THE EFFECT OF DIFFERENT PERCENTAGES OF BUTTERFAT ON THE PHYSICAL PROPERTIES OF ICE CREAM.

by

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INTRODUCTION

Ice cream has long been a favorite frozen product served for desserts and delicacies. Many years ago the nobles used frozen delicacies at banquets and important feasts. The French were always very fond of frozen dishes but in those days, the early infancy of the present ice cream industry, there was no means of obtaining the much desired delicacies except by the use of natural ice in those seasons of the year when natural ice was available. They had no means of storing ice or of producing artificial cold. For these reasons ice cream was for several centuries considered as a luxury to be had only at the time of festivals or on holidays.

As civilization progressed, with the development of this country and with the invention of the first refrigeration machines, it was possible not only to store natural ice thru the summer months but also to produce an artificial cold. It was then possible to manufacture frozen dishes thruout the year. The consumption of ice cream soon began to increase rapidly. As science has advanced, the food value of milk and other dairy products has been made known thruout the civilized world. This has resulted in a keen appreciation of the food value of ice cream and has brought about a marked increase in the demand for the different classes of this frozen product. A rapid development of the ice cream industry has resulted until the manufacture of ice cream has now become one of the most important industries. Its rapid progress during the past decade excels that of butter and cheese.

Leading authorities have criticized the ice cream industry for the absence of definite standards pertaining to the methods employed in its manufacture and for the lack of uniformity in composition of the frozen product. The progress attained has been difficult to appreciate.

The inability of the manufacturers of ice cream to arrive at definite standards has been partially due to the perishability of ice cream and to the varying standards enacted by the different states. An analysis of these state laws defining the fat and total milk solids required in commercial ice cream clearly indicates that these defects will remain until a Federal ruling definitely specifies the fat and total milk solids to be contained in ice cream.

A more important reason for the absence of a definite standard and the lack of a uniform product is that the manufacturer does not possess a practical knowledge of the factors involved,which are of vital importance in the process of manufacturing ice cream.

Considerable attention has been given to the experimental study of various phases of the ice cream industry. The work completed by various investigators has, however, dealt largely with the factors affecting the yield of ice cream, pasteurization and emulsifying of mixtures, and with bacteriological analysis of the mixture and of the frozen ice cream, special attention having been given to the types of bacteria that were able to survive when exposed to low temperatures for periods of time varying from one to seventy-two days. These studies have not resulted in conclusive evidence of a character that would tend to materially assist the ice cream manufacturer in standardizing his methods. The need for such uniformity prompted this investigation.

During the year of 1919 The Missouri Experiment Station outlined a project entitled "The Effect of Each Ingredient in the Manufacture of Ice Cream". The primary object of this investigation was to give to the manufacturer of commercial ice cream information that would prove of value to him in standardizing his methods. The experimental work here submitted is a part of this project, but is limited to a study of the effect of different percentages of butterfat upon the physical properties of commercial ice cream.

It will be noted that the apparatus designed and used in this investigation compares favorably with the type of equipment utilized under commercial conditions. This was considered of importance in making the results of the investigation directly applicable to commercial conditions.

REVIEW OF LITERATURE

Holdaway and Reynolds[1] made determination of the effect of binders upon the melting and hardness of ice cream. They concluded that the hardness of different kinds of eight and nineteen percent creams ranked in the following order from hard to soft: First, cream containing one ounce of gelatin per gallon of cream; Second, four ounces of gelatin; Third, corn starch; Fourth, gum tragacanth; Fifth, control cream. The different eight percent creams ranked as above in melting resistance. The hardness of thirty percent creams ranked in the same order except that the control creams ranked fourth and the gum tragacanth filler creams fifth. Ice cream without filler from eight to nineteen percent creams had about equal hardness while the thirty percent proved softer. As the percent of fat was increased, the power to resist melting was also increased. The melting point increased with the percent of fat, especially between eight and nineteen percent. Ice cream with a medium percent of fat and a large amount of gelatin proved hardest and most heat resistant. Gum tragacanth produced smooth, soft cream. With an increase in the percentage of fat and gum tragacanth, the power to resist pressure and heat decreased. Corn starch as a filler, compared favorably with gelatin but produced granular ice cream.

Davis[4] found that there was no uniform relationship between the consistency of an ice cream mixture and the percent of swell where different thickeners were used. Decreasing the amounts of sugar in the mixture below normal increased the percentage of swell and produced an unfavorable effect upon the finished product from the standpoint of flavor and texture. Increasing the amount of sugar above normal caused a decrease in the percentage of swell, produced a better texture and resulted in too sweet an ice cream.

The Virginia Station[2] made microscopical studies of ice cream, giving particular attention to smoothness and keeping quality or stability of texture ,and they stated that all normal points were closely associated. It was found that smoothness depended upon the amount and fineness of solids present other than those in true solution and, within limits, upon the size and distribution of ice crystals. These, in turn, depended upon the number and nearness of minute solid particles which interfere with crystallization. The keeping quality was dependent upon the disposition of the solids to separate from the liquids, which varied with the fineness of division of solids. The finer the division the better the keeping qualities, up to a point where solid merges into true solution.

The Cream and Milk Plant Monthly[3] states that fillers increase the viscosity of mixtures, prevent the formation of butter particles during the freezing, add strength to the cream film surrounding the moisture particles and insure a body with better keeping qualities.

Williams[5], in discussing the use of gelatin and its effects on quality, stated that this ingredient blended the cream and fruit flavor of the ice cream. When too much gelatin was used, the fruit flavor was not so pronounced. Gelatin that had been heated repeatedly produced an ice cream of a weak body. Best results were obtained when the gelatin was heated and used the same day and when it was held at a temperature of 160°F. before being mixed with the cream. In experimenting with homogenized cream, Williams, when using three gallon cans and an ordinary ice cream cabinet, found that in forty-eight hours cream with no gelatin had lost its identity and value. When a normal amount of gelatin was used the resulting cream, when held under the same conditions, was unchanged.

Hammer and Saunders[6] made a bacteriological study of the methods of pasteurizing and homogenizing ice cream. They recommended that, from the theoretical standpoint, gelatin should be added to the mixture shortly before freezing if the mixture was to be held for any length of time.

Factors which influence the yield and consistency of ice cream were investigated by Mortensen[7]. He found that the fillers, milk powder, gelatin, starch, and commercial powders do not increase or decrease the yield of the resulting ice cream.

Baer[8] found that emulsification of cream lowered the bacterial count, and that the addition to milk and cream, emulsified or not, of 2% solids, either in the form of skimmilk powder or condensed milk, improved the quality of the product. He also found that emulsified milk and emulsified mixtures made from butter and skimmilk, or butter, skimmilk powder and water, produced, under proper conditions, excellent ice cream. He stated that good flavored sweet butter and fresh, nonrancid powder must be used. The use of 2% additional milk solids in the form of skimmilk powder to ten gallons of ice cream mixture improved the ice cream, produced 5% additional swell, and retarded crystallization of the ice cream.

Frandsen and Rovner[10] investigated the substitutes used for conservation of sugar in ice cream making, and found that none of the substitutes tested would satisfactorily replace all the cane sugar in the ice cream mixture. They worked out four formulae which save from 30 to 50% of cane sugar, lower the cost of sweetening, and produce ice cream of satisfactory flavor and texture. These formulae are: First, 70% cane sugar and 30% corn syrup; Second, equal weights of cane sugar and corn sugar; Third, cane sugar and glucose invert syrup in the proportions of 1.25 to 4.5# respectively; Fourth, mixture of invert sugar, cane sugar, and corn syrup in proportions of 1.25# each of corn syrup and invert sugar to 2.25# of cane sugar.

Ayer, Johnson, and Williams[11] stated that grain syrups could not be successfully used as substitutes, because they gave a pronounced grain flavor and an acid taste when used to the extent of only 10 percent. Regarding corn sugar, they suggest the following combination:

	Pounds
Cane or invert sugar syrup.........	50
Corn Syrup.........................	50
Corn Sugar.........................	$31\frac{3}{4}$

They stated that some grades of corn sugar imparted a yellow color and a bitter flavor.

These authors worked out formulae saving from 30% to 50% of cane sugar in the mixture. When invert sugar and corn syrup were used as the only sources of sweetening, a rather noticeable syrupy flavor was imparted to the ice cream. It was thought that the hydrolizing of corn syrup in the presence of an acid enhanced its sweetening properties. Corn sugar can replace 50% of cane sugar in the mixture.

Reid[12] investigated the effect of varying increments of sugar on the manufacture of commercial ice cream. He found that an increase of sugar gave an increase in the overrun until 12% sugar was added, beyond that point a decrease in overrun resulted. The hardness of the cream decreased directly with the increase in the sugar content of the mixture. An increase in sugar beyond 10% showed a marked decrease in the power to resist summer temperatures. Syrup when used in place of only a part of the sugar appeared to have a similar effect on the above points but gave a closer body, an occasional off-flavor, and sometimes an undesirable yellow color.

DESCRIPTION OF APPARATUS USED IN EXPERIMENTAL WORK

Westphal Balance for Determining the Specific Gravity of Ice Cream Mixtures.

The Westphal Balance is a specially constructed instrument used for determining the specific gravity of liquids. It consists of a beam, a supported stand, a glass plummet carrying a thermometer, a vial, and a set of special weights with forceps for handling the weights. The stand is supported by thumb-screws which enable the operator to level the instrument before making determinations. A plum-bob is attached to one side of the upright portion of the stand to assist in levelling the instrument. Near the center of the beam are two knife-edges which rest upon the top of the stand. One end of the beam carries a weight which nearly balances the glass plummet. The other end is divided into ten equal parts. A knife-edge at the tenth division supports a hook from which the glass plummet is suspended by a fine thread. Beyond the knife-edge there is a screw carrying a nut to be used in adjusting the equilibrium when the plummet is suspended in the air. When the plummet is immersed in a liquid placed in the vial or balance jar, equilibrium is re-established by the addition of weights. The weights are placed on the marks which divide one end of the beam into ten parts. There are four sizes of weights, the largest representing the first decimal place or tenths; the next largest, the second decimal place or hundredths, etc. The value of the weight is determined by the number of the division mark, namely: the largest weight when placed on the first division would have a value of one tenth, while if the same weight was moved to the ninth division its value would be nine tenths.

To obtain the specific gravity of a mixture a representative sample is poured into the vial or balance jar and lowered to a temperature of 15°C. The glass plummet is then immersed in the center of the mixture and weights are placed upon the beam to restore equilibrium. The specific gravity may then be read direct from the beam.

It is essential to have the temperature of the mixture at exactly 15°C. as a slight variation will cause great differences in the specific gravity.

Viscosity Determinator.

In order that comparisons of the heaviness or lightness of each mixture under experiment might be made, an apparatus known as a "viscosity determinator" was devised.

Description of Apparatus. The "viscosity determinator is simply a glass funnel, six inches across the top, narrowing down to an outlet or neck of 3/8". To the 3/8" neck is attached, by means of rubber tubing, another piece of glass tubing, tapering from 3/8" to 3/16" at the outlet. The glass funnel is suspended by means of an iron ring and stand. Directly below the outlet is placed a 500 cubic centimeter graduate.

Before making determinations, two mixtures were prepared. The first formula used was such that it would compare with the heaviest mixtures used commercially and in experimental work. The second formula used was such that it would compare with the most lean mixtures in use. The two formulae gave the two extremes and between them a wide range of consistency, within which range the viscosity of many mixtures could be determined and compared. In order that the absolute viscosity might be known, a water determination was made and compared with these two mixtures.

When the preparation of each mixture was complete it was cooled to a temperature of 4.5°C. The funnel was filled with the mixture to a mark etched in the glass one-half inch from the top. The mixture was held in the funnel by a pinch cock operating on the rubber tubing. With the mixture at the desired temperature and the correct height in the funnel, the time was noted and the mixture allowed to flow into the graduate placed directly beneath the mouth of the glass tubing. During this period the funnel was kept filled to the etched mark in order that a constant weight and pressure would be exerted on the out-flowing mixture. This operation was allowed to continue until the graduate was filled to the 500 c.c. mark when time was again noted. The time required for 500 c.c. of the mixture to flow from the funnel was taken as the viscosity constant giving a direct reading. Mixtures containing a large percent of solids flow less rapidly, due to their heavy consistency. There is a direct relation between the viscosity of the mixture and the time required for 500 c.c. to flow into the graduate.

The temperature of the mixture was an important factor as a difference of only a few degrees above or below the constant temperature of 4.5°C. variated the results. A higher temperature lessened the viscosity and caused it to flow more freely. Opposite results were obtained when the mixture was cooled below 4.5°C. With a variation of 2-7 degrees in the temperature of the mixture it was possible to record a reading 12-15 points from the viscosity obtained when the mixture had a temperature of 4.5°C.

In order that the glassware would cause no variation in the temperature of the mixture the temperature of the room used was held at 4.5°C. for all determinations.

In conclusion we find:

1. The viscosity determinator as used is very inexpensive and its application simple.

2. This method of determining the viscosity can be applied regardless of the composition of the mixture.

3. A working knowledge of the mixture as to heaviness or leanness can be learned in a brief period of time.

4. The heavier mixture results in a more viscous product, more time being required for 500 c.c. of the mixture to flow thru the funnel when compared with a less viscous mixture.

Ice Cream Freezer for Experimental Determinations.

The ice cream freezer used in studying the effect of different percentages of butterfat in the manufacture of ice cream was constructed in two adjoining compartments, namely; the compartment for the freezers proper and the compartment called the auxiliary ice box. The total length of the box, over-all, was 5' 8", width of 25", with a height of 25 1/8" for the auxiliary box, and 12 9/16 for the freezing compartment.

The material used was red wood, this variety of wood being chosen due to its ability to resist shrinkage and absorption of brine or water. All joints were mortis and tenon, with the addition of white lead to protect against any leakage and loss of brine. The entire box received four coats of paint and two coats of white enamel to safeguard against any leakage or swelling of material which might tend to seriously delay the experiment at a crucial moment.

The auxiliary compartment of the freezer was 16" x 25 1/8" x 5' 8", and was separated from the freezer compartment by a partition consisting of a sliding door and hardware cloth. The partition formed a front for that part of the auxiliary compartment that extended above the freezer compartment; the sliding door served to complete the partition during the process of freezing. The

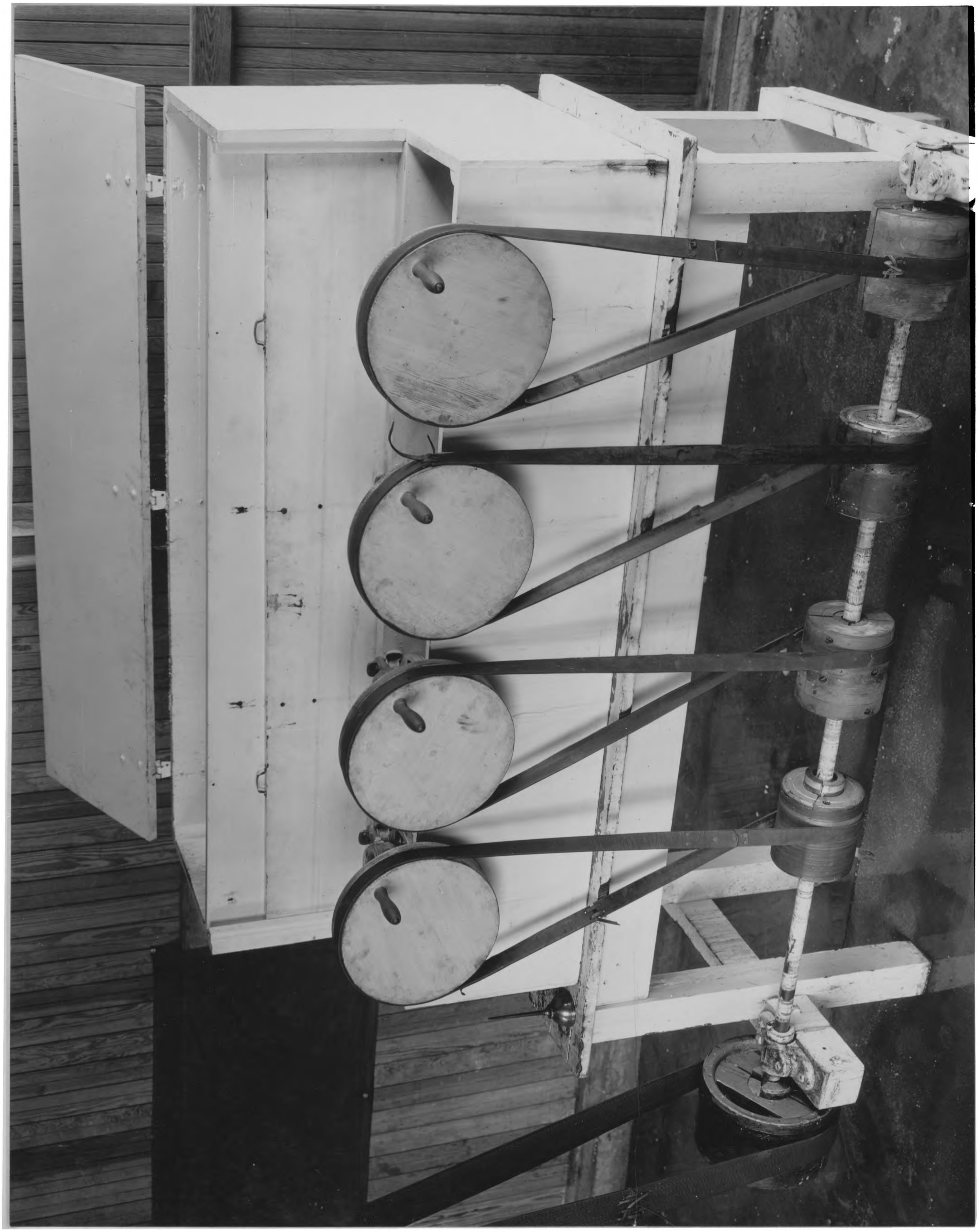

Fig. I. Front View of Freezer Showing

How Individual Freezers are Operated.

principal object of the hardware cloth was to retain all of the ice in the auxiliary compartment. It served as a partition when the sliding door was lifted to lower the temperature of the brine. In the rear of the auxiliary compartment three one-inch holes were placed to act as overflows and to allow for a lowering or raising of the brine when necessary. The overflow holes were plugged with rubber stoppers which could be removed when necessary. The sliding door was held in place by two strips of lath on each end of the auxiliary compartment. It had a handle in the center to assist in lowering or raising it as required. A hinged top was used on the auxiliaty compartment to form a cover when the freezer was not in use.

The freezer compartment proper was 9 7/8" x 12 9/16" x 5' 8". In this compartment were placed four one-gallon ice cream freezers, which had been stripped of the gallon packers and were so arranged that there was a space of 3½" between the cans and a space of 3" on each end. Along the sides of the compartment 2" was allowed between the walls and the edge of the can. This permitted a free working area. Each freezer had all the necessaty parts, i. e., a dasher, top, operating shaft, fly wheel, and handle. The base of each can was held in position by a basal pivot so placed that all cans would coincide with the above specifications. The four cans were so placed that each would conform to its original position, with fly wheel and handles operating in a straight line.

In the top of each can,two semicircles, an inch in diameter and four inches long, were cut for the purpose of observing the condition of the mixture while the freezers were in motion. With these two slots it was possible to observe exactly when freezing began and also to watch the mixture whip up and begin to harden. The maximum swell was easily determined in this way and the freezing could be stopped before any swell was lost. With a closed top it would have been necessary to stop the freezing continually, remove the can, and make observations all of which would introduce error in the experiment.

