensation. This would be undesirable and might prove harmful to the quality of the finished product.

Efforts have, therefore, been made, especially within recent years, to provide a practical and economical method of cooling the milk as soon as it arrives and of holding it at a low temperature until ready for heating and condensing. This has led to diverse practices, such as running the milk over a surface coil cooler into a jacketed tank, or cooling it by running it into a large tank equipped with cold air blowers, etc.

The latest improved method for refrigerating the milk consists of the use of large, usually circular, glass enameled steel tanks. These tanks are completely surrounded on their sides and bottom by a cold water or brine jacket and are equipped with a milk distributing device that causes the inflowing milk to be sprayed by gravity against the top of the sides of the tank and to percolate in a thin layer down the sides. In this manner the cooling is instantaneous, the entire sides of the tank being surrounded by the cooling medium. It is aimed to cool the milk to about 40 to 45 degrees F. and to hold it at this temperature until ready for manufacture.

These glass enameled tanks have many advantages; they minimize the initial cost of the necessary equipment, reducing the number of costly vacuum pans, and forewarmers, required; they cut down labor cost, because they reduce the equipment to fewer pieces to operate and to clean; they are of such construction that they are easily and quickly cleaned and readily kept in proper sanitary condition, the smooth and pore-free enamel yields more readily to the brush than copper surfaces; they avoid all possibility of chemical action of the milk on metal and, therefore, are a reliable safeguard against the development of metallic flavor in the milk.

The use of these large holding tanks also facilitates the standardization of the milk for fat and solids not fat. For detailed directions on standardizing see Chapter XXIX, page 253.

PART II.

MANUFACTURE OF SWEETENED CONDENSED MILK

CHAPTER IV.

DEFINITION

Sweetened condensed milk is cow's milk, condensed at the ratio of 2½ to 2¾ parts of fresh milk to 1 part condensed milk. It contains considerable quantities of sucrose, usually about 40 per cent, to preserve it. It is of semi-fluid consistency and reaches the market in hermetically sealed tin cans, varying in size from eight ounces to one gallon, and in barrels similar to glucose barrels, holding from three hundred to seven hundred pounds of condensed milk. When made properly, sweetened condensed milk will keep for many months, but is best when fresh.

HEATING

Purpose.—The first step in the process is to heat the milk to near the boiling point. There are three chief reasons for which the milk is heated, namely, to destroy most of the bacteria, yeast, molds and other organized and unorganized ferments, to facilitate the solution of the sucrose, and to prevent the milk from burning on to the heating surface in the vacuum pan.

DESTRUCTION OF FERMENTS.—When the fresh milk arrives at the factory it contains micro-organisms in varying numbers and of different species. In some cases disease-producing bacteria may be present, rendering the milk dangerous to the health and life of the consumer, were it not heated to temperatures high enough to destroy these germs. Again, milk may contain bacteria, yeast, molds and enzymes that cause it to undergo undesirable fermentations which, if allowed to pass into the condensed milk, may tend to shorten the life and impair the wholesomeness and marketable properties of the latter.

SOLUTION OF SUCROSE.—It is very essential that all the cane sugar which is added to the milk be completely dissolved, in order to lessen the tendency of the sugar to crystallize in the finished product. Undissolved sugar crystals in condensed milk act in a physical way much as bacteria in fluid milk do in a bacteriological way. They multiply rapidly, and such condensed milk usually precipitates its sugar before the product reaches the market. The presence of excessive sugar crystals makes the product gritty and causes the formation of a sediment in the bottom of the cans; this is objectionable to the consumer. When the milk is heated to the proper temperature before condensing, the solution of the cane sugar is facilitated and the tendency toward grittiness is minimized.

PREVENTION OF BURNING MILK ON HEATING SURFACE.—If cold milk comes in contact with a steam-heated surface and is not agitated vigorously, it bakes or burns onto this heating surface. The milk in the vacuum pan is heated or kept hot by means of the steam jacket and coils. These radiators are charged with steam under pressure and consequently give off a high degree of heat. If cold milk is drawn into the vacuum pan, the milk remains calm for a considerable length of time. During this time it is bound to bake or burn on the heating surface, giving the product a burnt flavor, causing it to contain brown specks and retarding the process of evaporation. If the milk is hot when it enters the pan, the reduced pressure in the pan causes it to boil violently at once, avoiding all danger of sticking to and burning on the heating surface and making possible maximum rapidity of evaporation.

Temperature.—In most factories the milk is heated to from 180 degrees F. to 200 degrees F. This temperature is sufficient to accomplish the three purposes. Heating the milk to the boiling point tends to give it a rather pronounced cooked flavor, which is objectionable. However, in the case of danger of contamination of the milk with resistant types of undesirable bacteria, it may become necessary to practice boiling the milk.

Manner of Heating.—Thorough, efficient and rapid heating of large volumes of milk to temperatures near the boiling point is a problem that requires careful consideration. The tendency of the milk to stick to the heating surface is a permanent obstacle and efforts to overcome this frequently result in sacrificing thoroughness of heating.

A variety of methods and numerous different types of machines are used for this purpose in the different milk condensing factories. Some use large copper kettles in which the milk is heated by turning steam direct into the milk. Others use jacketed copper kettles equipped with a revolving agitator. The milk is heated by turning steam under pressure into the jacket and the burning of the milk is prevented by keeping the milk in constant motion. Still others are heating the milk by means of large continuous pasteurizers in which case hot water or steam serves as the heating medium. The milk passes in a thin layer between two water-heated surfaces, one of which is revolving. In some factories the milk is forced through a series of pipes inclosed in a hot water or steam jacket.

Fig. 11.
The hot well or forewarmer
Courtesy of Arthur Harris & Co.

Finally, in some condenseries a combination of the continuous pasteurizer and the jacketed kettle is used. The milk is heated to nearly the desired temperature in the pasteurizer. From there it flows into the jacketed kettle. This kettle is so constructed that when steam is turned into the jacket, the milk rises and it flows over and off into the sugar well. This insures efficient heating and, at the same time, if operated properly, it prevents the baking of the milk on the heating surface. The disadvantage of this double system of heating is that the overflowing kettle has to be watched very closely.

Advantages and Disadvantages of Different Methods of Heating.—In most factories in this country the first named method is used. Steam is turned direct into the milk until it boils up. This is the oldest and most primitive method. While very simple in operation, this method has serious objections. At best, much of the steam used condenses in the milk, increasing the amount of water that has to be evaporated. It, therefore, prolongs the process of condensing and increases the cost of manufacture. This is especially true where the boilers are located at some distance from the hot wells and the steam pipes are not well insulated, causing the steam to be "wet." It is estimated that the amount of extraneous water thus added to the milk increases the bulk of the milk by about one-sixth of its original volume. The steam is often associated with impurities, such as cylinder oil from the engine, boiler compounds used in the boilers, scales from the inside of the pipes, etc. These various impurities cannot possibly improve, but may seriously injure the quality of the milk. It is quite probable, also, that the direct contact of live steam with milk has no beneficial effect on its ingredients. It is generally conceded by those who have given this matter careful thought, that the turning of steam direct into the

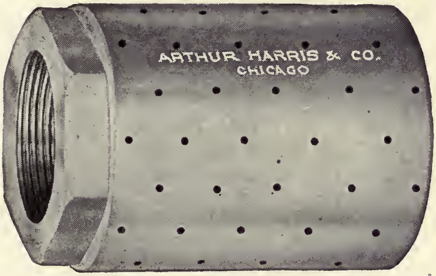

Fig. 12. Steam rosette for heating milk
Courtesy of Arthur Harris & Co.

milk shortens the life of the product and causes it to develop a stale flavor, which may degenerate into an oily flavor. The same defect is noted also when cream is heated by turning steam into it. The prolonged exposure of the milk to the condensing process, as the result of the addition to the milk of considerable quantities of condensed steam, further may be injurious to the milk.

Any method of heating that does not require direct contact of the steam with the milk is preferable, provided that it makes possible thorough heating to the required temperature without burning the milk. Practically all of the other methods above referred to accomplish this when properly applied.

ADDITION OF SUGAR

Considerable quantities of sucrose are added to the condensed milk for the purpose of preserving it.

Kinds of Sugar.— In order to convey to the milk preservative properties, that kind of sugar must be used which does not readily undergo fermentation and which has the power of inhibiting bacterial activity when dissolved in a concentrated solution. Glucose could be purchased at a very low cost, but it is not suitable for this purpose, since it is, in itself, very unstable and fermentable. It has no preservative qualities, even in concentrated solutions. Sucrose, saccharose, or cane sugar, $C_{12}H_{22}O_{11}$, properly refined, ferments with difficulty in concentrated solutions, and has the power of retarding the growth of bacteria and other ferments ordinarily present in sweetened condensed milk. It is, therefore, very satisfactory and useful in this connection.

Beet sugar, which is chemically identical with cane sugar, is used in European countries very largely in the place of cane sugar. On the continent the beet sugar industry is an important factor. With the climate adapted to the growing of sugar beets and the labor relatively cheap, beet sugar can be secured by the European condenseries at lower cost than cane sugar. In America, where the annual sugar cane crop is large and where the high cost of labor renders the expense of growing sugar beets relatively high, there is practically no difference between the price of cane sugar and beet sugar. When American beet sugar was used in the condenseries during the infancy of the beet sugar industry, this sugar was found undesirable, often giving rise to fermented condensed milk. It was then supposed by the condensed milk men that beet sugar contained very resistant spore-bearing bacteria, which followed the beets from the soil into the refined sugar. This conclusion is highly improbable, as the temperatures and chemicals employed in the process of beet sugar making are prohibitive of the passage of living bacteria from the soil to the finished sugar. It is possible, however, that the standard of refinement of American beet sugar, during the earlier days of its manufacture, was low and that some of the beet sugar on the market may have contained small amounts of acid, invert sugar and other impurities, ingredients of such a nature as to render the sugar prone to give rise to fermentation and, therefore, condemn its use in the milk condensery.

While the beet sugar on the market today appears to have reached a very high state of refinement and is, according to the best authorities, equal in purity to cane sugar, it is still shunned by the American condenseries, which insist that nothing but cane sugar will do. However, the total beet sugar production in the United States has more than trebled within the last ten years. In 1901 it amounted to one hundred eighty-four thousand tons and in 1911 it was six hundred six thousand and thirty-three tons. Again, whenever a shortage occurs of the sugar cane crop in the West Indies, raw European beet sugar is imported into the United States and it all emerges from our seaboard refineries as "pure cane sugar." It is not improbable, therefore, that the sugar supply of many American condenseries today consists at times largely of beet sugar, though it is purchased under the name of cane sugar.

There is no good reason why the best refined beet sugar, manufactured today in this country and elsewhere, should not give fully as good results for condensing purposes as the same quality of cane sugar. Tests made at the California Agricultural Experiment Station[1] led to the conclusion that the two kinds of sugar, cane sugar and beet sugar, were equally valuable for canning and identical in their behavior when of the same fineness of crystallization.

BEET SUGAR CANNOT BE DETECTED FROM CANE SUGAR.—While the raw sugar from the two different sources, the sugar cane and the sugar beet, takes on the character of the impurities from which it has not yet been freed (the raw product of the sugar cane is pleasant in flavor, the raw product from the sugar beet is acrid and disagreeable in flavor), the sucrose or so-called pure cane sugar, can be and is crystallized out, and in every case the sugar is identical in chemical composition, appearance and properties. "By no chemical test can the pure crystallized sugar from these two different sources be distinguished."[2]

Quality of the Sugar.— Since the sugar, sucrose, is added for the purpose of preserving the condensed milk, it is obvious that none but the best quality of refined sucrose is admissible. Low grade sucrose is a product dangerous to the condensed milk business. It is apt to contain sufficient quantities of acid and invert sugar, to give bacteria and yeast an opportunity to start fermentation. When once started, the destruction of the product is almost inevitable. In years of failure of the cane sugar crop, when the prices of sucrose soar high, condenseries yield frequently to the temptation of buying lower grades of sugar. The result invariably is an abnormally large output of condensed milk that "goes wrong."

[1] California Agricultural Experiment Station, Circular No. 33.
[2] United States Department of Agriculture, Farmers' Bulletin No. 535, 1913.

It is very important that the sugar in the factory be stored where it will keep dry. Sucrose has hygroscopic properties. When exposed to an atmosphere saturated with moisture it absorbs water. In damp storage it is prone to become lumpy, moldy and frequently sour. When these precautions are neglected there is danger of defective condensed milk, causing the cans on the market to swell, due to gaseous fermentation.

When the sugar reaches the milk through a chute from the floor above, the sugar chute and similar conveyors must be kept clean and dry. The lower end of the sugar chute is usually located directly over the steaming milk in the well room. In such cases there is always more or less danger of condensation in the chute of the vapors from the milk below. This causes the sugar to stick to and form a crust on the inside of the chute. This moist crust of sugar, when contaminated with bacteria, yeast or molds, is prone to start fermenting. When portions of this sour crust peel off and are carried into the milk below, they may cause entire batches of condensed milk to spoil, as the result of gaseous fermentation.

Adulteration of sugar with foreign admixtures, such as white sand, white clay, starch, or lime dust is rare, and occurs usually only in pulverized sugar. For the detection of these adulterants, add a spoonful of the suspicious sugar to a glass of hot water and stir. Pure sugar will dissolve completely, while most of the common impurities are insoluble and will settle to the bottom.

The purchase of coarsely granulated sugar is an effective safeguard, insuring freedom from these adulterants. Powdered sugar should not be used in the condensery.

Amount of Sugar.—The amount of sucrose used varies in different countries, with different manufacturing concerns, in different factories of the same company and at different seasons of the year. The normal variations range between twelve and eighteen pounds of sucrose per one hundred pounds of fresh milk. Most factories use about 16 per cent.

It is not advisable to overstep the limits above indicated. Condensed milk serves as a substitute for fresh milk. The more sucrose it contains, the greater is the difference in composition and properties between the condensed milk and the fresh milk. Sucrose is not as readily digested as the other ingredients of milk; therefore, the presence of excessive amounts of cane sugar in condensed milk tends to reduce its digestibility and its wholesomeness as a food. Again, while normal milk is a well-balanced food in itself, the presence of large amounts of cane sugar in it causes this equilibrium to be disturbed, the condensed milk being excessively rich in carbohydrates and relatively poor in proteids. These facts are specially significant where condensed milk is used for infant feeding and by persons with weak digestion.

On the other hand, sweetened condensed milk depends for its preservation on the sucrose. This class of condensed milk is not sterile and is prevented from rapid deterioration by the preservative action of the sucrose only. Therefore, the smaller the amount of sucrose it contains, the greater the danger from the activity of ferments and the less its keeping quality.

The relative prices of cane sugar and of fresh milk also govern the amount of cane sugar used in many factories. In summer, milk prices are low and sugar prices are high, while in winter the relative prices are reversed. Hence there is a tendency on the part of the manufacturer to use less sugar in summer than in winter.

Again, the amount of cane sugar used varies according to the kind of market for which the condensed milk is intended. Milk put on the market in hermetically sealed cans is generally exposed to more unfavorable conditions and is older by the time it reaches the consumer than milk sold in barrels. It is customary to use about sixteen pounds of cane sugar for every one hundred pounds of fresh milk for canned goods, and about twelve to fourteen pounds of cane sugar for barrel goods.

Finally, there is a strong tendency in some localities for sweetened condensed milk made in May and June, to thicken rapidly and become cheesy with age. This can easily be prevented by the use of more cane sugar in the milk manufactured during these months. (See Chapter XXIII on "Condensed Milk Defects.")

Mixing the Sugar.—The sugar is added to the hot milk before the latter enters the vacuum pan. In some factories a separate tank is provided for this purpose. Small portions of the hot milk are allowed to flow into this tank. To these the sugar is added. This tank is called the sugar well. It is usually equipped with a mechanical reversible stirrer, moving to and fro on an eccentric, to facilitate the solution of the sugar. The milk from the heater and from the sugar well runs into a tank sunk into the floor of the well room, the ground well, from which the mixed sweetened milk is drawn into the vacuum pan. In other factories the sugar well and ground well are one and the same tank, into which the milk runs direct from the heater. In this case it is advisable to set a wire mesh strainer (sixty to eighty meshes to the inch) over the sugar well. The sugar is placed into this strainer, a little at a time; the hot milk from the heater passing into and through the strainer dissolves the sugar. A paddle or stick should be used to stir the sugar in the strainer. For greater convenience and economy of labor, the sugar barrels and scales are placed on the floor over the well room. The sugar is transferred to the strainer below through a sugar chute which may be equipped at the lower end with an adjustable cut-off to regulate the sugar coming down. Other factories dissolve their sugar in boiling water in a separate tank, and draw this syrup into the vacuum pan together with the hot milk. This is a very commendable practice, as it minimizes the danger of undissolved sugar crystals to escape into the pan. Moreover, this watery syrup can be boiled without danger of giving the milk a cooked flavor.

CHAPTER V

CONDENSING

From the ground well in the well room the sweetened milk is drawn into the vacuum pan, where it is condensed under reduced pressure. The vacuum pan is usually located on the second floor over the well room, or in the well room itself, in which case it is elevated above the floor six to eight feet. The vacuum pan is connected with the vacuum pump, which should be installed near the pan.

Description of the Vacuum Pan.—The vacuum pan is a retort in which the milk is heated and evaporated in partial vacuum. The origin of the term "pan" has not been satisfactorily explained. In the early and experimental days of the manufacture of condensed milk, the milk was evaporated in open kettles, called pans.

It is probable that the name of this primitive apparatus was passed on to the more perfected machinery now in use.

The vacuum pans are constructed of copper, iron, steel or bronze. Practically all of the vacuum pans used for condensing milk are made of copper throughout; they are of various styles and sizes. The predominating size used in milk condenseries is the "six-foot pan." By the term six-foot is meant a retort measuring six feet in diameter.

There are two general types of vacuum pans on the market; pans that are relatively wide in diameter and shallow in depth, and pans of relatively narrow diameter and which have a deep body. Both types are claimed, by their respective manufacturers, to have special advantages, such as ease of operation, uniformity of action, economy of fuel and of water, and rapidity of evaporation; the opinions of the users of these pans are also at variance concerning their relative merits.

The advocates of the wide, shallow pan claim that this type of pan makes possible such an arrangement of the heating surface as to take care of the maximum amount of milk with the minimum depth of milk over the heating surface and that this arrangement is most desirable. They hold that because the wide and shallow pan offers a larger area of evaporating surface, it therefore makes possible more rapid evaporation than the narrow, deep pan. They further emphasize that in the wide, shallow pan, the milk boils more quietly, is under better control and is less apt to be carried over into the condenser and lost, than in the narrow, deep pan.

The advocates of the narrow, deep pan claim that their type of pan increases the rapidity of evaporation because it causes the milk to pass over the heating surface more rapidly. When the pan is in operation, the boiling milk travels from the center of the bottom toward the periphery where it rises, rolls over the coils, and returns to the center. It is claimed that a pan with a shallow jacket, such as the narrow, deep pans have, causes the milk to roll over higher, especially if the coils are close to the periphery and leave plenty of vacant space in the center of the pan. This, in turn, means more rapid circulation of the milk, causing it to pass over the heating surface at greater speed, and oftener, which naturally enables the milk to utilize more heat and, therefore, to evaporate more quickly. Because in such pans the milk rolls over higher, they require a deeper body.

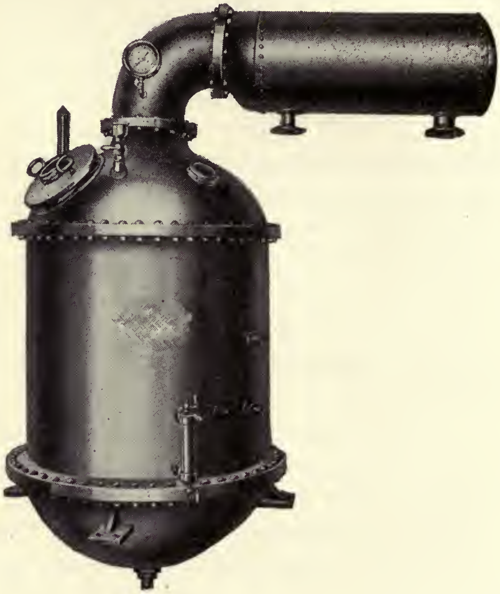

Fig. 13.
Vacuum pan and condenser
Courtesy of
Arthur Harris & Co.

The vacuum pan consists of four main parts, namely, the jacket, the body, the dome, and the condenser.

The jacket forms the bottom of the pan. The inside wall is copper, the outside cast iron. It is concave and in the case of a six-foot pan about two and one-half feet deep. It is equipped with two steam inlets and one outlet. The outlets for the coils are usually also brought through the jacket. In the center of the bottom there is an opening, two to three inches in diameter, for the discharge of the condensed milk and fitted with two valves and a nipple between, to facilitate the sampling of the condensed milk.

The body or vapor belt represents the main part of the pan. It is cylindrical, of varying height and is equipped with copper coils which have their outlets through the jacket. Their upper ends connect, through the body of the pan, with the main steam line. Most pans are equipped with two to three coils located at different elevations. Since steam should be turned into the coils only when they are covered with the milk, it is desirable to have several short independent coils rather than but one large one. This will give a larger range of the quantity of milk that can be condensed and increases the speed of evaporation. The coils vary in diameter from about three to five inches. The upper and outer coils are the larger ones. The diameter and length of the coils necessarily vary with and are limited by the capacity of the pan. The greater the total heating surface, consistent with easy access to all parts of the jacket and coils, the better. Other things being equal, the more square feet of heating surface, the less steam pressure, by the gauge, is required to furnish the necessary heat for maximum evaporation. This is important because high steam pressure in the jacket and coils means exposure of the milk to high temperature, which is undesirable. The heating surface should be sufficient to make possible the complete condensation of the steam in the jacket and coils. If the heating surface is inadequate, more steam has to be turned into the jacket and coils, in order to secure the necessary heat for rapid evapora-

Fig. 14. Vacuum pan and condenser
Courtesy of C. E. Rogers

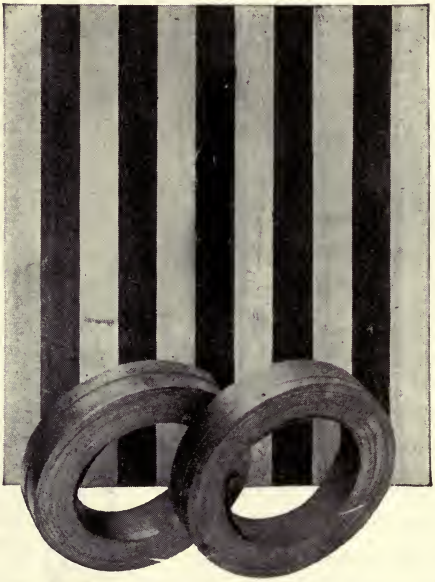

Fig. 15. Covering and insulation for vacuum pans
Courtesy of Arthur Harris & Co.

tion, than will condense; free steam will blow through and out of the coils, resulting in uneconomic and wasteful use of fuel, and jeopardizing the quality of the product. A properly constructed six-foot pan usually has not less than one hundred twenty to one hundred thirty square feet of heating surface.

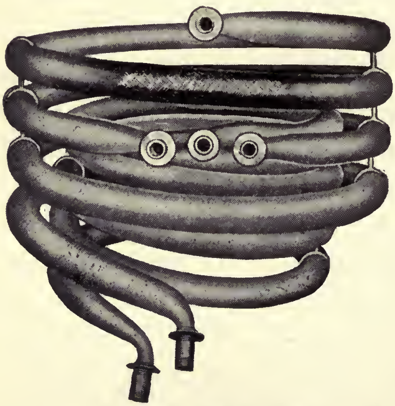

Fig. 16. Steam coils
Courtesy of Arthur Harris & Co.

In the latest improvement in coils each independent coil makes only one turn in the pan and the inner and outer coils have the same inlet and discharge and are placed on the same level. This permits of the installation of a larger number of independent coils, each placed at a different level. In this manner the coils can be utilized to better advantage. This is especially significant when the volume of milk in the pan is very small, making possible the operation of the lower coils independent of the upper coils and thereby avoiding the danger of burning the milk, which inevitably occurs when the heated coils are not completely submerged. This arrangement increases the heating efficiency of the pan, heat can be turned on the lowest coil almost immediately after starting operation, and toward the end of the batch, when the milk again boils low, some of the coils are still covered and can be used. The shorter length of these coils from inlet to exhaust also makes possible the simultaneous utilization of a greater volume of steam. These combined features materially increase the rapidity of evaporation and augment the capacity of the pan. These improved coils have the further advantage that their exhausts do not have to be carried through the jacket, but pass through the body of the pan.

Jacket and coils are connected independently with the direct steam main from the boiler. Each connection at the pan should carry a valve and a steam gauge on the pan-side of the valve. The main steam line and connections leading to pan should be properly insulated by proper pipe coverings, in order to supply the pan with as dry steam as possible.

The drips or discharge ends of the jacket and coils are connected with the boiler feed water tank. If the pan has sufficient heating surface and is operated properly, the drip ends of the jacket and coils should discharge warm water only, and not free steam. The jacket and coils should be free at the drip or discharge ends so that all condensation water may be quickly and continuously removed. This is necessary in order to make the most economical use of the steam and to secure high efficiency of evaporation. In order to guard against back pressure the drips may be equipped with suitable check valves.

Through the walls of the body of the pan also enters the milk draw pipe. This pipe connects with the hot well and through it the milk rushes into the pan. Immediately outside of the pan the milk pipe should be equipped with a valve to regulate the inflow. The size of the milk draw pipe and valve is governed by the capacity of the pan; usually two to three inches in diameter. Inside of the pan the milk pipe should be turned down. If this provision is not made, the milk shoots straight across the pan atomizing into a dense spray, which is partly drawn over into the condenser, causing loss of milk.

THE DOME rests on top of the body of the pan. It is equipped with a manhole, manhole cover, thermometer, vacuum gauge, sight glasses, lights and blow-down valve, or vacuum breaker. The manhole measures about fourteen to eighteen inches in diameter. It is closed by a solid brass cover with a well-fitting, ground surface flange. The cover carries a five-inch eye-glass or sight-glass through which the operator watches the boiling milk in the pan. The stem of the thermometer is enclosed in a brass casing and reaches to near the bottom of the pan. Some processors prefer a short thermometer which registers the temperature of the vapors instead of that of the milk. As both, the milk and the vapors are subjected to the same pressure, their respective temperatures are the same. The long-stem thermometer, the bulb of which is submerged in the milk, however, is more sensitive and registers changes in temperature more rapidly, because the milk is a better conductor of heat than the vapors. The vacuum gauge connects with the interior of the pan, and indicates the number of inches of vacuum. A mercury column may be used in the place of the vacuum gauge. In the rear of the dome there are two sight glasses. Through these the interior of the pan is illuminated by means of lamps, gas or electric lights. The "blow-down" valve, or vacuum breaker, serves to admit air into the pan in order to "break" the vacuum. This is necessary for readily drawing off the finished condensed milk. It is further needed to prevent the contents of the vacuum pan from being drawn over into the condenser, whenever the milk rises above a safe level.

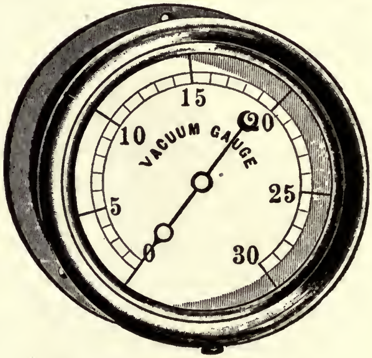

Fig. 17. Vacuum gauge
Courtesy of Arthur Harris & Co.

Fig. 18.
Thermometer for vacuum pan
Courtesy of Arthur Harris & Co.

A further accessory of the dome may be an automatic milk sampler. The sampler tube is carried through the wall of the dome and extends to near the bottom inside of the pan. Where this tube projects through the dome it is equipped with motor, pump, piston, striking cup and hydrometer. The striking cup at its upper end terminates in a small chamber equipped with a sight-glass through which the operator notes the position of the hydrometer.

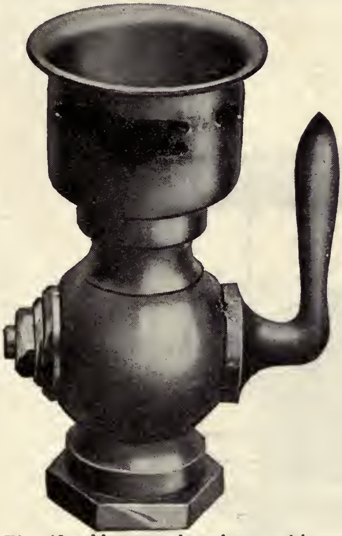

Fig. 19. Vacuum breaker or blow-down valve
Courtesy Arthur Harris & Co.

The Condenser.—The condenser is that portion of the condensing apparatus in which the vapors, rising from the boiling milk in the pan, are condensed to water. The condenser is attached to the dome of the pan. There are three types of condensers in use, the surface condenser, the barometric condenser and the wet-vacuum spray condenser.

THE SURFACE CONDENSER consists of a tube cylinder filled with brass tubes, mounted on a receiver. The water used for cooling circulates outside of the tubes and the vapors pass through the tubes, where they are chilled and condensed. This condenser has the advantage of enabling the operator to note the amount of condensation and to measure the amount of water actually condensed. The receiver at the bottom of the condenser should be so arranged that it can be drained at will and without interfering with or retarding the operation of the pan.

Fig. 20. The surface condenser
Courtesy of Buffalo Foundry & Machine Company

THE BAROMETRIC CONDENSER consists of a vertical cylinder of iron or brass, equipped with a spray jet, through which the cooling water enters the condenser. The vapors being drawn over from the violently boiling milk in the pan, are condensed by passing through this spray of cold water. This condenser discharges its water into a

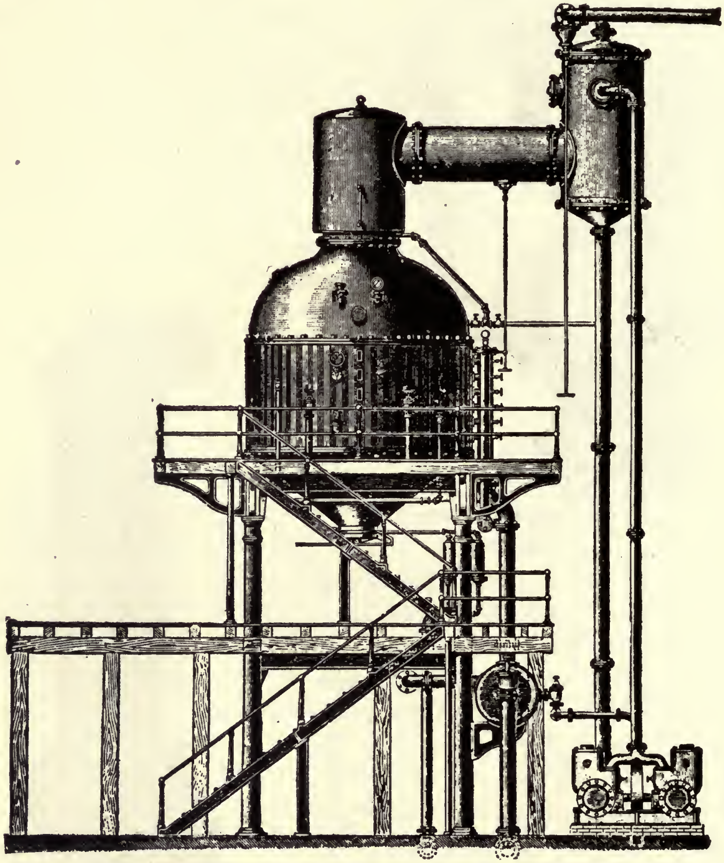

Fig. 21. Vacuum pan with dry vacuum barometric condenser
Courtesy of Arthur Harris & Co.

tight cistern in the ground. The condenser is placed so that its bottom flange is about thirty-five feet above the water level of the cistern in which the discharge pipe from the condenser terminates. The height of the condenser depends on the barometric pressure of the location where it is installed. The lower the altitude and, therefore, the higher the atmospheric pressure, the higher must the condenser be above the cistern. At the sea level, the atmospheric pressure sustains a water column about thirty-four feet high. This water column in the discharge pipe seals the vacuum and at the same time permits the water from the spray and the condensation water to escape automatically. The cistern in which the water column terminates should be of sufficient size to hold about one-third more water than the capacity of the entire length of the discharge pipe calls for and should have a large overflow into the sewer. When the pan is in operation and a uniform vacuum is maintained, the level of the water column remains constant and the excess water from the condenser overflows from the cistern into the sewer.

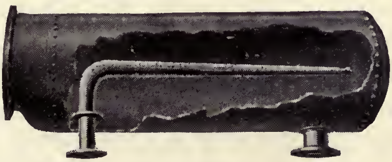

Fig. 22. The wet-vacuum spray condenser
Courtesy of Arthur Harris & Co.

THE WET-VACUUM SPRAY CONDENSER consists of a huge hollow cylinder of brass or iron, usually, but not necessarily, horizontal.

The horizontal spray condensers are usually equipped with a perforated spray pipe, placed lengthwise in the cylinder. This spray pipe should run close to the top side of the cylinder, so as to give the spray that escapes from the holes on the upper side of the spray pipe a chance to strike the top of the horizontal cylinder with force and to become atomized. The spray pipe connects at the end nearest the pan with the pipe supplying the cooling water. When the pan is in operation, a shower of cold water issues forth from the perforations of the spray pipe as the result of the reduced pressure in pan and condenser. The force with which the water escapes these perforations is further augmented by the fact that in most cases the water supply tank is located higher than the condenser. The hot vapors arising from the boiling milk in the pan are drawn over into the condenser, where they come in contact with the cold water spray and are condensed. The bottom of the condenser cylinder, at the end farthest from the pan is connected with the suction end of the vacuum pump through which the water and the condensed vapors in the condenser escape.

In the vertical spray condenser the condenser cylinder is upright, located either on top of the pan or at some distance, as is the case, for instance, where a catch-all is installed between pan and condenser. The interior arrangement of the vertical condenser varies somewhat with the different makes. The vertical condenser most widely used in American condenseries consists of a double insulated vapor tube setting on top of the pan. This insulated tube is surrounded by and connects with a spray chamber, which terminates at its top in a perforated metal plate and which has an opening in the side near the bottom that connects with the vacuum pump supplying the suction and that permits the escape of the condensed vapors and cooling water. The cooling water enters at the top of the condenser. Immediately underneath the water inlet it strikes a metal cone or disc which prevents the water from running into the vapor tube, and distributes it evenly over the perforated spray plate. The vapor rises into the vapor tube of the condenser and is drawn over into the spray chamber surrounding it, where the vapor is condensed by the spray of water issuing from the perforated spray plate which tops the spray chamber and which contains a large number of very small holes. As the water falls through these openings by gravity, the spray is uniform and constant and does not depend on the amount of water used, nor does it require water pressure on the condenser.

The chief difference between the wet-vacuum condenser and the barometric condenser is that in the wet-vacuum condenser the water from the condenser passes through the vacuum pump, while in the barometric condenser the water does not pass through the vacuum pump, but goes direct into the sewer and the vacuum is sealed by the barometric water column. So far as practical experience has shown, there is no material difference in the efficiency between these two types of condensers. The water column of the barometric condenser helps somewhat to maintain a uniform vacuum. It necessitates, however, the installation of the pan inconveniently high and requires somewhat more expensive machinery than is the case with the wet-vacuum condenser. The chief difference between both of these systems and the surface condenser is that, in the wet-vacuum and barometric condensers the condensed vapors mix with the cooling water, while in the surface condenser the condensed vapors are collected and carried off separately and without mixing with the cooling water. In the case of condensing liquids, the vapors of which are of commercial value, the surface condenser must be used. The surface condenser, however, is of relatively small capacity and the cooling water cannot be utilized as economically as in the case of the other systems. Where large quantities of vapors are to be handled and the vapors have no commercial value, as is the case in condensing milk, the barometric and wet-vacuum condensers are best suited; their operation utilizes the cooling water most economically.

CARE OF THE CONDENSER.—In the operation of the spray and jet condenser, special attention should be paid to the condition of the spray pipe, or spray plate. Especially, when the water used contains much organic matter, as is the case with water from a creek, pond or lake, there is a tendency of the spray pipe becoming filled and coated with slimy organic matter, causing the perforations to clog. This renders the distribution of the spray irregular and the control of the pan difficult. It causes great waste of water because much of the water is discharged from the condenser and lost without coming into direct contact with the vapors. The water is, therefore, not utilized economically and the difference between the temperature of the vapors and the discharge of the condenser is excessive. In order to avoid this the condenser should be cleaned out thoroughly at least once a week, or oftener if necessary, to keep the pores of the spray pipe free from obstructions. It is advisable to install condensers equipped with a manhole on top or at the end, otherwise access to the spray pipe is not sufficiently convenient to insure frequent inspection and thorough cleaning by the average operator.

The Expansion Tank, Catch-All, or Milk Trap.—This is a tank frequently installed between the dome of the pan and the condenser. Its purpose is to collect and reclaim any milk that may be carried over from the pan and to prevent its escape and loss through the condenser.

If the pipe through which the milk enters the pan is turned down and its end is carried to near the bottom of the pan, so as to avoid the formation of excessive milk spray, if the pan is operated carefully and if the milk is kept at a reasonably low level, there is very little danger of milk being carried over into the condenser in quantities sufficient to be of any consequence. Under these conditions the installation of a special milk trap between the pan and the condenser for the purpose of collecting the escaping milk spray and carrying it back to the pan is, therefore, an unnecessary expense.

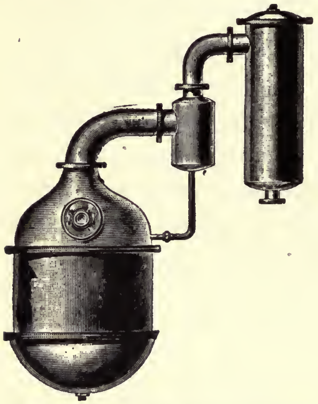

Fig. 23. Vacuum pan with milk trap
Courtesy of Arthur Harris & Co.

If the pan is small in comparison to the amount of milk to be condensed, and if it is forced beyond its intended capacity so that the milk boils up high, there usually is considerable loss of milk, as indicated by the foaminess and milky color of the exhaust of the vacuum pump. In such cases the mechanical loss of an average size batch may amount to several hundred pounds of milk. In order to not lose this milk, a milk-trap or catch-all may be installed between the pan and the condenser. The vapors loaded with the milk spray enter the trap near the top. The spray drops to the bottom of the trap, while the vapors are drawn over into the condenser, where they are condensed as usual. This trap may be constructed of sufficient size so as to serve as a reservoir to collect all the milk that is carried over, and at the conclusion of the process the contents of the trap are drawn from the bottom and are condensed with the next batch; or the bottom of the trap may be connected with the pan so that the milk thus carried over flows back into the pan automatically. In this case a small trap only is necessary.

It should be understood that the milk trap is only a remedy and not a preventive. Where the capacity of the pan is in proportion to the amount of milk to be condensed, as it should be, and where the pan is operated properly, the trap is unnecessary. The trap is an additional piece of apparatus to be kept clean. Unless it is so constructed that access can be had to all parts of its interior and unless it really is kept clean at all times, it may become a serious source of contamination.

The Vacuum Pump.—The vacuum pump is, strictly speaking, not a part of the vacuum pan, but its intimate connection with the pan makes it necessary to briefly consider it at this point. The suction end of the vacuum pump is connected with the end of the condenser farthest from the pan. The vacuum pump exhausts the pan, forming a partial vacuum. There are principally two types of vacuum pumps used in the milk condensery, the dry-vacuum pump and the wet-vacuum pump. The dry-vacuum pump is used in the factories with the dry-vacuum system, i. e., where the cooling water and the condensation water escape to the sewer direct and without passing through the vacuum pump, as is the case with the surface condenser and the barometric condenser. The wet-vacuum pumps are used with the wet-vacuum system, where the cooling water and the condensation water pass through the cylinder of the pump. The dry-vacuum pumps have the advantage of permitting the operation of the machine at a higher piston speed than the wet-vacuum pumps in which the water must be displaced at the end of each stroke. The cylinders of the dry-vacuum pump are cooled by water jackets. The initial cost of the dry-vacuum pumps, however, is greater than that of the wet-vacuum pumps.

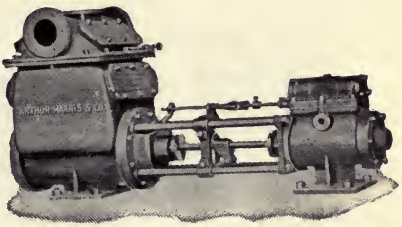

Fig. 24. Wet-vacuum pump
Courtesy of Arthur Harris & Co.

The efficiency of the vacuum apparatus depends very largely on the vacuum pump. Rapid evaporation at a relatively low temperature necessitates the maintenance of a high vacuum. The type, material, construction, workmanship, installation and operation of the vacuum pump should be such as to insure the maximum efficiency.

The pump should be placed on a good foundation and as near the vacuum pan as practicable in order that the full benefit of the vacuum may be realized. The suction pipe and all connections must be tight. The suction pipe must be of the size directed by the manufacturer, as short as possible and with few and easy bends. The grade of the suction pipe should be uniform in order to avoid air pockets.

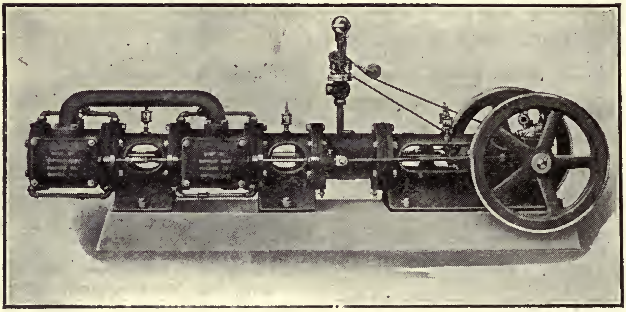

Fig. 25. Dry-vacuum pump
Courtesy of Buffalo Foundry & Machine Company

The water should be turned into the condenser before the vacuum pump is started. The pump should not run at a higher speed than is necessary to secure the required vacuum. Excessive speed means high steam consumption and heavy wear and tear on the pump. The amount of water supplied to the condenser should be regulated to suit the requirements. Ordinarily, and with a vacuum of twenty-five to twenty-six inches, the temperature of the condenser discharge should be about 110 degrees F. A lower temperature would cause excessive and uneconomic use of water. The basin on the vacuum cylinder should be kept filled with water to prevent admission of air to the cylinder through the stuffing box, and the spray pipe or jet in the condenser should be inspected often to make sure that the perforations are not clogged. The stuffing box of the cylinder should be well packed with a good quality of packing and the steam cylinder well oiled. Start the pump slowly. Belt-driven pumps, especially those equipped with a fly-wheel, insure greater uniformity of speed than direct-acting, steam-driven pumps. Steam-driven pumps should be furnished with a high grade governor. The vacuum pump should have a capacity proportionate to the size of the vacuum pan, amount of heating surface, steam pressure and temperature of condensing water.

Science and Practice of Evaporating in Vacuo.—PURPOSE OF CONDENSING IN VACUO.—The important advantages gained by evaporating milk under reduced pressure, or in vacuo, are: economy of evaporation, rapidity of evaporation, low temperature and large capacity of apparatus. All of these features are essential in the successful condensing of milk.

Rapid evaporation cannot take place until the milk is brought to the boiling point and is kept there until evaporation is completed. Under atmospheric pressure and at the seal level, the boiling point of water is 212 degrees F., the boiling point of milk is very slightly higher, about 214 degrees F. Evaporating of milk under atmospheric pressure in an open kettle, however, is a relatively slow process, requiring a long time, much fuel and large apparatus. Furthermore, exposure of the milk to 212 to 214 degrees F. long enough to complete evaporation would render the product unsuitable for market. The properties of some of its ingredients are altered, the product would assume a dark color and a marked cooked flavor as the result of the effect of heat. All of these objections are minimized and partly avoided by lowering the boiling point of milk. These objections, however, do not apply to evaporation under atmospheric pressure by film treatment, as is the case with the Continuous Concentrator described in Chapter XIV, page 133.

Relation of Pressure to Boiling Point.—The temperature at which milk boils depends on the pressure to which it is exposed.

The table below shows the boiling point of water at pressures ranging from atmospheric pressure at the sea level (14.72 pounds per square inch) to a complete vacuum.

BOILING POINTS OF WATER AT DIFFERENT VACUA.

Absolute pressure per square inch	Vacuum inches of mercury column	Vacuum millimeters of mercury column	Temperatures of boiling point of water, F.	Temperatures of boiling point of water, C.
14.720	0.00	00	212.00	100.00
14.010	1.42	36	209.55	98.5
13.015	3.45	88	205.87	96.8
12.015	5.49	139	201.96	94.3
11.020	7.52	191	197.75	91.9
10.020	9.56	243	193.22	89.5
9.020	11.60	295	188.27	86.75
8.024	13.63	346	182.86	83.7
7.024	15.67	398	176.85	80.5
6.024	17.70	450	170.06	76.8
5.029	19.74	502	162.28	72.5
4.029	21.78	553	153.01	67.2
3.034	23.81	605	141.52	60.8
2.034	25.85	657	126.15	52.3
1.040	27.88	708	101.83	38.7
.980	28.00	712	100.00	37.8
.735	28.50	724	90.00	32.2
.544	28.89	734	80.00	26.7
.402	29.18	741	70.00	21.1
.294	29.40	747	60.00	15.6
.216	29.56	751	50.00	10.0
.162	29.67	754	40.00	4.4
.127	29.74	756	32.00	

[1] By courtesy of the Buffalo Foundry & Machine Company.

The pressure or, correctly speaking, the vacuum, is expressed in terms of inches of mercury which the atmospheric pressure sustains. The mercury column is not a direct measure of the pressure, but it shows the difference between the atmospheric pressure and the absolute pressure in the vacuum chamber. The atmospheric pressure at the sea level is 14.7 pounds per square inch. It sustains a mercury column in an absolute vacuum of 30 inches at 62 degrees F., and of 29.922 inches at 32 degrees F. The absolute vacuum may be calculated by multiplying the atmospheric pressure by the factor 2.04. In case there is only a partial vacuum the mercury column sustained is lowered to the extent of the absolute pressure in the vacuum pan. The absolute pressure may be calculated as follows:

AV = Absolute vacuum which is thirty inches at the sea level.
V = Actual vacuum.
P = Atmospheric pressure which is 14.7 pounds at the sea level.
AP = Absolute pressure.

Example: The actual vacuum in the pan is 25 inches at the sea level. What is the absolute pressure?

$$\frac{P \times (AV - V)}{AV} = \frac{14.7 \times (30 - 25)}{30} = 2.45 \text{ pounds of absolute pressure per sq. inch.}$$

Relation of Altitude to Atmospheric Pressure.—At altitudes higher than the sea level, the atmospheric pressure is reduced and the mercury column is lowered, though the absolute pressure in the vacuum pan may be the same. Therefore, in factories located at high altitudes the mercury column will show fewer inches of vacuum at a given temperature and with a given absolute pressure.

The following table shows the barometric reading in inches of mercury column and the atmospheric pressure in pounds per square inch at different altitudes:

[1] BAROMETRIC READING CORRESPONDING WITH DIFFERENT ALTITUDES.

Barometric reading in inches of mercury	Atmospheric pressure in pounds per square inch	Altitude above sea level in feet	Barometric reading in inches of mercury	Atmospheric pressure in pounds per square inch	Altitude above sea level in feet
30.0	14.72	0	23.5	11.54	6412
29.7	14.60	264	23.0	11.30	6977
29.5	14.47	441	22.5	11.05	7554
29.2	14.35	710	22.0	10.80	8144
29.0	14.23	890	21.5	10.56	8747
28.7	14.11	1163	21.0	10.31	9366
28.5	13.98	1347	20.0	9.81	10648
28.2	13.86	1625	19.0	9.32	11994
28.0	13.74	1812	18.0	8.82	13413
27.5	13.50	2285	17.0	8.33	14914
27.0	13.26	2767	16.0	7.84	16506
26.5	13.02	3257	15.0	7.35	18201
26.0	12.77	3758	14.0	6.86	19996
25.5	12.53	4268	13.0	6.37	21891
25.0	12.27	4787	12.0	5.88	23886
24.5	12.03	5318	11.0	5.39	25981
24.0	11.78	5859			

[1] By courtesy of the Buffalo Foundry & Machine Company.

In the following table may be found the altitudes of various cities in the United States:

ALTITUDE IN FEET OF VARIOUS CITIES IN THE UNITED STATES.

By Courtesy of United States Department of Agriculture.

Akron, Ohio	940	Los Angeles, Cal.	267
Albany, N. Y.	22	Louisville, Ky.	453
Atlanta, Ga.	1032	Memphis, Tenn.	256
Baltimore, Md.	92	Milwaukee, Wis.	593
Birmingham, Ala.	600	Minneapolis, Minn.	812
Boston, Mass.	16	New Haven, Conn.	10
Buffalo, N. Y.	583	New Orleans, La.	6
Burlington, Vt.	112	New York City	54
Butte, Mont.	5555	Oklahoma City, Okla.	1197
Charleston, S. C.	12	Omaha, Neb.	1016
Chattanooga, Tenn.	672	Philadelphia, Pa.	42
Chester, Pa.	22	Phoenix, Ariz.	1082
Chicago, Ill.	590	Pittsburgh, Pa.	743
Cincinnati, Ohio	490	Providence, R. I.	11
Cleveland, Ohio	582	Richmond, Va.	51
Dayton, Ohio	740	Rochester, N. Y.	510
Denver, Colo.	5183	St. Louis, Mo.	455
Dallas, Tex.	430	Salt Lake City, Utah	4238
Des Moines, Iowa	805	San Francisco, Cal.	15
Detroit, Mich.	588	Santa Fe, N. M.	6952
Duluth, Minn.	609	Seattle, Wash.	10
Houston, Tex.	46	South Bend, Ind.	717
Indianapolis, Ind.	708	Spokane, Wash.	1908
Ithaca, N. Y.	411	Tampa, Fla.	15
Kansas City, Mo.	750	Washington, D. C.	25
Knoxville, Tenn.	890	Wichita, Kan.	1294
Lexington, Ky.	955	Vicksburg, Miss.	196
Little Rock, Ark.	264		

According to Kent[1] the relation of altitude to atmospheric pressure per square inch is as follows:

Altitude	*Pounds Pressure Per Square Inch*
At sea level	14.7
¼ mile above sea level	14.02
½ mile above sea level	13.33
¾ mile above sea level	12.66
1 mile above sea level	12.02
1¼ miles above sea level	11.42
1½ miles above sea level	10.88
2 miles above sea level	9.80

"For a rough approximation we may assume that the pressure decreases one-half pound per square inch for every 1,000 feet of ascent."

The absolute pressure in the pan of a factory located at Omaha, Neb., with an altitude of 1,016 feet above sea level, and condensing in an actual vacuum of twenty-five inches, would then be as follows:

Atmospheric pressure $= 14.7 - .5 = 14.2$ pounds per square inch.

Absolute vacuum $= 14.2 \times 2.04 = 28.97$ inches.

Absolute pressure $= \dfrac{14.2 \times (28.97 - 25)}{28.97} = 1.95$ pounds per square inch.

RELATION OF STEAM PRESSURE IN JACKET AND COILS, WATER IN CONDENSER, TEMPERATURE IN PAN AND VACUUM, TO RAPIDITY OF EVAPORATION.—The temperature of the vapors in the vacuum pan depends directly upon the pressure or vacuum under which they are generated. The more nearly complete the vacuum and, therefore, the lower the pressure, the lower the temperature, and, other conditions being the same, the more rapid the evaporation. The pressure in turn is governed by the capacity of the vacuum pump, the tightness of the joints, the steam pressure in jacket and coils and the amount and temperature of the water in the condenser.

[1] Mechanical Engineer's Pocket-Book, p. 581.

With a low capacity vacuum pump, or a pump running irregularly, or too slow, or too fast, and with leaky joints, the vacuum will always be low, and the pressure and temperature relatively high. Under these conditions the pan is difficult to operate and evaporation is slow.

With the above conditions under control and properly adjusted, the temperature and the rapidity of evaporation depend on the steam pressure in the jacket and coils and on the amount and temperature of the water used in the condenser.

Twenty-five pounds of steam pressure in the jacket and coils has been found to be about the maximum that can safely be used. With this steam pressure the milk coming in direct contact with the heating surface is exposed to about 267 degrees F. and there is a tendency for some of it to bake or burn on, which is undesirable. The walls of the jacket and coils are also subjected to considerable strain, since they are surrounded by an almost complete vacuum. Then again, if the pan has the proper amount of heating surface the capacity of the condenser and the water supply are in most cases insufficient to take care of and condense the vapors arising from the boiling milk in the pan, when the steam pressure in jacket and coils approaches or exceeds twenty-five pounds.. Most condenseries operate their pans with twelve to twenty pounds of steam pressure in jacket and coils. In the operation of some pans not more than about five pounds steam pressure can be used economically in jacket and coils, because the use of more steam causes the steam to blow through and out of the coils. This may be due to relatively large heating surface, or small evaporating capacity due to a small capacity pump or limited water supply to condenser.

The capacity of the condenser used in milk condenseries is very largely dependent on the water supply. Whenever the condenser is forced beyond its capacity, by using excessive steam in jacket and coils, the vacuum drops, the temperature rises and the process of evaporation is retarded.

The higher the vacuum the more rapid the evaporation. A rise in the steam pressure in the jacket and coils increases the rapidity of evaporation only as long as enough water passes through the condenser to maintain a high vacuum. As soon as the steam pressure in the jacket and coils reaches the point where the water in the condenser fails to promptly reduce the vapors, the vacuum drops, the temperature in the pan rises and evaporation is checked.

The condensing of milk requires immense quantities of water; experience has shown that it takes from two to three gallons of water to condense one pound of fresh milk. The water supply is one of the weakest links in most condenseries, so that economy of water is one of the important factors to be considered. The steam pressure in the jacket and coils should, therefore, be so regulated as to make it possible to maintain the maximum vacuum consistent with reasonably economic use of water. The experience of the best pan operators is that about fifteen pounds of steam pressure in the jacket and coils and a vacuum of twenty-five inches is practically the maximum that can be maintained under average conditions without taxing the usual water supply beyond its capacity. With a vacuum of twenty-five inches the temperature in the pan is about 135 degrees F., the temperature varying somewhat with the altitude of the factory. In some condenseries the temperature of the pan is kept at 150 degrees F. This practice may economize the water a trifle better, but the rapidity of evaporation is considerably lower.

Condensing at temperatures lower than 130 degrees F., without reducing the steam pressure in the jacket and coils, increases the rapidity of evaporation, but taxes the water supply beyond the reach of most condenseries. So much water has to be used in the condenser that it is not used economically, as is shown by the relatively low temperature of the water discharging from the condenser. The temperature of the condenser discharge bears a direct relation to the temperature of the vapors in the pan. Observations made in various factories and under different conditions by Hunziker and others showed that the condenser discharge was anywhere from 5 to 25 degrees F. lower in temperature than the vapors in the pan, the difference averaging about 15 degrees F.

The smaller the difference in temperature between the condenser discharge and the vapors in the pan, the more economic is the use of the water and vice versa. It is not advisable under average conditions to so operate the pan that the temperature of the condenser discharge drops below 110 degrees F., because of the wasteful use of water under such conditions.

The condensing of one pound of milk requires about one pound of steam and eighteen to twenty-five pounds of water. The quantity of heating steam used for condensing in vacuum is practically the same as that required by evaporating in open pans. In order to use the steam economically the pan should be so operated as to make possible its complete condensation by the time it leaves the jacket and coils. Whenever so much steam is used that it blows through and out of the jacket and coils without being condensed, there is great waste of fuel. For further details on this point see "Description of the Vacuum Pan."

Starting the Pan.—Before drawing the milk into the pan, the pan should be thoroughly rinsed with water, then steamed until the temperature rises to about 180 degrees F. or above. Then the manhole cover is put in place, all the air valves are closed, water is turned into the condenser and the vacuum pump is started. When the vacuum gauge shows over twenty inches of vacuum, the pan is ready for the milk.

Operating the Pan.—The valve of the milk pipe leading to the pan is now partly opened. The milk enters the pan automatically as the result of the reduced pressure in the pan. When the milk covers the jacket, steam is gradually turned into the jacket. As each coil becomes submerged in milk, the coils are charged with steam. At no time should steam be turned on the jacket and coils when they are not completely covered with milk, as such action would cause the milk to stick to and burn on the heating surface, the milk would assume a burnt flavor, it would become permeated with black specks and the evaporation would be retarded. On the start, but a few pounds of steam pressure should be used in the jacket and coils, to avoid burning, owing to the presence in the milk of considerable air. As the milk becomes more concentrated and settles down to uniform boiling, the steam pressure may be gradually increased until it reaches the maximum. The maximum pressure permissible must be governed by the amount of heating surface, the capacity of the vacuum pump and the temperature and amount of water available for use in the condenser. Under average conditions about fifteen pounds of steam pressure may be safely used.

During the early stages of the process, when the milk is of low density, the evaporative duty is high, probably about twenty-five to thirty-five pounds per square foot of heating surface with ten pounds of steam pressure. This gradually decreases and is lowest toward the end of the process.

When enough milk is in the pan to completely cover the jacket and coils, the milk intake should be reduced and regulated in accordance with the rate of evaporation. The milk is drawn into the pan continuously, but only as fast as it evaporates. It should be kept as much as possible at a constant level, and this level is preferably as low as is consistent with complete covering of the upper coil.

In order to secure maximum rapidity of evaporation, the vacuum pump should run at the proper speed and its operation should be uniform, a uniform vacuum and temperature should be maintained and the milk should be prevented from rising to an abnormally high level in the pan.

