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Factors Affecting the Per Cent of Fat in Cream from Farm Separators

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FACTORS AFFECTING THE PER CENT OF FAT IN CREAM FROM FARM SEPARATORS.[1]

C. H. ECKLES. H. S. WAYMAN.

OBJECT OF THE EXPERIMENTS.

One of the constant sources of friction between the average creamery and the seller of cream is the variations in the "test" as the per cent of fat in the cream is usually called. The cream seller sees no reason why the test should vary in cream from the same cows fed the same ration, milked by the same man every day, and when the same separator is used to separate the cream. When sudden variations occur in the test, the creamery operator is often blamed for carelessness or dishonesty. While variations in the test may be due to one of these causes, every creamery operator knows that considerable variations in the per cent of fat do occur in the cream of nearly every patron, when the testing is done as accurately and carefully as possible.

Some knowledge is available regarding the causes of these variations but it is not complete. A study of the dairy text books and other publications on the subject shows a wide difference of opinion on several points, and in others the printed statements are quite different from the observations of practical men.

The main object in view when these experiments were planned was to determine more accurately the causes of these constant variations in the per cent of fat in cream from hand separators. At the same time it was planned that the experiments undertaken should furnish data on as many points as possible regarding the operation of separators as affected by the conditions that are certain to vary as the separator is operated on the farm in the ordinary way. The conditions covered by the investigation were those which are certain to vary on every farm and include all the factors believed to be of any great practical importance.

They are as follows:

(1) Speed of separator.
(2) Temperature of milk separated.
(3) Rate of inflow to separator bowl.
(4) Richness of milk separated.

In addition to the above it is assumed without trial that the per cent of fat in cream is influenced by the amount of water or skim-milk used to flush out the bowl at the end of a run and by the adjustment of the cream screw.

[1] Circular No. 37 of this Experiment Station gives a discussion of this subject in a popular form.

GENERAL PLAN OF THE INVESTIGATION.

Five different makes of hand power, centrifugal cream separators were used: DeLaval No. —, (298694 F.); Empire 2B, (102872); Simplex No. 2, (1540); Tubular No. 9, (486274); U. S. No. 6. The same machines were used throughout the experiment.

Night and morning milk from the Agricultural College herd of Jerseys, Holsteins and Ayrshires was strained into a large vat, thoroughly mixed and a sample for fat determination taken. In all the experiments, except those on temperature, the milk in the vat was

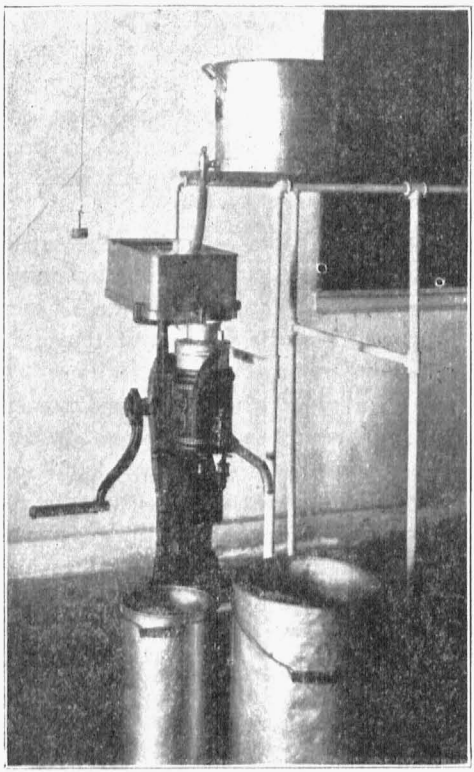


Fig. 1.
Showing arrangements for making the experiment.

then raised to 90° F. and held at that temperature for more than an hour in order that the full effect of the temperature might act on the fat and the serum. The milk was then divided into three lots, each lot to be used in making an experimental trial with a separator. For example, in studying the effect of speed of the separator, tests were made at full, three-fourths and half speed with the

same machines, for which purpose the three lots of the same milk were used. The same division of the milk into three lots was made in the experiments regarding temperature and rate of inflow. In considering the effect of the richness of milk only two divisions were made.

In preparing a separator for a test a double feed can was used as shown in Fig. No. 1. The height of the milk in the lower can was kept constant by adjusting the flow from the upper can by means of the faucet. The speed of the separator was accurately timed by the operator watching a pendulum adjusted to make the proper number of oscillations per minute. The separator bowl and parts were washed and brought to the temperature of the milk to be separated before each run. Each run was of six minutes duration. The first minute was preliminary to see that the machine was separating properly and to have a uniform time at which to begin the experimental runs. At the end of the first minute, the test proper begun and was continued five minutes. The time was taken by the second hand of a watch. One man operated the separator, gauging the speed by the pendulum and the other caught the skim-milk and the cream and kept the time.

At the end of the first minute after the cream began coming from the spout, vessels were shoved under the skim-milk and the cream spouts. These were removed at the end of the five minute run. It was found possible to take the time accurately within a fraction of one second. The cream and skim-milk obtained during the five minutes run was then weighed on a Troemer Solution scale which weighs up to 40 kilos and is sensitive to one gram. The samples for fat determination were taken from the entire quantity of the skim-milk and the cream obtained. Three runs were made in each case during one forenoon from the same milk.

The skim-milk was tested in Wagner doubleneck skim-milk bottles. The skim-milk was measured into the bottle with a 17.6 c. c. pipette. The whole milk was likewise tested in a common Babcock milk bottle. The cream for testing was weighed on a torsion balance. The cream bottle used was a nine inch bottle graduated to thirty per cent by two-tenths of one per cent. When the cream tested over 30 per cent, 9 grams instead of 18 were weighed out and the result multiplied by two. The test bottles were placed in a water bath at 130° for five minutes or more, before being read. Before reading the cream tests, a few drops of amyl alcohol colored with fuchsin was placed on top of the fat column to remove the meniscus. The reading was then taken at the line of division of the fat and alcohol. All testing apparatus was standardized and the same apparatus used throughout the experiment, except in case of breakage.

The same steam Babcock centrifugal machines were used throughout the experiment; the twenty-four bottle Agos machine was used for the skim-milk and the whole milk and the twelve bottle Jensen machine for the cream. The tests in all cases were made in duplicate.

PROCESS OF SEPARATION.

In order to study the causes of the variations above mentioned to the best advantage, it is necessary to first have clearly in mind the operation of a centrifugal separator. For this reason the ordinary process of separation is first explained, using in this connection the facts which are brought out by the experiments which are given in detail later on.

The separation of cream from milk by the centrifugal separator is based upon the principle of centrifugal force. Centrifugal force is that force generated by revolving bodies which tends to move from the axis of the revolving body along the radius in the direction of the circumference. Of two bodies, moving uniformly in the same circumference, the greater force is generated by the heavier body.

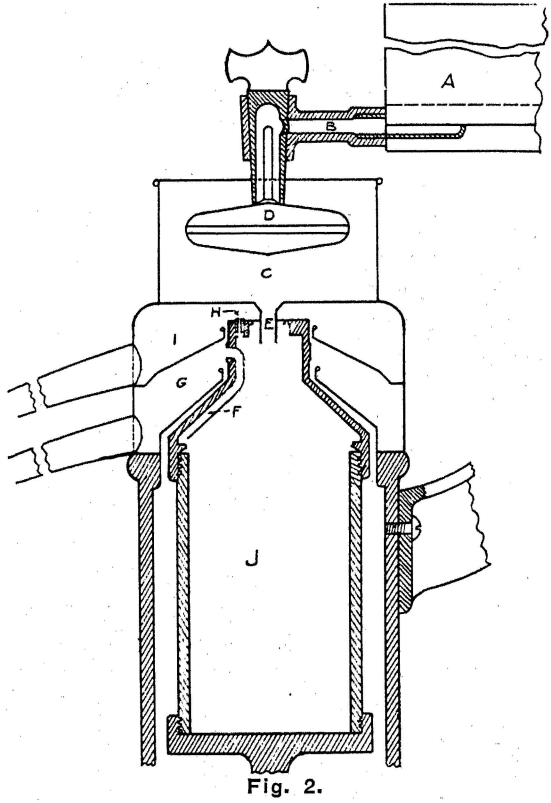


Fig. 2.
Vertical section of a cream separator bowl without inside fixtures.

Figure No. 2 shows a vertical section of a separator bowl and adjacent parts. The inside bowl fixtures are omitted to make the illustration simpler. The milk flows from the feed can, A, through the faucet, B, into the separator feed cup, C. At first the inflow to the feed cup is greater than the outflow from the feed cup, so the floater, D, is raised and partially cuts off the inflow. The milk flows from the tube E in the bottom of the feed cup into the separator bowl J. In some separators the milk enters the bowl at the top while others have a central tube which carries the milk to the middle or to the bottom of the bowl before it is discharged into the bowl proper. If the bowl is not in motion, the milk due to force of gravity fills the bowl from the bottom toward the top, but if the bowl is revolving rapidly as during separation, the centrifugal force generated is over a thousand times stronger than the force of gravity. The force of gravity is, therefore, overcome and the milk is immediately thrown to the side of the bowl thus filling from the side toward the center of the bowl. Since the skim-milk is heavier than the cream it is thrown to the extreme outer side of the bowl, forming a vertical wall of skim-milk. At the same time the fat is forced toward the center where a vertical wall of cream is formed. The most fat, therefore, is found near the center of the bowl while the least fat is found at the circumference of the bowl. The division between the skim-milk and the cream is increased as the center of the bowl is approached, until the cream is reached. In most types of bowls, under normal conditions of separation, the bowl never fills entirely full, leaving a vacant space at the center. When the separator has been in operation for a short time, a grayish white sediment gathers on the wall of the bowl. This is known as separator slime, and consists mostly of caseous matter not in solution in the milk and such insoluble foreign substances as have gained access to the milk. A horizontal section of the separator bowl would show the different walls of milk as follows:

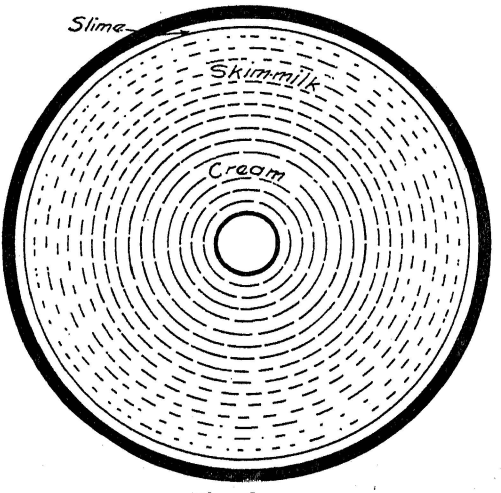


Fig. 3.
Horizontal section of a separator bowl.