All four freezers were set in an upright position and held in place by the operating shafting connected to the 12" fly wheel. The four shaftings were attached to the sides of the compartment on one end and to a 2 x 4 on the opposite end. This 2 x 4 ran the entire length of the box and was placed next to the sliding door. To each fly wheel was attached another wooden wheel of exactly the same circumference and two inches in thickness. This was attached to the metal fly wheel by four bolts. The purpose of the additional wheel was to allow for a belt by which to operate the freezer. All four fly wheels operated in a direct line. Thus it was possible to operate the four freezers from the one shaft and have all freezers in motion at the same time. If it was desired to stop one freezer during the experiment, this could be done by throwing the inch belt off the 12" pulley.

Fig. II. End View of Freezer Showing Position of

Compartments and Ice Cream Cans.

All handles were retained in place on each fly wheel so that in case of emergency the freezer could be operated by hand, and the experiment in operation at that time would not be lost. Each freezer had a belt running from the 12" drive wheel to an individual pulley on a line shafting directly below. These four pulleys were in turn operated by another pulley on the end of the line shafting and the belt driven from a shafting attached to an electric motor.

In operating the freezer, it was absolutely necessary that the speed of the four fly wheels be exactly the same. Otherwise, with a variation in the number of revolutions of the individual freezers, a variation in the overrun, proportional to the increase or decrease in speed of one freezer over another, would be expected. The four freezers were operated at a speed of 150 to 153 RPM, the slight variation of three revolutions making no material difference with results obtained. The individual freezers were of double action type with a single dasher, the fly wheel operating at 153 RPM, the can revolving at a rate of 106.4 RPM in one direction and the dasher operating at an equal speed in the opposite direction.

Method of Operation.

The salt and ice used in making the brine for all of the experimental work were mixed in the same way as in the commercial manufacture of ice cream, one part salt and nine parts of ice being used. With this type of apparatus, it was possible to bring the brine, which was standing in the freezer compartment, down from 50^{o}F to 20^{o}F in ten minutes. If the brine went below the desired temperature the addition of a small amount of water followed by thoro stirring was sufficient to bring the brine up to the temperature desired. The ice and salt were mixed simply by stirring with a large rake, pulverized ice being retained in the auxiliary compartment by the hardware cloth. After the brine had been tempered, the sliding door was lowered to the last notch, thus retaining a constant temperature during the freezing of the mixture under experiment.

The brine in the freezer compartment came up to within one inch of the top of the can, and a constant circulation was maintained by the rotary motion of the cans. With the brine at that depth a uniform freezing was assured throughout the can.

After the brine had been brought to the desired temperature, the mixture to be frozen was tested for its viscosity at a temperature of 4.5^{o}C, this temperature being constant for all mixtures. Twenty-one hundred grams of the mixture was then weighed into each of the four one gallon freezer cans. The dashers and the tops of the cans were then placed in position and the cans transferred to the freezing compartment where the freezing process started. The freezers were interchangeable as they were all the same make and size.

During the process of freezing, if it was desired to learn whether the cream had started to freeze or if the temperature of the ice cream was wanted at any stage of the freezing, the facts were obtained by shutting off the power and quickly noticing the condition of the mixture or in the case of taking the temperature the thermometer was inserted directly into the cream. This required but a fraction of a minute and the freezing process was continued.

Overrun Determinator.

In accordance with the most accurate methods now employed, the overrun was determined by a difference in weight. A given volume of the mixture was weighed before it was placed in the freezer and the same volume of frozen cream was weighed when the freezing of the mixture was complete. From the difference of these weights, the overrun or swell was calculated.

A beaker of 800 c.c. capacity, cleansed and dried, was balanced on the scales. The mixture was poured into the beaker until it was filled to capacity and the weights recorded. The beaker was again filled with the frozen mixture and the weights recorded. The difference in the weights represented the overrun in grams. Dividing the difference of the weights by the weight of the frozen mixture gave the percent overrun.

The overrun may be determined by the application of the following formula:

$$\frac{\text{wt. of mixture} - \text{wt. of cream}}{\text{wt. of cream}} = \%\ \text{overrun.}$$

This method of determining the overrun is rapid, easy, and accurate and is gaining favor among commercial manufacturers.

Hardness Determinator

The desirability of having an accurate method for determining the hardness of ice cream has been felt for a number of years. One or two stations have given this particular problem some study, and their results have led to the adoption of the apparatus used in this experiment.

The Virginia Station used an apparatus similar to this one but less elaborate in construction. This particular piece of apparatus was first used in investigations pertaining to the determination of the hardness of butterfat conducted by A. C. Perkins at the Missouri Station in cooperation with the Bureau of Animal Industry, U. S. Department of Agriculture.

In all of our experimental work relative to this problem, it was considered desirable to measure the degree of hardness of the ice cream with such accuracy that tests made at various times would be comparable.

Description of Apparatus and Method. The apparatus used, as shown in Figure III, comprises a firm support (A) and a separate light frame (B) carrying the penetrating needles and the weights. The support consists of a heavy iron base (c) into which are inserted two upright rods (d & e) about one meter long, one of which is hollow and

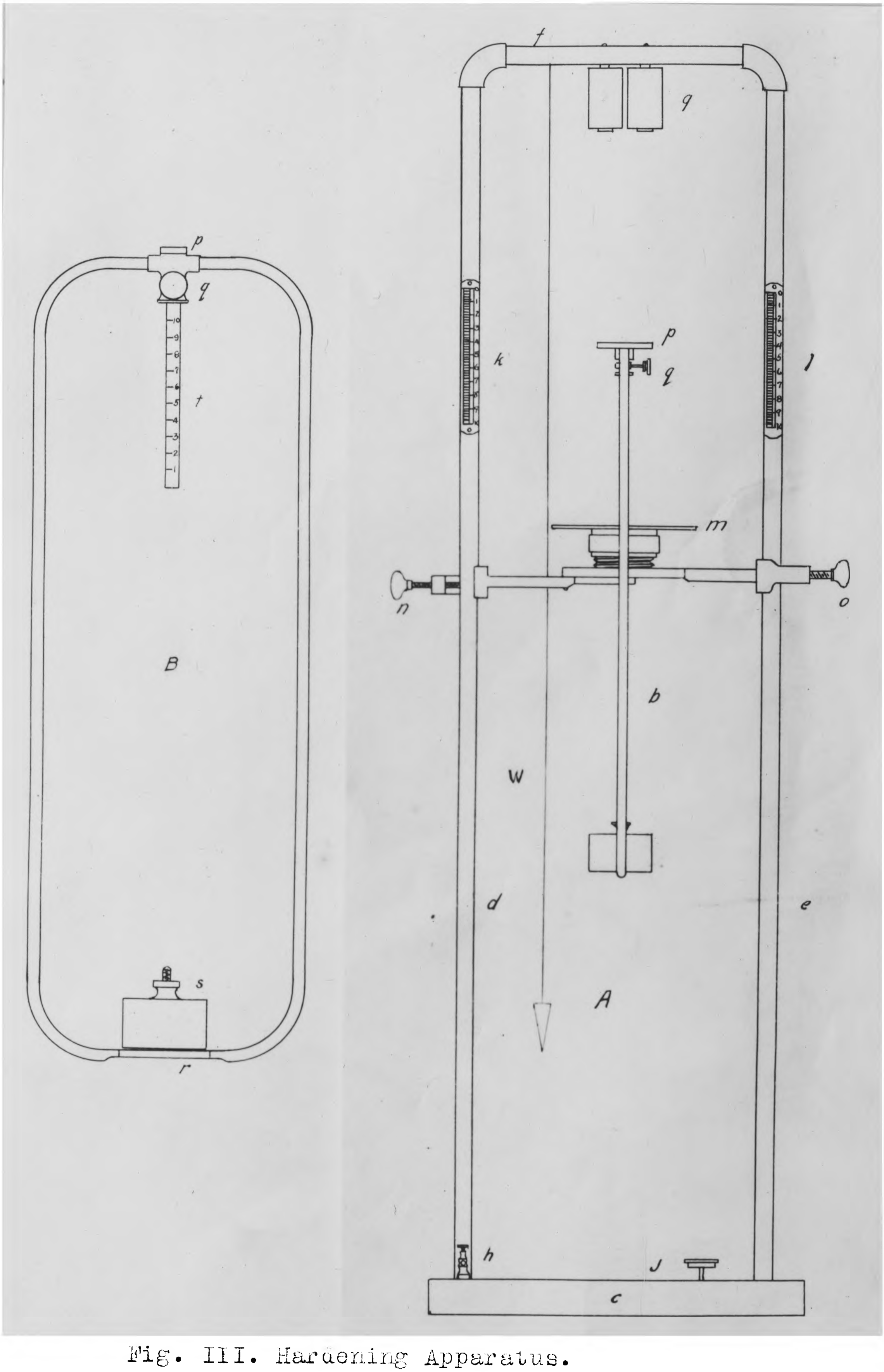

Fig. III. Hardening Apparatus.

contains wires connecting g, h and i*. These uprights are about 25 cm. apart and are joined at the top by a piece of hollow iron rod (f), to the center of which is suspended an electro-magnet (g). h and i are binding posts for attaching the batteries to operate the magnet. A key (j), attached to the base, serves for making and breaking the current thru the magnet. k and l are millimeter scales reading downward. Attached to the upright rods is an adjustable platform (m) for carrying the sample whose hardness is to be tested. The coarser adjustment of the height of the platform is secured by means of the clamps n and o. This adjustment does not need to be regulated except at rare intervals. A finer adjustment is secured by simply turning (m) which is supported from n o by a $1\frac{3}{4}$" nut screw. The frame (B) is of hollow brass tubing to get it as light as possible, while still retaining the necessary degree of strength. It is about 40 cm. long and 15 cm. wide. (p) is a piece of soft Swedish iron to be acted on by the electro-magnet. Directly beneath this, inside the frame, is a socket and set-screw (q) to hold the needle (t) in place. At the opposite end of the frame is a small platform (r) for carrying the weights, which are made with a hole drilled thru the center so that they can be placed over the screw projecting above the platform, and held firmly in place by the nut (s).

* i is not visible. It is on base (c) opposite (h) on the other side of the upright rod (d).

The frame (B), when carrying any one of the sets of needles, weighs 200 grams. Additional weights are provided, making possible any combination of exact multiples of 100 grams up to 1200.

A set of needles is provided, having cross sectional areas of 5/16 inch, or 7.93 mm.; 4/16 inch, or 6.35 mm.; and the smallest 3/16 inch, or 4.76 mm. They are cylindrical in shape and slightly more than 10 cm. long, being marked at a distance of 10 cm. from the end. The three needles are made of brass, machined down to the size desired. The scales (k and l) attached to the upright rods, previously referred to, are so placed that when the frame with needle and weights, if used, is held in place by the electro-magnet preparatory to making the test, the point of the needle is at zero on the scales. The height of the adjustable platform (m) is so arranged that the surface of the sample to be tested is at 100 mm. on the scale. The distance of fall before reaching the surface of the cream is always 10 cm.

Determination of Hardness.

In making the determination,the frame with a suitable needle and weight, if used, is suspended from the electro-magnet and the brick of cream to be tested is placed in position beneath the needle, the height being regulated as described above. The frame is then released by means of the key. The depth of penetration is ascertained by measuring with the metric rule, stretching a

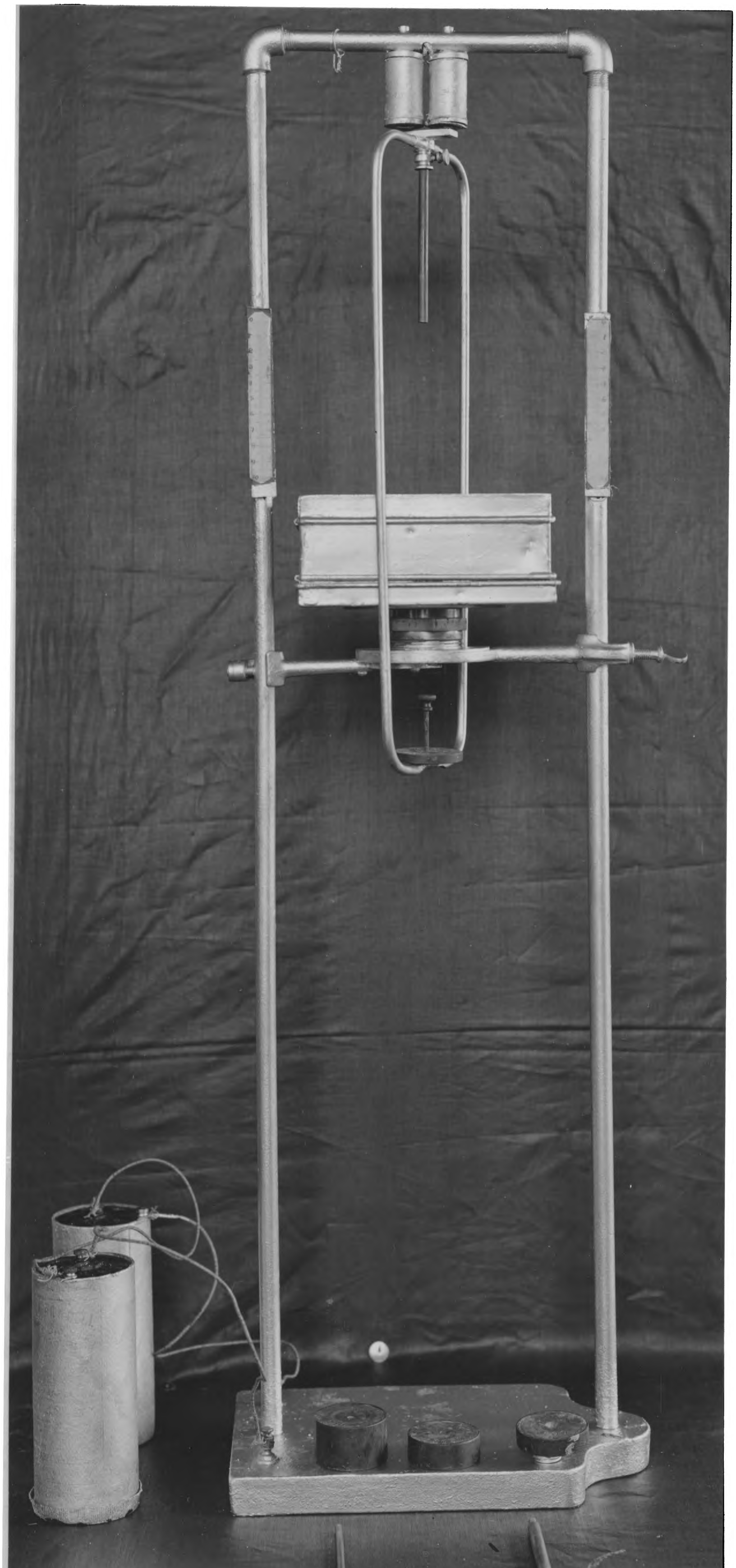

Fig. IV. Hardening Apparatus - Needle and Brick of Ice Cream in Position before Penetration.

fine wire from rule to rule and taking the reading from each. This gives a direct reading of the depth of penetration.

The tests are made by allowing a needle of the same diameter to penetrate the brick of ice cream twice in the center and twice near each end; making six penetrations in all. The point of penetration is varied from the center to points near the ends as there is a possibility of the cream being harder near the edge than in the center. The average of the six readings or penetrations is taken as the depth of penetration. All testing is done at a temperature at which there can be no change in the temperature of the ice cream being tested. Since the cross sectional area of the penetration needle is known and the depth of penetration has been ascertained, their product indicates the volume of ice cream displaced. Comparison can also be made between different samples by mms. of penetration.

The amount of weight employed and the size of the needle used depend, of course, on the character of the ice cream and the temperature at which the hardness is determined. With a proper combination of needles and weights, the needle will remain practically stationary in the ice cream after the initial plunge. If, however, too much weight or too small a needle be employed the needle continues to sink slowly making an accurate reading of the depth of penetration impossible. In the reverse case, with too large a needle or too little weight, the penetration is of course much less and the percentage of experimental error proportionately greater. To further offset chances of experimental error, the needle is tempered to the same degree of temperature as the ice cream under test.

The suspension of the weights far below the needle brings the center of gravity of the falling portion of the apparatus below the point of the needle, thereby causing the latter to assume invariably a vertical position, making it much easier to ascertain the true depth of penetration than would be the case if the point of the needle were at or below the center of gravity. After its release by the electro-magnet, the apparatus meets with no resistance whatever in its fall, except that offered by the air until the point of the needle reaches the surface of the ice cream.

It might be argued that gravity was acting thru a greater distance in the case of a sample which was penetrated 30 mm., than in the case of one which was penetrated only 15 mm.; or that the amount of friction on the sides of a small needle would be proportionately greater than that on a larger needle, on account of the greater surface area in proportion to its volume. These objections, if they are at all patent, would tend to counteract each other. In any extent their influence is not perceptible in the results, provided combinations of needles and weights which render

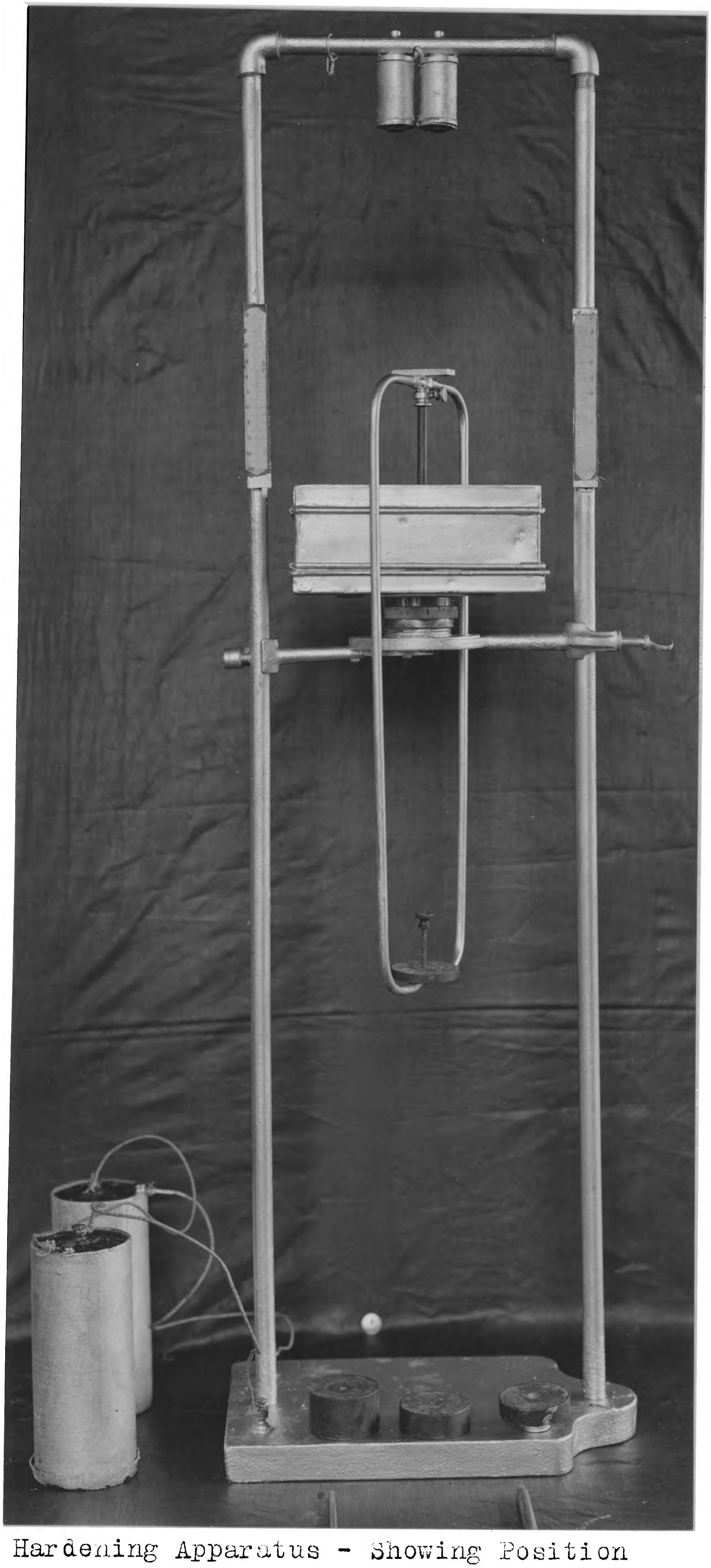

Fig. V. Hardening Apparatus - Showing Position of Needle in Penetrating Brick of Ice Cream.

accurate readings are chosen. In practice, it was endeavored to secure a combination of needles and weights which would give a penetration of about 25 or 30 mm.