Prevention of Accidents.—The operator should pay strict attention to the pan in order to avoid loss of milk due to accidents. He should watch the water supply and govern its use accordingly. If the water supply becomes exhausted, air is liable to be drawn into the pan through the condenser. This will cause the milk to drop suddenly and then rise in a body, threatening to escape through the condenser. Whenever air in considerable quantities is allowed to enter the pan while in operation, be it as the result of lack of water, or through any other cause, or when the vacuum pump is allowed to stop and live steam is turned into the milk in the pan, as is the case when the milk is superheated, the escape of milk may be avoided by immediately shutting the steam inlet to the jacket and coils, by closing the milk intake and by slightly opening the blow-down valve whenever the milk rises dangerously high. By skillful manipulation of the blow-down valve until the milk again settles down to uniform boiling, loss can be avoided and the process can be continued in the normal way.

By the time all the milk is in the pan, condensation is nearly completed, and from ten to twenty minutes further boiling usually gives the milk the desired density. Toward the end of the process the steam pressure in jacket and coils should be reduced to about five pounds or less. When the milk approaches the desired density, it is comparatively heavy and viscous and boils less vigorously. It therefore is more directly exposed to the heating surface. In the case of excessive steam pressure, its quality is jeopardized. If the batch is small so that the level of the milk drops below some of the coils, steam to the exposed coils should be turned off entirely.

Chapter VI.

STRIKING OR FINISHING THE BATCH

Definition.—When the boiling milk in the vacuum pan approaches the desired degree of concentration, the batch is "struck." The term "striking" is applied to the operation of sampling the condensed milk and testing the sample for density. This term very probably referred, originally, to the meaning of "striking the batch right," that is, stopping the process at the proper time, or when the milk is neither too thick nor too thin. It then expressed the result of the operation, while now it is used to mean the operation itself.

Ratio of Concentration.—Sweetened condensed milk intended for canned goods has a specific gravity of 1.28 to 1.30. This density is reached usually when the ratio of concentration is about 2.5:1, i. e., 2.5 parts of fresh milk are condensed to one part of condensed milk, assuming that about sixteen pounds of sucrose have been added to every one hundred pounds of fresh milk.

Occasionally the ratio of concentration is based on the proportion of water evaporated, in which case it is obviously much higher than when based on the amount of milk required to make one pound of condensed milk, because the added cane sugar takes the place of its own weight of water, and thereby acts as a diluent of the condensed milk. Thus let us assume that 16 pounds of cane sugar are added to every 100 pounds of fresh milk and that it takes 250 pounds of fresh milk to make 100 pounds of sweetened condensed milk., 100 pounds of sweetened condensed milk, therefore, contain $16 \times 2.5 = 40$ pounds of cane sugar. Using the sugar-free finished product as the basis for calculation, then, the ratio of concentration would be: $\frac{250}{(100\text{-}40)} = 4.17$ to 1.

Instead of giving the ratio of concentration, this basis of calculation determines the ratio of evaporation only. The results are, therefore, erroneous and misleading. It does not materially matter whether the diluent in the condensed milk is water or cane sugar, or both; the really important factor is the per cent milk solids in the condensed milk as compared with the per cent solids in the original fresh milk, and this relation is solely determined by the amount of fluid milk required to make one pound of condensed milk, or by the true and actual ratio of concentration. If it takes 2½ pounds of fresh milk for every pound of condensed milk, then the ratio of concentration is obviously 2.5 to 1 and not 4.17 to 1.

Methods.—To know just when the proper degree of concentration has been reached is difficult and requires patience. It is here where the processor can easily make or lose his wages. There are various indications reminding the observant processor that the milk in the retort is nearly "done," viz., time consumed for condensing, time elapsed since all the milk has been "drawn up," amount of condensed milk left in the pan and, most of all, the appearance and behavior of the boiling milk itself. Milk that has been sufficiently condensed assumes a glossy, glistening lustre, it boils over from the periphery towards the center, forming a small nucleus or puddle of foam in the center of the pan. An experienced and observant operator knows within a few minutes when the milk is condensed enough. This does not mean, however, that he should wait until the last minute before he "strikes" the batch, for even the most skillful and experienced processors are easily deceived by the mere appearance of the condensed milk through the sight glass.

The degree of concentration may be more accurately determined by taking a sample from the pan and testing it by various methods, such as by weighing a definite quantity of condensed milk on a sensitive scale, by the use of a resistance apparatus, or by the use of a specially constructed hydrometer. Of these the Beaumé hydrometer has been found the most suitable to use under average factory conditions.

Mechanical devices and methods, such as the above, can be depended upon, when all the conditions influencing the specific gravity of the liquid are under control, and when there is plenty of time for their manipulation. When the boiling and rapidly evaporating milk in the retort is approaching the proper density, however, quick action is essential. One minute over- or under-condensing may cause the milk to be either too thick or too thin for the market and may necessitate the "re-running" of the entire batch. These instruments are, therefore, often inadequate at the time they are needed most. There is not time to carefully measure and weigh out a sample of sweetened condensed milk, nor can the processor always wait until the hydrometer has found its equilibrium in as viscous a fluid as sweetened condensed milk. Again, the density or specific gravity of the finished product depends, outside of the degree of concentration, on many and fluctuating conditions, such as amount of heat applied toward the end of the process, the temperature of the sample when drawn and the per cent of fat and cane sugar in the condensed milk. It is for these reasons that arbitrary mechanical instruments and methods are not uniformly satisfactory and are liable to yield misleading results; while they are very desirable to use as a check, the experienced eye and good judgment of the processor are all essential. The following factory methods have been found satisfactory and reasonably reliable:

Draw a sample from the pan into a tin dipper, lower the dipper into a pail of ice water or snow. Stir the condensed milk with a metal-back thermometer until the condensed milk is cooled to 70 degrees F. Note the thickness of it. Or, finish the batch at a constant temperature, say 120 degrees F. Draw a sample into a tin cup and note the thickness by examining the milk when pouring from a teaspoon. The transparency of the milk when thus held against the light and the manner in which the milk piles up in the cup furnish a practical index to its density. The last method is preferable because of its greater rapidity.

USE OF BEAUMÉ HYDROMETER.—Beginners and inexperienced operators do well to take numerous samples from the batch in the operating pan and to start sampling early, so as to avoid over-condensing. The use of a Beaumé hydrometer, especially constructed for sweetened condensed milk, graduated from 30 to 37 degrees B. and with subdivisions of one-tenth degrees, is an additional safeguard to insure accuracy and uniformity of thickness. No definite figure at which the Beaumé hydrometer should be read can be stated that would show the proper density under all conditions. The Beaumé reading of sweetened condensed milk of the proper concentration varies with such factors as per cent of fat, per cent of sucrose and per cent solids, ratio of concentration and temperature of the condensed milk when the reading is taken. However, for general guidance, it may be stated that condensed milk of proper density, made from fresh milk of average richness and containing sucrose at the ratio of sixteen pounds of sugar per one hundred pounds of fresh milk, will show a Beaumé reading of about 33.5 degrees B. at 60 degrees F., or about 32 degrees B. at 120 degrees F. Sweetened condensed skim milk containing approximately 40 per cent sucrose will show a Beaumé reading at 60 degrees F. of about 37 degrees B., or about 35.5 degrees B. at 120 degrees F.

Fig. 26.
Beaumé hydrometer for sweetened condensed milk
Courtesy C. J. Tagliabue Mfg. Co.

CORRECTION OF HYDROMETER READING FOR TEMPERATURE.—The Beaumé hydrometers used in American condenseries are graduated to give correct readings at 60 degrees F. If the readings are to be correct, or if it is desirable to convert them into specific gravity, the condensed milk should have a temperature of 60 degrees F. Where this is not convenient, the observation may be made at any temperature convenient and the reading corrected as follows:

When the temperature is above 60 degrees F. multiply the difference between the observed temperature and 60 degrees F. by the factor .025 and add the product to the observed reading of the Beaumé hydrometer. When the temperature of the observed reading is below 60 degrees F. the corresponding product is deducted.

Example: Beaumé reading at 120 degrees F. is 31.2. Corrected reading is $31.2 + [.025 \times (120 - 60)] = 32.7$.

The specific gravity may be calculated when the Beaumé reading is known, by using the following formula:

$$\text{Specific gravity} = \frac{144.3}{144.3 - \text{B.}}\text{; B.} = \text{Beaumé reading}$$

Example: Beaumé reading, at 60 degrees F. is 33.1.

$$\text{Specific gravity} = \frac{144.3}{144.3 - 33.1} = 1.2976$$

In the following table are assembled figures showing the specific gravity of sweetened condensed milk of different Beaumé degrees, varying from 28 degrees B. to 37.8 degrees B.

SPECIFIC GRAVITY OF SWEETENED CONDENSED MILK OF DIFFERENT BEAUMÉ DEGREES

Beaumé at 60 degrees F.	Specific Gravity	Beaumé at 60 degrees F.	Specific Gravity
28.0	1.2407	33.0	1.2965
.2	1.2428	.2	1.2988
.4	1.2449	.4	1.3011
.6	1.2471	.6	1.3034
.8	1.2493	.8	1.3058
29.0	1.2515	34.0	1.3082
.2	1.2536	.2	1.3106
.4	1.2558	.4	1.3130
.6	1.2580	.6	1.3154
.8	1.2602	.8	1.3178
30.0	1.2624	35.0	1.3202
.2	1.2646	.2	1.3226
.4	1.2668	.4	1.3250
.6	1.2690	.6	1.3274
.8	1.2713	.8	1.3299
31.0	1.2736	36.0	1.3324
.2	1.2758	.2	1.3348
.4	1.2780	.4	1.3372
.6	1.2803	.6	1.3397
.8	1.2826	.8	1.3422
32.0	1.2849	37.0	1.3447
.2	1.2872	.2	1.3472
.4	1.2895	.4	1.3497
.6	1.2918	.6	1.3522
.8	1.2941	.8	1.3548

Sampling of Batch.—The samples can be drawn from the pan by operating the two valves at the bottom explained under "Description of Vacuum Pan." While the milk is condensing, the partial vacuum in the pan makes impossible the drawing off of the sample by simply opening the outlet. Instead of causing the milk to come out, air would rush in with violent force and would cause the milk in the pan to be thrown over into the con-

Fig. 27. A convenient device for sampling the condensed milk in the pan

Courtesy of Arthur Harris & Co.

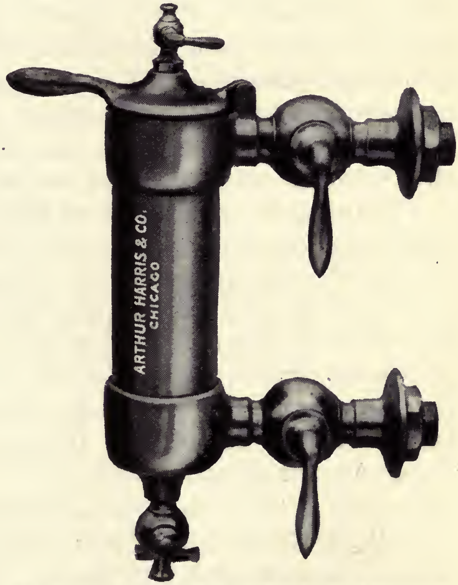

Fig. 28. A convenient device for sampling condensed milk in the pan
Courtesy of Arthur Harris & Co.

denser, besides dangerously jolting the machinery. For this reason the outlet is equipped with two valves, both of which are closed during the condensing process. For taking samples, open the upper valve. This allows the condensed milk to run into the nipple between the two valves. Now close the upper valve and open the lower one. The milk will run out freely. The first sample should be rejected, as it may contain water caught in the nipple.

For greater convenience and increased rapidity of sampling, especially constructed sample testers or striking cups, attached to the side of the body of the pan may be used. The latest invention for facilitating the sampling and striking is the automatic milk striker designed by Mojonnier Bros. Co., Chicago. This ingenious contrivance consists of a motor-driven piston pump. The suction tube carrying the piston extends from the dome of the pan into the boiling milk. This tube projects at its upper end through the wall of the dome and overflows into a hydrometer cylinder. This cylinder carries at its upper end a chamber permitting unhindered motion of the hydrometer and the end of this chamber which faces the operator is equipped with a sight glass and a light. In the cylinder reposes a Beaumé hydrometer. Whenever the operator desires to know the density of the condensed milk in the pan, he starts the motor. The pump immediately fills the cylinder and the hydrometer shows the density or Beaumé reading.

Drawing off the Condensed Milk.—As soon as the evaporation is completed, the steam is shut off from the jacket and coils, the water valve is closed, the vacuum pump stopped and the vacuum broken by opening the "blow-down" valve. The manhole cover is then removed and the vacuum pump started again in order to remove the hot air over the milk. The milk is drawn into 40-quart cans or into tanks or cooling vats. The condensed milk should be drawn from the pan as rapidly as possible to prevent its superheating while in the pan. In some factories a wire mesh or cloth strainer is attached to the outlet of the pan, so that the condensed milk is strained before it runs into the cans. This practice is unnecessary and objectionable, as it tends to retard the removal of the milk from the pan.

COOLING

The sweetened condensed milk, as it comes from the vacuum pan, has a temperature of about 115° F. to 130° F. If it were allowed to cool naturally, or on its own accord, i. e., if no effort were made to cool it promptly, it would superheat and this would cause it to become thick and cheesy in a short time. It is, therefore, essential that it be cooled at once. Formerly this was done by drawing the milk from the pan into 40 quart cans, setting these filled cans in tanks with ice water and stirring the condensed milk with a stick.

This was a very crude method, it involved much hard work and time, and the quality of the product was poor. It was soon found that the imperfect hand stirring caused excessive sugar crystallization, which made the milk sandy. The sudden chilling and irregular stirring of a saturated sugar solution like sweetened condensed milk are favorable to the formation of sugar crystals. Where the stirring is imperfect and irregular, all the milk is not kept in sufficient motion to insure uniform and gradual cooling. The milk next to the side of the cans is chilled too abruptly, favoring the formation of crystals. Vigorous stirring in itself is conducive of sugar crystallization.

Later the hand stirring was completely superseded by mechanical stirring, paddles closely scraping the sides of the cans being used. Instead of setting the paddles in motion, they are stationary and the cans revolve. The principle is similar to that of the vertical ice cream freezer. Heavy iron tanks, with a capacity of twelve to forty-eight 40-quart cans, are used for this purpose. The bottoms of these tanks are equipped with a system of cog wheels, set in motion by means of a gear at one end of the tank. The wheels have a diameter large enough to carry one can each. The cans are set on these wheels, the paddles are inserted and fastened to cross-bars and the power started. The cans should be heavily constructed to stand rough usage, without suffering indentations. Cans with irregular, depressed, or bulged sides cause the paddles to do poor work. Such cans should be slipped over a wooden horn, or other contrivance, and the indentations hammered out with a mallet. The paddles are held stationary by cross-bars and are forced against the periphery of the cans by springs. Attention should also be paid to the pivots on which the cog wheels rest. If they are warped, the wheels do not run true, so that it is not possible for the paddles to scrape the sides of the cans properly.

The sweetened condensed milk should be cooled gradually. Sudden chilling should be avoided. This is best accomplished by warming the water in the cooling tank to about 90 degrees F., before the cans are set in. The cans are then allowed to revolve for fifteen to twenty minutes before any cold water is turned into the tank. After that, cold water is turned in slowly until the temperature of the milk has fallen to about 70 degrees F. The entire time of cooling should last about two hours. The cans should revolve slowly, rapid stirring enhances the precipitation of sugar crystals. In order to scrape the sides of the cans efficiently, when the cans revolve slowly, (about five revolutions per minute) it is advisable to use two paddles in each can, scraping the cans at opposite sides. When the milk is sufficiently cooled the cans are stopped, the paddles lifted out, spraped and removed, and the cans taken out of the tank. This method of cooling sweetened condensed milk is still in vogue in the majority of condenseries. It is obiviously crude, laborious and time-consuming.

Fig. 29. Cooling tank for sweetened condensed milk
Courtesy Arthur Harris & Co.

In some factories the condensed milk is transferred from the pan direct into large tanks and is subsequently cooled by pumping it with a high pressure pump through a series of coils submerged in cold water. This method is labor and time-saving and the objectionable features of agitation are avoided. On the other hand, there is danger of too rapid chilling, which tends toward excessive sugar crystallization and the production of rough, sandy and settled milk.

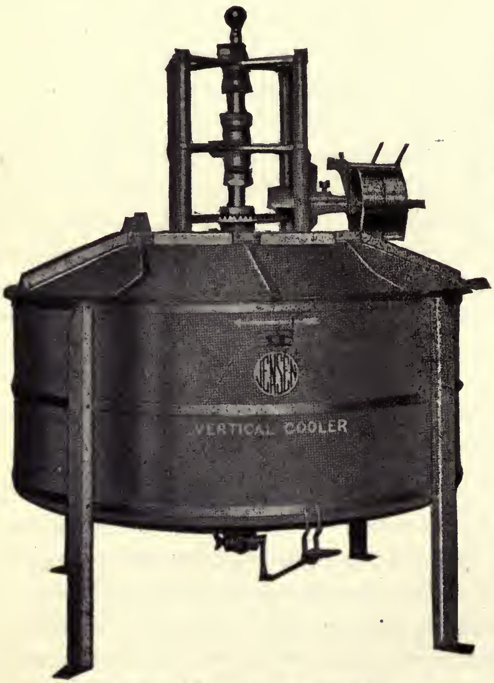

Fig. 30. Vertical coil cooler
Courtesy of Jensen Creamery Machinery Co.

Within recent years the use of circular tanks with jacket and vertically suspended, revolving coil, has been adopted in numerous factories with most satisfactory results, and this method of cooling this viscous product promises to greatly assist to solve the cooling problem. Rectangular vats with horizontal coils, which also have been tried for this purpose, however, are less desirable, as they tend to cause the condensed milk to foam excessively. This foaming is caused by the fact that the horizontal coil revolves into the milk, beating air into it. In the case of the circulator tank, the vertical suspended coil when revolving moves upward, out of the milk, thus avoiding incorporation of air and excessive foaming. The circular vat with the suspended vertical coil has the further advantage that the condensed milk does not come in contact with bearings and glands, these parts being entirely detached from the vat. For prevention of gritty and settled milk, see also Chapter XXIII on "Condensed Milk Defects," page 191.

Chapter VII.

FILLING

The sweetened condensed milk is put on the market in barrels and in hermetically sealed tin cans.

In Barrels.—Barrels, similar to glucose barrels, are generally used. They hold from three hundred to seven hundred pounds of condensed milk. New barrels should be used for this purpose. Barrels paraffined on the inside are most satisfactory, as they are more apt to be free from mold spores. Old glucose barrels are dangerous to use, as they often contain decaying remnants of glucose, which cause the condensed milk to ferment. The new barrels are steamed out and drained thoroughly. The filling is facilitated by the use of a large galvanized iron funnel with a discharge one and one-half inches in diameter, or an ordinary milk pail with a nipple one and one-half inches in diameter in the bottom of the pail. When filled, a double layer of cheese cloth is placed over the bunghole, and the bung is driven in level with the staves. The barrel goods are sold to bakeries and candy factories.

In Cans.—The canned goods are intended for the retail market. The cans used hold from eight ounces to one gallon of condensed milk. Most makes of tin cans for sweetened condensed milk have a small opening, three-eights to three-fourths inch in diameter through which they are filled. The cans known and sold under the trade name "sanitary can" are filled before the top is crimped on. Sweetened condensed milk is of a semi-fluid, viscous and sticky consistency. The successful and rapid filling of the cans without spilling the milk over the top of the can is, therefore,

Fig. 31. The solder seal

Fig. 32. The Sanitary can

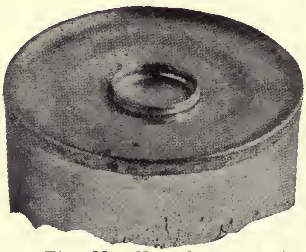

Fig. 33. The Gebee seal

Fig. 34. The McDonald seal

somewhat difficult. If done by hand the work is very slow. For this reason many ingenious machines have been devised which are more or less efficient in "cutting off" the milk without "slobbering." The filling machines now in use vary from the primitive hand filler, in which the condensed milk is "ground out" by the turning of a crank by hand, to the most perfect forms of automatic filling machines. In these filling machines, all parts coming in contact with the condensed milk are constructed of brass. They usually are equipped with a reservoir, receiving tank, or hopper, which has an automatic feed, usually a floating device attached to a valve, which regulates the inflow according to the discharge.

The discharge is adjustable to fill any size can with a remarkable degree of accuracy except gallons which are usually filled by hand. Machines of this type will fill from twenty-five thousand to thirty thousand cans per day (ten hours.)

These machines are of complex construction and must receive proper care. It is best to clean them thoroughly after each day's work. But, since their inlet and discharge are closed hermetically, the complete washing may be done once per week only, without seriously disturbing their efficiency or impairing the product. For thorough cleaning, the filler should be dissected, removing all detachable parts, such as valves, pistons, tubes, etc. When freed from all remnants of condensed milk, the parts should be scalded, dried and replaced in the machine. In order to guard against all possible contamination by remnants of wash water, it is advisable to reject the first few cans of milk of the next filling. When not in use, the filling machine should be covered with clean cloth, or oil cloth, to protect it from dust and flies, etc.

As soon as the cans are filled, they should be "capped." If allowed to stand open, dust, dirt and flies, or other insects are prone to reach their interior, and the prolonged exposure of the condensed milk to the air and light causes the surface to crust over and to develop a tallowy flavor.

SEALING

Kinds of Seals.—The seal must be air-tight and firm enough to prevent its breaking during the rough treatment to which the cans are exposed in transportation. There are several methods of sealing the cans, depending largely on the construction of the can. Most of the cans used are sealed with solder. There is a groove around the opening, the periphery of the cap fits into this groove and the latter is filled with solder. In the case of cans which are sealed without solder, the cap or the entire end of the can is criped onto the can so as to make a hermetical seal. The McDonald seal with the friction cap, the Gebee seal with the burr cap, and the Sanitary can seal with the top of the can crimped on after filling, are the chief types of solderless seals. In the case of the McDonald seal, a tightly fitting cap with a wide flange is pressed into the opening. The "capped" can passes under a series of steel rollers pressing the flange firmly against the top of the can. This seal is very simple, but is not very strong and not hermetically tight. In the case of the Gebee seal, a rim projects around the opening of the can. After the cap is inserted, it is crimped over this rim by means of a series of revolving dies. This seal is reasonably strong but not hermetically tight. The Sanitary can is entirely open at one end when filled. The cover or end is crimped around the periphery of the body of the can by means of revolving dies. This seal is reasonably strong and usually hermetically tight.

The chief advantages of the seals without solder lie in the saving of labor, and the reduction of the cost due to the omission of solder. The principal reason for which some of them are not used more generally by milk condensing companies, lies in the fact that these solderless seals are all patented. In most cases the inventors or patent holders are condensed milk manufacturers. They refuse to sell their patents at a reasonable price to other condenseries and they charge exorbitant royalties for the use of their patents by their competitors. With the possible exception of the "Sanitary can," solderless seals are not as reliable as solder seals.

Fig. 36. Soldering stove
Courtesy of Arthur Harris & Co.

Soldering Devices and Machinery. The sealing of all solderless seals is done by specially constructed sealing machines.

For seals with solder there are several machines on the market but much

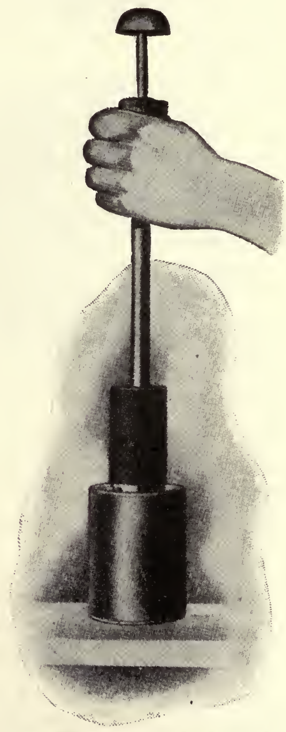

Fig. 35. A convenient device for soldering by hand

of this work is as yet done by hand. For this, different types of soldering coppers are in use and the copper tips are heated in soldering stoves or pots. Some soldering coppers have hollow circular tips with a diameter equal to that of the cap used. The hollow tip is telescoped by a rod which holds the cap in place and the periphery of the tip fits into the groove of the opening of the can, where it melts the solder. A rapid, neat and leakless seal can be made with this instrument.

Ordinary soldering coppers with a blunt point, such as are in general use by the tin smith, are not very satisfactory. Unless they are drawn out and filed down into a fine point, their use is not conducive of neat work, progress is comparatively slow and leakers are often numerous. When gas is available the automatic soldering copper may be used to advantage. In this tool the copper tip, which is long and slender is automatically heated by a current of gas passing through the handle and burning at the copper tip. The handle of the device is connected with the gas and air pipes by means of flexible rubber tubing. No time is lost waiting for the coppers to heat and the flame can be so regulated that the temperature of the copper tip is right and uniform. This is important, because perfect work is impossible unless the coppers have the proper temperature.

Machine-soldering is now rapidly replacing hand-soldering. The principle of the older types of soldering machines consisted of revolving discs on which the tin cans were placed. The cap was held in place by a vertical rod pressing on it. The solder was applied by hand, the hot soldering copper was held over the groove in the can while the cans revolved. This method had no particular advantage over the hand soldering. There was little, if any, saving of time and the quality of the work was not much, if any, better.

There are now on the market newer types of soldering machines, most ingeniously constructed and their operation in factories with large outputs economize labor and time. When operated by a skillful mechanic they do very creditable work.

Solder.—The solder used for sealing should be of standard composition. In this country, canning establishments are prone to use a very poor quality of solder. It contains from 45 to 55 per cent lead. Lead is a poisonous metal; its use in the canning industry should, therefore, be regulated by law. In Germany, the law requires that solder used in tin cans for food products must not contain over 10 per cent of lead.

Where the sealing is done by hand the solder is most conveniently used in the form of thin bars or wire. The wire is usually bought already cut up in segments, each segment furnishing solder enough to seal one can. In the newer types of soldering machines the solder wire is automatically fed from spools. The smaller the opening of the can, the less solder is necessary to complete the seal. An opening smaller than three-eights of an inch in diameter, however, cannot conveniently be used, owing to the difficulty of filling the can with this viscous product. The essential points of satisfactory sealing are: no "leakers" neat work, rapid work, small amount of solder. Aside from the size of the opening of the can, the amount of solder used depends on the experience of the sealer. Beginners usually make an uneven seal, waste much solder, and have many "leakers." This is largely due to their ignorance of the proper soldering temperature of the coppers. An experienced sealer will use from two to three pounds of solder per thousand tin cans with moderate-sized openings. He will seal from fifteen hundred to twenty-five hundred cans per day.

Soldering Flux.—The use of solder requires the application of soldering flux, to prepare the surface of the tin for the solder. The flux always precedes the solder. When the hot solder is applied, some of the flux is bound to sweat through, between cap and can, gaining access to the interior of the can. The common practice of using zinc chloride or other similar acid fluxes, which are highly poisonous, therefore, cannot be too strongly condemned. Their presence in the can may jeopardize the health and life of the consumer, as well as the marketable properties of the product. There are other fluxes which are absolutely harmless, and which, if properly used, give satisfactory results. Dry, powdered resin, or resin dissolved in alcohol or gasoline, are of this class. Ammonium chloride, while used in most tin shops, is not as well suited for this purpose.

Gas Supply.—A plentiful and steady supply of gas is very essential. Where natural gas or gas from a municipal corporation is not available, the factory must rely on its own generator. For the needs of the condensery a gasoline gas plant seems suitable. Gasoline gas is produced by forcing atmospheric air over or through a body of gasoline. The mixture of air and gasoline vapors forms the gasoline gas. The gas generators in use consist chiefly of carburetor, air pump or blower, and regulator. The carburetor usually has a series of cells, connected with one another by means of a system of syphon tubes. The interior of each cell is partitioned off with heavy cotton wicking. This wicking absorbs the gasoline by capillary attraction. The air, passing through the fine meshes of wicking, comes in contact with a large surface of gasoline.

The following are some of the essential points to be observed in the installation and operation of gas generators of this type: Sink the carburetor low enough (three to five feet below the surface of the ground if necessary) to permit the gas pipe to slant from the factory to the carburetor. If the gas pipe is horizontal, or inclined toward the factory, condensation water may collect in the pipe, obstructing the free passage of gas. This causes the gas either not to be available at all, or to reach the stoves in irregular gusts, which is equally unsatisfactory. Where the gas pipe slants toward the carburetor, the condensation water flows back into the carburetor, causing no obstruction. Use gasoline of the best quality only. Cheap grades form a residue and clog the generator. The gasoline is best bought in iron barrels; this prevents unnecessary loss by evaporation, which occurs in wooden barrels, especially in summer. The cells should not be filled more than two-thirds full; too much gasoline reduces the gas-generating capacity of the carburetor. If, during extremely cold weather, the carburetor refuses to generate gas, the injection of a pint of wood alcohol through the blow pipe into the cells, usually remedies the trouble. The gas plant and gasoline storage should be located in a separate building and at a reasonable distance from the main building, in order to minimize danger from fire.

PART III

MANUFACTURE OF UNSWEETNED CONDENSED MILK

EVAPORATED MILK

Chapter VIII.

DEFINITION

There are three kinds of unsweetened condensed milk on the market, namely, evaporated milk, formerly called eavaporated cream, plain condensed bulk milk and concentrated milk.

Evaporated milk is cow's milk condensed in vacuo at the ratio of about two to two and one-half parts of fresh milk to one part of condensed milk. It is of the consistency of thin cream and reaches the market in hermetically sealed cans varying in size from eight ounces to one gallon. Evaporated milk is preserved by sterilization in steam under pressure. When properly made, it will keep indefinitely, but is best when fresh.

QUALITY OF FRESH MILK

In the manufacture of evaporated milk the physiological normality and the chemical purity and sweetness of the fresh-milk are factors even more important than in the case of sweetened condensed milk. A uniformly satisfactory and marketable product cannot be manufactured, unless the milk is normal and pure in every respect. The reason for this largely lies in the fact, that defects the fresh milk may have, are greatly magnified and intensified by the high sterilizing temperature to which the evaporated milk is subjected. While, from the biological point of view, contaminations of this milk are largely rendered harmless by sterilization, defective fresh milk cannot be made into a marketable product, because such milk usually does not survive the process.

It should be understood that any condition or factor that, in the slightest degree, increases the tendency or ability of the casein to curdle, tends toward the formation of a hard, unshakable coagulum during sterilization, and makes the manufacture of a marketable product difficult. Abnormal milk of this type may come from cows approaching parturition, or too soon after calving, or milk from cows suffering from disease, generalized or local, or from cows in poor and abnormal physical condition, which may be brought about by poor care, over-feeding, feeding the wrong kinds of feed, or feed in poor condition, exposure to abnormally hot weather and flies, or any other condition which disturbs the physiological functions of the animal and thereby affects the physical, chemical, and physiological properties of the milk; or it may be due to improper care of the milk, causing it to be excessively contaminated with germ life, or to be relatively high in acid. All such milk renders the quality of the finished product uncertain and may result in heavy loss.

In view of these facts it is obvious that the greatest care should be exercised on the receiving platform, inspecting every can of milk, using the most reliable means, as recommended in Chapter III on "Control of Quality," p. 43, to detect suspicious milk, and rejecting all milk that fails to reach the sanitary standard adopted by the factory.

HEATING THE MILK

The equipment for heating the milk should be such as to enable the factory to heat the milk with the least possible delay, so as to avoid the development of acid or to make possible the prompt cooling of the milk upon its arrival to a temperature at which bacterial development is checked. In the manufacture of evaporated milk, the batches of condensed milk in the vacuum pan must be relatively small. This milk foams more in the pan than the heavier sweetened condensed milk. This factor reduces therefore, the capacity of the pan. If the milk is not cooled upon arrival, but is transferred immediately to the hot wells, it is advisable to use numerous small wells, rather than but one or a few large ones. These small wells fill rapidly and the milk can be heated without delay. This system makes it possible to render the bacteria inactive and harmless practically as soon as the milk arrives, minimizing the danger of acid formation.[1]

Steam may be saved if the milk is forewarmed by running it through coils inclosed in a chamber of exhaust steam, but the coils increase the labor and difficulty of cleaning. It is best to heat the milk to as near the boiling point as possible and hold it there for five to ten minutes, provided that the capacity of the factory warrants this delay. In this heating the casein of the milk is somewhat changed. There occurs partial, though invisible, precipitation, and the higher the temperature to which the milk is heated, the more pronounced is this change. This change is desirable, because the casein thereby surrenders, to a limited extent, its power and tendency to form a firm curd in the sterilizer.

CONDENSING

The same apparatus, the vacuum pan and pump, is used for condensing the milk, and the process of condensing is principally the same, as in the case of sweetened condensed milk. The fresh milk is condensed at the ratio of two to two and one-half parts of fresh milk to one part of condensed milk. In some factories it is customary to superheat the milk in the pan before it is drawn off, i. e., the steam to the jacket and coils is shut off, the water valve is closed, the vacuum pump is stopped and "live" steam is passed into the condensed milk. When the vacuum has dropped to about six to eight inches, and the temperature has risen to 180 to 200° F. the superheating is stopped, the steam is turned off, the vacuum pump is started again, and the condensing is completed. The superheating is frequently also done after the evaporated milk has been drawn from the pan. In this case, the process of evaporation is usually carried slightly beyond the desired density of the finished product, the evaporated milk is drawn from the pan into an open vat or kettle where steam is turned direct into the milk until the superheating is completed, which is indicated by its greater consistency and the slightly flaky condition of the curd. Then water is added to the superheated evaporated milk to bring the product back to the desired density.

The chief purpose of superheating is to partly precipitate

[1] See also Cooling Milk, p. 52, and Standardization, p. 253.

the curd. This minimizes the danger of the formation of too hard a curd in subsequent sterilization. It also lends the body of the milk the appearance of greater consistency, gives it a more viscous character and assists in the prevention of subsequent fat separation. The superheating of evaporated milk is not essential for the production of quality and marketable properties, but it is looked upon by many manufacturers as a safeguard against such defects as curdiness and fat separation. It is not improbable that its advantages are much overestimated, and in most factories the superheating process is entirely omitted.

The condensing of milk for the purpose of manufacturing evaporated milk may be done also in the absence of the vacuum pan, by the use of the "Continuous Concentrator," the construction and operation of which are described on pages 133 to 141.

STRIKING

The striking, or sampling and testing for density, of evaporated milk, is more easily accomplished than that of the sweetened condensed milk. When this product has nearly reached the proper density, it is not viscous and syrupy, containing no cane sugar. It resembles in consistency rich milk or thin cream and has a specific gravity of 1.05 to 1.075 at 15.5 degrees C. or 60 degrees F.

Samples are drawn from the vacuum pan as described under sweetened condensed milk and the density can be readily determined by means of a hydrometer. Beaumé hydrometers, registering from 5 to 15 degrees B., are generally used. As it is important that the determinations be accurate, the hydrometer should be sensitive and its scale should be subdivided into tenth degrees. The batch should be "struck" at a uniform temperature, say 120 degrees F., so as to avoid misleading readings of the hydrometer. A difference of a few tenths degrees Beaumé affects the behavior of the evaporated milk in the sterilizer very appreciably. If the density is too great the product may badly curdle during sterilization. If the density is too low the evaporated milk may be below the legal standard. It is advisable for the operator to use a pail of water of the proper temperature, when he strikes the batch, so that he can adjust the temperature of the milk in the hydrometer jar readily and quickly, and need not depend entirely on the temperature of the milk in the pan which may change several degrees while he is engaged in the operation of striking.

While the Beaumé hydrometers should be used at the temperature for which they are graduated, which is 60 degrees F., they answer all practical purposes at any other temperature: at 120 degrees F. for instance. The chief essential is to take the reading at some uniform and definite temperature and read the Beaumé at that same temperature in the case of every batch. In that way the results are comparable. The operator soon learns that at a given temperature the evaporated milk of proper density shows a certain Beaumé reading. When the reading is higher or lower, the milk has either been condensed too much or not enough. The use of the automatic "striker" described under "Striking Sweetened Condensed Milk," practically solves the control of the temperature of the sample taken.

The same formula, however, cannot be used under all conditions. No rule-of-thumb method of determining the density can therefore be established. Aside from the degree of condensation, the specific gravity of the milk varies with locality, season of year, quality of milk, etc. This means that what is the proper Beaumé reading in one locality, or at one season in the same locality, may be entirely wrong in another locality or at other seasons in the same locality. If uniformity in the density and behavior of the batches of evaporated milk is to be secured throughout the year, the operator must watch the behavior of his milk from day to day and from season to season and he must modify the Beaumé reading in accordance with the changing conditions. This is one of the all important stages of manufacture, where relentless and careful study and watchfulness are indispensable.

In order to make absolutely sure that the density of the evaporated milk is right, it is advisable to get it just as near right as possible in the pan and then draw the milk from the pan into a standardizing vat, large enough to accomodate the entire batch or several batches. The operator then tests the milk again and this second estimation he can perform more carefully, because he is then relieved of the responsibility of attending to the operation of the vacuum pan. If the evaporated milk happens to be a trifle too heavy he can dilute it with distilled water until the Beaumé reading is just right. See also "Standardization," Chapter XXXIX, page 253.

Correction of Beaumé Reading at Temperatures Other than 60 Degrees F.—At a temperature of 120 degrees F. the Beaumé reading of the finished batch of standard evaporated milk may vary between about 6 and 8 degrees B., according to season of year and locality. At 60 degrees F. the Beaumé reading is approximately 1.88 degrees B. higher.

If it is desired to record the Beaumé reading at the correct temperature, i. e., 60 degrees F., and it is not convenient to cool the evaporated milk to that temperature, the reading at any temperature may be corrected as follows: when the temperature at which the Beaumé reading is taken is above 60 degrees F., multiply the difference between the temperature of the observed reading and 60 by the factor .0313 and add the product to the observed reading.

Example: Beaumé at 120 degrees F. is 6.8; what is the reading at 60 degrees F.?

Answer: $6.8 + (60 \times .0313) = 8.68$ degrees B.

The corrected Beaumé reading is 8.68 degrees B. When the temperature at which the reading is made is below 60 degrees F., multiply the difference between the temperature of the observed reading and 60 by the factor .0313 and subtract the product from the observed reading.

Calculation of Specific Gravity from Beaumé Reading.—In order to record the density of the evaporated milk in terms of specific gravity, instead of Beaumé degrees, the following formula may be used:

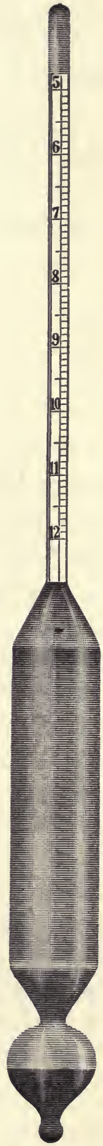

Fig. 37. Beaumé hydrometer for evaporated milk
Courtesy of C. J. Tagliabue Mfg. Co.

Specific gravity $= \frac{145.5}{145.5 - B}$; B = Beaumé reading at 60 degrees F.

Example: Beaumé reading at 60 degrees F. is 8 degrees B. What is the specific gravity?

$$\text{Specific gravity} = \frac{145.5}{145.5 - 8} = 1.0582$$

Chapter IX.

HOMOGENIZING

Purpose.—The introduction of the homogenizer in milk condensing factories is a comparatively recent innovation. The object of its use is to avoid the separation of the butter fat in the evaporated milk after manufacture.

The butter fat is present in milk in the form of minute globules. These fat globules are lighter than the rest of the ingredients of the milk. They, therefore, show a strong tendency to rise to the surface and to form a layer of thick cream in the cans. When these cans are subsequently subjected to agitation, as is the case in transportation, this cream churns, forming lumps of butter. This tendency of evaporated milk to separate in storage and churn in transportation is especially noticeable with milk rich in fat und in which the large fat globules predominate. In Jersey and Guernsey localities, it is more difficult, therefore, to manufacture evaporated milk that does not separate, than in Holstein and Ayrshire localities. While separated and churned evaporated milk is perfectly sound and in every way as valuable as a food, as it would be without this separation, it does not sell in this condition. It is rejected on the market.

This tendency toward fat separation can be minimized and frequently entirely prevented by increasing the viscosity of the evaporated milk. This can be accomplished by superheating the milk in the pan or after it leaves the pan, and by prolonging the sterilizing process, raising the heat very slowly or stopping the reel of the sterilizer at certain stages of the process. However, there are conditions when even these precautions do not permanently avoid separation of the fat. In such cases, the proper use of the homogenizer furnishes a reliable means to guard against this difficulty.

Principle of the Homogenizer.—The principle of the homogenizer is to force the milk under high pressure through exceedingly small, microscopic openings. By so doing the fat globules are broken up so finely that they fail to respond to the gravity force, they cannot rise to the surface and therefore remain in homogeneous emulsion. The value of the homogenizer lies in removing the fundamental cause of this separation. It reduces the fat globules to such small size that their buoyancy, or gravity force, is not great enough to overcome the resistance of the surrounding liquid.

The tendency of fat globules to separate out in homogenized evaporated milk is further reduced by the fact that the homogenizer also alters the physical condition of the casein, making it more viscous and thereby increasing the resistance which the fat globules must overcome in their upward passage.

Kinds of Homogenizers.—There are at this time two makes of homogenizers in use in this country, namely, the "Gaulin" and the "Progress" homogenizer.

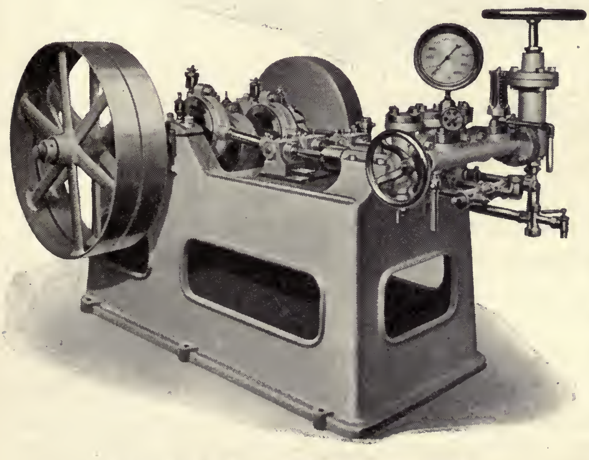

Fig. 38. The Progress homogenizer
Courtesy of Davis-Watkins Dairymen's Supply Company

In the Gaulin homogenizer, the milk is forced, by means of single-acting pumps, against an agate valve which presses against a ground valve seat. The milk has to pass between the ground surfaces of this valve and valve seat. This causes the fat globules to be divided very minutely. This type of homogenizer has not been used much as yet in the manufacture of evaporated milk and but little is known concerning its effect on this product.

In the Progress homogenizer the homogenizing principle consists of forcing the milk, by means of single acting pumps, between a series of discs with ground surfaces. The discs lay flat one upon the other, they are enclosed in a cylinder and are

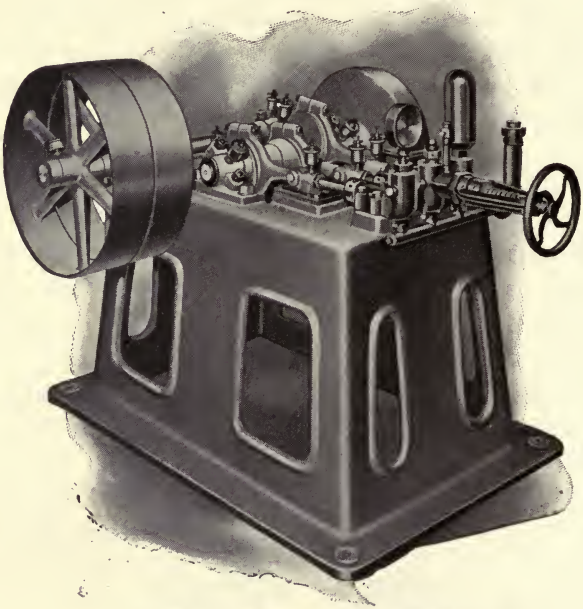

Fig. 39. The Gaulin homogenizer
Courtesy of Creamery Package Mfg. Company

held in place by a rod running through their center. The discs are pressed against each other by a heavy spiral screw, which regulates the pressure to which the milk is subjected. The milk passes from the center to the periphery of the discs. While being forced through the discs the fat globules are split up very finely. The discs used in this machine are of two types. One type has very fine irregular grooves. The milk shoots through these grooves against hard shoulders. The other type of discs has smooth surfaces but their area of contact is narrow. The milk passes through between these smooth surfaces.

The Progress homogenizer is used in numerous evaporated milk factories in this country and, where operated properly, it overcomes fat separation very satisfactorily, without damaging the other ingredients of milk.

Operation of the Homogenizer. — In order to avoid fat separation it is necessary to subject the milk to enough pressure to reduce the fat globules to about one-third their original size. If enough pressure is applied to divide the fat globules into much smaller units there is a tendency to also change the properties of the casein to such an extent as to cause it to give rise to copious precipitation, when the evaporated milk is sterilized, and making the finished product curdy and unmarketable. In this case the cure would be more disastrous than the original defect. Great care must, therefore, be exercised, guarding against the use of excessive pressure that would injure the casein. Experiments have shown that a pressure of between one thousand and fifteen hundred pounds per square inch is sufficient to prevent fat separation and is practically harmless as far as its objectionable effect on the casein in the evaporated milk is concerned.

The evaporated milk is run through the homogenizer hot, just as it comes from the vacuum pan or standardizing tank. The first pailful of milk passing through the machine should be returned to the supply tank, as on the start, the pressure is not uniform and homogenization is incomplete.

The pistons, cylinders, valves and pipes of the homogenizer should be kept in sanitary condition. They are difficult to clean. After homogenizing, the machine should be kept in operation, running water through it, until most of the remnants of evaporated milk are rinsed out; then hot water containing some active alkali should be pumped through; this should be followed by clean hot water and steam. Unless this machine is kept scrupulously clean, it may become a dangerous source of contamination, infecting the evaporated milk with spore forms that are exceedingly resistant and which are liable to pass into the finished product alive, in spite of the sterilizing process, causing the goods to be a complete loss, due to subsequent fermentation.

CHAPTER X.

COOLING

In the cooling of the evaporated milk, no attention need be paid to sugar crystallization. In this class of goods there is plenty of water to keep the milk sugar in ready solution. The evaporated milk can, therefore, be cooled as rapidly as facilities permit. The cooling may be accomplished in similar ways as are used for cooling fresh milk. From the homogenizer the evaporated milk is run over a surface cooler, or cooling coil. It is advisable to cover the coils with a jacket of galvanized iron, tin or copper, so as to avoid undue contamination of the milk from dust, flies, and other undesirable agents. In some condenseries the hot evaporated milk is forced through double pipes, cold water passing between the inner and outer pipe, or the coils through which the milk passes are submerged in a tank of cold water. The only objection to this system is that the pipes are more difficult to clean than in the case of an open surface cooler. Where this system is used, the pipes should be equipped with sanitary fittings so that they can be readily swabbed out from both ends. In other factories, the same cooling equipment is used as for sweetened condensed milk, with the exception that cold water is run into the cooling tank at once. In still other factories the cooling is done in vats or tanks by means of revolving coils which carry the cooling medium. If the evaporated milk is not

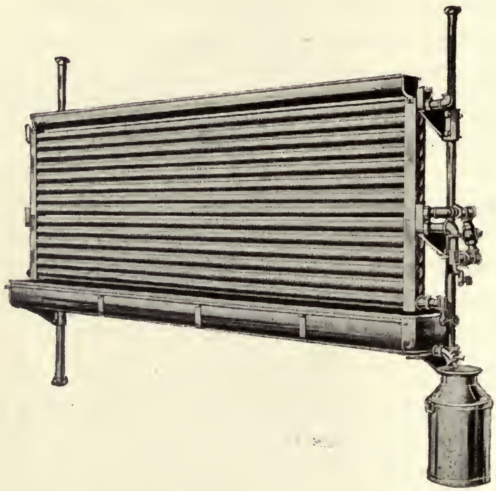

Fig. 40. Surface cooler for evaporated milk
Courtesy of Davis-Watkins Dairymen's Supply Co.

homogenized it should be cooled as soon as it leaves the vacuum pan.

Holding in tanks.—The establishment and enforcement of a Government standard of composition and the tendency of the manufacturer, in the face of increasingly keen competition which narrows down the margin of profit and demands more exacting attention to the cost of manufacture, to reduce his output to a uniform composition that complies with the Government standard but does not exceed it, have resulted in the adoption, especially among the larger condenseries of the practice of standardizing or unifying each day's output by mixing together all the batches of evaporated milk of one and the same day's make.

This practice necessitates the use of one or more large tanks with facilities for refrigeration of their contents. This need has been and is being admirably met by the installation of jacketed glass enameled circular tanks, ranging in capacity from about 15,000 to 60,000 pounds. These tanks are equipped with one or more propellers which serve to agitate the evaporated milk, mixing it and hastening the cooling. The propellers in the latest improved holding and cooling tanks are located near the side or periphery of the tank and are driven by independent motor, or by belt power. It has been found that the thus excentrically placed propeller, when set at the proper angle, is more efficient in its agitation and in bringing all portions of the evaporated milk in direct contact with the cooling jacket than is the case with the centrally located vertical agitator, which merely gives the contents of the tank a circular motion.

Fig. 42. Holding tank for evaporated milk
Courtesy of The Pfaudler Co.

In factories where these large glass tanks are installed, each successive batch of evaporated milk is transferred, at the conclusion of the process of evaporation and homogenization, to this large holding and cooling tank, where all the batches of the same days' make are cooled, mixed and held until the last batch is in the tank. The mixture is then standardized to the desired composition by the addition of distilled water, skim milk, or cream, according to needs. The evaporated milk in this tank is usually cooled to and held at 40 to 45 degrees. F. until next morning, when the filling into tins commences. See also "Standardization," Chapter XXXIX, page 253.

It should be understood that, at this stage of the process the evaporated milk is not sterile, nor does it contain cane sugar to preserve it, neither is it sufficiently concentrated to be preserved because of the absence ot moisture. If exposed to heat, such as summerheat, or even room temperature, its acidity will increase rapidly thereby rendering the subsequent sterilizing process difficult. Therefore, unless it is canned and sterilized immediately after it leaves the vacuum pan, or the homogenizer in case it is homogenized, it should be cooled promptly to a temperature low enough to check bacterial development, 40 to 45° F., or below. In the absence of holding tanks or vats with refrigerating facilities as described above, the cooled evaporated milk may be drawn into 40 quart milk cans, and set in the cold room, or these cans may be submerged in a tank of ice water.

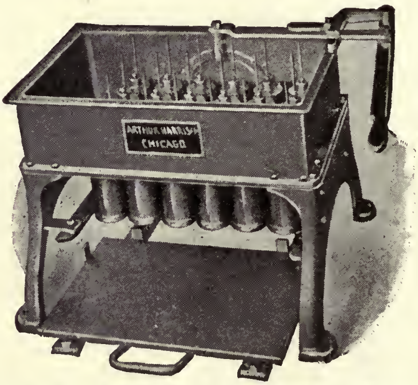

Fig. 41. Hand filling machine for evaporated milk
Courtesy of Arthur Harris & Co.

FILLING

The cooled evaporated milk is filled into tin cans ranging in size from eight ounces to one gallon. The gallon cans are usually filled by hand. The filling of the smaller cans is done by automatic filling machines.

Of late years much progress has been made in the construction of different types of filling machines for evaporated milk. The openings in the cans through which the cans are filled range from the Sanitary can, which is filled with the top of the can entirely removed, to the venthole can with an opening of not more than one-eighth inch in diameter. The filling machines are constructed to fill by gravity, under pressure, or in vacuo.

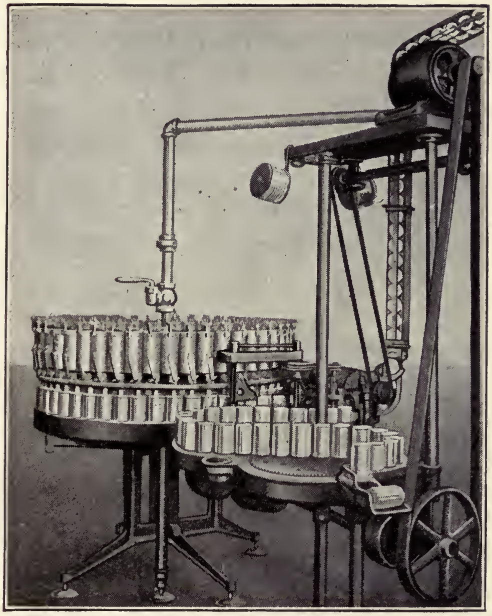

Fig. 43. Venthole filling machine
Courtesy of F. G. Dickerson Company

These filling machines should be thoroughly washed and freed from all remnants of evaporated milk adhering to the valves and other parts after each use. Remnants of milk left in any part of the filling machine decompose readily and impair the wholesomeness and marketable properties of the product. This is an important point and one too often neglected. Much of the spoiled evaporated milk may be the result of the use of unsanitary and unclean filling machines. The fact, that the evaporated milk is sterilized after it leaves the filling machine, is no excuse for unclean filling machines. The operator should bear in mind that the milk running through an unclean filling machine becomes contaminated with millions of bacteria. The more bacteria it contains, the more difficult it is to render it perfectly sterile. Furthermore, sporeforms are prone to develop in the decaying remnants of milk; these

Fig. 44. Venthole can
Courtesy of
F. G. Dickerson Company

spores are very resistant and require excessively high sterilizing temperatures to be destroyed.

In the filling of the venthole cans the foaming of the evaporated milk frequently causes serious annoyance. This can be avoided by having the milk at the proper temperature at the time of filling. Experience has shown that warm milk and milk excessively cold are most apt to foam profusely. Under average conditions, milk at a temperature of 60 to 70° F. generates the least amount of foam and at this temperature the filling is accomplished most readily.

SEALING

The filled cans should be capped and sealed at once. The seal must be hermetical and strong enough to withstand the strain of the subsequent sterilizing process. With the exception of the "Sanitary can," seals without solder have so far proven unsatisfactory in the canning of evaporated milk. They are prone to weaken in the sterilizer and cause "leakers." Most of the cans on the market containing evaporated milk are, therefore, sealed with solder. Sealing evaporated milk cans with solder is by far the safest method. For details of methods of sealing see Chapter VII.

For the sealing or tipping of the venthole cans an automatic tipper is usually attached to the filling machine, so that when the cans leave the filling machine, they have also been sealed.

It is exceedingly important that the sealing be done perfectly, because the minutests leaks cause the evaporated milk in the cans to become contaminated causing spoilage. In order to detect cans with imperfect seals all the cans, as they come from the filling and sealing machine, are carefully inspected for leaks. This may be done by the use of a test bath consisting of a narrow oblong trough, filled with hot water and through which the cans pass on an endless chain. In the case of leaky cans, the heat of the hot waterbath expands the air in the cans and causes it to escape through the leak in the seal and perculate upward in the water in the form of air bubbles. The operator standing over the test trough picks the cans which expel air bubbles out so that the defective seals can be mended.

Most condenseries manufacturing evaporated milk are now using a hot water bath for testing the sealed cans. But experience has shown that the hot water baths built on the continuous chain principle often fails to give the desired efficiency. This is not the fault of the machine, but it is due to the fact that it becomes very tiresome for the inspector to watch the moving line of cans in the water bath and he soon becomes careless and his work inefficient. It has been found that baths constructed and operated on the principle of submerging a whole tray full of cans, (usually 24 cans) at a time, give more satisfactory results, relieving the monotony and preserving more successfully the keenness of observation of the inspector.

The venthole filler is simple in construction, economical in operation and easily cleaned and kept in sanitary condition. The milk, from the time it comes within the range of the filler, is no longer exposed to contaminating influences, such as the hands of employes, insects, etc. The cans are uniformly filled to within one gram of the guaranteed weight and the vents or pin holes are automatically sealed with the minimum amount of solder. While the quantity of solder must necessarily vary with operating conditions, it is possible to limit the average amount of solder, under proper conditions, to 5 ounces per 1000 cans. The fact that the vent hole or pin hole filler operates by gravity, as to both, the empty cans and the inflowing evaporated milk, reduces the human and mechanical error to the minimum, once the machine is set for operation.

The acknowledged advantages of the venthole filler have made its general adoption and use rapid and it is estimated that today over 90 per cent of the evaporated milk is being canned by this type of filling machine.

CHAPTER XI.

STERILIZING

The sealed cans are now ready for the sterilizer. If they cannot be sterilized within an hour or two they should be submerged in ice water or placed in a refrigerating room until the sterilizer is ready for them. This precaution is especially advisable in summer.

Purpose of Sterilization.—The chief purpose of subjecting the evaporated milk to the sterilizing process is to kill all germ life and, therefore preserve the product permanently. When the hermetically sealed cans come from the sealing room, their contents are not sterile. The only means to preserve this milk is to subject it to temperatures high enough to kill all forms of ferments, organized and unorganized, vegetative cells and spores. The success of the manufacture of this product depends to a large extent on the process of sterilization.

Aside from this, the manufacturer aims to gain another commercially important condition, namely, to prevent the separation of the butter fat. Before sterilization, there is nothing to prevent the fat from separating out in the evaporated milk and from churning in transportation, unless the evaporated milk was homogenized. This is a highly undesirable characteristic, making the goods unmarketable. The sterilizing process helps to so change the physical properties of the milk, that this tendency of the fat to separate is greatly minimized. The sterilizing temperatures used, further lend to the evaporated milk a creamy consistency and yellowish color, giving the product a semblance of richness.

