
University of Vermont and State Agricultural College
Vermont Agricultural Experiment Station

BURLINGTON, VERMONT

THE PRODUCTION OF HIGH QUALITY
MILK

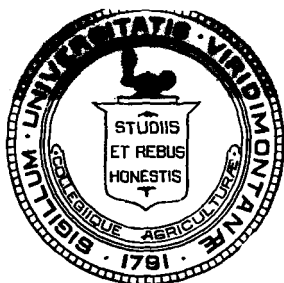
IV. THE INFLUENCE OF DELAYED COOLING, COMBINED WITH OTHER
COOLING PRACTICES, UPON THE QUALITY OF MILK

By J. M. FRAYER

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Cooling milk immediately to 50° F. is a fairly satisfactory procedure, even when it is held over night.

Cooling morning's milk immediately to 60° F. is a fairly satisfactory procedure.

Cooling night's milk to 60° F. is an unsatisfactory procedure.

Allowing milk to become warm once it has been properly cooled to 40° F. or below, is an unsatisfactory procedure.

Cooling milk immediately to and holding at a temperature of 40° F. or below seems to produce the best results in respect to its quality, both present and future.

Fresh milk, unsubjected to any cooling influence, suffers progressively for every hour of such delay.

The lower the initial temperature used the better.

BULLETIN 343: THE PRODUCTION OF HIGH QUALITY MILK

IV. THE INFLUENCE OF DELAYED COOLING, COMBINED WITH OTHER COOLING PRACTICES, UPON THE QUALITY OF MILK

By J. M. FRAYER

INTRODUCTION

It is universally conceded that milk should be cooled, but there is neither entire agreement nor complete knowledge touching details of the method used to accomplish that end. The influence of delayed cooling upon the quality of milk was dealt with broadly in bulletin 313 (1), of which the work herein reported was undertaken is a continuation and elaboration.

It was pointed out in the earlier bulletin that the situation in Vermont differs from that in many states in that very little milk is pasteurized within its borders. The problem is one of delivering milk to out-of-state processing plants which meet Board of Health regulations, particularly as to bacterial content. But although milk is pasteurized at the point of delivery little excuse exists for unsound cooling methods. Its importance seems to be one of degree only.

It would seem that official sanction should be accorded only to those cooling methods which best affect the ultimate product. Of course an ideal situation can not be arrived at over night. It never can be brought about by the process of evolution but should be the result of conscious effort and enlightened ideals. To argue that practices known to be inefficient are good enough because they are the best that can be obtained at the moment does not seem to be the right way to go about improving the situation.

State and municipal ordinances and codes are rarely very definite concerning cooling practice. Some prescribe "adequate" or "proper" cooling, without indicating what constitutes adequate or proper cooling, which apparently is often left to the discretion of the inspector. In most cases no distinction is made (as far as recommended cooling treatment is concerned) between milk that is to be sold raw, held raw for some time before pasteurization (as in Vermont) or delivered for immediate processing. However many recent investigators and the newer ordinances and codes recognize the importance of quick cooling. For example, the United States Public Health Service Milk Ordinance and Code (2) states that, "Milk must be cooled within one hour after milk-

ing to 50° F. or less, and maintained at or below that temperature until delivery, unless it is delivered to a milk plant for pasteurization or separation, in which case it must be cooled or pasteurized within two hours of the time of production." Strauch (3) says, "Milk should be taken from the barn to the milkhouse after each cow is milked and cooled to a temperature of 50° F. or lower and maintained below 50° F. until delivery." Gamble and Bowen (4) point out that, "Milk must be kept at a low temperature (50° F. or below) from the time it is produced until it is consumed if its quality is to be maintained." Macy (5) maintains that, "If milk is obtained from reasonably clean cows which do not give a high initial count (*i. e.*, normally or because of any inflammation of the udder-mastitis) milked into clean, dry utensils (especially milking machines and cans) and delivered to the pasteurizing plant within five or six hours after milking, without cooling, the bacterial count should not be excessive for use in pasteurizing. However, under average farm and plant practices these conditions are not always to be found, particularly the clean, dry utensils. If the utensils are not clean and dry, the initial count will tend to be so high that it will be impossible for the dairyman to deliver a satisfactory product without cooling adequately at once." Average farm practices of course are the ones that must be considered in outlining any cooling policy. Price, Hurd and Copson (6) and Marquardt and Dahlberg (7) in their recent studies deal principally with the mechanics of cooling. They conclude that the bacterial content of milk will not increase during the first 12 to 24 hours when kept in 10-gallon cans in a tank of water at 35° to 40° F. The context seems to imply that these cans are to be placed in the water promptly after being filled. It is shown that, without stirring, the temperature is dropped from 90° to 50° F. within two hours and to about 40° F. in three hours.