Effect of Temperature on the Hardness of Ice Cream at the Time of Testing.

A serious difficulty encountered was that of maintaining the ice cream at the temperature desired to perform the tests. It was soon determined, to secure results of value, we must maintain for several hours a constant temperature to within 0.5°C. This was accomplished by placing the bricks to be tested in the hardening vat and maintaining the brine at a temperature of 0.5°C. below that of the ice cream. With this arrangement we found it entirely feasible to control the temperature of the ice cream to within the limits described when the room registered within 3 to 5° of the temperature desired for the ice cream. The hardness of thirty bricks, making six penetration per brick, can be determined per hour.

The following conclusions may be cited; first, apparatus of this type is the most accurate of its kind for this particular piece of work; second, it is necessary that each brick of ice cream be held at a constant temperature for at least four hours; third, that the method as used is as rapid as any of the other proposed methods.

THE EFFECT OF DIFFERENT PERCENTAGES OF BUTTERFAT ON THE PHYSICAL PROPERTIES OF ICE CREAM

Method of Procedure.

The object of this investigation was to determine the effect of different percentages of butterfat on the physical properties of ice cream. The mixture used in each freezing was the same except for the fat content. All factors which enter into the manufacturing process such as type of freezer used, temperature of brine, speed of dasher, and amount of mixture used in each freezing were maintained at a constant.

The following is a brief outline of the procedure adhered to during process of freezing:

The ingredients of the mixture were weighed out, properly mixed together, and a sample taken and tested for fat and total solids. In addition, the acidity of the mixture was determined.

The mixture was then cooled to a temperature of 15°C. and the specific gravity determined. When the mixture had been further cooled to a temperature of 4.5°C. the viscosity was determined. Twenty-one-hundred grams of the mixture was carefully weighed into each of the four one-gallon freezer cans and brought to a uniform temperature of 4.5°C.

Two freezings were frozen at one time as this would facilitate a more careful observation. When the maximum overrun had been reached and the mixture frozen to a desirable consistency, it was removed from the freezer, the overrun determined, and three bricks placed in the hardening box. Two additional freezings were frozen out in the same manner. Each freezing was labeled, and all data on each freezing of the same mixture was recorded. All bricks were hardened for a period of one day after which time one brick from each freezing was first tested for hardness and then scored. A second brick from each freezing was used for the determination of its ability to withstand summer temperatures. The third brick was kept at a constant temperature in the hardening box until five days old when it was scored to determine the effect of fat on the keeping qualities. All observations were made on each freezing and each mixture divided into four freezings which made it possible to obtain the results of four freezings of each mixture.

The following basic formula was used:

81 % cream
12 % sugar
7% skimmilk powder

Gelatin and vanilla were added at the rate of 6 oz. of each to 100 pounds of mixture.

The variation of the amount of fat in the cream variated the percentage of butterfat in the ice cream. The fat content of the mixture used in the investigation was from 4% fat to 20% fat, increasing the fat 2% for each new mixture. One mixture containing 25% fat was frozen out as a check upon ice cream with extremely high fat content.

These mixtures include all mixtures used in the commercial manufacture of ice cream in so far as percentage of butter-fat is concerned.

For convenience and to save unnecessary expense, only 20 pounds of each mixture was prepared. This quantity was sufficient for making all necessary tests and for four freezings. Each mixture required twenty-one-hundred grams of mixture.

Table No. I.

Showing the Percent Composition of Mixtures.

Composition: Fat	Composition: Solids Not Fat (serum solids only)	Calculated: Total Solids	Composition Determined: Fat	Composition Determined: Solids Not Fat (includes added sugar, binder and flavor)	Composition Determined: Total Solids
4%	13.46	29.71	4	25.5	29.5
6%	13.32	31.77	6	25.5	31.5
8%	13.14	33.39	8.1	25.4	33.5
10%	12.95	35.20	10	25.0	35.0
12%	12.79	37.04	12.1	24.9	37.0
14%	12.61	38.86	14	24.7	38.7
16%	12.37	40.62	16	24.9	40.9
18%	12.25	42.50	18	24.3	42.3
20%	12.07	44.32	19.9	24.2	44.1
25%	11.63	48.88	25	24.0	49.0

The first part of Table No. I gives the percentage composition of the mixture as it was calculated, while the second part gives the percentage composition determined by analysis. The mixture was tested for fat by the glacial acetic and hydrochloric acid modification of the

Babcock test. The total solids were determined by the Farrington high pressure oven method. The solids not fat were obtained by subtracting the fat from the total solids. The solids not fat as determined, include all the solids of the mixture except the fat, while the calculated solids not fat include only the serum solids present in the cream and skimmilk powder.

The mixture was tested for acidity according to Mann's acid test and the results obtained are given in Table No. II.

Table No. II

Showing the Percent Acidity of the Ice Cream Mixtures.

Fat Content	Age of Milk and Cream (hours)	Age of Mixture (hours)	Percent Acidity of Mixture
4%	24	4	.25
6%	24	4	.25
8%	24	4	.23
10%	24	4	.25
12%	24	4	.24
14%	24	4	.24
16%	24	4	.24
18%	24	4	.24
20%	24	4	.24
25%	24	4	.24

The Relation of the Specific Gravity to the Butterfat Content of Ice Cream Mixtures.

When the mixture had aged four hours at a temperature of from 50 to 65°F., it was cooled to 15°C. and the specific gravity determined by the use of the Westphal Balance previously described.

Table No. III

Showing the Effect of Different Percentages of Butter Fat on the Specific Gravity of the Ice Cream Mixture.

Fat Content	Temperature of Mixture	Specific Gravity
4%	15°	1.104
6%	15°	1.102
8%	15°	1.098
10%	15°	1.093
12%	15°	1.088
14%	15°	1.085
16%	15°	1.081
18%	15°	1.076
20%	15°	1.071
25%	15°	1.066

A study of Table No. III shows that an increase in the fat content of the mixture reduces its specific gravity. This was expected since the specific gravity of butterfat is less than that of the water which it re-

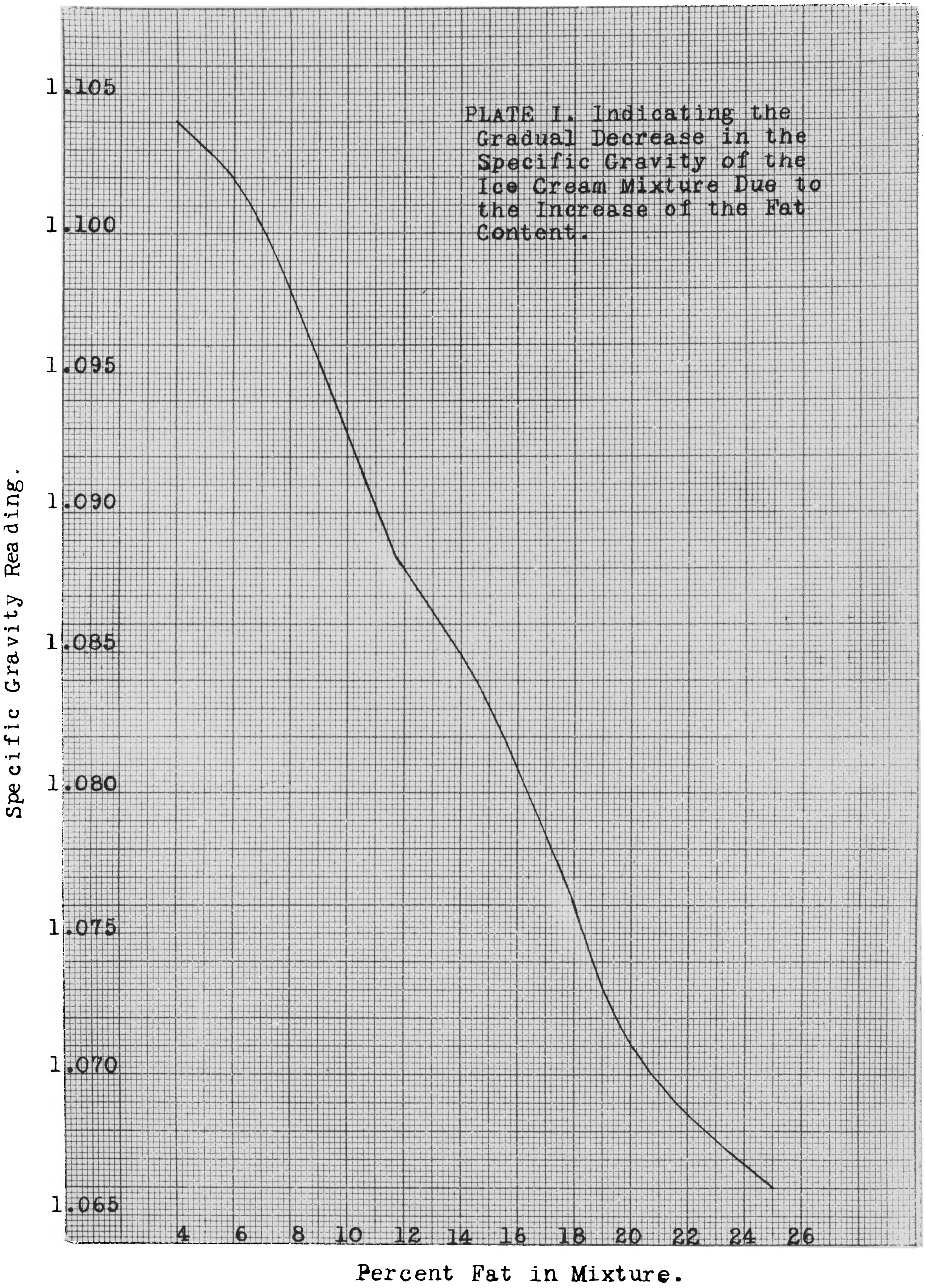
PLATE I. Indicating the Gradual Decrease in the Specific Gravity of the Ice Cream Mixture Due to the Increase of the Fat Content.
Specific Gravity Reading.
1.105
1.100
1.095
1.090
1.085
1.080
1.075
1.070
1.065
4
6
8
10
12
14
16
18
20
22
24
26
Percent Fat in Mixture.

places. By a careful examination of Plate I it is more readily seen that the decrease in the specific gravity of the mixture, as the fat content is increased, tends to become uniform, the graph appearing as approximately a straight line.

The Relation of Different Percentages of Butterfat to the Viscosity of Ice Cream Mixtures.

To determine the effect of additional increments of butterfat on the viscosity of the ice cream mixture, each mixture was cooled to 4.5°C. and run thru the "viscosity determinator" and the viscosity expressed in time. A citation is as follows: It requires one minute and twenty-four seconds for 500 c.c. of the 4% mixture to pass thru the determinator, and the viscosity is then expressed as 1.24. The viscosity of water at the same temperature is 1.00.

Table No. IV.

Showing the Effect of Different Percentages of Butterfat on the Viscosity of the Ice Cream Mixture.

Fat Content	Hours Aged	Percent Acidity	Temperature of Mixture	Viscosity.
4%	4	.25	4.5°	1.24
6%	4	.25	4.5°	1.29
8%	4	.23	4.5°	1.35
10%	4	.25	4.5°	1.40
12%	4	.24	4.5°	1.47
14%	4	.24	4.5°	1.54
16%	4	.24	4.5°	2.02
18%	4	.24	4.5°	2.15
20%	4	.24	4.5°	2.30
25%	4	.24	4.5°	3.50

Temperature Recorded in Centigrade.

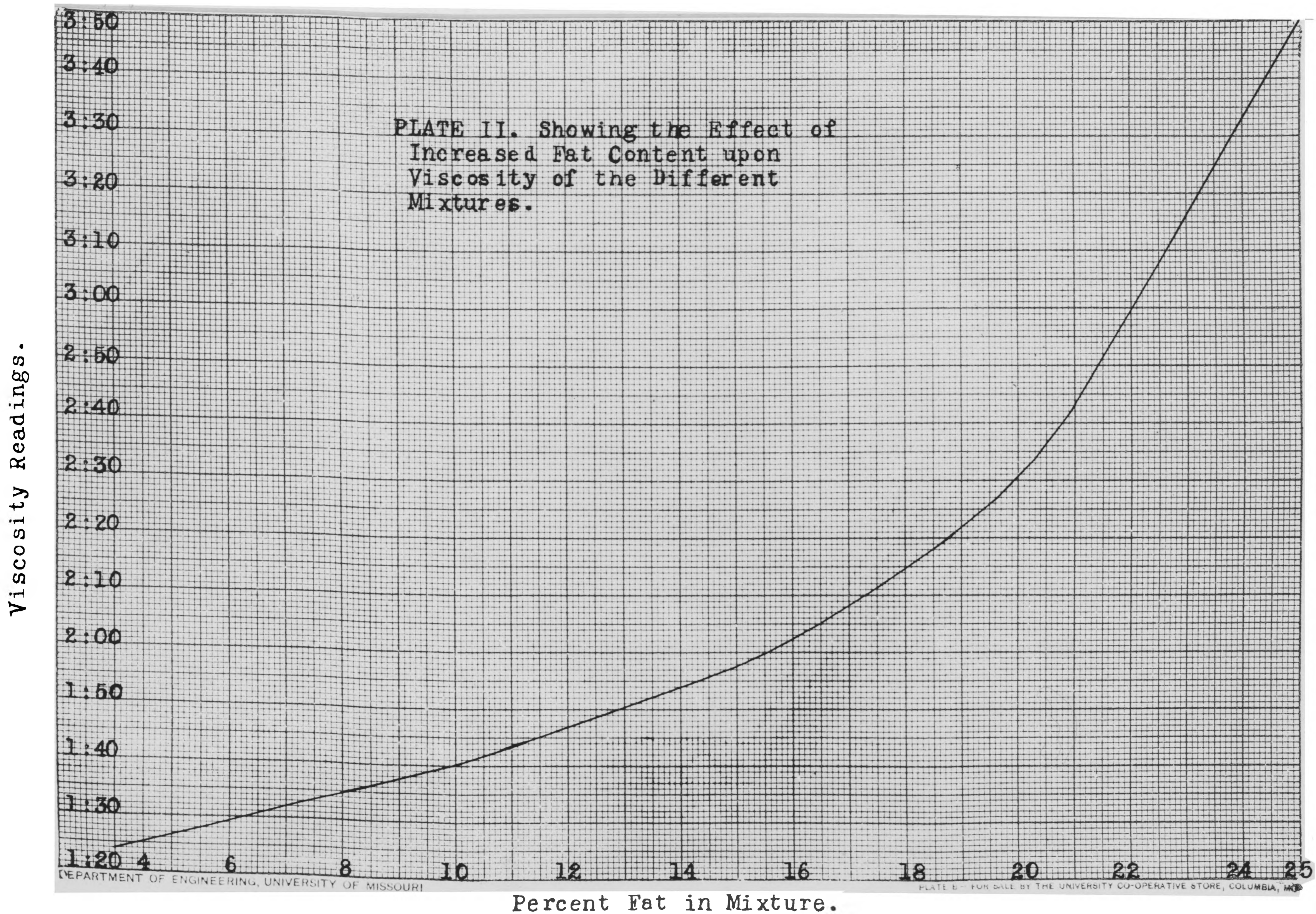
PLATE II. Showing the Effect of Increased Fat Content upon Viscosity of the Different Mixtures.
3:50
3:40
3:30
3:20
3:10
3:00
2:50
2:40
2:30
2:20
2:10
2:00
1:50
1:40
1:30
1:20
4
6
8
10
12
14
16
18
20
22
24
25
DEPARTMENT OF ENGINEERING, UNIVERSITY OF MISSOURI
Viscosity Readings.
Percent Fat in Mixture.

Table No. IV shows a gradual increase in the viscosity as the fat content is increased. This indicates that the butterfat content of the ice cream mixture bears a very definite relation to the viscosity of the mixture. Each additional increment of 2% fat increases the absolute viscosity five and one-half seconds. However, from the 20% mixture to the 25% mixture the viscosity increases more rapidly, which is undoubtedly due to the very high fat content.

The Effect of Different Percentages of Butterfat on the Freezing Process.

The factors having an important relation to the freezing of the mixture which were considered are:

Temperature of the Brine. This temperature was held constant at -5°C. for all freezings. The maximum swell was most easily obtained with the brine at that temperature.

Temperature of the Mixture. Before freezing, the temperature of the mixture was taken and the mixture heated or cooled to 4.5°C. The operation was carried out as follows: Twenty-one hundred grams of the mixture was weighed into the one-gallon freezer can, the dasher and top were placed in working position and the temperature brought to 4.5°C. by placing the can in brine and rotating the dasher. Any variation in this temperature would alter the length of time required for the mixture to begin freezing.

Time Required for the Mixture to Begin Freezing. The time when the freezer was started was observed, also the time at which the mixture started to freeze. This time was obtained by careful observation of the mixture thru the openings in the freezer tops. A change in the general appearance of the mixture indicated that crystals were forming. This observation was verified by stopping the freezer and examining the mixture for the presence of ice crystals. The formation of ice crystals indicated that the freezing point of the mixture had been reached. The time required to lower the temperature of the mixture from 4.5° C. to its freezing point is known as the time required to begin freezing.

Time Whipped. The freezing process was continued and the mixture whipped until the maximum amount of air had been incorporated and a consistency obtained which would compare favorably with previous freezings. The maximum overrun was determined by observing the rise of the mixture in each freezing thru the openings of the freezer tops. The freezing mixture could be seen to gradually climb the sides of the can until the maximum amount of air had been incorporated when it would cease to swell. The length of time required to produce this swell was taken as the time whipped. The consistency of the semi-solid cream was also examined.

Total Time to Freeze. The total time to freeze is the time required to begin freezing plus the time whipped. This also may be expressed as total time required to lower the temperature of the mixture to the crystallization point in addition to the time required to incorporate the maximum quantity of air giving maximum swell to the mixture.

Temperature of the Frozen Cream. When the maximum swell had been obtained, the temperature was determined by inserting a thermometer directly into the semi-

Table No. V.

Showing the Effect of Different Percentages of Butter

Fat on the Time Required to Freeze the Mixture.

	4% Fat	6% Fat	8% Fat	10% Fat	12% Fat	14% Fat	16% Fat	18% Fat	20% Fat	25% Fat
Wt. of Mix. in Freezer.	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100
Temp. of Mixture.	4.5°	4.5°	4.5°	4.5°	4.5°	4.5°	4.5°	4.5°	4.5°	4.5°
Temp. of Brine.	-5.0°	-5.0°	-5.0°	-5.0°	-5.0°	-5.0°	-5.0°	-5.0°	-5.0°	-5.0°
Time to Begin Freezing	2:15	2:30	2:15	2:15	2:22	2:25	2:32	2:37	2:40	2:36
Time Whipped	15:00	15:00	15:00	14:45	14:30	12:09	12:00	11:53	11:38	10:48
Total Time to Freeze the Mix.	17:15	17:30	17:15	17:00	16:52	14:54	14:32	14:30	14:18	13:24
Temp. of Frozen Cream.	-3°	-3°	-3°	-3°	-3°	-3°	-3°	-3°	-3°	-3°

Temperature Recorded in Centigrade, Weights in Grams and Time in Minutes and Seconds.

solid cream. This observation gives a comparison of the temperatures of the finished product of different mixtures.