Most of the separators have inside fixtures in the bowl which aid in the separation. These fixtures are in the form of cones, disks or perforated, corrugated, pieces which divide up the milk into thin layers and serve especially to prevent the mixing of the incoming stream of milk with the skim-milk and the cream as they are separated. The skim-milk may be discharged from either the bottom or top of the bowl. In Fig. 2, it will be seen that the skim-milk tube, F, opens into the bowl at the extreme side of the bowl. Here the milk which has been subjected to the most complete separation is found. The tube runs upward and toward the center of the bowl. The skim-milk is discharged from the tube at a point nearer the center of the bowl than is the opening where the skim-milk enters the tube. The tube is made in this manner in order to lessen the force with which the skim-milk is discharged from the bowl, as the nearer the opening is located to the center of the bowl the less the centrifugal force at that point. The great force acquired by the skim-milk as it enters the tube at the circumference of the bowl is lost as it approaches the center of the bowl through the tube because of the centrifugal force the skim-milk has to overcome in passing toward the center of the bowl.

In regard to the manner in which the skim-milk and cream are discharged from the bowl the statements usually found in text books do not agree with our results. It has been assumed that under normal conditions of separation the skim-milk tube runs to its full capacity. Our experiments indicate that, under normal separation, the skim-milk tube seldom, if ever, runs over half full. The drawings in Fig. No. 4 will aid in explaining this point.

A shows a vertical section of a separator bowl when only a small quantity of milk has entered. The milk has been thrown to the side of the bowl forming a wall, the inner line of which is vertical. The inner line of the milk in the bowl and the skim-milk in the skim-milk tube forms a straight line. As the inflow to the bowl con-

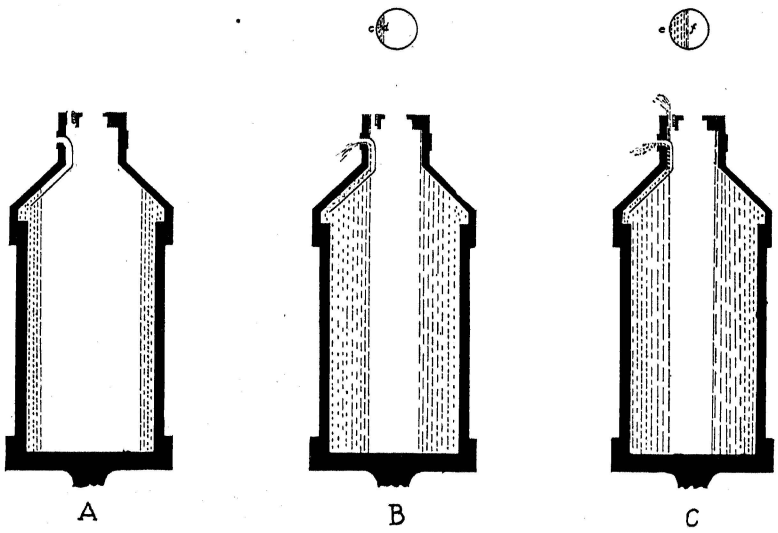


Fig. 4.

Vertical section of a separator bowl. Shows method of discharging skim-milk and cream.

tinues, the wall of milk moves nearer to the center of the bowl as in drawing B, until the skim-milk begins to flow from the skim-milk tube. The bowl has not filled enough at this stage to allow the cream to run out. Above the bowl an enlarged horizontal section of the skim-milk tube cut through the neck of the bowl is shown. The capacity of the skim-milk at this stage is determined by the space cd. Only a small part of the tube contains skim-milk, the rest is empty. It is understood, of course, that the skim-milk tube runs full from the opening of the tube in the bowl up to the beginning of the curve, the capacity of the tube is determined by the quantity which flows through at cd. As the inflow continues the thickness of the wall of milk in the bowl is increased until the cream begins to run from the cream opening; at the same time the capacity of the skim-milk tube is increased to ef as shown in C. The wall of milk in the bowl increases until the discharge from the skim-milk and the cream openings is equal to the inflow to the bowl. Even at this stage, the skim-milk tube does not run to its full capacity.

The fact that the skim-milk tubes do not run to their full capacity is shown clearly by the following experiment which was carried out

with the Empire Separator No. 1A. In making this test water was used in place of milk as it served the same purpose. The cream screw of the separator was set to skim-cream containing about forty per cent fat. The machine was first run under normal conditions for five minutes. The amount of water delivered from the skim-milk tube was found to be 18,983 grams. The cream outlet to the separator bowl was then filled with sealing wax and the separator again operated for five minutes in the ordinary manner. All the water which was used in the machine represented the normal inflow of milk and came out through the skim-milk tubes, the total amount being 22,035 grams. A third trial was made under same conditions as second except the milk was fed into separator bowl faster than normal by using a feed cup from a larger machine. The inflow of water was increased until the point was reached where the water began to come out at the center of the bowl around the feed cup. This would indicate that the bowl was filled as near the limit as possible and that the skim-milk tube must be run to its full capacity. The total amount of water passing though the milk tube in this trial was 33,833 grams. The conclusion from this trial is that under normal conditions of separation the skim-milk tube in this separator did not deliver more than half of its actual caacity of skim-milk. The only other explanation possible of this cappacity of the skim-milk tube to carry more than the normal amount is that a slightly greater centrifugal force was acting in the second and third trials than in the first on account of the water in the bowl being larger. This would tend to force the liquid out through the skim-milk tubes at greater speed and in that way increase their capacity. This is clearly not sufficient to account for the increase of over eighty per cent capacity of skim-milk tubes. The only conclusion seems to be that under normal conditions the skim-milk tube did not run much over half of its actual capacity.

HOW THE PER CENT OF FAT IN CREAM IS CHANGED.

Every user of a cream separator knows that, to obtain a cream containing a high per cent of butterfat, the cream screw is turned toward the center of the bowl, and in the opposite direction to obtain thin cream. The explanation generally given is that by turning the crew toward the center richer cream is obtained because the richer cream is found near the center of the bowl. This is true but is not the entire explanation. The per cent of fat in the cream, other things being equal, depends on the relative quantities of skim-milk and cream delivered from the separator. Any change in the separator which will change the relative quantities of these two products will effect the per cent of fat in the cream. When the cream opening is moved toward the center of the bowl, the capacity

of the skim-milk tube is increased. The following drawing of a portion of the top of the bowl of a common type of separator shows the skim-milk tube and the cream opening and illustrates this fact.

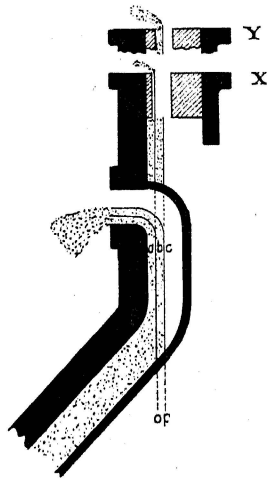


Fig. 5.

Skim-milk and cream outlet indicating how cream screw controls richness of the cream.

Let the line X show the position of the cream opening, and the line O the inner line of the wall of cream when the separator is set for thin cream. The capacity of the skim-milk tube is represented by ab. Now the cream opening is turned toward the center of the bowl to obtain cream of a high per cent of fat. Let the line Y represent the position of the cream opening and the line P the inner line of the wall of the cream when the separator is set for rich cream. As the cream opening is turned toward the center of the bowl, the wall of milk in the bowl increases until the cream can again flow out through the cream opening; that is, the inner line of the wall of cream moves from O to P. At the same time, the capacity of the skim-milk tube is increased from ab to ac. More skim-milk can, therefore, flow from the skim-milk tube when the cream screw is set for rich cream than when set for thin cream.

The amount of fat obtained in the cream is practically the same whether the separator is set to deliver a cream containing forty per cent fat or lower per cent. This difference is shown in Fig. No. 6. where a blank space represents the skim-milk, the black space the fat and the shadded portion the cream. The total amount separated by the machine remains the same in both cases, the real difference being the proportion between the cream and the skim-milk. When

the cream screw is adjusted to deliver thin cream, the opening is so placed in relation to the skim-milk tube that only a small part of

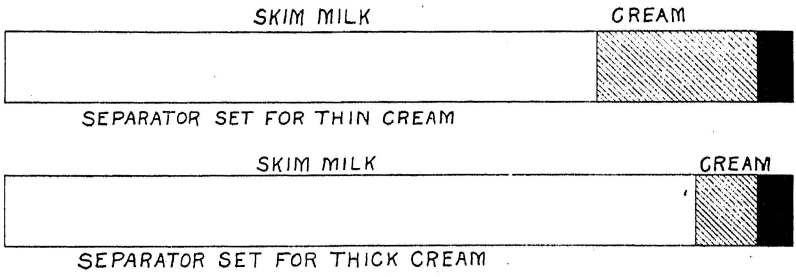


Fig. 6.
Graphic illustration of the effect of changing the cream screw.

the capacity of the latter is utilized. When the cream opening is moved nearer the center the inside wall of the cream is moved towards the center which makes it possible to utilize more of the capacity of the skim-milk tube. As a result, a larger quantity of skim-milk flows out and the quantity of cream is reduced.

EFFECT OF SPEED OF SEPARATOR.

These trials were carried out according to the methods mentioned previously. Each machine was tested at the speed recommended by the manufacturers; at three-fourths, and at one-half this speed. The results obtained are shown in the following tables.

TABLE 1.

EFFECT OF SPEED.

Empire Separator No. 2B (102872).

Full speed .....50 revolutions of crank per minute.
Three-fourths speed...40 revolutions of crank per minute.
Half speed .....27 revolutions of crank per minute.

Temperature of Milk Uniformly 90°.