It should be pointed out that their temperature curve declines rather rapidly and, therefore, does not essentially constitute the type of delayed cooling here under discussion. It is the writer's contention that while the temperature of the cooling medium is extremely important, the length of time elapsing before the freshly drawn milk is first subjected to its influence is also of prime importance. Quickly subjecting milk to low temperature sharpens the declining temperature curve and quickly brings the milk through the optimum temperature zone at which most bacteria found therein grow best, to temperatures at which they multiply with increasing difficulty, if at all. Johns (8) comments on the marked influence of delayed cooling on subsequent bacterial growth.

How do bacteria grow and why? First, bacteria reproduce by fission (one cell dividing to make two); second, they reproduce, therefore, at a logarithmic rate (*i. e.*, 1, 2, 4, 8, 16, etc.); third, different kinds reproduce at different rates, by which is meant that their generation times (time from one complete separate cell to two separate cells), under identical food and temperature conditions, are different; fourth, temperature varies the generation times of all bacteria. Broadly speaking, body temperature (98.6° F.) is optimum for most of bacteria ordinarily found in milk. With a few exceptions the lower the temperature the longer the generation time. Table 1 indicates how theoretically it is that bacterial counts increase numerically in successive generations and how this increase works out on a percentage basis. This table should be borne in mind as being interpretive of subsequent tables in this bulletin.

TABLE 1. FIVE-SAMPLE BACTERIAL COUNTS, INCREASED AT A LOGARITHMIC RATE SHOWING PERCENTAGE INCREASES CORRESPONDING TO EACH GENERATION

Percentage Increase	Generation	Number of bacteria per cc.				
0	0	10,000	20,000	30,000	40,000	50,000
100	1st	20,000	40,000	60,000	80,000	100,000
300	2nd	40,000	80,000	120,000	160,000	200,000
700	3rd	80,000	160,000	240,000	320,000	400,000
1,500	4th	160,000	320,000	480,000	640,000	800,000
3,100	5th	320,000	640,000	960,000	1,280,000	1,600,000
6,300	6th	640,000	1,280,000	1,920,000	2,560,000	3,200,000

It will be noted that milk with an initial bacterial count of 10,000 per cc. theoretically increases 6,300 percent in six generations or to 640,000 per cc., which is just within the Boston minimum requirements; that milk with an initial bacterial count of 20,000 per cc., under the similar time and temperature conditions will also increase 6,300 percent in six generations or to 1,280,000 per cc., which is just over the Boston minimum requirements. An initial count of 50,000 per cc. does not seem large yet it will increase in six generations to 3,200,000 per cc., etc. A proper conception of some of these facts is necessary to an understanding of the initial importance of small things.

Of course every single cell found as an original contamination does not live. For example, every single cell of an original 10,000 does not divide at exactly the same time and create 10,000 more cells. Probably at a certain phase during the life cycle, called the logarithmic growth phase or period of most luxuriant growth, it approaches such a condition. However, it is highly improbable that these cells are ever

all in the same growth phase at the same time or even that they ever all live and grow.

For the purposes of this discussion, when one generation is referred to it is meant that, on the average, every cell has divided once, which must be roughly true when one finds two cells where there had been only one cell before. This is said with the understanding that the factor of experimental error and other inequalities inherent to the plate count method of determining the number of bacteria present in a given sample of milk sometimes afford strange results. These errors, according to the law of averages, are not expected to be always in one direction. Hence when dealing with a reasonably large number of counts and obtaining a geometric mean for an average, the usual individual inequalities tend to be balanced and the actual trend indicated. It would seem then that the general problem of proper cooling is one of prolonging the average generation time.

The specific problem here considered, in part, is one of measuring certain effects of delay in subjecting milk to that treatment which is known to be necessary to prolong the average generation time and, in part, one of measuring the effect of failing to hold milk continuously at a low temperature.