From Table No. V it is seen that the variation in the time required for the mixtures to begin freezing was of minor consideration until the mixture with 10% fat had been frozen. The mixtures ranging in fat content from 10% to 20 % required considerable more time to begin freezing proving that with each additional increment of fat, more time is necessary for the mixtures to reach the freezing point. Several investigators have proved that fat has no effect on the freezing point of milk--but in the present work the rate of cooling is under consideration.

Plate III shows that as the fat content of ice cream is increased, a longer period of time is required for the mixture to pass thru a certain temperature change and reach the freezing point. This indicates that the mixtures containing the additional increments of fat liberated their B. T. U.'s more slowly-which proves that fat is a poorer conductor of heat.

As the fat content of a mixture is increased, the water content is necessarily decreased in the mixture. The increased fat content of each mixture was allowed

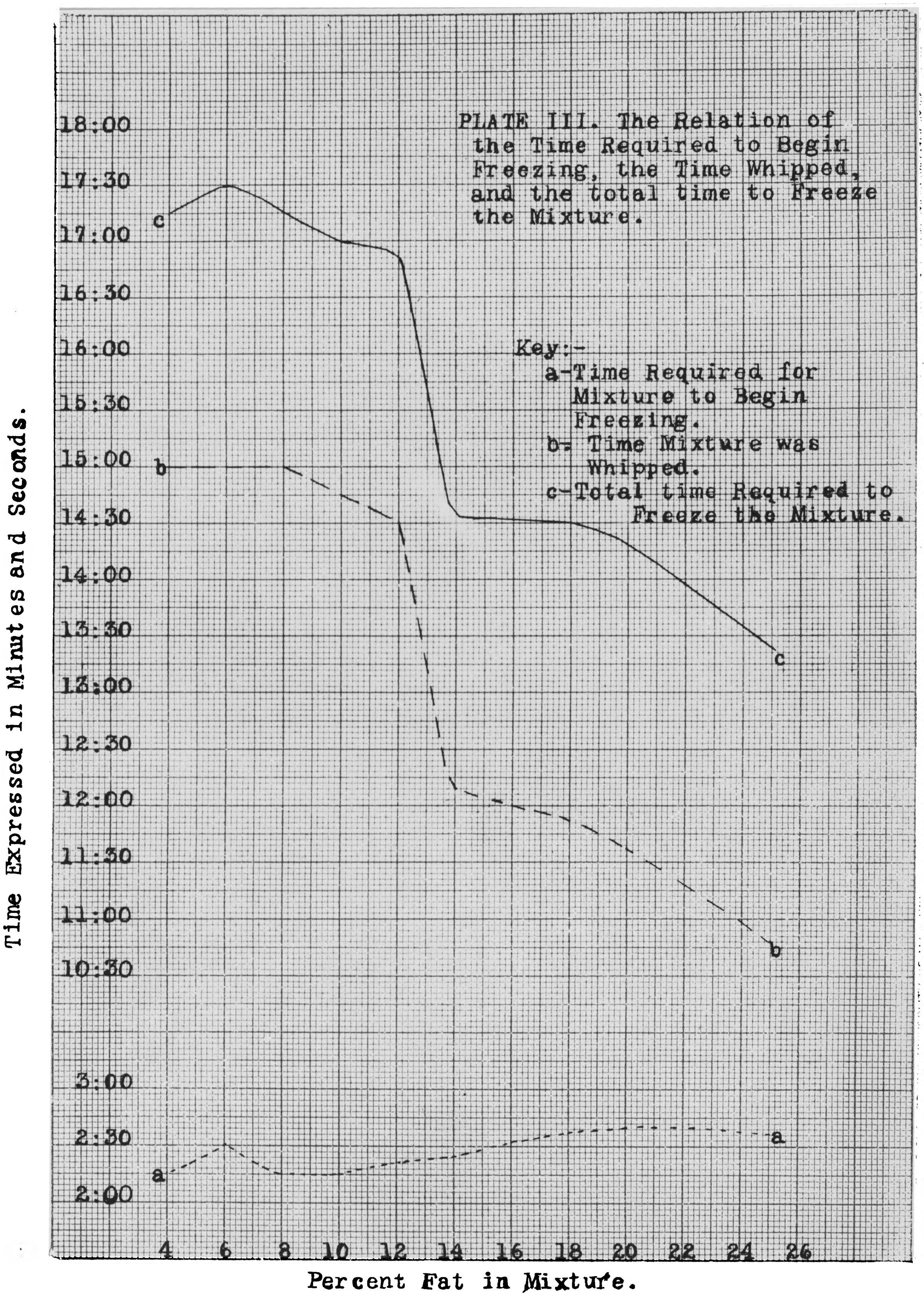
PLATE III. The Relation of the Time Required to Begin Freezing, the Time Whipped, and the total time to Freeze the Mixture.
Key:-
a-Time Required for Mixture to Begin Freezing.
b= Time Mixture was Whipped.
c-Total time Required to Freeze the Mixture.
Time Expressed in Minutes and Seconds.
18:00
17:30
17:00
16:30
16:00
15:30
15:00
14:30
14:00
13:30
13:00
12:30
12:00
11:30
11:00
10:30
3:00
2:30
2:00
4 6 8 10 12 14 16 18 20 22 24 26
Percent Fat in Mixture.
a
b
c

for by maintaining the serum solids at a constant and decreasing the moisture content. Water is known to be one of the best conductors of heat and by replacing this element thru increasing the fat content it necessarily follows that with each additional increment of fat the mixture would retain its B. T. U. 's over a longer period of time.

The effect of increasing the fat content and the relation to the time required to whip the cream is also shown in Table No. V. A continual decrease in time required to whip is noted as the fat content is increased. The curve in Plate III illustrates this decrease which becomes more pronounced in those mixtures containing more than 12% fat.

The decrease in the time required for whipping is due to the increased fat content which increases both the viscosity and total solids. As the viscosity of the mixture increases, the air is more rapidly incorporated and retained. The increased solids of the mixtures assist in retaining the air incorporated in the ice cream.

Table No. V and Plate III show that the total time required to freeze the mixture decreased with an increase in fat. This would indicate that the time required for the whipping of the mixture decreases more rapidly than did the time required to begin freezing which was increased by the addition of fat. This table shows that by increasing the fat content, the time required to freeze the mixture can be shortened considerably more than half a minute for each additional 2% of fat.

Another interesting fact shown by the same table is the uniformity of the temperature of the cream as it was taken from the freezer. There was practically no variation in the temperatures of the mixtures, proving that fat has no effect on the temperature of the frozen cream as it comes from the freezer. This feature substantiates the finding of several investigators.

From the above data, we conclude that the retardation of the rate of cooling of the mixture and the requiring of less time to whip can be said to have a direct relation to the percentage of butterfat in the mixture. The total time for freezing the mixture is decreased by the addition of fat. However, it would not be advisable in the commercial field to increase the fat content as a means of decreasing the time required for freezing a batch, because the time saved would be negligible when compared with the cost of the additional fat.

The Effect of Different Percentages of Butterfat on the Resulting Overrun.

In furthering the progress of this investigation,the objective was to get the greatest possible overrun on each freezing and maintain the same consistency in all the batches when drawn from the freezer. Considerable difficulty was encountered,and it was not always possible to get the maximum overrun within a range of one percent.

Table No. VI.

Showing the Effect of Different Percentages of Butter Fat on the Overrun of the Ice Cream Mixture.

Fat Content	Specific Gravity	Weight of Mixture	Weight of Ice Cream	Per Cent Overrun
4%	1.104	1432	755	89.7
6%	1.102	1437	757	89.8
8%	1.098	1440	755	90.7
10%	1.093	1436	748	92.0
12%	1.088	1434	749	91.5
14%	1.085	1428	747	91.2
16%	1.081	1422	744	91.1
18%	1.076	1414	741	90.8
20%	1.071	1387	735	88.7
25%	1.066	1372	740	85.4

The overrun was quickly determined by using the apparatus and methods previously described. As soon as each batch was drawn,the overrun was determined and recorded giving an opportunity to compare the results obtained in differ-

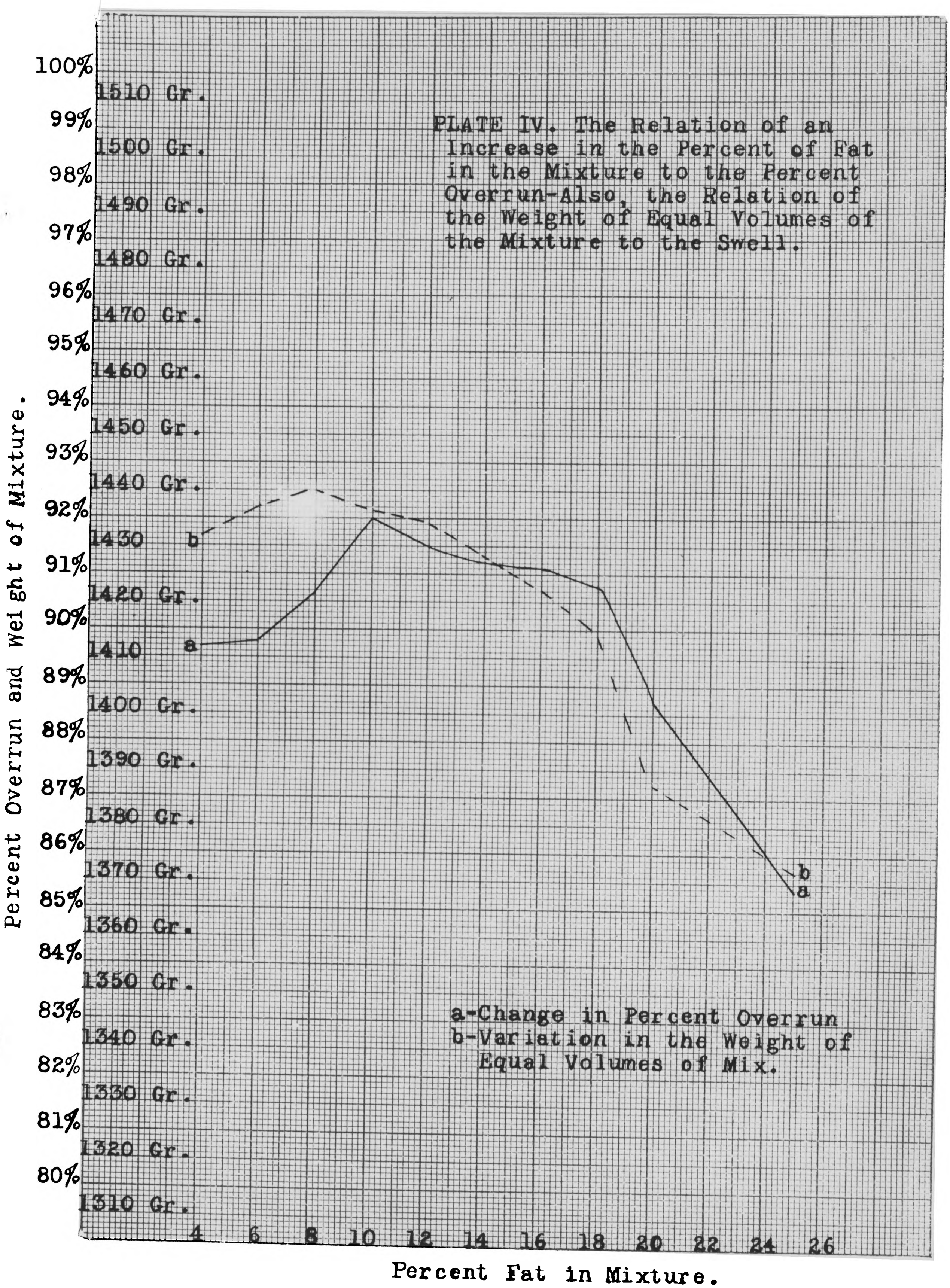

PLATE IV. The Relation of an Increase in the Percent of Fat in the Mixture to the Percent Overrun-Also, the Relation of the Weight of Equal Volumes of the Mixture to the Swell.

ent freezings of the same mixture.

It will be seen from Table No. VI that the percent overrun has a total variation of only 6.6%. This variation occurs when freezing the mixtures with fat content from 10% to 25% which is an increase of 15% in the fat content. Considering the overrun of the mixture with butterfat tests from 4% to 10%, it will be noted that an increase of 2.3% overrun was obtained with an increase of 6% fat. The maximum overrun was obtained when freezing the 10% mixture indicating that less than 10% fat will give a lower overrun as is also true of mixtures containing an excess of 10% fat. From Plate IV it is readily seen that a variation of the fat content from 10% decreases the percent overrun in the same proportion, 1% of fat decreasing the overrun slightly more than four-tenths of one percent.

It is known that the viscosity of the mixture has a marked influence on the perdent of overrun that can be obtained, that is, when the mixture is aged to increase its viscosity, a greater overrun is obtainable. The mixtures frozen in this investigation were not aged. The increased viscosity is due to increasing the fat content which does not increase the overrun except as stated in the freezing of 4%, 6%, 8%, and 10% mixtures. As the fat content increases above 10%, the effect of the additional fat appears to overcome the effect of the increased viscosity resulting in a lower overrun. When the fat content of a mixture is 10% or less, the effect of the viscosity of the mixture, is greater than the effect of the fat in determining the overrun.

Table No. VII.

Showing the Effect of Different Percentages of Butter Fat on the Hardness of Ice Cream.

Fat Content	4%	6%	8%	10%	12%	14%	16%	18%	20%	25%
Temp. of Brine.	-11°	-11°	-11°	-11°	-11°	-10.50°	-11°	-11°	-11°	-10°
Hours Tempered	7½	7½	7½	7½	7½	7½	7½	7½	7½	7½
Temp. of Ice Cream.	-10.4°	-10.5°	-10.0°	-10.2°	-10.2°	-9.7°	-10.1°	-10.0°	-10.3°	-9.0°
Size of Needle mm.	6.35	6.35	6.35	6.35	6.35	6.35	6.35	6.35	6.35	6.35
Penetration										
Center	23.0	25.0	25.0	24.0	23.5	26.0	25.2	22.5	23.0	24.5
End	24.0	26.0	26.0	25.0	23.5	25.0	24.2	23.0	23.7	26.0
End	25.0	26.0	26.0	25.0	23.5	25.0	24.0	23.5	23.7	25.7
Average	24.0	25.7	25.7	24.7	23.5	25.3	24.5	23.4	23.5	25.4

Temperatures Recorded in Centigrade and penetration in millimeters.

The Effect of Different Percentages of Butter Fat on the Hardness of Ice Cream.

In preparing the different creams for this test, we considered it desirable that each brick of a particular mixture have a uniform temperature, Such a uniform temperature for all mixtures was obtained with considerable difficulty. This was due to the type of apparatus employed,as difficulty was experienced in the use of the hardening box in maintaining a constant brine temperature.

Four bricks of each different mixture were placed in the hardening box where the temperature of the brine was held constant at -11°C. for seven hours. Holding the bricks at this low temperature,tempered them to a uniform temperature. The hardness of each brick was determined by making six penetrations, two in each end and two in the center, thus giving a check upon the uniformity of the hardness of the cream. Making six penetrations on each brick and using four bricks from each mixture gave a total of twenty-four determinations for each change in the fat content of the mixture and would eliminate any effect which the overrun might have upon the hardness of the cream. No weights were necessary to give appreciable penetrations which were determined with accuracy.

From a study of Table No. VII or a comparison of the curves on Plate V,an absence in the uniformity of

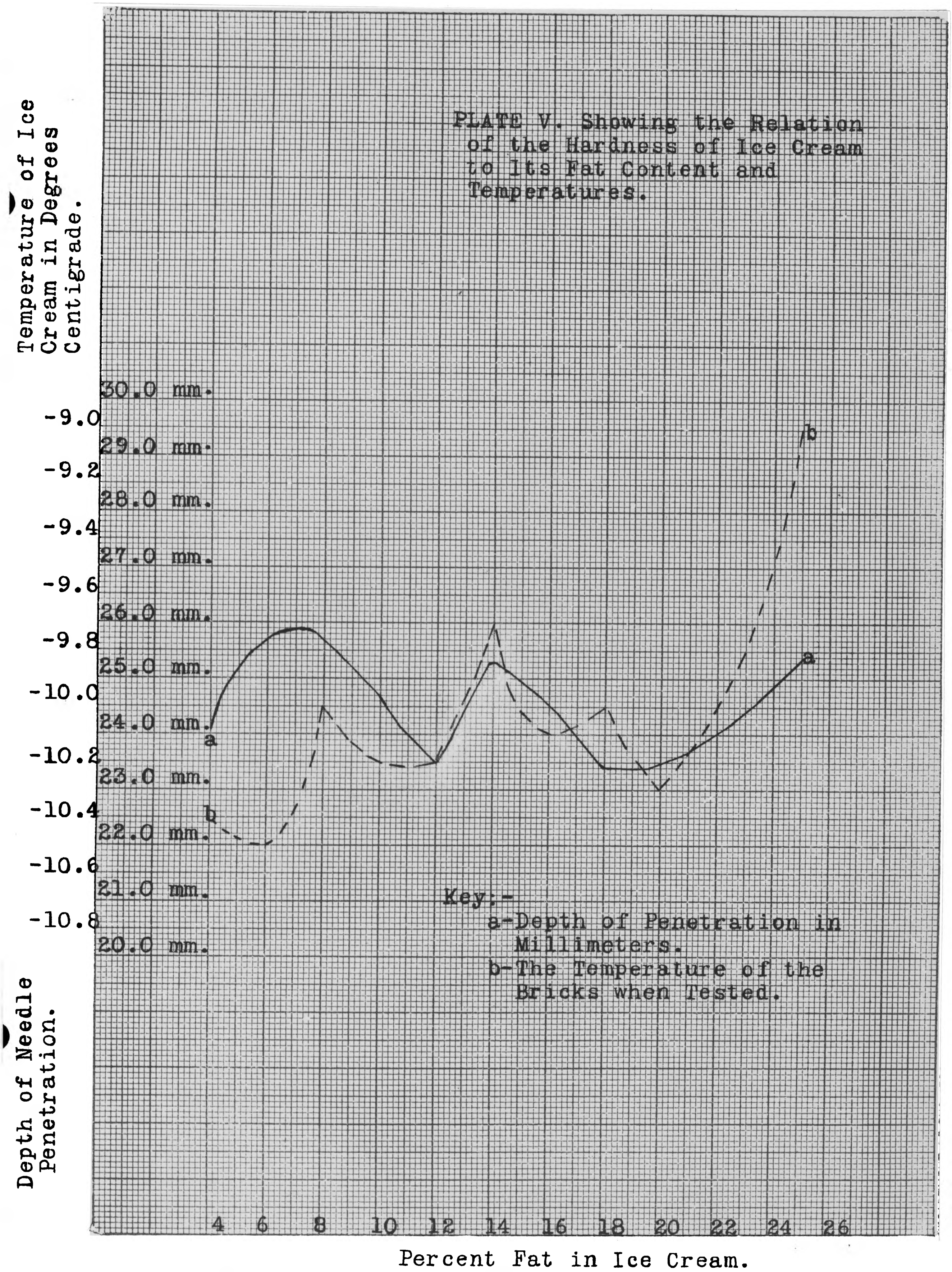

PLATE V. Showing the Relation of the Hardness of Ice Cream to Its Fat Content and Temperatures.

the penetrations is noticeable. There is a direct relation of the uniform penetration to the temperature, which indicates that the temperature of the cream has an appreciable effect upon the hardness. Since there is no uniform variation in the depth of penetration,it is evident the fat content of ice cream has no influence on its hardness.
The results of this investigation collaborates the investigation completed at the Virginia Station,showing that fat content had no apparent effect on the hardness of the ice cream.