Sterilizers. — The predominating apparatus used for sterilizing is a huge, boiler-like, hollow, iron cylinder or box. It opens either at one end or on the side. Its interior is equipped with a revolving framework, steam inlet and exhaust, a water distributing pipe running the entire length of

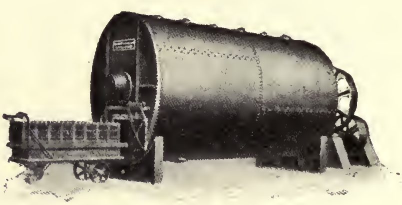

Fig. 45. Sterilizer for evaporated milk. Courtesy of Arthur Harris & Co.

the sterilizer and a water exhaust. The sterilizer carries on its exterior a steam gauge, a vacuum gauge, a water gauge, a blow-off valve and a high-temperature thermometer (registering to about 280 degrees F.). In some makes of sterilizers the interior frame-work does not revolve on its axis, but moves back and forth by means of a direct-acting, steam-driven piston, attached to the back end of the sterilizer. The purpose of keeping the cans in motion while heat is applied, is to heat the contents rapidly and uniformly, and to prevent the evaporated milk from baking onto the sides of the cans. A still other form of sterilizer is the continuous sterilizer in which the unsterilized cans pass into and the sterilized cans escape from the heating chamber in continuous procession.

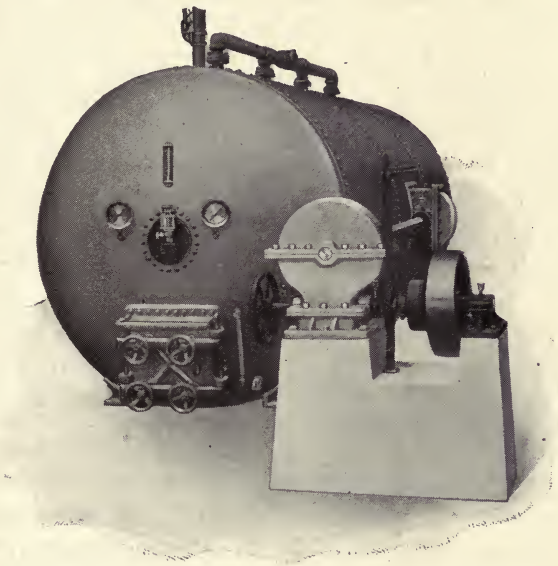

Fig. 46. Sterilizer for evaporated milk
Courtesy of The Engineering Company

Loading the Batch-Sterilizer.—The sealed tin cans are placed in heavy iron trays, usually holding twenty-four 16-ounce cans or six 1-gallon cans. The loaded trays are slid and locked into the framework in the interior of the sterilizer. The sterilizer is closed with heavy iron doors and the framework is put in motion. In some makes of sterilizers the interior consists of a large perforated iron box revolving on its axis. In this case the cans are simply piled into this box; no trays being used.

Uniform Distribution of Heat.—Where no water is used in the sterilizer during the sterilizing process, it is important that there be a free air space between every two layers of cans, so as to allow the steam to circulate freely and to come in direct contact with every can. When the cans are piled into the sterilizer six to twelve layers deep without any free air space between layers, the cans in the center do not receive as much heat as those at the sides, ends, top and bottom. This causes irregular heating and imperfect sterilization.

A satisfactory means of insuring even distribution of heat is to fill the sterilizer about one-thirdful of water, so that, when the sterilizer is in operation the cans pass through this water, with each revolution of the frame work. Water distributes the heat uniformly, rapidly and there is no danger of the formation of air pockets between the cans. Since the heat is applied by steam under pressure the temperature of the water is equal to that of the steam in the sterilizer. This precaution is especially necessary in the case of baby-size cans (eight ounces) which are usually piled in stacks more than two deep. When sterilizing in the absence of water there is danger of lack of uniformity of the amount of heat they receive.

Temperature and Time of Exposure.—When the sterilizer is filled with the cans and closed, the frame work is set in motion and steam is turned into the sterilizer. In order to hasten the heating and expel all the air, the exhaust and safety should be left open until the temperature has risen to 212 degrees F. This temperature is usually reached in about ten to fifteen minutes. The exhaust and safety are then closed.

From this point on, the process must depend on locality, season of year and condition, properties and concentration of the milk. No formula can be laid down which can be depended on to give uniformly satisfactory results under all conditions. Nor does the proper sterilization depend on one particular formula. There are numerous ratios of temperature, time of exposure and extent of agitation, which when adjusted to local conditions may give satisfactory results. The temperature should be high enough and the duration of exposure long enough to insure absolute sterility of the product and to give the milk sufficient body to prevent the separation of the butter fat in subsequent storage. The temperature should not be so high nor the duration of exposure so long, as to cause the formation of a hard, unshakable curd and dark color.

Some processors use a very short process with high temperatures, others raise the heat gradually and not to quite so high a degree. The more gradual heating is preferable, as it gives the product a better body and more viscosity, which is necessary to keep the fat from separating in storage. The author's judgment in this matter is, that it is not safe to raise the temperature to less than 230 degrees F. and it is advisable to heat the milk to 234 to 236 degrees F., provided that the milk is in condition to stand this heat without the formation of too firm a curd. Where the maximum temperature to which the milk is raised in the sterilizer is 230 degrees F. or thereabout, the raise of the last ten degrees should occupy from thirty-five to forty-five minutes, and this time should be about evenly distributed over the last ten degrees.

Of recent years, the practice of stopping the reel of the sterilizer, either at intervals or when the maximum temperature has been reached, has been adopted by some of the manufacturers. In this case, the temperature usually is rapidly raised to about 240° F., and after keeping the reel running at this temperature for a few minutes (about two minutes) the reel is stopped and this temperature is maintained for from 15 to 20 minutes, with the cans laying still. When the "hold" is completed, the cooling proceeds in the usual way. Some condenseries stop the reel for several minutes once or twice when the temperature has been lowered and before it has dropped to below 212° F.

This method of sterilizing, by stopping the reel, has the advantage of developing in the cans a soft, custard-like coagulum, giving the product a very heavy consistency and making it appear rich and creamy. It represents a form of superheating, however, which if not done with great care, may prove disastrous, causing the evaporated milk to spontaneously thicken and become cheesy in consistency upon storage.

In his efforts to insure complete sterility the operator should understand that the size of the cans may influence the sterilizing efficiency. It takes more time and agitation to sterilize gallon cans than small cans. At a time of the year when the milk contains micro-organisms of relatively high resistance to heat, as is often the case especially in fall and winter, the per cent loss of gallon cans due to "swell heads" may become disastrously large, unless the manufacturer makes a special effort to adjust his process for gallon cans.

The installation and efficient use of automatic temperature controllers and recorders is of material assistance for securing uniform results of sterilization. These accessories are made use of in numerous factories, and have proven to be of valuable help to the manufacturer. Aside from the fact that they actually do facilitate the temperature control, they automatically make for increased efficiency of the operator. The knowledge of the

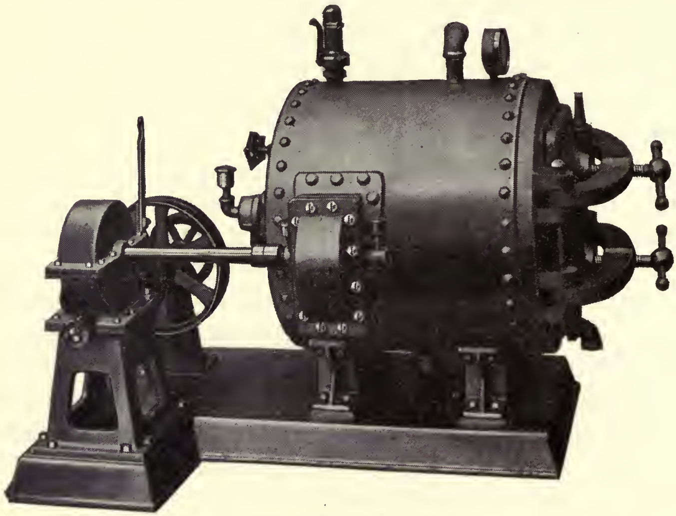

Fig. 47. Pilot sterilizer
Courtesy of The Engineering Company

operator that his work is permanently recorded and checked up exerts a beneficial effect on his performance.

The operation of an experimental or pilot sterilizer also has proven a great help in the accurate determination of the amount of heat which the evaporated milk of any batch requires, to produce the desired viscosity, body and color and that it will stand without becoming hopelessly curdy. These machines are of small size, accomodating only a few cans.

A few sample cans of each batch are placed in the pilot sterilizer and run through the process. Thus the proper process to be used for the entire batch in the large sterilizer may be adjusted according to the behavior of the contents of the sample cans in the pilot sterilizer.

Qualifications of the Processer.—The operator, or the person directing the sterilizing process, should thoroughly appreciate the complexity of the product, understand the cause and effect of the many influencing factors, study the ever-changing conditions and modify the process in accordance with prevailing conditions. He should know that during the exceedingly hot summer days, when the cows suffer from heat and are pestered with flies, the milk will not stand as much heat without badly curdling in the sterilizer as under more favorable conditions. He should know that toward and during the fall months the organisms normally present in milk are more resistant and require higher heat to be destroyed, than earlier in the season.

Rapid and Uniform Cooling.—As soon as the required heat has been given the milk in the sterilizer, the steam should be turned off and the exhaust and drain should be opened. When the temperature has dropped to about 220 degrees F., cold water should be turned into the sterilizer while the cans are constantly in motion, until the cans are cool enough to handle. There should be enough cold water available to reduce the temperature to 70 or 80 degrees F. in twenty minutes for gallons and in ten to fifteen minutes for small size cans. The water pipe should be so arranged as to distribute the water uniformly over the entire length of the sterilizer.

If the process is to be sucessful, the processor must have as nearly perfect control of the heat as possible. This means especially, that there must be plenty of water available to insure rapid cooling and the water must be distributed over the cans uniformly. Insufficient water supply and uneven distribution of the water in the sterilizer, means that some of the cans are exposed to the sterilizing heat longer than others, causing lack of uniformity in the smoothness and color of the milk of different cans of the same batch. Delayed cooling, owing to insufficient water supply, has the further disadvantage of causing the cans to bulge badly, owing to the difference in pressure between the interior and exterior of the cans. This is especially noticeable in gallon-size cans, the ends of which may become badly distorted, present an unsightly appearance and their seams and seals may be weakened to the extent of producing "leakers."

Fractional Sterilization.—In the early days of the manufacture of evaporated milk the product was sterilized by fractional sterilization. This method has now been largely abandoned, but is occasionally used when the milk happens to be in very abnormal condition. The milk is heated in the sterilizer to considerably lower temperatures than those stated above, and this heating is repeated on two or three successive days. The principle of this process is to kill all vegetative forms of bacteria during the first heating. This gives the spores a chance to develop into vegetative forms by the second and third days, which forms are then destroyed during subsequent heating. This system of sterilization is not practical for general use. It is too great a tax on the capacity of the average factory and increases the cost of manufacture. It should, therefore, be made use of only in exceptional cases, when it is known that a certain batch of milk could not be put through the higher sterilizing temperatures without causing the product to become permanently curdy.

SHAKING

Purpose.—The purpose of shaking the evaporated milk is to mechanically break down the curd that may have been formed in the process of sterilization and to give the contents of the cans a smooth and homogeneous body.

The high temperatures to which the evaporated milk is subjected in the sterilizer have a tendency to coagulate the casein. In the case of normal, fresh milk the casein coagulates at a temperature of 269 degrees F. In the evaporated milk, made from perfectly normal and sweet, fresh milk the casein curdles at much lower temperatures, and the higher the ratio of concentration, the lower the temperature required to precipitate the casein. It seems that the concentration of the milk intensifies the properties of milk to coagulate when subjected to heat. This factor is probably largely, though not necessarily, wholly due to the increase of the per cent of lactic acid in the evaporated milk, due to the concentration. If the fresh milk contains .17 per cent lactic acid, a concentration of two and one-fourth parts of fresh milk to one part of evaporated milk causes the evaporated milk to contain $.17 \times 2.25 = .38$ per cent lactic acid. With this amount of acid acting on the casein, it is not difficult to understand why a coagulum is often formed in the sterilizer. While the formation of this coagulum may be partly avoided, under certain conditions it appears in every factory and there are more batches, especially in summer, that come from the sterilizer coagulated than otherwise.

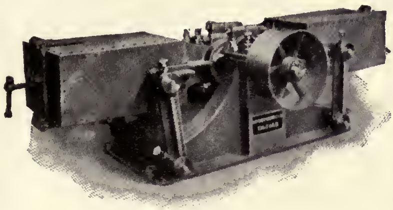

Fig. 48. Shaker
Courtesy of Arthur Harris & Co.

In this condition the product is not marketable. Some means must be provided, therefore, to break up this curd and reduce the contents of the cans to a smooth, homogeneous and creamy body. For this purpose a mechanical shaker is used.

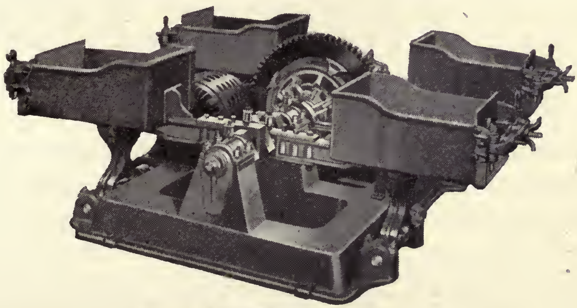

Fig. 49. Shaker
Courtesy of The Engineering Company

Method of Shaking.—The shaker consists of one or more heavy iron boxes or boxes made of black iron pipes. These boxes are attached to an eccentric. The trays filled with evaporated milk cans are firmly wedged into these boxres. When the shaker is in operation, the cans are shaken back and forth violently, causing the curd in the cans to be broken up.

Speed of the Shaker.—If the shaker is to perform its work properly, it must have long enough a stroke and run fast enough to cause most vigorous agitation. The stroke should be not less than about two and one-half inches and the eccentric should revolve not less than three hundred to four hundred times per minute. In order to accomplish this without wrecking the machine, the shaker must be fastened securely to a solid foundation.

From one-fourth to two minutes' shaking is usually sufficient to completely break down a soft curd. When shaking for five minutes does not produce a smooth milk, the product is usually hopelessly curdy and no amount of additional shaking will remedy the defect.

In some cases it has been possible, however, to improve the curdy product by shaking again after a day or two. Under certain conditions, age seems to have a slight mellowing effect on the curd.

Efficiency of Different Types of Shakers.—Some shakers have a straight, horizontal, back and forth motion. Others have a rotary or elliptical motion; the latter are not considered as effective in their work as the former. Some of the sterilizers in which the interior frame holding the cans, moves back and forth, are advertised to shake the milk as well as sterilize it. Experience has shown, however, that the shaking performed by these sterilizer-shakers is not sufficient and that the use of a separate shaker is necessary.

Formation of Curd not Desirable nor Necessary.—It should be understood that the processor should aim to get only a very slight and soft curd in his product, that can be shaken out in the shaker in one-fourth to one-half minute. When the curd produced is firm, even prolonged shaking will not prevent the appearance in the finished product of specks and small lumps of curd. Such milk is rejected on the market.

The formation of curd during the sterilizing process is not desirable and is not necessary as far as the marketable properties of the evaporated milk is concerned. It is unavoidable, however, under many conditions and as long as it can be confined to a soft curd that readily shakes out, no harm is done.

INCUBATING

From the shaker, the cans are transferred to the incubating room. This is a room with a temperature of 70 degrees to 90 degrees F. The evaporated milk remains there ten to thirty days.

The purpose of incubation is to detect defective milk and defective cans before they leave the factory. If the contents of any of the cans have not been completely sterilized, or if any cans have the minutest leak, the evaporated milk therein will spoil within the time of incubation. Such milk either sours, curdles or becomes solid, or it undergoes gaseous fermentation, causing the appearance of "swell heads." The more nearly perfect the process of sterilization and the better the construction and seal of the cans, the fewer are the spoiled cans. This incubation process is strictly a preventative measure. It is omitted in many factories where the cans are labeled, packed and shipped to their destination at once, or put in ordinary storage in the factory.

Chapter XII.

PLAIN CONDENSED BULK MILK

Definition.—This is an unsweetened condensed milk made from whole milk, or partly, or wholly skimmed milk, condensed in vacuo at the ratio of about three or four parts of fluid milk to one part of condensed milk. It is usually superheated to swell and thicken it, and it has the consistency of rich cream. It is sold in 10-gallon milk cans to ice cream factories and in milk bottles to the direct consumer. Plain condensed bulk milk is not sterile, nor is it preserved by sucrose. Its keeping quality is similar to that of a high quality pasteurized milk.

Quality of Fresh Milk.—The sweeter and purer the fresh milk or skim milk, the better will be the quality of this product. Old milk, or skim milk in which the acid development has made considerable headway, tends to form a lumpy, plain condensed bulk milk. However, since this milk is not subjected to sterilizing temperatures and is used up quickly after manufacture, the quality of the fresh milk from which it is made, is not of such magnitude as in the case of evaporated milk.

Heating.—In the manufacture of plain condensed bulk milk the heating is accomplished much in the same manner as in the case of sweetened condensed milk and evaporated milk. The milk is usually heated by turning steam direct into it; though many of the more efficient types of milk and cream pasteurizers could be used to excellent advantage for this purpose.

It is advisable, however, to heat this milk only to about 150 to 160 degrees F. in order to secure a nice "liver" (coagulum), when it is superheated in the pan. If the milk is heated to the boiling point in the forewarmers, it does not respond to the superheating in the pan as satisfactorily.

Condensing.—The condensing of plain condensed bulk milk is done in the vacuum in a similar manner as described under evaporated milk, except that the evaporation is carried farther. See also Chapter XIV on "The Continuous Concentrator," pages 133 to 141.

Superheating.—When the condensation is nearly completed the milk in the pan is superheated. This is accomplished by shutting off the steam to the jacket and coils, closing the valve that regulates the water supply of the condenser, stopping the vacuum pump and blowing steam direct into the milk in the pan, for the purpose of swelling and thickening it. During this process the temperature rises to between 180 and 200 degrees F. When the milk has become sufficiently thick or, in the language of the processor, has produced the "proper liver" (coagulum) the steam is shut off, water is again turned into the condenser and the vacuum pump is started up. As soon as the vacuum has risen to from twenty-five to twenty-six inches and the temperature has dropped to about 130 degr. F. the process is complete, the vacuum is released and the condensed milk is drawn off. The superheating usually occupies about twenty-five to thirty minutes.

The completion of the superheating, or the point when the superheating should cease, may also readily be detected by the examination of a sample of the product. As soon as the condensed milk begins to show a flaky condition of the curd, the purpose of superheating has been accomplished. The amount of superheating necessary and that the milk will stand, will largely depend, aside from the sweetness of the original milk, on the extent of the concentration. The higher the ratio of concentration, the less superheating is required to secure the desired results.

Striking.—The striking, or sampling and testing for gravity is done with a Beaumé hydrometer, the same, or a similar one, as is used for evaporated milk. The scale should extend to 15 degrees Beaumé. The batch should be struck before and after superheating.

Factories which standardize their product to a certain established density, usually condense the milk to a point slightly beyond that desired. Then, after superheating, they determine the amount of water required to reduce the finished product, and then add the required amount of water before the condensed milk is cooled. It is advisable to use distilled water for this purpose.

Ratio of Concentration.—The ratio of concentration varies largely with the fat content of the milk, although the locality and season of year are also influencing factors. Whole milk is condensed at the ratio of about three parts of milk to one part of condensed milk, while the ratio of concentration for skim milk is about 4 to 1. The proper density varies somewhat with locality and season of year. Roughly speaking, whole milk has reached the proper density when the Beaumé reading at 120 degrees F. is about 10 degrees B. and skim milk has reached about the proper density when the Beaumé reading at 120 degrees F. is about 14 degrees B. When the ratio of concentration exceeds 4 to 1, there is danger of gritty condensed milk due to the precipitation, in this concentrated product, of crystals of milk sugar.

Cooling.—The plain condensed bulk milk is usually drawn into 40 quart milk cans, placed in cooling tanks containing revolving cogwheels, as described in Chapter VI, under "Cooling Sweetened Condensed Milk," and is cooled to as near the freezing point as facilities permit.

Recently this crude and laborious method of cooling has been superseded in many of the larger condenseries by more modern ways. While the plain condensed bulk milk becomes too thick and sluggish during the process of cooling to make possible the use of surface coolers, and internal-tube coolers, it can be readily cooled in vats equipped with revolving discs, or in horizontal coil vats especially constructed for this purpose and in which the lower part of the vat is constricted and the coil sets very low in this constricted part, so as to agitate the milk vigorously and at the same time prevent the incorporation of air, by being completely submerged, or in circular vats equipped with a vertically suspended coil. The vertical coil vat has the further advantage in that it eliminates from the milk, all bearings and glands and it expells, rather than incorporates air, from the condensed milk.

When cooled the condensed milk is ready for the market. If held in the factory, it should be placed in a cold room or should be otherwise protected against temperatures sufficiently high to cause it to sour. When kept at 40° F. or below the danger from souring is largely eliminated. If transported long distances during warm weather, it should be shipped in refrigerator cars.

CHAPTER XIII.

CONCENTRATED MILK

Definition.—Concentrated milk is cow's milk, either whole milk, or partly or wholly skimmed milk, condensed at the ratio of three to four parts of fresh milk to one part of concentrated milk. It is not condensed in vacuo, but in open vats by passing currents of hot air through the milk. It is sold largely in pint and quart bottles for direct consumption. It is not sterile and therefore keeps for a limited time only. Its keeping quality is similar to that of a high grade of properly pasteurized milk. The process by which the concentrated milk is manufactured is known as the "Campbell Process." This process was invented by J. H. Campbell of New York City, in 1900 and patented in 1901.

Apparatus Needed.—The principal parts are: the evaporating vat with hot water jacket and coils, and air blast registers or nozzles near the bottom of the vat; an air blower which furnishes the air blast; an air heater through which the air blast passes and from which the heated air is conducted into the milk; a water pump circulating hot water through the jacket and coils; an auxiliary evaporating tank for completing the evaporation; and a spray pump which throws the spray of milk drawn from the bottom of the main evaporating vat into the auxiliary tank and for transferring the partly condensed milk from tank 1 to tank 2.

Operation of Campbell Process.—The milk is heated to about 100 degrees F. and allowed to flow into evaporating tank 1

Water at temperatures ranging from 100 to 125 degrees F. is forced through the coils and jacket. Hot air is then passed into the milk. The temperature of the air is regulated so as to keep the temperature of the evaporating milk down to 120 degrees F. on the start, and to finish the evaporation between 90 and 100 degrees F. The air blast is so introduced as to keep the milk along the heating surface of the jacket and coils in circulation and, therefore, prevent largely the baking of the milk on the heating surface. After the milk has been evaporated to a certain degree of concentration, say 2:1, it is transferred to the auxiliary evaporating tank where the condensation is completed. This transfer is not necessary, but is resorted to solely as a convenience, in order to continue treatment of the reduced bulk of material in a smaller tank and leave the larger tank free for treating a fresh batch of milk, and further, because there are no obstructing coils in the auxiliary tank, interfering with the drawing off of the finished and thick condensed milk. In this process, as now used, the milk is usually first separated and the skim milk only is condensed. The cream is subsequently added to the condensed skim milk.

Advantages and Disadvantages of Campbell Process.—The initial cost of installing the necessary machinery is much less than where vacuum evaporation is practiced. The low heat applied makes it possible for the finished product to retain the properties of raw milk, leaving the albumenoids and lime salts in their original and easily digestible form.

This process is applicable only in the manufacture of unsweetened condensed milk. Unless subsequently sterilized, the product will keep for a short time only. This process has at the present time only very limited use. It can hardly be considered as an important branch of the condensed milk industry.

Chapter XIV.

CONDENSING MILK BY CONTINUOUS PROCESS

The processes of condensing milk described in preceding chapters, are exclusively confined to the intermittent or batch-principle of evaporation. That is in the case of the vacuum pan. the fresh milk runs into the pan until the capacity of the pan is reached and no condensed milk leaves the pan until the condensation of the entire batch is completed. Then the pan must be emptied before more milk can be drawn in. In a similar manner, in the Campbell process, evaporation of the entire batch must be completed before any of the finished product leaves the evaporating vat or tank. The operation in either case is intermittent and not continuous.

Of more recent years, equipment and processes have been developed that make possible continuous operation. That is the fresh milk enters the machine and the condensed milk leaves it simultaneously and continuously. So far two types of continuous machines have been perfected sufficiently to make them commercially practical and usable, namely the Buflovak Rapid Circulation Evaporator, invented and manufactured by the Buffalo Foundry and Machine Co., Buffalo, N. Y., and the Continuous Concentrator, invented by the By-Products Recovery Co., Toledo, Ohio, and manufactured by the Creamery Package Manufacturing Co., Chicago.

BUFLOVAK RAPID CIRCULATION EVAPORATOR

This type of Evaporator has been developed from the standard return-flue tubular boiler and adopted for the special purpose of handling foamy and delicate liquors.

Construction.—The Buflovak Rapid Circulation Evaporator consists of a horizontal cylindrical vapor body. To this is bolted an inclined cylindrical steam-chest.

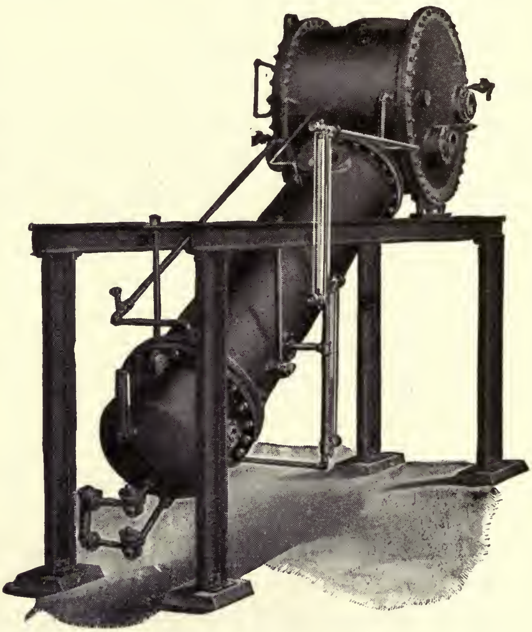

Fig. 50. The Buflovak rapid circulation evaporator
Courtesy of Buffalo Foundry & Machine Co.

The vapor body is equipped with a

baffle plate which extends across its cylindrical part and leaves openings at both ends of the vapor body for the vapors to escape, the ends or heads of the vapor body being dished outward. The vapor body also carries the milk inlet, vapor outlet and spy glasses.

The steam chest which is attached to the lower part of the vapor body, is divided by a solid partition into two compartments. The upper and larger compartment is filled with tubes which are expanded in the flue-sheets, closing both ends. The tubes themselves are open at both ends. They are two inches in diameter and from six to eight feet long. The lower and small compartment, called the downtake, is entirely open at both ends. The steam chest is equipped with a steam inlet, a liquor outlet and a condensation outlet or drip. The steam is around the tubes and the milk is inside the tubes.

Operation.—This machine is operated under vacuum of from 26 to 28 inches mercury column, the vapor outlet being connected with a condenser and vacuum pump.

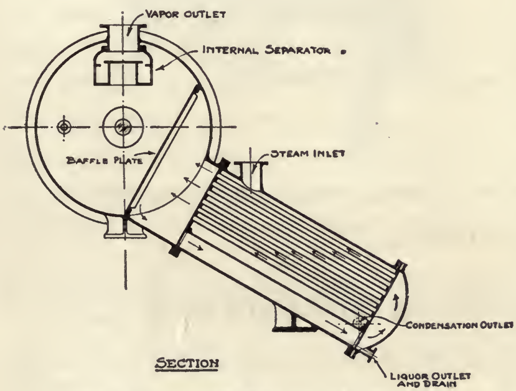

Fig. 51. Cross section of Buflovak rapid circulation evaporator
Courtesy of Buffalo Foundry & Machine Co.

The fluid milk enters the vapor body and flows down into the bottom of the downtake of the steam chest, from where it rises in the tubes and finds its level. The level of the milk in the tubes is kept low, the coefficient of the heat transmission being highest when the milk level in the tubes is about one-third of the tube length above the lower flue-plate, and it is regulated by automatic float controls in the larger machines. The steam that is turned into the steam chest, causes the milk in the tubes to boil. The vapor thus arising from the milk, together with a portion of the milk rises and passes through the upper part of the tubes at a very high speed, and is thrown with great force against the ribs of the baffle plate which extends across the whole cylindrical length of the vapor body.

The liquid or condensed milk returns through the downtake to the lower part of the steam chest where it escapes from the machine. The vapor passes at both ends of the baffle plate into the vapor space above and from there through the entrainment separator for reclaiming escaping milk, and then to the condenser attached to the outlet of the vapor body.

The upper part of the tubes becomes covered with a climbing film of milk. This together with the high speed of the milk in the tubes (100 feet per second or more) increases the capacity of the heating surface, and the small amount of milk in circulation, together with the low level of the milk in the tubes, reduces the possibility of foaming, confining the foam to and breaking it up in the upper part of the tubes where film evaporation takes place.

The escape of the condensed milk is continuous and the degree of concentration is controlled by a valve regulating the outlet. The condensed milk runs by gravity from the steam chest into a reservoir located under the evaporator. In this case the reservoir must be under the same vacuum as the evaporator. In some cases it is recommended to have an intermediate storage tank removing the condensed milk from the evaporator by a specially constructed steam pump.

THE CONTINUOUS CONCENTRATOR

The inflow of the fluid milk and the outflow of the condensed milk are continuous. The milk is condensed under atmospheric pressure at 212° F. A rapidly revolving agitator throws the milk in a thin film against the steam-heated and continuously polished periphery of a jacketed copper drum. By keeping the heating surface clean and bright, and the milk rapidly moving, the power of the milk to absorb and utilize heat is greatly augmented and the rapidity of evaporation increased.

Description of Continuous Concentrator.—The continuous concentrator consists of a hollow copper drum. The copper shell is surrounded by a steam jacket which is insulated. The space between inner shell and jacket is about one inch.

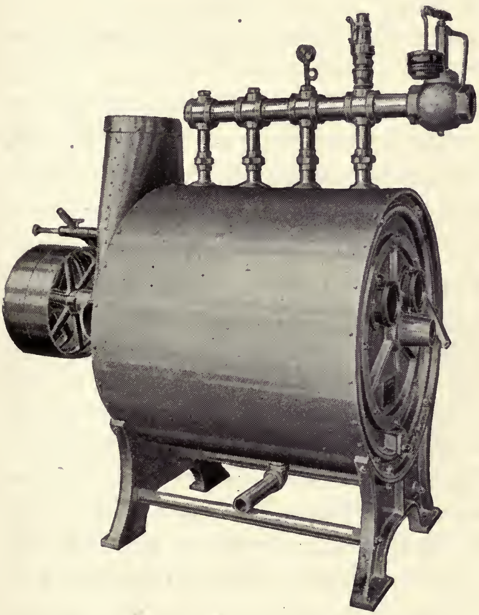

Fig. 52. The continuous concentrator
Courtesy of The Creamery Package Mfg. Co.

This drum carries in its interior, a revolving dasher with four or more blades, according to the size of the machine, and similar to an ice cream freezer or a flash pasteurizer. The edge of these blades comes in direct contact with the inner surface of the shell which is the heating surface, so that when revolving, each blade constantly removes from the heating surface any milk that adheres to it.

The blades are pressed against the heating surface by the centrifugal force that is generated when the machine is in motion. The arms to which the blades are attached are equipped with stops that control their pressure against the heating surface so as to insure continuous and uniform pressure. The shaft which carries the dasher passes through the front and rear heads of the concentrator and carries a pulley back of the rear head, to which the power is transmitted.

The rear of the concentrator terminates in the exhaust chamber of the condensed milk vapors, which escape through a galvanized iron flue to the outside. The vapors are not condensed by water, but escape into the atmosphere. The rear wall is equipped with the intake of the fluid milk. In order to permit the milk to feed the concentrator by gravity, without necessitating inconveniently high elevation of the forewarmer, the intake is located at the bottom.

In the front head, in close proximity to the periphery of the concentrator is located the outlet of the condensed milk. Its distance from the inside wall of the concentrator determines the thickness of the film of condensed milk that is allowed to form on the heating surface, and the amount of milk that is retained in the concentrator. According to the amount of superheating intended, this film may vary from $\frac{1}{8}$ to $\frac{1}{2}$ inch in thickness and the amount of milk retained in the machine may vary from 6 to 12 quarts.

The front head is equipped with a cover which is fastened to the rim with screw bolts and which carries a spy glass through which the operator may watch the process. At the conclusion of the operation this cover is removed and the dasher and blades are taken out, so that both the shell and the dasher can be readily washed. Over the top of the concentrator extends the steam line, a 3 inch pipe, with $1\frac{1}{2}$ inch laterals, supplying the steam jacket, and insuring uniform distribution of heat. The steam line is also equipped with regulator and steam gauge. At the bottom of the concentrator is located the exhaust and regulating drip valve.

The continuous concentrator is constructed of diverse sizes and capacities, the most common of these sizes are the following:

Diameter	Length	Capacity when Concentrating at the ratio of 3:1	Boiler Capacity required H. P.
3 feet	4 feet	4000 lbs.	100 H. P.
3 feet	3 feet	3000 lbs.	80 H. P.
3 feet	2 feet	2000 lbs.	40 H. P.

Speed of Agitator.—The proper speed of the continuous concentrator is expressed in terms of rim speed, that is the distance which the blades travel per minute. It has been found that the rim speed which is sufficient to move the film of milk in the machine properly, is about 2500 feet per minute. In order to insure a rim speed of 2500 feet per minute, the blades in a 3 feet diameter machine must revolve $\frac{2500}{3x3.14} = 265$ times per minute. In a six foot diameter wheel, the same rim speed would require $\frac{2500}{6x3.14} = 133$ revolutions per minute of the spider.

Again it has been found that the blades should be not more than about 2½ feet apart. A three foot diameter concentrator, therefore, requires four blades while concentrators with larger diameter require a larger number of blades in order to keep the distance between blades within the limit of two and one-half feet.

Operation of Continuous Concentrator.—The operation of the continuous concentrator is simple and the ratio of concentration of the product can be regulated as desired.

Heating of Milk.—Similar as in case of evaporation in vacuo, it is desirable, if not necessary, to heat the milk before it enters the concentrator. This not only increases the capacity of the machine, but it also prepares the casein in the milk for the superheating to which the milk is subjected in the concentrator. Any method of forewarming or preheating may be used for this purpose, but since the milk flows to and through the concentrator, in a continuous stream, it is preferable to also use a forewarmer of the continuous type. The milk should be heated to about 185 to 200° F. and the forewarming should be so arranged that the milk is exposed to this temperature for 5 to 10 minutes before it enters the concentrator.

Condensing.—The concentrator is steamed, the parts of the agitator are assembled and installed in their proper place, the cover is securely bolted over the opening in the front head and the machine is ready for operation. Before starting the agitator a small amount of milk is permitted to flow into the concentrator so as to avoid the blades from running over the dry heating surface, cutting the copper. Simultaneously with the starting of the agitator the steam is turned into the jacket and then the milk intake valve is opened.

The steam pressure on the jacket is kept uniform, preferably at 40 to 50 lbs. of steam. This machine evaporates the milk at atmospheric pressure. The temperature of the milk in the concentrator therefore, is practically the same as that of boiling water—212° F.—at the sea level and varies only with the altitude of the location. The ratio of concentration is regulated by the rate of the milk inflow. As the milk inflow is increased, the ratio of concentration is reduced, because the amount of evaporation being constant, a smaller proportion of the water is taken out of the milk.

The density is determined by the use of the Beaumé hydrometer. If the density is greater than desired, more milk is allowed to flow into the machine. If the density is lower than desired the inflow of milk is reduced.

Cooling of Condensed Milk.—From the discharge spout the condensed milk is run over a continuous cooler from which it escapes ready for packing in whatever form it is intended for. The disc continuous cooler has proven very suitable for this purpose.

No subsequent superheating of the concentrated milk is necessary. This product can be made of any consistency desired, regardless of concentration, according to the thickness of the film that is allowed to form in the concentrator, and this in turn depends on the distance of the discharge from the periphery of the machine.

Type of Products that can be made by the Use of the Continuous Concentrator.—The continuous concentrator can be used for the manufacture of all types of unsweetened condensed milk, such as plain condensed bulk milk, evaporated milk, condensed buttermilk, condensed whey.

For sweetened condensed milk, it would be necessary to delay the addition of the sugar until after condensing, in which case the sugar would have to be added in the form of a syrup. This phase has not as yet been worked out on a practical scale, and demands further investigation before definite directions can be given.

When properly operated, the continuous concentrator yields a product of excellent flavor and good quality. Contrary to popular assumption, that milk exposed to so hot a heating surface (40 to 50 lbs. steam pressure which equals a temperature of about 260° F. to 280° F., develops a pronounced cooked flavor, this product is remarkably free from this off-flavor, its solubility is not materially affected, and its body is smooth.

CHAPTER XV.

CONDENSED BUTTERMILK

The value of buttermilk as a chicken feed is rapidly gaining recognition. Buttermilk, similar to skim milk and whole milk, is a highly satisfactory feed for fattening chickens. Its value is enhanced by the superior quality of the meat from buttermilk-fed chickens and by increased egg production of laying hens. For similar reasons buttermilk which is the foundation of a good hog, is becoming a more and more indispensable part of the ration fed to pigs and hogs.

Since the great bulk of butter is manufactured during the summer season the main supply of buttermilk is confined to the summer months. In summer the output of buttermilk far exceeds the demand for this product and much of it goes to waste for lack of a suitable market for it. In winter, on the other hand, the output of buttermilk is small and insufficient to supply the demand.

In order to stop this waste of buttermilk in summer, to utilize it economically and profitably and to equalize the supply throughout the year, some of the large creameries of the country have found it practicable and profitable to condense the surplus buttermilk. Information from chicken feeders and hog feeders shows that, when re-diluted to the consistency of the original buttermilk, this condensed buttermilk gives equally as satisfactory results as the fresh buttermilk.

Manufacture.—There are many methods whereby buttermilk can be and is being reduced in volume. The most common ones are: Separation of whey by gravity, evaporation in vacuo. evaporation by blowing hot air through it, evaporation by the continuous concentrator, centrifugal separation.

Separation of Whey by Gravity.—Much of the so-called condensed buttermilk that reaches the market is not the result of evaporation of a portion of the water contained in the buttermilk, but is produced by permitting the curd to settle by gravity and then drawing off and rejecting the whey.

In this case the fluid buttermilk is pumped into a wooden tank, either a horizontal vat or a vertical stave tank. The tank usually contains several outlets with gates, located at different heights, to facilitate the removal of the whey. The tank may or may not be equipped with steam pipes for heating. The buttermilk is heated to boiling point in these tanks either by blowing live steam into it, or by running steam through the pipes installed in the tank. This heat is maintained for several hours. This causes the casein to contract and settle to the bottom in the form of fine particles of curd, leaving on top a clear whey. This whey is drawn off through the gates located above the stratum of curd. The residue, consisting largely of casein, water and some lactic acid and milk sugar, represents the condensed buttermilk. The concentration, or more correctly speaking, the reduction in volume thus effected, is at the ratio of about 4 to 5 parts of fluid buttermilk to one part of condensed buttermilk. It is obvious that in this form of concentration all of the valuable food elements of the buttermilk are not reclaimed. Most of the milk sugar and much of the lactic acid escape in the whey and are lost. However, the equipment required for this process is very simple and inexpensive and the process requires no special knowledge on the part of the creamery personnel.

Evaporation in Vacuo.— This is accomplished in a similar manner as is the case in the manufacture of sweetened condensed milk. The buttermilk is condensed in the vacuum pan. Earlier trials of this method did not prove entirely satisfactory, especially because of the tendency of the curd in the buttermilk to stick to the coils and the sides of the pan. Another objection was the relatively high initial cost of equipment—the vacuum pan and pump.

In order to avoid the sticking of the curd, attempts have been made to neutralize the buttermilk before evaporation by the addition to it of such alkalies and alkaline earths as sodium carbonate, sodium bi-carbonate, milk of lime, ammonium hydrate, and ammonium carbonate.

Since one of the virtues, for which buttermilk is of special value for feeding purposes, is its relatively high content of lactic acid, it is obvious that by neutralization the manufacturer is robbing the condensed buttermilk of the very ingredient that renders it most wholesome and dietetically valuable.

Furthermore, while, with the exception of milk of lime, these alkalies add nothing to the product that is of acknowledged benefit as a food, the addition of caustic alkalies in quantities sufficient to reduce the precipitation of the curd and to prevent its sticking on to the pan, is detrimental to the wholesomeness of the finished product.

There are now several firms in this country who claim to have perfected a method of condensing buttermilk in vacuo, that eliminates most of the difficulties formerly encountered and the expensive copper pan is being replaced for this purpose by one of cheaper material.

Evaporation by Blowing Hot Air through the Buttermilk.—This refers to the Campbell process of making concentrated milk as described on page 132. This method has not come into general use and its practicability for concentrating buttermilk is as yet untried.

Evaporation by the "Continuous Concentrator."—There is every reason to believe that the use of the "Continuous Concentrator" for condensing buttermilk is a commercially practical proposition. Experiments have demonstrated that a condensed buttermilk of very good quality can be made by this process and a very high degree of concentration can be accomplished. It is probable that the future will see many of these machines installed in creameries for the purpose of condensing buttermilk. See also "Condensing Milk by the Continuous Process," pages 133-141.

Concentration by Centrifugal Separation.—For many years, efforts have been made to remove the water from the buttermilk by centrifugal separation. Machines are now on the market and in use, in which the curd of the buttermilk collects on the walls of a revolving basket while the whey is centrifuged out. These machines are similar in principal to the well-known laundry centrifuge. They have been successfully used by creameries that are engaged in the manufacture of buttermilk cheese. Their operation, however, is intermittent only. When the basket fills up with the curd, the machine must be stopped and the curd removed.

For the purpose of handling large volumes of buttermilk daily these centrifuges are obviously not well adapted. They are too limited in capacity and in speed and in volume of performance. Efforts to devise a centrifuge for continuous operation, similar to the cream separator, have so far failed. The specific gravity of the curd in the buttermilk is so nearly like that of the whey, that the centrifugal separator refuses to discharge a liquid rich in curd and one of practically clear whey. Experiments by the author have demonstrated that, no matter how the outlets of the discharges are adjusted, both liquids have practically the same composition.

Packing Condensed Buttermilk.—Condensed buttermilk is usually filled in wooden barrels, similar to glucose barrels. On account of its high lactic acid content it keeps without spoiling for a considerable length of time. For prolonged storage, it should be held in the cold. Its keeping quality naturally depends largely on the method of condensation, the degree of concentration and the amount of acid present. Condensed milk produced by evaporation of a portion of its water contains more lactic acid than that which is the result of gravity separation. Evaporated condensed buttermilk may keep for months at ordinary temperature. Wheyed-off condensed buttermilk will spoil in a few weeks, if held at ordinary temperatures.

Chemical Composition of Condensed Buttermilk.—The composition of condensed buttermilk naturally varies with the composition of the original buttermilk and the nature and the degree of concentration. Since these three factors are not constant, the composition of the finished product may vary within comparatively wide limits.

The following analyses show the composition of two samples of buttermilk condensed in a vacuum pan.

Composition of Condensed Buttermilk

	Not neutralized	Partly neutralized by ammonium hydroxide
Total solids	51.48	40.90
Moisture	48.52	59.10
Ash	3.93	3.70
Curd	18.93	15.38
Lactose	26.30	15.76
Lactic acid	3.60	2.52
Ammonium hydroxide	.00	.88
Total	101.28	97.34

Uses of Condensed Buttermilk.—Most of the condensed buttermilk is sold to chicken feeders. It brings from about four to six cents per pound.

Condensed buttermilk has also found a limited demand as human food. It is claimed to be a most wholesome, readily digestible, nutritious and palatable food. Its wholesomeness and digestibility are attributed to its high lactic acid content. It is best put on the market in glass bottles. Its keeping quality is enhanced by the high per cent of lactic acid it contains.

CONDENSED WHEY, MYSEOST, OR PRIMOST

The condensing of whey is a practice which originated in Scandinavia. The original process consisted of straining the whey into a kettle or large open pan over a fire. "The albuminous material that precipitates and rises to the surface is skimmed off."[1] The whey is evaporated as rapidly as possible with constant and thorough stirring. When it has reached about one-fourth of its original volume the albumin previously skimmed off is returned and stirred thoroughly to break up all possible lumps. When the whey has attained the consistency of thickened milk it is poured quickly into a wooden trough and stirred with a paddle until cool, to prevent the formation of large sugar crystals. It can then be molded into the desired form for market.

[1] United States Department of Agriculture, Bureau of Animal Industry, Bulletin No. 105.

A more rapid method of making primost is to evaporate the whey in the vacuum pan. When the syrup has reached the desired density it is drawn off, allowed to cool and pressed into bricks. The product has a yellowish-brown color, gritty texture and sweetish taste. The evaporation of whey in vacuo is as yet a rare practice and the demand for the finished product is very limited.

Experiments with the "Continuous Concentrator" have demonstrated that condensed whey of good quality can readily be prepared with this machine. The concentration can be carried as far as 15 to 1; whey so condensed escapes from the concentrator still in liquid form, but changes to a solid upon cooling, the milk sugar in this supersaturated solution crystallizing completely. If made of sour whey, the product thus obtained has a splendid clean and sharp acid flavor. This product promises to have excellent dietetic properties, and also to lend itself admirably for cooking purposes.

PART IV.

FROM FACTORY TO CONSUMER

CHAPTER XVI.

STAMPING

Every well regulated condensing factory, selling condensed milk in hermetically sealed tin cans, employs some system of marking the cans. This is important for future reference.

When defective condensed milk is returned to the factory, the marks on the cans tell the manufacturer the date of manufacture, and his own record on file in the factory shows the conditions under which the defective milk was made. In this way defects can usually be traced to their causes and the recurrence of similar trouble can be avoided.

In some factories the batches of condensed milk are numbered from one up, and the cans are stamped with the respective batch number. This method is simple but may prove undesirable, since it informs the competitors also of the date of manufacture of competing brands. In most factories a code of letters and figures is used, designating the factory, the date, and the number of the batch of each day. Thus for instance: a concern has three factories, A, B and C. X stands for the current year, the letters E, F, G, H, I, J, K, L, M, N, O, P indicate the twelve months of the year, respectively, the figures 1, 2, 3, 4, etc., represent the day of the month and also the batches of condensed milk made in one day.

Example: A can of condensed milk belongs to the second batch made April 9, 1918, at factory B. The can would be stamped as follows: B 9 H X 2.

The cans are usually stamped on the bottom, that is, on the end which carries the cap. The stamping is done by the sealer. Small interchangeable rubber letters and figures are used. The stamping ink should contain a drier and be waterproof. In small factories the stamping is done by hand. It can be done very rapidly. In large factories an automatic stamping outfit is attached to the filling, sealing or labeling machine and the cans are stamped automatically while they are being filled, sealed, or labeled.

INSPECTING

The sealed and stamped cans are placed, with caps down, in wooden trays holding twenty-four medium-sized cans. All trays of one batch are stacked together. A card indicating number and date of batch and number of cans in the batch is attached to the stack and a copy of the same is filed in the office. The cans are placed with their caps down in order to detect "leakers" (cans with defective seals). Before labeling, the trays should be taken down, the cans turned over and examined for leaky seals. Unless the factory is behind in filling orders the cans will have been in stock at least twenty-four hours or usually longer. In the case of sweeetened condensed milk, if any seals are defective, a little condensed milk will have oozed out by that time. Inexperienced sealers are prone to cause a high percentage of leaky cans. A careful sealer may reduce the number of leakers to .1 per cent.

Checking the Work of the Sealers.—In order to regulate and improve the work of the sealers and to locate those doing poor work, it is advisable to number the sealers and supply each with small tin tags bearing his or her respective number. Each sealer drops one tag into each tray of cans sealed by him. The inspectors record the number of leakers found in each tray. Thus each sealer is charged up with the leakers he made.

Disposition of Leaky Cans.—Small leaks, in the case of sweetened condensed milk, can usually be soldered over successfully and the mended cans are returned to their respective batches. In the case of very defective seals, attempts at mending generally cause the milk in the can to burn, forming a brown crust on the cap, which spoils the can for the market. The contents have a burnt taste and smell, and upon stirring, brown and black specks of burnt milk appear. It is best to cut bad leakers open and pour the contents into the succeeding batch of milk.

Importance of Inspection.—The above description of inspection refers to sweetened condensed milk. This work is neglected in many factories, though it is very important. It may save labels and boxes, as well as much unnecessary labor in unpacking cases with leaky cans, and washing, relabeling and repacking them in new, clean cases.

In the case of evaporated milk (unsweetened, sterilized) all cans coming from the incubating room should be individually shaken by hand. All cans showing no signs of bulging, and the contents of which shake with the characteristic sound and behavior of a liquid, pass inspection. If the ends of the cans are bulging or the contents do not respond to the shaking with the characteristic sound of normal milk, they are rejected, as the evaporated milk in them has either undergone gaseous or curdling fermentation, and is spoiled.

LABELING

Labeling Machines.—In the early days of the milk condensing industry, the labeling of the cans was done by hand, involving much time and considerable expense. Today, especially constructed labeling machines are almost exclusively used for this purpose. The efficiency of these machines is such, that they have become a permanent fixture in practically every condensery selling canned goods. They are adjustable to various sizes of cans and can be operated by hand, motor, or belt power.

Principle of Labeling Machines.—The cans are placed into a chute from which they roll into the machine by gravity. They are caught by two endless belts which draw them through the machine. They first pass over the paste box, which contains an automatically revolving wheel covered with a thick layer of felt. The felt is saturated with paste or glue from the paste box. Each can comes in contact with the paste wheel and receives a touch of paste. Then the cans pass over the label box containing a stack of labels, face down. Each can picks up one label which is automatically wrapped around the can as it runs through the machine. The label box is equipped with an automatic feeder which pushes the labels up as fast as they are being used. The labeled cans leave the machine over a chute which slants from it. As they are removed they are packed directly into cases.

Wrinkles and Rust Spots on Labels.—The attractiveness of the package depends, largely, on the neatness of the label. The use of too thin, too thick, or too much paste causes the labels to wrinkle on the cans. The paste should have the consistency of heavy dough and the paste wheel should be so adjusted that it barely touches the passing cans.

Frequently the labels of the cans show stains and spots. This is especially true in the case of old goods, and is due either to a poor quality of paper, the use of sour paste or the storing of the labeled goods in damp places. Sour paste corrodes the cans and causes them to rust. The rust penetrates the label and spoils the appearance of the package. Trouble of this kind can be avoided by preparing fresh paste every day. Paste saved from the previous day is prone to sour and should not be used. The storing of the labeled goods in damp places also often causes rust spots as well as moulds on the labels. Thin and soft paper labels more easily than thick, stiff and glossy paper. In the latest types of labeling machines the use of ordinary paste has been largely superseded by that of specially prepared glue, which removes most of the objectionable features of the ordinary paste, does not damage the label and makes a neater package.

PACKING

The labeled cans are packed in cases holding from six to ninety-six cans, according to the size of the cans. (One case holds six 1-gallon cans; forty-eight 14-, 15-, 16-, and 20-ounce cans; or seventy-two to ninety-six 8-ounce cans).

The sides, bottom and top of the cases should be of material about three-eights of an inch to one-half inch thick, the ends three-fourths of an inch to seven-eights of an inch thick. The cases are usually bought in the "knock-down" shape and are made up in the factory. Sixpenny cement-coated wire nails are most suitable for this purpose. The cases are most economically nailed by the use of nailing machines, which nail one entire side or one side and one end simultaneously. The cans are usually placed into the cases direct from the labeling machine. In some factories, packing machines, which pack twenty-four medium-size cans in one operation, are used. Formerly condensed milk cans were packed exclusively in wooden cases. Within the last few years the use of paste-board and fibre boxes has been adopted in many condenseries. These boxes are proving very serviceable for domestic trade, and prior to the price advance on paper material caused by the world war, they made possible a considerable saving in the cost of the package.

Marking the Cases.—One end of each case is stenciled with the number of the batch; over the other end is pasted a case label, representing, enlarged, the brand of the label on the cans within. In the place of the case label, the respective brand may be printed on or burnt into the wood. The burnt stencilling is usually done by the manufacturer of the shooks. One side of each case is usually marked "Condensed Milk" or "Evaporated Milk," as the case may be; the other "Keep in cool, dry place." If sweetened condensed milk is exposed to excessive heat for a considerable length of time, as is often the case in storehouses or in the hold of steamers, where the cases may be stowed against the boiler room, it becomes brown, thickens rapidly and develops a stale flavor. Evaporated milk also darkens when exposed to heat and depreciates in flavor. It should, therefore, be kept in a cool place. The humidity of the storage room has no effect on the condensed milk proper, the cans being hermetically sealed. Prolonged exposure to dampness, however, will moisten the paste under the labels. This causes the labels to wrinkle and the paste to become sour and musty. The sour paste corrodes the cans and rust spots penetrate the labels. Such cans also may soon become coated with mildew.

Packing Condensed Milk for Export.—In the case of condensed milk bought by the United States Government, the cans are dipped in a solution of shellac before they are labeled, or the tin plate or empty cans are bought by the manufacturer already lacquered. Cans for export trade and in many instance for the home market, are wrapped into heavy, soft paper, bearing on the outside a copy of the respective brand. This wrapping paper takes up the space between the cans and prevents the cans from being damaged on their long journey and by rough usage. This wrapping is usually done by hand. Some makes of labeling machines, however, have an attachment for wrapping the cans so that when the cans leave the machine they are wrapped as well as labeled. The cases are reinforced with a band of strap iron around each end. Where the cases have to be loaded and unloaded numerous times, as is the case with export shipments, they are in danger of being torn to pieces, unless such special precautions are taken.

CHAPTER XVII.

STORAGE

Purpose of Storing.—The purpose of storing condensed milk is largely the same as that of storing butter and other produce, namely, to keep the product from the time of large supply and low prices, to the time of small supply and high prices. In summer time, the market is usually flooded with condensed milk throughout the country, the demand for it is at ebb tide and the prices are low. In winter, there is usually a great shortage of condensed milk, the demand far exceeds the supply and prices soar high. The storing of summer milk may be necessary, also, in order to enable the manufacturer to fill his contracts and supply his trade in winter. This is especially true where the factories of a concern are located in new territories where the patrons produce an excessively small amount of winter milk.

Plain condensed milk and concentrated milk which are not sterile and contain no cane sugar to preserve them, keep but a few days at ordinary temperatures and should, therefore, be sold and used as soon as possible after manufacture. If their storage is unavoidable, they should be held as near the freezing point as possible. For prolonged storage it might be advantageous to freeze them. However, reliable data on this phase of the industry are lacking.

Evaporated milk, sold in hermetically sealed cans, is supposed to be entirey sterile, and, if made properly, will keep indefinitely. There is a constant tendency, however, for the fat to separate out, which naturally is augmented by prolonged storage. Again, the lactic acid in the evaporated milk gradually acts on the can, causing the tinplate to become dull and the contents to aquire a disagreeable metallic flavor. When stored for an excessively long time this chemical action may be sufficient to cause the evolution of considerable quantities of hydrogen gas, swelling the cans.

Sweetened condensed milk which is preserved by about 40 per cent. of sucrose, will keep apparently unchanged for a considerable length of time. It is best, however, when fresh. Bacteriological examinations have shown that, while moderate age does not change the outward appearance of this condensed milk, the bacteria in it gradually increase and the milk gradually develops a stale flavor. White and yellow "buttons," lumps, or nodules of a cheesy texture and flavor, probably due to some fungus growth, are also prone to appear in the condensed milk. Age, also, causes it to become darker in color. These defects are especially apparent in old milk which has not been kept at a low temperature. Again, sweetened condensed milk made in May and June has a strong tendency to thicken with age and to become entirely solid.

In some cases a part of the sweetened condensed milk made during the summer months is stored in large cylindrical wooden or iron tanks sunk into the ground, or installed in the basement of the factory, where the condensed milk remains at an even temperature. As the demand for the product increases and the supply of fresh milk decreases, condensed milk is drawn from these tanks to fill the increasing orders.

Effect of Storage Temperature.—Most, if not all the changes which condensed milk is prone to undergo in storage are retarded, if not entirely prevented, when stored at the proper temperature. Temperatures of 60 degrees F. or above are too high for satisfactory storage for a prolonged period of time and the higher the temperature the greater the resulting defect.

Temperatures below the freezing point of water are also undesirable. The evaporated milk freezes and while so doing it expands sufficiently to swell the cans. Although this swelling disappears when the contents of the cans dissolve again, yet the swelling action tends to weaken the cans and may give rise to subsequent leakers. Again the melted evaporated milk is prone to be grainy as the result of freezing. This is due to the fact that when freezing, the watery portion separates from the curd and the latter contracts. When the milk thaws up the curd remains contracted and fails to form a smooth emulsion with the remainder of the milk.

The sweetened condensed milk does not freeze, because it contains so concentrated a sugar solution that its freezing point is usually far below the refrigerating temperature. If it is packed in solder-sealed cans there is usually no bad effect from cold storage. However, when packed in cans sealed with the friction cap or the burr cap, difficulties may arise. These seals are not air-tight. Excessively low storage temperatures cause the contents to shrink appreciably. Suction is formed and air is drawn in through the seal. When these cans again warm up, the viscous milk in the cans seals the microscopic openings, the air and the liquid expand but the air finds no exit. This causes the cans to swell. While the quality of the milk in these cans is not impaired in the least, the swelled cans suggest gaseous fermentation, which means spoiled milk and which is invariably rejected on the market.

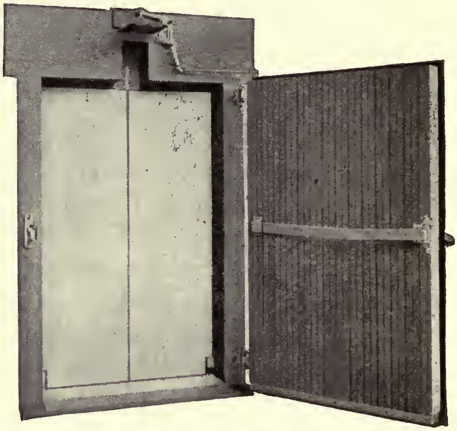

Fig. 53. The Stevenson cold storage door
Courtesy of Stevenson Co.