PROCEDURE

In these studies, as well as in those previously reported, it was deemed extremely important to secure samples varying in bacterial flora, produced under diverse conditions, such as hand and machine drawn, under good and not so good sanitary conditions, etc.; in other words, to secure average milk. It was also deemed very important that the milk reach the laboratory as soon as possible after it was drawn and strained. This time rarely if ever exceeded 20 minutes. It was immediately distributed among as many sterile jars (in sets of five) as were needed for the particular study, a process which never exceeded 10 minutes' duration. All samples were cooled at one hour intervals, commencing with 0, to the temperature and under the conditions later described, a process which rarely exceeded 20 minutes' duration. The total time from cow to complete cooling of the 0 sample probably averaged 50 minutes and never exceeded 60 minutes. Hence when later it is said that a sample was cooled in 0 hours, the time elapsing before the milk was subjected to rapid cooling after being distributed in jars in the laboratory is being indicated. This elapsed time was uniform and the results so far as the time element is concerned

should be comparable. Of course every effort was made so to handle the samples as not to augment their bacterial contents.

The master samples were sub-sampled from time to time for purposes of making plate counts and carrying on the methylene blue reduction test. The methylene blue tubes were examined at 15-minute intervals night and day until complete reduction occurred. Whenever it was thought likely that reduction would occur within the 15-minute period, they were examined at one-minute intervals. The technic described in "Standard Methods of Milk Analysis" was closely followed for both the plate count and the methylene blue reduction test. Duplicates were always taken. For reasons discussed in bulletin 313, averages of bacterial counts were obtained from the geometric mean instead of the arithmetic average.

The graphs dealing with average bacterial counts are simply a frank comparison of numbers as such. They are not intended to indicate the logarithmic relationships that undoubtedly exist. It is deemed of more importance to simplify them to the extent of showing numbers as compared with other numbers, using the arithmetic scale, than further to complicate them with the changing logarithmic scale, which is not easily comprehended at a glance. It should be understood that an increase in bacterial counts from 10,000 to 20,000 per cc. is just as significant as is an increase from 100,000 to 200,000 or from 1,000,000 to 2,000,000 bacteria per cc.

The average bacterial counts and reduction times hereinafter shown, whether graphically, in tabular form or by way of percentage increases or decreases, are presented only for the purpose of indicating trends, to show what may be expected to happen under the conditions specified. They do not show absolute values. For example, it would be illogical to deduce that because these averages show that fresh milk cooled at once to 50° F. has a bacterial count of 14,000 per cc. and a reduction time of 10 hours and 34 minutes, while fresh milk delayed four hours in cooling has a bacterial count of 41,000 per cc. and a reduction time of eight hours and 19 minutes, that therefore all fresh milk, when cooled at once and exhibiting a bacterial count of 14,000 per cc., would reduce in 10 hours and 34 minutes or that all fresh milk when cooled with a delay of four hours and having a bacterial count of 41,000 per cc. would reduce in eight hours and 19 minutes. However it would seem that, all things being equal, certain deductions as to probable trends can safely be made from the figures hereafter shown.

STUDY 1

In this study certain current cooling practices were approximated as closely as possible. They involve the use of both night's and morning's milk before and after cooling to 40° F. at the country receiving plant. All samples were divided into two series of five parts immediately on receipt at the laboratory. One series was handled as morning's milk, the other as night's milk. It seemed better to use identical milks for both series than to take separate samples in the morning and at night, since a direct comparison was afforded of the bacterial counts and reduction times of identical milks handled under the conditions specified. Two initial cooling temperatures were used and reported (trials 1, 2).

TRIAL 1

This trial was divided into two parts, one representing morning's and the other night's milk. The five samples of each of the two series were cooled to 50° F. after delays of 0, 1, 2, 3 and 4 hours respectively. Since identical milks were used and similarly handled, only one sub-sample was taken from each of five samples directly after they had been cooled to 50° F. The five samples representing morning's milk were held at 50° F. for periods of 4, 3, 2, 1, and 0 hours. For example, the sample that was cooled immediately was held four hours; that whose cooling was delayed one hour was held three hours, etc. After the last sample had been cooled to 50° F. and sub-sampled for plate count and reduction time determination, all were cooled to 40° F. and again sub-sampled. They were placed in a temperature controlled mechanical refrigerator and held at 40° F. for 22 hours, taken out and sub-sampled, replaced for another 24 hours (making a total of 46 hours at 40° F.), then taken out and for the last time sub-sampled for plate count and reduction time determination.

