INTRODUCTION.

Milk is a bulky product, expensive to transport, and very susceptible to contamination, which in a short time renders it unpalatable. In its natural state it contains about 87 per cent of water, which is a comparatively worthless constituent.

Efforts to reduce the water content of milk, leaving the solids in a more concentrated form without destroying their food value, and at the same time improving the keeping qualities, have resulted in developing the manufacture of both condensed milk and desiccated milk or milk flour. The condensing processes now used reduce the volume of milk to one-half or one-fifth its original bulk, and if the product is carefully sterilized or preserved with cane sugar and sealed in air-tight containers it becomes easily transportable and keeps for long periods in any climate.

The desiccating processes now perfected remove practically all the water in milk, leaving a dry powder soluble in water. In the manufacture of this product whole milk is reduced to about one-eighth, and skimmed milk to about one-eleventh the original volume. By this means the volume is reduced to a minimum, and the keeping quality, particularly of dried skim milk, is superior.

CONDENSED MILK.

Removing a portion of the water from milk, leaving a product of good keeping quality which may be restored to its normal consistency without injuring its natural flavor, is a problem that has been studied for many years. It is claimed that during the first half of the last century foreign inventors evaporated a part of the water from milk, and, with the addition of cane sugar, made what was then known as condensed milk (see Scientific American, export edition, July, 1905). The early patents of De Heine (1810), Newton (1835), and Grimwade (1847) show that much attention was given to the subject before the present generation was born. The successful manufacture of condensed milk on a commercial basis, however, dates from 1856,
when Gail Borden, who has been called the father of the condensed-milk industry, built the first milk-condensing factory at Wolcottville, Conn.

During the last 25 years great strides have been made toward perfecting various processes for successfully producing condensed and evaporated milks. The industry is no longer in its experimental stage, but has reached a point where, with proper equipment and skilled operators, there is no uncertainty about obtaining a satisfactory product. During this time the industry has attained vast proportions, and there are now in this country over 300 milk-condensing plants, located in 24 States, and representing an investment of over $15,000,000 in buildings and equipment. These plants have a capacity of over 15,000,000 pounds of milk daily. Census reports show that the value of condensed milk made in the United States during the year 1909 was $33,563,129, and that during the period from 1880 to 1905 the production of condensed milk increased 1,202 per cent.

The term "condensed milk" is generally applied to milk from which a portion of the water has been removed, thus reducing its bulk and weight, and increasing its density and percentage of solids. It is made from whole milk or from partially or wholly skimmed milk, according to the use for which it is intended. In trade circles, however, the term "condensed milk" is applied to milk that is concentrated and preserved with cane sugar. The term "plain condensed milk" is applied to milk that is concentrated and sold in bulk without being sterilized or preserved with sugar, and the term "evaporated milk" is applied to milk concentrated and preserved in cans by sterilization. Evaporated milk contains nothing but normal milk reduced to about one-half of its original bulk, while the sweetened condensed milk contains fully one-third cane sugar. Evaporated milk has, to a large extent, taken the place of sweetened condensed milk.

Before the pure-food laws prohibiting misbranding were in force, unsweetened concentrated milk was frequently labeled "Evaporated cream," but as the product was made from milk and sometimes from skim milk, it was plainly a violation of such laws, and the practice was finally discontinued.

Besides evaporated milk put up in cans, large quantities of plain condensed milk made from skimmed or partially skimmed milk are manufactured. The keeping qualities of this class of goods are about equal to those of pasteurized milk or cream and range from a few days to a week or two, depending on the temperature at which it is held. This product is usually shipped in 40-quart milk cans and is used largely by confectioners and ice-cream manufacturers.

To produce a condensed milk of good flavor and keeping quality the milk to be treated must be of a superior grade. This is so
important that the large concerns engaged in the business employ trained men to examine the herds and ascertain that there are no diseased cows, that the stables and surroundings are in good sanitary condition, that the attendants who do the work are healthy and cleanly attired, and that the milk is properly cared for and cooled before it is delivered to the condensery.