The temperatures at which condensed milk can be stored with least objectionable results, range between 32 and 50 degrees F.

Advisability of Storing.—A heavy stock of condensed milk is a severe drain on the working capital of the condensery involving the cost of the fresh milk, cane sugar, tinplate, boxes, solder, labels, coal and labor.

Unless the manufacturer has successfully overcome and mastered all of the principal condensed milk defects, and, unless his experience justifies him in believing that his goods will stand the trials of storage, he will find it advisable not to manufacture more than he can promptly dispose of. Even at best, the condensed milk will be from three to six months old before it is all consumed, and, if it is at all subject to deterioration, the sooner it is consumed the better.

But even if the condensed milk comes out of storage in good condition, the condition of the market may be such that the goods cannot be sold at a profit, and if the market happens to take a demoralizing slump at the time the goods are ready to leave the storage, the manufacturer may suffer heavy loss. This condition has occurred repeatedly within the last ten yars.

TRANSPORTATION

The plain condensed bulk milk and concentrated milk are highly perishable products. If shipped considerable distances they should be placed in refrigerator cars.

The evaporated milk and sweetened condensed milk in hermetically sealed cans, and the latter also in barrels, can safely be shipped in ordinary box cars. The cases weigh from fifty to sixty-five pounds, and the barrels from three hundred to seven hundred pounds. Care should be taken that the cars used for this purpose are clean and did not previously carry goods with strong and obnoxious odors, such as fertilizers, as these odors are prone to follow the condensed milk to its destination. Strong box cars, in good repair only, should be used. Even at best, the cases and cans suffer more or less damage in transportation. Cars with leaky roofs should be condemned, as transportation in them may cause the package to suffer in appearance. If shipped on steamboats, it should be specified to stow the cases away from the boiler room, as prolonged exposure to high temperatures causes the condensed milk to deteriorate.

CHAPTER XVIII.

MARKETS

A large proportion of the canned condensed milk, both sweetened and unsweetened, supplies localities, territories and countries where the dairy industry is yet in its infancy, or where geographic and climatic conditions bar the profitable husbandry of the dairy cow. Thus, we find some of the best condensed milk markets in the tropics, in the arctic regions, in the army and navy, on ocean liners and in mining and lumber camps. In these markets condensed milk has, in many cases, become as great a necessity as fresh milk is to the inhabitants within the temperature zone. The consumption of canned condensed milk in our home markets has, also, been increasing rapidly within recent years, and is today assuming astonishing proportions. The rapid growth of the ice cream industry has further developed a splendid and ever-increasing market for plain condensed bulk milk.

It is estimated that the canned condensed milk is from three to six months old before it reaches the consumer. It is usually sold through the medium of a jobber or broker and not direct from manufacturer to retailer. In its transit to the distant markets, it is subjected to many delays; first, by its storage in the factory, then the time in transportation, next, the delay in the warehouse of the jobber, broker or wholesale dealer. From there it gradually finds its way to the shelves of the retailer, where there is again considerable delay before it reaches the pantry of the consumer.

Market Prices of Condensed Milk.—The price of condensed milk is not controlled by the general market of dairy products, nor by any board of trade; there is no consistent uniformity of price throughout the country as is the case of butter and cheese. The price of condensed milk does not necessarily follow the rise and fall of the butter and cheese markets, but in the long run it is usually affected by abrupt fluctuations of prices of these other dairy products, largely on account of the influence of such fluctuations on the supply to the condensery of fresh milk. It is chiefly governed by local conditions of supply and demand, composition of product and reputation of the individual brand. Condensed milk is sold under hundreds of different brands or labels. While one and the same concern may sell scores of different brands, the brand itself has very little, if anything, to do with the quality or composition of the contents of the can. Each brand usually sells at its own special price, although the various brands put on the market by the same concern often contain the same quality of milk and may be filled with condensed milk from one and the same batch. It is customary in most factories to fill the cans before they are labeled and the orders for different brands of condensed milk are filled from the same general stock. The brands serve largely as an instrument to increase the sales and "dodge" competitors.

Sweetened condensed milk, packed in hermetically sealed cans, sells from about $3.25 to $5 per case of 48 sixteen-ounce cans and the cans retail at from 5 to 20 cents each, according to the size of the cans and market conditions.

Evaporated milk, unsweetened condensed milk in hermetically sealed cans, sells from $2.25 to $4.00 per case, according to the size of the cans and market conditions.

Bulk milk, both sweetened and unsweetened, goes direct from the manufacturer to the purchaser who uses it at prices agreed upon by the contracting parties. The sweetened condensed milk is sold in barrels holding from three hundred to seven hundred pounds (usually about six hundred pounds) to candy and caramel factories, bakeries and confectioners. The price varies from four to ten cents per pound according to the per cent. of fat, demand und supply. When there is a general "epidemic" of bad canned condensed milk, as is often the case in years when the price of sugar is high, due to failure of the sugar cane crop, and many manufacturers are tempted to use inferior cane sugar, which they buy at a comparatively low cost, this spoiled condensed milk is usually turned into candy shops and bakeries, where it is sold for "a song." This condition has always a depressing influence on the price of sweetened condensed bulk milk, which, during such seasons, may have to be sold at a loss. Some milk condensing concerns operate their own candy shops which take care of the condensed milk that is rejected on the market.

Plain or unsweetened condensed milk is sold in 1-gallon to 10-gallon cans to ice cream factories, the price varying from twenty-five to ninety cents per gallon, according to fat content, concentration and market conditions. The market for this class of goods is not very constant, but the profits are generally high. It reaches ebbtide in winter when the demand for ice cream is small. Limited quantities of plain condensed bulk milk are also sold in milk and cream bottles for direct consumption. The concentrated milk finds the same markets as the plain condensed bulk milk.

The above range of prices of the several types of condensed milk refers to the market conditions which prevailed while the industry was protected against competition with goods from abroad by an import tariff of 2c per pound or $1.00 per case of condensed milk, and to conditions prior to the advent of the European war in 1914.

In 1913, the United States, by Act of Congress, removed the import tariff, placing condensed milk on the free list. This Act became effective in the fall of the same year. Its immediate effect was a rapid increase in the importation of European condensed milk, which was offered for sale at relatively low prices, decreased the sale of domestic goods and caused the holdings of condensed milk to accumulate in large quantities. Condensed milk prices depreciated rapidly throughout 1914 and reached the bottom in the fall of that year when financial limitations compelled many concerns to move their goods at any price. At that time the bottom prices of condensed milk were approximately as follows:

Sweetened condensed milk per case..........$2.50
Evaporated milk per case.................... 1.90

The losses suffered by this slump in the condensed milk market, caused by the influx of cheap foreign goods in the absence of a protective tariff, were enormous and caused bankruptcy of numerous of the financially limited concerns. The outlook for the future of the industry looked very uninviting at best, but the situation was saved and market conditions reversed by the urgent food requirements of the Allied nations in the European war, and after the entrance of the United States into the World War, by large orders for the American army and navy.

The extraordinary and very urgent demand for condensed milk by the U. S. Government and by its allies boosted the prices of this product to a level not attained since the Civil war. The profits per case were augmented manyfold of those of normal periods and the prices paid the farmer in some localities rose to as high as $3.50 per hundred weight and 75 cent per pound of butterfat. This situation naturally made it easy for the milk condensing factories to encroach on the milk and cream supply territory of the creameries and cheese factories, whose products experienced only a relatively moderate increase in price, and not at all proportionate with the soaring of condensed milk prices.

In the summer of 1917, the Federal Food Administration, in an effort to control the prices and profits of condensed milk, ruled that the profits on condensed milk shall not exceed 30 cents per case on an average for the year, this being considered the average pre-war profit. This did not mean that the government guaranteed a profit of 30 cents per case, it merely meant that 30 cents per case was the maximum profit the condenseries were allowed to make. This ruling applied only to condensed milk sold to the government, it did not refer to the goods sold to the domestic trade nor to export contracts. The national committee of condensed milk men who met with the Federal Food Administration Committee, however, agreed to apply the same ruling to their product sold to the domestic trade.

Profits on condensed milk supplied to the allied nations, however, were in excess of this figure, partly because of high prices payed for this export milk and partly because of the greatly reduced cost of selling and distributing.

The following figures show wholesale condensed milk prices in 1916 and 1917:

	January 1916 per case.	June 1917 per case.
Sweetened condensed milk, per case	$6.50	$8.75
Evaporated milk, per case	3.85	5.75

Early in 1918, this condensed milk boom suffered an abrupt check from the fact that the transatlantic bottoms available proved entirely inadequate to handle the vast stores of goods which were intended to be shipped to the Allies and to the American forces in France. Thus, the Allied Provision Export Commission was forced to reduce its orders for shipment of condensed milk from this country to one fourth the regular monthly amount and the American government ceased ordering additional supplies of condensed milk for its overseas forces.

In the meantime, the condensed milk firms in this country had contracted for an increased supply of fluid milk at high prices with their farmers, many new factories had been erected and the output of the old factories was vastly increased. With the sudden reduction of orders from the Allies and the complete absence of orders from the U. S. Government, large quantities of condensed milk, produced at high cost began to stack up in our factories, causing serious fianancial embarassment to the condensed milk concerns and placing many of the financially limited companies on the brink of disaster. The outlook for a rapid increase in the ocean-going bottoms during the summer of 1918 promises to permanently relieve this temporarily embarassing situation of the condensed milk industry.

Commercial Stocks of Condensed Milk.—Bulletin No. 7 of the United States Food Surveys[1] shows that the total condensed milk stocks January 1, 1918, amounted to 310,881,660 pounds. Of this total the milk condenseries held 22.8 per cent; the storage warehouses, 7.7 per cent; the wholesale dealers, 35.4 per cent; and the retail dealers, 27.2 per cent. The remainder, amounting to 6.9 per cent was held by a miscellaneous group of firms.

Stocks of Condensed Milk Reported for January 1, 1918, with Comparative Figures for Jan. 1, 1917, by Classes of Business.

Class of Business.	Total Stocks Reported for Jan. 1, 1918. Pounds.	Comparative Figures from Firms Reporting for both 1918 and 1917		
		1918 Stocks.		1917 Stocks.
		Pounds.	Per Cent of 1917.	Pounds.
Total	310,881,660	252,477,297	143.3	176,233,345
Milk Condenseries.	70,825,746	68,446,813	252.8	27,073,128
Storage Warehouses	23,864,774	10,769,896	204.6	5,262,791
Cold Storages	4,502,077	3,365,032	668.6	503,280
Warehouses	19,362,697	7,404,864	155.6	4,759,511
Wholesale Dealers.	110,198,428	98,317,135	121.9	80,648,372
Wholesale Grocers	91,377,772	82,642,228	108.1	76,484,205
Meat Packers	11,220,326	9,741,702	368.4	2,644,461
Other Wholesale Dealers	7,600,330	5,933,205	390.4	1,519,706
Retail Dealers	84,575,145	63,227,472	110.5	57,238,147
Retail Grocers	54,011,146	39,980,275	108.8	36,746,660
General Stores	29,791,437	22,739,673	113.1	20,097,645
Other Retail Dealers	772,562	507,524	128.9	393,842
Miscellaneous	21,417,567	11,715,981	194.9	6,010,907

[1] Food Surveys, Bureau of Markets, U. S. Department of Agriculture, Vol. 1, No. 7. Special issue, June, 1918.

Exports and Imports.—Canned condensed milk only need be considered here.

The United States Bureau of Statistics reports the following imports and exports of condensed milk for the years 1911 to 1917 inclusive:

Exports and Imports of Condensed Milk for the Years 1911 to 1917, inclusive.[1]

	Exports		Imports.	
Years	Pounds	Dollars	Pounds	Dollars
1911	12,180,445	936,105	630,308	46,088
1912	20,642,738	1,651,879	698,176	61,671
1913	16,525,918	1,432,848	1,778,044	135,724
1914	16,209,082	1,341,140	14,599,339	1,089,440
1915	37,235,627	3,066,642	33,624,189	2,556,787
1916	159,577,620	12,712,952	18,174,505	1,515,354
1917	259,102,213	25,129,983	18,375,698	1,746,446

Prior to 1914 the United States exported condensed milk chiefly to North America, Oceanica and Asia, small quantities were also exported to South America, Africa and Europe. About 60 per cent. of all the export condensed milk went to countries of the North American Continent, Canada and Panama being the leading markets. During the last few years, immediately preceding the world war, our exports to Canada had fallen off very rapidly. In 1911 the exports to Canada amounted to only about 15 per cent. of the total exports of condensed milk to the same country in 1908. The rapid development of the milk condensing industry in Canada, within the last decade was largely responsible for this situation. From 1907 to 1911 there was an annual decrease in the total exports of the United States. In 1907 they amounted to $2,191,000.00 as against $936,105.00 in 1911.

Prior to 1913, the imports of condensed milk into the United States were likewise very limited. This was largely due to the protective tariff on imported goods, which was an effective agent to exclude foreign brands from American markets.

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[1] United States Department of Commerce and Labor, Bureau of Statistics for 1911 to 1917.

In the fall of 1913, Condensed Milk was placed on the "free list." This resulted in an immediate and rapidly growing influx of condensed milk from European countries, such as Switzerland, Denmark, Holland, Sweden, Norway, Germany and England. At first the bulk of the influx consisted of sweetened condensed milk, but later evaporated milk also arrived in increasingly large quantities, causing havoc in our domestic markets, and almost unprecedented depression in the industry in the Fall of 1914. At the same time, the exports further decreased and ceased almost entirely.

In 1915 the food shortage in the allied countries and their need of condensed milk for their armies and navies began to counteract the effect of the removal of the protective tariff. Imports rapidly decreased and finally ceased almost entirely, while large and repeated contracts for exports to the Allies brought about an unprecedented growth of our export trade of condensed milk at attractive prices. Our exports were further increased by the fact that the war deprived non-combatant countries in South America, Asia and Africa of their usual imports of this commodity from the now warring countries, opening up the world markets to the United States.

These events have resulted in partial elimination of foreign condensed milk from our domestic markets and in a fifteen fold increase of our exports of condensed milk in 1917 over 1914.

CHAPTER XIX.

CHEMICAL COMPOSITION OF CONDENSED MILK

Sweetened Condensed Milk.—Sweetened condensed milk contains all the constituents of fresh milk and considerable but varying quantities of sucrose. Its composition, therefore, depends on such factors as: composition of the fresh milk from which it is made; the degree of condensation and per cent. of cane sugar added. As all of these factors vary in milk from different localities, and in milk of the same factory at different seasons of the year, no hard and fast rule can be given. The following figures merely show the average composition of sweetened condensed milk as obtained from the results of analyses of a large number of different brands.

Average Composition of Sweetened Condensed Milk

Water			26.5 per cent.
Milk solids.	fat	9.0 per cent.	32.6 per cent.
	proteids	8.5 per cent.	
	milk sugar	13.3 per cent.	
	ash	1.8 per cent.	
Cane sugar			40.9 per cent.
		Total	100.0 per cent.

Water.—The water content is largely governed by the degree of condensation and the per cent. of cane sugar. American brands average from 24 per cent to 28 per cent water. In exceptional cases milk has been found to contain as low as 21 per cent. and as high as 34 per cent. water.

Milk Solids.—The per cent. of milk solids is largely governed by the per cent. of milk solids in fresh milk and the degree of condensation. In the majority of brands the solids fluctuate between 30 and 34 per cent.; in extreme cases analyses have shown as low as 28 per cent. and as high as 40 per cent. milk solids. The relative proportion in which the various solid constituents are present is the same as that in the fresh milk from which the condensed milk is made, provided that the fresh milk was not skimmed previous to condensing.

Butterfat.—The butter fat in sweetened condensed whole milk fluctuates from about 8 to 12 per cent., according to locality, season of year and degree of condensation. Sweetened condensed milk sold in barrels is usually partly or wholly skimmed and is, therefore, low in fat. It has been suggested that a small portion of the milk fat is lost during the process of condensation, and this theory is frequently resorted to by condensed milk men to explain why their milk is low in fat. It has been claimed by some that the volatile fats (volatile fatty acids) are lost during the process of condensation. This claim is not well founded, since repeated experiments[1] have conclusively demonstrated that condensed milk contains the normal amount of volatile fatty acids. It has further been experimentally proven that the condensed milk, when made properly and from whole milk, contains fat equal in amount to that found in the fresh milk used. A reasonable allowance should be made, however, for loss of milk due to spilling and wasting in pipes and retainers. Experience has shown that this loss amounts to about fifty to one hundred pounds of milk per average batch under normal conditions.

Proteids.—The per cent. of proteids in the condensed milk varies with the per cent of proteids in the original milk and the degree of concentration. It fluctuates usually between 7.5 and 9 per cent. The heating previous to condensing coagulates a portion of the milk albumin and alters the casein to the extent that it is not precipitated in the normal way, when rennet is added to the diluted condensed milk. In early spring when the majority of the cows supplying the condensery freshen, there is a tendency of the jacket and coils in the vacuum pan to become coated more or less heavily with a layer of semi-solid milk. This very probably is due to the relatively high per cent. of albumin which sticks to the heating surface. This thickened milk, when mixed with and stirred in water, usually dissolves without much difficulty. See also "Defects of Sweetened Condensed Milk," page 202.

While, in most analyses of sweetened condensed milk, the per cent. of proteids nearly equals that found in the fresh milk multiplied by the degree of concentration, there is a tendency toward a slight loss of this constituent due to precipitation in the forewarmers.

Milk Sugar.—Sweetened condensed milk contains from about 12.5 to 15 per cent. of milk sugar, the amount varying according to the degree of concentration and per cent. of milk sugar in the fresh milk. The milk sugar is not known to undergo any material changes as the result of the condensing process. If condensed milk is recondensed, it assumes a darker color which is largely due to the caramelizing of a part of the milk sugar, caused by the action of prolonged exposure to heat. The milk

[1] Hunziker and Spitzer, Indiana Agricultural Experiment Station Bulletin No. 134, 1909.

sugar in condensed milk crystallizes very readily and causes the condensed milk to become sandy and settled. Chemical analyses of this sugar sediment show that it consists principally of milk sugar. The primary cause of this property lies in the fact that sweetened condensed milk contains so little water (about 26.5 per cent.) that the milk sugar is present in the form of a supersaturated solution; therefore, any condition which favors sugar crystallization will tend to produce this defect.[1] Milk sugar requires from five to six times its weight of water at ordinary temperatures for complete solution. In sweetened condensed milk the milk sugar has access to only about twice its weight of water (12.5 to 15 per cent lactose to 25 to 27 per cent. water).

Ash.—The per cent. of ash is largely dependent on the degree of condensation. It usually varies from 1.5 to 2 per cent. It is quite constant in fresh milk (normal fresh milk contains uniformly about .7 per cent. ash). The per cent. of ash in sweetened condensed milk may serve, therefore, as a reasonably reliable factor in determining the degree of condensation. The heating of milk, before condensing, precipitates and renders insoluble a portion of the mineral solids, principally the lime salts.

Sucrose.—The purpose of the presence of sucrose in this product is to preserve it. Most of the sweetened condensed milk on the market contains from 37 to 43 per cent. sucrose, or cane sugar. Wider variations, however, are not infrequent. In some cases analyses showed as low as 30 per cent. and in others as high as 48 per cent. cane sugar. Cane sugar dissolves in one half its weight of water, so that under normal conditions there is sufficient water in the condensed milk to keep the sucrose in solution. The amount of sucrose in milk does not appreciably affect the power of the milk to dissolve milk sugar, nor does the per cent of lactose present materially affect the power of the milk to dissolve sucrose.

Specific Gravity.—The specific gravity of sweetened condensed milk falls within the limits of 1.24 to 1.35. Foreign

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[1] For further details on causes of settled sweetened condensed milk see Chapter XXIII, page 196.

brands average higher in specific gravity than American brands. The specific gravity of sweetened condensed milk is controlled by the degree of condensation, the per cent. of fat and the per cent. of cane sugar. Milk condensed at the ratio of about 2.5 parts of fresh milk to 1 part of condensed milk and containing about 9 per cent fat and 40 per cent cane sugar, has a specific gravity of about from 1.28 to 1.29. The specific gravity of sweetened condensed skim milk may go as high as 1.35, and, if it contains an excess of cane sugar, it may be still higher.

Chemical Analyses of Sweetened Condensed Milk of Eighteen Different Brands

Brand	Milk solids per cent.	Water per cent.	Fat per cent.	Proteids per cent.	Lactose per. cent.	Ash per cent.	Sucrose per cent.
[1] "Silver Spoon" Hires' Condensed Milk Co.	31.90	28.68	8.40	9.12	12.56	1.91	40.38
[3] "Eagle" Borden's Condensed Milk Co.	31.08	25.99	8.72	8.15	12.35	1.83	42.93
[2] "Reindeer" Truro Condensed Milk Co.	31.23	27.33	9.56	8.32	13.42	1.80	41.44
[3] "Tip Top" Bordens' Condensed Milk Co.	36.57	21.67	10.07	9.35	15.00	2.15	41.76
[3] "Challenge" Borden's Condensed Milk Co.	31.74	24.84	8.23	8.57	13.02	1.92	43.42
[3] "Sweet Clover" Mohawk Condensed Milk Co.	32.84	24.07	9.31	8.71	12.95	1.87	43.09
[3] "Arrow" Wisconsin Condensed Milk Co.	31.15	26.83	8.00	8.49	12.87	1.79	42.02
[3] "Blue Bell" American Condensed Milk Co.	35.56	26.50	9.31	9.50	14.80	1.95	37.94
[3] "Red Cross" Mohawk Condensed Milk Co.	34.78	27.14	11.07	7.92	14.03	1.76	38.56
[3] "Rose" Borden's Condensed Milk Co.	30.82	24.76	8.88	8.06	12.07	1.81	42.97
[3] "Magnolia" Borden's Condensed Milk Co.	31.98	26.32	8.64	7.84	13.50	2.00	42.00
[3] "Rustic" Michigan Condensed Milk Co.	30.00	27.63	8.60	7.07	12.60	1.73	41.00
[2] "Milk Maid" Anglo-Swiss Condensed Milk Co.	35.69	25.65	9.65	8.78	15.17	2.09	38.66
[2] "Jubilee" The Manitoba Dairy Co.	29.40	32.15	9.62	8.61	11.30	1.85	38.45
[2] "Export" Baldwin Condensed Milk Co.	32.24	26.69	11.50	8.50	12.35	1.80	41.07
[2] "Owl" Canada Milk Condensing Co.	31.61	30.84	10.61	8.47	12.40	1.81	37.55
[2] "Nestle" Henry Nestle	32.91	28.04	8.06	7.68	15.23	1.94	39.05
[3] "Upper Ten" U. S. Condensed Milk Co.	33.65	27.88	8.80	8.34	14.66	1.85	38.47

[1] Spitzer, Indiana Agricultural Experiment Station, 1910.

[2] McGill, Inland Rev. Dept., Ottawa, Bulletin No. 144, 1908.

[3] Cochran, Special Report of Analysis of Condensed Milks and Infants' Foods, Pennsylvania Department of Agriculture, 1905.

Evaporated Milk.—The same factors which control the chemical composition of sweetened condensed milk, also govern that of the unsweetened product, with the exception that the cane sugar is absent.

The following figures represent, in round numbers, the average composition of evaporated milk as obtained from analyses of a large number of American brands.

Average Composition of evaporated milk

Water			73 per cent.
Milk solids	fat	8.3 per cent	27 per cent.
	proteids	7.5 per cent	
	lactose	9.7 per cent	
	ash	1.5 per cent	
			100 per cent.

The chemical and physical properties of the various ingredients in unsweetened condensed milk are affected to a greater extent than in the case of sweetened condensed milk. This is largely due to exposure of the evaporated milk to high temperatures in the sterilizer.

Water and Solids are governed by the degree of concentration and the relative per cent of the same constituents in the fresh milk. The per cent of solids admissible in evaporated milk is largely dependent on the chemical and physical properties of the milk and the sterilizing temperatures employed. Excess in solids in this product jeopardizes its marketable properties, owing to the tendency of the proteids to form hard lumps of curd during the sterilizing process. Evaporated milk very low in solids tends toward the separation of its butter fat in storage. Analyses show a range of from 23 to 31 per cent solids. Since the per cent of solids necessary and possible to be contained in marketable evaporated milk, largely depends on the properties of milk, and, since these properties again are principally controlled by locality, season of year, crop, feed and weather conditions and the quality of the fresh milk, the solids in milk from any given season of the year may vary very considerably. In some localities and at certain times of the year the best results may be obtained with evaporated milk containing 28 per cent solids. In other localities it may be difficult at certain seasons of the year, to incorporate more than 24 per cent solids without injuring or destroying the marketable properties of the product.[1]

Butterfat.—The fat varies with the per cent of fat in the fresh milk and with the degree of concentration. No fat is lost during the process of condensing and sterilizing.[2] It has been claimed by some that in the process of manufacture, the volatile fatty acids escape and that the evaporated milk therefore contains less fat than the fresh milk from which it is made, times the degree of concentration. If this were true the loss of fat in the evaporated milk would not exceed .25 of 1 per cent. But analyses show that the fat in the evaporated milk is entirely normal in composition and contains the same proportion of volatile fatty acids as the fat in the fresh milk.

The Composition of Milk Fats in Evaporated Milk[2]

Date of Manufacture	Reichert Meissl number	Iodine number	Melting point of mixed fats	Melting point of insoluble fatty acids
August, 1908	28.48	33.64	33.3 degrees C.	41.0 degrees C.
November, 1908	29.52	33.60	33.4 degrees C.	41.2 degrees C.

In the evaporated milk there is a strong tendency for the fat to separate out during storage and to churn in transportation. This is largely avoided by the proper adjustment of the sterilizing process and by use of the homogenizer.

Proteids.—The proteids vary with the per cent of total proteids in the fresh milk and the degree of concentration. Similar to the case of sweetened condensed milk there is a tendency of a slight loss of proteids in evaporated milk due to mechanical adhesion of a part of the precipitated curd to the heating surfaces in the forewarmers and in the vacuum pan.

Most of the coagulable milk albbumin is precipitated. Fresh milk contains about .16 per cent of albumin that is not coagulable by heat.[3] The relation of soluble and insoluble curd is

[1] Hunziker, Indiana Agricultural Experiment Station, Twenty-first Annual Report, 1908, pages 67-68.
[2] Hunziker and Spitzer, Indiana Agricultural Experiment Station, Bulletin No. 134.
[3] Hunziker, Indiana Agricultural Experiment Station, Bulletin No. 143.

shown in the following table which represents analyses of different brands of evaporated milk.

Soluble and Insoluble Curd in Evaporated Milk[1]

Brand	Insoluble curd per cent	Soluble albumin per cent	Total proteids per cent
Gold Milk	8.44	.46	8.90
Columbine	7.41	.49	7.90
Every Day	7.54	.46	8.0
Gold Milk	7.37	.33	7.70
Star	7.86	.30	8.16
Morning Glory	8.28	.34	8.62
Carnation	6.49	.52	6.91
Beauty	8.39	.39	8.78
Van Camp's	7.52	.42	7.94
Monarch	6.77	.52	7.29
Diadem	7.06	.42	7.48
Reindeer	6.88	.52	7.40
Wilson's	6.89	.49	7.38
Dundee	7.21	.44	7.65
Average	7.436	.429	7.865

The above figures show that, in the evaporated milk, practically all of the coagulable albumin is changed to insoluble curd. The brands analyzed contained evaporated milk condensed at the ratio of 2 to 2.4 parts of fresh milk to 1 part of evaporated milk. The soluble albumin found corresponds with the albumin not coagulable by heat, normally found in fresh milk, times the ratio of concentration.

The casein is largely precipitated by the sterilizing heat, but is present in the form of very finely divided particles. This is due to the mechanical shaking to which the evaporated milk is subjected in the sterilizer and in the shaker. In many batches of evaporated milk the precipitation of the casein during sterilization is so fine that the product is perfectly smooth without

[1] Hunziker, Indiana Agricultural Experiment Station, Bulletins No. 134 and 143.

shaking. The casein in evaporated milk does not respond to the action of rennet as does the casein in fresh milk.

Milk Sugar.—The milk sugar is present in per cent corresponding with that of the original milk, times the degree of concentration. A portion of it has undergone oxidation (caramelization) due to the high sterilizing temperatures. It gives to the evaporated milk a yellow to light brown color. The higher the sterilizing temperature and the longer the exposure of the evaporated milk to this heat, the darker is its color.

Ash.—The mineral constituents also are present in nearly the same proportion to the other solids, as in fresh milk. They are largely rendered insoluble by the sterilizing process. The lime constituents frequently are found in the bottom of the cans in the form of hard, whitish, insoluble granules.

Since the ash in normal fresh milk is practically constant, averaging about .70 per cent, the per cent of ash in the evaporated milk is frequently used as a factor in determining the degree of concentration. The results may, however, be very misleading, since, when the ash is precipitated in the form of granules, it is practically impossible to mix it back into the milk in order to obtain a representative sample for analysis.

The Specific Gravity ranges from 1.05 to 1.08, according to the degree of concentration and the specific gravity of the original milk. It averages about 1.065.

Plain condensed bulk milk is of very varying composition, depending largely on the degree of concentration and the per cent of fat present. It is usually made from partly or wholly skimmed milk and is condensed at the ratio of 3 to 4 parts of fresh milk to 1 part of condensed milk. The same fact applies to the composition of concentrated milk.

Chemical Analyses of Twenty-four Different Brands of Evaporated Milk[1]

Brand	Solids	Water	Fat	Curd	Lactose	Ash	Total
Gold Milk.....	29.25	70.75	9.42	8.44	9.75	1.54	99.90
Columbine	24.63	75.37	7.45	7.41	8.56	1.36	99.98
Every Day....	26.20	73.80	8.07	7.54	9.10	1.47	100.15
Gold Milk.....	27.18	72.82	9.07	7.39	9.23	1.49	100.00
Star	29.04	70.90	8.35	7.86	10.37	1.62	99.16
Morning Glory	31.08	68.92	10.48	8.26	10.47	1.67	99.82
Carnation	23.81	76.19	8.05	6.49	7.55	1.24	99.49
Beauty	28.38	71.62	8.47	8.39	9.94	1.56	99.98
Van Camp's...	27.89	72.11	8.69	7.52	9.66	1.54	99.52
Wilson's	25.23	74.77	8.70	6.53	8.68	1.37	100.05
Monarch	26.70	73.30	8.09	6.77	10.35	1.44	99.95
Diadem	24.96	75.04	8.16	7.06	7.92	1.33	99.51
Reindeer	26.66	73.34	8.08	6.88	10.21	1.45	99.96
Dundee	27.04	72.96	8.73	7.21	9.36	1.48	99.74
Sundry samples							
1........	28.02	71.98	8.93	7.68	9.86	1.61	100.06
2........	31.99	68.01	9.68	8.49	11.88	1.69	99.75
3........	26.01	73.99	8.18	6.77	9.24	1.46	99.64
4........	27.33	72.67	9.04	6.93	9.42	1.51	99.57
5........	29.37	70.63	9.71	7.34	10.52	1.56	99.76
6........	21.12	78.88	7.30	5.78	6.78	1.12	99.86
7........	23.25	76.75	7.98	6.19	7.96	1.25	100.13
8........	25.48	74.52	8.68	6.34	8.67	1.35	99.56
9........	26.62	73.38	9.20	7.00	9.18	1.37	100.13

[1] Hunziker and Spitzer, Indiana Agricultural Experiment Station, Bulletin No. 134, 1909.

CHAPTER XX.

SANITARY PURITY AND DIETETIC VALUE OF CONDENSED MILK

Sanitary Purity.—From the point of view of freedom from pathogenic and other harmful micro-organisms, all forms of condensed milk are superior to the average market milk. In the first place, the manufacture of a marketable condensed milk makes essential eternal vigilance in the control of the quality of the fresh milk. It is safe to state that in no milk plants does the quality of the fresh milk accepted, receive more careful attention and average higher than in the milk condensery. The foundation of the condensed product, the fresh milk, therefore, is of a relatively high standard of purity.

Again, the temperature to which the milk is subjected is sufficiently high to destroy the germs of practically all milk-borne diseases; so that, unless the condensed milk becomes infected with pathogenic germs after condensing and before the tin cans are hermetically sealed, practically all danger from disease germs is eliminated. In the case of evaporated milk the marketable product is free from all forms of germ life. The only exception to this rule would apply to concentrated milk, in the manufacture of which the milk is not heated to temperatures detrimental to the life of bacteria.

Dietetic Value.—The dietetic value of condensed milk is largely dependent on the effect of heated milk on its nutritive value and on digestion. As far as condensed milk is concerned, there are no available data that would throw any light on this subject. The results of feeding experiments with heated, pasteurized or sterilized milk vs. raw milk, however, may furnish a logical guide as to the dietetic effect of condensed milk. Milk pasteurized at high temperatures, or sterilized, may be considered comparable, as far as the effect of heat is concerned, to condensed milk.

Doane and Price[1] report the following experimental results: "Raw milk is more easily digested when fed to calves than either

[1] Doane and Price, Maryland Agricultural Experiment Station, Bulletin No. 77, 1901.

pasteurized, or cooked milk. Contrary to theory, cooked milk, when fed to the calves used in these experiments, caused violent scouring in the majority of trials. A majority of physicians in charge of children's hospitals corresponded with, favored the use of raw milk for infants when the milk is known to be in perfect condition, but favored pasteurized milk under ordinary conditions. With one exception all the physicians corresponded with, discouraged the use of cooked, or sterilized milk for infant feeding."

Rosenau* states that "Comparative observations upon infants under the same conditions show that they flourish quite as well upon heated milk as upon raw milk. Laboratory experiments as well as chemical observations coincide with the view, that heated milk is quite as digestible as raw milk. In fact it is now claimed to be more so. Metabolism experiments indicate that the utilization of calcium and iron in the body is more complete in children fed upon boiled cow's milk, than in those fed upon raw cow's milk."

Stutzer[1] who conducted experiments of artificial digestion reports in favor of boiled milk, while similar investigations made by Ellenberger and Hofmeister[2] showed no difference in the digestibility between raw and cooked milk.

Rodet[3] who experimented with dogs noticed a slight difference in favor of boiled milk. Bruning[4] fed dogs, pigs, rabbits, and guinea pigs with raw and sterilized milk and reports that all results were in favor of the sterilized milk. Bruckler's[5] experiments with dogs showed that the animals gained more in weight on sterilized milk than on raw milk, but that their general health, vigor and vitality was better when fed raw milk. Variot[6] observed no difference in the effect on infants between raw and boiled milk.

Peiper and Eichloff made post mortem examinations on numerous dogs which had been fed for prolonged periods on raw

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* Rosenau, United States Department of Agriculture, Bureau of Animal Industry, Circular No. 153, 1910.
[1] Stutzer, Landw. Versuchs-Stationen, 40, p. 307.
[2] Ellenberger & Hofmeister, Bericht ueber das Veterinarwesen Koenigreich Sachsen, 1890.
[3] Rodet, Compt. rend. soc. biol., 48, p. 555.
[4] Bruning, Muenchner Mediz., Wochenschrift, No. 8, 1905.
[4] Bruning, Zeitschrift fuer Tiermed, 10, p. 110, 1906.
[5] Bruckler, Jahrbuch fuer Kinderheilk, 66, p. 343, 1907.
[6] Variot, Comp. rend., 139, p. 1002, 1904.

and boiled milk, respectively. In the dogs fed on boiled milk the marrow of the bones was highly anaemic, the articulation of the bony structure looser, the ash content of the bones and the blood lower, and there was more sodium chloride and less fibrin in the blood than in the case of the dogs fed on raw milk.

Storck* and others attribute such infantile diseases as rickets and scurvy to the feeding of boiled milk.

It is generally assumed that, because the lime and phosphoric acid of milk become largely insoluble when milk is heated to sterilizing temperatures, these elements in sterilized milk are not sufficiently available to supply the needs of the growing organism. In experiments with dogs Aron and Frese** found that the utilization of the lime is not affected by heating the milk and that, as far as the assimilation of the lime by the growing organism is concerned, it is immaterial in what form the lime is present. Even when fed in difficultly soluble form, as tertiary lime phosphate, the lime was utilized as well as the lime of normal raw milk.

The fact that the phosphorus (phosphoric acid), needed for the building up of the bony structure, and which is present in milk largely in organic combination as casein and as lecithin, is changed by heat to inorganic combinations, the lecithin phosphorus by saponification, and the casein phosphorus by changes in the casein molecule, suggests a poorer retention of the inorganic phosphorus by the animal body. Cronheim and Mueller[1] who studied this phase of nutrition could detect no appreciable difference as to the assimilation of phosphorus by feeding sterilized and raw milk, respectively. Their results were rather in favor of sterilized milk.

Grimmer[2] holds that digestive and intestinal disorders in infants are possibly largely due to biological disturbances, modifying the bacterial flora of the intestines, and to the absence of lecithin and unorganized ferments in heated milk. He reports that the addition to boiled milk of substances rich in lecithin, such as the yolk of egg, also ferments, such as pepsin, trypsin, and emulsin produce a marked improvement in such cases.

* Storck, zit. n. Knusel, Studien ueber die sog. sterilisierte Milch des Handels. Diss., Luzern, 1908.
** Aron and Frese, Grimmer Chemie u. Physiologie der Milch, 1910.
[1] Cronheim and Mueller, Jahrbuch fuer Kinderheilk, 57, p. 45, 1903.
[2] Grimmer, Chemie and Physiologie der Milch, 1910.

The foregoing citations suggest that our knowledge of the dietetic effect of heated or boiled milk is exceedingly limited and that the results obtained and conclusions drawn by the various investigators are at variance. In experiments with the living organism, and confined to so few specimen as seems to have been the case in the work reported, the factors of individuality and environment are a constant stumbling block, magnifying the limit of experimental error and weakening the conclusiveness of the results. On the basis of our present knowledge it seems reasonable to conclude that, as far as the digestibility of its inherent ingredients is concerned, condensed milk, when consumed in properly diluted form, varies but little, if any, from raw milk. The absence in condensed milk of ferments, such as enzymes, which are destroyed in the process and which may assist digestion, may be considered the most important defect of condensed milk from the dietetic point of view.

In the case of sweetened condensed milk, however, the nutritive ratio of the normal milk is decisively disturbed by the presence of large quantities of sucrose. Even when diluted to far beyond the composition of normal and original fluid milk, the per cent. of cane sugar is still high, causing the nutritive ratio of such milk to be abnormally wide and unbalanced. The carbohydrates are present far in excess of the protein, fat and ash. If fed to infants exclusively and for a prolonged period of time, the growing organism is bound to suffer from malnutrition and at the expense of muscular development.

Furthermore, it is conceded by the medical profession that sucrose is not a suitable form of carbohydrates for infants. It is not as digestible as lactose, it changes the bacterial flora of the intestines, enhancing the development of butyric acid and other gas-forming and putrefactive germs at the expense of Bacillus bifidus, which is the natural inhabitant of the intestine in normal, milk-fed babies.

Sweetened condensed milk is generally highly advertised by the manufacturer as a suitable food for babies; it is frequently recommended by physicians and in some instances, it is claimed to have agreed with babies who were unable to take care of milk in any other form. It is not improbable that in these extremely isolated cases of baby feeding, when all other feeds failed, the true virtue attributed to the sweetened condensed milk, lay in the fact that the mothers carefully followed the directions on the label for dilution. The directions specify that the condensed milk be diluted with ten to sixteen parts of water. The majority of cases of digestive disorders in bottle-fed babies are undoubtedly the result of the natural tendency of the mother to feed her child too much milk or too rich milk. When we consider that the ratio of concentration in sweetened condensed milk is only about 2.5 to 1, it is obvious that a dilution of 10 or 16 to 1 is a great relief to the over-taxed digestive organs of infants, previously fed on milk too rich for normal digestion. The immediate change of the health and disposition of these babies for the better, as the result of turning from a prolonged siege of too rich food to the very dilute condensed milk, is therefore not surprising.

The manufacturer of sweetened condensed milk in this country is inclined to load his product excessively with sucrose. He does this largely in an effort to increase the keeping quality and to guard against the development of fermentations in the finished article that ruin the goods for the market. While a certain amount of sucrose is necessary to preserve this milk, yet, if the product is manufactured from a good quality of fresh milk, as it should be, and when the proper sanitary conditions are maintained in all departments of the factory, sixteen pounds of cane sugar per one hundred pounds of fresh milk is entirely sufficient. He should bear in mind that sweetened condensed milk is used and accepted by the consumer as a substitute for market milk, and it is the manufacturer's moral duty to retain in this substitute the normal properties and composition of the product which it is supposed to replace, as nearly as is consistent with the production of a wholesome and marketable product.

Growth-Promoting and Curative Properties.[1]—Recent discoveries by Hart of the University of Wisconsin, McCollum and Davis, formerly of the University of Wisconsin and now at John Hopkins University, Osborne & Mendell of Yale University and other eminent nutrition experts have demonstrated, that before complete growth can occur in a young animal, or for prolonged maintenance, or for the preven-

[1] Journal of Biological Chemistry 1913 to 1917.

tion of certain diseases, the diet, besides being adequate as regards its content of proteins, carbohydrates, fats and salts, must contain certain, at present unidentified accessory substances. These substances are of two classes, namely those that are fat-soluble, and those that are water-soluble. The absence in the diet of either or both of these accessory substances causes stunting of growth and the development of certain characteristic diseases.

In the absence of the fat-soluble accessory substance the diet produces certain diseases of which sore eyes and ultimate blindness are characteristic. In the absence of the water-soluble accessory substance, the diet gives rise to the disease of beriberi. In either case, normal growth is not obtained, the whole organism is stunted, and the cycle of life is abbreviated.

The fat-soluble substance for man is most readily available in the butterfat of milk, in egg fat, and in cod liver oil. It is not contained in the ordinary animal fats such as lard nor in any of the vegetable fats. It is also found in the leaves of plants, but these are not consumed in the normal diet of man in sufficient quantities to supply the necessary amount of the fat-soluble accessory substances.

The water-soluble accessory substances are present in a larger variety of foods and are known to constitute a part of the skim milk portion of milk.

It is obvious from the above that milk furnishes not only the required protein, carbohydrates, fats, and salts, but it also supplies these fat- and water-soluble accessory substances, which are so indispensible to the normal and full development of the young, which make for full stature of the adult and which keep the individual and the race in healthy condition.

Condensed milk made from whole milk is in no way robbed of these accessory elements. The heat to which the condensed milk is subjected in the process of manufacture neither destroys nor weakens them so far as experimental data now available show. This is true of all kinds of condensed milk and evaporated milk made from whole milk. From the standpoint of these growth-promoting and curative properties, all forms of condensed milk are, therefore, equally desirable for infant feeding, for children and for the adult, as is whole milk.

On the other hand, skim condensed milk is not a satisfactory food for the growing young. It lacks the indispensible fat-soluble accessory and unless supplemented by egg yolk, cod liver oil, or butter, its consumption by the young in the place of whole milk, or in the place of condensed milk made from whole milk, will prove disastrous to the growth and well-being of those who are restricted to such a diet.

Nor does imitation condensed milk, such as the "Hebe" product, in which the butterfat has been replaced by a vegetable fat, supplement the lacking fat-soluble accessory substance. The public should clearly understand that in milk or condensed milk, there is no substitute for butterfat and when the butterfat is removed the product no longer can take the place of milk. See also "Addition of Artificial Fats," page 230.

CHAPTER XXI.

CONDENSED MILK STANDARDS AND LAWS

The Federal Food and Drugs Act, passed June, 1906, and which went in force January 1, 1907, has raised the standard of excellence of condensed milk to no small degree. It has served as a purifier of the entire industry putting a premium on the product of the honest manufacturer and insuring the public against condensed milk of inferior food value.

Prior to the enforcement of this act, three states only had definite standards and laws regulating the composition of condensed milk. In the absence of a federal law, car loads of condensed skim milk were unloaded and sold as condensed milk in states and cities which had no laws or ordinances prohibiting the sale of condensed skim milk, labeled condensed milk. The Federal Food and Drugs Act, executed through the offices of the Interstate Commerce Department, put a stop to this fraud, protecting the public from these inferior goods, eliminating the manufacture, traffic and competition of an unlawful product, enhancing the business of legitimate manufacture and raising the standard and integrity of the industry.

Federal Standards.[1]—The Federal Standards for sweetened

[1] United States Department of Agriculture, Circular No. 19; also Indiana Agricultural Experiment Station Bulletin No. 143.

condensed milk and evaporated milk which went into force January 1, 1907, are as follows:

"Sweetened Condensed Milk is milk from which a considerable portion of water has been evaporated and to which sugar (sucrose) has been added and contains not less than 28 (twenty-eight) per cent of milk solids, of which not less than 27.5 (twenty-seven and five-tenths) per cent is milk fat."

This standard for milk solids in sweetened condensed milk is reasonable, just, adequate and attainable under all normal conditions. Sweetened condensed milk in hermetically sealed tin cans averages about 32 per cent milk solids, and the per cent of milk solids can be increased considerably above this average without injuring the marketable properties of the product. Manufacturers of sweetened condensed milk well know from costly experience, that it would not do to drop the per cent of milk solids to or below 28 per cent. Such milk would be too thin to hold the sugar in suspension, the sugar would tend to settle to the bottom of the cans, rendering the product unsalable, though not necessarily unwholesome. Again, this thin milk does not keep well, it is prone to undergo fermentation. The manufacture of a good quality of salable sweetened condensed milk requires that the fresh milk be condensed at the ratio of about $2\frac{1}{2}:1$. With this ratio of concentration it is obvious that it is not difficult to incorporate 28 per cent, or over, of milk solids in sweetened condensed milk at all times.

The Federal requirement of butterfat in sweetened condensed milk, i. e. that not less than 27.5 per cent of the total milk solids be milk fat, is also, in most cases attainable. In localities, however, where the factory is supplied almost exclusively with low-testing milk, such as Holstein milk, there is danger of the product falling below the above standard in butterfat content at times. Eckles[1] reports that the butterfat in milk from Holstein cows kept by American Experiment Stations averaged 28 per cent of the total solids. This fact can leave no doubt that, while some of the Holstein milk shows a higher ratio of fat, a considerable portion of the Holstein milk produced must necessarily contain considerably less than 28 per cent of fat in the

[1] Eckles—Dairy Cattle and Milk Production, P. 33, 1911.

total solids. In such cases, therefore, it would be necessary, in order to meet the above fat standard, to reinforce the natural milk, as produced by the cow, by the addition of cream or butter.

From the standpoint of the ready and efficient enforcement, such a standard again has its difficulty. In order to determine accurately whether the fat content in the finished product represents 27.5 per cent of the total milk solids, it is necessary to also determine accurately the per cent of milk solids, and this in turn means the determination of the per cent sucrose. But experience has amply demonstrated that in sweetened condensed milk, containing both lactose and sucrose, it is exceedingly difficult to correctly separate these sugars for accurate quantitative analysis.

For these reasons, therefore, the author,[1] in 1910, recommended that the standard for sweetened condensed milk be changed to 28 per cent milk solids and 8 percent fat; and this change became effective in 1917, as per Food Inspection Decision 170,[2] which reads as follows:

"Sweetened condensed milk, sweetened evaporated milk, sweetened concentrated milk, is the product resulting from the evaporation of a considerable portion of the water from the whole, fresh, clean, lacteal secretion obtained by the complete milking of one or more healthy cows, properly fed and kept, excluding that obtained within fifteen days before and ten days after calving, to which sugar (sucrose) has been added. It contains, all tolerances being allowed for, not less than twenty-eight per cent (28%) of total milk solids, and not less than eight per cent (8%) of milk fat.

The Federal Standard for Evaporated Milk which went in force January 1, 1907, reads as follows:

"Evaporated Milk is milk from which a considerable portion of water has been evaporated and contains not less than 28 (twenty-eight) per cent milk solids, of which not less than 27.5 (twenty-seven and five-tenths) per cent is milk fat."

Unfortunately, for the moral effect of the law and for the progress of the condensing industry, the standard of evaporated milk was made so high, evaporated milk shall contain 28 per cent solids, that it was found to be beyond the reach of the manu-

[1] Hunziker, Indiana Agricultural Experiment Station Bulletin No. 143, 1910.
[2] U. S. Dept. of Agr. Food Inspection Decision 170, March 31, 1917.

facturer to comply with it under most conditions without impairing the marketable properties of the product. The results of this error have confronted many an honest manufacturer with unsurmountable difficulties. He was compelled to choose between two equally unsatisfactory alternatives, i. e., either to manufacture a product below standard, violating the law, or to close his factory.

Modified Evaporated Milk Standard.—The unreasonableness of the Federal Standard for evaporated milk was experimentally demonstrated by results of investigations conducted at the Indiana Agricultural Experiment Station.[1] Further extensive investigations were made by the United States Bureau of Chemistry.[2] Finally, in March, 1911,[3] the standard was modified to read as follows:

"1. Evaporated milk should be prepared by evaporating fresh, pure whole milk of healthy cows, obtained by complete milking and excluding all milkings within fifteen days before calving and seven days after calving, provided that at the end of this seven day period the animals are in a perfectly normal condition.

"2. It should contain such percentages of total solids and of fat that the sum of the two shall be not less than 34.3 and the percentage of fat shall be not less than 7.8 per cent.

"3. It should contain no added butter or butter oil incorporated either with whole milk or skimmed milk or with the evaporated milk at any stage of manufacture."

This modified standard was an improvement over the original standard which it superseded. However, the requirements of solids were still too high.

Difficulties of Meeting These Standards for Evaporated Milk.—While these standards can be complied with in some localities and under certain favorable conditions, they are beyond the reach of the manufacturer in other localities and under less favorable conditions. The manufacturer is compelled, in order to produce a marketable product, to use sufficiently high tem-

[1] Hunziker, Indiana Agricultural Experiment Station Bulletin No. 143, 1910.
[2] Results not published.
[3] United States Department of Agriculture, Food Inspection Decision No. 131, 1911.

peratures in the sterilizer to render the milk absolutely sterile. This he must accomplish without causing the product to become curdy.

The degree of concentration of the evaporated milk directly controls its curdling properties. The higher the degree of concentration, the greater is the danger of a curdy product. Unfortunately, many of the agents which regulate the ease with which milk curdles, are not under the control of the operator. They have to do with breed, period of lactation, condition, care and feed of the cows, season of year, climatic and weather conditions and the care and chemical, physical and physiological properties of the milk on the farm. It so happens that in localities, where dairying has not as yet reached a high state of development, where cows are exposed to inclement weather, or in the southern tier of the dairy belt, where the cows suffer from the sweltering heat of the summer months and are pestered with flies, and where the available water for cooling the milk on the farm is not very cold, the milk is more prone to curdle, than in highly developed dairy countries, or in localities of the cooler regions of the dairy belt, etc.

The properties of milk to curdle, whatever the agents causing them may be, are intensified by the degree of concentration. It is, therefore, necessary for the successful manufacture of a salable product to regulate this.

A further objection to both, the original and the modified standard for evaporated milk is that, where milk is bought and paid for on the basis of butterfat contained therein, as it should be, the factory receiving high-testing milk, labors financially under a distinct disadvantage. The reason for this is that in high-testing milk, such as Jersey and Guernsey milk, the butterfat constitutes about 34 per cent of the total solids, while in low-testing milk, such as Holstein milk, the butterfat constitutes only about 28 per cent of the total solids. In order to meet the requirements for milk solids, more butterfat has to be put into the evaporated milk per case, where high-testing milk is condensed than in the case of low-testing milk. Consequently, the cost per case, of the manufacture of such milk is greater than that of low-testing milk. These standards, therefore, discriminate in favor of manufacturers and breeds of low-testing milk, such as milk from Holsteins and Ayrshires, and against manufacturers and breeds of high-testing milk, such as milk from Jerseys and Guernseys.

Putting the Composition of the Evaporated Milk on the Label.—As the result of these difficulties, numerous manufacturers protested against these standards and succeeded in obtaining from the Government temporary concessions to the effect that "there would be no violation of the Food and Drugs Act if the percentage composition of the goods was plainly stated on the label in connection with the name of the substance, although this might be lower than that required by Food Inspection Decision No. 131." This information was issued by the Government to the condenseries in the form of a circular letter.

As the result of this concession, many condenseries, which experienced difficulties in complying with the original standard, adopted individual standards of composition in accordance with their local conditions and they stated on the label, in more or less legible type, the percentages of solids and fat below which their goods would not drop.

Subsequent investigations by the Government, however, seemed to indicate that this form of labeling was misleading to the public and would, therefore, be in violation of the Food and Drugs Act. Consequently, the concession of permitting individual standards was then withdrawn.

The Federal Board of Food Inspection continued to further consider the advisability of modifying the evaporated milk standard, and finally decided on the following standard for evaporated milk, which is now in force and which became effective April 2, 1915:[1]

Condensed milk, evaporated milk, concentrated milk, is the product resulting from the evaporation of a considerable portion of the water from the whole, fresh, clean, lacteal secretion obtained by the complete milking of one or more healthy cows, properly fed and kept, excluding that obtained within fifteen days before and ten days after calving, and contains, all tolerances being allowed for, not less than twenty-five and five-tenths per

[1] United States Department of Agriculture, Food Inspection Decision 158, April 2, 1915.

cent (25%) of total solids and not less than seven and eight-tenths per cent (7.8%) of milk fat.

Condensed Skim Milk.—The original standard for condensed skim milk[1] which went in effect January 1, 1907, was as follows:

"Condensed skim milk is skim milk from which a considerable portion of water has been evaporated."

Subsequently this standard was superseded to more adequately control the manufacture and sale of condensed skim milk by the following standard[2] which became effective March 31, 1917.

Condensed skimmed milk, evaporated skimmed milk, concentrated skimmed milk, is the product resulting from the evaporation of a considerable portion of the water from skimmed milk, and contains, all tolerances being allowed for, not less than twenty per cent (20.0%) of milk solids.

Sweetened condensed skimmed milk, sweetened evaporated skimmed milk, sweetened concentrated skimmed milk, is the product resulting from the evaporation of a considerable portion of the water from skimmed milk to which sugar (sucrose) has been added. It contains, all tolerances being allowed for, not less than twenty-eight per cent (28.0%) of milk solids.

Explanatory Notes Concerning the Federal Food and Drugs Act; Its Relation to the Interstate Commerce Law, and to the Federal Standards of Purity for Food Products.[3]

Any article of food entering into interstate commerce should conform to the requirements of the Federal Law (Pure Food and Drugs Act).

If sold other than in the original package in the state received, it should conform with the laws of that state.

The term "Original Packages" used in the act generally means the package in which articles are transported in interstate commerce, as distinguished from the unit packages usually displayed on the shelves of retailers.

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[1] United States Department of Agriculture, Circular No. 19, 1907.

[2] United States Department of Agriculture, Food Inspection Decision 170, March 31, 1917.

[3] Hunziker, Indiana Agricultural Experiment Station Bulletin No. 143, 1910.

Section 9 of the act provides that parties who make a guarantee that products are not adulterated or misbranded within the meaning of the Food and Drugs Act, shall be amenable to the prosecutions, fines and other penalties which would attach in due course to the dealer, if the products are found to be violative of the law.

Under these provisions, prosecutions may be directed against manufacturers if they ship or deliver for shipment in interstate or foreign commerce adulterated or misbranded articles of food, or if they guarantee that such articles are not adulterated or misbranded, consignees may be prosecuted if they sell, in original packages, adulterated or misbranded articles of food which they have received in interstate commerce.

With respect to the "Standards of Purity for Food Products" it is not contended that these standards have the force of law. It is believed, however, that they represent fairly what are understood generally by reputable manufacturers, dealers, and consumers to be the ingredients of the products described therein. This test has been applied by the courts in cases tried under the Act where adulteration and misbranding have been charged of articles of food sold under names recognized in the "Standards," but which were found, on examination, not to conform thereto. It is apparent, therefore, that the safe course for manufacturers, jobbers, etc., engaged in interstate commerce who wish to have their products free from exceptions under the Food and Drugs Act, is to see to it that they conform to the standards described in Circular No. 19, U. S. Department of Agriculture, and as stated on pages 503 to 505 of this bulletin.[1]

REQUIREMENTS OF COMPOSITION OF CONDENSED MILK FOR WAR CONTRACTS

Requirements of condensed milk sold to the U. S. Government.—The composition of condensed milk and evaporated milk must meet the Federal Standards as specified in Food Inspection Decision 158 for evaporated milk and in Food Inspection

[1] These explanations were secured through the courtesy of Geo. W. McCabe, Office of the Solicitor, U. S. Department of Agriculture, Washington, D. C., upon request by letter in 1910. They equally apply to the Food Inspection Decisions which superceeded Circular No. 19.

Decision 170 for sweetened condensed milk and condensed skim milk.

Requirements of Condensed Milk for Export to the Allied Nations.—Condensed milk shall contain not less than 9.2 percent butterfat.

In order to meet the high butterfat requirement in condensed milk furnished to the Allies, American condenseries which receive largely low-testing milk are compelled to reinforce their product with butterfat. This is done either by removing a portion of the skim milk, or by the addition to the milk of butterfat in the form of cream or unsalted butter.

CHAPTER XXII.

COST OF MANUFACTURE

General Discussion.—The cost of manufacture varies, in a general way, with the organization and size of the factory, capacity of machinery and the amount of the output. These variations are further modified by the cost of available labor, the price of milk, cane sugar, tin cans, box shooks, coal and other supplies, etc.

In a properly organized plant the cost of manufacture per case of finished product decreases with the increase of the output, provided that the capaciy of the machinery is sufficient to take care of such increase. When the plant is forced beyond its capacity, the factory operates at a disadvantage, and the extra labor and possible waste and losses tend to increase the cost per case. When the output drops below 100 to 150 cases per day, profitable manufacture becomes difficult, the overhead expense is out of proportion with the business, the factory cannot take advantage of rebates in the purchase of supplies, the factory labor is relatively high, because skilled men have to do manual labor, and occasional losses due to spoiled goods devour the profits of a comparatively large portion of the entire output.