Determination of the Time Required for Ice Cream with Different Percentages of Butterfat to Melt Under Summer Temperatures.

The stability of ice cream may be defined as the power or ability to withstand exposure to high temperature and retain a salable form and attractive appearance. This is one of the most important properties of ice cream, since it is the property that determines the length of time required for ice cream to lose its original form when exposed to the average summer conditions.

Several factors such as the temperature of the ice cream, the percent overrun, the use of binders and fillers, and different ingredients influence this property, increasing or decreasing the length of time required to melt the cream.

The object of this particular part of the work was to determine the effect of different percentages of butterfat in ice cream on its ability to resist summer temperature. The experimental ice cream was exposed to a constant temperature of 30°C. or 86°F. which was assumed to be the average summer temperature at which commercial ice cream is exposed while being consumed.

Apparatus used in this determination was a pair of scales for weighing the cream and rectangular paraffined boards of a suitable size upon which to place the bricks of cream. A cheese vat was used for the purpose of maintaining a constant temperature during the melting period. The vat used for melting purposes was equipped with a sliding door to assist in maintaining a constant temperature. The water jacket was connected to both cold water and live steam, making possible the use of any desired temperature. The bricks were brought to a uniform temperature by tempering for five hours in the hardening box. The rectangular paraffined boards were carefully weighed and the bricks of cream were placed on them. A photograph was taken of the bricks of cream as they then appeared. The gross weight was obtained by weighing each brick and recording the total weight of the form and ice cream. The bricks then were exposed to a constant temperature of 30°C. by placing them in a melting vat for one hour when each brick was reweighed and a photograph taken showing the appearance of the bricks at this stage. The condition of each brick was recorded and the bricks were again placed in the melting vat and exposed for a second hour. At the end of this period the same procedure was followed as that at the end of one hour. This procedure was continued until the bricks gave the appearance of no further melting. With each mixture, three hours time was required to complete the melting of each set of bricks.

Table No. VIII gives the data regarding the melting determination showing the percent loss in weight. In securing the data, four bricks of ice cream containing the same percent of fat were melted and the

Table No. VIII.

Stability of Ice Cream When Exposed to Summer Temperatures.

Per Cent Fat	Temp. of Vat	Temp. of Ice Cream	Orig. wt. of Brick	Loss in wt. after melting 1 hr.	2 hrs.	3 hrs.	Loss in Percent. 1 hr.	2 hrs.	3 hrs.
4%	30°	-10.4	525.00	326.00	490.00	515.00	62.1	93.3	98.1
6%	30°	-10.5	531.00	323.00	486.00	515.00	60.8	91.5	97.0
8%	30°	-10.0	510.00	291.00	454.00	485.00	57.1	89.0	95.1
10%	30°	-10.2	502.00	259.00	416.00	462.00	51.6	82.9	92.0
12%	30°	-10.1	555.75	266.75	428.75	496.00	48.0	77.1	89.2
14%	30°	-10.6	531.25	233.25	404.50	459.00	43.9	76.1	86.4
16%	30°	-10.3	570.25	203.50	372.00	466.50	35.7	65.2	81.8
18%	30°	-10.0	525.75	158.50	316.00	391.00	30.1	60.1	74.4
20%	30°	-10.3	529.00	132.00	292.25	350.25	25.0	55.2	66.2
25%	30°	- 9.0	528.25	1.00	61.25	211.00	0.19	11.5	39.9

Temperatures recorded in Centigrade and weights in grams.

results averaged. One brick from each of the four freezings, representing one mixture, was selected for this determination. It will be noted that the temperature of the melting vat was held close to a constant temperature thruout all determinations, a maximum variation of 2°, above or below, being tolerated. The temperature of the ice cream was not constant, as the conditions under which the cream was hardened were such as to make this impossible. However, the maximum variation was only 1.6° which had very little apparent effect on the melting of the cream indicated by the very uniform variation in the curves shown on Plate VI. The original weight of the brick varied more than any other one factor, but it is believed that this variation had little effect on the stability of the ice cream.

The loss in weight represents in each case the total loss in weight during the specified period of time. The loss in percent is computed on the same basis. For example: the 4% cream lost 62.1% of its original weight during the exposure of the first hour and 93.3% of its original weight during two hours exposure.

It should be noted that there is a direct relation between the increased fat content and the ability of the ice cream to resist summer temperatures. This is indicated by Table No. VIII which shows that the 4% cream lost 98.1% of its total weight during three hours melting as compared with ice cream containing 25% butterfat which lost only 59.9% of its total weight during a similar period

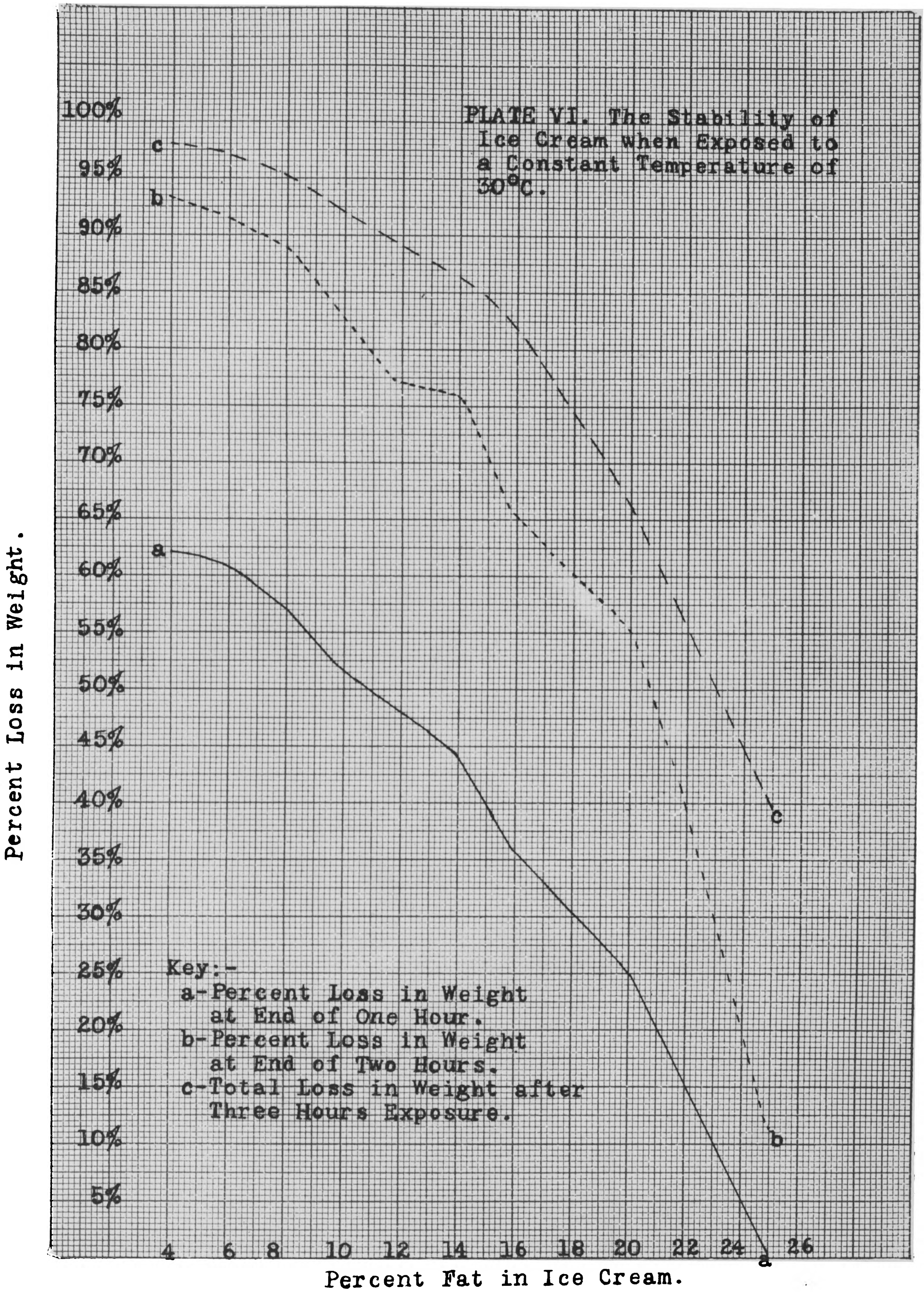
PLATE VI. The Stability of Ice Cream when Exposed to a Constant Temperature of 30°C.
Percent Loss in Weight.
Percent Fat in Ice Cream.
100%
95%
90%
85%
80%
75%
70%
65%
60%
55%
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
4
6
8
10
12
14
16
18
20
22
24
26
a
b
c
Key:-
a-Percent Loss in Weight at End of One Hour.
b-Percent Loss in Weight at End of Two Hours.
c-Total Loss in Weight after Three Hours Exposure.

of time. The gradual decrease in the percent of loss in weight accompanying the increase in fat content can be more easily understood by referring to the curves on Plate VI. There was a marked difference in the percent loss in weight as the fat content increased, indicating that a variation of 2% fat in ice cream containing a high fat content will have a greater influence on the resisting power than the same variation of fat in cream having a low fat content.

Views of the Ice Cream Containing Different Percentages of Butterfat When Exposed to Summer Temperature.

Fig. VI. Original Bricks before Exposure to Summer Temperature of 30°C.

The results of the melting of ice cream with a butterfat content of 4%, 6%, and 8% indicate that the bricks had lost their definite form and appeared to be entirely melted at the end of the second hour, although the ice cream continued to soften and run from the form until only a small amount was left. The difference in percent loss at the end of the third hour represents the difference in the

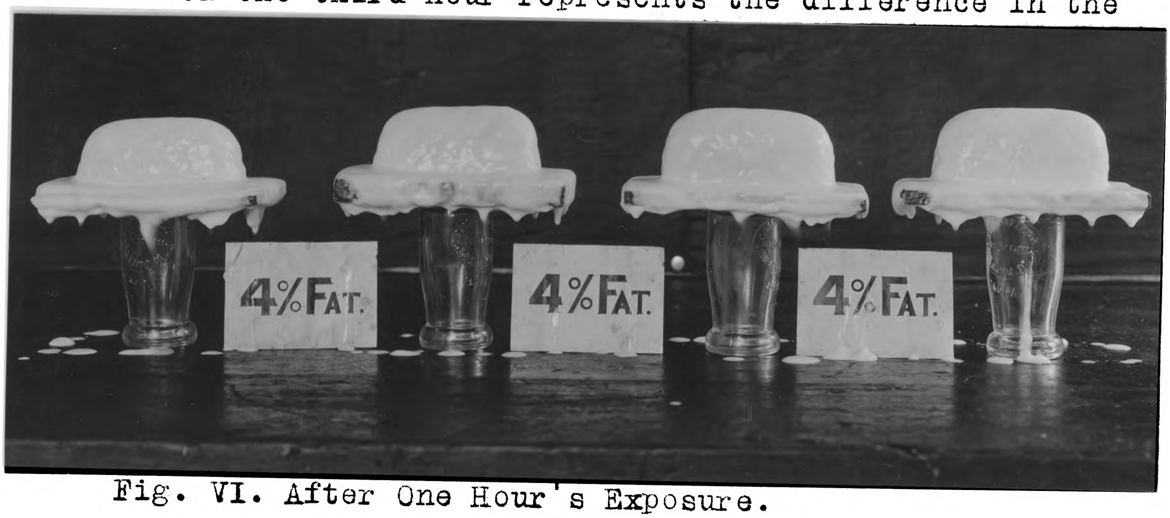

Fig. VI. After One Hour's Exposure.

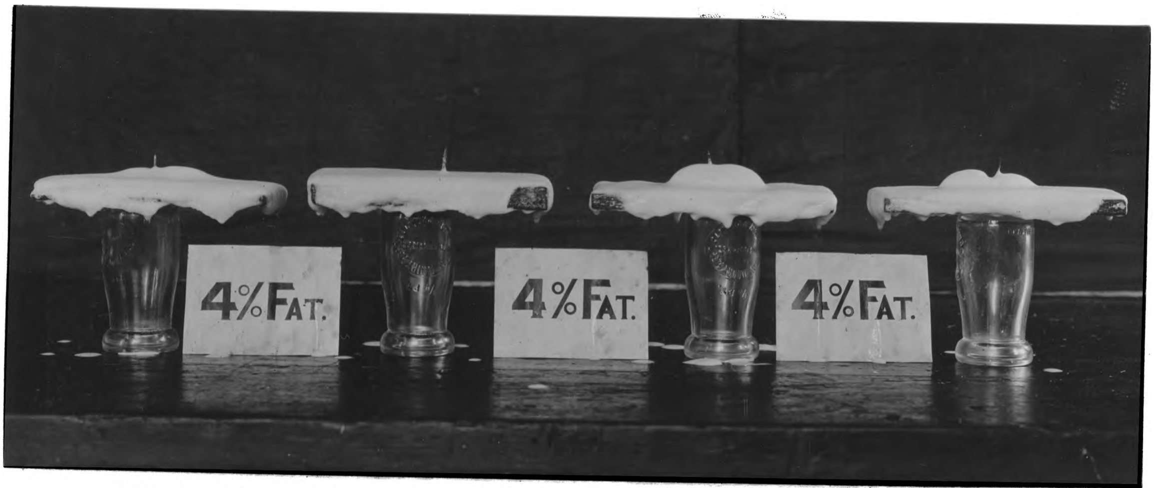

Fig. VI. After Two Hour's Exposure.

residue left on the form which was due primarily to an increase in the viscosity caused by an increase in the fat content.

It was determined that as the fat content of the mixture was increased, the cream had a tendency to retain its original form over a longer period of time. The bricks containing the higher percentages of fat, such as that of the 18% and 20%, softened with a rise in temperature but retained their original shape while the cream low in fat dripped off as rapidly as melted.

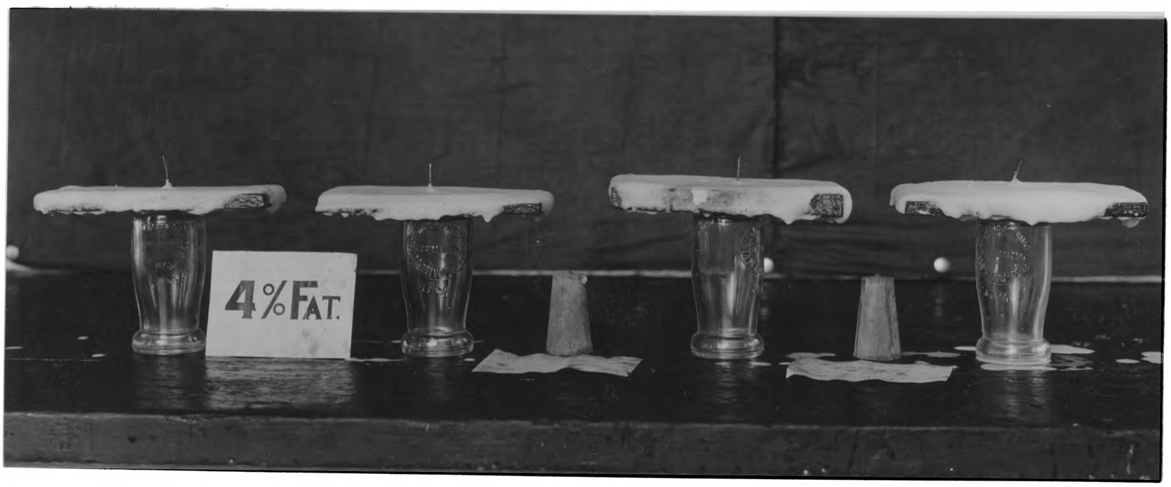

Fig. VI. After Three Hour's Exposure.

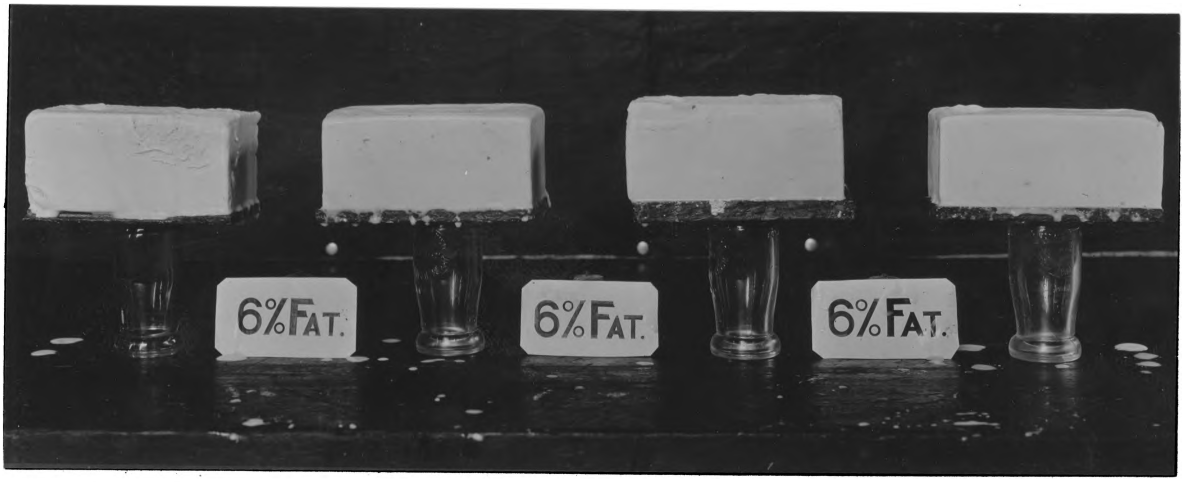

Fig. VII. Original Bricks before Exposure to Summer Temperature of 30° C.

The difference in weight lost at the end of the first hour between the ice cream containing 4% and 6% fat was marked altho the appearance of the bricks, in size and shape was similar. The corners of the bricks had melted and fallen giving the appearance of an oval, covered with a thin layer of honeycombed cream. As can be seen from Figures VI and VII the bricks were less than one half the original size. An exposure of two hours left the form covered with a coating of a syrupy, sticky substance comprised principally of sugar and butterfat.

Fig. VII. After One Hour's Exposure.

Fig. VII. After Three Hour's Exposure.

This had a pronounced honeycombed appearance, and the air bubbles were large and easily recognized. The small percentage of fat present and the correspondingly large amount of water accounts for the heat quickly breaking down the small ice crystals and liberating the air. As soon as the ice cream with a low fat content had softened, the air pockets lost their form, due to the absence of sufficient viscosity which would produce adequate surface tension on the air pocket.

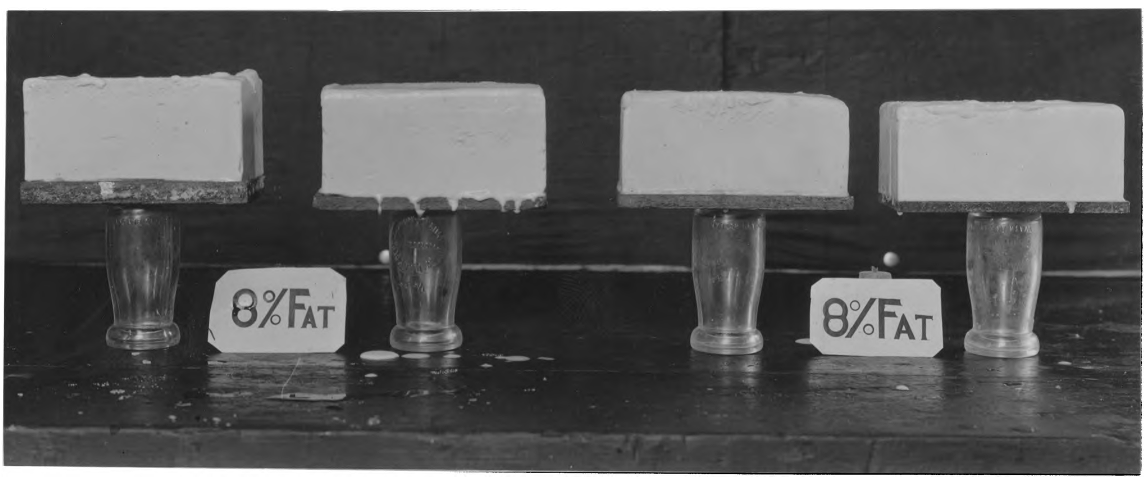

Fig. VIII. Original Bricks before Exposure to Summer Temperature of 30°C.