Trial No.	Speed	Kilograms	Kilograms of skim-milk in 5 min.	Total Kilograms separated in 5 min.	Proportion of cream to skim-milk	Per cent of fat in cream	Per ct. fat in skim-milk	Per ct. fat in whole milk
	Full speed	4.894	17.190	22.084	1—3.51	21.8 21.7	.03 .03	5.15
1	Three-fourths speed	5.244	16.627	21.871	1—3.17	19.9 20.0	.11 .10	5.15
	Half speed	5.698	16.191	21 889	1—2.84	16.8 16.9	.48 .49	5.15
	Full speed...	5.040	17.161	22.201	1—3.40	21.0 20.9	.03 .03	5.1
2	Three fourths speed	5.332	16.616	21.948	1—3.11	18.8 18.8	.13 .13	5.1
	Half speed... .	5.587	16.334	21.921	1— 2.92	16.3 16.4	.62 .63	5.1
	Full speed	2 470	19.780	22.250	1—8.00	40.6 40.8	.08 .09	4.9
3	Three-fourths speed	3.030	18.924	21.954	1—6.24	32.0 31.8	.21 .23	4.9
	Half speed	3.535	18.355	21.890	1—5.19	24.0 24.0	.80 .80	4.9
	Full speed.....	2.421	19.980	22.401	1—8.25	41.4 41.8	.03 .03	5.0
4	Three-fourths speed	3.193	18.714	21.907	1—5.86	29.6 29.8	.14 .16	5.0
	Half speed	3.511	18.371	21.882	1—5 23	24.0 24.0	1.1 1.1	5.0

TABLE 2.

EFFECT OF SPEED.

DeLaval Separator No. — (298694 F.).

Full speed . . . . . 45 revolutions of crank per minute.
Three-fourths speed . . 37 revolutions of crank per minute.
Half speed . . . . . 22 revolutions of crank per minute.

Temperature Uniformly 90°.

Trial No.	Speed.	Kilograms	Kilograms of skim-milk in 5 min.	Total Kilograms separated in 5 min.	Proportion of cream to skim-milk	Per cent of fat in cream	Per cent of fat in skim-milk	Per cent of fat in whole milk
	Full speed	5.865	22.435	28.300	1—3.82	20.0 20.1	.06 .07	4.8
5	Three-fourths speed	5.893	22.495	28.388	1—3.81	19.8 19.8	.14 .15	4.8
	Half speed	4.965	23.330	28.295	1—4.69	20.0 20.1	1.1 1.1	4.8
	Full speed.	5.783	22.767	28.550	1—3.93	21.7 21.8	03 .03	4.6
6	Three-fourths speed	5.760	22.720	28.480	1—3.94	21.4 21.6	.14 .14	4.6
	Half speed	6.050	22.302	28.352	1—3.68	18.2 18.2	.62 .62	4.6
	Full speed	3.300	25.417	28.717	1—7.70	42 35	.06	5 1
7	Three-fourths speed	3.824	24.715	28.539	1—6.46	35.10	.20	5.1
	Half speed	5.348	23.012	28.360	1—4.30	22.65	1.05	5.1
	Full speed.	3.863	24.793	28.656	1—6.41	34.25	.05	4.8
8	Three-fourths speed	4 423	24.026	28.449	1—5.43	28.85	.19	4.8
	Half speed.	5.225	23.267	28.492	1—4.45	21.05	1.05	4.8

TABLE 3.

EFFECT OF SPEED.

Tubular Separator No. 9 (486274).

Full speed..... .....45 revolutions of crank per minute.
Three-fourths speed...34 revolutions of crank per minute.
Half speed.....22 revolutions of crank per minute.

Temperature Uniformly 90°.

Trial No.	Speed	Kilograms	Kilograms of skim-milk in 5 min.	Total Kilograms separated in 5 min.	Proportion of cream to skim-milk	Per ct. of fat in cream	Per ct. of fat in skim-milk	Per ct. of fat in whole milk
	Full speed.	6.924	21.070	27.994	1—3.04	20.0 20.0	.03 .03	5.25
9	Three-fourths speed	6 755	21.355	28.108	1—3.16	20.4 20.4	.10 .08	5.25
	Half speed	6.837	20.201	27.038	1—2.95	17.6 17.5	.90 .90	5.25
	Full speed.	6.890	20.734	27.624	1—3 00	18.9 18.9	03 .03	5 1
10	Three-fourths speed	6.717	19.596	26.313	1—2.92	18.3 18.4	.11 .10	5.1
	Half speed	6.522	19.231	25 753	1—2.95.	16.8 16.7	.70 .70	5.1
	Full speed.	2.151	23.065	25.216	1—10.72	51.2 51.2	.06 .06	5.4
11	Three-fourths speed	3 003	24.698	27.698	1—8.23	42.4 42.4	.15 .16	5.4
	Half speed	3.175	21.504	24.679	1—6.72	32.2 32.2	1.00 1.00	5.4
	Full speed	3.221	24.469	27.690	1—7.65	40.0 40.0	.08 .09	5.0
12	Three-fourths speed	3.543	24.087	27.630	1—6.88	36.0 35 8	.14 .14	5.0
	Half speed	3.784	21.564	25.348	1—5.66	27.6 27.4	1.00 1.00	5.0

TABLE 4.

EFFECT OF SPEED.

U. S. Separator No. 6.

Full speed ... . 60 revolutions of crank per minute.
Three-fourths speed ..45 revolutions of crank per minute.
Half speed.... .....30 revolutions of crank per minute.

Temperature Uniformly 90°.

Trial No.	Speed.	Kilograms	Kilograms of skim milk in 5 min.	Total Kilograms separated in 5 min.	Proportion of cream to skim-milk	Per cent of fat in cream	Per cent of fat in skim-milk	Per cent of fat in whole milk
	Full speed.....	2.054	16.264	18.318	1— 7.93	44.4 44.2	.03 .03	5.1
13	Three-fourths speed	2.235	15.340	17.575	1— 6.84	37.6 37.8	.09 .10	5.1
	Half speed	2.370	14.765	17.135	1— 6.23	33.0 33.0	.33 .33	5.1
	Full speed	1.642	17.184	18.826	1—10.46	52.90	.03	5.0
14	Three-fourths speed	1.853	15.875	17.728	1— 8.56	42.00	.10	5.0
	Half speed.	2.203	15.138	17.341	1— 6.87	30.75	.45	5.0
	Full speed	1.817	17.539	19.365	1— 9.65	52.75	.04	
15	Three-fourths speed	1.939	16.109	18.048	1— 8.30	42.80	.10	
	Half speed	3.825	14.621	18.446	1— 3.82	19.20	.71	
	Full speed.	3.289	15.286	18.575	1 —4.64	27.20	.02	
16	Three-fourths speed	3.183	15.088	18.277	1— 4.74	26.60	.05	
	Half speed	3.519	14.022	17.541	1— 3.98	22 10	.26	

TABLE 5.

EFFECT OF SPEED.

Simplex Separator No. 2 (1540).

Full speed ....50 revolutions of crank per minute.
Three-fourths speed..37 revolutions of crank per minute.
Half speed .... 25 revolutions of crank per minute

Temperature Uniformly 90°.

Trial No.	Speed.	Kilograms	Kilograms of skim-milk in 5 min.	Total Kilograms separated in 5 min.	Proportion of cream to skim-milk	Per cent of fat in cream	Per cent of fat in skim-milk	Per cent of fat in whole milk
	Full speed...	3.126	16.684	19.810	1—5.33	31.3 31.3	.02 .03	5.0
17	Three-fourths speed	3.200	16.522	19.722	1—5.16	30.2 30.1	.06 .06	5.0
	Half speed	3.128	16.532	19.660	1—5.29	29.0 28.9	.31 .32	5.0
	Full speed	2.448	17.490	19.938	1—7.14	39.6 39.8	.03 .03	5.1
18	Three-fourths speed	2.708	16.896	19.604	1—6.23	35.4 35.6	.06 .05	5.1
	Half speed	3.052	16.576	19 628	1—5.43	30.0 29.8	.20 .23	5.1
	Full speed	4.238	15.645	19.883	1—3.69	21.4 21.4	.03 .03	4.9
19	Three-fourths speed	3.863	15.975	19.838	1—4.13	23.2 23.1	.07 .07	4.9
	Half speed	3.206	16.433	19.639	1—5.11	26.8 26.8	.25 .25	4.9
	Full speed	4.365	15.723	20.088	1—3 59	20.6 20.6	.03 .03	4.8
20	Three-fourths speed	3.975	15.969	19.944	1—4.03	22.2 22.2	.05 .06	4.8
	Half speed	2.868	16.826	19.694	1—5.85	28.0 28.2	.36 .36	4.8

The typical effect of speed on the propertion of cream to skim-milk, the per cent of fat in the cream, the loss of fat in the skim-milk, and the total capacity of the separator is shown in the following charts which are representative trials with the U. S separator.

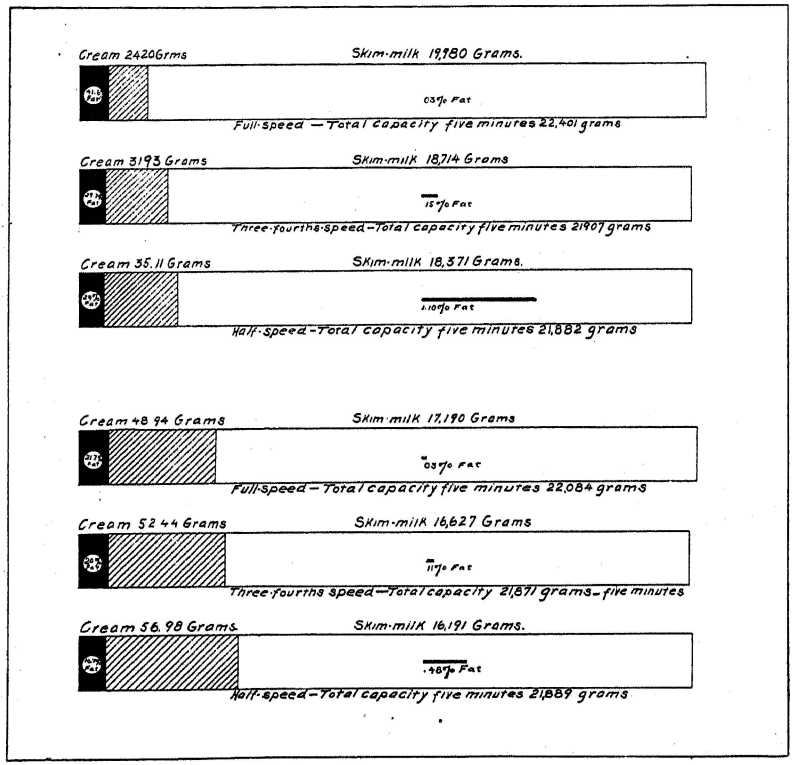


Fig. 7.