The price of milk fluctuates with season and proximity and strength of competing markets. The fluctuations embrace a range from $1.00 to $2.00 per one hundred pounds of fluid milk, or twenty-five cents to fifty cents per pound of butter fat. Maximum war-prices up to and including May 1918 were $3.50 per 100 pounds of milk and 75 cents per pound of butterfat.

Cane sugar varies in price largely with the season and with the success or failure of the sugar cane crop. Sugar prices usually reach their climax in fall and their minimum price in late winter or early spring. The variations usually fall within the limits of $4.00 and $6.50 per one hundred pounds of sugar. Maximum war price was 7¼c per pound.

Tin cans vary in price with style of can and whether made in the condensery or bought from a can-making concern. Some factories are paying more or less heavy royalties for the privilege of using certain patents of cans. Cans intended to be sealed without the use of solder, but which are guaranteed to make a hermetical seal, are generally higher in price than those in the sealing of which solder is used. This difference in price, however, is offset, in part at least, by the cost of the solder and gasoline. Cans purchased from can-making concerns usually are more expensive than cans manufactured in the condensery. This holds true only where the tin-shop of the condensery is properly equipped and efficiently manned. The cost of cans bought from can-making concerns is about fifty-five cents per case, varying somewhat with size and style of can; when made in the condensery the price may be lowered from 10 to 20 per cent. Maximum war price was 90 cents per case.

The cost of coal varies with quality and locality. Under average conditions, the condensing and packing of one pound of fluid milk requires about three-tenths of a pound of coal or thirty to forty pounds per case. A good quality of "mine run" can be laid down at the factory in states near the coal region, like Indiana and Illinois for about $2.50 per ton, or in northern states, like Wisconsin, for about $3.30 per ton. The cost of coal per case, therefore, may vary from about three and eight-tenths to six and a half cents per case. Where natural gas or refuse from lumber mills are available, the cost of fuel may be reduced materially by the use of these substitutes for coal. Maximum war price raised the cost of coal about 12c per case.

Solder and gasoline for sealing the cans average about three and a half cents per case. The price of solder is about twenty-seven cents per pound and the solder used per case of forty-eight cans, amounts to about one-tenth of a pound. Maximum war price raised it to about 7c per case.

For venthole cans the amount of solder needed is from .3 to .5 of one ounce per case.

The labels vary in price according to quality of paper, and elaborateness of printing. The average cost of labels is about four cents per case. Maximum war price about 8 cents per case.

The box shooks and nails per case cost about eight to ten cents. Maximum war price raised this item to about 10 cents per case.

The labor, including factory labor, the office personnel and the manager's salary is about twenty-five cents per case, varying obviously with the organization and output of the factory. War conditions practically doubled the cost of labor, making it about 50 cents per case.

The interest on the investment and insurance amount to about two and a half to three cents per case. A factory manufacturing two hundred cases of condensed milk per day requires an investment of about $25,000 for building and equipment and about $10,000 for operating capital.

The expense of freight and other transportation ranges from about five to twenty cents per case, according to distance. It may average about twelve cents per case. War conditions raised the freight to about 15 cents per case.

The selling expense varies considerably with the organization of the sales department and the type and extent of advertising done. Under favorable conditions it may be held down to from fifteen to thirty cents per case. If premiums are awarded the cost is about ten cents extra. The introduction of new brands often incurs an expense as high as $1.00 per case. The average sales expense may be consistently placed at thirty to forty cents per case. War conditions increased the selling expense for domestic trade about 50 per cent.

For convenience sake the cost per case may be grouped as follows:

SWEETENED CONDENSED MILK

Cost per case of forty-eight cans containing forty-six and four tenths pounds of condensed milk, net.

	1913.	1917.	*Increase due to war conditions.
116 pounds milk @ 1.50..........	1.74	3.48	100%
18.6 pounds, using 16 lbs. per 100 lbs. milk, cane sugar @ 5c....	.93	1.35	45%
Tin cans	.45	.90	100%
Boxes	.075	.10	33⅓%
Labels	.04	.08	100%
Solder and gasoline............	.035	.07	100%
Coal	.045	.12	150%
Labor	.25	.50	100%
Interest on investment and insurance	.03	.03	No Increase
Freight	.12	.15	25%
Selling expense	.30	.45	50%
Total cost per case...........	4.015	7.23	80%

EVAPORATED MILK

Cost per case of forty-eight tall-size cans containing fifty-four pounds of evaporated milk, net.

	1913.	1917.	Increase due to war conditions.
110 pounds milk @ 1.50..........	1.65	3.30	100%
Tin cans	.55	.96	75%
Boxes	.075	.10	33⅓%
Labels	.04	.08	100%
Solder and gasoline............	.02	.04	100%
Coal	.045	.12	150%
Labor	.25	.50	100%
Interest on investment and insurance	.03	.03	No Increase
Freight	.12	.15	25%
Selling expense	.30	.45	50%
Total cost per case...........	3.080	5.73	86%

* The figures showing per cent increase due to war condition were compiled by Professor A. C. Anderson, Mich. Agr. College, who conducted an extensive study on cost of manufacture of sweetened condensed milk.

PART V

CONDENSED MILK DEFECTS, THEIR CAUSES AND PREVENTIONS

Chapter XXIII.

CLASSIFICATION OF DEFECTS

If we recognize in fresh cow's milk an article of food, highly complex in composition, subject to many and complex changes and to rapid deterioration unless handled carefully and skillfully, then the successful manufacture of condensed milk, a product more complex in its composition and exposed to more diverse, more varying and, in most cases, more unfavorable conditions than fresh milk, must involve a knowledge that extends beyond the mere mechanical knack of heating, adding sugar, evaporating, sterilizing, cooling, filling, sealing and packing.

The simplicity of the process tends to belittle and hide the complexity of the product. Anybody can acquire the routine knowledge of condensing milk, but few can make a uniformly good quality of condensed milk. It, therefore, happens that defective condensed milk is made now and then in most, if not all condenseries, and that the output of a poor quality of condensed milk is not necessarily always the exception but quite often the rule.

Many are the defects which cause condensed milk to be rejected on the market and numerous are the avenues that may lead to the manufacture of defective milk. The milk faults may be of mechanical, physical, chemical, or bacteriological origin, or they may be due to a combination of two or more of these forces. In some instances the defects can be detected in milk during, or immediately after the process, in which case they may be remedied, or their recurrence prevented. But more often, several weeks may pass before abnormalities develop and before the manufacturer realizes that something is wrong with the milk. In the meantime, the conditions which originally produced the milk defect may have so changed, that it is exceedingly difficult to locate the seat of the original trouble.

DEFECTIVE SWEETENED CONDENSED MILK

The following are the chief and most common defects of sweetened condensed milk:

1. Sandy, rough or gritty
2. Settled
3. Thickened and cheesy
4. Lumpy, white or yellow buttons
5. Blown or fermented
6. Rancid
7. Putrid
8. Brown
9. Metallic.

Sandy, Rough or Gritty Sweetened Condensed Milk

General Description.—This is condensed milk in which a portion of the milk sugar has been precipitated in the form of crystals, the size of the crystals depending on the conditions causing crystallization. First-class sweetened condensed milk is smooth and velvety. Such milk is not entirely free from sugar crystals, but they are so minute in size that they do not rob the condensed milk of its natural smoothness. In sandy or gritty condensed milk the crystals are very numerous and large enough to grind between the teeth, similar to salt crystals in gritty butter. The presence of these crystals is also noticeable to the naked eye; the milk looks candied.

Causes and Prevention.—The sugar crystals which render the condensed milk rough and sandy consist largely of milk sugar. The solubility of milk sugar is relatively low. Milk sugar requires about six times its weight of water at ordinary temperature for complete solution. Condensed milk contains from 12.5 to 15 per cent. milk sugar and only about 26.5 per cent. water. The ratio of milk sugar to water in sweetened condensed milk, therefore, is 1:2, while for complete solution it should be 1:6. The milk sugar in this product is present in a supersaturated solution and any condition which favors sugar crystallization strongly tends to precipitate this milk sugar, because there is more of it present in the milk than the available water is capable of readily keeping in solution. The chief factor that prevents the milk sugar from precipitating very badly is the great viscosity of the condensed milk. This is largely due to the caseous matter and the cane sugar.

Cane Sugar Content.—It has been argued that the large amount of sucrose which sweetened condensed milk contains, is the principal cause of sandy milk and of sugar sediment in the bottom of the tin cans, and that a reduction in the amount of sucrose lessens the tendency of the sugar to crystallize and the milk to become sandy. This line of reasoning is erroneous. The presence, in water, of sucrose in solution does not materially lessen the power of the water to dissolve milk sugar, provided that the sucrose solution is not a saturated one. Sweetened condensed milk, contains about 35 to 45 per cent. sucrose and 24 to 28 per cent. water. Sucrose dissolves in one half its weight of water. The sweetened condensed milk does not, therefore, contain a saturated solution of sucrose.

The chief factors causing milk sugar crystallization and sandy condensed milk are: incomplete solution of the sucrose, excessive chilling in the vacuum pan, superheating in the vacuum pan, improper cooling, excessive stirring, and warming up too cold condensed milk with the help of agitation.

Incomplete Solution of Sucrose.—If the finished product is to be smooth and free from sandiness, it is essential that the sucrose which is added to the hot, fresh milk be thoroughly dissolved before the mixture reaches the vacuum pan. Undissolved sugar crystals in a medium as highly concentrated as sweetened condensed milk have much the same effect in a physical way, as have bacteria in fresh milk in a biological way; they multiply rapidly. Therefore, if all the sugar added to the fluid milk is not completely dissolved, the undissolved sugar crystals give rise to wholesale precipitation of the milk sugar in this product after manufacture. Complete solution of the cane sugar can best be accomplished by heating the liquid, milk or water, in which the sugar is to be dissolved, to the boiling point and by boiling the mixture for several minutes; or by placing the sugar on a large wire mesh strainer (about eighty meshes to the inch) which stretches across the sugar well and allows hot milk to run over this sugar into the well below. In this way the sugar crystals must dissolve before they can reach the sugar well.

One of the safest methods of insuring complete solution of the cane sugar is to dissolve it in a separate kettle in a sufficient quantitiy of boiling water (preferably distilled water) and boiling the syrup for five to fifteen minutes. If the syrup thus made is given a few minutes rest it should become perfectly clear; by its clearness, the purity of the sugar can also be observed. If a scum forms at the top it should be removed; then the hot sugar syrup is drawn into the pan. Care should be taken that the milk already condensing in the pan has not become too concentrated, otherwise sugar crystallization may set in. It is advisable to inject the sugar syrup gradually, rather than to wait until nearly all the milk is in the pan.

Excessive Chilling in the Pan.—The cause of grittiness of condensed milk may lie in the pan itself. Where the water used for condensing is very cold, and where one end of the spray pipe in the condenser is very close to the goose neck of the pan, as is the case with most of the vacuum pans in use, which are equipped with horizontal spray condenser the chilling of the vapors and of the spray of milk rising from the pan is so sudden, that sugar crystals are prone to form in the spray and along the walls of the pan. These crystals either stick to the side of the pan, or fall back into the milk where they later multiply and cause the milk to become sugary. Trouble from this source can be avoided by either raising the temperature of the water that goes to the condenser which is, however, not practical under most conditions, or by closing the holes in that portion of the spray pipe which is nearest the pan. This can easily be done by wrapping a piece of galvanized iron or tinplate around the portion of the spray pipe to be closed, or by filling the holes with solder, or by replacing the old spray pipe by a new and shorter one, properly constructed.

Superheating at End of Batch.—Sometimes the manufacturer is persistently troubled with the appearance of crystals in the condensed milk of monstrous size, as large as rice kernels; this condition arrives usually very gradually. During the first few days after manufacture, only a few of these large crystals may appear in some of the cans. In the course of a few weeks, all of the cans may contain specimen of these "rice crystals" which increase in number until the entire contents of the cans are one mass of "rice crystals," rendering the milk unsalable. The direct causes of this particular kind of sugar crystallization are excessive concentration of the condensed milk, the use of too much steam pressure in the coils and jacket when condensation is near completion, delay in the drawing off of the condensed milk from the pan, and leaky steam valves in the pipes leading to jacket and coils.

Toward the end of the condensing process the milk becomes heavy, thick and syrupy, and boils with much less violence. If, at this stage of the process, excessive steam pressure is used in the jacket and coils, the milk is superheated, often causing the precipitation of "rice crystals." Again, where the finished condensed milk is drawn from the pan very slowly, either owing to too small an outlet in the bottom of the pan, or because the milk is forced to run through a strainer attached to the outlet, or because the finished condensed milk is retained in the pan as the result of an accident, in all of these cases there is danger of superheating, and therefore, of the production of these large crystals. This danger is especially great, where the valves of the steam pipes leading to the jacket and coils are leaking, as is often the case. The avoidance of excessive concentration and the removal of any conditions that tend to expose the finished or the nearly finished condensed milk to excessive heat will usually prevent further trouble of this sort.

Improper Cooling.—The method used for cooling the sweetened condensed milk after it leaves the vacuum pan is another important factor determining the smoothness or grittiness of the finished product. The chief principles involved here are the rapidity and extent of cooling and the amount of agitation to which the condensed milk is subjected.

In order to fully appreciate the importance of strict attention to details in the cooling process of sweetened condensed milk, it should be understood, that the formation of sugar crystals in concentrated solutions is enhanced by sudden chilling and by excessive agitation of these solutions. The sudden and irregular chilling of a part or all of the sweetened condensed milk in the cooling cans is the result of the use of badly dented cans, poorly fitting paddles, a warped condition of the pivots on which the cog wheels in the bottom of the cooling vat revolve, too cold water, and the application of too much cold water.

The paddles must scrape all parts of the sides of the cans, from top to bottom. This is possible only when the cans are intact and their sides are smooth and free from indentations. The paddles must be adjusted properly so that their edges fit snugly against the sides of the cans, they must be firmly fastened to the cross bars and forced against the sides of the cans by springs. In order that the cans may run true they must properly fit into the rim of the cog wheels in the bottom of the cooling vat and the pivots on which the cog wheels revolve must be perpendicular. If the pivots are warped, the cog wheels cannot run true and the cans wobble; this causes uneven and incomplete scraping of the sides of cans by the paddles.

The water in the cooling vat should not be cold, but have a temperature of about 90 degrees F. when the cans, filled with the hot condensed milk, are set into the vat. The cold water should flow into the vat slowly and be evenly distributed throughout the vat. This is best accomplished by the installation of a perforated pipe running the entire length of the vat. The cooling must be gradual.

Excessive Stirring.—The cans should revolve slowly. Rapid revolution causes excessive agitation of the condensed milk, which stimulates the formation of crystals. About five revolutions per minute is satisfactory. In order to make more effective the proper scraping of the cans by the paddles when the cans revolve slowly, it is advisable to install two paddles in each can, touching the periphery of the can on opposite sides.

When the milk has been cooled to between 60 and 70 degrees F., the water should be drawn from the cooling vat, or the cans should be removed at once. For other methods of cooling see "Cooling," page 94.

Warming Up of Too Cold Condensed Milk.—Finally, if the condensed milk is cooled to too low a temperature, either by mistake, or as the result of the cans of cooled milk standing in a very cold room over night, so that the condensed milk is too thick to run through the filling machine, it is best to warm it up by simply allowing it to stand in a warm room. The practice of setting the cans back into the cooling tank and revolving them in warm water is objectionable, since this stirring of the milk, while it is warming, seems invariably to produce wholesale sugar crystallization, and therefore, causes the condensed milk to become very gritty. (See also Settled Condensed Milk).

Settled Sweetened Condensed Milk.

General Description.—By the term "settled milk" the condensed milk man refers to condensed milk which has precipitated and thrown down a portion of its sugar, forming a deposit of sugar crystals in the bottom of the can or barrel. This deposit may vary in amount from a very thin layer to a layer an inch deep or more, according to the character and age of the milk. The nature of this sediment also differs in different cases of settled milk. It may be soft, and upon stirring may mix in and dissolve readily, or it may be very dry and hard, in which case it sticks to the bottom of the can with great tenacity, and can be removed and mixed into the milk with difficulty only. Like gritty milk, settled milk is a very common condensed milk defect. Though it does not render the product less wholesome, it is an undesirable characteristic. Such milk is usually rejected on the market and results in a partial loss to the manufacturer.

Causes and Prevention.—It is obvious, for reasons above referred to, that the conditions leading up to the production of settled milk, are closely related to those that cause milk to become gritty. Condensed milk cannot drop its milk sugar, unless the latter is present in the form of crystals. The absence of crystals then; means that condensed milk will not settle; but experience has shown that it is a practical impossibility to manufacture sweetened condensed milk which contains no sugar crystals Sugar crystals are always present in it, and the fact that the milk is not sandy or gritty, does not necessarily mean that it will not settle. Nevertheless, the removal of conditions conducive of sandy or gritty milk, diminishes the tendency of the formation of sugar sediment. The succesful and uniform production of condensed milk that does not settle, however, involves additional conditions that are not controlled by the factors causing gritty milk.

Effect of Density on Sugar Sediment.—One of the chief of these conditions is the density of the condensed milk. The thinner the condensed milk, the greater the difference between the specific gravity of the liquid portion and that of the sugar crystals; therefore, the more readily will the crystals sink to the bottom. The viscosity of thin condensed milk, also, is less than that of thick milk, offering less resistance to the force of gravity of the crystals. In the manufacture of sweetened condensed milk that has the proper density, about 2.5 to 2.8 parts of fresh milk are condensed into one part of condensed milk. If the evaporation is stopped sooner, so that the ratio is much less than 2.5 to 1, the condensed milk is usually too thin to hold its sugar crystals in suspension.

Effect of Fat Content on Sugar Sediment.—The per cent. of fat in milk, also, influences the specific gravity of the condensed milk, and therefore, has some effect on the settling of the sugar crystals, although to a relatively slight degree. Nevertheless, sweetened condensed skimmed milk will settle less readily than sweetened condensed whole milk.

Effect of Cane Sugar Content on Sugar Sediment.—The per cent. of cane sugar materially influences the specific gravity and viscosity of the condensed milk. Milk with a high per cent. of sucrose is heavier, more viscous and drops its sugar crystals less rapidly than milk with a low per cent. of sucrose.

Turning the Cans to Prevent Sugar Sediment.—Concerns who have been continually troubled with settled milk often resort to the practice of turning their cases daily, or at other regular intervals. This keeps the precipitated crystals in motion, but it does not prevent the settling entirely. Moreover, milk destined to settle, as the result of defects in the process, cannot be prevented from dropping its crystals after it leaves the factory. Some concerns have stooped to printing on their labels statements similar to the following: "A sediment in the bottom of this can indicates that this condensed milk is absolutely pure and free from harmful ingredients." Advice of the above denomination is obviously ridiculous as well as untrue.

Adding Powdered Milk Sugar.—It has been explained that after the condensed milk is cooled it contains sugar crystals. If those crystals are large, their cubic content is relatively great in proportion to their surface. Their buoyancy is, therefore, sufficient to overcome the resistance of the surrounding liquid and they will drop to the bottom, forming a sediment. If these crystals are very small and fine they are not objectionable and they usually do not cause settled milk, because their gravity force is insufficient to overcome the resistance of the viscous syrup. It has been further shown that the size of the sugar crystals is largely determined by the size of the first crystals present. Experience has demonstrated that the addition to the condensed milk before cooling, of very fine sugar crystals, such as powdered milk sugar contains, encourages the formation of very small crystals and tends to guard against the development of large and coarse crystals during subsequent cooling. Hence sugar sediment may be greatly minimized, if not entirely prevented, by adding to the hot sweetened condensed milk, a small amount of powdered milk sugar, add at the rate of a teaspoon full of milk sugar per one hundred pounds of condensed milk. The milk sugar must be added as soon as the condensed milk comes from the pan, if the milk is allowed to cool before the milk sugar is added, its effectiveness is largely lost.

In order to insure the full desired action of the added powdered milk sugar, this powder must be transferred to the condensed milk in such a manner as to prevent its formation into lumps. It must be evenly and finely distributed over and in the condensed milk. The use of a flower sifter has been found most suitable for this purpose.

Thickened and Cheesy Sweetened Condensed Milk

General Description.—The term "thickened and cheesy" condensed milk applies to condensed milk that thas become thick and in some cases solid. This is a very common trouble with milk manufactured in late spring and early summer. The milk thickens soon after its manufacture and continues thickening until it assumes the consistency of soft cheese, without the development of acid. In this condition it usually has a peculiar stale and cheesy flavor, disagreeable to the palate. Such milk is invariably rejected on the market.

Causes and Prevention: Effect of Colostrum on Thickening.—It has been suggested that this spontaneous thickening is due to the presence in the fresh milk of colostrum milk, because this defect appears at a time when the majority of the cows supplying the condensery freshen. This explanation can hardly be considered correct and there is no experimental evidence available substantiating it. If the presence of colostrum milk were the cause of it, the thickening would take place during the process, as the result of the action of heat on the albuminoids. This is not the case. This thickening begins some days and often some weeks after manufacture and increases as the milk grows older.

Effect of Cow's Feed on Thickening.—Again, the cause of this defect has been attributed to the change in feed, the cows being turned from dry to succulent feed at the time when this tendency of the condensed milk to thicken occurs. There is no reliable evidence, however, of how the succulent pasture grasses on which the cows feed can bring about this thickening action in the condensed milk.

Effect of Bacteria on Thickening.—A third and far more reasonable explanation is that this thickening is the result of a fermentation process. It is quite probable that the thickening of sweetened condensed milk is closely related to the sweet-curdling fermentation in fresh milk. The sweet-curdling of fresh milk is a fermentation characteristic of, and frequent during late spring and summer. It is caused by certain species of bacteria which are capable of producing a rennet-like enzyme, which has the power to curdle milk in the sweet state. These bacteria are known to be closely associated with dirt and filth, especially from the feces, and gain access to the milk usually on the farms where the production and handling of milk is not accomplished under most sanitary conditions.

It is further known, as the result of analyses that, in spite of the large per cent. of cane sugar which sweetened condensed milk contains, the bacteria in it increase with the age of the milk. The thickening of the sweetened condensed milk in early summer, therefore, very probably is the result of a slow curdling of its casein, caused by enzymes which are produced by bacteria. It has further been demonstrated that condensed skim milk thickens more readily than condensed whole milk, which may be explained by the fact that condensed milk without butter fat represents a more favorable medium for bacterial growth. Furthermore, it has been conclusively demonstrated by the writer and others that the addition of cane sugar to condensed milk, in excess of that present in normal condensed milk, greatly retards thickening. This fact suggests that the higher per cent. of sucrose has an inhibiting effect on the enzyme-producing bacteria, and perhaps, on the action of the enzyme itself. This condensed milk defect can be prevented entirely by using, during the summer months, eighteen pounds of sucrose per one hundred pounds of fresh milk, so that the condensed milk contains about 45 per cent. sucrose.

Effect of Finishing in Pan With High Steam Pressure on Thickening.—Abnormally thick condensed milk is also the result of overheating the condensed milk in the vacuum pan toward the close of the process. The batch should be finished with low steam pressure in the jacket and coils, not to exceed five pounds of pressure, and the milk should be drawn from the pan at once after condensation is completed. The superheating to which the condensed milk is subjected in the pan, when finishing with a high steam pressure in jacket and coils, or when the milk is not drawn from the pan promptly when the vacuum pump is stopped, or when an effort is made to condense to a very high degree of concentration, is almost sure to cause the finished product to spontaneously thicken with age and this tendency is especially pronounced in the spring and early summer.

Effect of Age on Thickening.—Finally, all sweetened condensed milk has a tendency to thicken with age. Exposure to high storage temperature (summer heat) hastens this action. The rapidity of thickening in storage increases with the increase in temperature. This tendency is very much reduced, therefore, by protecting the goods from high temperatures and by storing them below 60 degrees F. (See Chapter on "Storage," page 152.)

Lumpy Sweetened Condensed Milk

General Description.—Lumps of varying denominations are not infrequently found in sweetened condensed milk. They may be soft and permeate the contents of the can throughout, or may appear especially in the form of a "smear" along the seams of the can; or again, they may float on the surface, in which case they are usually hard and cheesy, and either white or yellow in color. Their presence gives the contents of the can an unsightly appearance at best, and in many cases, they spoil its flavor. They naturally suggest to the consumer that something is wrong with the condensed milk, and cause him to reject the whole package.

Causes and Prevention.—The chief causes of lumpy condensed milk are: poor quality of fresh milk, unclean pipes in factory, milk from fresh cows, acid flux in tin cans, and unclean and contaminated tin cans.

Poor Quality of Fresh Milk and Unclean Factory Conditions.—Upon opening the can of condensed milk, even shortly after it is filled, the lid is covered with large and small lumps and specks sticking to the tin, presenting a very uninviting appearance. This condition can usually be traced back to a poor quality of fresh milk, containing too much acid. Very often, too, the cause lies in the factory itself, where it is due to lack of cleanliness. A thorough inspection of milk pipes and pumps generally shows accumulations of remnants of milk which get into the milk of the succeeding batch. Where this condition exists, it is noticeable that the first batch of the day contains more specks and lumps than the succeeding ones. These lumps do not, as a rule, grow larger in size nor increase in number with the age of the condensed milk, but they injure its appearance to the eye, and certainly cannot add to the wholesomeness of the milk. They might easily become the cause of the formation of ptomains. A more rigid inspection of all the fresh milk as it arrives at the factory and thorough scouring of all milk tanks and milk pumps, pipes and conveyors usually prevents the recurrence of this defect.

Milk from Fresh Cows.—During early spring there is a strong tendency of the jacket and coils in the vacuum pan to become coated with a thick layer of gelatinous and lumpy milk. This is probably due to the fact that milk during these months comes largely from freshened cows and may contain some colostrum milk which coagulates when subjected to heat, or that the proteids of milk from these fresh cows are abnormally sensitive to heat. This thickened material usually does not leave the pan until most of the condensed milk has been drawn off. It, therefore, appears in the last one or two cooling cans. If the milk in these cans is mixed with the rest of the condensed milk, the lumps will appear again in the tin cans. The last cans drawn from the pan should, therefore, be kept separate. The contents of these remnant cans may be redissolved in hot water and should be recondensed in a succeeding batch. In this way the manufacturer sustains practically no loss. In order to prevent these lumps from getting into the cooling cans, some factories attach a strainer to the outlet of the pan. This practice is as unneccessary, as it is damaging to the milk in the pan. The straining greatly retards the removal of the milk from the pan, and the milk is held in the hot pan so long, as to cause partial superheating which is otherwise detrimental to its quality.

Comparative Composition of Gelatinous Coating of the Jacket and Coils and of Normal Condensed Milk of the Same Batch, made April 23, 1908

	Coating of jacket and coils	Normal condensed milk
Moisture	24.76 per cent.	30.34 per cent.
Lactose	13.12 "	13.16 "
Fat	9.50 "	7.44 "
Curd	8.14 "	7.30 "
Ash	1.42 "	1.80 "
Acid	.33 "	.40 "
Sucrose	41.36 "	40.02 "
	98.63 per cent.	100.46 per cent.

The above analyses were made in order to determine the difference in chemical composition between that part of the batch which, in the spring of the year, forms a gelatinous coating on the jacket and coils and that part which remains normal. The figures do not show as great a difference, as the physical comparison of the two products would suggest. Possibly the most significant point these analyses show is that, while the proteids in the coating are higher, the ash is lower than in the normal condensed milk.

A large portion of the ash of milk is present in chemical combination with the casein, which does not curdle by heat, while the albumin, which is coagulated by heat, contains only a very small amount of ash. Therefore, the fact that an increase in the proteids of this gelatinous coating is accompanied by a decrease in the ash content, would suggest that the proteids of the coating of the jacket and coils consist of more albumin and less casein than the proteids of the normal condensed milk of the same batch. Since this coating of the jacket and coils occurs only in the spring of the year, when most of the cows freshen, it is reasonable to assume that this coating is the result of the acceptance at the factory of milk too soon after calving and which contains excessive quantities of proteids and other substances which are highly sensitive to heat, such as albumin, colostrum, etc.

Excess of Acid in Condensed Milk and Acid Flux in Tin Cans.—The presence in the condensed milk of organic and mineral acids, in excess of the amount which normal fresh milk contains, is conducive of the formation of lumps.

Excessive amounts of acid in condensed milk may be the result of fermentations, usually due to a poor quality of sugar, or of the use of acid flux in the making and sealing of the tin cans. Condensed milk that shows acid or gaseous fermentation usually contains lumps. The acid which it develops as the result of the fermentation, curdles the casein with which it comes in contact.

One of the most common channels through which condensed milk may become contaminated with acid mechanically, is the use of cans, in the manufacture and sealing of which acid flux was used. The acid flux generally used contains zinc chloride. The flux precedes the solder and some of it is bound to sweat through the seams into the interior of the cans. Zinc chloride is a highly poisonous product and its use in the manufacture of tin cans, which are intended for receptacles of human food, should be prohibited by law. Aside from its injurious effect on the health and life of the consumer, its presence, even in small quantities in condensed milk, is a detriment to its market value. In such cans there accumulate, usually along the seams, lumps and smeary substances which have been found to consist of casinate of zinc.

Most commercial soldering fluxes consist largely of zinc chloride and are highly acid, although many of these are advertised as acid-free fluxes. In order to avoid condensed milk containing lumps from this source, cans should be used, in the manufacture of which a strictly acid-free flux is used and which are sealed with acid-free flux. Dry, powdered resin or resin dissolved in alcohol or gasoline are harmless in this respect and are just as effective fluxes, as acid flux.

Unclean and Contaminated Tin Cans.—Finally, there frequently appear in sweetened condensed milk, species of lumps which are firm and cheesy and which usually float on top of the milk in the can. These are called buttons. Some are white, others are yellow. These buttons appear in old milk more frequently than in milk that has been in storage for a short time only. They grow in size and sometimes one "button" covers the entire surface of the condensed milk in the can. Their origin is not well understood, but they are supposed to be the result of fungus growth. It is not improbable that they are produced by molds, the spores of which gain access to the condensed milk in the factory, or to the cans before they are filled. These "buttons" appear in the canned goods and in the barrel goods. Their occurrence can be minimized by protecting the condensed milk and the empty cans from dust and other impurities, by sterilizing the cans immediately before use, and by paraffining and thoroughly steaming the barrels before filling.

Blown, or Fermented Sweetened Condensed Milk

General Description.—One of the most disastrous troubles in the manufacture of sweetened condensed milk is the appearance of "swell heads." This term is applied to cans of condensed milk, the contents of which have undergone gaseous fermentation, the resulting pressure causing the ends of the cans to bulge or swell, and frequently to burst open the seams. In the case of barrel goods, the pressure may cause the barrel head to blow out. This gaseous fermentation is usually, though not always, accompanied by the development of acid and the formation of lumps.

This fermented milk is worthless for any purpose and means a total loss to the manufacturer. The loss is generally augmented by the fact that this trouble does not become noticeable at once; its development requires several weeks, so that large quantities of condensed milk may have been manufactured before it is apparent that the milk is defective. Some of the goods may have reached the market before the cans begin to swell, in which case the reputation of the respective brand is jeopardized. In some instances entire batches show this defect, while in others only a few cans or cases of each batch are blown.

Causes and Prevention.—This defect may be brought about through various channels. In most cases it is due to contamination of the milk, on the farm or in the factory, with specific micro-organisms which are capable of fermenting one or more of its ingredients, in spite of the preservative action of the sucrose; or the condensed milk may contain highly fermentable substances such as glucose or invert sugar, so that the germs normally present in the condensed milk become active and produce gas; or the milk may not be condensed to a sufficient degree of concentration, or may not contain adequate quantities of sucrose, to render it immune to the bacteria normally present. The cans may also bulge without bacterial action, as the result of exposure to a wide range of temperatures, causing mechanical contraction and expansion of the contents.

Contamination With Specific, Gas-Producing Bacteria and Yeast.—This is by far the most common cause of blown milk. While the micro-organisms which, under normally sanitary production of milk and factory conditions, gain access to the condensed mik, are largely inhibited and do not ferment the sweetened condensed milk, there are certain specific forms of bacteria and yeast whose growth is not retarded by the concentrated sugar solution of this product. Contamination of the condensed milk with these specific organisms is usually the result of highly unsanitary conditions in the handling of the condensed milk.

The products of fermentation depend on the particular type and species of micro-organisms involved. In most cases the sucrose is the chief constituent attacked, but the lactose, also, is capable of gaseous fermentation, though instances of lactose fermentation in sweetened condensed milk are not common.

The gaseous fermentation of lactose is largely caused by bacteria, yeast and molds which contain the lactose-splitting enzyme "lactase," which has the power of hydrolyzing the lactose. While the species of organisms which cause lactic acid fermentation from lactose are very numerous, those containing the enzyme lactase and thereby causing gaseous fermentation from lactose, are less frequent, at least, as far as their access to milk and condensed milk is concerned. It is generally understood, though not experimentally proven, that species of micro-organisms which do not contain the enzyme lactase have no gas-producing action on lactose.

The great majority of cases of gaseous fermentation of sweetened condensed milk are the result of the action of micro-organisms on the sucrose, especially those which contain the enzyme "invertase." The majority of yeasts secrete invertase and ferment sucrose, producing alcohol and carbon dioxide to the same extent as in the case of glucose fermentations. The process is considerably slower, however, especially at the start, owing to the fact that inversion of the sucrose must precede fermentation. For this reason gaseous fermentations of sweetened condensed milk do not become noticeable until the product is one or several weeks old.

Contamination With Yeast on the Farm.—In most cases of yeast fermentations of sweetened condensed milk, the source of contamination lies in the factory. While such contamination may and often does occur on the farm, the yeast cells, though they may be spore-bearing, are destroyed by the heat to which the fresh milk is subjected in the forewarmers and before it reaches the vacuum pan. The thermal death point of all forms of yeast which have come to the attention of the writer in connection with a vast number of investigations of fermented condensed milk was below 180 degrees F. If all the milk is properly heated in the forewarmers to 190 degrees F. or over, there is, therefore, little danger of fermented milk, caused by contamination of the fresh milk on the farm with yeast. If, however, the heating is incomplete, or if some of the milk passes into the vacuum pan without having been properly heated, there is danger of milk, contaminated with these yeasts, to result in fermented condensed milk.

Contamination with Yeast in the Factory.—As previously stated, yeast fermentation of condensed milk can almost invariably be traced back to contamination in the factory. After the milk leaves the forewarmers, or hot wells, it is never again heated to temperatures high enough to destroy these destructive yeast cells. The channels through which yeast contamination may occur in the factory are many.

Contaminated Sugar.—The sucrose itself may be contaminated with yeast. This is frequently the case and especially so if the sugar is exposed to dampness, and if flies, bees, ants or cockroaches have access to it.

Again, the sugar may reach the milk through a sugar chute. The lower end of the chute is usually located directly over the steaming milk in the hot well. The vapors arising from below may be condensed in the chute, causing its inside walls to become damp, and sugar will adhere to the damp surface, forming a crust. If the crust is not removed daily, its contamination with yeast and other dangerous micro-organisms is almost inevitable and whenever this crust peels off and drops into the milk, the contamination may be carried into the finished product, giving rise to gaseous fermentation.

Contaminated Machinery and Milk Conveyors.—Remnants of milk may lodge in the condenser, in the vacuum pan, in the pipes conveying the milk and condensed milk, in the cooling cans or coils, in the supply tank of the filling machine, or the filling machine itself. These remnants are all subject to contamination and may become the source of fermented condensed milk. The strictest attention to scrupulous cleanliness and continuous inspection of all parts of conveyors and apparatus which come in contact with the milk are the only consistent safeguards against trouble from this source.

Contamination Through "Cut-opens."—It is customary to empty the contents of sample cans which are cut open for any purpose, back into the condensed milk of suceeding batches. If these samples happen to be contaminated with the fermenting

Fig. 54. Gaseous fermentation in sweetened condensed milk

Fig. 55. Yeast cells causing gaseous fermentation
This species is capable of fermenting sugar solutions containing 85% sucrose.

germs, the defect is naturally propagated from batch to batch and it is exceedingly difficult to locate the source of the trouble. It is obvious that all suspicious "cut-opens" should be rejected and that all "cut-opens" that are utilized should be emptied into the hot well where their contents are boiled up again.

Dangerous Effect of Poor Quality of Sugar.—Sweetened condensed milk is not sterile. There is no part of the process that would render it sterile and, from the time it leaves the vacuum pan to the time when the tin cans are hermetically sealed, it is exposed to contamination with microbes, even though the factory observes the most rigid attention to scrupulous sanitation and cleanliness. Most of these microbes are harmless and their growth is inhibited by the preservative action of the cane sugar. If, however, a poor quality of sucrose is used, which may contain traces of invert sugar, or acid, etc., many of these common species of micro-organisms, harmless in normal condensed milk, find an opportunity to develop and cause gaseous fermentation. The presence of invert sugar makes unnecessary the action of invertase in order to start fermentation; thus, microbes which do not secrete invertase and are otherwise harmless, may become detrimental in the presence of invert sugar, added to the milk in the form of a poor quality of cane sugar. In a similar way the use in condensed milk of commercial glucose, as a substitute of a part of the cane sugar, and in order to reduce the cost of manufacture, is bound to cause disastrous results. Nothing but the best refined, granulated sucrose should be used, the best is the cheapest.

Dangerous Effect of High Acid in Milk.—Acids have the power of inverting sucrose. The inversion by acid is especially active in the presence of heat. The milk in the vacuum pan is condensing at 130 to 150 degrees F. These temperatures are most favorable to inversion of a portion of the sucrose in the presence of acid. The higher the acid content of the milk, the more active is the inversion. Since invert sugar is the very ingredient necessary to cause bacterial action in the finished product, it is essential that the acidity of the milk to be condensed, should be held down to the minimum in order to avoid trouble from this source.

Contamination with Butyric Acid Bacteria.—Frequently the troublesome microbe is not a yeast, but belongs to a species of bacteria highly resistent to heat, and which fail to be destroyed by heating the milk to the boiling point. In this case, the contamination usually originates on the farm. Organisms of this kind, which infest the milk on the farm in this connection, largely belong to the butyric acid group. The most prominent among them are Granulobacillus saccharo-butyricus mobilis or Bacillus saccharobutyricus, Bacillus esterificans, Bacillus dimorphobutyricus. The putrefactive forms of butyric acid organisms, such as Bacillus putrificus, Plectridium foetidum, Plectridium novum, etc., do not seem to thrive in sweetened condensed milk.

The contamination may occur from dust of hay and other fodder, grain, bedding, or the unclean coat of the udder and surrounding portions of the animal, or from milking with wet and unclean hands, or from remnants of milk in unclean utensils.

It is noticeable that the great majority of cases of blown milk appear during late summer and early fall, when the crops are harvested and the air in the barn is frequently loaded with dust from the incoming crops. Gelatin plates exposed in the stable before and during the filling of silos showed an enormous increase of colonies on the plates exposed during the filling of the silos. Milk drawn under such conditions is naturally subjected to excessive contamination, unless special precautions are observed.

A very common source of these butyric acid organisms also is remnants of milk in pails, strainers, coolers, cans and any other utensils with which the milk may come in contact, also polluted water used for rinsing the utensils. The cheese-cloth strainer, owing to the fact that it is difficult to thoroughly clean and that it is very seldom really clean, is a very serious menace in this respect. Under average farm conditions, unless a new cloth strainer is used at each milking, it is safe to condemn it entirely and to recommend the use of a fine wire mesh strainer containing about eighty meshes to the inch. On some farms the milk is held in a set of old cans which are kept on the farm and which never reach the can washer at the factory. Just before hauling time these cans are emptied into the clean cans from the factory. These old cans are often not washed properly and sometimes not at all. The remnants of milk in these cans breed these undesirable germs and contaminate the fresh milk. It is obvious that such a practice is bound to jeopardize the quality and life of the finished product and may constitute a continuous cause of blown milk.

Effect of Amount of Sucrose.—Since the sucrose contained in sweetened condensed milk is the chief agent preserving it, it is obvious that enough of it must be added to insure adequate preservative action. Experience has shown that about 39 to 40 per cent. of sucrose is required to preserve the condensed milk under average conditions. A higher per cent. of sucrose would naturally intensify the preservative action and inhibit the growth of the bacteria normally present more completely; but if enough sugar were added to also inhibit the growth of and make harmless those violent gas-producing butyric acid bacteria and yeast cells, which thrive in sweetened condensed milk containing 40 per cent. sucrose, the product would be objectionable from the consumer's point of view. The logical avoidance of "swell heads" as the result of these undesirable germs, therefore, must ever lie in prevention, rather than cure. The sanitary standard of production on the farm and of the process in the factory must be raised to and maintained on a level where the milk is protected from contamination with these micro-organisms.

The writer[1] has isolated yeast from fermented sweetened condensed milk that produced vigorous gas formation in media containing as high as 85 per cent. sucrose (600 grams sucrose in 100 cc. whey bouillon).

Effect of Too Thin Condensed Milk.—Condensed milk that is too thin is, also, prone to start fermenting, since it is deficient in the chief preserving agents, i. e., density and per cent. of sucrose. It is not safe to put goods on the market, with a ratio of concentration much less than 2.5:1.

Effect of Excessively Low Temperatures.—The cans of sweetened condensed milk may also bulge in the case of cans with non-hermetical seals, exposed successively to excessive cold and to room temperature. In this case, the condensed milk is entirely normal and unaffected, and the bulging is the result of mechanical contraction and expansion by cold and heat. This is possible only where the seal of the cans is not entirely hermetical. In the case of the Gebee seal with the burr cap, and the McDonald seal with the friction cap, the seal is not absolutely air-tight. While the pores between cap and can are microscopic in size, and not large enough to permit the contents from leaking out, they are sufficient to admit air. The cans are usually filled with the condensed milk at a temperature of about 70 degrees F. If the filled and sealed cans are exposed to a very low temperature, as may be the case in winter, in store houses or in transit, the milk and the air in the cans contract. This contraction is intensified by the fact that the sweetened condensed milk does not freeze. Its concentration is so great that its freezing point is usually below the most extreme cold storage tem-

[1] Hunziker, Results not published.

perature. This contraction of milk and air in the cans produces a partial vacuum, causing air to be drawn into the cans through the microscopic openings of the seal. When the cans are subsequently moved into places with a more moderate temperature, the milk and the air in the cans expand, but the milk on the inside of the cans forms a seal preventing the escape of the surplus air. The result is that the ends of the cans bulge. This phenomenon has been experimentally determined by the author[1] While the contents of such cans are perfectly normal, the package suggests fermented milk and may be rejected on the market.

It is evident, from the above data, that the swelling of the cans, as the result of exposure to excessively low temperatures, can readily be avoided, either by protecting the cans against excessive cold, or by using cans that are sealed with solder. The solder-seals are hermetical so that no air can be drawn into the cans when a partial vacuum is formed in their interior as the result of the contraction of air and milk.

Rancid Sweetened Condensed Milk

General Description.—Sweetened condensed milk may develop a distinctly rancid flavor and odor, a defect which renders it unmarketable.

According to the best authority, there are many agents which may be active in the production of rancidity. The fact that in rancid butter are usually found to predominate certain species of organisms, such as the fungi of Penicilium Glaucum, Penicilium Roqueforti, Cladosporium butyri, Oidium lactis, Actinomycoces odorifora, yeast and various bacterial species, such as Bacterium fluorescens, Bacterium prodigiosum, Bacillus mesentericus, etc., and that these species are capable of making butter rancid, has led to the conclusion that they may be the cause of rancidity, either by direct action, or by the secretion of fat-splitting enzymes. It is, therefore, quite possible that some of these species, or similar groups of species, may be instrumental in developing rancidity in sweetened condensed milk. It has been further found that the milk products from certain individual cows, or cows under certain physiological conditions are more prone to develop a rancid flavor, than milk products from other cows or cows under other conditions.

[2] Hunziker, Results not published.

Relation of Polluted Water to Rancidity.—Polluted and filthy water is usually contaminated with fungi and bacteria belonging to the species enumerated above and which have been found to be able to produce rancidity. It is, therefore, not improbable, where such water is used in the factory in the washing of cans, conveyors, kettles, pipes, etc., in the condenser of the vacuum pan and in the cooling tanks, as is frequently the case, that the contamination of milk with it may result in the development of rancidity.

Relation of Climate to Rancidity.—It is frequently claimed that condensed whole milk shipped to the tropics turns rancid, owing to exposure of this milk, rich in fat to a warm climate. Advantage is sometimes taken of this argument, to justify violations of the law by skimming all, or a part of the milk before condensing. This matter has been thoroughly investigated. All experimental results show that sweetened condensed milk, made properly and in conformance with the law, and containing all the butter fat of the original whole milk, does not turn rancid at any temperature.

Putrid Sweetened Condensed Milk.

General Description.—Sweetened condensed milk is best when fresh. With age it gradually develops a stale flavor which frequently develops into a putrid odor and flavor.

Causes and Prevention.—The purer the fresh milk and the cane-sugar, and the more careful the processor, the longer will the condensed milk retain its pleasant flavor, provided that it is stored at a reasonably low temperature. Age, however, will cause the best sweetened condensed milk to become stale. The appearance of the stale flavor is usually hastened when heating the fresh milk with direct steam; also, where the fresh milk is not heated to a sufficiently high temperature (below 176 degrees F.) the condensed milk will break down rapidly with age, usually developing a putrid flavor and odor. This defect rarely appears where the fresh milk is heated to 180 degrees F. or above. This phenomenon is probably due to the presence in milk of active enzymes, such as galactase, gradually decomposing the proteids. The action of most of these enzymes is destroyed when the milk is heated to 176 degrees F. or above.

Metallic Sweetened Condensed Milk.

General Description.—Sweetened condensed milk frequently is pregnant with a very distinct metallic flavor suggesting copper.

Causes and Prevention.—This can usually be traced back to an unsanitary condition of the dome of the vacuum pan. The sugar and acid in the boiling milk in the pan tend to cause the formation of copper oxide and copper salts, on those sections of the interior surface of the pan which are not daily completely cleansed.

The dome of the pan is neglected in many condenseries from the standpoint of thorough cleaning. If it is permitted to go uncleansed for a considerable period of time, it becomes coated with copper salts and when the pan is again in operation, the boiling milk and its spray wash these metallic salts down incorporating them in the condensed milk.

That the copper in the dome is being acted on can be very readily determined by wiping the inside surface of the dome off with a wet sponge, then analyzing the expressed liquid that the sponge has absorbed. This liquid will be found to contain varying amounts of copper, according to the state of cleanness of the dome.

In order to avoid metallic flavor in sweetened condensed milk, the dome should be washed down daily with similar care as is given the cleansing of the jacket, body and coils, and each morning, before the milk is allowed to enter the pan, the entire pan, including dome and gooseneck, should be thoroughly rinsed down with plenty of clean water.

Brown Sweetened Condensed Milk

General Description.—Some of the sweetened condensed milk on the market has a brown color, suggesting chocolate pudding. In this condition it is usually rejected by the consumer.

Causes and Prevention.—All sweetened condensed milk not held at a low temperature grows darker in color with age. If manufactured properly and not exposed to unfavorable conditions, this brown color appears very gradually and not until the condensed milk is many months old. If exposed to high temperature in storage or transportation, when stowed against the boiler room in the hold of the steamer, or laying on the shelves of the warm grocery store or drug store, etc., it turns brown rapidly. Condensed milk in cold storage retains its natural color indefinitely. Where milk is recondensed (the condensed milk is redissolved either in water or in fresh milk and condensed a second time), the product is always darker in color. This brown color is due to the oxidizing action of heat on both, the lactose and the sucrose, a portion of the sugar caramelizing. Experience has shown that the sugar is more sensitive to the oxidizing action of the heat of recondensing, than when condensed the first time.

CHAPTER XXIV.

DEFECTIVE EVAPORATED MILK AND PLAIN CONDENSED BULK MILK

The following are the chief defects of unsweetened condensed milk: curdy, grainy, separated and churned, blown or fermented, brown, gritty, metallic.

Curdy, Plain Condensed Milk and Evaporated Milk

General Description.—Curdy, unsweetened condensed milk is a term used for milk in which a part of the casein is precipitated in the form of lumps of various sizes. The appearance of lumps of curd in this product is a defect that may render the goods unsalable.

Causes and Prevention.—Lumps are usually due to a poor quality of fresh milk, the use of excessive heat in the sterilizing process and too high a degree of concentration.

Lumps in Plain Condensed Bulk Milk.—Lumps are prone to appear in plain condensed bulk milk, as this class of goods is usually made from fresh milk that may be slightly sour, as is the case in creameries and in milk plants where the surplus and the returned milk is often manufactured into plain condensed bulk milk. This defect can be avoided by neutralizing the milk before heating, with an alkali (sodium bicarbonate or lime water), heating less intensely, by not carrying the condensing process quite so far. If the plain condensed bulk milk comes from the pan in lumpy condition, it can usually be reduced to a smooth body by passing it through an ice cream freezer at ordinary temperatures.

Lumps of Curd in Evaporated Milk.—The danger of lumpiness, or curdiness in evaporated milk is greatly augmented by the fact that, in addition to the causes named under plain condensed bulk milk, the sterilizing process must be dealt with. The high sterilizing temperature used, tends to precipitate the proteids of milk, and the temperature cannot be reduced below certain limits without impairing the keeping quality of the product. Most of the evaporated milk, after sterilization, is subjected to the shaking process in which the coagulum in the cans is reduced to a homogeneous creamy fluid, provided that the curd is not too hard. A curd will form in the sterilizer in the majority of cases. If it is soft enough, so that it can be completely broken up, no harm is done. If it is so firm that mechanical shaking fails to cause it to disappear, then the evaporated milk will reach the market in lumpy condition and is difficult to sell.

Effect of Quality of Fresh Milk.—The quality of fresh milk is all important in preventing lumpy evaporated milk. The milk must come from healthy cows in good, normal physical condition. It must not contain colostrum milk nor be stripper milk and it must receive the best of care on the farm and reach the factory perfectly sweet. Milk that is not of high quality in every respect should not be received at the factory.[1]

Effect of Concentration.—The more concentrated the evaporated milk, the greater the danger of lumpiness. All the conditions causing lumpiness are intensified by the degree of concentration. The manufacturer must, therefore, study the behavior of his product at different degrees of concentration, and then decide how much evaporation it will stand without developing subsequently a permanent curd in the sterilizer.[1]

Effect of Sterilization.—The coagulum is formed in the sterilizer. The higher the temperature, other conditions being the same, the firmer the curd. The lowest temperature that will efficiently sterilize the evaporated milk should, therefore, be used. Since the sterilizing temperature to be maintained cannot be modified below certain limits, it is necessary, when the milk is very sensitive to the heat, to lower the degree of concentration. In some factories fractional sterilization is resorted to with

[1] For detailed discussion of relation of quality of fresh milk to curdiness of evaporated milk see Chapter VIII on "Manufacture of Evaporated Milk," "Quality of Fresh Milk," p. 104.

batches of milk that are suspicious. By so doing, lower temperatures can be used effectively, but this process calls for much more labor, increases the cost of manufacture and decreases the capacity of the factory.

Effect of Fractional Curdling.—Experience has shown that, if the proteids in evaporated milk are partly precipitated by heat before the milk reaches the sterilizer, the curd, or lumps formed in the sterilizer are less firm and can be shaken out more readily. It is, therefore, advisable to heat the milk in the forewarmers to as near the boiling point as possible and to hold it at that temperature for at least five minutes before it is drawn into the pan. The superheating of the evaporated milk before it leaves the pan is an additional safeguard against the formation of excessive curd in the sterilizer.

Effect of Homogenizing Evaporated Milk.—Excessive pressure in the homogenizer tends to so change the physical properties of the casein as to render it more sensitive to the sterilizing process. Evaporated milk, homogenized under excessive pressure almost invariably forms a firm, unshakable curd in the sterilizer. The homogenizing pressure should be kept down to one thousand to fifteen hundred pounds.[2]

Acid Flux in the Cans Causes Lumps.—Similar as in the case of the sweetened condensed milk, the presence of acid flux in the cans of evaporated milk causes lumpiness. The acid that reaches the interior of the cans causes the milk coming in contact with the seams to curdle. Only acid-free flux should be used in the manufacture and sealing of the cans.

Grainy Evaporated Milk

General Description.—This term is sometimes applied to lumpy milk, in which case it means the same. By grainy milk, however, is generally understood milk which contains a sediment of a white granular appearance, which is insoluble.

Causes and Prevention.—This granular sediment is largely found in the hermetically sealed cans after the sterilizing process. It is due to excessively high sterilizing temperatures or too long

[1] For detailed discussion of relation of concentration to curdiness of evaporated milk see Chapter VIII on "Striking."
[2] For detailed discussion of the effect of homogenizing on curdiness see Chapter IX on "Homogenizing" and Chapter XXIV on "Separated and Churned Evaporated Milk."

exposure of the milk to the process. It consists largely of the mineral matter of milk, rendered insoluble and precipitated by heat. The use of lower sterilizing temperatures or the shortening of the period of sterilization will help to avoid this defect.

Evaporated milk in the condensation of which the "Continuous Concentrator" was used, has a tendency to show slight grainy condition, though this is barely perceptible.

Separated and Churned Evaporated Milk

General Description.—This is a very common defect. A portion of the butter fat of the contents of the hermetically sealed cans, has separated and appears in the form of lumps of cream or of churned butter, on top of the evaporated milk. While this separated evaporated milk is normal in quality and wholesomeness, its appearance condemns it.

Causes and Prevention.—As explained in Chapter IX on "Homogenizing," p. 110, the fundamental cause of separated and churned evaporated milk lies in the difference of the specific gravity between the butter fat and the rest of the milk constituents. The fat globules, being lighter than the serum, tend to rise to the surface, forming a layer of thick cream. When this separated evaporated milk is subjected to agitation, as is the case in transportation, this cream churns into lumps of butter. This tendency of the fat to separate in storage and churn in transportation, increases with the increase of the size of the fat globules, because the larger the globules, the larger is their cubic content in proportion to their surface. This fact is based on the well known physical law, that the surfaces of two spheres are to each other as the squares of their diameters, and the cubic contents of two spheres are to each other as the cubes of their diameters. The cubic contents determine the gravity force, or buoyancy, while the surfaces control the resistance force. Therefore, the larger the fat globules the greater is their buoyancy and the weaker is the relative resistance which they must overcome in their upward passage.

Effect of Locality and Season.—Since the predominating size of fat globules in milk, varies with breed and period of lactation of the cows, the ease with which evaporated milk separates and the difficulty of overcoming this defect, differ greatly with locality and season of year. The fat globules in milk from the Channel Island breeds, average two to three times as large as those in milk from the Holsteins and Ayrshires. Therefore, factories located in Holstein and Ayrshire territories are not troubled nearly as much with fat separation in evaporated milk, as factories in localities where Jerseys and Guernseys predominate.

Again, the fat globules are largest at the beginning of the period of lactation and decrease in size as the period of lactation advances.

Relation of Breed and Period of Lactation to Size of Fat Globules[1]

Months of period of lactation	Breeds of dairy cows					
	Jersey 25 cows	Guernsey 20 cows	Holstein 9 cows	Ayrshire 33 cows	Holderness 20 cows	Devon 16 cows
1st month	1104	928		687		546
2nd "	1098	1063	640	580	661	585
3rd "	1228	954	576	624	607	450
4th "	1097	659	256	426	501	547
5th "	1149	839	396	384	397	319
6th "	846	737	595	399	324	355
7th "	1017	584	340	322	329	270
8th "	733	568	310	298	379	200
9th "	715	408	384	241	325	250
10th "	571	426	284	248	336	228
Average for year	955.8	716.6	420.1	420.9	427.6	375

In order to equalize the output of evaporated milk throughout the year, condensing concerns make every effort to induce their patrons to time the breeding of their cows in such a way that the fresh cows are distributed throughout the year. The result of this practice is, that the milk supply of these factories represents at all times a mixture of milk from cows at all stages of their period of lactation. This naturally equalizes the behavior of the finished product as far as separation of the fat is concerned, facilitating the control of this separation. On the other hand, in localities of factories, newly established, summer milk is largely produced and the majority of cows freshen in the spring. This causes a marked increase of the size of the average fat globules in early summer, rendering the manufacture of evaporated milk, that does not separate its fat, more difficult.

[1] Hunziker, Mills and Spitzer, "Moisture Control of Butter." Indiana Agricultural Experiment Station, Bulletin No. 159, 1912, pp. 330-334.

Effect of Degree of Concentration.—Other conditions being the same, the more concentrated the product the less the danger of fat separation in the finished product. The reason for this lies in the fact that with the concentration the viscosity and the resistance force of the evaporated milk increase, hindering the fat globules in their upward passage. This is partly offset by the increase in the specific gravity of the product, but the increase of the resistance force exerts a stronger influence against separation of the fat, than the increase of the gravity force exerts in favor of fat separation.

However, as the concentration increases, the evaporated milk becomes more sensitive to the sterilizing process and beyond certain limits it would be necessary to reduce the temperature or the length of exposure to heat, or both, in order to prevent the more highly concentrated milk from becoming permanently curdy. If, in order to increase the viscosity, the degree of concentration is carried so far that the sterilizing process has to be shortened, nothing is gained but much may be lost. It is obvious, therefore, that the degree of concentration does not furnish a practical basis for controlling fat separation.

Effect of the Sterilizing Process.—Prolonged exposure of the evaporated milk to the sterilizing heat tends to so change the physical properties of the albuminoids, as to render the product more viscous. Within the limits of the necessary sterilizing heat, long exposure to moderate heat is more effective in this respect than short exposure to a high degree of heat. Since the greater viscosity tends to keep the fat globules from rising, the use of a prolonged sterilizing process, in which the heat is applied slowly, is more effective in preventing fat separation in the evaporated milk than a rapid, short process, in which the temperature used is very high.