Fig. VIII. After One Hour's Exposure.

The low percentage of solids weakened the body making it difficult for the ice cream to retain a definite shape. With an increased fat content, a change in the appearance of the bricks exposed to the summer temperature was observed. The ice cream containing 8% or 10% butter fat has less of the honeycombed appearance after two hour's exposure, and at the end of the third hour's exposure the residue on the paraffined forms resembled whipped cream in appearance.

Fig. VIII. After Three Hour's Exposure.

Fig. IX. Original Brick before Exposure to Summer Temperature of 30°C.

Fig.IX. After One Hour's Exposure.

Fig. IX. After Two Hour's Exposure.

Fig. IX. After Three Hour's Exposure.

Fig. X. Original Brick before Exposure to Summer Temperature of 30°C.

With the 12% ice cream, it was noticed that the cream softened more uniformly, retaining a shape resembling that of the original brick. The melted portion reamined intact giving the brick a thick covering of soft cream resembling whipped cream in appearance. The air bubbles in this cream were small, closely arranged, and had a shape which was uniform and easily retained. The honeycombed appearance observed in creams with a lower percentage of fat had practically disappeared, and at the end of the third hour considerable of the residue

Fig. X. After One Hour's Exposure

Fig. X. After Two Hour's Exposure.

was left on the form as shown by Figure X. This residue had the undesirable, sickening flavor of whipped butter-fat, due to the excess fat content and its temperature. This undesirable taste became more pronounced as the fat content was increased above 12%, but the bricks continued to retain their shape and structure much longer, and the honeycombed appearance entirely disappeared. These differences can be observed by a study of Figures XI, XII and XIII.

Fig. X. After Three Hour's Exposure.

Fig. XI. Original Brick before Exposure to Summer Temperature of 30°C.

Fig. XI. After One Hour's Exposure.

Fig. XI. After Two Hour's Exposure.

Fig. XI. After Three Hour's Exposure.

Fig. XII. Original Bricks before Exposure to Summer Temperature of 30°C.

Fig. XII. After One Hour's Exposure.

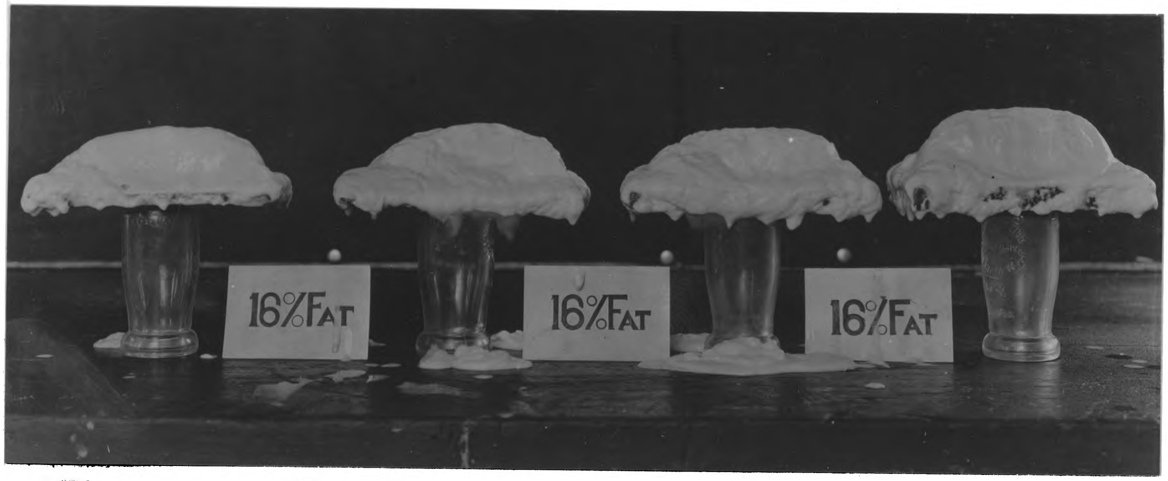

Fig. XII. After Two Hour's Exposure.

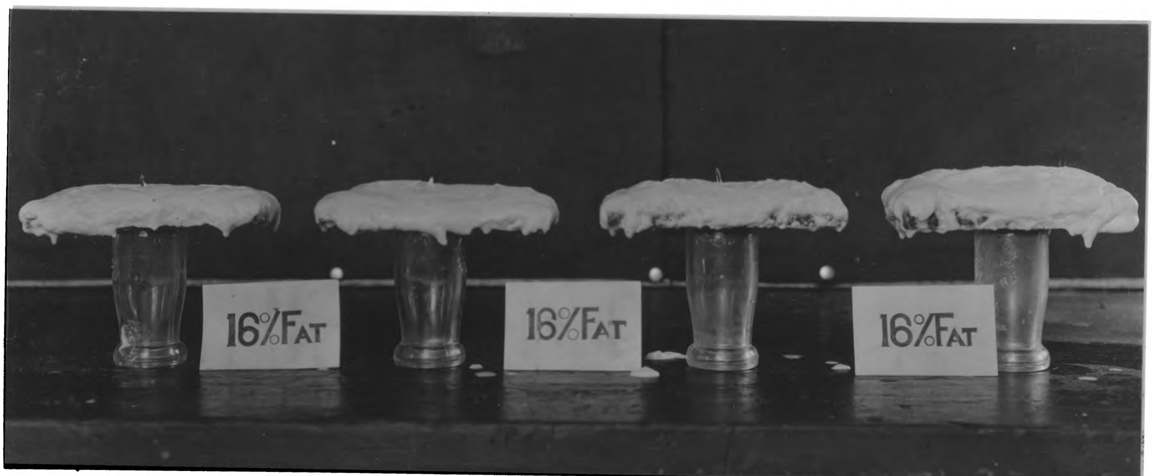

Fig. XII. After Three Hour's Exposure.

Fig. XIII. Original Brick before Exposure to Summer Temperature of 30°C.

Fig. XIII. After One Hour's Exposure.

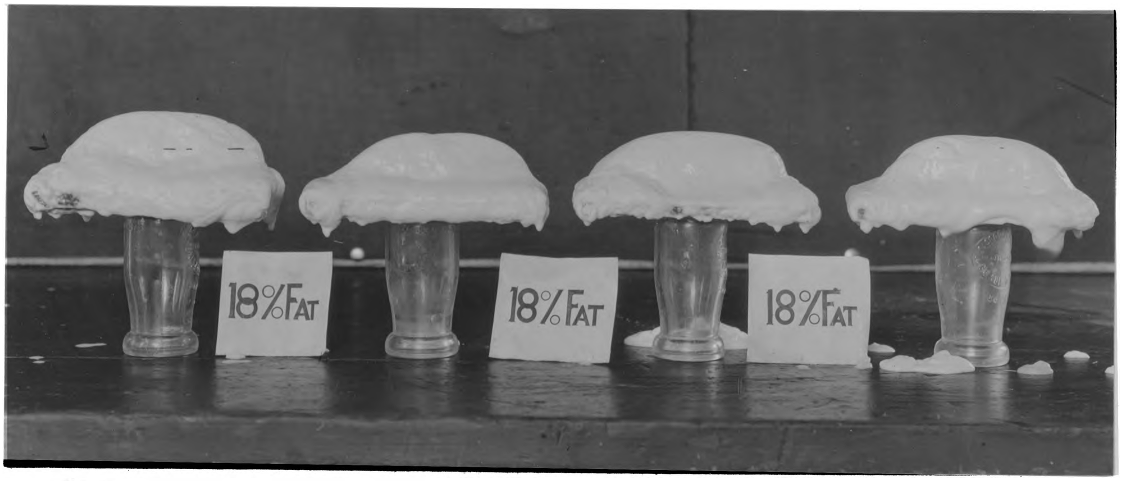

Fig. XIII. After Two Hour's Exposure.

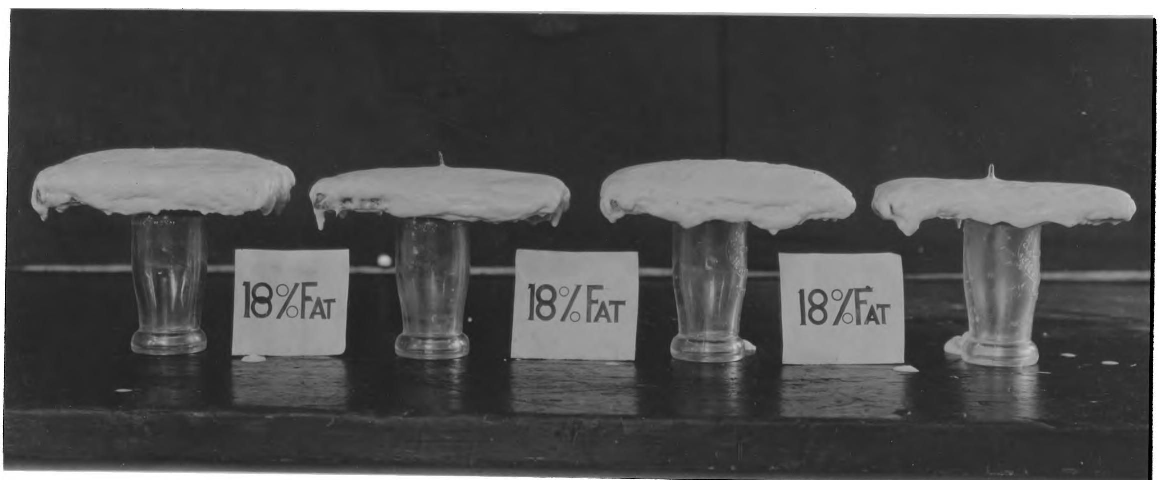

Fig. XIII After Three Hour's Exposure.

Fig. XIV. Original Brick before Exposure to Summer Temperature of 30°C.

The ice cream with 20% butterfat content retained 75% of its original weight when exposed one hour. The bricks had sagged, the corners were weakening and breaking away, but the original structure was still retained in fine condition. Exposure of two hours completely softened the bricks and much of the melted portion sloughed off. The structure was still well retained, indicating that the structure of the ice cream is an important factor in the stability test and that an increase in fat content tends

Fig. XIV. After One Hour's Exposure.

Fig. XIV. After Two Hour's Exposure.

to bring about this desirable structure.

The exposure of the 20% cream for a period of three hours reduced the original weight 66.2%. The cream had slumped in shape, spreading at the bottom, and a small portion had sloughed off. The flavor of the residue, which was principally fat, was sickening, flat, and undesirable due to the absence of sugar which had settled out.

Fig. XIV. After Three Hour's Exposure.

Fig. XV. Original Brick before Exposure to Summer Temperature of 30°C.

The cream containing 25% fat gave practically no change in weight or appearance during the first hour. At the end of the second hour, the cream had softened to the extent that spreading at the base was apparent. This would suggest that the loss in weight was due to evaporation of moisture, as none of the cream had sloughed off.

Fig. XV. After One Hour's Exposure.

Fig. XV. After Two Hour's Exposure.

At the end of the third hour, a small portion had broken over the sides and each brick was sagging. The outward appearance of the bricks was of a yellowish tint, while the texture was brittle. The viscosity of the mixture together with the structural shape of the air pockets **caused** the residue to retain its original structure and resist the extreme temperatures. Figure XV clearly indicates the condition of this cream at the end of the first, second, and third hours, respectively.

Fig. XV. After Three Hour's Exposure.

Conclusions.

1. There is a direct relation between the fat content of ice cream and its stability or the resistance offered to summer temperatures. Each additional increment of butterfat strengthens the ability of the ice cream to resist summer temperatures.

2. The ability of an ice cream to resist summer temperatures is closely allied to the structure of the frozen cream.

3. The higher the percentage of butterfat in the mixture, the more resistant the structure becomes when exposed to summer temperatures for a given period of time.

Table No. IX.

Showing the Effect of the Percent Overrun on the Stability of

Ice Cream When Exposed to a Summer Temperature of 30° C.

Per Cent Butter Fat	Percent Overrun	Temp. of Vat	Temp. of Ice Cream	Orig. wt. of Brick	Loss in weight after melting. 1 hr.	2 hrs.	3 hrs.	Loss in Percent 1 hr.	2 hrs.	3 hrs.
8%	83.1	30°	-9.7°	519	359	487.5	---	69.2	94.0	---
	88.5	30°	-10.0°	510	291	454	485	57.1	89.0	95.1
10%	87.6	30°	-10.2°	502	259	416	462	51.6	82.9	92.0
	91.7	30°	-9.8°	511	242.5	420	478	47.4	82.2	93.5
12%	87.6	30°	-10.2°	521	291	425.5	487	55.9	81.7	93.5
	91.5	30°	-10.1°	555.75	266.75	428.75	496	48.0	77.1	89.2
14%	91.2	30°	-10.6°	531.25	233.25	404.5	459	43.9	76.1	86.4
	92.7	30°	-9.7°	563	186	405	488	33.0	71.9	86.7
16%	81.7	30°	-9.9°	541	329	468	500	60.8	86.5	92.4
	92.7	30°	-10.1°	516	178	350	420.8	34.5	67.8	81.5

Temperatures recorded in Centigrade, and weights in grams.

The Relation of Different Percentages of Overrun to the Stability of Ice Cream.

During the past few years the manufacturers of commercial ice cream have learned, from experience, that there is an indefinite relation between the overrun and the ability of an ice cream to resist summer temperatures.

To determine the relation of the overrun to the stability of different ice creams, the same apparatus and methods were employed as when determining the relation of fat and stability. Mixtures varying in fat content from 8% to 16% were prepared in duplicate. Eight freezings of each mixture were made. The overruns obtained were such as would give four freezings with a low overrun and four with a high overrun of the same mixture. One brick from each freezing was exposed to summer temperature for three hours and the results recorded. Table No. IX shows the averaged results of each mixture.

A study of Table No. IX shows that in each set of duplicate freezings, those freezings with the greatest overrun proved the more stable. This indicates that an increase in the percent overrun will retard the melting of the ice cream. It will be observed that the bricks having the highest overrun also had the highest temperature. This condition would suggest that the cream with the highest overrun would melt faster. The curves on

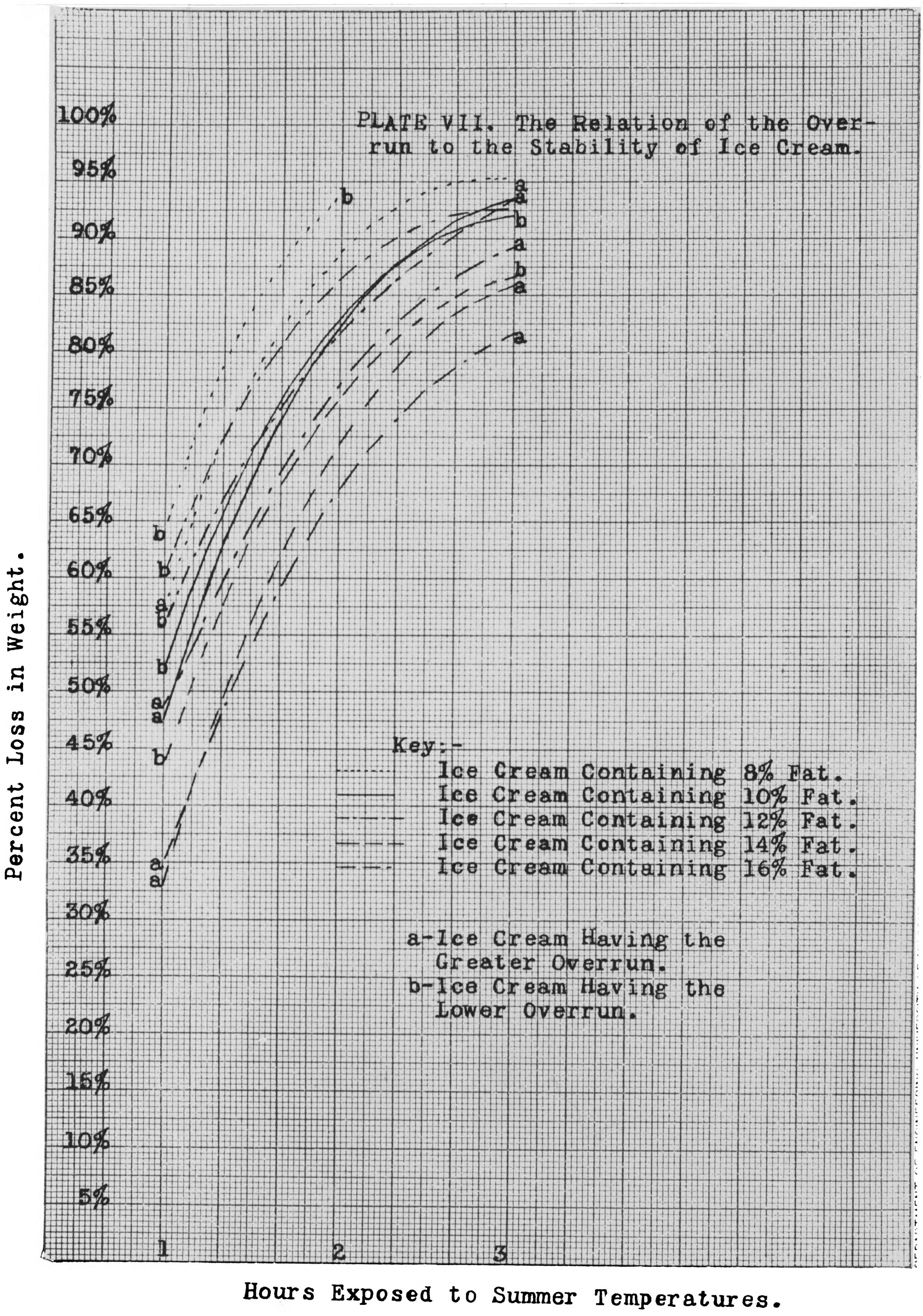
PLATE VII. The Relation of the Over-run to the Stability of Ice Cream.
Percent Loss in Weight.
100%
95%
90%
85%
80%
75%
70%
65%
60%
55%
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
1
2
3
Hours Exposed to Summer Temperatures.
Key:-
Ice Cream Containing 8% Fat.
Ice Cream Containing 10% Fat.
Ice Cream Containing 12% Fat.
Ice Cream Containing 14% Fat.
Ice Cream Containing 16% Fat.
a-Ice Cream Having the Greater Overrun.
b-Ice Cream Having the Lower Overrun.

Plate VII show that such did not take place, but that the batch having the greatest swell was invariably the one offering the greatest resistance. This indicates that the overrun of an ice cream mixture has more influence on its ability to withstand summer temperature than the temperature of the cream when first exposed.

Close-up Views Showing the Structure and Texture of Ice Creams Containing Different Percentages of Butter Fat.

In making a study of the effect of fat on the body, texture, and appearance of the cream it was realized that any description would be inadequate. It is very difficult to describe the body, texture, or appearance of any particular cream and give a definite and clear mental picture of the cream. For this reason, the preceding description has been mainly a comparison applied in comparing the qualities of ice cream. As a means of conveying a clear mental picture of the difference in the structure and texture of the ice creams, photographs of the broken cream are presented.

In the taking of these pictures when the camera had been set for photographing, a slab from a brick of the ice cream to be photographed was cut off with a chilled knife. This gave an opportunity to observe the structure and texttture of the ice cream.