To make doubly sure that the quality of the milk received is right, an expert, with a keen sense of taste, inspects every can of milk received, and if any unnatural flavor is detected the can of milk is rejected and returned to the producer. This extreme care is absolutely necessary, because any objectionable flavor becomes intensified and can not be eliminated during the various processes to which the milk in subjected. Milk is usually condensed in a vacuum pan, although a few concerns concentrate milk in an open pan in the following manner: The milk is run through a centrifugal separator and the cream removed. The skim milk is then pasteurized and run into rectangular vats provided with several pipes by means of which air is forced through the milk by a blower. During the process the skim milk is held at about 140° F., and the air, which is often heated by passing over steam coils, carries off the moisture in the milk, thus reducing its volume to the required consistency, usually about 4 to 1. After being thus treated it is known as concentrated skim milk. If concentrated whole milk is desired the cream which has been pasteurized is restored and emulsified in an agitator.

The equipment of a condensing plant using a vacuum pan depends upon the kind of product made, although the process used and the machinery required are similar for all condensed-milk products.

For the manufacture of “plain condensed milk” the equipment consists of a boiler, engine, scales and weigh can, receiving vats, milk heater, hot wells, vacuum pan and condenser, vacuum pump, cooling tank, and cans. If skimmed milk is condensed, a separator is necessary, as well as vats, pasteurizers, and coolers for handling the cream.

In the manufacture of sugared condensed milk the same equipment is necessary as for plain condensed milk, and in addition a tank is sometimes provided for dissolving sugar before adding it to the milk in the vacuum pan. If the product is put up in cans, machines for filling and sealing cans are necessary, also for making cans when they are not purchased from outside can manufacturers.

For making evaporated milk an equipment similar to that used in the manufacture of plain condensed milk is required, except that a tubular cooler is used for cooling the product instead of the cooling tank, and machinery for filling and sealing cans is also required; also a device for sterilizing the product in the cans, and a shaker for violently shaking the filled cans after sterilization.
A late innovation in equipping a milk condensery is the homogenizer. Difficulty is sometimes experienced by those engaged in producing evaporated milk in preventing a separation of the solids after it has been kept for a time, the lighter solids going to the top and the heavier ones to the bottom. As homogenizing normal milk prevents (partially at least) cream from rising, it is claimed that it will have a like effect on milk to be evaporated.

The granulation of the milk sugar, which gives evaporated milk the appearance of containing some kind of an objectionable grit, is also said by some to be overcome by the use of a homogenizer. This machine, however, has not been in use sufficiently long definitely to determine its value for the purposes mentioned.

The equipment of condenseries is quite uniform, but considerable variation is noted in operating, especially in the temperatures used. It is evident that no hard and fast rules can be laid down to follow under varying conditions. The following description of the process used in making the different grades of condensed milk and the cost of equipping was contributed by a gentleman who has had extensive practical experience in its manufacture and in manufacturing and installing such machinery, and probably is as nearly correct as can be obtained:

"Plain condensed milk" is made from whole milk, from part whole and part skimmed milk, and from skimmed milk. To get the desired density it is necessary to condense the whole milk 3 to 1 and the skimmed milk about 4 to 1.

The milk to be condensed is put into hot wells and heated with steam to a temperature of 150° to 156°. It is then drawn into the vacuum pan and condensed, if whole milk, to 10° Baumé, and if skimmed milk to 14° Baumé. As soon as the desired density is reached the milk is then superheated by blowing steam into the milk in the vacuum pan until the milk becomes thick. The temperatures used in this process vary from 175° to 200°.

As soon as the milk is sufficiently thick the steam is shut off and water is run into the condenser to secure the proper consistency. The vacuum pump is then started slowly, and the vacuum drawn up to about 26 inches. The vacuum is then released, and the milk is drawn into 10-gallon cans and placed in the cooling tank and cooled to 36° or 38° F. by first cooling as cold as possible with water and then shutting off the flow of water to the cooling tank and turning the brine or ammonia through the coils in the side of the cooling tank.