It should be understood from the discussion in previous chapters that, in regulating the process of sterilization, the processor should be governed by the condition and behavior of the milk and that on the one hand the degree and duration of heat should always be sufficient to insure absolute sterility of the product, while on the other he must guard against the formation of an unshakable curd.[1]

[1] For detailed discussion see Chapter XI on "Sterilizing," page 120.

Effect of Superheating.—The superheating of the milk before sterilization and the stopping of the reel of the sterilizer as explained under "Sterilization," page 120, also tend to so increase the viscosity of the evaporated milk as to minimize its tendency to separate its fat. But here again good judgment is required, otherwise there is danger of spontaneous thickening of the product after manufacture.

Turning the Cans in Storage.—Many manufacturers, in an effort to avoid fat separation, have adopted the practice of turning their goods in storage at regular intervals. This operation naturally interferes with and retards the rising of the fat to the surface, as long as the goods remain in the factory. After they leave the factory this control must of necessity cease and if the evaporated milk, owing to the process of manufacture and the condition of the product, is destined to separate its fat, the turning of the cases, while at the factory, cannot permanently prevent separation. Where the goods are consumed immediately after they leave the factory, this practice may serve the purpose; but, since the large bulk of evaporated milk manufactured, is exposed to prolonged storage, its advantage is very limited.

Effect of Homogenizing.—Under average conditions careful attention to the precautions above discussed will greatly minimize and often prevent fat separation. At best, however, much of the evaporated milk on the market shows signs of separation after sixty to ninety days and some of it even after two weeks, for the fundamental cause of separation, the difference in gravity between the fat globules and the rest of the milk constituents, is still present; then again, under less favorable conditions, even the above precautions may not prove adequate to keep the fat from separating.

The introduction of any agent or process, therefore, capable of permanently removing this fundamental cause, must prove a lasting benefit to the manufacturer of evaporated milk. This agent has been found in the homogenizer. The homogenizer makes it possible to divide the fat globules so finely, that their buoyancy or gravity force is not great enough to overcome the resistance of the surrounding liquid. They are unable to rise to the surface, but remain in homogeneous emulsion.

It is quite probable that aside from the reduction of the size of the fat globules, the efficiency of the homogenizer to prevent fat separation is due also to the physical change of the casein as the result of homogenization. The casein becomes more viscous.

The chief objection to the use of the homogenizer is its effect on the casein of the milk, when subjected to excessive pressure. Beyond certain limits of pressure homogenization so affects the casein, that the latter is more prone to curdle in the sterilizer. However, experience has amply shown that the maximum pressure required to prevent fat separation in the finished product, is not great enough to seriously affect the behavior of the casein during sterilization. Hence, the proper regulation of the pressure and the intelligent use of the homogenizer, furnish a satisfactory and reliable means to prevent fat separation. Under average conditions, the use of sufficient pressure to reduce the fat globules to one-third of their original size, practically destroys the power of the fat globules to rise to the surface. A pressure of approximately one thousand pounds per square inch, makes possible this reduction of the size of the fat globules.[1]

Fermented Evaporated Milk.

General Description.—Fermented evaporated milk is evaporated milk, which after sterilization, has undergone fermentation. The type of fermentations found in this product varies with locality, season of year and factory conditions. The contents of the cans may have soured with curd formation, or a curd may have formed without acid development, or the fermentation may be gaseous, in which case the cans bulge, and these gaseous fermentations may be accompanied by acid formation or by putrefactive products. In all cases of fermented milk the product is entirely worthless. These defects are usually, though not always, detected during the period of incubation.

Fermented evaporated milk is the result, either of incomplete sterilization, or of leaky cans. The causes of fermented evaporated milk differ with the specific type of fermentations produced; they will be discussed separately and as relating to the respective types of fermentations.

Acid Fermentation, Sour, Curdled, Evaporated Milk

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[1] For details on the use of homogenizer see Chapter IX on "Homogenizing," page 105.

General Description.—Upon opening the cans the contents are found to be sour and curdy.

Causes and Prevention.—This condition is the result of the presence of acid producing species of micro-organisms, usually of the lactic acid type, which sour the milk, and the acid produced curdles the casein. Since the majority of the lactic acid bacteria are not resistant to heat and are destroyed at relatively low heat, this defect is not usually caused by incomplete sterilization. The temperature of sterilization, though it might be insufficient to kill spore forms, is high enough to make it impossible for lactic acid bacteria to pass the process alive.

The only way in which this defect can occur is through subsequent contamination of the contents of the cans with these germs, and the only possible channel, through which this subsequent contamination may occur, is leaky cans, or leaky seals. A careful examination of the cans of sour, curdled evaporated milk usually shows faulty cans or faulty seals.

Bitter Curd

General Description.—When the cans are opened the contents present a solid coagulum, generally noticeably white in color and very bitter to the taste, similar to the bitterness of dandelions. There is a separation of practically clear whey, the curd does not break down readily upon shaking and the acid reaction of the mixture of curd and whey is about .35 to .40 per cent., which is normal for evaporated milk.

Causes and Prevention.—Microscopic examinations under high magnification of cultures in sterile milk show the presence of very small bacilli. The milk forms a firm coagulum in five to seven days and when over one week old the curd has the same strong, bitter taste as that in the cans. The bitterness increases with age. These bacilli grow best at 90 degrees F. They are facultative anaerobes, developing both, in aerobic and anaerobic media, but prefer anaerobic conditions.

In the cases under observation no spores were detected and exposure for fifteen minutes to 212 degrees F. destroyed these germs. The above findings do not exclude the possibility of spore formation under conditions very unfavorable to growth and life.

The presence of this species of bitter curd organisms suggests incomplete sterilization of the evaporated milk. The striking whiteness of the curd in all cases that have come to the writer's attention, is further proof of the correctness of this deduction. It indicates that these cans received relatively little heat in the sterilizer, otherwise the curd would have a darker color. This defect usually does not show up in all the cans of one and the same batch, but only in a limited portion of each batch. This fact suggests that the distribution of heat in the sterilizer is not uniform, some cans getting less heat than others.

This defect occurs generally in summer, a fact which may be due to one or both of the following conditions:

While it is well known that there is a variety of species of bacteria, yeast and torula that are capable of producing a bitter curd, either direct, or through the secretion of casein-curdling enzymes, and while these different species of micro-organisms come from a variety of sources, the most common sources are, the soil, pasture, water and the udder itself. It is a noteworthy fact that this defect is most commonly found in milk and milk products when the cows are on pasture. It is, therefore, probable that, in most cases, this troublesome germ is carried into the milk on the farm.

Again, in summer, at a time when this defect generally occurs, the effect on the cows of the summer heat and flies, and the tendency toward high acid in milk, render the milk most sensitive to the sterilizing heat. The operator finds it difficult to avoid the formation of a disastrous curd in the sterilizer. In order to guard against this trouble he is tempted to either lower the temperature, or shorten the duration of the sterilizing process. This tends towards incomplete sterilization. A very frequent result of this incomplete sterilization in the early summer months, is the formation of a bitter curd. When the processor returns to the proper sterilizing process, the occurrence of bitter curd in the cans disappears and the product is normal.

A further safeguard against the recurrence of this trouble lies in providing for uniform distribution of heat in the sterilizer. If the cans have to be stacked in deep tiers, which is undesirable and should be avoided, slats should be placed over the top of every second row of cans. This will make possible the free access of steam to at least one end of each can. If the circulation of steam in the sterilizer is poor, the uniform distribution of heat can be facilitated by filling the sterilizer about one-third full of water so that, with every revolution of the framework, the cans have to pass through this water once. The water reaches every nook in the interior of the sterilizer, distributing the heat much more uniformly than the steam. If these precautions fail to remedy the trouble, then the entire process is inadequate and either more heat, or longer exposure to the same heat is necessary.

It is obviously imperative that the fresh milk, as it arrives at the factory, be subjected to the most rigid inspection on the platform, in order to guard against the processing of unduly contaminated milk.

Blown Evaporated Milk (Gaseous Fermentation)

General Description.—The ends of the cans bulge out very noticeably, frequently so much so that the seams of the cans burst open. This is due to gaseous fermentation causing high pressure in the cans. The pressure is often so great that upon opening the cans, most of the contents are blown out with tremendous force. In some cases of blown evaporated milk, the contents have an acid odor, pleasant and aromatic. In most instances, however, they give off very foul odors and suggesting hydrogen sulfide, not unlike aggravated cases of Limburger cheese. These odors are exceedingly penetrating and difficult to remove from anything they come in contact with.

Causes and Prevention.—The bacteria causing gaseous fermentations in evaporated milk usually belong to the anaerobic group of butyric acid species and in most cases, though not always, the putrefactive types prevail, such as Bacillus putrificus, Plectridium novum and Plectridium foetidum, especially the latter, because of its extraordinary power of resistance to heat. Plectridium foetidum is an obligatory anaerobe and it absolutely refuses to grow under aerobic conditions. It is an actively motile, medium-sized organism with flagella and spores. At one end it has an Indian club-like enlargement, in which appears the spore. The bacillus resembles a kettle-drum stick similar to B. tetani. Under strictly anaerobic conditions, and incubated at 90 degrees F., it ferments milk in four days. The milk first curdles, then gradually the curd dissolves (digests) completely, leaving a clear yellow liquid, similar in appearance to butter oil. The fermentation is accompanied by the evolution of a penetrating foul odor. This organism survives exposure for 15 minutes to 245 degrees F. Its thermal death point lies between 245 and 250 degrees F.

Plectridium foetidum, as well as most of the other species of anaerobic, spore—bearing butyric acid bacilli and bacteria, is present abundantly in cultivated soil, in field crops and even on the kernels of the grain. Since this type of evaporated milk defect is characteristic, especially, of the product manufactured during the late summer and early fall months, it is very probable that the dust incident to the harvesting of the field crops, furnishes the chief source of contamination of the milk.

Fig. 56. The result of gaseous fermentation

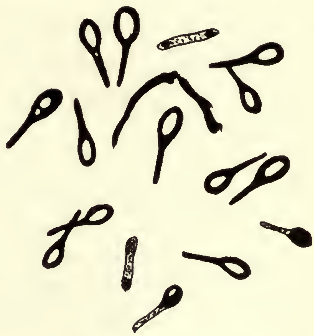

Fig. 57. Plectridium foetidum, a highly resistant species of anaerobic microorganisms, causing "swell heads" of evaporated milk

In order to avoid the occurrence of blown, fermented, evaporated milk, therefore, it is necessary to employ the highest sterilizing temperatures, or the longest exposure to the sterilizing heat, or both, consistent with freedom of the milk from curdiness. Experience has shown that the use of the ranges of temperature and time of exposure, given under Chapter XI on "Sterilizing," guard effectively against this defect.

Blown Evaporated Milk Due to Freezing.—If the evaporated milk is exposed to storage temperatures below the freezing point of water, the contents of the cans will freeze. While freezing, the contents expand sufficiently to cause the ends of the cans to bulge. When the cans are subsequently transferred to warmer temperatures, so that their contents melt again, the milk contracts and the cans resume their normal shape.

While the wholesomeness and flavor of the product are not affected by the freezing process, the remelted evaporated milk is usually less smooth and often slightly grainy. This is due to the fact that, during the process of freezing, there is a partial separation of the watery portion from the caseous material. The casein contracts and the watery portion freezes. When melted, the emulsion is less complete than it was before freezing. The casein remains in its contracted form and robs the product of its original smoothness.

Blown Evaporated Milk Due to Chemical Action.—While properly processed evaporated milk is perfectly sterile, and from the biological point of view, keeps indefinitely, the cans of very old evaporated milk may bulge, as the result of the action of the acid in the milk on the container. Evaporated milk contains from .35 to .50 per cent. acid (calculated as lactic acid). When the tin cans are filled with the evaporated milk, the tinplate is bright and untarnished, both, inside and out. After the sterilizing process, the inside surface of the cans is dark and dull. This is caused by the combined action of acid and heat, which seems to weaken the tinplate. This phenomenon is further illustrated by the fact that where creameries pasteurize their skimmilk and return it to the patrons in the milk cans hot, the milk cans are short-lived; they soon corrode and begin to leak.

The acid in the evaporated milk continues to act on the tinplate of the can after manufacture and in the case of very old evaporated milk, the acid may decompose a considerable part of the iron. This action is accompanied by the evolution of hydrogen gas, which causes the cans to bulge. This action is hastened by continued exposure of the goods to high temperatures (summer heat). This fact was experimentally demonstrated,[1] also, by scratching the bottom of tin cans on the inside with a file, then filling the cans with a .4 per cent, solution of lactic acid and acetic acid, respectively. After sealing, the cans were sterilized in the autoclave, so as to avoid any possibility of bacterial action. After cooling, these sterilized cans were incubated for some time at 90 degrees F. The cans containing the dilute acid began to

[1] Hunziker and Wright, Indiana Agricultural Experiment Station. Results not published.

swell, while the check cans, containing distilled water only, remained normal.

Brown Evaporated Milk

General Description.—It is the aim of the processor to so govern the sterilizing process as to give the evaporated milk a rich, yellow, creamy color. Frequently, this color limit is overstepped to the extent of imparting to the evaporated milk a brown color, suggesting coffee with milk in it. In this condition evaporated milk fails to appeal to the consumer.

Causes and Prevention.—The dark color in evaporated milk is due to the oxidizing action of excessive heat on the milk sugar, causing the milk sugar to caramelize. This can be avoided by reducing the sterilizing temperature, or shortening the sterilizing process, or both. The storing of evaporated milk at high temperatures (summer heat) also tends to deepen its color with age.

Gritty Plain Condensed Bulk Milk

General Description.—Grittiness in the unsweetened goods appears usually only in the plain condensed bulk milk. It is a defect which renders the product undesirable for ice cream making.

Causes and Prevention.—The chief cause of this defect is too great concentration. Plain condensed bulk milk which is not condensed over 3.5 parts of fresh milk to 1 part of condensed milk does not become gritty. When the concentration exceeds 4:1, the milk sugar begins to crystallize out, making the product gritty. Milk sugar requires about six times its weight of water for complete solution in cold water. When condensed at the ratio of 4:1 or over, the plain condensed bulk milk contains considerably less than five parts, by weight, of water to one part of milk sugar. This high concentration, together with the practice of storing this product at refrigerating temperatures in order to preserve it, is responsible for the grittiness. This trouble can, therefore, easily be prevented by not condensing to quite as high a degree of concentration.

Metallic Evaporated Milk and Plain Condensed Bulk Milk.

General Description.—Both evaporated and plain condensed bulk milk may show a metallic and puckery flavor, though this defect is rather rare.

Causes and Prevention.—The metallic flavor may be due to the same cause as metallic sweetened condensed milk, i. e. an unsanitary condition of the vacuum pan, in which case its recurrence can be readily avoided by thoroughly cleaning all parts of the pan including the dome and the goose neck, and rinsing down the whole pan thoroughly with clean water each morning before operations begin.

Unsweetened condensed milk made by the use of the "Continuous Concentrator" may have a metallic flavor when the scrapers in this machine are improperly adjusted, causing them to cut into the copper walls and thereby incorporating metallic copper in the product. This source of metallic flavor can be removed by proper adjustment of the revolving spider and its essential parts.

Evaporated milk may also show a metallic flavor as the result of chemical action of the acid in the milk on the can. This occurs usually only upon prolonged storage. Very old evaporated milk is very prone to have a metallic flavor from this source. It is obvious that this can best be avoided by endeavoring to move the goods sufficiently rapidly to limit the age of the milk to a reasonable period of time.

Cans, in the manufacture and sealing of which an acid flux is used, are prone to give the contents a puckery, metallic flavor, due to the zinc chloride and hydrochloric acid present. This can be avoided by using cans only in the manufacture of which a non-acid flux, such as gasoline-resin flux, is used, and by using a non-acid flux for sealing the filled cans.

CHAPTER XXV.

ADULTERATIONS OF CONDENSED MILK

It is the sense of the Federal Pure Food Act that the addition to condensed milk of any substance except sucrose, and the abstraction of any substance from milk except water, is an adulteration.

Skimming.— Condensed milk made from partly or wholly skimmed milk must be labeled and sold as condensed skimmed milk in order to comply with the Pure Food regulations. However, it is possible for condenseries receiving fresh milk, rich in butter fat, to skim a part of that milk and have their product still conform with the food standards.

Skimmed sweetened condensed milk can readily be detected by its whitish color, while condensed whole milk has normally a rich yellow color. When diluted, to the consistency of ordinary milk, skimmed condensed milk, both the sweetened and the unsweetened, foams very profusely when shaken, while diluted condensed whole milk behaves similar to ordinary whole milk.[1]

Addition of Artificial Fats.—In order to lower the cost of manufacture, attempts have occasionally been made to skim the fresh milk and substitute the abstracted fat by artificial fats of animal or vegetable origin.

Recent improvements in the method of manufacture have made it possible to manufacture evaporated milk, made from skim milk to which foreign fats, especially vegetable oils, such as cocoanut oil, have been added. This milk has every appearance of, and will commercially keep as well as genuine evaporated milk. A representative of this imitation evaporated milk is the "Hebe" product. This product consists of skim milk to which have been added vegetable fats to replace the butter fat. The mixture is homogenized in order to form a complete emulsion, then it is evaporated, filled in cans and sterilized in a similar manner as the genuine evaporated milk.

The Federal law requires that the composition and ingredients of these imitation products appear plainly on the label of the package.

It should be clearly understood by the manufacturer, the dealer and the consumer that this imitation milk is inferior to the genuine evaporated milk, in the fact that it lacks the important growth-promoting and curative properties which are inherent in whole milk. If sold on its own merits, and in accordance with the Federal law, there can be no logical objection to the imitation product, but if offered to the consumer as the genuine article the manufacture and sale of imitation evaporated milk is a heinous crime against humanity.

Experiments conducted at Ohio State University, by Mr. J. L. Hutchison, instructor in the Department of Agricultural

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[1] For chemical tests of butter fat in condensed milk, see Chapters XXXI and XXXII.

Chemistry under the direction of Professor O. Erf, Chief of Department of Dairy Husbandry and Dr. J. F. Lipman, Professor of Agricultural Chemistry, demonstrated that "Hebe" milk, when fed to young white rats, resulted in malnutrition accompanied by stunted growth, sore eyes and death of some of the experimental rats, in a similar manner as did other rations in which the fat-soluble vitamines were lacking.

Mothers who buy evaporated milk for feeding infants and children should be cautioned to observe carefully whether or not they receive the genuine article. Imitation evaporated milk is not a baby food. Babies and growing children need butterfat for their best development. If canned milk is used for infant feeding, it should be made from whole milk only. (See also pp. 176 to 178).

Addition of Commercial Glucose.— Commercial glucose belongs to a group of starch products in which dextrose is the leading constituent. It is manufactured by the action of dilute acids in starch and starchy matter, or occasionally woody fibre. In this country it is almost wholly made from maize starch.

Starch glucose occurs in commerce in several forms, varying from the condition of pure anhydrous dextrose, through inferior kinds of solid sugar, to the condition of a thick syrupy liquid, colorless and transparent, resembling molasses in consistency and glycerine in appearance; it contains a large proportion of dextrin. In connection with the manufacture of condensed milk the term "glucose" refers to this thick, syrupy liquid. It is added to the condensed milk with a view of substituting a portion of the sucrose and thus reducing the cost of manufacture. It has also been suggested that the presence of commercial glucose in condensed milk prevents the precipitation of sugar crystals. Experiments have shown, however, that condensed milk containing varying amounts of glucose, will become sandy just as readily as normal condensed milk.

That glucose cannot be used as a substitute for sucrose, is obvious from the fact that its presence defeats the very object for which sucrose is added. Instead of serving as a preservative, as is the case with the best refined, granulated cane sugar, glucose acts as a most effective fermentative. It has been explained that the presence in sucrose of traces of invert sugar, or levulose and glucose, causes condensed milk to ferment. Glucose belongs to the monosaccharides. Its chemical formula, like that of levulose, is $C_6H_{12}O_6$, it oxidizes readily and under the influence of yeast and other micro-organisms it ferments, yielding mainly alcohol and carbon dioxide. Its presence in condensed milk, therefore, is prone to start fermentation, and the manufacturer who uses it with a view of lessening the cost of manufacture of condensed milk is, indeed, practicing poor economy. There is no adulteration of sweetened condensed milk that will produce such inevitable disaster as the addition to it of glucose. Aside from this fact, the law prohibits the addition of anything except sucrose.

Addition of Bi-Carbonate of Soda, Ammonium Hydroxide, Lime Oxide and Lime Hydrate and Other Alkali.—These alkalies and alkaline earths are frequently added to a poor quality of fresh milk, for the purpose of neutralizing the excess of acid and preventing the milk from curdling when exposed to heat. If used in reasonable quantities, they interfere in no way with the quality and healthfulness of the product, and may in exceptional cases prevent great loss. If used in excess, the milk will foam very badly in the vacuum pan, which renders the process of condensing a difficult one and the finished product has a bitter flavor. Under ordinary conditions, their use is entirely unnecessary and simply means additional labor and expense. The above agents and also viscogen, are sometimes used with the view of thickening the product and increasing the output. Experimental results,[1] however, showed that these agents cannot be used in large enough quantities to produce the above results without materially lowering the quality of the product.

Addition of Cream of Tartar.— Cream of tartar is used extensively in the manufacture of candies and caramels. Its purpose is to make the sugar in these products precipitate in the form of very fine and soft crystals. Condenseries, which have been continually troubled with sugar crystallization and sugar sediment, have tried to overcome this defect by adding cream of tartar to the sweetened milk in the vacuum pan. Cream of tartar is an acid salt (acid potassium tartrate, $KH.C_4H_4O_6$), and it is this acid which in the manufacture of candy causes the fine and soft grain of the sugar. It is obvious that if enough cream of tartar were added to condensed milk to produce the desired effect on the sugar,

[1] Hunziker. Experiments not published.

the acid present would curdle the milk. Its use is of no value to the manufacturer of condensed milk.

Addition of Starch.— The pasty and thick consistency of sweetened condensed milk frequently suggests to the public that it contains starch. This is erroneous, for it is doubtful if condensed milk is ever adulterated with starch. There would be nothing gained by so doing, and the presence of starch in condensed milk could be readily detected with iodine. Iodine gives the starch cells a deep blue color.

PART VI.

MANUFACTURE OF MILK POWDER

Chapter XXVI.

DEFINITION

Milk powder, dry milk, pulverized milk, dehydrated milk, desiccated milk, is made from cow's whole milk, or partly or wholly skimmed milk, to which sugar, or alkalies, or both may, or may not have been added, and which has been evaporated to dryness, either under atmospheric pressure, or in vacuo.

KINDS

The milk powders on the market vary chiefly in their solubility and fat content. The bulk of the milk powders is produced from wholly or partly skimmed milk. Most of the milk powders of the early days of this industry contained added cane sugar and alkalies. The purpose of the addition of alkalies was to lend greater solubility to the proteids.

The process of manufacture, however, has been improved to the extent to where the solubility of the proteids can now be preserved without the admixture of alkalies. Most of the milk powders put on the market in this country are free from admixture of any substances foreign to normal milk.

HISTORY AND DEVELOPMENT OF INDUSTRY

The origin and history of the milk powder industry are very closely related and intimately connected with that of the condensed milk industry. The fundamental purpose of the two products is one and the same, i. e., to preserve milk as nearly as possible in its natural condition, and to reduce its bulk to the minimum, so as to make possible its economical transportation to all parts of the world.

The difference between milk powder and condensed milk is mainly one of degree of concentration. It is not surprising, therefore, that the inventions of processes of manufacture of the two products date back to about the same period, the middle of last century, and in most cases the inventors of the one product had also in mind and gave due consideration to the possibilities of the other.

The first commercially usable process was invented by Grimwade who secured the English patent in 1855. His process consisted briefly of first adding carbonate of soda or potash to the fresh milk, then evaporating in open jacketed pans and with constant agitation, until a dough-like substance was obtained; then adding cane sugar; the mixture was then pressed between rollers into ribbons, further dried and then pulverized. The alkali, in the form of carbonate of soda or potash, was added in order to render the casein more soluble, and the purpose of the admixture of the sugar was to produce granulation of the dough toward the end of the process. The evaporation in open pans was later superseded by the use of the vacuum pan. The Grimwade process of manufacturing milk powder was in practice for some years.

The introduction and rapid development of the condensed milk industry and the difficulty of the economic manufacture of a marketable milk powder of good keeping quality, had a retarding effect on the development of the milk powder industry. While occasional new processes were invented and new patents granted, the commercial development of the industry dates back only to the closing years of the nineteenth century. Within the last decade the industry in this country and in Europe has been growing rapidly. Today there are in operation in the United States numerous milk powder factories.

The bulk of the milk powder manufactured now is made from skimmed milk. The manufacture of whole milk powder is as yet very limited and is confined to the filling of specific orders for the same, because of its low keeping quality. The fact that whole milk powder becomes rancid under similar conditions, as is the case with butter, and that it must be refrigerated in order to keep, is overshadowing the many and distinct advantages of this concentrated product. Until this obstacle is removed and the manufacturer is able to put on the market a whole milk powder that has the desired keeping properties, the development of this industry cannot reach the proportions justifiable by the great usefulness of this valuable product and comparable with the manufacture of other forms of preserved milk and dairy products.

QUALITY OF FRESH MILK

What has been stated concerning the necessity of a high quality of fresh milk in the successful manufacture of condensed milk, is equally true in the manufacture of milk powder. The fresh milk must be normal in its properties. It must be produced under strictly sanitary conditions and receive the proper care on the farm. It is especially essential that it arrive at the factory perfectly sweet, since acidity tends to lower the solubility of the finished product.

DESCRIPTION OF THE PRINCIPAL PROCESSES OF MANUFACTURE

Numerous processes for the manufacture of milk powder have been invented and patented in this country and in Europe. Many of these processes differ but slightly from one another. For convenience's sake these processes are herein classified in accordance with the fundamental principles of evaporation involved:

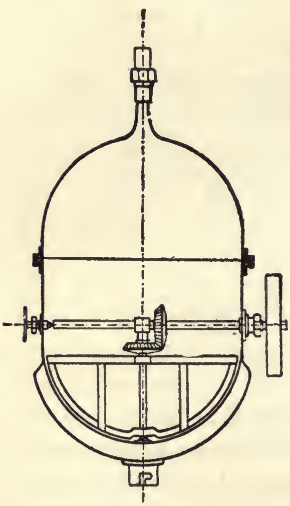

Fig. 58. The Wimmer milk powder machine

1. **The Wimmer Process.**— The milk is boiled in a vacuum pan similar to that used in the manufacture of condensed milk. The vacuum pan has a deep steam jacket for heating, but in the place of the usual coils, the pan is equipped with a mechanical stirrer. The milk is condensed at a relatively low temperature and the stirrer revolves until the water content of the milk is reduced to about 30 per cent and the milk has become porous and crumbly, though it still forms a compact mass. The drying is then completed in the open air and without additional heating. The product is then ground to a powder. This is the process invented by Ole Bull Wimmer of Copenhagen, Denmark.

2. **The Just-Hatmaker Process.**—The milk sprays in a thin film over two steam heated cylinders or drums, about sixty inches long and twenty-four inches in diameter. The cylinders are about

one-eighth of one inch apart and revolve in opposite directions. The milk reaches the drums from a supply tank located in the center above the drums. In order to insure a continuous and uniform supply of milk, a constant level of about four inches of milk is maintained in the supply tank. This process was invented by J. R. Hatmaker of London, and was patented in 1902. Its objectionable feature lies in the fact that the excessive heat at which the milk is evaporated impairs the solubility of the product. The cylinders are charged with two to three atmospheres of steam pressure, causing

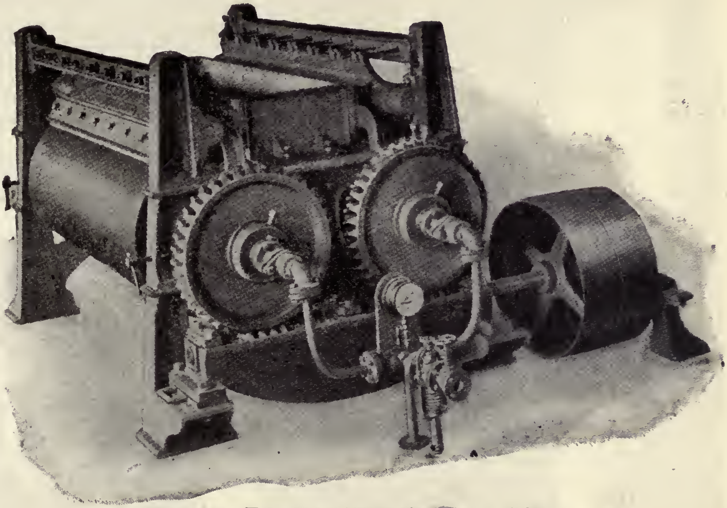

Fig. 59. The Just-Hatmaker milk drier

the heating surface to have a temperature of about 250 to 280 degrees F.

The Ekenberg Process.—This process was invented by Martin Ekenberg, of Stockholm, Sweden, in the year 1899, and is covered by a number of United States patents, one of the earlier of which is patent No. 764995, issued in 1904.

The Ekenberg Exsiccator, or milk drier, consists of a revolving, steam heated nickel drum, inclosed in a vacuum chamber. The ends of the drum form bell-shaped bowls, dished outward. The drum is equipped with knives or scrapers, which remove the film of dried milk that gathers on the drum. Attached to the vacuum chamber there is a smaller chamber which serves to receive the dried milk as it is scraped from the drum. This is separated from the large vacuum chamber by a series of air locks, so that the material may be removed without breaking the vacuum in the large chamber.

The milk, as it enters the vacuum chamber, is sprayed into the concave ends of the drum. In this manner it is fore-condensed. It is then withdrawn from the vacuum chamber by a pump, and

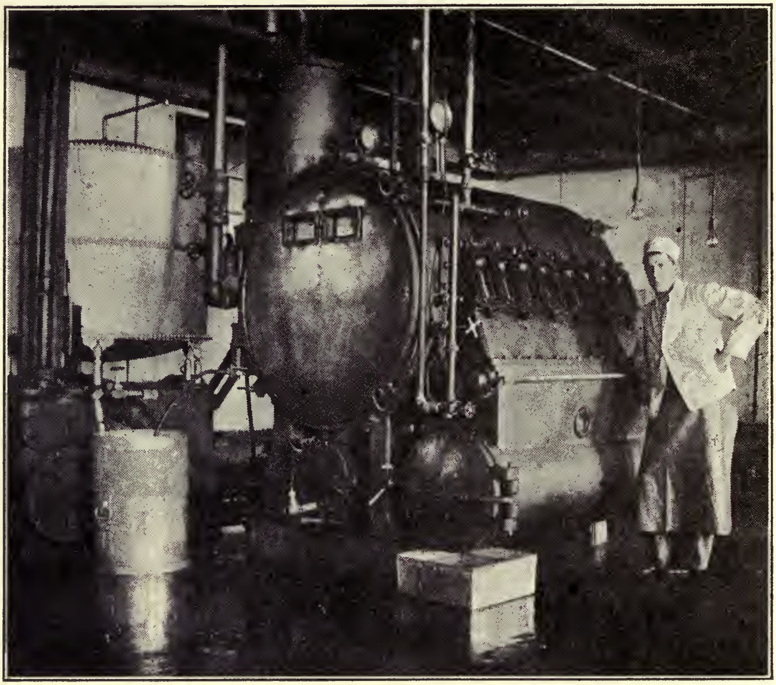

Fig. 60. The Ekenberg milk drier

returned again, this time being sprayed upon the periphery of the drum. The milk remains on the drum only long enough for it to make three-quarters of a revolution.

After the dried milk is removed from the exsiccator, it is placed in a special drying chamber at a temperature of 90 degrees F. where it remains long enough for the milk sugar to crystallize. This is usually accomplished in about an hour. After this it is ground and sifted in a similar manner as is the case in the milling of wheat flour.

It is then ready for the market, which it reaches packed in either tins, boxes, or barrels.

The fact that the milk is evaporated under reduced pressure makes it possible to accomplish the drying at a relatively low temperature, although the film of drying milk is naturally exposed for a very brief time to the direct heat of the drum, and which obviously varies with the steam pressure in the drum. The manufacturers claim that the drying of the milk takes place at a temperature of about 100 degrees F. and that the milk at no time reaches temperatures higher than 120 degrees F.

The Buflovak Process.— The principle of drying milk and other liquids on a steam- or hot water-heated revolving drum has been put to extensive application through the activities of the Buffalo Foundry & Machine Co., Buffalo, N. Y. This company has, during the last decade, invented, constructed and perfected the "Buflovak" vacuum drum drier. Patents were granted their engineer, Mr. O. S. Sleeper, by the United States Government in 1911, 1913, 1914, 1915 and 1916. All these patents were assigned to the Buffalo Foundry and Machine Co.

These patents pertain to the drum drier as used for whole milk, skim milk, buttermilk and milk products in general. They are applicable to other products as well as to milk, but for milk they are made specially accessible for cleaning and for sanitary control.

The Buflovak drier consists of a casing in which revolves a steam-heated, polished drum. The milk is fed to the surface or periphery of this drum by a pan located beneath the drum and placed lightly against the drum. The pan has an overflow along one side for the automatic removal of the surplus milk not taken up by the drum. To the bottom of this casing is supplied a quantity of milk. This is pumped to the supply pan under the drum, the overflowing milk running back into the lower portion of the casing. There is slight pressure in the supply pan which causes the drum to take up a heavy and even coating. Near the supply pan is installed a leveling arrangement which levels off and equalizes the layer of milk on the drum. As the drum revolves and the layer of milk reaches what is termed the front of the machine it is continuously removed in the form of a dry film by a stationary scraper. At this point the machine is provided with a breaker which consists of a shaft with a number of rods projecting through the same, which revolves to break up the film of dried milk as it leaves the drum. This does not reduce the film to a powder, but causes the material to be sufficiently broken up to allow it to fall into the receiver where it can be easily handled for removal.

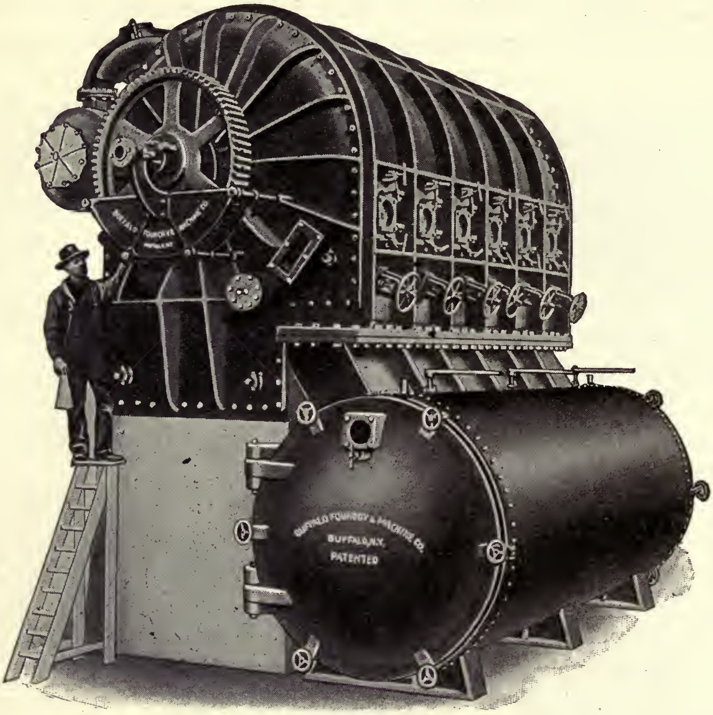

Fig. 61. The Buflovak vacuum drum drier
Courtesy of Buffalo Foundry & Machine Company

The receiver is a large cylindrical pan placed below the scraper at the front of the machine. Observation glasses are placed so that all internal parts may be seen while being operated. The receiver is equipped at each end with a door of the full width of the receiver, facilitating the rapid removal of the dried milk.

Aside from the circulating pump for supplying the milk to the feed pan, there is a condenser and a dry vacuum pump. Before the vapors reach the condenser, they pass through a dust collector. This is water-sealed and prevents the accumulation in the vapor pipe of any dust that may escape from the drum and pass to the condenser.

This drier is operated under a high vacuum, permitting rapid evaporation at a relatively low temperature. The actual drying time of the film of milk on the drum is about 6 to 7 seconds. The operation is continuous and at the conclusion of the day's run the machine is washed out. If subsequently closed up and evacuated for a few minutes, the entire interior will be dry insuring a sanitary condition of the machine.

4. The Campbell Process.—A current of warm air passes through the milk upward until the milk has become thick. The remainder of the drying is accomplished by exposure to heated air. The dried milk is then ground to a powder. This is the Campbell process, invented in 1900 and patented by J. H. Campbell of New York in 1902.

5. The Merrell-Gere Process.— The milk is condensed in the vacuum pan to about one-third to one-fourth its volume. The con-

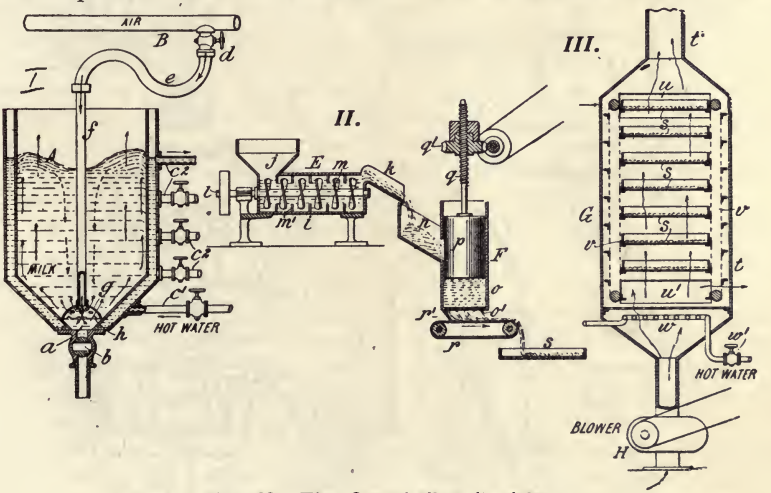

Fig. 62. The Campbell milk drier

I A concentrated vessel, a outlet, b valve, c hot water jacket, c^1 hot water pipe, c^2 discharge of jacket, B air pipe, e connecting hose, f stand pipe, g air-distributing disc, t air chamber.—II E pug mill, i cylinder, j hopper, k chute, l horizontal shaft, m blades for stirring, m′ projections for scraping blades, F Vermicelli-machine, n hopper, o cylindrical chamber, p piston, q spiral screw, q′ worm-wheel, o′ small holes, r endless traveling apron, s tray with perforated bottom.—III G drier, t body of drier, H blower, t′ flue, u opening to insert trays, u′ opening for removing trays, vv endless chains with projections for supporting trays, w coil heater, w′ pipe circulating hot water.

densed but still fluid milk is forced under pressure through a fine jet, causing it to be atomized and sprayed into a current of hot air, in an evaporating chamber. This atomized liquid forming a mist offers the maximum surface for evaporation of its water. The hot air absorbs the moisture of the milk almost instantly and the milk drops to the bottom of the chamber in the form of a snow-like powder. No grinding is necessary. This process was invented by L. C. and I. S. Merrell and W. B. Gere, assignors to Merrell-Soule Co., of Syracuse, N. Y., and patented July 23, 1907. The following are the claims of the patentees:

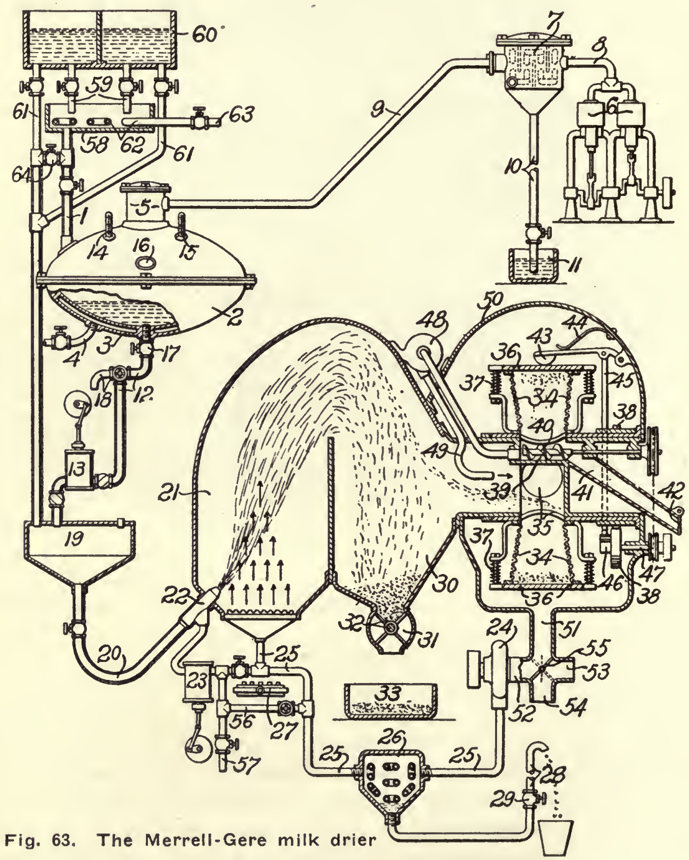

Fig. 63. The Merrell-Gere milk drier

1 intake of milk, 2 vacuum pan, 3 jacket, 4 steam intake into jacket, 5 dome of pan, 6 vacuum pumps, 7 condenser, 10 water column, 11 overflow

cistern for dry vacuum system, 12 discharge pipe of pan, 13 pump, 14 pressure gauge, 15 thermometer, 16 sight-glass, 17 regulating valve, 18 two-way draw-off cock for sampling, 19 reservoir, 21 desiccating chamber, 22 spray jet, 23 force pump, 24 air pump, 25 compressed air, 26 air drying chamber, 27 air heater, 28 stand-pipe, 29 drip valve, 30 depository of part of powder, 31 outlet of powder, 32 rotary gate, 33 receptacle, 34 rotary dust collector consisting of tubular screen partitions, 35 openings connecting with desiccating chamber, 36 head closing tubular screen, 37 springs, 38 gear for rotating dust collector, 39 receptacle, 40 screw conveyor removing powder into 41 which is a chute, 42 automatic discharge valve, 43 beater to remove adhering powder, 44 spring of beater, 45 rod, 46 toothed rack, 47 driving shaft, 48 suction pump to facilitate removal of powder, 49 conduit, 50 casing inclosing dust collector, 51 discharge of casing, 52, 53 and 54 terminal branches, 55 rotary valve, 56 auxiliary valve conduit, 57 supplementary valve conduit, 58, 59, 61, 62, 63 and 64 equipment for treating either colloids or crystalloids separately.

"CLAIMS:

1. "The process of obtaining the solid constituents of liquids and semi-liquids, in the form of powder, which process consists in concentrating the substance by removing a large percentage of the water therefrom, converting the concentrated mass into a fine spray, bringing such spray into a current of dry air or gas having an avidity for moisture so that substantially all the remaining liquid constituents are separated thereby, conveying the dry powder into a suitable collecting space away from the air or gas current, and discharging the air or gas separately from the dry powder.

2. "The process of obtaining the solid constituents of liquids and semi-liquids, in the form of powder, which process consists in concentrating the substance by removing a large percentage of water therefrom, converting the concentrated mass into a spray, bringing such spray into a current of dry heated air or gas having an avidity for the moisture of the substance treated, retaining the atoms momentarily in said current so that substantially all the remaining moisture is converted into vapor and the product is prevented by the cooling effect of such evaporation from undergoing chemical change, conveying the dry powder into a suitable collecting space away from the vaporizing current, and discharging the air or gas separately from the dry powder.

"In witness whereof we have hereunto set our hands this 7th day of August, 1906."

LEWIS C. MERRELL.
IRVING S. MERRELL.
WILLIAM B. GERE.

Witnesses:
H. E. CHASE,
HOWARD P. DENISON."

In the above classification of processes, only those processes have been discussed which produce true milk powders without the admixture of alkalies or sugar and which are commercially practical. Numerous other processes have been patented, especially in European countries. Most of these require the addition to the milk of either alkalies, or sugar, or both, or else their application has not been found commercially successful.

CHAPTER XXVII.

PACKING FOR THE MARKET

The dried milk, reduced to a fine powder, is put on the market in packages of various types and sizes. Small packages are usually put up in tin or fibre cans holding from eight ounces to ten pounds of milk powder. These cans are closed with a friction cap. The bulk of dried milk is put up in barrels which are lined with parchment paper similar to the lining of sugar barrels. Milk powder should be stored in a dry atmosphere. When exposed to dampness it is prone to absorb moisture. In this condition its life is shortened, as it becomes mouldy and spoils.

COMPOSITION OF MILK POWDER

Milk powder is made from whole milk, partly skimmed milk and skim milk. The following figures show the composition of milk powders manufactured by the several different processes.

Composition of Milk Powders Manufactured by Different Processes.

Process	Fat per cent.	Proteids per cent.	Lactose per cent.	Sucrose per cent.	Ash per cent.	Water per cent.
Whole milk						
[1]Merrell and Gere	29.20	26.92	36.48		6.00	1.40
[2]J. R. Hatmaker	21.70	28.70	35.10		6.50	8.00
Half skimmed						
[1]Merrell and Gere	15.12	33.30	39.70		6.90	5.00
[2]J. R. Hatmaker	13.00	30.57	48.85		7.28	8.30
Process not known	15.80	37.45	33.11		7.34	6.30
Skimmed						
[1]Merrell and Gere	1.00	37.00	47.00		8.00	7.00
J. R. Hatmaker	1.00	37.28	46.30		8.00	7.40

[1] Larsen and White, Milk Technology.
[2] C. Huyge, La poudre du lait, Revue générale du lait, Vol. 3, No. 14, 1904.

DEFECTS OF MILK POWDERS

High Water Content.—In order to insure keeping quality, milk powders must be as free from moisture as possible. Milk powders are not sterile, nor are they supposed to contain preservatives, such as sucrose and chemicals. Their only safeguard against bacterial fermentation and spoiling is their comparative freedom from water. Unless the process fulfills this requirement, milk powders will not keep and their chief virtue, which renders them most valuable, is forfeited.

Insoluble Milk Powders.—If milk powders are to take the place of fresh milk or condensed milk on the table of the consumer, they must be readily soluble. One of the greatest obstacles in the progress of the milk powder industry has been that the dried milk of most of the processes failed to be readily and completely soluble. Earlier processes prescribed the admixture to the milk of alkalies in order to preserve the solubility of the proteids, which otherwise were rendered insoluble by the high heat of the respective processes. It is obvious that a dried milk, the solubility of which can be retained only by the admixture of alkalies, is a poor substitute for milk, and the very principle of adding chemicals to a food product like milk, is contrary to our ideal of honest and successful manufacture of high quality of product. In the most approved processes now in use, the milk is never exposed to temperatures high enough to render the proteids of the resulting milk powder insoluble, and in their applications the use of solvents is unnecessary.

Non-miscible Milk Powders.—The miscibility of the dried milk with water depends, aside from its solubility, on the physical condition of its butter fat and the casein. If the process employed is such as to destroy the globular form of the fat globules, it is impossible to reduce the dried milk to a homogeneous fluid, similar to normal fresh milk. The fat in such milk will rise to the surface quickly, similar to the fat in a mixture of oil and water.

In fresh and normal milk the casein is present, not in solution, but in suspension. The particles of casein are very minute and form an intimate mechanical union with the water. In this condition they are present in the form of a homogeneous emulsion with the other ingredients of the milk. When the milk is desiccated at high temperatures, the particles of casein lose their property of emulsifying and when the desiccated milk is redissolved, the casein fails to be miscible, dropping to the bottom in the form of finely divided, insoluble curd. In order to produce milk powder which is miscible in water, the process and heat used must be such as to permit the casein to pass into the finished product in its natural state.

Rancid Milk Powder.—From the biological point of view, milk powder, properly made and with a minimum moisture content, cannot decompose. Unfortunately, one of the constituents of dried milk, the butter fat, is prone to undergo chemical changes upon exposure to light, heat and air. The less stable fatty acids evidently yield to chemical disintegration, giving the product a rancid and tallowy flavor. Experimental data showing the exact action that is responsible for this deterioration are not available. It is not improbable that both, hydrolysis and oxidation enter into this problem. Even the most experienced manufacturers of milk powder, using the most perfected processes now known, admit that milk powder made from whole milk, or partly skimmed milk, will become rancid when exposed to air, light and ordinary temperatures.

Experience has amply demonstrated that whole milk powder will deteriorate and become rancid and tallowy very much under the same conditions as butter. In order to prevent whole milk powder from becoming rancid, it must be stored in the cold.

MARKETS

Owing to its relatively poor keeping quality, the markets for whole milk powder are limited. It is a most ideal substitute for fresh milk or condensed milk, if used when fresh or whenever, in its storage and transportation, it can be protected by cold. This requirement, however, is a serious obstacle to its omni-usefulness and will remain a hindrance to its introduction in the pantry of the consumer, until the manufacturer succeeds in correcting this defect.

Skim milk powder, on the other hand, is free from this drawback, and when properly made and kept dry, it keeps indefinitely. It has become a most valuable dairy product and its uses are manifold. It is used in the consumer's kitchen, in bakeries and confectioners' establishments, in the manufacture of ice cream, fermented milk beverages, and starters for cream ripening where milk and skim milk are not available; in the preparation of baking powder, of pure lactic acid cultures for creameries and cheese factories, of drugs, choice toilet soaps, etc. In European countries the chocolate factories purchase vast quantities of skim milk powder in the manufacture of milk chocolate and allied products, and manufacturers of diverse prepared food products, such as cereals, soups, noodles, and vegetables, furnish additional markets for this new dairy product.

Commercial Stocks of Dried Milk.[1]—Commercial stocks of milk powder as reported in the Food Surveys of January 1, 1918, amounted to 13,296,422 pounds. Of this total the ice cream manufacturers held 19.1 per cent; warehouses, 19.4 per cent; wholesale dealers, 14.8 per cent; bakers, 13.3 per cent, and retail dealers, 1.9 per cent. The remainder, amounting to 31.5 per cent of the total, was held by a miscellaneous group of concerns, such as cheese factories holding 1,327,459 pounds; creameries, 712,020 pounds; confectioners, 621,428 pounds; ice cream manufacturers, 569,249 pounds, and other miscellaneous classes 929,289 pounds.

Chapter XXVIII.

DRIED BUTTERMILK AND DRIED WHEY

These by-products of the creamery and cheese factory can be reduced to a powder in a similar way and by the same processes and machinery as are used in the manufacture of dried milk and dried skim milk.

Dried buttermilk makes a splendid chicken feed, both for egg production and for fattening chickens. It is best diluted to about the original buttermilk (one part powder in ten parts water) and mixed with the grain feed into a mush. Like fresh buttermilk, so is dried buttermilk a wholesome, nutritious and easily digested food and recommends itself especially to persons with weak digestion. When properly made, buttermilk powder keeps indefinitely and may, therefore, be available for immediate use at all times.

The following analyses show the composition of buttermilk powder and of the fresh buttermilk from which it was made:

[1] Food Surveys, Bureau of Markets, U. S. Dept. Agriculture, Volume I, No. 7. Special Isslue, June, 1918.

COMPOSITION OF BUTTERMILK POWDER.

	Fresh buttermilk	Buttermilk powder
Butter fat	1.17 per cent	11.70 per cent
Proteids	3.00 per cent	36.24 per cent
Lactose	2.97 per cent	35.50 per cent
Ash	.85 per cent	8.25 per cent
Acidity	.60 per cent	6.00 per cent
Iron (Fe_2O_3)	.00 per cent	1.92 per cent
Water	91.63 per cent	4.32 per cent
Total	100.22 per cent	103.93 per cent

[1] The buttermilk of which the composition is shown in the above table was made at the plant of the Buffalo Foundry and Machine Company, Buffalo, N. Y., under the supervision of the writer. The machine used was of the Buflovak type. The buttermilk was furnished by Schlosser Bros., of Frankfort, Indiana. This batch of buttermilk happened to be abnormally high in butter fat; therefore the large butter fat content of the finished product. The iron found in the dried buttermilk is probably due to the fact that the drying drum of the desiccator was of iron and was acted upon by the high per cent of lactic acid. About thirty pounds of steam pressure were used in the drying drum, the temperature in the vacuum chamber was 125 degrees F. and the vacuum twenty-five to twenty-six inches of the mercury column.

This buttermilk powder had a nice, clean, acid taste, it was much relished by all who sampled it and, when fed to chickens for fattening, produced satisfactory gains in weight.

Whey powder is manufactured in a similar manner. Its chief value lies in its usefulness in the diet of infants and invalids, with whom the consumption of casein produces digestive disturbances. Since fresh whey is often not obtainable, the whey powder, the good keeping quality of which permits of keeping it on hand, furnishes an admirable substitute. When made from sour whey, it offers many advantages in cooking and baking and should be especially well suited for such dishes as pan cakes, etc.

The chief objection to these desiccated dairy by-products, such

[1] Hunziker, Indiana Agricultural Experiment Station, Twenty-sixth Annual Report, 1913.

as dried skim milk, dried buttermilk and dried whey, is that the cost of reducing them to dryness is somewhat out of proportion with their actual market value, as compared with the raw or condensed product. Dried skim milk, for instance, sells at 13 to 14 cents per pound. When diluted to the consistency of the raw skim milk, one pound of powder yields about ten or eleven pounds of skim milk, costing between $1.25 to $1.40 per hundred pounds, which is almost the price of fresh whole milk. It is obvious that the average creamery cannot afford to make starter at the rate of $1.25 to $1.40 per hundred pounds.

For the same reason the demand for dried buttermilk and dried whey is as yet very limited. These products, in their natural state, contain too small a proportion of the valuable ingredients, and they are too cheap to justify the high cost of manufacture, in order to place them on the market in the dry form. This, of course, does not apply to the use of dried skim milk for the many industrial purposes mentioned, where properties other than the mere food value determine the real merits, value and usefulness of the product.

The above figures and statements refer to conditions prior to the world war. The great need of food products and the wave of conservation that has been accentuated by the drain on the food supply of the world, resulting from the destruction, waste and stoppage of production in the warring countries, has given the utilization of these valuable by-products a new impetus, and their manufacture into marketable and transportable commodities promises rapid development for the benefit of mankind.

MALTED MILK[1]

Definition.—The product known as malted milk is that resulting from the combination of whole milk with the extract of malted barley and wheat flour, and the mixture is reduced to a dry form by desiccation in vacuo.

History of Malted Milk Industry.—The process of the manufacture of malted milk was invented by Mr. William Horlick, of Racine, Wis., in the year of 1883. The product was first placed on the market under the name of "Malted Milk," given it by its inventor, in 1887.

[1] Information on Definition, History and Process of Manufacture, received through the courtesy of Horlick's Malted Milk Co., Racine, Wis., March 8, 1918.

The convenience, nutritive value and digestibility of this product recommended themselves to and were appreciated by the medical profession, and its relishing properties appealed to the public. The industry grew rapidly and is today assuming large proportions.

Fig. 64. Vacuum pan for malted milk
Courtesy of Arthur Harris & Co.

Manufacture of Malted Milk.—A mash is prepared by mixing wheat flour with barley malt of good diastatic quality. This mash is raised to the proper temperature for a sufficient length of time to insure the complete conversion of the insoluble starch into the soluble malt sugars dextrin and maltose. This conversion is closely akin to starch digestion in the human system, hence the resulting liquid is essentially a predigested product, claimed to be of much value as a special food for infants and invalids.

This extract is combined with whole milk and reduced to a dry powder in a vacuum at such a low temperature as will thoroughly pasteurize the malted milk and yet preserve its digestibility.

Uses of Malted Milk.— Malted milk is the only milk powder made from whole milk that will keep indefinitely in any climate. It, therefore, combines with its acknowledged high degree of nutrition, the indispensible growth-promoting and curative properties contained in whole milk.

It is placed on the market both in powder and in tablet form. Its high digestibility, nutritive value and health-protective properties render it most valuable as a wholesome food for infants and invalids, and its compactness and keeping quality facilitate its transportation to and use in all parts of the globe. Malted milk, therefore, is of special merit for use in countries and territories which are barred by their geographical location and climate from the profitable husbandry of the dairy cow, and where the limitations of transportation render the availability of fluid milk difficult or impossible.

Federal Standards for Milk Powder, Skim Milk Powder and Malted Milk.[1]—The following standards of dried milk products were adopted by the United States Department of Agriculture March 16, 1917, and became effective March 31, 1917, as per Food Inspection Decision 170:

"DRIED MILK is the product resulting from the removal of water from milk, and contains, all tolerances being allowed for, not less than twenty-six per cent (26%) of milk fat, and not more than five per cent (5%) of moisture.

DRIED SKIMMED MILK is the product resulting from the removal of water from skimmed milk and contains, all tolerances being allowed for, not more than five per cent (5%) of moisture.

MALTED MILK is the product made by combining whole milk with the liquid separated from a mash of ground barley malt and wheat flour, with or without the addition of sodium chlorid, sodium bicarbonate and potassium bicarbonate in such a manner as to secure the full enzymic action of the malt extract and by removing water. The resulting product contains not less than seven and one-half per cent (7.5%) of butter fat and not more than three and one-half per cent (3.5%) of moisture."

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[1] United States Department of Agriculture, Food Inspection Decision 170, March 31, 1917.

PART VII.

STANDARIZATION, TESTS AND ANALYSES OF MILK, CONDENSED MILK AND MILK POWDER

Chapter XXIX.

STANDARDIZATION

Prior to the enactment of the Federal Food and Drugs Act, which became effective January 1, 1907, the milk condensing factories made no special effort to place on the market a product of any definite and specific composition. The milk was condensed, either as whole milk, no matter what the original composition of the fluid milk was, without modification, or it was partly skimmed or wholly skimmed, before condensing. If any effort towards modification of the composition was made, such effort was practically wholly confined to the regulation of the fat content of the finished product and even in such cases wide fluctuations were quite frequent.