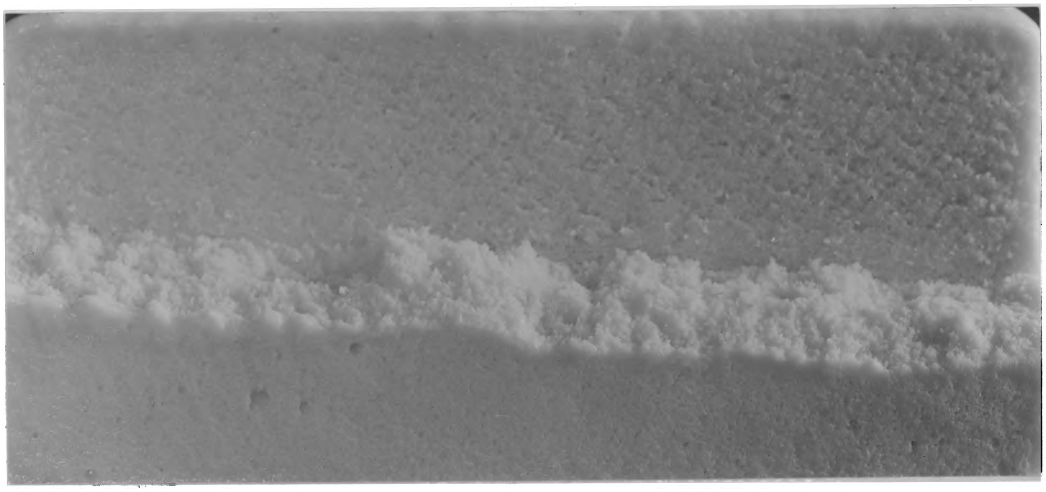

Fig. VI. Showing a Close-Up of the Texture of the 4% Ice Cream.

Figure VI shows the coarse, open,granular texture of the 4% ice cream. The porous condition of the cream and the size of the particles as they project from the broken surface are discernible. In comparing Figures VI and VII an improvement in body, texture, and appearance is seen. A closer texture in Figure VII is indicated by the smaller granules and a less porous body. This change is due entirely to the increase in the fat content.

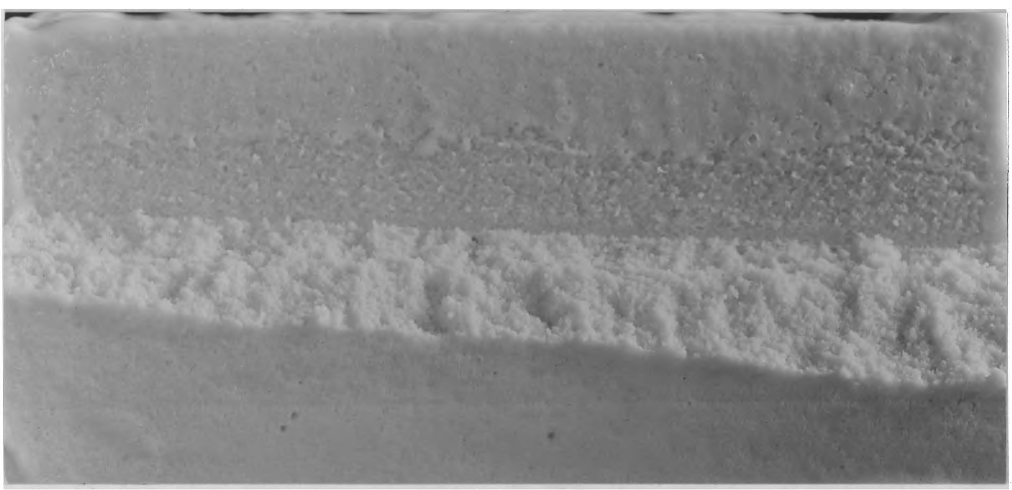

Fig. VII. Showing a Close-Up of the Texture of the 6% Ice Cream.

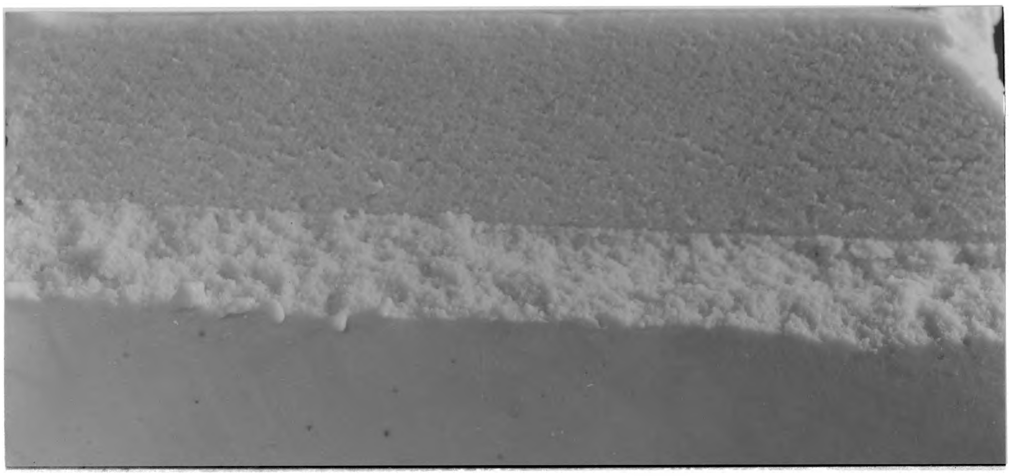

Fig. VIII. Showing a Close-Up of the Texture of the 8% Ice Cream.

In Figure VIII showing the structure of the 8% ice cream, it is noticeable that the granules are much finer, the body is less porous, and the texture closer than in Figures VI and VII. The influence of the fat content on the body and texture is evident.

Figure IX, when compared with Figure VIII, shows how much closer is the texture of a 10% ice cream than that of an 8% ice cream. The broken portion of the 10% ice cream closely resembles the appearance of broken steel, indicating a texture that is desirable and typical of a good ice cream.

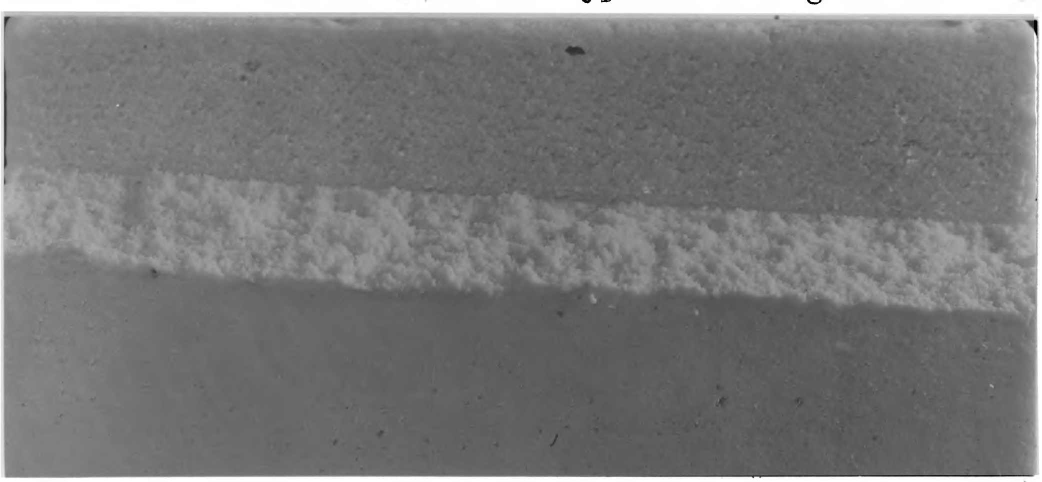

Fig. XI. Showing a Close-Up of the Texture of the 10% Ice Cream.

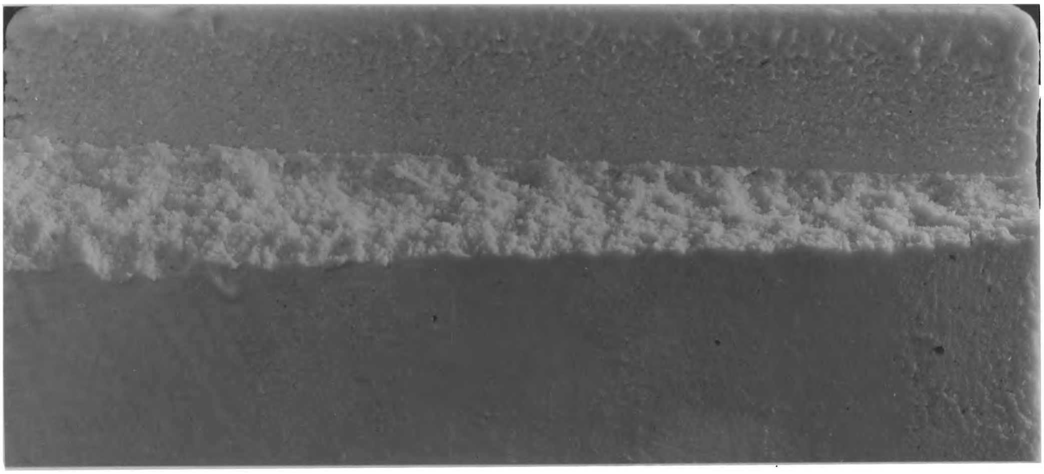

Fig. X. Showing a Close-Up of the Texture of the 12% Ice Cream.

The 12% ice cream shown in Figure X, when compared with Figures VI, VII, VIII, and IX, indicates that a higher fat content produces an ice cream that is closer in texture and firmer in body.

Figure XI shows, by the smoothness of the break, a still closer texture in the 14% cream. The particles are very small and the porous appearance of the 4%, 6%, and 8% ice creams is absent. This texture is too close for a desirable commercial ice cream.

Fig. XI. Showing a Close-Up of the Texture of the 14% Ice Cream.

Fig. XII. Showing a Close-Up of the Texture of the 16% Ice Cream.

There is a very decided change in the appearance of the structure and texture of the 16% ice cream shown in Figure XII and that of the 10% cream shown in Figure IX. The 16% cream shows a much closer texture and a more solid body. This ice cream broke down below the edge of the knife indicating the tenacity and adhesiveness of the ice cream in contrast to the square clean break of the 10% and 12% creams.

The 18% ice cream shown in Figure XIII also shows the increasing adhesiveness due to the increase in butterfat content. The texture is too close for a desirable ice cream.

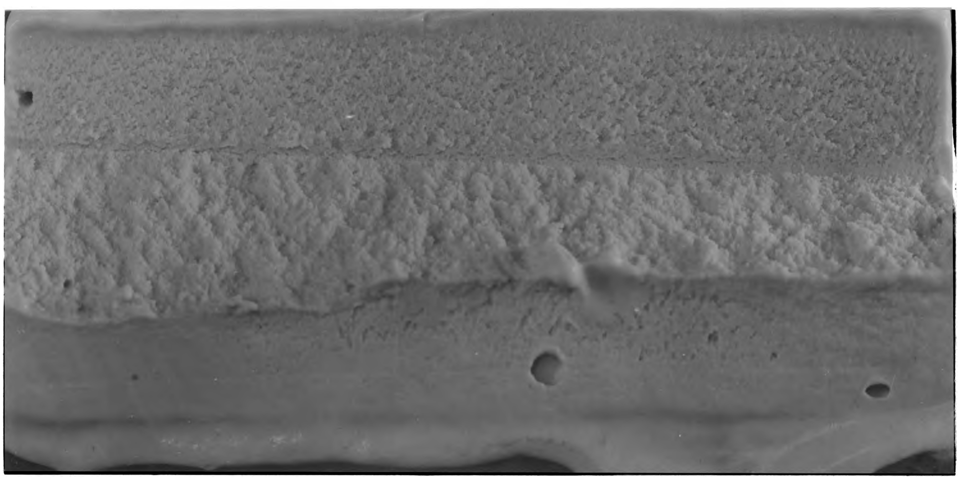

Fig. XIII. Showing a Close-Up of the Texture of the 18% Ice Cream.

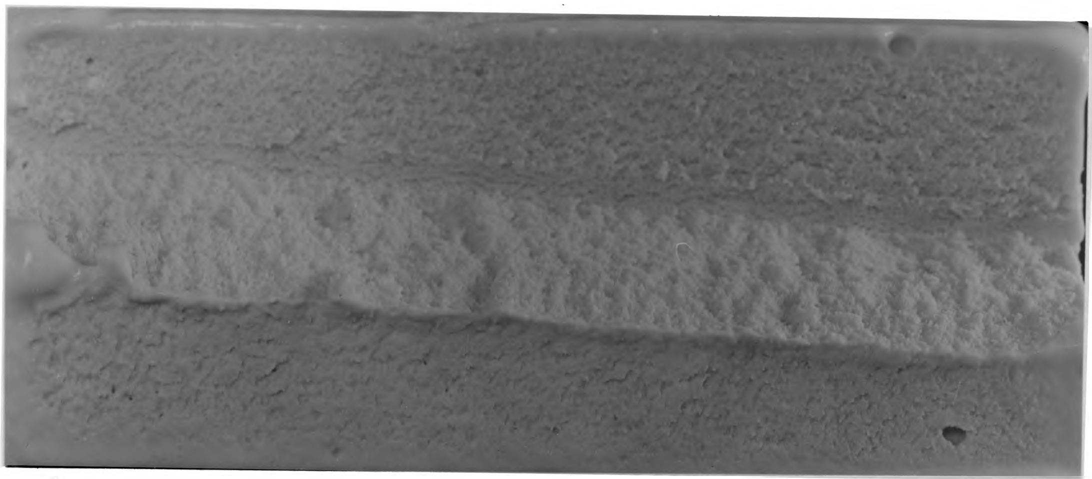

Fig. XIV. Showing a Close-Up of the Texture of the 20% Ice Cream.

Figure XIV shows the increasing closeness of the texture as it appears in the 20% ice cream. The surface of the broken portion of this cream resembles the appearance of broken jelly.

An even closer texture is observed in the 25% ice cream as shown by Figure XV. This figure shows the difficulty experienced in breaking off a portion of the brick. This was due to the adhesiveness and tenacity caused by the high percentage of fat in the ice cream.

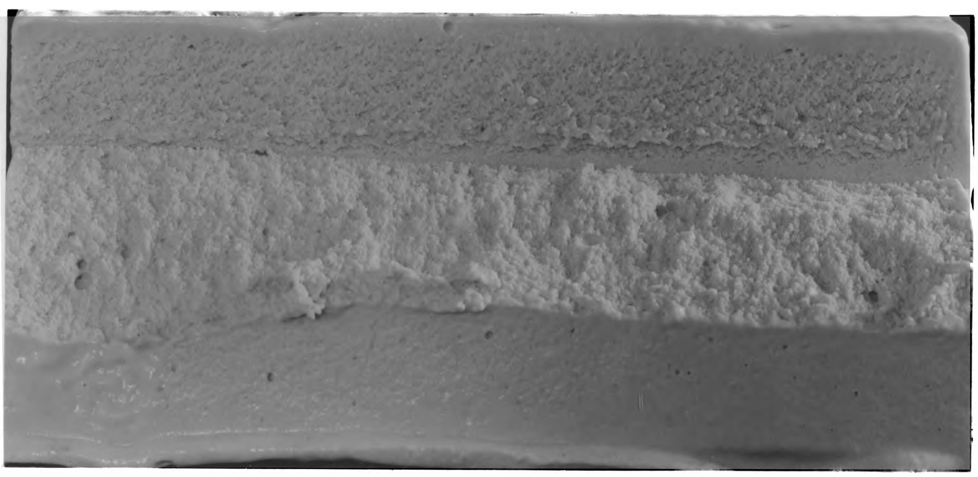

Fig. XV. Showing a Close-Up of the Texture of the 25% Ice Cream.

A comparison of Figures VI, IX, XII, and XV demonstrates the complete changes in the structure and texture of the ice cream. This change in a large measure accounts for the ability of different ice creams to withstand summer temperatures. A gradual increase in the closeness of the cream shows the direct relation of the butterfat content of the ice cream to its body, texture, structure, and appearance.

The Effect of Different Percentages of Butterfat on the Flavor, Body, Texture, Richness and Appearance of Ice Cream.

The effect of fat upon the specific gravity, viscosity, time required to freeze the mixture, hardness and stability of ice cream has been determined by mechanical tests. There are, in addition, certain physical properties which can be determined only by a careful judging or comparison of the ice cream.

The hardened ice cream was judged by two instructors and a student assistant in the Department of Dairy Husbandry, special attention being given to any noticeable difference in the flavor, body, texture, richness and appearance of the ice cream from the different mixtures at the age of one day. The ice cream was then held in storage for five days and again scored to determine the influence of the fat content when ice cream was stored. Two bricks from each of the four freezings of each mixture were hardened under the same conditions as the bricks used in determining the hardness and stability. The bricks were tempered by holding them at least five hours at a constant temperature. This procedure gave all bricks a uniform hardness and eliminated any variation which might be due to a difference in the temperature of the ice cream.

Judging Ice Cream for Flavor.

Flavor, being the most important property of ice cream, received first consideration. Ice Cream should have a clean, desirable ice cream flavor and must not be too cold or too warm. The most desirable flavor will depend entirely upon the desires of the individual consumer.

Ice Cream - Age One Day.

The four percent ice cream possessed an undesirable flavor, was flat and very cold. The coldness of the cream was attributed to the low percentage of fat and solids and the high moisture content. The flavor was considered very inferior to a desirable commercial ice cream.

The six percent ice cream possessed a clean flavor, which was not entirely desirable and was colder than an ice cream should be. The cream melted rapidly in the mouth due to the low solid content which also accounts for the coldness.

The eight percent ice cream had a flavor more closely resembling that of a typical ice cream than did the 4% and 6% ice cream. This cream did not, however, have the delicate flavor typical of ice cream containing higher percentages of fat.

The ten percent ice cream gave a delicate, desirable, and typical ice cream flavor. The coldness was moderate, and it was free from an undesirable after taste. The flavor of this ice cream would, without question, meet the demand of the average market.

The twelve percent ice cream had a typical ice cream flavor and was free from any excessive sweetness and undesirable coldness. The additional 2% of fat, when compared with the 10% cream, produced a slight excess of fat for the average trade, altho this excess was not sufficiently pronounced to prove detrimental.

The fourteen percent ice cream produced a flavor that was considered not entirely desirable. A slight butterfat flavor was noticeable giving the product somewhat of a flat flavor and a thin coating was left inside the mouth. An aftertaste of butterfat was noticeable.

The flavor of the sixteen percent cream was so rich as to give an undesirable taste. The coating of the mouth and the after taste were even more noticeable than that of the ice cream with lower percentages of fat. These two defects would tend to discourage the sale of such ice cream because the desirable, delicate ice cream flavor was not entirely perceptible.

The eighteen percent ice cream had a clean, somewhat sweet flavor but was so rich in butterfat as to be somewhat sickening, and a small quantity satisfied the appetite. The butterfat after-taste was very objectionable.

The twenty percent ice cream had so pronounced a butterfat taste as to overshadow the flavoring used. Very little of this particular ice cream was consumed, due to the undesirable butterfat flavor and after-taste. The coldness had disappeared and this ice cream would be described as a warm cream. The butterfat coating in the mouth was very perceptible.

The twenty-five percent ice cream had a very pronounced butterfat taste. A thick coating of the mouth was very noticeable and left a pronounced undesirable after-taste. The high fat content combined with the sugar gave the ice cream such a flavor that it required only a small portion to satisfy the appetite.