Graphic illustration of the effect of speed of separator on capacity, amount of cream, per cent fat in cream, and loss in skim-milk.

In Fig 7. the capacity of the separator in five minutes is represented by the length of the rectangles. At the left end of each rectangle the fat is represented by the black, the total cream by the solid black and shaded space, while the skim-milk is represented by the large blank space to the right. The proportion of butterfat in the skim-milk is represented by the length of the black horizontal line in the open space.

TABLE 6.

Typical Effect of Speed on Richness of Cream.

Speed of Separator	Trial No 3		Trial No. 2		Trial No. 8		Trial No. 6	
	Per cent of fat in cream	Ratio cream to skim-milk	Per cent. of fat in cream	Ratio cream to skim-milk	Per cent. of fat in cream	Ratio cream to skim-milk	Per cent. of fat in cream	Ratio cream to skim-milk
Full speed.	40.6	1—8.00	20.9	1—3 40	42.3	1-7.70	21.7	1—2.9
Three-fourths speed ...	31.8	1—6.24	18.8	1—3.11	35.1	1—6.46	21.4	1—3.9
One-half speed ...	24.0	1—5.19	16.3	1—2.92	22.6	1—4 30	18.2	1—3.6

It will be observed that with the exception of the Simplex separator when set for thin cream, the greater the speed of the machine the higher the per cent of fat in the cream and the less the proportion of cream to skim-milk. The higher per cent of fat in the cream at the higher speed is due chiefly to the fact that the increase in speed results in a larger proportion of skim-milk. This leaves a less amount to come out of the cream tube and consequently a higher per cent of fat. The increased speed causes the skim-milk to flow out through the skim-milk tube with greater speed and in this manner increases the capacity of the skim-milk tube. If the cream and skim-milk openings were so constructed that the cream opening was farther from the center of the bowl than the skim-milk opening, the increase in speed would cause an increase in the quantity of cream discharged instead of the skim-milk and therefore a thinner cream would be obtained as the speed increased. This is the case with the Simplex separator as explained later.

The greater per cent of fat in the cream at the higher speed is also due in a very small degree to the fact that the greater centrifugal force at the higher speed causes a more complete separation of the fat from the skim-milk. The effect of speed on the per cent of fat in the cream is much more marked when the cream screw is set for a high per cent of fat in the cream than when set for thin cream. This is illustrated by the following example from the first and third run with the Empire:

TABLE 7.

Effect of Speed on Thick and Thin Cream.

Speed of Separator	Trial No. 3		Trial No. 1	
	Separator set for thick cream		Separator set for thin cream	
	Per cent fat in cream	Ratio cream to skim-milk	Per cent fat in cream	Ratio cream to skim-milk
Full speed....	40.7	1—8.00	21.7	1—3.51
Three-fourths speed	31.9	1—6.24	19.9	1—3.17
One-half speed.....	24.0	1—5.19	16.8	1—2.84

The difference in the per cent of fat in the cream between full and half speed when the separator is set for thick cream is 16.7% while the difference when the separator is set for thin cream is only 4.9%. The greater difference in the per cent of fat in the cream when the separator is set for thick cream is due to the greater proportion of skim-milk to cream at the high speed when the separator is set for thick cream than when set for thin cream. In Table 7 when the separator run at half speed is set for thick cream, the proportion of cream to skim-milk is 1—5.19; at full speed the proportion is 1—8. At full speed there is 54.1% more of skim-milk to each pound of cream than there is at low speed. When set for thin cream, the difference in the proportion between the skim-milk and the cream when the separator is run at half and at full speed changes from 1—2.48 to 1—3.51 parts, which is 23.5% more than skim-milk for each pound of cream when the separator, set for thin cream, is run at full than at half speed. This relatively greater increase of skim-milk between half and full speed when the separator is set for thick than for thin cream is due to the fact that when the separator is set for thick cream the capacity of the skim-milk tube is greater than when set for thin cream. This fact was explained in the discussion on page 225. In Fig. 8 the two drawings show a horizontal section of a skim-milk tube cut through the tube just before the cream is discharged from the bowl.

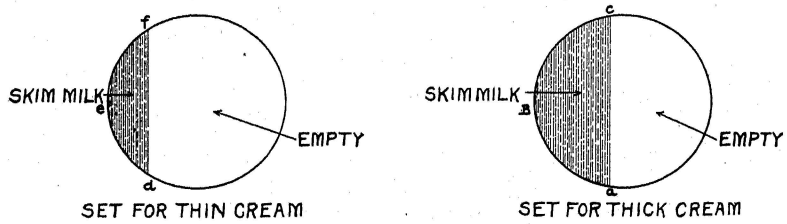


Fig. 8.

Cross section of skim-milk tube, separator set for thin and thick cream.

The same increase in centrifugal force is more effective in increasing the outflow through the large area ABC than it is through the smaller area DEF, because there is relatively less friction in proportion to the quantity of skim-milk discharged, on the surface of the tube ABC than there is on the surface DEF. At the same time when the separator is set for thick cream, the thick cream with its higher viscosity encounters more resistance than the thin cream in passing through the cream opening. This has the same effect as reducing the capacity of the cream tubes and tends to increase the outflow through the skim-milk tubes. Since the per cent of fat in the cream is affected by the amount of skim-milk discharged in proportion to the inflow of milk to the separator bowl, we find a greater increase in the per cent of fat in the cream by increased speed when the separator is set for thick cream.

TABLE 8.

Effect of Speed on Skim-milk.

Speed of Separator.	Trial No. 3.		Trial No. 13.	
	Per cent fat in skim-milk	Ratio cream to skim-milk	Per cent fat in skim-milk	Ratio cream to skim-milk
Full speed	.08	1—8.00	.03	1—7.93
Three-fourths speed	.22	1—6.24	.10	1—6.84
One-half speed	.80	1—5.19	.33	1—6.23

Within ordinary limits the higher the speed the less the amount of fat remaining in the skim-milk, because the higher speed increases the centrifugal force and causes a more complete separation of the butter fat from the milk.

The difference in the per cent of fat lost in the skim-milk does not vary to any marked extent whether the separator is set for thin or thick cream. Most separators under normal conditions will separate as efficiently when the cream contains forty per cent fat as when it contains twenty per cent. For cream with an exceedingly high fat content this does necessarily hold good.

TABLE 9.

Effect of Speed on Capacity of Separator.

Weights are Grams in Five Minutes.

Trial.	Full speed.	Three-fourths speed.	Half speed.
No. 2	22,201	21,948	21,921
No. 6	28,550	28,480	28,352
No. 12	27,624	26,313	25,753
No. 15	18,318	17,575	17,135
No. 22	20,000	19,945	19,853
Average	23,334	22,852	22,605

Table No. 9 shows that the rate of inflow to the separator is increased uniformly by the speed although this increase is relatively small. At first thought it seems self evident that the faster the separator is run, the greater will be the capacity of the separator; that is, the more milk will run through it in a given time. However, the cause of this increase is not so apparent. The capacity of the separator is determined by the amount of milk which flows into the bowl. According to the construction of the inflow to the separator the speed of the bowl in itself would have no effect on the amount of milk which would flow into the bowl, were it not for another factor namely, suction. The milk flows from the separator feed cup into the bowl by force of gravity. The inflow to the bowl is in no way hindered by the milk in the bowl because as the milk enters the bowl it is thrown to the side of the bowl leaving the center hollow. No difference then how rapidly the increased speed causes the skim-milk and cream to be discharged from the bowl, this increased discharge will not make a greater inflow possible. The increased inflow of capacity shown by increased speed is due to suction. When separators fed at the top of the bowl are run without a supply of milk a suction can easily be observed into the separator bowl through the feed cup opening, through the separator bowl, and out at the skim-milk openings. The presence of air in the skim-milk is always noticeable in the form of foam and is much more prominent with some styles of separators than in others. There is also a suction in at the cream pan passing over the stream of cream as it flows outward. Part of this current of air is drawn upwards over the top of the bowl and mixes with the milk as it flows into the separator bowl. This air passes out with the skim-milk.

The remainder of the air drawn in at the cream tube passes along the outside of the revolving bowl between it and the bottom of the cream pan and also comes out of the skim-milk tube.

The air around the outside of the bowl and inside of the frame is set in motion and forced out through the drain hole in the frame. The air to replace that discharged through the drain hole enters between the bowl and the skim-milk pan. The above statements apply to all separators used in the experiments except the Tubular. The suction through the bowl in the Tubular, however, is similar to that in the other separators. This suction through the bowl affects the capacity to some extent. When milk is being separated, in all except the Tubular, the air passes in at the opening of the cream pan; part of this air goes through the feed hole of the separator bowl and out at the skim-milk opening. The passage of the air through the bowl in this manner results from the centrifugal force forcing some of the air out of the bowl with the skim-milk. This causes a suction and the air is drawn into the bowl through the milk inflow. The suction which draws the air in through the milk inflow also acts on the milk entering at the same opening, thus having some effect upon the rate of inflow. The suction is increased with a higher speed which accounts for the influence observed of the speed on the capacity.

The effect of this suction on rate of feed was demonstrated as follows: The Empire separator 1A was operated under normal conditions except water was used instead of milk. Beginning after the machine had been in operation for one minute, the water passing through in five minutes was weighed and found to be 22,575 grams. Then with conditions the same in regard to the height of water in the feed can the separator bowl was removed from the frame. The water was allowed to pass through the hole in the bottom of the feed cup and drop into a funnel. The faucet was opened to full cepacity as in the normal separation. After the water had been running from the tube for one minute was caught as before for five minutes. The amount passing through the feed spout under these conditions was 21,495 grams or 1,080 grams less than when fed into the separator when it was in motion. This increase must be due to the suction on the milk as it flows into the bowl.

The general tables show that the capacity of the separator does not vary to any extent whether set for thick or thin cream.

Variation with the Simplex Separator Due to Speed.

Speed.	Grams cream in 5 minute	Grams skim-milk in 5 min.	Total capacity 5 minute	Ratio cream to skim-milk	Per cent fat in cream	Per cent fat in skim-milk	Per cent fat in whole milk	Temperature milk separated
Full speed	4,365	15,723	20,088	1—3.59	20.6	.03	4.8	90° F.
¾ speed	3,975	15,969	19,944	1—4.03	22.2	.05	4.8	90° F.
½ speed	2,868	16,826	19,694	1—5.85	28.1	.36	4.8	90° F.
Full speed	2,448	17,490	19,938	1—7.14	39.7	.03	5.1	90° F.
¾ speed	2,708	16,896	19,604	1—6.23	35.5	.05	5.1	90° F,
½ speed	3.052	16,576	19,628	1—5.43	29.9	.22	5.1	90° F.