Sugared milk to be put up in cans is made from whole milk and is condensed 4 to 1 and 1 pound of sugar added to each 3 quarts of milk condensed. The milk is heated in the hot wells as hot as possible by steam blown into the milk through a heater head. It is then drawn into the vacuum pan and condensed. There are different methods used in adding the sugar to the milk. Some manufacturers have a separate tank, where the sugar is dissolved either in hot milk or hot distilled water, and the sirup so made drawn into the vacuum pan gradually with the fresh milk; others draw nearly all the milk into the vacuum pan and dissolve the sugar in the hot wells in the milk left there for that purpose. It is then drawn into the vacuum pan after the milk is condensed.

Sugared condensed milk to be sold in bulk is made from part or all skimmed milk in the same way as the canned goods, except that 1 pound of sugar is added for each 4 quarts of skimmed milk to be condensed. This class of goods
Evaporated milk is made from whole milk and is heated in the hot wells the same as for sugared condensed milk. This milk is condensed in the vacuum pan until it has the required percentage of solids and butter fat desired by the manufacturer. After the milk is condensed it is run over a pipe cooler and cooled to about 60° and is then put into small cans and sealed. As soon as it is sealed it is put into the sterilizer and heated to about 240°. While in the sterilizer the milk is kept in motion, so that the contents of the cans will be heated through evenly. The time required depends upon the size of the cans and the condition of the milk and varies from 18 to 45 minutes. As soon as the milk is sterilized it is immediately cooled in the sterilizer, and when cold it is removed from the sterilizer and shaken in a shaker until it is smooth.

A small condensed-milk plant for making plain and bulk-sugared condensed milk with a capacity to condense 10,000 pounds of milk a day can be built complete for about $7,500; a 20,000-pound capacity plant will cost about $13,000, and a 40,000-pound capacity plant will cost about $20,000. The above estimate is based upon complete equipment and plain but substantial building.

The cost of the plant to make canned goods depends largely on how completely it is equipped and whether the cans are manufactured in the plant or purchased from some can-manufacturing company. The cost of canned-goods plants ranges from $20,000 to $200,000, depending on the size and style of the equipment and building. It is not practical to make canned goods where the milk supply is less than 15,000 pounds per day.

MARKETS.

The market at the present time is mainly with bakers and confectioners, but when the nutritious properties and keeping qualities of dry milk are better known it may become a household article of common use.
In May, 1911, there were 10 factories engaged in desiccating milk in the United States, located in five States, namely, Vermont, New Jersey, New York, Michigan, and California. The amount of milk powder produced in the calendar year 1910 by the various plants in the country was approximately 8,500,000 pounds. The capacity of the plants then in operation was 891,000 pounds of liquid milk per day of 10 hours, or 325,215,000 pounds per year. Assuming the yield of dry milk to be at the rate of 9 pounds to 100 pounds liquid milk, the yearly capacity of dry milk for the plants then in operation was 29,269,350 pounds.

MACHINERY.

The machinery for drying milk is specially constructed for the purpose under various patents, and is therefore, expensive. Factories are often equipped with apparatus made by mechanics in the vicinity of the plant, although there are manufacturers who make such machinery on order. The various systems are generally protected by patents, and already more than 60 patents have been issued covering devices for making this product.

PROCESSES.

Drying milk from which the fat has been removed seems to be a success. It converts a wholesome and nutritious article of food into a condensed form, convenient to handle and transport, and ready at all times and under any circumstances for immediate use whenever and wherever wanted. Milk is changed by the drying process from a quickly perishable, bulky, and inconvenient substance to transport into a product requiring comparatively little space, and its keeping qualities are practically unlimited.