The five samples representing night's milk were similarly handled so far as initial cooling to 50° F. was concerned. However, they were held at 50° F. for periods of 17, 16, 15, 14 and 13 hours, thus covering the range of time elapsing between night milking and morning delivery at the receiving station. For example, the sample which was cooled at once was held 17 hours at 50° F.; that whose cooling was delayed one hour was held 16 hours at 50° F., etc. All were then cooled to 40° F., sub-sampled, held at 40° F. for 22 and 46 hours, and sub-sampled after each holding period.

Twelve different lots of milk were used, involving 440 separate plate counts and 440 separate reduction time determinations.

TABLE 2. AVERAGE (GEOMETRIC MEAN) BACTERIAL COUNTS AND AVERAGE REDUCTION TIMES OF MILK INITIALLY COOLED TO 50° F., GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

MORNING'S MILK												
Cooling delayed	A—Cooling to 50° F. delayed as indicated			B—Held at 50° F. for 4, 3, 2, 1 and 0 hours—then cooled to 40° F.			C—Held 22 hours at 40° F.			D—Held 46 hours at 40° F.		
	Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time	
	Hrs.	Min.	Hrs.	Min.	Hrs.	Min.	Hrs.	Min.	Hrs.	Min.	Hrs.	Min.
0 hours	14,000	10	34	13,800	9	35	14,500	10	30	14,500	11	24
1 hour	14,000	10	8	14,000	9	10	17,000	9	47	19,000	10	28
2 hours	17,800	9	58	18,000	9	5	24,500	9	35	24,000	10	30
3 hours	25,000	9	21	28,000	8	54	32,000	9	15	37,000	9	49
4 hours	41,000	8	19	41,000	8	6	50,000	8	47	59,000	9	19

AVERAGE BACTERIAL COUNTS OF MILK INITIALLY COOLED TO 50° F.

The average bacterial counts derived from this trial are grouped in tables 2 and 3, according to the length of time cooling was delayed.

It can safely be deduced from these figures that milk suffers bacteriologically for every hour of delayed cooling; that morning's milk cooled at once to 50° F. and further cooled within five hours to 40° F.,

TABLE 3. AVERAGE (GEOMETRIC MEAN) BACTERIAL COUNTS AND AVERAGE REDUCTION TIMES OF MILK INITIALLY COOLED TO 50° F., GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

NIGHT'S MILK												
Cooling delayed	A—Cooling to 50° F. delayed as indicated			B—Held at 50° F. for 17, 16, 15, 14 and 13 hours—then cooled to 40° F.			C—Held 22 hours at 40° F.			D—Held 46 hours at 40° F.		
	Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time	
	Hrs.	Min.	Hrs.	Min.	Hrs.	Min.	Hrs.	Min.	Hrs.	Min.	Hrs.	Min.
0 hours	14,000	10	34	14,800	9	29	14,000	10	26	17,800	10	49
1 hour	14,000	10	8	18,000	9	20	19,500	10	3	27,000	9	52
2 hours	17,800	9	58	22,500	8	52	26,000	9	31	39,000	9	7
3 hours	25,000	9	21	39,000	8	20	41,000	8	31	60,000	8	12
4 hours	41,000	8	19	55,000	7	45	69,000	7	41	105,000	7	42

is nearly as good at the end of 46 hours as it was when fresh, while the same milk with a delayed cooling of four hours has almost as large a bacterial count when fresh as it has after being held 46 hours at 40° F. It is further to be noted that the morning's milk cooled at once, although

held four hours at 50° F. before cooling to 40° F., exhibited a lower bacterial count than the sample whose cooling was delayed four hours before cooling to 50° F. and held 0 hours before further cooling to 40° F.

It can also be safely deduced that in the case of night's milk cooled to and held at 50° F. until the time that it is delivered to the receiving station where it is cooled to and held at 40° F. for 46 hours, the samples which were cooled at once have increased but slightly in bacterial con-

TABLE 4. AVERAGE (GEOMETRIC MEAN), MINIMUM AND MAXIMUM BACTERIAL COUNTS; AVERAGE, MAXIMUM AND MINIMUM REDUCTION TIMES OF MILKS WHOSE FIRST COOLING TO 50° F. WAS DELAYED AS INDICATED. GROUPED ACCORDING TO HOLDING CONDITIONS (TIME AND TEMPERATURE).