With the enforcement of the Federal Food and Drugs Act, the milk condenseries found themselves called upon to manufacture a product that would comply with the Federal standards established and which prescribed the minimum per cent of fat and milk solids permissible in condensed milk.

It became necessary therefore to guard against the production of condensed milk, the per cent fat and milk solids of which fell below the specified standard. And later, with the rapid development of the condensed milk industry, competition gradually compelled the individual concerns to not only avoid the manufacture of an illegal product by causing its valuable components to fall short of the percentage required by the standard, but to so modify the composition as to not have the finished product materially exceed the required standard, in order to keep down the cost of manufacture. Furthermore, in the case of bulk condensed milk, which goes to confectioners and ice cream manufacturers, the buyer often specifies in his order the desired composition of the product, necessitating standardization to meet these special demands.

These factors and conditions inevitably led to the adoption of the practice of carefully standardizing condensed milk for fat and milk solids. The details of methods used for standardizing vary considerably with different manufacturers. The principle upon which standardization is based, however, is obviously very much the same under all conditions, and variations in details affect the results largely only with reference to the degree of accuracy.

Some manufacturers standardize the fluid milk before condensing, others prefer to standardize after evaporation only, while still others standardize both, the fluid milk and then again the finished product just prior to canning. Each of the three methods is practical and the double method of standardizing before and after condensation is obviously the most exact. In the case of sweetened condensed milk standardization before condensation is preferable inasmuch as the admixture to the finished product of water, skim milk or cream is not advisable from the standpoint of keeping quality, unless these products have been previously properly pasteurized. In the case of evaporated milk, which is much thinner, more miscible and which is subsequently sterilized, these objections are largely removed.

The materials generally used for standardizing are skim milk, condensed skim milk, cream, butter and water. Water is used only to lower the per cent total solids, or the degree of concentration, and is of service only after condensation of the milk.

The calculations employed for standardization are identical for all forms of condensed milk and milk powder, both sweetened and unsweetened. The addition of cane sugar to the fluid milk does not alter the ratio of fat to milk solids, since the added sugar merely displaces a portion of the water in the finished product.

The per cent total solids in the condensed milk is controlled primarily by the degree of concentration as determined by the Beaumé hydrometer or by gravimetric analysis and it may be further modified by the addition of water to the finished product in case condensation has passed beyond the desired point.

Aside from this, the fundamental effort of standardization is confined to securing the desired proportion of butter fat to milk solids not fat. When this is accomplished all that is necessary to insure the required composition is to subject the product to the necessary degree of concentration.

Standardizing the Fluid Milk.—In order to properly standardize the fluid milk it is necessary to know the required per cent fat and solids not fat in the finished product and the per cent fat and solids not fat in the milk to be standardized and then to calculate the proportion of fat and solids not fat needed in the fluid milk. This calculation is most conveniently made by allegation. This then shows the amount of fat or solids not fat, as the case may be, that must be added to secure the desired proportion of these ingredients and from this the amount of cream, or butter, or skim milk that must be used for standardizing can be readily determined.

EXAMPLE 1.

The standard for evaporated milk is 7.8 per cent fat and 25.5 per cent total solids, or (25.5 — 7.8) = 17.7 per cent solids not fat.

Amount fluid milk in batch, 7,000 pounds.

Fat in fluid milk, 3.3 per cent.

Solids not fat in milk, 9.0 per cent.

Fat wanted in evaporated milk, 7.8 per cent.

Solids not fat wanted in evaporated milk, 17.7 per cent.

What per cent fat should fluid milk contain?

How much cream, testing 25 per cent fat, must be added?

Answer: s. n. f. in c. m. : s. n. f. in r. m. = f. in c. m. : $\times$; $\times$ = % f. required in r. m.

s. n. f. = solids not fat.
f. = fat.
c. m. = condensed milk.
r. m. = raw or fluid milk.

17.7 : 9. = 7.8 : $\times$; $\times$ = 3.966% fat.

The raw milk must contain 3.966% fat.

How much 25% cream is required to raise the per cent fat in the 7,000 pounds of milk testing 3.3% fat to 3.966%?

3.3		21.04
	3.96	
25.		.66
		21.70

Enough 25% cream must be added to the raw milk so that each 21.7 pounds of standardized milk contains .66 pounds of added cream and 21.04 pounds of the original milk. Hence $21.7 : .66 = 7000 : \times$; $\times = 213$. lbs. of cream.

Total batch, 7000 pounds.
25% cream, 213 pounds.
3.3% milk, 6787 pounds.

EXAMPLE 2.

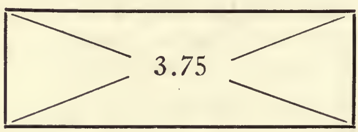
Amount of fluid milk in batch, 7,000 pounds.
Fat in fluid milk, 4.5 per cent.
Solids not fat in fluid milk, 8.5 per cent.
Fat wanted in evaporated milk, 7.8 per cent.
Solids not fat wanted in evaporated milk, 17.7 per cent.

How much fat should fluid milk contain? How much skim milk must be added?

Answer: $17.7 : 8.5 = 7.8 = \times ; \times = 3.75\%$. The fluid milk must contain 3.75% fat.

How much skim milk must be added to lower the per cent fat in the fluid milk to 3.75%?

4.5 3.75



.0 .75

4.50

Enough skim milk must be added to the fluid milk so that each 4.5 pounds of standardized milk contains .75 pounds of added skim milk and 3.75 pounds of original milk. Hence $4.50 : .75 = 7000 : \times ; \times = 1167$ pounds of skim milk.

Total batch, 7000 pounds.
Skim milk, 1167 pounds.
4.5% milk, 5833 pounds.

Standardization of Finished Product.—In a similar manner standardization may be accomplished after condensation. In this case the proportion of solids is best increased or the proportion of fat reduced by the addition of condensed skim milk in the place of ordinary skim milk, while the proportion of fat is increased by the addition of cream as explained under Standardization of Fluid Milk.

If it is desired to lower the total solids in the finished product, without affecting the proportion of solids not fat to fat, the necessary amount of water required is determined as follows:

EXAMPLE.

Evaporated milk in batch, 3000 pounds.
Total solids in evaporated milk, 27.%.
Total solids desired, 25.5%.
How much water must be added?
Answer:

27.		25.5
	25.5	
0		1.5

To each 25.5 pounds evaporated milk must be added 1.5 pounds water. Hence $25.5 : 1.5 = 3000 : X$; $X = 176.5$ pounds of water.

Original batch evaporated milk,	3000	pounds.
Water added,	176.5	pounds.
Standardized evaporated milk,	3176.5	pounds.

The results of standardization in which cream is used to alter the proportion of fat to solids not fat, are not absolutely mathematically accurate, because of the fact that the per cent of solids not fat in the cream is somewhat lower than in milk. This causes a slight shortage of solids not fat in the standardized product. This error is so slight, however, that it may be considered within the limits of the experimental error and for all practical purposes this method of standardization may be accepted as reliable and accurate.

CHAPTER XXX.

PRACTICAL METHODS OF SYSTEMATIC EXAMINATION OF PRODUCT FOR MARKETABLE PROPERTIES

The manufacturer should know at all times the quality and keeping quality of his product. He should have a systematic check, not only on his product stored in the factory, but also on the goods in transit and on the market, in order to promptly detect goods that show signs of deterioration. This will enable him to investigate the cause of the defect, to prevent its recurrence and to avoid spoiled goods from reaching the consumer. The following simple method of systematic examination has been found effective in keeping a reliable check on each batch until the product is old enough to have proved its immunity from the usual specific defects.

Number of Samples Needed.— Five cans of every batch of condensed milk or evaporated milk, bearing the corresponding batch number, are reserved for this purpose. For convenience's sake these sample cans are best stored on shelves about fifteen inches wide and five inches apart. These dimensions are sufficient to conveniently accommodate five 16-ounce cans of one and the same batch and placed in a row, one behind the other. These shelves should be installed in a place, preferably the office, where the cans may be exposed to similar changes and extremes of temperature, as is the case in transit and in the retail store. The cans of sweetened condensed milk should be placed on these shelves bottom-side up. The cans of evaporated milk should be placed on the shelves right-side up.

Frequency of Examination.—Every day one can of condensed milk or other product, one, three, ten, thirty and sixty days old, respectively, is opened and the contents are carefully examined for thickness, smoothness, sugar sediment, curdiness, fat separation, color, flavor, fermentation changes, etc.

Technique of Examination.— Since the temperature of the product influences its apparent thickness, it is desirable to examine the condensed milk at a uniform temperature, preferably 60 or 70 degrees F. This is best accomplished by the use of a water-tight tray of galvanized iron or tin, about twelve inches long, nine inches wide and three and one-half inches deep, with an overflow about two and one-half inches above the bottom. Every day at a regular hour the samples of the ages above stated are placed into this tray, containing water at the desired temperature (60 to 70 degrees F.), about thirty minutes before the cans are opened. All cans should be placed in the tray right-side up.

Upon opening the cans, the coating on the lid shows the presence of sugar sediment and of lumps of curd in the case of sweetened condensed milk, and a layer of thick and buttery cream in the case of evaporated milk. A perfectly clear lid, without any coating, indicates the freedom of the product from these defects. In the case of fermented milk the ends of the cans are usually bulged. Upon opening, a part of the contents is forced out. The thickness is estimated by inserting a spatula, or spoon, or by pouring, and the flavor and smoothness are determined by tasting.

The observations should be carefully recorded in a book reserved for this purpose, and any changes observed as the milk advances in age should be noted.

Interpretation of Results.—Most of the physical and mechanical defects appear in milk from one to ten days old. Defects resulting from fermentation processes generally become noticeable two to three weeks after manufacture.

Fluctuations in the thickness, from batch to batch, indicate lack of proper attention on the part of the pan-man to the "striking" of the batches. Sugar sediment shows the need of closer attention to the solution of sucrose and the cooling of the condensed milk. Lumps and buttons suggest the acceptance of a poor quality of fresh milk, or unsanitary condition of milk cans, vats, pipes and conveyors in the factory, or unclean tin cans. Fat separation and curdiness of evaporated milk suggest a faulty process. Fermentation of sweetened condensed milk urges investigation of the quality and condition of the sugar and of the sanitary condition of all apparatus and conveyors of milk, condensed milk and sugar, from the forewarmers to the sealing machine. Fermented evaporated milk points to incomplete sterilization or leaky tin cans, etc.

Systematic Examination a Necessary Feature of Economic Manufacture.—Manufacturers who neglect to conduct a systematic examination of their product similar to that outlined above frequently argue that they cannot afford to waste five cans out of every batch.

This is indeed a mistaken conception of economy. With the exception of fermented milk, the "cut-opens" can be emptied into the succeeding batch, so that all that is lost is the tin cans. Fermented goods cannot be utilized anyway, neither on the market nor elsewhere. Their loss, therefore, will occur whether in the form of "cut-opens" or cans intended for the trade.

The slight waste incurred by cutting open cans with sound contents is insignificant as compared with the incalculable savings which this practice may make possible by the early detection of faulty goods and the prevention of their recurrence, by enabling the manufacturer to withdraw suspicious goods from the market before they have ruined the reputation of the respective brands, and by furnishing a reliable check on the work of the employees, whose knowledge, that their product is subjected to, and must pass a rigid examination, acts as a moral stimulus for high quality, skill and carefulness.

CHAPTER XXXI.

CHEMICAL TESTS AND ANALYSES OF MILK, SWEETENED CONDENSED MILK, EVAPORATED MILK AND MILK POWDERS

In assembling these methods of analyses, preference has been given the "Official and Provisional Methods of Analysis," published by the American Association of Official Agricultural Chemists.[1] The official methods have been modified and supplemented by other methods in numerous cases wherever, in the judgment of the writer and others, such modifications and substitutions are better adapted for analysis of these special products. A special effort has further been made to include in this chapter modifications and abbreviations of tests and analyses, adapted for the use of the factory operator, whose knowledge, skill, facilities and time are too limited to enable him to successfully follow the directions of the official methods, or to execute delicate and difficult chemical analyses.

[1] United States Department of Agriculture, Bureau of Chemistry, Bulletin No. 107, 1912. Also Journal of the Assn. of Official Agr. Chemists, Vol. II, No. 3, Nov. 15, 1916.

For practical factory tests of fresh milk on the receiving platform, determining its fitness for condensing, the reader is referred to Chapter III, "Inspection of Milk at the Condensery," pp. 44 to 49.

Milk

SPECIFIC GRAVITY

Aerometric Method by Means of the Quevenne Lactometer.—Use an accurate Quevenne lactometer with thermometer attachment and a lactometer cylinder about ten inches high and one and one-half inches wide. Fill the cylinder with milk at a temperature between 55 and 65 degrees F. Insert the lactometer and when it has found its equilibrium, note the point on the scale at the surface of the milk. The correct temperature is 60 degrees F. For every degree Fahrenheit above 60 add one-tenth point to the observed reading, and for every degree Fahrenheit below 60 deduct one-tenth point from the observed reading. This rule holds good only when the range of temperature is within the limits of 55 degrees and 65 degrees F.

The specific gravity is calculated by adding 1,000 to the lactometer reading and dividing the sum by 1,000. Example: Lactometer reading is 31 at 65 degrees F. Corrected reading is 31.5;

$$\text{specific gravity is } \frac{31.5 + 1000}{1000} = 1.0315.$$

Gravimetric Determination.—This consists of the filling of a perfectly dry picnometer or other graduated flask of known measure with milk at the standard temperature (60 degrees F., or 15.5 degrees C.) and weighing the flask and contents. The weight of the flask is then deducted from the weight of the flask plus contents and the difference is divided by the weight of an equal volume of water at standard temperature. The result is the specific gravity of the milk.

The Westphal balance method furnishes another accurate means of determining the specific gravity. Both the gravimetric method and the Westphal balance method, while accurate when operated by the skillful chemist, require considerable time. Experimental comparisons have demonstrated that for all practical purposes the Quevenne hydrometer, when accurately graduated, yields correct results, and the simplicity and rapidity of its operation render its use in the determination of the specific gravity of milk highly advantageous and satisfactory.

TOTAL SOLIDS

By Means of the Babcock Formula.—For rapid and reasonably accurate work the total solids of milk may be determined by the use of the Babcock formula, which is as follows:

$$\text{Total solids} = \frac{L}{4} + 1.2 \times f.$$

L = Quevenne lactometer reading.
f = per cent of fat.

Example: Lactometer reading is 32; per cent fat is 4.

$$\text{Total solids} = \frac{32}{4} + 1.2 \times 4 = 12.8 \text{ per cent.}$$

Gravimetric Method.—"Heat from three to five grams of milk at the temperature of boiling water until it ceases to lose weight, using a tared flat dish of not less than 5 c.c. diameter. If desired, from fifteen to twenty grams of pure, dry sand may be previously placed in the dish. Cool in a desiccator and weigh rapidly to avoid absorption of hygroscopic moisture."

ASH

"Weigh about twenty grams of milk in a weighed dish, add 6 c.c. of nitric acid, evaporate to dryness and ignite at a temperature just below redness until the ash is free from carbon."

TOTAL NITROGEN

Place about five grams of milk in a Kjeldahl digestion flask and proceed, without evaporation, as described under "Gunning Method" for the determination of nitrogen. Multiply the percentage of nitrogen by 6.38 to obtain nitrogen compounds.

Gunning Method

APPARATUS

(*a*) *Kjeldahl flasks for both digestion and distillation.*—These are flasks having a total capacity of about 550 c.c., made of hard, moderately thick and well-annealed glass. When used for distillation the flasks are fitted with rubber stoppers and bulb tubes, as given under distillation flasks.

(*b*) *Kjeldahl digestion flasks.*—These are pear-shape, round-bottomed flasks, made of hard, moderately thick, well-annealed glass, having a total capacity of about 250 c.c. They are 22 c.m. long and have a maximum diameter of 6 c.m., tapering gradually to a long neck, which is 2 c.m. in diameter at the narrowest part and flared a little at the edge.

(*c*) *Distillation flasks.*—For distillation a flask of ordinary shape, of about 550 c.c. capacity may be used. It is fitted with a rubber stopper and with a bulb tube above to prevent the possibility of sodium hydrate being carried over mechanically during distillation. The bulbs may be about 3 c.m. in diameter, the tubes being of the same diameter as the condenser and cut off obliquely at the lower end, which is fastened to the condenser by a rubber tube."

PREPARATION OF REAGENTS

"(*a*) *Potassium sulphate.*—This reagent should be pulverized before using.

(*b*) *Sulphuric acid*—The sulphuric acid should have a specific gravity of 1.84. It should be C. P. containing no nitrates nor ammonium sulphate.

(*c*) *Sulphuric acid.*—*N*-10 *solution.*

(*d*) *Standard alkali solution.*—The strength of this solution relative to the acid must be accurately determined, N-10 solution.

(*e*) *Metallic mercury or mercuric oxid.*—If mercuric oxid is used it should be prepared in the wet way, but not from mercuric nitrate.

(*f*) *Granulated zinc or pumice stone..*—One of these reagents is added to the contents of the distillation flasks, when found necessary, in order to prevent bumping.

(*g*) *Potassium sulphid solution.*—A solution of forty grams of commercial potassium sulphid in one liter of water.

(*h*) *Sodium hydroxid solution.*—A saturated solution of sodium hydroxid free from nitrates.

(*i*) *Indicator.*—A solution of cochineal is prepared by digesting and frequently agitating three grams of pulverized cochineal in a mixture of 50 c.c. of strong alcohol and 200 c.c. of distilled water for a day or two at ordinary temperatures. The filtered solution is employed as indicator.

DETERMINATION

Place the substance to be analyzed in a digestion flask, employing from 0.7 to 3.5 grams, according to its proportion of nitrogen. Add 10 grams of powdered potassium sulphate and from 15 to 25 c.c. (ordinarily about 20 c.c.) of sulphuric acid. Conduct the digestion by starting with a temperature below boiling point and increasing the heat gradually until frothing ceases. Digest for a time after the mixture is colorless, or nearly so, or until oxidation is complete. Do not add either potassium permanganate or potassium sulphid. Dilute, neutralize, distil and titrate with standard alkali. In neutralizing, it is convenient to add a few drops of phenolphthalein indicator, by which one can tell, when the acid is completely neutralized, remembering that the pink color, which indicates an alkaline reaction, is destroyed by a considerable excess of strong fixed alkali.

CASEIN AND ALBUMIN

"(*a*) CASEIN.—The determination should be made when the milk is fresh, or nearly so. When it is not practicable to make this determination within twenty-four hours, add one part of formaldehyde to twenty-five hundred parts of milk and keep in a cool place. Place about 10 grams of milk in a beaker with about 90 c.c. of water at 40 degrees to 42 degrees C., and add at once 1.5 c.c. of a 10 per cent acetic acid solution. Stir with a glass rod and let stand from three to five minutes longer. Then decant or filter, wash two or three times with cold water by decantation and transfer precipitate completely to filter. Wash once or twice on filter. The filtrate should be clear, or nearly so. If it be not clear when it first runs through, it can generally be made so by two or three repeated filtrations, after which the washing of the precipitate can be completed. Determine nitrogen in the washed precipitate and filter by the Gunning method. To calculate the equivalent amount of casein from the nitrogen multiply by 6.38.

In working with milk which has been kept with preservatives, the acetic acid should be added in small proportions, a few drops at a time, with stirring, and the addition continued until the liquid above the precipitate becomes clear or very nearly so.

(*b*) ALBUMIN.—Exactly neutralize with caustic alkali the filtrate obtained in the preceding operation (a), add 0.3 c.c. of a 10 per cent solution of acetic acid and heat the liquid to the temperature of boiling water until the albumin is completely precipitated, collect the precipitate on a filter, wash and determine the nitrogen therein. Nitrogen multiplied by 6.38 equals albumin," or

To the filtrate of the casein determination add 0.3 c.c. of 10 per cent acetic acid, boil until the albumin is completely precipitated and proceed as directed in previous paragraph.

In the place of the above methods the per cent of albumin may be determined by subtracting the per cent of casein from the per cent of total nitrogen.

MILK SUGAR (LACTOSE)

OPTICAL METHOD

PREPARATION OF REAGENTS

"(*a*) *Acid mercuric nitrate.*—Dissolve mercury in double its weight of nitric acid, specific gravity 1.42, and dilute with an equal volume of water. One cubic centimeter of this reagent is sufficient for the quantities of milk mentioned below. Larger quantities may be used without affecting the results of polarization.

(*b*) *Mercuric iodid with acetic acid.*—Mix 33.2 grams of potassium iodid, 13.5 grams of mercuric chlorid, 20 c.c. of glacial acetic acid and 640 c.c. of water."

Determine the specific gravity of the milk by means of a delicate hydrometer, or, if preferred, a pycnometer. The quantity of sample to be taken for the determination varies with the specific gravity and is to be measured at the same temperature at which the specific gravity is taken. The volume to be measured is indicated in the following table, which is based upon twice the normal weight of lactose (32.9 grams per 100 metric c.c.) for the Ventzke sugar scale.

Place the quantity of milk indicated in the table in a flask graduated at 102.6 c.c., add 1 c.c. of the acid mercuric nitrate solution or 30 c.c. of the mercuric iodid solution (an excess of these reagents does no harm), fill to the mark, shake, filter through a dry filter and polarize. It is not necessary to heat before polarizing. If a 200 m.m. tube is used, divide the polariscope reading by 2 (or, if a 400 m.m. tube is used, by 4) to obtain the per cent of lactose in the sample.

VOLUME OF MILK CORRESPONDING TO A LACTOSE DOUBLE NORMAL WEIGHT

Specific Gravity of Milk.	Volume of Milk for a Lactose Double Normal Weight Ventzke Scale.	Specific Gravity of Milk.	Volume of Milk for a Lactose Double Normal Weight Ventzke Scale.
	C. C.		C. C.
1.024	64.25	1.031	63.80
1.025	64.20	1.032	63.75
1.026	64.15	1.033	63.70
1.027	64.05	1.034	63.65
1.028	64.00		
1.029	63.95	1.035	63.55
1.030	63.90	1.036	63.50

LOW'S VOLUMETRIC METHOD MODIFIED

PREPARATION OF REAGENTS

"(*a*) *Copper sulphate solution.*—Dissolve 34.639 grams of $CuSO_4 .5H_2O$ in water and dilute to 500 c.c.

(*b*) *Alkaline tartrate solution.*—Dissolve 173 grams of Rochelle salts and 50 grams of sodium hydroxid in water and dilute to 500 c.c.

(*c*) *Mixed solution.*—Mix equal volumes of solutions (*a*) and (*b*) immediately before use.

(*d*) *Standardization of the thiosulphate solution.*—Prepare a solution of sodium thiosulphate, dissolving 24.659 grams of pure crystals to 1,000 c.c. Weigh 6.36 grams copper foil. Dissolve by warming in minimum amount of nitric acid and water required. Boil to expel the red fumes, add 160 c.c. strong bromine water and boil until the bromine is thoroughly expelled. Remove from the heat and add a slight excess of strong ammonium hydroxid; 223 c.c. is about the right amount. Again boil until the excess of ammonia is expelled, as shown by a change of color of the liquid, and partial precipitation. Now add a slight excess of strong acetic acid (100 to 130 c.c. of 80 per cent acid) and boil for a minute. Cool to room temperature and dilute to 1,000 c.c. Titrate a known amount (10 to 15 c.c.) of the copper solution, to which 10 c.c. of a 25 per cent solution of pure potassium iodid has been added, with the thiosulphate solution until the brown tinge has become weak, then add sufficient starch liquor to produce a marked blue coloration.

Continue the titration cautiously until the color due to free iodin has entirely vanished. The blue color changes toward the end to a faint lilac. If at this point the thiosulphate be added drop by drop and a little time be allowed for complete reaction after each addition, there is no difficulty in determining the end point within a single drop. One cubic centimeter of the triosulphate solution will be found to correspond to .00636 grams of copper."

DETERMINATION OF COPPER

"After washing the precipitated cuprous oxid, cover the gooch with a watch glass and dissolve the oxid by means of 5 c.c. of warm nitric acid (1:1) poured under the watch glass with a pipette. Catch the filtrate in a flask of 250 c.c. capacity, wash watch glass and gooch free of copper; 50 c.c. of water will be sufficient. Boil to expel red fumes, add 5 c.c. of bromin water, boil off the bromin and proceed exactly as in standardizing the thiosulphate."

DETERMINATION OF LACTOSE

Place 50 c.c. of the mixed copper reagent in a beaker and heat to the boiling point. While boiling briskly add 100 c.c. of the lactose solution containing not more than 0.300 grams of lactose and boil for six minutes. Filter immediately through asbestos and wash. Obtain the weight of lactose equivalent to the weight of copper found from the following table:

"TABLE FOR THE DETERMINATION OF LACTOSE (SOXHLET-WEIN)"

Milli-grams of copper	Milli-grams of lactose	Milli-grams of copper	Milli-grams of lactose	Milli-grams of copper	Milli-grams of lactose	Milli-grams of copper	Milli-grams of lactose	Milli-grams of copper	Milli-grams of lactose
100	71.6	160	116.4	220	161.9	280	208.3	340	255.7
101	72.4	161	117.1	221	162.7	281	209.1	341	256.5
102	73.1	162	117.9	222	163.4	282	209.9	342	257.4
103	73.8	163	118.6	223	164.2	283	210.7	343	258.2
104	74.6	164	119.4	224	164.9	284	211.5	344	259.0
105	75.3	165	120.2	225	165.7	285	212.3	345	259.8
106	76.1	166	120.9	226	166.4	286	213.1	346	260.6
107	76.8	167	121.7	227	167.2	287	213.9	347	261.4
108	77.6	168	122.4	228	167.9	288	214.7	348	262.3
109	78.3	169	123.2	229	168.6	289	215.5	349	263.1
110	79.0	170	123.9	230	169.4	290	216.3	350	263.9
111	79.8	171	124.7	231	170.1	291	217.1	351	264.7
112	80.5	172	125.5	232	170.9	292	217.9	352	265.5
113	81.3	173	126.2	233	171.6	293	218.7	353	266.3
114	82.0	174	127.0	234	172.4	294	219.5	354	267.2
115	82.7	175	127.8	235	173.1	295	220.3	355	268.0
116	83.5	176	128.5	236	173.9	296	221.1	356	268.8
117	84.2	177	129.3	237	174.6	297	221.9	357	269.6
118	85.0	178	130.1	238	175.4	298	222.7	358	270.4
119	85.7	179	130.8	239	176.2	299	223.5	359	271.2
120	86.4	180	131.6	240	176.9	300	224.4	360	272.1
121	87.2	181	132.4	241	177.7	301	225.2	361	272.9
122	87.9	182	133.1	242	178.5	302	225.9	362	273.7
123	88.7	183	133.9	243	179.3	303	226.7	363	274.5
124	89.4	184	134.7	244	180.1	304	227.5	364	275.3
125	90.1	185	135.4	245	180.8	305	228.3	365	276.2
126	90.9	186	136.2	246	181.6	306	229.1	366	277.1
127	91.6	187	137.0	247	182.4	307	229.8	367	277.9
128	92.4	188	137.7	248	183.2	308	230.6	368	278.8
129	93.1	189	138.5	249	184.0	309	231.4	369	279.6
130	93.8	190	139.3	250	184.8	310	232.2	370	280.5
131	94.6	191	140.0	251	185.5	311	232.9	371	281.4
132	95.3	192	140.8	252	186.3	312	233.7	372	282.2
133	96.1	193	141.6	253	187.1	313	234.5	373	283.1
134	96.9	194	142.3	254	187.9	314	235.3	374	283.9
135	97.6	195	143.1	255	188.7	315	236.1	375	284.8
136	98.3	196	143.9	256	189.4	316	236.8	376	285.7
137	99.1	197	144.6	257	190.2	317	237.6	377	286.5
138	99.8	198	145.4	258	191.0	318	238.4	378	287.4
139	100.5	199	146.2	259	191.8	319	239.2	379	288.2
140	101.3	200	146.9	260	192.5	320	240.0	380	289.1
141	102.0	201	147.7	261	193.3	321	240.7	381	289.9
142	102.8	202	148.5	262	194.1	322	241.5	382	290.8
143	103.5	203	149.2	263	194.9	323	242.3	383	291.7
144	104.3	204	150.0	264	195.7	324	243.1	384	292.5
145	105.1	205	150.7	265	196.4	325	243.9	385	293.4
146	105.8	206	151.5	266	197.2	326	244.6	386	294.2
147	106.6	207	152.2	267	198.0	327	245.4	387	295.1
148	107.3	208	153.0	268	198.8	328	246.2	388	296.0
149	108.1	209	153.7	269	199.5	329	247.0	389	296.8
150	108.8	210	154.5	270	200.3	330	247.7	390	297.7
151	109.6	211	155.2	271	201.1	331	248.5	391	298.5
152	110.3	212	156.0	272	201.9	332	249.2	392	299.4
153	111.1	213	156.7	273	202.7	333	250.0	393	300.3
154	111.9	214	157.5	274	203.5	334	250.8	394	301.1
155	112.6	215	158.2	275	204.3	335	251.6	395	302.0
156	113.4	216	159.0	276	205.1	336	252.5	396	302.8
157	114.1	217	159.7	277	205.9	337	253.3	397	303.7
158	114.9	218	160.4	278	206.7	338	254.1	398	304.6
159	115.6	219	161.2	279	207.5	339	254.9	399	305.4
								400	306.3

BUTTER FAT

THE BABCOCK TEST

STANDARD GLASSWARE.[1]

(a) Standard milk test bottles, graduated to 8 per cent and with sub-divisions of .1 per cent.

(b) Pipette graduated to 17.6 c.c.

(c) Acid measure graduated to 17.5 c.c.

(d) Centrifuge-Babcock tester.

(e) Water bath for reading at 135 to 140 degrees F.

(f) Calipers for measuring fat column.

(g) Sulphuric acid, specific gravity 1.82 to 1.83.

DETERMINATION

Pipette 17.6 c.c. of the properly mixed sample of milk into the milk test bottle. Add 17.5 c.c. of acid and shake until all the curd

Fig. 65. Babcock tester
Courtesy of Creamery Package Mfg. Company

is completely dissolved. Both milk and acid should have a temperature of 55 to 70 degrees F. If milk and acid are too warm, set the sample bottles and the acid jar into a trough or tub of water at 55 to 70 degrees F. for thirty minutes before testing. The test

[1] Hunziker, Indiana Agricultural Experiment Station, Circulars 41 and 42, 1914.

bottles containing the mixture of milk and acid are then whirled in the Babcock tester for five minutes at about one thousand revolutions per minute, in the case of a tester with a twelve-inch diameter wheel. Fill the test bottles to the bottom of the neck with hot water. The water should be soft, preferably rain water or distilled water. If hard tap water is used it should be boiled to precipitate the carbonates, otherwise the test may be difficult to read, owing to the presence of bubbles of gas on top of the fat column. Revolve again at full speed for two minutes, fill the test bottles to near the top of the graduation with hot water. Whirl in the centrifuge for one minute. Now set the test bottles in the water bath at 135 degrees F. for five minutes. The test is now ready to be read. The figures on the test bottles represent per cent. In the case of the 8 per cent standard milk test bottle the sub-divisions represent tenths per cent. Read from the bottom of the lower curve to the top of upper curve of the fat column, including the meniscus in the reading.

GRAVIMETRIC METHOD—PAPER COIL

"Make coils of thick filter paper, cut into strips 6.25 by 62.5 c.m., and thoroughly extract with ether and alcohol, or correct the weight of the extract by a constant obtained for the paper. From a weighing bottle or weighing pipette, transfer about 5 grams of milk to the coil, care being taken to keep the end of the coil held in the fingers, dry. Dry the coil, dry end down, on a piece of glass at the temperature of boiling water; transfer to an extraction apparatus and extract with absolute ether or petroleum ether boiling at about 45 degrees C.; dry the extracted fat and weigh."

ROESE-GOTTLIEB METHOD

"Weigh 10-11 grams of the milk into a Röhrig tube or some similar apparatus, add 1.25 c.c. of concentrated ammonium hydroxid (2 c.c. if the sample is sour) and mix thoroughly. Add 10 c.c. of 95 per cent alcohol by volume and mix well. Then add 25 c.c. of washed ether and shake vigorously for thirty seconds, then 25 c.c. of petroleum ether (redistilled slowly at a temperature below 60 degrees C.) and shake again for thirty seconds. Let stand twenty minutes, or until the upper liquid is practically clear. Draw off as much as possible of the ether-fat solution (usually 0.5-0.8 c.c. will be left) into a weighed flask through a small quick-acting filter. The flask should always be weighed with a similar one as a counterpoise. Re-extract the liquid remaining in the tube, this time with only 15 c.c. of each ether, shake vigorously thirty seconds with each and allow to settle. Draw off the clear solution through the small filter into the same flask as before and wash the tip of spigot, the funnel and the filter with a few c.c. of a mixture of the two ethers in equal parts. For absolutely exact results the re-extraction must be repeated. This third extraction yields usually not more than about 1 mg. of fat (about 0.02 per cent on a 4 gram charge) if the previous ether-fat solutions have been drawn off closely. Evaporate the ethers slowly on a steam bath, then dry the fat in a boiling water oven to constant weight.

Confirm the purity of the fat by dissolving in a little petroleum ether. Should a residue remain, remove the fat completely with petroleum ether, dry the residue, weigh and deduct the weight. Finally correct this weight by a blank determination on the reagents used."

Sweetened Condensed Milk

PREPARATION OF SAMPLE

Pour the contents of the can into a bowl or on a glass plate. Scrape out the can thoroughly, removing all the sugar sediment from the top and bottom of the can. Mix thoroughly with pestle or spatula until a homogenous emulsion is secured. This is important, as it is exceedingly difficult to secure a representative sample otherwise.

If it is desired to use a 40 per cent solution as directed in the determination of the individual ingredients, weigh accurately 40 grams of the properly mixed contents of the can into a 100 c.c graduated flask. Add 60 c.c. of water. The sweetened condensed milk mixes somewhat difficultly with the water. Complete solution is facilitated by adding the water in several installments, shaking after each addition until condensed milk sediment adheres no longer to the bottom and sides of the flask.

SPECIFIC GRAVITY

AEROMETRIC METHOD BY MEANS OF BEAUMÉ HYDROMETER

APPARATUS

Beaumé Hydrometer.—Use a specially constructed Beaumé hydrometer with mercury bulb, and a scale of 30 to 37 degrees B., graduated to tenths degrees. Length over all, twelve inches; length of spindel, six inches; length of empty bulb, four and one-quarter inches; width of empty bulb, thirteen-sixteenths of one inch.

Hydrometer Jar.—Use a glass or tin cylinder with substantial base, minimum length twelve inches, minimum width one and a half inches.

DETERMINATION

The Beaumé hydrometer is graduated to read correctly at 60 degrees F. (15.5 degrees C.). At this temperature the sweetened condensed milk is too viscous for rapid and accurate work. Warm the condensed milk to 100 degrees F. or above and correct the Beaumé reading by adding to the observed reading .025 points for every degree Fahrenheit above 60. At a temperature of 100 degrees F. or above, the reading can be made in fifteen minutes or less, after the hydrometer is inserted in the milk.

The specific gravity is determined by the use of the following formula:

$$\text{Specific gravity} = \frac{144.3}{144.3 - B}$$

B = Beaumé reading at 60 degrees F.

Example: Observed Beaumé reading at 120 is 31.6.

$$\text{Corrected reading} = 31.6 + [(120 - 60) \times .025] = 33.1$$

$$\text{Specific gravity} = \frac{144.3}{144.3 - 33.1} = 1.2977$$

The following table shows the specific gravity of sweetened condensed milk when the Beaumé reading is known.

Beaumé	Specific gravity	Beaumé	Specific gravity	Beaumé	Specific gravity
0	1.000	16.5	1 130	29.7	1.260
0.7	1.005	17.1	1.135	30.2	1.265
1.4	1.010	1.77	1.140	30.6	1.270
2.1	1.015	18.3	1.145	31.1	1.275
2.7	1.020	18.8	1.150	31.5	1.280
3.4	1.025	19.3	1.155	32.0	1.285
4.1	1.030	19.8	1.160	32.4	1.290
4.7	1.035	20.3	1.165	32.8	1.295
5.4	1.040	20.9	1.170	33.3	1.300
6.0	1.045	21.4	1.175	33.7	1.305
6.7	1.050	22.0	1.180	34.2	1.310
7.4	1.055	22.5	1.185	34.6	1.315
8.0	1.060	23.0	1.190	35.0	1.320
8.7	1.065	23.5	1.195	35.4	1.325
9.4	1.070	24.0	1.200	35.8	1.330
10.0	1.075	24.5	1.205	36.2	1.335
10.6	1.080	25.0	1.210	36.6	1.340
11.2	1.085	25.5	1.215	37.0	1.345
11.9	1.090	26.0	1.220	37.4	1.350
12.4	1.095	26.4	1.225	37.8	1.355
13.0	1.100	26.9	1.230	38.2	1.360
13.6	1.105	27.4	1.235	38.6	1.365
14.2	1.110	27.9	1.240	39.0	1.370
14.9	1.115	28.4	1.245	39.4	1.375
15.4	1.120	28.8	1.250	39.8	1.380
16.0	1.125	29.3	1.255	40.1	1.385

GRAVIMETRIC DETERMINATION

Dilute a measured portion of a 40 per cent solution with an equal volume of water, use 5 c.c. of the diluted mixture, corresponding to 1 gram of the condensed milk and proceed as directed under "Milk," page 262.

TOTAL SOLIDS

Dilute a measured portion of a 40 per cent solution with an equal volume of water, measure 5 c.c. of the diluted mixture, corresponding to 1 gram of the condensed milk into an evaporating dish containing 15 to 20 grams of pure dry sand and proceed as directed under "Milk," page 262.

ASH

Ignite the total solids at very low redness, cool, and weigh. See "Milk," page 262.

PROTEIDS

Determine nitrogen in 5 c.c. of the 40 per cent solution according to the Gunning method, see "Milk," page 262, and multiply the results by 6.38.

LACTOSE

Dilute five grams of a 40 per cent solution to about 40 c.c. and add .6 c.c. of Fehling's copper solution. Nearly neutralize with sodium hydroxide, make up to 100 c.c., filter through dry filter and determine lactose in an aliquot as directed under "Milk—Determination of Lactose," page 266.

FAT

MODIFIED BABCOCK TEST

Weigh eighteen grams, or measure 16.1 c.c. of the 40 per cent solution into a standard Babcock milk test bottle. Add 4 c.c. of commercial sulphuric acid, specific gravity 1.82 to 1.83. Shake immediately until acid is thoroughly mixed with the milk. Whirl in Babcock tester for six minutes at full speed. The centrifuge must run smoothly. Stop the tester gradually and remove the bottles carefully so as not to break the layer of floating curd. Decant the clear whey by slowly inclining the bottle. Now add two-thirds of a 17.6 c.c. pipette full of water. After thoroughly shaking to emulsify the curd and to wash it free of sucrose, add 4 c.c. sulphuric acid, shake, whirl and decant as before. Then add one 17.6 c.c. pipette full of water, 17.5 c.c. of sulphuric acid and complete the Babcock test in the usual way as directed under "Milk," page 269. Multiply the reading by 2.5.

This method yields very satisfactory results with sweetened condensed milk containing not less than 4 to 5 per cent fat. With condensed milk of a lower fat content the decanting of the clear whey is difficult, since the curd in the partly skimmed product is too heavy to float in the form of a firm cheese.

THE ROESE GOTTLIEB METHOD

As practiced in the Dairy Laboratory, Bureau of Chemistry, Department of Agriculture

"Weigh out 4 to 5 grams of the homogeneous sample of condensed milk into a Röhrig tube (Zeit. Unters Nahr. u. Genussm., 1905, 9:531) or some similar apparatus and dilute with water in the tube to about 10.5 c.c.—or, if preferred, weigh into the tube 10 to 11 grams of a 40 per cent solution of the substance—add 1¼ c.c. of concentrated ammonium hydroxid (2 c.c. if the sample be sour) and mix thoroughly with the milk. Add 10 c.c. of 95 per cent alcohol and mix well. Then add 25 c.c. of washed ethyl ether and shake vigorously for half a minute, then add 25 c.c. of petroleum ether (redistilled slowly at a temperature below 60 degrees C. preferably) and shake again for half a minute. Let stand 20 minutes or until the upper liquid is practically clear and its own lower level constant. Draw off of the ether solution as much as possible—usually 0.5 to 0.8 c.c. will be left—into a weighed flask through a diminutive quick acting filter, of selected paper. The flask should always be weighed with a similar one as counterpoise.

"Re-extract the liquid remaining in the tube, this time with only 15 c.c. of each ether, shaking vigorously half a minute with each, and allow to settle.

"Draw off the clear solution through the small filter into the same flask as before and wash the tip of the spigot, the funnel and the filter with a few c.c. of a mixture of the two ethers in equal parts (previously mixed and free from deposited water).

"For perfectly exact results the re-extraction must be repeated. This extraction yields usually not more than about a milligram of fat, if the previous ether-fat-solutions have been drawn off closely—an amount averaging about .02 per cent on a 4-gram charge.

"Evaporate the ether slowly on a steam bath, then dry the fat in a boiling water oven until loss of weight ceases.

"Prove the purity of the fat by dissolving in a little petroleum ether. Should a residue remain, wash the fat out completely with petroleum ether, dry the residue, weigh, and deduct the weight. (This should not often be necessary.)

"Finally deduct the weight obtained by blank determination on the chemicals used.

"By this method practically absolute results can be obtained."

SUCROSE

Determine by difference, deducting the milk solids (ash plus proteids plus lactose plus fat) from the total solids, or invert the sucrose, determine the total invert sugar, deduct from this the lactose calculated as invert sugar and calculate the difference as sucrose.

MILK SOLIDS

Deduct the per cent sucrose from the per cent total solids. The difference represents the per cent milk solids.

Evaporated Milk

PREPARATION OF SAMPLE

Shake the can of evaporated milk vigorously before opening. If, upon opening the can, separated cream or small lumps of butter are found to adhere to the seams and around the junction of the ends and the body, set the can in a water bath at 130 degrees F. for ten minutes or until all fat is completely dissolved. Then pour the entire contents into a beaker and pour back and forth several times until a homogeneous mixture is secured. If it is known before opening the can that the contents are separated, submerge the whole can in a water bath at 130 degrees F. for ten minutes, then shake, open and proceed as above.

If it is desired to use a 40 per cent solution, as directed under the determination of the individual ingredients, weigh accurately 40 grams of the properly mixed contents of the can into a 100 c.c. graduated flask. Add 60 c.c. water and mix thoroughly by shaking or stirring.

SPECIFIC GRAVITY

AEROMETRIC METHOD

APPARATUS

Beaumé hydrometer.—Use a special Beaumé hydrometer with a scale ranging from five to twelve points, graduated to tenths degrees and mercury-weighted. Length over all eleven inches, length of spindle six inches, length of empty bulb four inches and width of empty bulb seven-eighths inch.

Hydrometer jar.—Use a glass or tin cylinder with substantial base. Minimum height ten inches and minimum width one and a half inches.

DETERMINATION

The Beaumé hydrometer is graduated to read correctly at 60 degrees F. (15.5 degrees C.). For every degree Fahrenheit above

60 add .0313 points to the observed reading. For every degree Fahrenheit below 60, deduct .0313 points from the observed reading.

The specific gravity is determined by the use of the following formula:

$$\text{Specific gravity} = \frac{145.5}{145.5 - B}$$

B = Corrected Beaumé reading

Example: Beaumé reading at 80 degrees F. is 7.8

$$\text{Corrected reading} = 7.8 + [(80 - 60) \times .0313] = 8.43$$

$$\text{Specific gravity} = \frac{145.5}{145.5 - 8.43} = 1.0615$$

Equally good results may be obtained by diluting the evaporated milk with an equal weight of water. Then take the Quevenne lactometer reading at 60 degrees F. Multiply the reading by 2, add 1000, and divide by 1000.

GRAVIMETRIC DETERMINATION

Dilute the evaporated milk with four times its weight of water and proceed as directed under "Milk," page 262.

TOTAL SOLIDS

BY MEANS OF SPECIFIC GRAVITY AND BABCOCK FORMULA

Determine the specific gravity as above directed. Multiply by 1000 and subtract 1000. Then use the following formula:

$$\frac{L}{4} + 1.2 \times f$$

L = The figure derived from the specific gravity by above calculations

f = per cent fat

Example: Evaporated milk tests 7.8 per cent fat and has a specific gravity of 1.0615

$$L = (1.0615 \times 1000) - 1000 = 61.5$$

$$\text{Total solids} = \frac{61.5}{4} + 1.2 \times 7.8 = 24.74 \text{ per cent.}$$

For rapid determination of the total solids of evaporated milk the factory operator is referred to the following tables from which the per cent total solids may be read at a glance when the Beaumé reading at 60 degrees F. and the per cent fat are known.

Per Cent Solids of Evaporated Milk

The Beaumé Degrees at 60 Degrees F. are Indicated in the Horizontal Line at the Top. The Per Cent of Fat is Shown in the Vertical Column at the Left

	Beaumé reading at 60 degrees Fahrenheit									
FAT PER CENT	8.0	8.1	8.2	8.3	8.4	8.5	8.6	8.7	8.8	8.9
	Solids per cent.	Solids per cent.	Solids per cent.	Solids per cent.	Solids per cent.	Solids per cent.	Solids per cent.	Solids per cent.	Solids per cent.	Solids per cent.
6.0	21.75	21.94	22.13	22.32	22.52	22.71	22.90	23.10	23.29	23.49
6.2	21.99	22.18	22.37	22.56	22.76	22.95	23.14	23.34	23.53	23.73
6.4	22.23	22.42	22.61	22.80	23.00	23.19	23.38	23 58	23.77	23.97
6.6	22.47	22.66	22.85	23.04	23.24	23.43	23.62	23.82	24.01	24.21
6.8	22.71	22.90	23.09	23.28	23.48	23.67	23.86	24.06	24.25	24 45
7.0	22.95	23.14	23.33	23.52	23.72	23.91	24.10	24.30	24.49	24.69
7.2	23.19	23.38	23.57	23.76	23.96	24.15	24.34	24.54	24.73	24.93
7.4	23.43	23.62	23.81	24.00	24.20	24.39	24.58	24.78	24.97	25.17
7.6	23.67	23.86	24.05	24.24	24.44	24.63	24.82	25.02	25.21	25.41
7.8	23.91	24.10	24.29	24.48	24.68	24.87	25.06	25.26	25.45	25.65
8.0	24.15	24.34	24.53	24 72	24.92	25 11	25.30	25.50	25.69	25.89
8.2	24.39	24.58	24.77	24.96	25.16	25.35	25.54	25.74	25.93	26.13
8.4	24.63	24.82	25.01	25.20	25.40	25.59	25.78	25.98	26.17	26.37
8.6	24.87	25.06	25.35	25.44	25.64	25.83	26.02	26.22	26.41	26.61
8.8	25.11	25.30	25.49	25.68	25.88	26.07	26.26	26.46	26.65	26.85
9.0	25.35	25.54	25.73	25.92	26 12	26.31	26.50	26.70	26.89	27.09
9.2	25.59	25.78	25.97	26.16	26.36	26.55	26.74	26.94	27.13	27.33
9.4	25.83	26.02	26.21	26.40	26.60	26.79	26.98	27.18	27.37	27.57
9.6	26.07	26.26	26.45	26.64	26.84	27.03	27.22	27.42	27.61	27.81
9.8	26.31	26.50	26.69	26.88	27 08	27.27	27 46	27.66	27.85	28.05
10.0	26.55	26.74	26.93	27.12	27.32	27.51	27.70	27.90	28.09	28.29
10.2	26.79	26.98	27.17	27.36	27.56	27.75	27.94	28.14	28.33	28.53
10.4	27.03	27.22	27.41	27.60	27.80	27.99	28.18	28 38	28.57	28.77
10.6	27.27	27.46	27.65	27.84	28.04	28.23	28.42	28.62	28.81	29.01
10.8	27 51	27 70	27.89	28.08	28.28	28.47	28.66	28.86	29.05	29.25
11.0	27 75	27.94	28.13	28.32	28.52	28.71	28.90	29.10	29.29	29.49
11.2	27.99	28.18	28.37	28.56	28.76	28.95	29.14	29.34	29.53	29.73
11.4	28.23	28.42	28.61	28.80	29.00	29.19	29.38	29.58	29.77	29.97
11.6	28.47	28.66	28.85	29.04	29.24	29.43	29.62	29.82	30.01	30.21
11.8	28.71	28.90	29.09	29.28	29.48	29.67	29.86	30.06	30.25	30.45

Per Cent Solids of Evaporated Milk (Continued)

The Beaumé Degrees at 60 Degrees F. are Indicated in the Horizontal Line at the Top. The Per Cent of Fat is Shown in the Vertical Column at the Left

	Beaumé reading at 60 degrees Fahrenheit									
FAT PER CENT	9.0	9.1	9.2	9.3	9.4	9.5	9.6	9.7	9.8	9.9
	Solids per cent	Solids per cent.	Solids per cent.	Solids per cent	Solids per cent.	Solids per cent.	Solids per cent.	Solids per cent.	Solids per cent.	Solids per cent
6.0	23.68	23.88	24.08	24.27	24.47	24.66	24.86	25.06	25.26	25.45
6.2	23.92	24.12	24.32	24.51	24.71	24.90	25.10	25.30	25.50	25.69
6.4	24.16	24.36	24.56	24.75	24.95	25.14	25.34	25.54	25.74	25.93
6.6	24.40	24.60	24.80	24.99	25.19	25.38	25.58	25.78	25.98	26.17
6.8	24.64	24.84	25.04	25.23	25.43	25.62	25.82	26.02	26.22	26.41
7.0	24.88	25.08	25.28	25.47	25.67	25.86	26.06	26.26	26.46	26.65
7.2	25.12	25.32	25.52	25.71	25.91	26.10	26.30	26.50	26.70	26.89
7.4	25.36	25.56	25.76	25.95	26.15	26.34	26.54	26.74	26.94	27.13
7.6	25.60	25.80	26.00	26.19	26.39	26.58	26.78	26.98	27.18	27.37
7.8	25.84	26.04	26.24	26.43	26.63	26.82	27.02	27 22	27.42	27.61
8.0	26.08	26.28	26.48	26.67	26.87	27.06	27.26	27.46	27.66	27.85
8.2	26.32	26.52	26.72	26.91	27.11	27.30	27.50	27.70	27.90	28.09
8.4	26.56	26.76	26.96	27.15	27.35	27.54	27.74	27.94	28.14	28.33
8.6	26.80	27.00	27.20	27.39	27.59	27.78	27.98	28 18	28.38	28.57
8.8	27.04	27.24	27.44	27 63	27.83	28.02	28.22	28 42	28.62	28.81
9.0	27.28	27.48	27.68	27.87	28.07	28.26	28.46	28.66	28.86	29.05
9.2	27.52	27.72	27.92	28.11	28.31	28.50	28.70	28.90	29.10	29.29
9.4	27.76	27.96	28.16	28.35	28.55	28.74	28.94	29.14	29.34	29.53
9.6	28.00	28.20	28.40	28.59	28.79	28.98	29.18	29.38	29.58	29.77
9.8	28.24	28.44	28.64	28.83	29.03	29.22	29.42	29.62	29.82	30.01
10.0	28.48	28.68	28.88	29.07	29.27	29.46	29.66	29.86	30.06	30.25
10.2	28.72	28.92	29.12	29.31	29.51	29.70	29.90	30.10	30.30	30.49
10.4	28.96	29.16	29.36	29.55	29.75	29.94	30.14	30.34	30.54	30.73
10.6	29.20	29.40	29.60	29.79	29.99	30.18	30.38	30 58	30.78	30.97
10.8	29.44	29.64	29.84	30.03	30.23	30.42	30.62	30.82	31.02	31.21
11.0	29.68	29.88	30.08	30.27	30.47	30.66	30.86	31.06	31.26	31.45
11.2	29.92	30.12	30.32	30.51	30.71	30.90	31.10	31.30	31.50	31.69
11.4	30.16	30.36	30.56	30.75	30.95	31.14	31 34	31.54	31.74	31.93
11.6	30.40	30.60	30.80	30.99	31.19	31.38	31 58	31.78	31.98	32.17
11.8	30.64	30.84	31.04	31.23	31.43	31.62	31.82	32.02	32 22	32 41

Per Cent Solids of Evaporated Milk (Continued)

The Beaumé Degrees at 60 Degrees F. are Indicated in the Horizontal line at the Top. The Per Cent of Fat is Shown in the Vertical Column at the Left

	Beaumé reading at 60 degrees Fahrenheit									
FAT PER CENT	10.0	10.1	10.2	10.3	10.4	10.5	10.6	10.7	10.8	10.9
	Solids per cent.	Solids per cent.	Solids per cent.	Solids per cent.	Solids per cent.	Solids per cent.	Solids per cent.	Solids per cent.	Solids per cent.	Solids per cent.
6.0	25.65	25.85	26.05	26.25	26.45	26.65	26.85	27.05	27.25	27.45
6.2	25.89	26.09	26.29	26.49	26.69	26.89	27.09	27.29	27.49	27.69
6.4	26.13	26.33	26.53	26.73	26.93	27.13	27.33	27.53	27.73	27.93
6.6	26.37	26.57	26.77	26.97	27.17	27.37	27.57	27.77	27.97	28.17
6.8	26.61	26.81	27.01	27.21	27.41	27.61	27.81	28.01	28.21	28.41
7.0	26.85	27.05	27.25	27.45	27.65	27.85	28.05	28.25	28.45	28.65
7.2	27.09	27.29	27.49	27.69	27.89	28.09	28.29	28.49	28.69	28.89
7.4	27.33	27.53	27.73	27.93	28.13	28.33	28.53	28.73	28.93	29.13
7.6	27.57	27.77	27.97	28.17	28.37	28.57	28.77	28.97	29.17	29.37
7.8	27.81	28.01	28.21	28.41	28.61	28.81	29.01	29.21	29.41	29.61
8.0	28.05	28.25	28.45	28.65	28.85	29.05	29.25	29.45	29.65	29.85
8.2	28.29	28.49	28.69	28.89	29.09	29.29	29.49	29.69	29.89	30.09
8.4	28.53	28.73	28.93	29.13	29.33	29.53	29.73	29.93	30.13	30.33
8.6	28.77	28.97	29.17	29.37	29.57	29.77	29.97	30.17	30.37	30.57
8.8	29.01	29.21	29.41	29.61	29.81	30.01	30.21	30.41	30.61	30.81
9.0	29.25	29.45	29.65	29.85	30.05	30.25	30.45	30.65	30.85	31.05
9.2	29.49	29.69	29.89	30.09	30.29	30.49	30.69	30.89	31.09	31.29
9.4	29.73	29.93	30.13	30.33	30.53	30.73	30.93	31.13	31.33	31.53
9.6	29.97	30.17	30.37	30.57	30.77	30.97	31.17	31.37	31.57	31.77
9.8	30.21	30.41	30.61	30.81	31.01	31.21	31.41	31.61	31.81	32.01
10.0	30.45	30.65	30.85	31.05	31.25	31.45	31.65	31.85	32.05	32.25
10.2	30.69	30.89	31.09	31.29	31.49	31.69	31.89	32.09	32.29	32.49
10.4	30.93	31.13	31.33	31.53	31.73	31.93	32.13	32.33	32.53	32.73
10.6	31.17	31.37	31.57	31.77	31.97	32.17	32.37	32.57	32.77	32.97
10.8	31.41	31.61	31.81	32.01	32.21	32.41	32.61	32.81	33.01	33.21
11.0	31.65	31.85	32.05	32.25	32.45	32.65	32.85	33.05	33.25	33.45
11.2	31.89	32.09	32.29	32.49	32.69	32.89	33.09	33.29	33.49	33.69
11.4	32.13	32.33	32.53	32.73	32.93	33.13	33.33	33.53	33.73	33.93
11.6	32.37	32.57	32.77	32.97	33.17	33.37	33.57	33.77	33.97	34.17
11.8	32.61	32.81	33.01	33.21	33.41	33.61	33.81	34.01	34.21	34.41

GRAVIMETRIC DETERMINATION

Dilute a measured portion of a 40 per cent solution with an equal volume of water, use 5 c.c. of the diluted mixture, corresponding to 1 gram of the evaporated milk and proceed as directed under "Milk," page 262.

ASH

Ignite the total solids at very low redness, cool, weigh, see "Milk," page 262.

PROTEIDS

Use 5 c.c. of a 40 per cent solution, determine nitrogen according to the Gunning method as directed under "Milk," page 262, and multiply result by 6.38.

LACTOSE

Dilute 10 grams of a 40 per cent solution to about 40 c.c. and add .6 c.c. of Fehling's copper solution; nearly neutralize with sodium hydroxide, make up to 100 c.c., filter through dry filter, and determine lactose in an aliquot as directed under "Milk," page 266.

FAT

THE MODIFIED BABCOCK METHOD[1]

Carefully weigh 4.5 grams of well-mixed evaporated milk into the 8 per cent test bottle. Add one 17.6 c.c. pipetteful of water. Add 17.5 c.c. of sulphuric acid and shake until the curd in the test bottle is completely dissolved. Whirl at usual speed (one thousand revolutions per minute) for five minutes. Mix equal portions of water and sulphuric acid in glass beaker. For one or two tests, one pipetteful of water and one acid measure full of acid are sufficient. Fill test bottle to slightly below the bottom of the neck with the hot diluted acid. Whirl for two minutes. If the fat collected at the base of the neck is not clear, shake the bottle until all the curdy matter is completely dissolved, fill the bottle to about the 8 per cent mark with hot water, whirl for one minute and read the test at 135 degrees F. The fat column must be read from the top of the upper meniscus to the bottom of the lower meniscus. Multiply the reading by 4. This gives the correct per cent of fat.