Probably over 90 per cent of the milk powder produced at the present time is made of skim milk. From 100 pounds of whole milk of average quality 3.5 pounds of butter fat and 9 pounds of dry skim milk can be secured. Dry skim milk powder has the appearance of ordinary flour made from grain. It absorbs moisture readily, which must be avoided by using containers that are as nearly as possible air tight and moisture proof and by storing in cool, dry places. This grade of dry milk possesses in a condensed form all the valuable properties of fresh sweet skim milk. It can be used in the dry form by bakers and confectioners, or, if desired, it can be converted back to its original liquid state by adding the amount of water that has been extracted from it. In drying whole milk more difficulties are encountered. The keeping qualities of dry whole milk
are not equal to those of skim milk. The fatty part has a tendency to become rancid, and, where rancidity does not develop, when some months old it loses its freshness and lacks the fine flavor of fresh milk; at least such has been the case with samples tested under the writer’s observation. Its keeping qualities are superior to those of liquid milk, however, and it is a very desirable substitute when fresh milk can not be obtained.

Besides milk powder from whole milk and from skim milk, there are upon the markets intermediate grades, frequently sold under coined names. It may be well to state that dry whole milk of average quality contains about 27 per cent fat, varying somewhat according to the richness of the milk. In some instances whole milk reinforced with cream has been dried which contains from 30 to 40 per cent butter fat.

Two distinct methods of drying milk are in use, from which several systems have been evolved. In one method the milk, in the form of a spray, is forced into a chamber of hot air, with an air current driving the dry particles against a screen, which arrests the solid portions and allows the air to pass on. A more general device is the heated cylinder, to which milk is caused to adhere in a film, quickly drying, and, as the cylinders revolve, the dried matter is scraped off in sheets or ribbons. These are collected and, if necessary, further dried and then reduced to a fine powder. In most instances the milk is partially condensed in a vacuum pan before entering the drying machine.

The following extracts from authorized descriptions of some of the various systems in use will give a general idea of the modification of the two methods above described:

**EKENBERG SYSTEM.**

As the milk is received at the factory it is filtered through cotton as it passes to the receiving vat. From this vat the milk passes directly through a heater, where the temperature is raised to 90° F., and without stopping in its flow it passes to a battery of separators, which remove the butter fat and at the same time further clarify the milk. The cream from the separators passes to a pasteurizer, which not only heats but promptly cools again. The cream is at once run into cans and placed in cork-insulated pools, which are cooled to a low temperature by brine coils supplied by an artificial ice plant. The cream is later taken from the pools and reunited with the separated milk for the higher grades of powdered milk. The separator milk flows directly to a pasteurizer and, after being reduced to a low temperature, flows at once to an insulated tank, from which it is drawn directly to the exsiccators. The exsiccator
is the name given to the machine invented by Dr. Martin Ekenberg for the purpose of removing the water content of milk and other liquids. It is not necessary to go into the minor details of the construction of this machine, and it would be difficult to do so, as some of its parts are exceedingly complicated. Briefly, however, it consists of a large vacuum chamber in which is hung a milk cylinder which nearly fills the vacuum chamber. This cylinder is supported at its axes by trunnions, one of which extends outside of the chamber, providing a means to revolve the cylinder. Connected with the vacuum chamber and in front of it is another chamber, also under vacuum. This chamber is known as the products chamber, and is separated from the vacuum chamber by a series of gates, the use of which permits the maintenance of a constant vacuum in the vacuum chamber and the opening from time to time of the products chamber.

There is also attached to the vacuum chamber a milk chamber which is constantly under vacuum, and into which the milk is drawn from the outside. Another important part of the apparatus is a specially constructed condenser to which is attached the suction pipe of a large vacuum pump, and this is also provided with a large stream of water, which, passing constantly through the condenser, cools the vapors, reducing them to water, which is carried away.

To the milk chamber is attached a pump which forces the milk through a spray pipe on to the revolving cylinder. The cylinder is heated slightly by exhaust steam, and on account of the high vacuum the thin layer which is deposited by the spray pipe upon the cylinder is quickly dried upon the surface of the cylinder, and a series of silver knives removes this film of dried milk. It passes directly into the products chamber, and by manipulating the gates it may be removed from the products chamber without the loss of the vacuum in the remainder of the apparatus.

The temperature of the milk at no time has thus far gone above 120° F., and in fact it rarely exceeds 110° F.