The above table shows that the results obtained from the Simplex separator run at different speeds do not correspond with those obtained with the other separators.

When the separator is set for thick cream, other things being equal, the higher the speed, the less the amount of cream, the higher the per cent of fat in the cream, the greater the amount of skim-milk, and the less the per cent of fat in the skim-milk. These results correspond with those from the other separators. However, when the separator is set for thin cream the results are as follows: The greater the speed, other things being equal, the greater the amount of cream, the less the per cent of fat in the cream, the less the amount of skim-milk and the less the per cent of fat in the skim-milk. The results are the reverse of those obtained when the separator is set for thick cream. The cause of these differences is due to the relative position of the skim-milk and the cream openings. When the cream opening on the Simplex is set for thin cream the outer portion of the cream opening is farther from the center of the bowl than the outer side of the skim-milk openings. In the other separators used, the skim-milk openings are farthest from the center of the bowl. With the Simplex as the speed is increased, the greatest force is exerted at the cream opening, therefore more cream is obtained in proportion to the inflow of milk to the bowl and consequently thinner cream is discharged from the cream opening.

EFFECT OF TEMPERATURE OF MILK SEPARATED.

The milk was placed in a large vat and brought to the temperature 70° F. One five minute run with the separator was made at this temperature. The remaining milk was then heated to 80° and a second five minute run made. The remainder of the milk was then heated to 90° F. and the third five minute run made. The only variation in the condition of these lots separated was the temperature. The methods of separation, sampling and testing followed were as previously described.

TABLE 10.

Effect of Temperature—De Laval Separator.

Trial No.	Temperature	Kilograms of cream in 5 minutes	Kilograms of skim-milk in 5 minutes	Total Kilograms separated in 5 minutes	Proportion of cream to skim-milk	Per cent of fat in cream	Per cent of fat in skim-milk	Per cent of fat in whole milk
	90	5.905	22.217	28.122	1—3.76	21.5 21.5	.07 .07	4.8
25	80	5.983	22.512	28.495	1—3.76	21.2 21.1	.11 .125	4.8
	70	5.963	22.720	28.683	1—3.81	21.2 21.2	.14 .14	4.8
	90	5.890	22.635	28.525	1—3.84	20.7 20.6	.06 .08	4.7
26	80	6.005	22.603	28.606	1—3.43	20.4 20.6	.06 .07	4.7
	70	5.985	22.730	28.715	1—3.80	20.2 20.2	.125 .11	4.7
	90	3.120	25.574	28.694	1—8.19	40 4 40.4	.06 .07	4.8
27	80	3.010	25.620	28.630	1—8.54	41.2 41 4	.09 .09	4.8
	70	3.037	25.724	28.761	1—8.46.	42.0 42.0	.08 .11	4.8
	90	3.355	25.122	28.477	1—7.47	37.0 37 0	.03 .04	4.7
28	80	3.155	25.627	28.782	1—8.11	40.0 40.0	.05 .05	4.7
	70	3.048	25.720	28.768	1—8.43	41.2 41.4	.06 .06	4.7

Speed uniformly 45 turns of the crank per minute.

TABLE 11.

Effect of Temperature—Tubular Separator.

Trial No.	Temperature	Kilograms of cream in 5 minutes	Kilograms of skim-milk in 5 minutes	Total Kilograms separated in 5 minutes	Proportion of cream to skim-milk	Per cent of fat in cream	Per cent of fat in skim-milk	Per cent of fat in whole milk
	90	6.680	20.121	26.801	1—3.00	18.6 18.8	.03 .03	4.9
21	80	6.725	21 108	27.833	1—3.15	19.6 19.5	.03 .03	4 9
	70	4.806	21.401	26.207	1— 4.45	24.8 24.6	.04 .05	4.9
	90	3.127	24.274	27.401	1— 7.83	40.8 40.8	.02 .02	5.0
22	80	2.693	24.735	24.428	1— 9.16	46.0 46.4	.03 .03	5.0
	70	2.436	24.973	27.409	1—10 33	48.4 48.6	.21 .21	5.0
	90	5.053	20.498	25.551	1— 4.05	21.9 21.9	.03 .03	4.6
23	80	4.695	21.193	25.888	1— 4.50	24.1 24.1	.03 .03	4.6
	70	4.620	20.645	25.265	1— 4.46	23.8 23.8	.03 .03	4.6
	90	5.140	20.890	26.030	1— 4.06	21.5 21.5	.02 .03	4.5
24	80	4.820	20.125	24.945	1— 4.17	22.0 22.0	.03 .03	4.5
	70	4.200	20.505	24 705	1— 5.09	25.4 25.4	.03 .04	4.5

Speed uniformly 45 turns of crank per minute.

TABLE 12.

Effect of Temperature—U. S. Separator No. 6.

Trial No.	Temperature	Kilograms of cream in 5 minutes	Kilograms of skim-milk in 5 minutes	Total Kilograms separated in 5 minutes	Proportion of cream to skim-milk	Per cent of fat in cream	Per cent of fat in skim-milk	Per cent of fat in whole milk
	90	2.135	15.984	18.119	1—7.46	42.4 42.4	06 .07	5.5
33	80	2.102	16.085	18.187	1—7.65	42.8 43.2	.06 .06	5.5
	70	2.175	16.727	18.902	1—7.67	41.2 40.8	.12 .11	5.5
	90	4.278	14.008	18.286	1—3.27	20.1 20.2	.04 .04	5.0
34	80	4.158	14.090	18.248	1—3.38	20.8 20.8	.04 .05	5.0
	70	4.082	14.100	18.182	1—3.45	21.0 21.0	.04 .04	5.0
	90	4.193	13.947	18.140	1—3.32	20.0 20.0	.04 .04	5.0
35	80	4.201	14.116	18.317	1—3.37	20.0 20.1	.05 .10	5.0
	70	4.153	14.136	18.289	1—3.40	19.7 19.8	.04 .05	5.0
	90	2.032	15.755	17.787	1—7.75	38.0 37.8	.02 .02	5.7
36	80	2.047	15.698	17.745	1—7.66	37.6 37.4	.025 .025	5.7
	70	2.023	15.883	17.906	1—7.85	37.8 37.6	.025 .025	5.7

Speed uniformly 55 turns of crank per minute.

TABLE 13.

Effect of Temperature—Empire Separator No. 2B.

Trial No.	Temperature	Kilograms of cream in 5 minutes	Kilograms of skim-milk in 5 minute s	Total Kilograms separated in 5 minutes	Proportion of cream to skim-milk	Per cent of fat in cream	Per cent of fat in skim-milk	Per cent of fat in whole cream
	90	4.715	17.635	22.350	1—3.73	20 4 20.4	.03 .04	4.5
29	80	4.785	17 530	22.315	1—3.65	20.1 20.1	.04 .04	4.5
	70	4.730	17.640	22.370	1—3.72	20.0 20.0	.10 .10	4.5
	90	4 740	17.553	22.293	1—3.70	19.0 19.1	.02 .03	4.2
30	80	4.808	17.510	22.318	1—3.64	18.3 18.4	.05 .05	4.2
	70	4.625	17.745	22.370	1—3.83	19 1 19.2	.08 .07	4.2
	90	2.325	19.720	22.045	1—8.48	36.8 36.8	.03 .04	4.1
31	80	2.305	19.960	22.265	1—8.60	37.2 37.0	.02 .03	4.1
	70	2.100	20.065	22.165	1—9.55	39.2 39.6	.09 .10	4.1
	90	2.325	19.720	22.045	1—8.48	36.8 36.8	.03 .04	4.1
32	80	2.295	19.960	22.255	1—8.68	37.0 37 2	.05 .05	4 1
	70	2.067	20 265	22.332	1—9.78	39.2 39.2	.04 .04	4.1

Speed uniformly 55 turns of crank per minute

TABLE 14.

Effect of Temperature—Simplex Separator No. 2.

Trial No.	Temperature	Kilograms of cream in 5 minutes	Kilograms of skim-milk in 5 minutes	Total Kilograms separated in 5 minutes	Proportion of cream to skim-milk	Per cent of fat in cream	Per cent of fat in skim-milk	Per cent of fat in whole milk
	90	4.238	15.645	19.883	1—3.68	21.4 21.4	.03 .03	4.9
37	80	4.178	15.732	19.910	1—3.76	21.9 21.9	.04 .04	4.9
	70	4.000	15.815	19.815	1—3.95	22.3 22.3	.06 .06	4.9
	90	4.360	15.720	20.080	1—3.60	20.6 20.5	.03 .03	4.8
38	80	4.282	15.797	20.079	1—3.69	21.4 21.3	.03 .03	4.8
	70	4.100	15 820	19.920	1—3.80	21.8 21.9	.03 .03	4.8
	90	2.440	17.510	19.950	1—7.17	38.0 38.0	.03 .03	4.75
39	80	2.311	17.715	20.026	1—7.70	38.8 38.8	.03 .03	4.75
	70	2.028	17.968	19.996	1—8.85	43.2 43.2	.03 .03	4.75
	90	2 467	17.615	20.082	1—7.13	39.6 39.8	.03 .03	5.1
40	80	2.392	17.655	20.047	1—7.38	40.6 40.8	.03 .03	5.1
	70	2.307	17.684	19.991	1—7.65	41.2 41 4	.03 .03	5.1

Speed uniformly 50 turns of crank per minute.