MORNING'S MILK

Holding conditions (time and temp.)	Bacterial counts			Reduction times					
	Average (Geo. mean)	Minimum	Maximum	Average		Maximum		Minimum	
				Hrs.	Min.	Hrs.	Min.	Hrs.	Min.
Cooling delayed 0 hours									
A	14,000	3,350	81,000	10	34	13	15	6	22
B	13,800	3,250	81,000	9	35	12	30	6	..
C	14,500	4,700	72,000	10	30	15	..	5	15
D	14,500	3,800	73,000	11	24	16	52	6	15
Cooling delayed 1 hour									
A	14,000	2,550	118,000	10	8	13	10	5	30
B	14,000	3,800	95,000	9	10	12	15	5	15
C	17,000	5,000	125,000	9	47	13	15	5	..
D	19,000	5,200	115,000	10	28	15	30	5	..
Cooling delayed 2 hours									
A	17,000	4,700	191,000	9	58	13	15	4	45
B	18,000	4,800	200,000	9	5	11	30	4	45
C	24,500	7,100	265,000	9	35	13	52	4	45
D	24,000	7,500	241,000	10	30	14	45	4	30
Cooling delayed 3 hours									
A	25,000	5,000	374,000	9	21	13	15	3	45
B	28,000	5,600	425,000	8	54	12	30	4	..
C	32,000	5,600	520,000	9	15	15	..	3	45
D	37,000	6,900	535,000	9	49	14	57	3	15
Cooling delayed 4 hours									
A	41,000	6,300	640,000	8	19	11	15	3	15
B	41,000	6,300	640,000	8	6	11	15	3	15
C	50,000	8,600	790,000	8	47	15	..	3	15
D	59,000	10,600	860,000	9	19	14	30	3	..

HOLDING CONDITIONS

- A—Cooling to 50° F. delayed as indicated.
 B—Held at 50° F. for 4, 3, 2, 1 and 0 hours.
 C—Held 22 hours at 40° F.
 D—Held 46 hours at 40° F.

tent. The cumulative effect of delayed cooling again is manifested in counts on milk whose cooling was delayed four hours, held at 50° F., 13 hours and then cooled to and held at 40° F. for 46 hours. This is important in that it indicates that milk promptly cooled to 50° F. will keep longer than will milk whose cooling has been delayed.

It is further to be noted that night's milk, cooled at once to 50° F., although held 17 hours before cooling to 40° F., showed a lower bacterial count than did the sample whose cooling was delayed four hours and held 13 hours at 50° F. before further cooling to 40° F.

TABLE 5. AVERAGE (GEOMETRIC MEAN), MINIMUM AND MAXIMUM BACTERIAL COUNTS; AVERAGE, MAXIMUM AND MINIMUM REDUCTION TIMES OF MILKS WHOSE FIRST COOLING TO 50° F. WAS DELAYED AS INDICATED. GROUPED ACCORDING TO HOLDING CONDITIONS (TIME AND TEMPERATURE).

NIGHT'S MILK									
Holding conditions (time and temp.)	Bacterial counts			Reduction times					
	Average (Geo. mean)	Minimum	Maximum	Average		Maximum		Minimum	
				Hrs.	Min.	Hrs.	Min.	Hrs.	Min.
Cooling delayed 0 hours									
A	14,000	3,350	81,000	10	34	13	15	6	22
B	14,800	3,100	93,000	9	29	13	..	5	30
C	14,000	2,600	95,000	10	26	13	45	5	45
D	17,800	1,800	156,000	10	49	13	45	5	30
Cooling delayed 1 hour									
A	14,000	2,600	118,000	10	8	13	10	5	30
B	18,000	2,900	149,000	9	20	12	45	4	45
C	19,500	2,700	207,000	10	3	14	45	4	45
D	27,000	2,400	425,000	9	52	14	30	3	45
Cooling delayed 2 hours									
A	17,800	4,700	191,000	9	58	13	15	4	45
B	22,500	3,100	350,000	8	52	12	30	3	45
C	26,000	4,900	378,000	9	31	13	45	3	30
D	39,000	4,700	1,580,000	9	7	12	15	2	45
Cooling delayed 3 hours									
A	25,000	5,000	374,000	9	21	13	15	3	45
B	39,000	5,000	700,000	8	20	12	15	3	..
C	41,000	8,400	890,000	8	31	12	52	3	..
D	60,000	7,800	1,770,000	8	12	12	..	2	30
Cooling delayed 4 hours									
A	41,000	6,300	640,000	8	19	11	15	3	15
B	55,000	12,200	1,190,000	7	45	10	45	2	15
C	69,000	8,200	2,360,000	7	41	10	15	2	15
D	105,000	9,700	3,640,000	7	42	10	45	2	15

HOLDING CONDITIONS

A, C, D as in table 4.