When the dried film of milk reaches the outside air it is slightly moist and flexible, and in order to crystallize the lactose or milk sugar which comprises from one-third to one-half the total weight of the dried milk it is necessary to place the product in a heated chamber at 90° F. from 20 minutes to an hour.

When removed from the drying chamber the product is in the form of dry, crisp chips and ribbons as thin as paper and as brittle as a wax wafer. It is then reduced to a very fine powder by specially constructed mills, which grind without heating or in any way injuring the delicate elements of which the milk is composed. As the milk powder comes from the mill it is packed ready for the consumer.
Robert Stauf, of Posen, Germany, devised a process for producing dry powders from blood, milk, etc., by atomizing these liquids into supplementary regulated currents of heated air. The amount of air and heat supplied was sufficient to completely absorb and vaporize the moisture of the liquid and the resulting dry powder was separated from the moisture-laden air by means of a screen. The screen retained the powder and the air passed off through the screen. The Stauf process was the first spray drying process to be commercially used in the United States.

The drying machine is comparatively simple, being composed of two polished metal cylinders placed side by side and slightly separated from each other. They are mounted in a heavy, solid iron framework, and revolve inversely at the rate of about six revolutions per minute. They are heated in the interior by superheated steam, at a pressure of about 45 pounds to the square inch, which makes the outer temperature of the rollers considerably above 212° F. The milk is introduced into the machine by a pipe which runs between the rollers, about 6 inches above their convergence, and as soon as the milk strikes the rollers evaporation commences. The milk passes gradually between the cylinders and is carried in a thin, uniform layer upon each, the layer being thinner than the thinnest tissue paper. Whatever water is not evaporated at the point of convergence is dried out of the layer in its passage on the revolving hot cylinder, until the film reaches a knife held in contact with the cylinder, which removes the milk in long, continuous sheets, which fall into a receptacle below, where they are broken into innumerable small pieces by the fall and rapidly cool. To collect and carry off the steam arising from evaporation the machine is provided with a large hood leading into a pipe. On an upper floor an exhaust fan is located connected with all these different pipes, thus carrying the steam rapidly out of the hoods and keeping the building absolutely free of it. As soon as the boxes into which the sheets or rather broken pieces of dry milk fall from the rollers are filled, they are wheeled to a brushing machine, where the product is reduced to a uniform powder, and after having been spread on large hardwood tables to cool thoroughly, is ready for packing and storing or shipping.

The milk is pumped into a large round copper vessel, where it is agitated and heated by sterilized air blasts preparatory to its being pumped into rectangular concentrating vessels. These concentrat-
ing tanks are provided with a circulating medium of hot water surrounding them and coils in their interior. They are also provided with pipes and fan-shaped nozzles for the introduction of sterilized air below the surface of the milk. This air is under pressure and is allowed to escape when the tanks are charged with milk, and causes the water vapor to be driven off. The milk here has a violent rolling motion. As the product becomes concentrated the temperature is lowered. The opening of a valve permits the mass to fall into the large roller drums with tapered ends, which are located on a lower floor. These roller drums are tin plated and are perfectly smooth on the inside, with cone-shaped ends. An air blast is then introduced into the head of the drum. The latter revolving about two turns per minute carries the pasty product up on its side, and as it approaches the top it falls back through the dried atmosphere, the air thus carrying away the moisture. This paste soon becomes too heavy to be carried up by the revolving of the drum and rolls into a large mass, the cone-shaped ends causing it to move unequally, and twisting and grinding it into small particles. These are then conveyed to the drier drums, where the desiccation is completed. These drier drums have a novel construction. Sterilized air is forced through a central shaft having lateral arms extending down into the mass, where the constant rolling of the drum exposes all parts to the desiccated air. When the product is bone dry, it is conveyed to a grinder, which brings it to about the consistency of corn meal, and it is then packed.

THE PASSBURG SYSTEM.

The Passburg dryer is a large steam-heated iron drum revolving in a vacuum chamber. The milk is fed to it cold, and is scraped off by a steel knife, in thin sheets, and is perfectly dry when taken from the receiver.