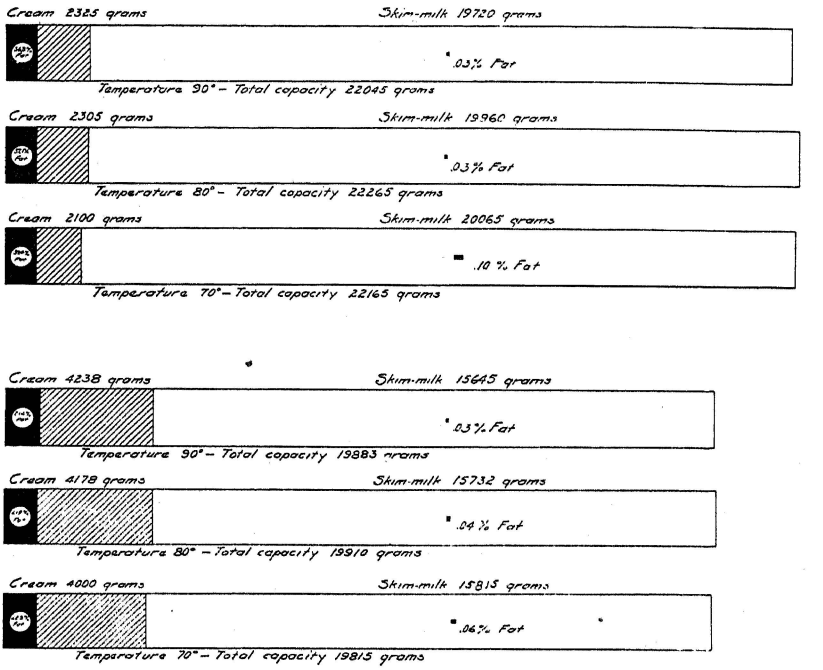


Fig. 9.
Graphic illustration of the influence of temperature.

Figure 9 is based upon trial No. 48 of the Simplex and trial No. 31 of the Empire. It shows representative results of the effect of temperature of milk separated. This figure is similar in construction to Figure 7. The limits chosen, seventy to ninety degrees, represent the limits within which nearly all milk is separated under ordinary conditions. The results obtained, therefore, refer only to milk separated within those limits, altho the results probably apply to any temperature within reasonable limits.

It has generally been assumed and, in fact, has been so stated in one Experiment Station Bulletin, that the higher the temperature of the milk separated the richer the cream. Our results indicate the reverse is true.

TABLE 15.

Typical Effect of Temperature of Milk on Per Cent of Fat in the Cream.

Temperature of milk.	Trial 21		Trial 30.		Trial 40.		Trial 49.	
	Per cent fat in cream	Proportion cream to skim-milk	Per cent fat in cream	Proportion cream to skim-milk	Per cent fat in cream	Proportion cream to skim-milk	Per cent fat in cream	Proportion cream to skim-milk
90° F.	40.8	1—7.83	19.0	1—3.70	36.8	1—8.48	20.5	1—3.60
80° F.	46.2	1—9.16	18.3	1—3.64	37.1	1—8.60	21.3	1—3.69
70° F.	48.5	1—10.33	19.1	1—3.83	39.4	1—9.55	21.8	1—3.80

Table 15 shows that the lower the temperature of the milk separated, the greater the per cent of fat in the cream and the less the proportion of cream to skim-milk. This statement applies to all separators but is more marked when the separator is set for thick cream than for thin cream.

The thicker cream is obtained at the lower temperature because the cold cream is more viscous and encounters more resistance in passing through the cream opening than does the warm cream. The result is the same as reducing the capacity of the cream tube. More skim-milk is forced from the bowl through the skim-milk opening. Those authorities who hold that the colder the milk, the richer the cream give as a reason that at the higher temperature more milk flows through the bowl because it is less viscous. "This increase will show itself chiefly in the amount of cream, as the higher temperature has a greater relative effect upon the cream than it has upon the milk." In the above experiments a greater amount of milk did not always flow through the separator at the higher temperature. The reason for the thinner cream at the higher temperature seems to be the effect of the temperature on the cream as explained rather than to an increased amount of milk flowing into the bowl. If the inflow was increased at the higher temperature, it would tend to produce a thinner cream but such increase does not occur.

In Table 15 the results show that when the separator is set for thin cream, the temperature of the milk has much less effect on the per cent of fat in the cream than when set for thick cream. In fact, when the separator is set so as to deliver as low as twenty per cent cream, the temperature of the milk had very little effect upon the percent of fat in the cream with the exception of the Tubular which seems to be more sensitive in this respect than the others. The reason why the temperature of the milk affects thin cream less

than thick is that the thick cream has a more marked viscosity than thin cream, and therefore is more retarded in its escape through the cream tube.

TABLE 16.

Effect of Temperature of Milk Upon Per Cent of Fat in Skim-milk.

Temperature of Milk	Per cent. of fat in skim-milk				
	Trial 22	Trial 30	Trial 40	Trial 44	Trial 39
90° F.	.02	.02	.03	.06	.03
80° F.	.03	.05	.02	.06	.03
70° F.	.21	.07	.09	.11	.03

Table 15 shows that the colder the milk separated the greater the per cent of fat in the skim-milk. The greater viscosity of the colder milk renders more difficult the movement of the fat globules through the milk serum and for this reason a less complete separation is accomplished when the milk is at a low temperature.

The capacity of the machines did not vary to any extent whether set for a high or a low per cent of cream. The only factor which could cause an increase in the capacity would be that the milk at the higher temperature might flow into the bowl more rapidly than the colder milk which is more viscous. However, the trials in this experiment show this factor to be too small to be appreciable.

EFFECT OF RICHNESS OF MILK SEPARATED.

In making these trials the milk was mixed in a vat, sampled for fat determination, heated to 90° F., and divided into two lots. One lot was separated under normal conditions. The skim-milk obtained from the first lot was used in reducing the second lot to about three per cent fat. The second lot was then sampled, temperature raised to 90° F., if below that temperature, and separated under the same conditions as previously described. The results are shown in the following tables.

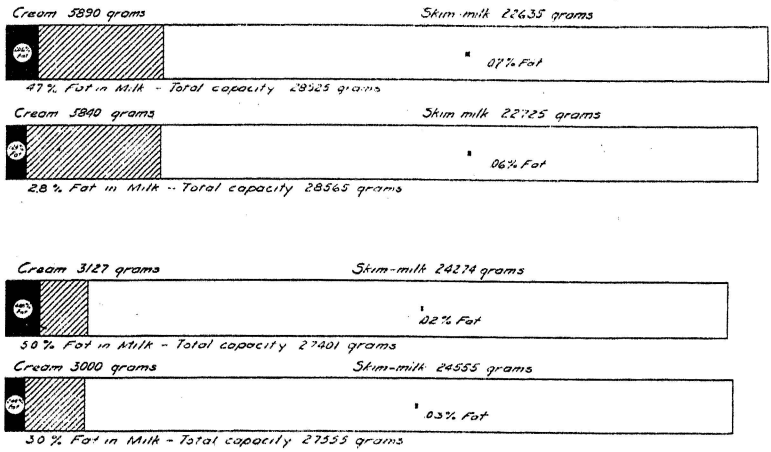


Fig. 10.

Graphic illustration of the richness of milk.

TABLE 17.

Tubular Separator.

Trial No.	Per cent. of fat in milk separated	Kilograms of cream in 5 min.	Kilograms of skim-milk in 5 minutes	Total Kilograms separated in 5 min.	Proportion of cream to skim-milk	Per cent. of fat in cream	Per cent. of fat in skim-milk	Revolutions of separator crank per min.
59	5.15	6.924	21.070	27.994	1–3.05	20.0 20.0	.03 .03	45
	3.15	6.699	21.544	28.243	1–3.21	12.6 12.7	.04 .04	45
60	5.1	6.890	20.734	27.624	1–2.00	18.9 18.9	.03 .03	45
	2 8	6.237	20.108	26.345	1–3.22	12.0 12.0	.03 .03	45
61	5.0	3.221	24.469	27.690	1–7.64	40.0 40.0	.08 .08	45
	3.2	3.140	24.529	27.669	1–7.81	24.8 24.8	.04 .05	45
62	5.0	3.127	24.274	27.401	1–7.83	40.8 40 8	.02 .02	45
	3.0	3.000	24.555	27.555	1–8.18	24.4 24.4	.03 .03	45

Temperature uniformly 90°

TABLE 18.

U. S. Separator.

Trial No.	Per cent. of fat in milk separated	Kilo grams of cream in 5 min.	Kilo grams of skim-milk in 5 min.	Total Kilo grams separated in 5 min.	Proportion of cream to skim-milk	Per cent. of fat in cream	Per cent. of fat in skim-milk	Speed of separator Revolutions
63	5.0	4.278	14.008	18.286	1–3.27	20.1 20.2	.04 .04	60
	4.1	4.084	14.068	18.152	1–3.44	16.8 16.9	.05 .05	60
64	5.0	4.226	14.025	18.251	1–3.30	20.8 20 8	.03 .04	60
	3.2	4.201	14.315	18.516	1–3.40	13.0 13.0	.025 .02	60
65	4.95	2.251	15.412	17.663	1–6.85	35.8 35.8	.08 .08	60
	3.0	1.891	15.617	17.508	1–8.24	25.2 25.0	.05 .05	60
66	4.0	1.930	16.065	17.995	1–8.32	36.4 36.4	.03 .03	60
	2.7	1.695	15.915	17.610	1–9 36	26.2 26.2	.02 .02	60

Temperature uniformly 90°.

TABLE 19.

Simplex Separator.

Trial No.	Per cent. of fat in milk separated	Kilo grams of cream in 5 min	Kilo grams of skim-milk in 5 min.	Total Kilo grams separated in 5 min.	Proportion of cream to skim-milk	Per cent. of fat in cream	Per cent. of fat in skim-milk	Speed of separator Rev.
67	4.8	4.365	15.723	20.088	1–3.60	20.6 20.6	.03 .03	50
	3.0	4.091	16.031	20.122	1–3.91	13.3 13.3	.03 .03	50
68	4.9	4.238	15.645	19.883	1–3.69	21.4 21.4	.03 .03	50
	3.0	4.201	15.965	20.166	1–3.80	12.7 12.8	.03 .03	50
69	5.1	2.467	17.615	20.082	1–7.13	39 6 39.8	.03 .03	50
	3.05	2.209	18.070	20.279	1–8.21	27.2 27.2	.03 .03	50
70	4.75	2.440	17.510	19.950	1–7.17	38.0 38.0	.03 .03	50
	2.9	2.215	17.812	20.027	1–8.02	26.0 26.0	.03 .03	50

Temperature of milk uniformly 90°.

TABLE 20.

Empire Separator.