[1] Hunziker and Spitzer, Indiana Agricultural Experiment Station, Bulletin No. 134, 1909.

Instead of weighing 4.5 grams into the test bottle, a 4.3 c.c pipette may be used. After emptying the pipette into the bottle it should be rinsed twice and the rinsings discharged into the test bottle.

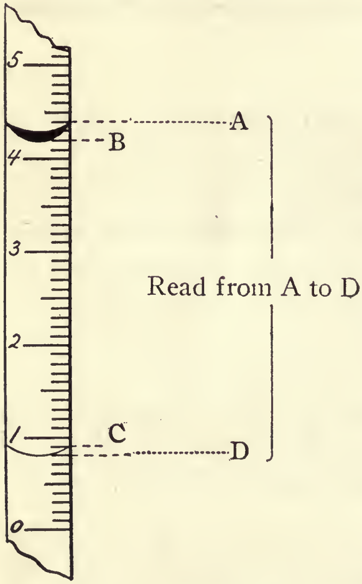


Fig. 62
Reading the Babcock test

For making numerous tests from the same sample it is advisable to dilute the evaporated milk with equal parts of water, by weight; then weigh nine grams of this dilution into the test bottle and add one-half pipetteful of water.

THE ROESE-GOTTLIEB METHOD

Proceed as directed under "Sweetened Condensed Milk," page 274.

Milk Powder

TOTAL SOLIDS

Weigh 5 grams of the milk powder in a drying bottle or evaporating dish and place in drying oven at 100 to 105 degrees C. until constant weight is secured.

ASH

Weigh two grams of the milk powder in a weighed platinum dish and proceed as directed under "Milk," page 262.

PROTEIDS

Use five grams of the milk powder and proceed as directed under "Milk," page 262.

MILK SUGAR (LACTOSE)

Dissolve ten grams of milk powder in 90 c.c. of water. Warm and stir until a satisfactory solution is effected and proceed as directed under "Milk," page 266, and multiply result by 10.

SUCROSE

For the determination of sucrose proceed as directed under "Sweetened Condensed Milk," page 275.

FAT

THE BABCOCK TEST METHOD.—Dissolve ten grams of milk powder in 90 c.c of water. Warm and mix until a complete solution is effected. Then proceed as directed under "Milk," page 269, and multiply the result by 10.

"ROESE-GOTTLIEB METHOD.—Weigh one gram of the powder in a 30 c.c. lipped beaker. Rub up with 9 c.c. of water and 2 c.c. of concentrated ammonium hydroxid, digest on steam bath until the casein is well softened and the whole resembles milk. Cool, transfer to Röhrig tube or similar apparatus, using 10 c.c. of 95 per cent alcohol for rinsing, followed, after shaking contents of tube, by 25 c.c. of washed ethyl ether. Shake vigorously for one-half minute and proceed as in the determination of fat in sweetened condensed milk."

CHAPTER XXXII.

THE MOJONNIER TEST FOR FAT AND SOLIDS [1]

The Mojonnier test for fat and solids in milk and milk products represents the use of chemical apparatus and mechanical devices of a high degree of precision, ingeniously invented, scientifically modified and especially adapted for accurate tests of dairy products. It offers methods of fat and solids estimations that combine the accuracy of official chemical analysis with the rapidity of factory tests. It has been introduced in and is successfully used by most of the progressive milk-condensing factories in the country, and it is admirably filling a long-felt demand for reliable and accurate methods of testing milk, condensed milks and milk powders and for standardizing these products under factory conditions.

[1] Directions furnished through courtesy of Mojonnier Bros. Co., Milk Engineers, Chicago.

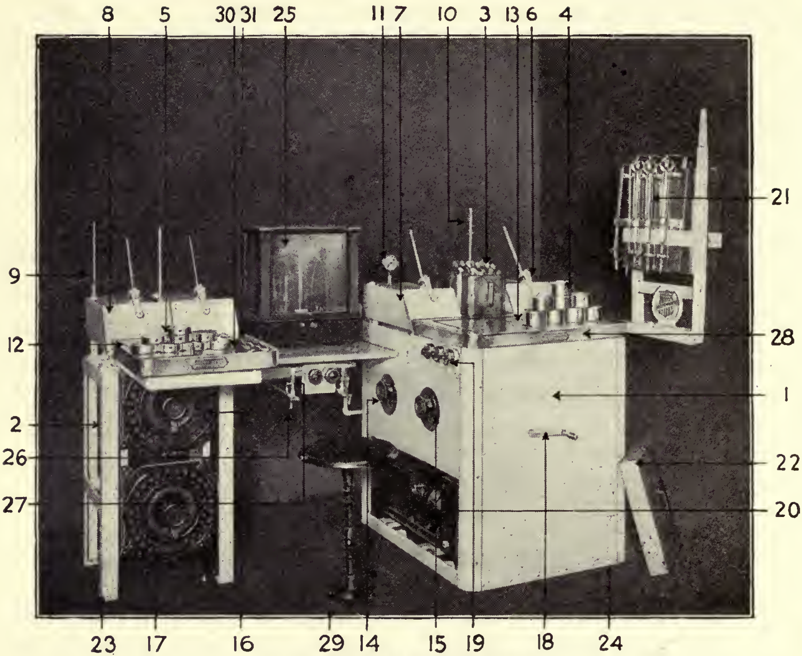


Fig. 66. The Mojonnier tester
Courtesy of Mojonnier Bros. Company

EQUIPMENT

Install the tester on a solid foundation in a room protected against excessive fluctuations in temperature.

1. Tester for butter fat.
2. Tester for total solids.
3. Fat extraction flasks.
4. Eight 3½-inch aluminum dishes without covers and with tall counterpoise which tares the eight dishes, for fat tests.
5. Eight 3-inch aluminum dishes with covers and short counterpoise, for solids tests.
6. Fat oven. Keep temperature at 135° C.
7. Cooling chamber.
8. Solids oven. Keep temperature at 100° C.
9. 250° C. thermometer for solids oven. Have mercury bulb fit snugly into brass mercury well. Brass mercury well must always form good contact with hot plate.

10. 250° C. thermometer for fat oven. Observe same precautions as in (9).

11. Vacuum gauge on main suction line, registers either or both ovens.

12. Solids plate. Must be level and held at 180° C.

13. Fat plate. Hold at 135° C.

14. Rheostat for fat plate. Lever must make good contact with one button, not with two at a time. When right button has been found that maintains constant temperature, mark this point on rheostat rim. When starting tester each day, turn handle on full until temperature has risen to within right point, then turn back to previously marked button.

15. Rheostat for oven. Observe same precautions as in (14).

16. Rheostat for solids oven. Observe same precautions as in (14).

17. Rheostat for solids plate. Observe same precautions as in (14).

18. Handle for centrifuge.

19. Snap switches for each hot plate showing temperature and time for treating samples at various points.

20. Power unit, consisting of vacuum pump, water circulating pump and motor for same. Keep pump filled to air cock with oil furnished with tester.

21. Automatic burettes and cans holding the water, ammonia, alcohol, ethyl ether and petroleum ether, placed in the order in which they are used. Each division on burettes delivers the proper amount of the desired reagent for a single extraction.

22. Hood, to be placed over fat dishes when evaporating off ether.

23. Legs, to be fastened to floor with lag screws.

24. This side need not be fastened to floor. If necessary to take out power unit disconnect connections in rear of machine and move this part of machine forward.

25. Chemical balance. Keep level, clean and handle carefully. Raise knife edges gradually and with care. Clean balance daily. Keep weights clean. When weights show signs of wear, order new ones.

26. Cock, to exhaust vacuum from oven when cock (27) is closed. Must be kept closed when vacuum is turned on oven.

27. Cock, that switches vacuum from main line into vacuum oven. Set of cocks at right is for solids oven, set of cocks at left is for fat oven.

28. Hole in top of fat plate holder, communicating with suction fan, on power unit. Run exhaust pipe on suction fan out of window and keep hood over the dishes in order to drive all ether fumes from room.

29. Stool, to be screwed to floor.

DIRECTIONS FOR OPERATING MOJONNIER TEST

Preliminary directions for tests of both Fat and Solids. (See also list of precautions appended, pp. 292-294.

(1) Wash solids dishes with warm water and fat dishes with gasoline. Dry with a towel and place into heated vacuum oven for five minutes with vacuum on. At the end of five minutes put these dishes into cooler and, with the pump still running, keep them there for five minutes before weighing. Do not turn off motor until last dish is weighed out of cooling chamber.

(2) While dishes are being heated and cooled, wash pipettes with water, alcohol and ether and dry by applying vacuum at exhaust cock upon tester. Always use clean and dry pipettes for each different sample. Aim to clean pipettes as well as all glassware, immediately after using.

(3) It is very important to keep extraction flasks clean. Wash these with warm water immediately after extraction is finished. Wash with washing powder and shot when necessary.

(4) After aluminum dishes have been in cooler for at least five minutes, weigh accurately to .0001 gram, using the proper counterpoise. Weigh solids dishes with cover on. Fat dishes do not have covers. Fat dishes should be cooled for seven minutes before being weighed.

(5) Use weighing pipettes as follows: Fill five-gram pipette up to five-gram mark for butter fat, and one-gram pipette up to one-gram mark for total solids. If duplicates are to be run fill two pipettes from the same sample. As pipettes are filled place lower end into cleaned and dry rubber tubes which are pressed upon knobs at ends and center of weighing cross. Either five or less samples for butter fat or five or less for total solids may be pipetted out.

(6) Weigh the cross with the pipettes containing the milk on chemical balance accurately to .0001 gram. Run milk from pipette into proper flask, or 3-inch dish if making solids test. The pipettes may be distinguished by the number upon each cross. Replace pipette and weigh again. Difference in weight gives weight of sample. Repeat until all samples are run into proper flasks, and into weighed solids dishes if solids are determined along with the fat.

For fat in Sweetened Condensed Milk use a five-gram sample. The five-gram pipette delivers approximately five grams between the five-gram mark and the base of the bowl of the pipette.

Some operators prefer to mix 200 grams of sweetened condensed milk with 200 grams of water, weighing these carefully upon a Harvard trip scale sensitive to .1 gram. In this case care must be exercised to obtain the exact weight of both milk and water and to stir these thoroughly with glass or metal rod before taking sample. A tall tumbler, a one-pound bottle or a quart cup make good containers in which to make mixture. A ten-gram sample of this mixture is used. This is best weighed out by using two five-gram pipettes on weighing cross.

For total solids weigh out ½ (.5000) to ¾ (.7500) gram of this mixture. If the undiluted milk is used take as nearly (.2500) gram as possible.

For regular 8 per cent plain bulk condensed milk use same size samples and treat same as evaporated milk. For 12 per cent superheated condensed milk mix 100 grams milk with 300 grams water upon Harvard trip scale. Weigh ten-gram sample of this mixture into flask for fat and a two-gram sample into solids dish for solids. Multiply percentages obtained by four for correct percentages, when a 1 to 4 dilution is made.

FRESH MILK, SKIM MILK, WHEY, BUTTERMILK

BUTTER FAT DETERMINATION

(1) Use the ten-gram pipettes for measuring out ten grams of milk into cleaned but not necessarily dried Mojonnier extraction flask. Use only ten-gram pipettes furnished with tester and do not use 10 c.c. pipettes. The pipette is graduated to deliver ten grams of milk after allowing all milk to run out and letting it drain for fifteen seconds longer, then blowing gently to remove last drop.

The pipette must be perfectly clean and dry before being used. Wash frequently with sulphuric acid, water, alcohol and ether to insure having a clean pipette.

(2) Make extractions exactly as in test for butter fat in condensed milk, excepting that in second extraction only 15 c.c. of each ether need be used.

(3) Percentage butter fat is obtained by multiplying the weight of the extracted butter fat by 10.

(4) If any of these products have soured badly, double the quantity of ammonia in the regular extraction and shake until all particles are dissolved.

TOTAL SOLIDS DETERMINATION

(1) Determine total solids as in evaporated milk, excepting that a two-gram sample is weighed out, and no water need be added to spread the milk over the bottom of the dish.

SWEETENED CONDENSED MILK, EVAPORATED MILK AND CONDENSED BULK MILK

BUTTER FAT DETERMINATION

(1) Remove flask from holder and run 4 c.c. water (one charge on water burette) into each flask. Be careful not to add more. Shake well until all of sample is mixed with water. This can be done without inserting cork.

For Sweetened Condensed Milk, if not diluted with water, add 6 c.c. of hot water with a pipette. To get hot water place fat dish filled with distilled water upon solids plate. If sweetened milk has been previously diluted with water and a ten-gram sample has been used, it is not necessary to add water.

It is very necessary to shake the flasks containing the sweetened condensed milk very thoroughly after the addition of each reagent. Sweetened condensed milk requires more shaking than any other liquid milk product.

(2) Before replacing flask into holder, add 1½ c.c. c.p. ammonia. Shake well so that all of sample is well mixed with ammonia. This can be done without inserting cork.

(3) Add 95 per cent alcohol up to base of top bulb of extraction flask. Insert cork, using best quality corks only. Replace

flask into flask holder. Shake thoroughly and see that no milk adheres to any part of flask undissolved. In case particles of milk stick to side of flask, shake thoroughly until these are washed away. It is of the utmost importance to shake thoroughly at this point.

(4) Add 25 c.c. ethyl ether, insert corks and shake vigorously, lengthwise of flask, with liquid in large bulb of flask, and small bulb extended upward. Stop shaking at end of five seconds until all liquid has run into large bulb and repeat vigorous shaking for four five-second periods.

(5) Add 25 c.c. petroleum ether and shake in same way.

(6) Place extraction flasks into centrifuge and whirl for thirty turns at speed of about 600 R. P. M. Double time for sweetened condensed milk.

(7) Place four 3½-inch dishes in line on shelf adjoining hot plate, keeping them in order in which their weights were posted upon record sheet. Aim to have numbers on flasks correspond with number of dishes.

(8) Pour ether extraction to dividing line into proper dishes and slide dishes over onto hot plate, which should be held at a temperature of 135 degrees C., as indicated by thermometer inserted in nickel plated mercury well.

(9) Repeat the extraction, adding first alcohol enough to bring line close up to top of small neck of flask, then 25 c.c. ethyl ether, and then 25 c.c. petroleum ether, and shake vigorously after the addition of each of above three reagents for four 5-second periods.

(10) Whirl in centrifuge for thirty turns.

(11) Move aluminum dishes back upon shelf adjoining hot plate and pour the second extraction into proper dishes. Never pour extraction into hot dish. Remove dish from hot plate as soon as ether is all evaporated.

(12) When all of ether has evaporated place dishes into vacuum oven, which should have a temperature of 135 degrees centigrade. Keep them there for five minutes after the vacuum gauge shows at least twenty-two inches of vacuum.

(13) Place dishes into cooler for seven minutes, with pump outfit running. See that water is running through cooling plates.

(14) Place counterpoise for dish and the approximate weight for fat on right hand balance pan.

(15) Transfer dish to left hand balance pan and weigh quickly to 0.10 milligram (0.0001 gr.).

(16) Weight of fat divided by weight of sample taken, multiplied by 100, represents per cent butter fat.

TOTAL SOLIDS DETERMINATION

(1) The temperature of the hot plate in the solids vacuum oven must be 100 degrees C. The temperature of the outside solids plate must be 170 degrees to 180 degrees C.

(2) To weighed milk in solids dish add about 1 c.c. water and distribute mixture evenly over bottom of dish. For sweetened condensed milk use hot water.

(3) Place not more than two dishes at once upon hot plate, which must be perfectly level. Allow all visible moisture to evaporate. During the evaporation turn the dishes around with crucible tongs, slowly, so as to produce an even boiling over the whole bottom surface of the dishes. The dishes must be watched carefully during the evaporation. This step should require not more than two minutes. The end point is reached when bubbling and crackling ceases and sample shows first trace of brown. Vigorous boiling without spattering and complete evaporation are fundamentally essential.

(4) Place dishes into vacuum oven, which must be at 100 degrees C., and turn on the vacuum. Heat for ten minutes. In the case of sweetened condensed milk keep it for twenty minutes in vacuum oven. The gauge should register not less than twenty-two inches of vacuum. If for any reason you cannot obtain at least twenty-two inches of vacuum then leave dishes in oven for twice the regular time.

(5) Remove from oven and place into cooler. Allow dishes to cool for five minutes.

(6) Weigh dishes with covers on in the same manner that the butter fat dishes were weighed, being careful to weigh quickly and very exactly.

(7) Weight of dry solids divided by weight of milk taken, multiplied by 100, represents per cent total solids.

POWDERED MILK AND MALTED MILK

Method of Sampling

Mix the sample thoroughly, making sure that it is sufficiently pulverized and representative of the entire lot to be tested. Transfer the pulverized sample promptly to a sealed jar. Mix before removing portions for testing.

BUTTER FAT DETERMINATION

(1) Weigh out rapidly, to prevent absorption of moisture from the air, about one gram of milk powder into butter boat. In case of malted milk, weigh out a 0.5 gram sample.

(2) Add 8.5 c.c. of hot water to flask. Insert cork. Heat flask in water boat and shake thoroughly until the sample is well mixed.

(3) Add 1.5 c.c. (one charge) ammonia, and shake thoroughly.

(4) Add alcohol up to line on small neck of flask. Insert cork. Replace flask into flask holder. Shake flask thoroughly with cork inserted. Use best quality cork only.

(5) Cool flask by running cold water over lower end of extraction flask, if flask is very hot. This is not ordinarily necessary.

(6) Add 25 c.c. ethyl ether. Insert corks, shake vigorously until all butter is dissolved out of boat. Then add 25 c.c. petroleum ether and repeat operation.

(7) Centrifuge flasks, turning handle thirty turns after centrifuge has reached a speed of about 600 R. P. M.

(8) Pour off extractions into proper weighed 3½-inch aluminum dishes. Repeat above extraction, adding first alcohol, then 25 c.c. of each ether. Excepting for very accurate work a third extraction is not necessary.

The second extraction will remove all but .10 to .15 per cent of the butter fat. For factory control work this would be a good margin of safety.

(9) Evaporate off ether at 135 degrees C. on "fat plate," and when all of ether is off, dry fat in fat oven held at 135 degrees C. for five minutes after the vacuum has reached at least twenty-two inches.

(10) Cool, weigh and calculate per cent butter fat.

TOTAL SOLIDS DETERMINATION

(1) Use .3000 gram sample. Add 2 c.c. distilled water to the sample in this dish. Mix milk powder and water thoroughly with the blunt rod.

(2) Continue the determination as under evaporated milk, but continue heating in the vacuum oven for twenty minutes.

LIST OF PRECAUTIONS TO OBSERVE IN OPERATING MOJONNIER TESTER

(1) Before the reagents are put into the cans be sure that the cans are thoroughly cleaned by washing all parts first with warm water, then alcohol and then ether. Every third or fourth time cans are filled, empty out last portion of reagents and use for cleaning purposes.

(2) The bottom of all dishes should be kept as flat as possible. Any bulging may be worked out by resting dishes upon marble plate in front of balance, rubbing entire bottom surface with thumbs. Operator should observe this every time dishes are cleaned. This is very important.

(3) The calcium chloride in the coolers should be changed every three or four weeks. The same calcium chloride may be used over and over by drying the used calcium chloride in the tin dishes placed upon hot plates held at 135 degrees centigrade for at least 5 hours.

(4) The bottles should be whirled in the centrifuge until the ether extraction is perfectly clear. About 30 turns at a normal speed is to be recommended. For sweetened condensed milk this time must be doubled.

(5) Be sure to keep extraction flasks perfectly clean. Wash often with sulphuric acid and washing powder, if necessary. If particles cling to the sides put in small shot, washing powder, and hot water and shake thoroughly.

(6) Keep temperature regulated as nearly to standard temperature as possible.

(7) Never pour off extraction into a hot dish. Remove dish from plate before second extraction is run into dish.

(8) Be careful to pour off ether into dishes slowly at first and gradually increase stream until full stream is running.

(9) In using weighing pipettes make sure that neck of flask is free from water when pipette is inserted.

(10) Always use clean and dried pipettes.

(11) If the samples for solids have to stand for any length of time add the water just as soon as they are measured out, otherwise there is a tendency to dry and a good mixture with the water cannot be obtained. Keep dishes upon marble plate beside the balance, and not on hot plate support.

(12) Redistill ether and petroleum ether, unless they are known to be pure. This is unnecessary if these are bought from a reliable firm.

(13) Make sure that water is always running through cooling plate. Watch pipe back of cooler. If tester is located in cold room in winter add a gallon of denatured alcohol to tank to prevent freezing.

(14) Always aim to weigh empty dishes just before you are ready to use them. It is not advisable to weigh them a long time before they are used.

(15) It is fundamentally important to see that weights are read and posted rightly. Operator should keep his weights in systematic order upon balance pan. When a reading is taken it should be checked at least three times. *Learn to make weighings absolutely right.*

(16) Every operator should from time to time have a sample checked by a thoroughly reliable laboratory.

If results on fat are high as compared with check results, the cause may be one of the following:

(a) Not keeping bottom of dishes flat.

(b) Improper shaking and centrifuging shown by non-fatty residue in dish.

(c) Improper reagents (if in doubt run test upon reagents substituting water for milk).

(d) Temperature in fat oven too low.

(e) Dirt has gotten into dish after ether was poured into it.

(f) Improper reading or posting of weights. Weights have lost weight from use.

If results on fat are low as compared with check results the cause may be one of the following:

(a) Leaky corks. Use best corks obtainable.

(b) Insufficient shaking.

(c) Adding too much water.

(d) Having dividing line too low, so that too much ether is left behind. If such is the case add distilled water to bring line to the proper height or make a third extraction.

(e) Too high temperature in vacuum oven.

(f) Not having water running through cooler. Tank must be kept filled.

(g) Improper reading or posting of weights.

If results on total solids are too high, as compared to check results the cause may be one of the following:

(1) Bottoms of dishes are not kept flat.

(2) Evaporation upon solids plate has not been carried far enough. Be sure to manipulate dish so that vigorous boiling takes place upon the entire surface of the bottom of the dish. Do not remove dish until all visible moisture is off or until first trace of brown coloration appears.

(3) Improper reading or recording of weights. Weights have lost weight from use.

(4) Dirt has fallen into dish after sample has been weighed into it.

(5) Temperature in vacuum oven is too low.

(6) Vacuum is not up to standard.

If results on total solids are too low, the cause may be one of the following:

(1) Sample is browned too much upon outside hot plate.

(2) Temperature in vacuum oven is above 105 degrees C.

(3) Milk spattered from dish. This will not happen if temperature is kept at 180 degrees C.

(4) Improper reading or recording of weights.

(5) Water is not running through cooler.

CHAPTER XXXIII.

DETECTION OF ADULTERANTS AND PRESERVATIVES IN MILK

Addition of Water and Skim Milk and the Removal of Cream

FREQUENCY OF ADULTERATION.—Experience has shown that where milk is received from a large number of patrons, as is the case in most milk condensing factories, some of the milk may be and frequently is being tampered with before it reaches the factory. In the case of condenseries buying and paying for the milk on the butter fat basis, neither the watering nor the skimming of the milk results in any material direct loss to the factory. Excessive skimming, however, does reduce the yield of the finished product somewhat, inasmuch as a small amount of solids is removed with the cream. Excessive watering necessitates the expenditure of slightly more fuel to remove the extraneous water in the process of evaporation.

Where the condensery buys and pays for its milk by the hundred weight, however, it is obviously essential that such adulterations be guarded against by eternal vigilance.

TAKING AND PRESERVING OF THE SAMPLE.—In order to minimize the work of testing without interfering with the effectiveness of the control, it is advisable to take composite samples. Use pint jars with tight lids; label the jars with the number of the respective patron and place them in numerical order on conveniently located shelves on the receiving platform. In the case of the route system of receiving milk, the samples of milk from each route should be stored together. Use a dipper holding one ounce of milk; by pouring a dipperful of milk of each patron each day into the respective jars, enough milk is collected in each jar at the end of two weeks to test with the lactometer and the Babcock tester every two weeks.

In order to preserve the samples in proper condition drop a large corrosive sublimate tablet into each empty jar and after each addition of milk, mix the corrosive sublimate with the milk by giving the jar a rotary motion. Add one dipperful of each patron's milk daily into the jars.

TESTING THE COMPOSITE SAMPLES.—At the end of every two weeks test the samples with the Quevenne lactometer and the Babcock test. The samples should have a temperature of 55 to 65 degrees F. In summer and at any other time when the temperature naturally is much higher or lower, place the sample jars into a tank or tub of water at the desired temperature, from one-half hour to an hour before testing. For directions for the use of the lactometer and the Babcock tester, see "Milk," Chapter XXXI, page 262. If the milk contains corrosive sublimate, deduct one-half point from the lactometer reading for each tablet in one pint of sample.

INTERPRETATION OF RESULTS.—The lactometer reading and the per cent fat alone furnish a pretty safe index to the freedom from, or presence of adulteration of the milk. From these two factors other guides, such as the specific gravity, per cent of total solids and per cent of solids not fat of milk, and specific gravity of the milk solids may be calculated. These are of additional assistance to the inspector. All of these factors vary considerably with the individuality, breed, period of lactation and feed of the cows, so that considerable latitude must be allowed in determining whether or not any given sample of milk has been adulterated. These variations are greatest between individual cows and between different breeds, but they also are quite striking in milk of the same cows from day to day and at different stages of the period of lactation. In mixed herd milk, such as the condensery largely receives, the composition is comparatively uniform on consecutive days. Whenever possible, in the case of suspicious milk received at the factory, samples should be secured direct from the stable for comparison.

The following may be considered reasonable limits of composition beyond which normal milk seldom trespasses, and milk not falling within these limits may be regarded with suspicion.

	Minimum	Maximum	Average
Per Cent Fat.	2.5		4
Specific gravity of milk	1.029	1.034	1.032
Per cent total solids	11.50		12.3
Per cent solids not fat	7.75	9.25	8.5
Specific gravity of milk solids	1.25	1.36	1.33

These factors are affected by the skimming and watering of milk as follows:

Cream removed or skim milk added	Fat *low* Specific gravity of milk *high* Total solids *low* Solids not fat *high* Specific gravity of milk solids *high*
Water added	Fat *normal* or *low* Specific gravity of milk *low* Total solids *low* Solids not fat *low* Specific gravity of milk solids *normal*
Cream removed and water added	Fat *low* Specific gravity of milk *normal* Total solids *low* Solids not fat *low* or *normal* Specific gravity of milk solids *normal* or *high*

The total solids are determined by the formula:

$$\frac{L}{4} + 1.2 \times f.$$

The solids not fat are determined by the formula

$$\frac{L}{4} + .2 \times f$$

The specific gravity of the milk solids is determined by the formula

$$\frac{t}{\dfrac{t - 100s - 100}{s}}$$

L = Quevenne lactometer reading at 60 degrees F.; f = per cent fat; t = total solids; s = specific gravity of milk.

Example of milk that is normal.—Quevenne lactometer reading at 60 degrees F. 32, fat 4 per cent.

Answer:

Specific gravity of the milk = 1.032

Total solids $\frac{32}{4} + 1.2 \times 4 = 12.8$ per cent.

Solids not fat $\frac{32}{4} + .2 \times 4 = 8.8$ per cent.

Specific gravity of milk solids

$$\frac{12.8}{12.8 - \frac{100 \times 1.032 - 100}{1.032}} = 1.32$$

Example of milk to which water has been added.—Quevenne lactometer reading at 60 degrees F. 26, fat 3.8 per cent.

Answer:

Specific gravity of milk = 1.026

Total solids $\frac{26}{4} + 1.2 \times 3.8 = 11.06$ per cent.

Solids not fat $\frac{26}{4} + .2 \times 3.8 = 7.26$ per cent.

Specific gravity of milk solids

$$\frac{11.06}{11.06 - \frac{100 \times 1.026 - 100}{1.026}} = 1.295$$

Example of milk from which cream was removed or to which skimmed milk was added.—Quevenne lactometer reading at 60 degrees F. 35, fat 2 per cent.

Answer:

Specific gravity of milk $= 1.035$

Total solids $\frac{35}{4} + 1.2 \times 2 = 11.15$ per cent.

Solids not fat $\frac{35}{4} + .2 \times 2 = 9.15$ per cent.

Specific gravity of milk solids

$$\frac{11.15}{11.15 - \frac{100 \times 1.035 - 100}{1.035}} = 1.446$$

Example of milk from which cream was removed and to which water was added.—Quevenne lactometer reading at 60 degrees F. 32, fat 2 per cent.

Specific gravity of milk $= 1.032$

Total solids $\frac{32}{4} + 1.2 \times 2 = 10.4$ per cent.

Solids not fat $\frac{32}{4} + .2 \times 2 = 8.4$ per cent.

Specific gravity of milk solids

$$\frac{10.4}{10.4 - \frac{100 \times 1.032 - 100}{1.032}} = 1.425 \text{ per cent.}$$

Determination of Added Water by the Acetic Serum—the Sour Serum—and the Copper Serum Methods[1]

ACETIC SERUM.—TENTATIVE

"(*a*) *Zeiss immersion refractometer reading.*—To 100 c.c. of milk at a temperature of about 20° C. add 2 c.c. of 25 per cent acetic acid (sp. gr. 1.035) in a beaker and heat the mixture, covered with a watch glass, in a water bath for twenty minutes at a temperature of 70° C. Place the beaker on ice water for ten minutes and separate the curd from the serum by filtering through a 12.5 cm.. folded filter. Transfer about 35 c.c. of the serum to one of the beakers that accompanies the control-temperature bath used in connection with the Zeiss immersion refractometer, and take the refractometer reading at exactly 20° C., using a thermometer graduated to tenths of a degree. A reading below 39 indicates added water; between 39 and 40, the addition of water is suspected.

(*b*) *Ash.*—Transfer 25 c.c. of the serum to a flat-bottomed platinum dish and evaporate to dryness on a water bath. Then heat over a low flame (to avoid spattering) until the contents are thoroughly charred, place the dish in an electric muffle, preferably with pyrometer attached, and ignite to a white ash at a temperature not greater than 500° C. (900° F.). Cool and weigh. Express the result as grams per 100 c.c. Results below 0.715 gram per 100 c.c. indicate added water. Multiply by the factor 1.021 (dilution of the acetic serum being 2 per cent) to obtain the result on the sour serum ash.

SOUR SERUM.—TENTATIVE

"(*a*) *Zeiss immersion refractometer reading.*—Allow the milk to sour spontaneously, filter and determine the immersion refractometer reading of the clear serum at 20° C. A reading below 38.3 indicates added water.

(*b*) *Ash.*—Determine the ash in 25 c.c. of the serum, obtained in (*a*), as directed in (*b*). Results below 0.730 gram per 100 c.c. indicate added water.

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[1] Journal of the Asso. of Official Agr. Chemists, Vol II., No. 8, Nov. 15, 1916.

ZEISS REFRACTOMETER READING OF COPPER SERUM. TENTATIVE

"To one volume of copper-sulphate solution (72.5 grams of copper sulphate per liter, adjusted if necessary to read 36 at 20° C. on the scale of the Zeiss immersion refractometer, or, to a specific gravity of 1.0443 at $\frac{20° C.}{4}$) add four volumes of milk. Shake well and filter. Determine the Zeiss refractometer reading of the clear serum at 20° C. A reading below 36 indicates added water.

(In conjunction with the copper, acetic or sour serum refraction method, the determination of the ash of the sour serum or of the acetic serum should be made in all cases where the indices of refraction fall below the minimum limit so as to eliminate all possibility of abnormal milk.)"

DETECTION OF ARTIFICIAL COLORING [1]

Leach's Method

"Warm about 150 c.c. of milk in a casserole over the flame and add about 5 c.c. of acetic acid, after which slowly continue the heating nearly to the boiling point while stirring. Gather the curd, when possible, into one mass by the stirring rod, and pour off the whey. If the curd breaks up into small flakes separate from the whey by straining through a sieve or colander. Press the curd free from adhering liquid, transfer to a small flask, and macerate for several hours (preferably over night) in about 50 c.c. of ether, the flask being tightly corked and shaken at intervals.

1. "DETECTION OF ANNATO (IN THE ETHER EXTRACT)

"Decant the ether extract as obtained above into an evaporating dish, place on the water bath, and evaporate the ether. Make the fatty residue alkaline with sodium hydroxid, and pour upon a very small wet filter while still warm. After the solution has passed through, wash the fat from the filter with a stream of water and dry the paper. If, after drying, the paper is colored orange, the presence of annatto is indicated. Confirm by applying a drop of stannous chlorid solution, which, in presence of annatto, produces a characteristic pink on the orange-colored paper.

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[1] United States Department of Agriculture, Bureau of Chemistry, Bulletin No. 107.

2. "DETECTION OF ANILIN ORANGE (IN THE CURD)

"The curd of an uncolored milk is perfectly white after complete extraction with ether, as is also that of a milk colored with annatto.

"If the extracted fat-free curd is distinctly dyed an orange or yellowish color, anilin orange is indicated. To confirm the presence of this color, treat a lump of the fat-free curd in a test tube with a little strong hydrochloric acid. If the curd immediately turns pink, the presence of anilin orange is assured.

3. "DETECTION OF CARAMEL (IN THE CURD)

"If the fat-free curd is colored a dull brown, caramel is to be suspected. Shake a lump of the curd, as in (2), with strong hydrochloric acid in a test tube and heat gently. In the presence of caramel the acid solution will gradually turn a deep blue, as will also the white, fat-free curd of an uncolored milk, while the curd itself does not change color. It is only when this blue coloration of the acid occurs in connection with a brown colored curd, which itself does not change color, that caramel is to be suspected, as distinguished from the pink coloration produced at once under similar conditions by anilin orange."

4. "LYTHGOE'S TEST FOR ANILIN ORANGE

"Treat about 10 c.c. of the milk with an equal volume of hydrochloric acid (sp. gr. 1.20) in a porcelain casserole and give the dish a slight rotary-motion. If an appreciable amount of anilin orange is present, a pink color will at once be imparted to the curd particles as they separate."

Detection of Sucrose in Milk to Which Sucrate of Lime[1] (Viscogen) Has Been Added

25 c.c. of milk or cream are shaken in a small Erlenmeyer flask with 10 c.c. of a 5 per cent solution of uranium acetate, allowed to stand for five minutes and filtered through a folded filter. If the filtrate is not clear, pour through filter again until clear. To 10 c.c. of the filtrate 2 c.c. of a cold saturated solution of ammonium molybdate and 8 c.c. of hydrochloric acid (one part of 25 per cent acid to seven parts of water) are added. The mixture is shaken

[1] Barthel, Milk and Dairy Products.

and placed in a water bath at 80 degrees C. for five minutes. In the case of the presence of sucrose the solution becomes more or less blue according to amount of sucrose present. Upon standing in the water bath for a longer time the blue color becomes deeper. At the end of ten minutes it is deep blue, while in the absence of sucrose at the end of five minutes the color is faintly green, which deepens, but never acquires a blue shade. By means of this method as little as .05 per cent sucrose can be detected.

Detection of Lime in Milk[1]

Shake 250 c.c. of milk at 15 degrees C. with 10 c.c. of a 10 per cent solution of hydrochloric acid. Let stand at room temperature for half an hour. Filter, returning the first portion of filtrate to the filter. Cover filter to prevent evaporation.

Pour 104 c.c. of the filtrate (equal to 100 c.c. of milk) into a 200 c.c. flask, add 10 c.c. of a 10 per cent solution of ammonia and fill the flask to the mark with water at 15 degrees C. Let stand for thirty minutes. Filter through folded filter, pouring back on the filter the first portion of the filtrate. Test 100 c.c. of filtrate (equivalent to 50 c.c. of milk) with 10 c.c. of 5 per cent ammonium oxalate solution and proceed with the determination of the lime in the usual way, but without warming the liquid.

According to Baier and Neumann and corroborated by Luhrig, in normal milk the lime in the serum is present to the extent of thirteen to eighteen milligrams per 100 c.c. In milk to which sucrate of lime has been added the results are correspondingly higher.

Detection of Gelatin[2]

"Prepare an acid solution of mercuric nitrate by dissolving mercury in twice its weight of nitric acid of 1.42 specific gravity, and diluting this solution to twenty-five times its bulk with water. To 10 c.c. of the milk or cream to be examined, add an equal volume of the acid mercuric nitrate solution, shake the mixture, add 20 c.c. of water, shake again, allow to stand five minutes, and filter. If much gelatin is present the filtrate will be opalescent and cannot be obtained quite clear. To a portion of the filtrate contained in a test

[1] Barthel, Milk and Dairy Products.

[2] United States Department of Agriculture, Bureau of Chemistry, Bulletin 107, 1912.

tube, add an equal volume of a saturated aqueous solution of picric acid. A yellow precipitate will be produced in presence of any considerable amount of gelatin, while smaller amounts will be indicated by a cloudiness. In the absence of gelatin the filtrate obtained will remain perfectly clear."

Detection of Preservatives

CARBONATE OR BICARBONATE OF SODA[1] (HILGER'S METHOD)

Dilute 50 c.c. of milk with 250 c.c. of water. Heat and precipitate with a small quantity of alcohol. Filter, evaporate the filtrate to one-half its original volume and test with litmus for an alkaline carbonate.

FORMALDEHYDE (HEHNER'S METHOD)

Dilute the milk with an equal volume of water. Fill a test tube one-half full. Add commercial sulphuric acid, specific gravity 1.82-1.84. The acid should be allowed to flow down the side of the tube so as to avoid excessive mixing of acid and milk. If formaldehyde is present a violet ring forms at the junction of milk and acid. By this test the presence of one part of formaldehyde in two hundred thousand parts of milk can be detected. When more than .05 per cent formaldehyde is present the violet color does not appear.

The same color reaction is obtained when the acid is added to the milk in the Babcock test.

Farrington and Woll[2] recommend the following method: Measure 5 c.c. of milk in a white porcelain dish, add 5 c.c. of water, and 10 c.c. of hydrochloric acid containing a trace of ferric chloride (Fe_2Cl_6). Heat the mixture. If formaldehyde is present a violet color appears.

BORIC ACID AND BORATES[3]

"Render decidedly alkaline with lime water about 25 grams of the sample and evaporate to dryness on a water bath. Ignite the residue to destroy organic matter. Digest with about 15 c.c. of water, add hydrochloric acid, drop by drop, until all is dissolved, and add 1 c.c. in excess. Moisten a piece of delicate turmeric paper with the solution; if borax or boric acid is present, the paper on

[1] Barthel, Milk and Dairy Products.
[2] Farrington & Woll, Testing Milk and Its Products.
[3] United States Department of Agriculture, Bureau of Chemistry, Bulletin 107, 1912.

drying will acquire a peculiar red color, which is changed by ammonium hydroxid to a dark blue-green, but is restored by acid.

A preliminary test may be made by immersing a strip of turmeric paper in about 100 c.c. of liquid foods, to which about 7 c.c. of concentrated hydrochloric acid has been added. Solid and pasty goods may be heated with enough water to make them thoroughly fluid, hydrochloric acid added in about the proportion of 1 to 13, and tested in the same manner."

BENZOIC ACID[1]

"Add 5 c.c. of dilute hydrochloric acid to 50 c.c. of the milk in a flask and shake to curdle. Then add 150 c.c. of ether, cork the flask and shake well. Break up the emulsion which forms by aid of a centrifuge, or if the latter is not available extract the curdled milk by gently shaking with successive portions of ether, avoiding the formation of an emulsion. Transfer the ether extract (evaporated to small volume if large in bulk) to a separatory funnel and separate the benzoic acid from the fat by shaking out with dilute ammonium hydroxid, which takes out the former as ammonium benzoate. Evaporate the ammoniacal solution in a dish over the water bath till all free ammonia has disappeared, but before dryness is reached, add a few drops of ferric chlorid reagent. The characteristic flesh-colored precipitate indicates benzoic acid. Care should be taken not to add the ferric chlorid until all the ammonia has been driven off, otherwise a precipitate of ferric hydrate is formed."

SALICYLIC ACID[2]

Acidulate 20 c.c. of milk with sulphuric acid and shake with ether. Evaporate the ether solution and treat the residue with alcohol and a little iron-chloride solution; a deep violet color indicates the presence of salicylic acid.

HYDROGEN PEROXIDE[3]

(Wilkinson and Peters' Method)

Add four drops of an alcoholic solution of 4 per cent benzidine (paradiamidophenyl) and 2 drops of acetic acid to 10 c.c. of milk. If hydrogen peroxide is present the milk assumes a blue color: .005 grams of hydrogen peroxide in 100 c.c. of milk can be detected by this method.

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[1] United States Department of Agriculture, Bureau of Chemistry, Bulletin 107, 1912.
[2] Farrington & Woll, Testing Milk and Its Products.
[3] Barthel, Milk and Dairy Products.

CHAPTER XXXIV.

BACTERIOLOGICAL ANALYSES

While it is obviously beyond the scope and purpose of this volume to discuss in detail the technique of bacteriological analyses and microscopic preparations of the milk products described herein, it is deemed advisable to offer some suggestions that may serve for guidance of those who are not familiar with bacterial fermentations in condensed milk.

Sampling.—Take samples of all products contained in open receptacles, such as fluid milk, plain condensed bulk milk, barreled sweetened condensed milk and milk powder, in sterile, cotton plugged test tubes, or in small sterile glass-stoppered bottles, and keep them in a cool place, preferably not above 35 degrees F. until ready to use. Keep canned condensed milk sealed in the original package until ready to use. If already open, invert a petri dish or a beaker over the can to avoid contamination from the air.

Dilution for Numerical Counts.— Make dilutions in 250 c.c. glass-stoppered flasks. Before opening sealed cans, thoroughly wipe off the entire top with a sterile piece of cheese cloth soaked in a saturated solution of mercuric bichloride or a 5 per cent solution of carbolic acid and flame the top of the can. Open evaporated milk cans by punching a hole into its top, large enough to insert the discharge end of a graduated pipette. Open sweetened condensed milk cans with a sterile knife or a sterile can opener.

In the case of fluid milk and evaporated milk, measure with a sterile graduated pipette two cubic centimeters of the product and 198 cubic centimeters of sterile water into the 250 c.c. flask. In the case of plain condensed bulk milk, sweetened condensed milk and milk powder, use tared flasks holding about 150 cubic centimeters, weigh into them two grams of the product and add enough sterile water at a temperature of 98 degrees F. to make up 100 cubic centimeters. Use a sterile spoon or spatula to transfer the product to this flask. A wide-mouth flask is preferable.

The above represents the first dilution. The flask should be carefully shaken until a hemogeneous mixture is obtained and the soluble portions have been completely dissolved.

From this first dilution further dilutions are made in sterile water in glass-stoppered flasks, according to requirements. The dilutions should be sufficient to limit the number of colonies on the plates to about 50 to 100 per plate. Whole milk, as it arrives at the factory, usually shows from 100,000 to 1,000,000 bacteria per c.c.. Evaporated milk should be practically sterile unless the can shows signs of fermentation in which case the number of bacteria present will depend on the age of the sample can; dilutions as high as 1:1,000,000 are recommended in such cases. Plain condensed bulk milk when fresh contains from about 1,000 to 100,000 bacteria per c.c., when several days old and in the absence of refrigeration, its germ content is often much greater. Sweetened condensed milk averages from about 500 to 500,000 bacteria per c.c. The bacterial content of milk powder is variable, no approximation can here be offered.

Plating.—For plating the following media are recommended:

Media for Total Counts and also for acidifiers

4 grams beef extract
10 grams peptone
30 grams lactose
4 grams sodium chloride
12 grams thread agar
1000 c.c. distilled water
Acidity 0.1 per cent.

For acidifiers add 1 c.c. of sterile litmus solution to each plate before pouring the agar.

Media for Liquefiers

4 grams beef extract
10 grams peptone
30 grams lactose
4 grams sodium chloride
150 grams gelatin
1000 c.c. distilled water.
Acidity 0.1 per cent.

Media for Yeasts and Molds

4 grams beef extract
10 grams peptone
12 grams agar
1000 grams whey

Acidity 0.2 per cent.

Add 1 c.c. of sterile one per cent tartaric acid solution to each plate before pouring the medium over the dilution.

Incubation.—Incubate agar, litmus agar and whey agar plates at 35 degrees C. (95 degrees F.) for at least three days before making counts. Incubate gelatin plates at 21 degrees C. (70 degrees F.) for four to five days before making counts.

Making Counts.—The colonies on the plates are counted most conveniently by placing the plates over a standard counting plate. In the absence of such a plate, place the petri dish upside down on a dark surface and draw, with a blue crayon, radial lines, dividing the field into segments. For plates containing not to exceed 100 colonies eight to sixteen segments are sufficient for easy counting.

Qualitative Determinations.—Numerical counts on the four kinds of media recommended above usually furnish a fair general idea of the types of bacteria present.

For the detection of gas-producing species, nutrient bouillon containing three per cent lactose and three per cent sucrose, respectively, in fermentation tubes, or nutrient agar containing three per cent lactose and three per cent sucrose, respectively, in test tubes, are serviceable.

Cans of sweetened condensed milk that show gaseous fermentation (swell heads) are usually due to certain species of yeast, which thrive best in media containing sucrose.

Cans of evaporated milk that show gaseous fermentation (swell heads) are usually caused by anaerobic putrefactive bacteria, of which *Plectridium foetidum* is a most frequent representative, see "Blown Evaporated Milk," page 226. This type of micro-organisms requires strictly anaerobic cultural conditions. Under limited laboratory facilities the anaerobic conditions are best produced by the use of oxygen-absorbing chemicals, such as pyrogallol to which potassium hydroxide is added. Use dry commercial pyrogallol and potassium hydroxide sticks, in proportion of 1 gram pyrogallol to .7 gram potassium hydroxide, dissolved in about 2 c.c. of water.

Place 50 grams of pyrogallol into the bottom part of a large size desiccator. Have the rim of the desiccator and the corresponding rim of the cover covered with a mixture of half paraffine and half bee's wax. Pour into the pyrogallol in the desiccator 100 c.c of water and then throw in 35 grams of potassium hydroxide. Quickly insert culture tubes, or plates, and close the desiccator with the cover, turning the cover so as to secure a perfect seal. Apply three permanent screw clamps.

Anaerobic germs of the type of *Plectridium foetidum* grow best in freshly sterilized milk. In the case of *Plectridium foetidum* the milk first curdles, then digests, forming a clear yellow liquid. The digestion begins at the surface and proceeds downward. These cultures develop a most penetrating foul odor, resembling that of spoiled eggs.[1]

The technique and methods for determining the bacteriological flora with reference to cultural and morphological characteristics of individual species of microbes present, are identical to those used in the bacteriological study of milk and other similar products, and which are fully described in standard manuals on bacteriology.

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[1] For further details on the technique of Anaerobic Cultures see Hunziker Review of Existing Methods for Cultivating Anaerobic Bacteria. Journal of Applied Microscopy and Laboratory Methods, Vol. V, Nos. 3, 4, 5, 6.

LEGAL STANDARDS FOR DAIRY PRODUCTS BY STATES, 1915.*

States.	Milk.			Skim milk.	Cream.	Butter.			Whole-milk cheese.	Skimmed-milk cheese.	Condensed milk (sweetened).		Evaporated milk (unsweetened).		Ice cream (plain).		Ice cream (fruit and nut).	
	Total solids.	Solids not fat.	Fat.	Total solids.	Fat.	Fat.	Water.	Salt.	Fat.	Fat.	Total solids.	Fat.	Total solids.	Fat.	Fat.	Gelatin.	Fat.	Gelatin.
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per cent.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Alabama																		
Alaska [2]																		
Arizona [3]																		
Arkansas [1]																		
California		8.50	3.00	8.80	18.0	80.0			[4] 50.0	Half-skimmed, [4] 25.0.	24.5	7.70	25.5	7.80	10.0	0.6	8.0	0.6
Colorado			3.00		16.0	80.0	16.00			(5)	28.0	7.70	(6)	(6)	14.0		12.0	
Connecticut	11.75	8.50	3.25		16.0	(7)	(7)	(7)			28.0	[4] 31.00	(6)	(6)				
Delaware [1]																		
District of Columbia	12.50	9.00	3.50	9.30	20.0	83.0	12.00	5.00	(8)	(8)	(8)	(8)	(8)	(8)		(9)		(9)
Florida		8.50	3.25	9.25	18.0	82.5					28.0	7.70	24.0	7.80	12.0			
Georgia		8.50	3.25	9.25	18.0	82.5	16.00		(7)		(7)	(7)	(7)	(7)	12.0		10.0	
Hawaii	11.50		2.50		18.0													
Idaho	11.20	8.00	3.20	9.30	18.0	82.5	16.00		[4] 50.0		28.0	[4] 27.60	(7)	(7)	14.0	(10)	12.0	(10)
Illinois		8.50	3.00	9.25	18.0	82.5			[4] 50.0		28.0	7.70	25.5	7.70	8.0		8.0	
Indiana		8.50	3.25	9.25	18.0	82.5	16.00		[4] 50.0		34.3	7.80	25.5	7.80	8.0	.7	8.0	.7
Iowa	12.00		3.00		16.0	80.0				(11)	(7)	(7)	(7)	(7)	12.0	1.0	10.0	1.0
Kansas			3.25		18.0	80.0	16.00		[4] 50.0						14.0		12.0	
Kentucky		8.50	3.25	9.25	18.0	82.5			[4] 50.0		28.0	[4] 27.66	28.0	[4] 27.66	14.0		12.0	
Louisiana		8.50	3.50	8.00	(7)	(7)	(7)	(7)	(7)		(7)	(7)	(7)	(7)	10.0	1.0	8.0	1.0
Maine	11.75	8.50	3.25		18.0				[4] 50.0	(12)	26.5	[4] 29.50	26.5	[4] 29.50	14.0	(13)	12.0	(13)
Maryland	12.50		3.50	9.25	18.0						34.3	7.80			4.0		6.0	
Massachusetts	12.15		3.35	[14] 9.30	15.0						(15)	(15)			7.0		7.0	
Michigan	12.50		3.00		18.0	80.0			[4] 30.0	(16)	(7)	(7)	(7)	(7)	10.0	.7	8.0	.7
Minnesota	13.00	9.75	3.25		20.0		16.00		[4] 45.0	(17)	28.0	8.00	25.5	7.80	12.0		12.0	
Mississippi [7]																		
Missouri	12.00	8.75	3.25	9.25	18.0	82.5			[4] 50.0		28.0	[4] 27.67	28.0	[4] 27.67	14.0		12.0	
Montana	11.75	8.50	3.25		20.0	82.5	16.00								12.0	1.0	10.0	1.0
Nebraska			3.00		18.0										14.0		12.0	
New Hampshire	12.00			8.50	18.0	80.0	16.00		(7)		(7)	(7)	(7)	(7)	14.0	.2	14.0	.2
New Jersey	11.50		3.00	9.25	16.0	82.5			[4] 50.0									
New Mexico [1]																		
Nevada	11.75	8.50	3.25	9.25	18.0	82.5	16.00		[4] 50.0		28.0	[4] 27.50	25.5	7.80	14.0		12.0	
New York	11.50		3.00		18.0					(18)	(19)	(19)						
North Carolina	11.75	8.50	3.25	9.25	18.0	82.5			[4] 50.0		25.5	7.80	25.5	7.80	10.0		8.0	
North Dakota	12.00		3.00		15.0	(7)	(7)	(7)	(7)		(7)	(7)	(7)	(7)	14.0	(20)	12.0	(20)
Ohio	12.00		3.00						(21)		(22)	(22)						

* United States Dairy Division, Legal Standards for Dairy Products, May 1, 1916.

Oklahoma [15]																		
Oregon	11.70	8.50	3.20		18.0	80.0	16.00		30.0	(23)			32.3	7.80	12.0	1.0	9.0	1.0
Pennsylvania	12.00		3.25	(7)	18.0	(7)	(7)	(7)	32.0	(24)	(7)	(7)	(7)	(7)	8.0	.5	6.0	.5
Philippine Islands	11.75	8.50	3.25	9.25	18.0	82.5			[4] 50.0		28.0	[4] 27.50	25.5	7.80	14.0		12.0	
Porto Rico [15]																		
Rhode Island	12.00		2.50			82.5			[4] 50 0		25 0	7.80	25.0	7.80	8.0	1.0	8.0	1.0
South Carolina [1]																		
South Dakota		8.50	3.25	9.25	18.0	80.0			[4] 50.0		28.0	[4] 27.50	28.0	[4] 27.50	14.0		12.0	
Tennessee	12.00	8.50	3.50	9.00	20.0	82.5	15.99		[4] 50.0		25.5	7.80	25.5	7.80	8.0		7.0	
Texas	12.00	8.50	3.25	9.25	18.0	82.5			(7)		(7)	(7)	(7)	(7)	8.0		6.0	
Utah	12.00	8.80	3.20		18.0	80.0	16.00		30.0	(25)	(7)	(7)	(7)	(7)	(7)	(7)	(7)	(7)
Vermont	11.75	8.50	3.25	9.25	18.0	82.5			[4] 50.0		28.0	[4] 27.50	34.3	7.80	14.0		12.0	
Virginia		8.50	3.25	9.25	18.0	82.5	16.00		[4] 50.0		28.0	[4] 27.50	28.0	[4] 27.50	8.0	(23)	8.0	(23)
Washington	12.00	8.75	3.25	9.30	18.0				30.0	(26)								
West Virginia [1]																		
Wisconsin		8.50	3.00	9.00	18.0	82.5			[4] 50.0		28.0	8.00	28.0	8.00	14.0		12.0	
Wyoming [7]																		
United States		8.50	3.25	9.25	18.0	82.5	[27] 16.00		[4] 50.0		28.0	[4] 27.50	25.5	7.8	14.0		12.0	

[1] No State standards.
[2] No Territorial standards.
[3] Federal standards for all food products. Fillers in ice cream may be used if large label is displayed in all places of sale.
[4] Percentage of fat based on total solids.
[5] Must be labeled.
[6] Classed as condensed.
[7] United States standard.
[8] United States food and drugs act of 1906 applies to the District of Columbia.
[9] Should be labeled.
[10] Not allowed.
[11] Must be so branded.
[12] Defined, but no standard.
[13] Any amount if fat is maintained.

No reports gave standards for powdered milk.

[14] Solids in fat.
[15] Must correspond on stated dilution to State standards for milk.
[16] Any less than 30.
[17] All below 45.
[18] Less than 13 marked skim; 13 to 18, medium skim; 18 or over, special skim.
[19] Must correspond to 11.5 per cent solids in crude milk; one-fourth to be fat.
[20] Two ounces in 10 gallons if labeled gelatin ice cream.
[21] Full cream, 30. Standard, 21.
[22] Must correspond to 12 per cent of solids in crude milk; one-fourth to be fat.
[23] Less than 7.5, skim; 7.5 to 15, three-fourths skim; 15 to 30, half skim.
[24] Three-fourths cream, 24; one-half cream, 16; one-fourth cream, 8. Skim, less than 8.
[25] Less than 30.
[26] Less than 30; less than 15 not allowed.
[27] Less than 16. This applies to all butter made in United States territory.

INDEX

D

E

F

G

H

I

J

L

M

N

O

P

Q

R

S

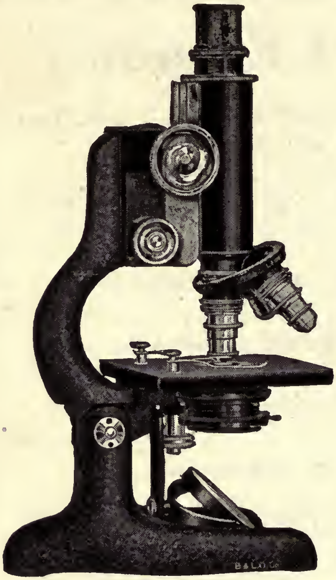
T

V

W

Y

INDEX TO ADVERTISERS



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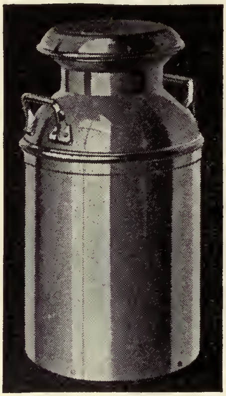
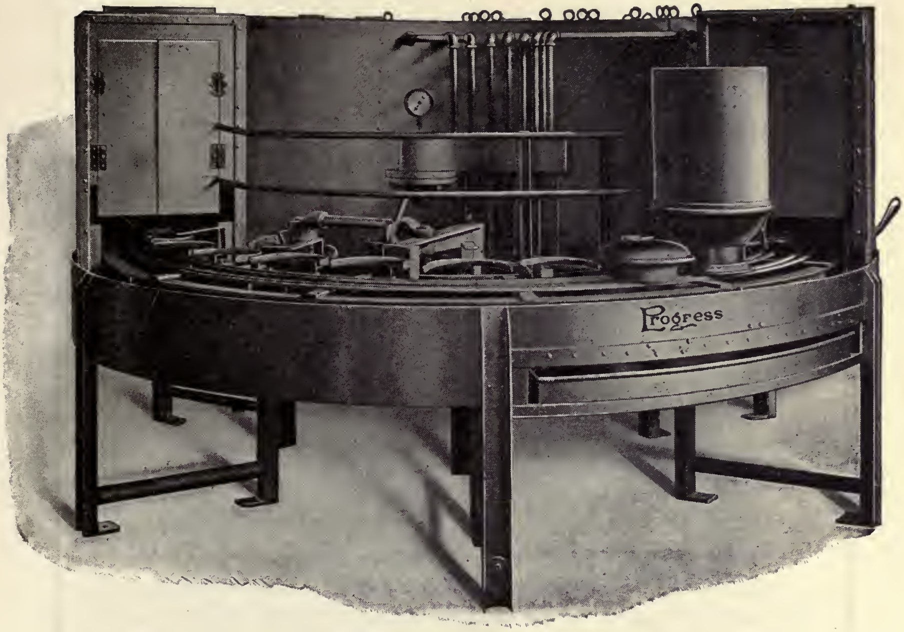


CLEVELAND

TIGER


Progress


Cream City SANITARY MILK CANS
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