A careful study of these ice creams, ranging from four to twenty-five percent in butterfat content, shows that the 4% and 6% creams were cold, flat, and lacking in flavor. It should be noticed, however, that altho the 4% and 6% creams were too cold for a desirable ice cream they were not as cold as sherbets. The flavor of the ice cream improved with increasing increments of fat until the most typical ice cream flavor was obtained in the 10% cream. When more than 10% fat was used, a butterfat flavor developed, becoming more pronounced with additional increments of butterfat. This type of flavor became undesirable in the 14% cream and completely overshadowed the typical ice cream flavor in the 20% and 25% ice creams. The coldness of the ice cream became less pronounced with increasing increments of fat. An undesirable coating of the mouth was noticed in the 14% cream. This became more perceptible as the fat content of the cream increased.

Ice Cream - Age Five Days.

The four percent and six percent ice creams possessed an insipid, flat, and old-butterfat taste. This undesirable flavor appeared principally in the after-taste. The coldness, due to the low fat and total solids content, was sufficient to cause an unpleasant sensation.

The eight percent showed an improvement over the 4% and 6% ice creams but did not possess a particularly desirable flavor. The coldness and the old-butterfat taste were less pronounced.

The ten percent ice cream was clean of flavor, being free from any undesirable butterfat taste, coldness, or excessive sweetness. It was in a salable condition.

The twelve percent ice cream had all of the desirable qualities of the 10% ice cream except for a slightly more pronounced coating left in the mouth and an old-butterfat taste in the melted portion.

In the fourteen percent ice cream the butterfat taste was becoming more pronounced as was the coating of the mouth. The partially melted ice cream gave a more pronounced old-butterfat flavor.

The sixteen percent ice cream possessed a sickening flavor if any quantity was consumed. The butterfat flavor was pronounced, and the coating of the mouth was so noticeable as to be objectionable.

The eighteen percent ice cream was clean of flavor but not desirable or typical, due to the pronounced butterfat taste. The old taste appeared very pronounced, especially in the partially melted portion, and there was a slightly rancid taste suggesting a breaking down of the fats. This would indicate that ice cream with this percentage of butterfat could not be stored for a period of five days and remain marketable.

The twenty percent ice cream was similar to the 18% cream, the butterfat flavor predominating. An off-flavor was present and there was an unpleasant after-taste. This ice cream would not prove marketable.

The twenty-five percent ice cream had a rich butterfat flavor which, together with the sweetness produced by the sugar, gave a flavor which resembled the flavor of syrup candy. The old taste was less perceptible than in the 20% cream, but the coating of the mouth with butterfat was the most pronounced of all ice creams judged.

It is evident from this study that ice creams with 4% and 6% fat, when stored for five days, have an undesirable after-taste, a slight old-taste, and are cold. An increase in the fat content of the ice cream to 8% and 10% produced marked improvement in the flavor. The coldness and the old-butterfat taste were less pronounced in the 8% cream and entirely absent in the 10% ice cream. With the addition of another 2% of fat there was an old-butterfat taste in the melted portion of the cream. The old-butterfat taste became more pronounced as the fat content of the ice cream was increased to 20%. The 18% ice cream developed a slightly rancid taste, indicating that ice cream with this percentage of butterfat could not be stored for a period of five days and remain marketable. The combination of the butterfat flavor and sugar in the 25% ice cream resembled the flavor of syrup candy and partially overshadowed the old-taste.

Judging the Ice Cream for Body and Texture.

The body and texture of ice cream are second in importance only to flavor. They have a decided influence on the firmness of the cream and the desirable feeling in the mouth when eating ice cream. The most desirable body in ice cream is a firm and mellow one which when combined with a smooth velvety texture that is entirely free from graininess or lumpiness gives a perfect product in regard to body and texture.

Ice Cream - Age One Day.

The ice creams containing four percent and six percent fat while firm in appearance were watery, melting rapidly in the mouth. The texture in each cream was open, porous, and coarse giving a rough, granular feeling resembling that of grapenuts on the tongue. The six percent cream when compared with the four percent cream showed a slight improvement in both body and texture but both would be classed as inferior products.

The eight percent cream had a firmer body, and less wateriness was observed than in the 4% or 6% creams. The texture was open, rough, and was termed coarse. There was a noticeable improvement in both body and texture over the 4% and 6% ice creams.

The body of the ten percent ice cream was free from wateriness and retained its stability a desirable length of time. The texture was smooth, desirable and medium close.

The twelve percent ice cream was mellow and firm of body, and was entirely free from wateriness. The stability was very desirable. The texture was smooth and velvety but appeared somewhat close. Compared with the 10% ice cream,the body was improved but the texture too close.

The fourteen percent ice cream had lost some of the mellowness present in the 10% and 12% creams. The texture was close and smooth but not velvety. The increased fat content impaired both the body and texture. This indicates that the ice creamswith the most desirable fat content were the 10% and 12% creams.

The increased fat content of the sixteen percent ice cream showed its effect on the stability and it was with some difficulty that the product was dissolved in the mouth. The texture was close, velvety, and somewhat rubbery. The high fat content appeared to be seriously effecting the body and texture of the ice cream.

The eighteen percent ice cream was mellow, tough, and rubbery, melting away very slowly in the mouth. The texture was very close, smooth and velvety, due to the high fat content.

The twenty percent ice cream required considerable effort to swallow,indicating that it was firm and stable. The texture was too close, smooth and velvety, giving the ice cream a doughy texture, the evidence of which appeared when the product was scraped with a spoon.

The twenty-five percent ice cream was more difficult to dissolve in the mouth than the 20% cream. The texture was the smoothest, most velvety and closest of all the ice creams studied. The doughiness, toughness and rubberiness were more pronounced than in the 20% cream. The texture and body were unsatisfactory.

The effect of fat on the body and texture was very noticeable. The body of the 4% and 6% creams was firm in appearance but was watery and melted rapidly in the mouth. The 8% and 10% creams showed marked improvement. The body of the ice cream continued to improve until the fat content had been increased to 16% when the product acquired rubberiness. A further increase in the fat content increased the toughness and rubberiness until the maximum fat content of 25% gave a body and texture that proved very undesirable. The texture of the cream shows possibly a closer relation to the fat content. In the 4% and 6% creams, the texture resembled that of sherbets, appearing open, coarse, and porous. With each additional increment of fat, the texture improved until in the 10% cream the most desirable texture was obtained. A closer texture was noticeable as the fat content was further increased. The 14% cream appeared too close in texture, and, when a fat content of 20% had been reached, the texture had become doughy.

Ice Cream - Age Five Days.

Both the four percent and six percent ice creams were similar to the product when one day old, each having a firm body and being watery, lacking stability in the mouth. The texture was coarse and open, feeling rough on the tongue.

The eight percent ice cream proved more stable than the 4% and 6% creams, melting with less rapidity when in the mouth. An improvement of the texture was noticeable, due to the absence of ice crystals.

The ten percent ice cream had a texture that was smooth, desirable, and medium close, and the body proved very satisfactory.

The twelve percent ice cream was firm and mellow in body. The texture was smooth and close.

The fourteen percent ice cream showed no noticeable difference at five days compared with its condition at one day. The excessive firmness and the rubbery feeling were the principal defects.

The sixteen percent and the eighteen percent ice creams were smooth, mellow, tough, and rubbery. The high fat content gave a very close texture. The excess fat caused the finished product to lose much of its desirability.

The twenty percent ice cream had a body that was very firm, with a marked doughy consistency and, due to the adhesiveness of the fat, appeared in rolls when the surface of the ice cream was scraped with a spoon. The texture was very close, appearing almost as a solid mass, giving the ice cream a smooth and velvety feeling.

The twenty-five percent ice cream was firmer of body than the 20% cream and when first placed in the mouth gave evidence of being smooth, but on swallowing the melted portion was somewhat gritty, and a coarse feeling was noticeable. It dissolved with considerable difficulty. The texture was the closest of any of the ice creams studied.

A study of ice creams ranging from 4% to 25% in butterfat content shows the 10% and the 12% ice creams to be the most desirable when body and texture are both considered. These creams, at five days, retained the same desirable qualities as when one day old. The ice creams with a lower fat content were more open, coarse, and granular. Those with higher fat content showed no perceptible change during storage, but they were more tough and rubbery in body and closer in texture with each additional increment of butterfat.

Judging Ice Cream for Richness.

The official, when judging ice cream, considers the richness, as the product must satisfy the legal requirements, for fat and total solids, of the state in which it is sold. The ice cream is given a score of zero or perfect. In discussing the results of this investigation, a different method was used, as the object sought was to determine the effect of the butterfat on the richness of the ice cream as indicated by the flavor. This is a comparative method and one that is practiced by the consumer.

Ice Cream - Age One Day.

The four percent ice cream was not rich enough to satisfy the demands of the average consumer.

The six percent ice cream showed a slight improvment over the ice cream containing 4% fat, but both were so cold as to discourage their consumption.

The eight percent ice cream met the legal requirements of this state. The richer flavor and warmer feeling in the mouth were more desirable than in the case of the 4% and 6% creams.

The ten percent ice cream had a desirable richness that was very noticeable. A large quantity of this ice cream would be eaten.

The twelve percent and fourteen percent ice creams had a pleasing richness. On account of their richness, smaller amounts would be consumed.

The excessive richness of the sixteen percent ice cream was very noticeable, and the quantity of it that would be consumed would be insufficient to have the desired cooling effect upon the consumer.

The eighteen percent, twenty percent, and twenty-five percent ice creams proved too rich and were considered undesirable. The high fat content gave a sickening taste that discouraged consumption.

The richness of the different ice creams studied increased in direct proportion to the fat content. Ice creams containing less than 10% fat cannot be classified as being rich enough to gain the approval of the average consumer. The 10% and 12% ice creams proved most desirable in richness. With each additional increment of fat, the richness became less desirable. The quantity of ice cream required to satisfy the appetite was directly proportional to the fat content.

The richness of the ice cream was not affected by holding the ice cream in storage for a period of five days.

Judging Ice Cream for Appearance.

Ice cream should have an attractive appearance and a desirable uniform color. In judging the ice cream studied in this investigation each brick was cut in half and the appearance noted.

Ice Cream - Age One Day.

The four percent and six percent ice creams had the same outside appearance as did the 10% ice cream, but when the bricks were cut in half the 4% and 6% ice cream appeared open, porous, and granular. The granules resembled corn meal in shape and size. Both ice creams were white in color.

The eight percent ice cream showed a marked improvement over the 4% and 6% cream. The texture was closer but continued to resemble finely ground cornmeal. The color of this ice cream was desirable.

The ten percent ice cream lacked the undesirable granular appearance present in the 4%, 6%, and 8% creams. The additional fat produced a closer texture. The color was very desirable.

The twelve percent and fourteen percent ice creams possessed a desirable external color appearance. Internal examination found the texture to be firm and close.

The sixteen percent, eighteen percent, and twenty percent ice creams showed no noticeable difference in their outward appearance from the creams containing a lesser percentage of butterfat. When the bricks were cut open for internal examination, a very close texture was observed, this being the closest with the 20% cream. The color was intensified, giving the ice cream a very rich appearance.

The twenty-five percent ice cream had a noticeably richer external appearance. The internal appearance was closer in texture and structure than any of the ice creams studied. The appearance resembled that of dough, and the color was so dark a yellow as to be considered objectionable.

The increased fat content caused very little difference in the external appearance of the ice cream studied. When the bricks of ice cream were cut in half and the internal appearance examined, the increased fat content was very noticeable. The open, porous, and granular appearance of the 4% and 6% creams became less pronounced until in the 10% and 12% creams the texture was considered desirable.

Ice creams containing in excess of 14% butterfat, were considered to have a texture that was too close. The 20% and 25% creams had a texture that presented an appearance resembling broken jelly. The color of the ice cream when cut in half showed a direct relation to the increase in fat, the most desirable color being obtained in the 10%, 12%, and 14% creams.

Ice Cream - Age Five Days.

The four percent and six percent ice creams showed no apparent difference in appearance following storage for five days. The texture was open, coarse, and granular, altho slightly closer than when one day old. The color remained unchanged during the storage.

The eight percent ice cream remained grainy and open in texture and light in color, there being no noticeable change during storage.

The ten percent and twelve percent ice creams had a medium close and desirable texture and were free from the granular appearance presented by the 4%, 6%, and 8% creams. The color was desirable, indicating that the optimum amount of fat was present.

The fourteen percent ice cream had a slight yellowish tinge and a somewhat closer body.

The sixteen and eighteen percent ice creams showed a very close texture, appearing the same as when one day old. The color was very yellow, due to the high fat content.

The twenty percent and twenty-five percent ice cream were exceedingly close in texture, resembling a solid mass. No change of color was observed in these creams. The external and internal appearance, the color, and the texture of ice creams with varying increments of fat were not affected by holding the ice cream in storage five days. The color and texture varied directly with the fat content. The 10% and 12% ice creams were the most desirable in appearance.

SUMMARY

This investigation is a part of a project of the Missouri Experiment Station, the object of which is to determine the effect of each ingredient in the manufacture of commercial ice cream. The particular ingredient studied was butterfat.

The object of this investigation was to determine the effect of butterfat on the physical properties of ice cream, including a determination of the relation of the fat content to the following properties of the mixture; the specific gravity, the viscosity, and the time required for freezing. The relation of the fat content of ice cream to the physical properties of the finished product was determined. The physical properties of the finished product are as follows; body, texture, hardness, overrun, and stability.

Several of the ingredients used in the manufacture of ice cream have been studied and their relation to the manufacturing process determined, at least, in part. The results of this experimental work show that the addition of different amounts of these ingredients in the manufacture of an ice cream will increase or decrease the maximum overrun, vary an ice cream as to its hardness and its ability to retain its original form when exposed to summer temperature.

The ice creams studied ranged in fat content from 4% to 25% inclusive. Beginning at 4%, the fat content was increased in increments of 2% until the mixture contained 20% fat. It was then increased 5% in order to get a mixture containing 25% fat. This range included all the variations in fat content that would likely be used by commercial manufacturers.

Experimenting with these different percentages of fat, we found that with each additional increment of 2% of fat, the specific gravity uniformly decreased. The viscosity of the mixture showed a gradual increase with each additional increment of fat. This increase in viscosity was more apparent when the mixture contained larger percentages of fat. Butterfat was found to have a decided influence on the viscosity of the mixture because the fat was more viscous than the water which it replaced.

It was determined that the length of time required for a mixture to begin freezing varied directly with the fat content. An increase of 21% fat increased the time required to begin freezing by twenty-five seconds. This increase in time to begin freezing was due to the fact that the increased fat content caused a decrease in the water content of the mixture and also because the fat added did not liberate heat units as rapidly as the water. Each mixture was cooled to the same temperature before being placed in the freezer, and the brine in the freezer was held at the same constant temperature during each freezing so that any variation in the time required to begin freezing the mixture was due entirely to the variation in the fat content.

The results obtained in determining the effect of fat on the time required to whip the mixture indicated a very marked and definite relation. With an increase in the fat content, the time required to whip the mixture was decreased. This made it possible to whip an equal quantity of air into the cream containing the highest percentage of fat, in a much shorter period of time. This was undoubtedly due to the increase in viscosity. The decrease in the time required to whip the mixture was found to be greater than the increase in the time required to begin freezing the mixture. This resulted in a decrease in the total time required to freeze the mixtures with the higher fat contents.

The temperature of the frozen ice cream was practically constant thruout the entire experiment, showing that there was no relation of the fat content to the freezing point of the ice cream.

The effect of fat on the overrun was very interesting. It did not vary directly with the viscosity which has previously been considered the most important factor in determining the overrun. It was found that the overrun did increase slightly with increased viscosity until the mixture contained 10% fat. When the fat content increased above 10%, the overrun decreased, altho the viscosity continued to increase. At this point the fat content, therefore, offset the increase in the overrun that might have been obtained by an increased viscosity.

The difference in the consistency of ice cream was found to be due to the difference in the percentage of water frozen, since it is the water only that freezes in the mixture. As the fat content increased, the water content decreased, thereby decreasing the quantity of water to be frozen. More time was required to cool this smaller quantity of water to the freezing point, because the cooling process of the mixture was retarded by the slow liberation of B. T. U.'s from the fat. With the increased fat content, more B. T. U.'s had to be removed which required a longer period of time. When the freezing point had been reached, the mixture began to whip or to incorporate air during which time the greater percentage of the water present in the mixture was frozen into crystals.

It was determined that there was no direct relation between the fat content of the different mixtures and the hardness of the ice cream. The slight variation in the penetrations recorded were due entirely to variations in the temperatures of the hardened product. The fact that these variations were not uniform and that the average of all determinations found checked with results obtained by Reid in his work with sugar, showed that fat had no effect on the hardness of the ice cream.

The determination of the rapidity with which the ice cream containing different percentages of fat melted when exposed to summer temperatures demonstrated the effect of fat upon the stability of ice cream.

It was found that ice cream containing a small amount of fat melted very rapidly and that but a small portion of the original brick remained when exposed for a period of two hours. An increase in the fat content, however, retarded the melting process by increasing the resistance offered to summer temperatures. This influence of the fat content was indirect, because the increase in fat changed the structure of the ice cream, thereby inhibiting the absorption of heat units. It was found that a variation in the overrun obtained during the freezing of the ice cream had a very decided effect on its stability. Increasing the overrun of ice creams strengthened their ability to withstand summer temperatures.

The scoring of the ice cream at the end of one and five days, respectively, demonstrated that ice cream containing 10% or 12% fat would maintain a salable condition after five days storage. The ice creams containing less than 10% fat, presented defects in body and texture; while those containing an excess of 12% fat had an old-taste and acquired a tough or rubbery body. The fat content of the ice cream had a marked influence on the body, texture, appearance, color, richness, and flavor of the ice cream. Each increase of 2% in the fat content of the cream produced a perceptible increase in the closeness of the texture, the firmness and smoothness of the body, the warmth of the taste, and the deepness of the butterfat color. The most desirable flavor, body, texture, richness, and appearance was obtained in the manufacture of the 10% and 12% ice creams.

CONCLUSIONS

The following conclusions may be drawn from the experimental work presented relating to the effect of butterfat upon the physical properties of ice cream.

1. The fat content has a direct relation to the specific gravity of the mixture. Each addition of 2% fat causes a decrease of .004 in the specific gravity of the mixture.

2. There is a direct relation between the fat content and the viscosity of the mixture. This relation is directly proportional to the addition of each increment of fat.

3. An increase in the percent of fat in the mixture increases the length of time required for the mixture to begin freezing. The length of time required to cool mixtures with varying fat contents, when under identical conditions, and when equal amounts of the different mixtures are cooled, will increase with each addition of fat.

4. The length of time required to whip the semi-frozen cream to the consistency desired decreases with additional increments of fat.

5. The total time required to freeze equal amounts of mixtures, containing different percentages of butterfat, is decreased by the addition of fat.

6. The percent of fat in the ice cream has no effect on the temperature of the frozen cream when the temperature

reading is obtained from the freezer.

7. A direct relation exsists between the fat content of the mixture and the overrun. A decrease in the percent of fat in the mixture, below 10% gives a marked decrease in the percent overrun. An increase in the fat content above 10% gives a marked decrease in the percent overrun.

8. The fat content of the mixture has a greater influence on the percent overrun than does the viscosity of the mixture. The effect of the fat content is in opposition to the effect of the viscosity of the mixture.

9. There is no relation between the fat content of the mixture and the hardness of the ice cream. The temperature of the ice cream has a much greater influence on the hardness.

10. The fat content had a marked influence upon the ability of ice cream to offer resistance to summer temperatures. The ability to resist melting when exposed to summer temperature is increased with each addition of 2% fat.

11. There is a direct relation between the fat content of the ice cream and the desirability of the flavor, body, texture, richness, appearance, and the keeping qualities of the cream.

12. A mixture containing 10% fat appears to result in the most desirable ice cream. This cream is not too expensive for the manufacturer to sell at a reasonable

price because it is comparatively low in fat content; it yields a high overrun; it is easy to handle; it has the most desirable and typical flavor, body, texture, appearance, and richness; and it will not develop defects during a five day storage period.

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