Trial No.	Per cent. of fat in milk separated	Kilograms of cream in 5 minutes	Kilograms of skim-milk in 5 min.	Total Kilograms separated in 5 min.	Proportion of cream to skim-milk	Per cent. of fat in cream	Per cent. of fat in skim-milk	Speed of Separator
71	5.15	4.894	17.190	22.084	1–3.51	21.7 21.8	.03 .03	55
	3.4	5.096	17.883	22.979	1–3.50	13.6 13.6	.03 .03	55
72	5.1	5.040	17.161	22.201	1–3.40	21.0 20.9	.03 .03	55
	3.1	4.921	17.345	22.266	1–3.52	12.1 12.2	.03 .03	55
73	4.9	2.470	19.780	22.250	1–8.00	40.6 40.8	.08 .09	55
	3.2	2.163	20.310	22.473	1–9.3	28.4 28.6	.03 .03	55
74	5.0	2.421	19.980	22.401	1–8.25	41.4 41.3	.03 .03	55
	3.1	2.406	19.731	22.137	1–8.22	23.4 24 0	.03 .03	55

Temperature uniformly 90°.

TABLE 21.

DeLaval Separator.

Trial No.	Per cent. of fat in milk separated	Kilograms of cream in 5 min.	Kilograms of skim-milk in 5 min.	Total Kilograms separated in 5 min.	Proportion of cream to skim-milk	Per cent. of fat in cream	Per cent. of fat in skim-milk	Speed of Separator
75	4 8	5.905	22.217	28.122	1–3.76	21.5 21.5	.07 .07	45
	3.0	5.856	22.775	28.661	1–3.88	13.4 13.3	.06 .03	45
76	4 7	5.890	22.635	28.525	1–3.84	20.6 20 7	.06 .08	45
	2.8	5.840	22.725	28.565	1–3.89	12.4 12.4	.05 .06	45
77	4.8	3.120	25.574	28.694	1–8.19	40.4 40.4	.06 .07	45
	3.0	3.005	25 569	28.574	1–8.52	24.6 24.6	.03 .03	45

Temperature uniformly 90°.

Typical results are shown graphically by Fig. 10 based on the figures from trial No. 76 with the DeLaval, and trial No. 62 with the Tubular.

The only marked variation due to difference in the richness of the milk separated is the per cent of fat in the cream. The per cent of fat in the cream varies practically in direct proportion with the per cent of fat in the milk separated.

TABLE 22.

Typical Effect of Richness of Milk Separated on Per Cent of Fat in Cream.

Trial No.	Per cent fat in milk separated	Per cent fat in cream	Estimated Per cent fat in cream
62	5.0 3.0	40.8 24.4	40.6
63	5.0 4.1	20.1 16.8	20.4
67	4.8 3.0	20.6 13.3	21.3
72	5.1 3.1	21.0 12.2	20.0
75	4.8 3.0	40.4 24.6	39.3

Table 22 shows the per cent of fat in cream obtained from milk of similar composition except with a large variation in the fat. For example, in trial No. 62 when five per cent milk was separated 40.8% fat was obtained in the cream. When milk, similar to the first lot, was reduced to three per cent, 24.4% fat was obtained in the cream; other conditions were exactly the same. This illustrates the rule that the per cent of fat in the cream is practically in direct proportion to the fat in the milk separated. Taking the figures in trial No. 62 for example, 3:5::24.4:x (x—40.6%).

If the fat in cream varied exactly in direct proportion to the fat in the milk, the five per cent milk of the first trial should have delivered 40.6% fat. In actual trial 40.8% fat was obtained which is practically that estimated by direct proportion. The fourth column in Table 22 shows such estimates calculated by proportion from the lower to the higher. It will be observed the estimate, as a rule, comes very close to the actual.

The per cent of fat in the cream should vary as the per cent of fat in the milk separated, because the total inflow to the bowl of three or five per cent milk is practically the same in a given time.

As the position of the cream screw is not changed, practically the same relative amounts of cream and skim-milk are obtained. Since nearly all of the fat in the milk is found in the cream, the per cent of fat in the cream must vary in direct proportion to the per cent of fat in the milk separated.

The difference in the per cent of fat in cream due to the richness of the milk separated is greater when the separator is set for thick than for thin cream, as would necessarily follow from the facts above demonstrated.

SHOWING GREATER VARIATION IN RICH THAN IN THIN CREAM.

Position of cream screw	Per cent fat in milk	Per cent fat in cream	Difference in per cent fat in cream
Tubular separator set for thick cream	5.0	40.8	16.4
	3.0	24.4	
Tubular separator set for thin cream	5.25	20.0	7.4
	3.15	12.6	

Within ordinary limits the richness of the milk has no appreciable effect upon the loss of fat in the skim-milk or upon the capacity of the machine. The results are as would be expected. A popular error is that more cream is obtained when rich milk is separated than when milk poorer in fat is used. The data presented shows this is not the case.

TABLE 23.

EFFECT OF HEIGHT OF MILK IN FEED CAN.

DeLaval Separator No. —.

Trial No.	Height of Milk in Feed Can	Kilograms of cream in 5 minutes	Kilograms of skim-milk in 5 min.	Total Kilograms separated in 5 min	Proportion of cream to skim-milk	Per cent of fat in cream	Per cent. of fat in skim-milk	Per cent. of fat in whole milk
	1 in. from top	5.783	22.767	28.550	1–3.93	21.7 21.8	.03 .03	4.6
53	Middle	5.775	22.343	28.117	1–3.86	21.4 21.5	.03 .04	4.6
	1 in. from bottom	4.414	17.932	22.346	1–4.06	22.2 22.4	.02 .02	4.6
	1 in. from top	3.378	25.057	28.435	1–7.41	37.6 37.6	.06 .08	4 5
54	Middle	3.320	24.458	27.778	1–7.36	37.4 37.4	.07 .08	4·5
	1 in. from bottom	2.350	20.737	23.087	1–8.82	44.4 44.4	.06 .06	4.5

Temperature uniformly 90°. Speed, 45 turns per minute.

EFFECT OF THE RATE OF INFLOW.

These experiments were carried out as previously described. Three runs were made with each lot of milk; first, with the feed can full of milk; second, half full; and third, with the milk one inch from the bottom.

It would seem that with the small size cream separators where the supply of milk is regulated with a faucet and float that there would be no chance for variation in the rate of inflow. However,

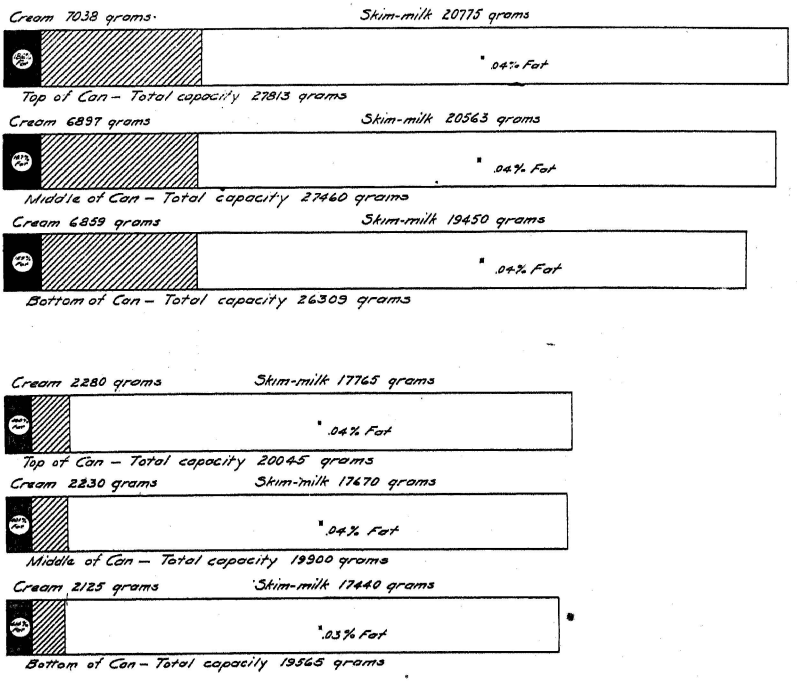


Fig. 11.

Illustrates graphically influence of the amount of milk in supply can.

even with this type of separator there are some chances for such variations. These variations in inflow may result from a difference in the point to which the faucet is opened, or from the height of milk in the supply can. The more milk there is in the supply can, the greater is the pressure on the regulating float and the larger the inflow into the bowl. Larger types of machines fed directly from a vat through a faucet are subject to more variation in inflow under ordinary conditions than the small machines.

In the experiments reported the rate of inflow was changed by varying the height of the milk in the supply can and in other trials by opening the faucet only a part of its full capacity. These trials were carried out with each of the machines but on account of the comparatively small influence of this factor the results are reported only for one separator (Table 23). Figure 11 is based upon the data obtained from the Simplex, and the Tubular and shows typical results.

TYPICAL EFFECT OF CHANGE IN THE RATE OF INFLOW.

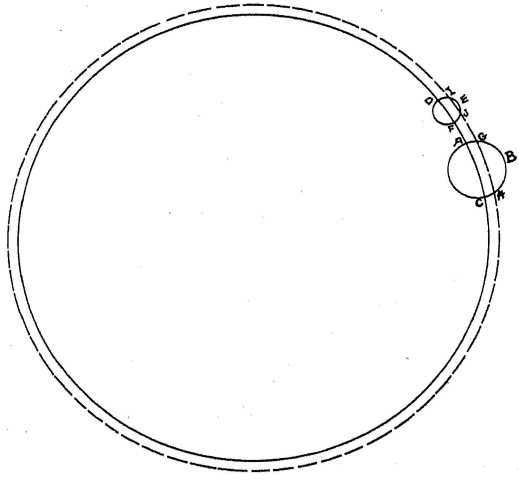
Height of milk in feed can	Trial No. 53		Trial No. 54		Trial No. 45		Trial No. 47	
	Per cent of fat in cream	Proportion cream to skim-milk	Per cent of fat in cream	Proportion cream to skim-milk	Per cent of fat in cream	Proportion cream to skim-milk	Per cent of fat in cream	Proportion cream to skim-milk
Top of can ...	21.7	1—3.93	37.6	1—7.41	20 8	1—3.31	35.8	1—6.84
Middle of can.	21.4	1—3.86	37 4	1—7.36	21 4	1—3.26	37.2	1—7.11
Bottom of can.	22.2	1—4.06	44.4	1—8.82	20.8	1—3.26	37.0	1—7.0

The above table shows that the per cent of fat in the cream is changed but not to a marked extent by the slight variation in rate of inflow, brought about by a change in the height of the milk in the feed can. The extent of this variation differs widely with various makes of separators, depending upon the construction of the supply can and the size of the faucet. This is observed in the above table where in Trial No. 54 the effect is much more marked than in Trial No. 47. It will also be noticed that like the other factors considered, the effect is the most marked when the machine is adjusted to separate a cream containing a high per cent of fat. Anything that reduces the rate of inflow, such as not opening the faucet to its full extent brings about the characteristic results.

In general a decrease in the inflow results in, (1) less cream in proportion to skim-milk; (2) the per cent of fat in the cream is higher; (3) the loss of fat in the skim-milk is not appreciably affected.

The explanation of the thicker cream with a decreased inflow is as follows: As the inflow of milk decreases the vertical line representing the inside wall of milk in the bowl moves farther towards the circumference of the bowl, that is, a less amount of milk and cream are in the bowl at any one time. The moving of the cream line towards the outside of the bowl decreases the capacity of the cream tube to deliver cream. At the same time the capacity of the

skim-milk tube is also decreased. The effect is the same as moving the cream screw nearer the center to cause the bowl to deliver thicker cream, but the results are brought about in a different manner in the two cases. When the cream screw is turned toward the center, a richer cream is obtained because the capacity of the skim-milk tube has been increased, and the capacity of the cream tube decreased, as already explained. When the inflow to the bowl is decreased, causing the vertical line of cream to move farther from the center of the bowl, the capacity of both the skim-milk tube and the cream tube is decreased, but the capacity of the cream tube is decreased in greater proportion than the skim-milk tube. Fig. No. 12 shows how the decreased inflow has a greater effect on the cream opening than on the skim-milk opening. The drawing rep-



resents a horizontal section of a skim-milk tube and a cream tube of a machine of the type of the Empire at a point just before the respective products are discharged from the bowl.

The large, solid circle represents the inner wall of the cream in the bowl when there is a normal inflow into the bowl. The medium solid circle represents the section through the skim-milk opening and the small solid circle represents the cream opening. The large dotted circle represents the inner wall of the cream when the inflow is reduced. When there is a large inflow, the capacities of the skim-milk tubes and the cream opening are determined by the areas AGBHC and DIEJF, while when the inflow is lessened the capacities of the skim-milk tubes and the cream opening are reduced to GBH and IEJ. It is evident that the decreased inflow shows a greater effect on the smaller opening, which is the cream opening. The following figures from Trial No. 55 show typical results.

EFFECT OF INFLOW ON RELATIVE DISCHARGE OF SKIM-MILK AND CREAM.

TABLE 24.

Inflow to Separator in five minutes		Skim-milk discharged in five minutes		Cream discharged in five minutes	
Grams.	Per cent.	Grams.	Per cent.	Grams.	Per cent.
20,045	100	17,765	88.7	2,280	11.3
15,660	100	14,225	90.8	1,435	9.2

From the above we see that when there is a large inflow to the bowl, 88.7% of the contents is discharged through the skim-milk tube and 11.3% through the cream opening. When the separator is run under the same conditions except that the rate of inflow is reduced, the contents discharged through the skim-milk tube is 90.8% and through the cream tube 9.2%. It is evident, therefore, that as the inflow is decreased the amount of cream is less in comparison to the milk inflow and therefore would be a richer cream than if a larger inflow had taken place.

The facts above presented have been explained in an entirely different manner by most authors of dairy text-books.

According to McKay and Larsen [1] "The greater the inflow to the separator, the more and thinner cream will be obtained, and with a diminished inflow the less and thicker cream is obtained. This is due to the fact that with a given velocity of the machine the skim-milk discharge remains practically constant. So if more milk is turned on, the only place where the discharge can increase is through the cream outlet; and if the inlet is diminished, the cream will diminish until a certain time when the amount of milk which runs into the machine equals the amount discharged through the skim-milk outlet, and then there will be little or no cream. This is aptly illustrated by Wing, 'If the milk is turned into the bowl at such a rate that .8 escapes through the skim-milk outlet, we shall have .8 and .2 cream. If, now, we reduce the rate of inflow by .1, we shall get just as much skimmed milk and one-half as much cream.'"

It will be noticed according to these authorities the skim-milk tube runs to its full capacity under normal conditions of separation, and the only place that an increase in the inflow could be discharged is through the cream opening. That is to say, the full effect of a change in inflow comes on the cream. In the first part of this article it was shown that under normal conditions of separation the skim-milk tube does not run full. On the other hand, in Table 24 it was shown that an increase or a decrease in the inflow effects the dis-

1 Principles and Practice of Butter-making, p. 138.

charge from both the skim-milk and the cream openings, and it does not, by any means, all come on the cream discharge. In Table 24 we observe that the quantity of both skim-milk and cream is reduced as the inflow is reduced, but it is a fact that the proportion of skim-milk is somewhat increased.

In the text books referred to above the statement is made "That as the inlet is diminished, the cream will diminish until a certain time, when the amount of milk which flows into the machine equals the amount discharged through the skim-milk outlet, and then there will be little or no cream." Referring again to Table 24 it is seen that under normal conditions of separation when there was an inflow of 20,045 grams of milk, 17,765 grams of skim-milk were obtained in five minutes. If, now, according to the statement above, the inflow is decreased to 17,765 grams there would be little or no cream. In this trial the inflow was reduced to 15,660 grams and still a large quantity of cream was obtained.

The results in Table No. 23 show that the per cent of fat lost in the skim-milk is practically the same whether the rate of inflow is large or small. In these trials as the inflow is never above the designated capacity of the machine, but either equal to or below, a variation in the per cent of fat lost in the skim-milk is not expected. If the capacity of the separator was overcrowded, a greater loss in the skim-milk might occur. The Indiana Experiment Station found that overcrowding the separator will result in incomplete skimming. When the rate of inflow is reduced below normal a more complete separation is not accomplished.

TABLE 25.

EFFECT OF ACIDITY.

Separator	Trial No.	Per cent. acid in milk	Kilograms of cream in 5 minutes	Kilograms of skim-milk in 5 minutes	Total Kilograms separated in 5 min.	Proportion of cream to skim-milk	Per cent. of fat in cream	Per cent. of fat in skim-milk	Per cent. of fat in whole milk
Empire	59	sweet .19	2.520	19.875	22.395	1–7.88	41.8	.08	5.0
		sour .39	2.350	20.123	22.473	1–8.90	44.8	.06	5.0
Tubular	60	sweet .19	5.534	16.514	20.098	1–2.95	17.7	.07	4.75
		sour .39	5.472	16.643	22.115	1–3.04	17.7	.06	4.75
	61	sweet .19	7.038	20.775	27.813	1–2.97	18.6	.04	4.9
		sour .4	6.881	20.923	27.804	1–3.04	18.8	.03	4.9

Temperature, uniformly 90°. Speed, 45 turns per minute.

Table 25 shows the results of separating sweet milk as compared with the same after some acid has been developed. In making these tests sufficient milk was taken for two separations. One portion was separated at once while sweet, the other portion allowed to stand until sufficient acid developed to be easily noticeable to the taste. The acidity was tested by using tenth normal KOH with phenolphthalein as an indicator. The results are expressed as lactic acid. The results show but little effect in any way from the development of acid except there is a tendency for the per cent of fat to be increased from the sour milk, especially when the cream screw is so adjusted that cream is delivered with a high per cent of fat. This comes about from the fact already explained on page 546 that cream with a high viscosity is retarded in its passage through the cream tube and in this way a smaller proportion of cream is secured and the per cent of fat in the cream is higher.

Acid in the milk has no effect on the thoroughness of skimming within the limits investigated nor upon the capacity of the machine. It is a well known fact that when sour milk is run through a separator a larger deposit of separator slime results. This finally reaches a point where the skim-milk tubes become partially clogged and the outflow from the cream tube is increased accordingly and the per cent of fat in the cream decreased.

Effect of Dirt in the Tubes.—In rare cases the skim-milk or cream tubes may become partly obstructed. This is most apt to occur from lack of proper cleaning which may allow an accumulation of dirt in the tube. A small obstruction in the skim-milk tube as a rule does not make a marked change in the operation of the machine. If the cream opening is partly closed, however, the cream becomes smaller in quantity and richer.

Clogging of the Bowl.—After a separator has been in operation some time the separator slime accumulates to the extent that the skim-milk tubes are often partly closed and as a result a larger quantity flows out of the cream opening resulting in a lower per cent of fat. If the accumulation of slime continues the skim-milk tubes may become entirely clogged.

CONCLUSIONS.

In addition to the adjustment of the cream screw and the amount of water or skim-milk used to flush out the cream the main factors affecting the per cent of fat in separator cream are: (1) Speed of machine; (2) temperature of milk; (3) per cent of fat in milk; (4) rate of inflow.

An increase in the speed causes the skim-milk to flow out with a greater velocity which increases the capacity of the skim-milk tubes. As a result there is a larger proportion of skim-milk, and the cream has a higher per cent of fat. This rule holds with all machines tried except the Simplex when adjusted to deliver thin cream, in which case the reverse is true. The effect due to a change in speed is much more marked when the cream screw is set to deliver cream having a high per cent of fat than is the case when thinner cream is separated. The rate of inflow is affected to a very slight extent by the speed of the bowl through the suction produced as a result of a partial vacuum in the revolving bowl.

The loss of fat in the skim-milk is greater if the speed is much below normal. There is considerable difference in this respect due to the construction of the machine. In general at three-fourths of the normal speed the loss in the skim-milk is around .2 per cent or about three times the loss at normal speed.

Contrary to the statements found in most text books reducing the temperature of the milk causes a higher proportion of skim-milk and a small amount of cream with a higher per cent of fat. The result is much more pronounced when the separator is adjusted to deliver cream with a high per cent of fat. The rate of inflow to a separator bowl is not affected appreciably by the temperature of the milk. The effect of temperature both on the loss of fat in the skim-milk and on the per cent of fat in the cream varies with the construction of the machine. Within the limits of 70° to 90° F. the variation in the loss of fat in the skim-milk is not very marked but the loss is greater at the lower temperature. An increase in the per cent of fat in the cream brought about by a lower temperature of the milk separated is caused by the higher viscosity of the cold cream reducing the capacity of the cream outlet.

The per cent of fat in cream varies in direct proportion to the per cent of fat in the milk. The ratio of cream to skim-milk is not changed by a variation in the richness of the milk separated. The rate of inflow and the loss of fat in the skim-milk is not affected appreciably by the per cent of fat in the milk.

The rate of inflow changes the ratio of cream to skim-milk to some extent but the difference does not all come on the cream outflow as is generally stated in text books. A reduction in inflow reduces both the cream and the skim-milk but the former somewhat more in proportion than the latter. A smaller inflow therefore increases the per cent of fat in the cream more or less.