B—Held at 50° F. for 17, 16, 15, 14 and 13 hours—then cooled to 40° F.

The average bacterial counts are compared graphically in chart 1, according to the length of time cooling was delayed. The same figures are shown in tables 4 and 5 as in tables 2 and 3 except that they are re-grouped according to holding conditions (time and temperature). Furthermore the minimum and maximum bacterial counts making up the averages are shown. It will be seen that both the large and small counts progressively increase the longer cooling has been delayed, and that the small counts increase less rapidly than do the large counts.

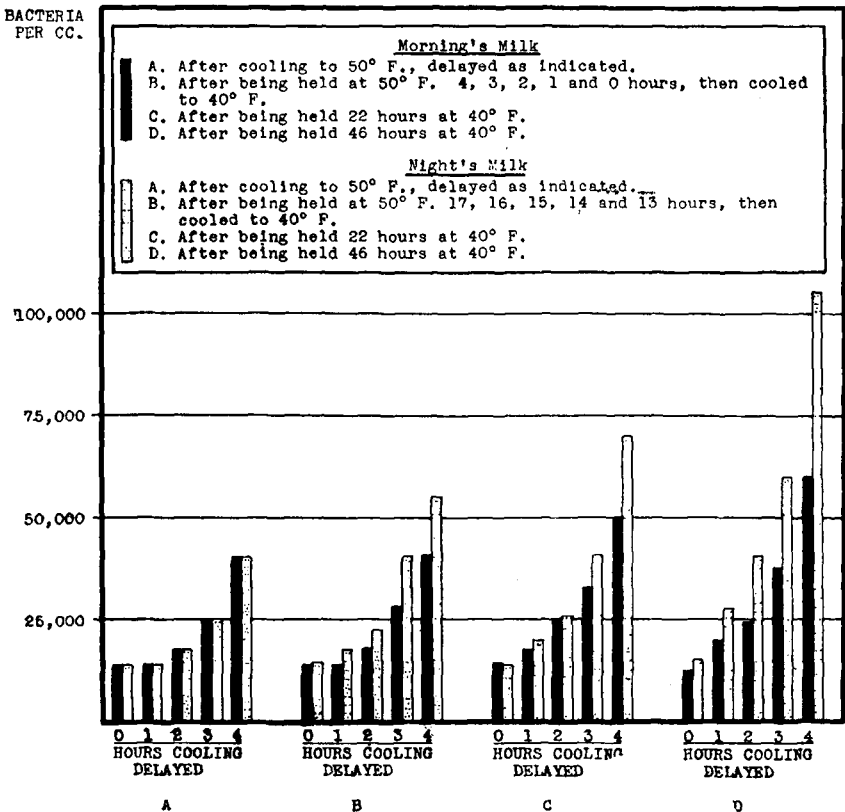


CHART 1. Study 1—Trial 1. Average bacterial counts

The trends earlier discussed are indicated in another way in tables 6 and 7 by showing percentage increases in bacterial counts over those in fresh milk cooled at once. It will be observed that fresh milk whose cooling was delayed four hours shows an increase of about 192 percent (between first and second generation); that fresh milk cooled

at once to 50° F., held four hours at that temperature and then cooled to and held at 40° F. for 46 hours shows an increase of only 39 percent; while milk whose cooling to 50° F. was delayed four hours, held 0 hours at 50° F., then cooled to and held at 40° F. for 46 hours suffered to the extent of about 321 percent or to a point which theoretically

TABLE 6. PERCENTAGE INCREASES OR DECREASES IN AVERAGE BACTERIAL COUNTS AND PERCENTAGE INCREASES OR DECREASES IN AVERAGE REDUCTION TIMES IN MILKS HELD 1 TO 4 HOURS BEFORE COOLING TO 50° F., OVER THOSE IN SAMPLES COOLED AT ONCE GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

MORNING'S MILK								
Cooling delayed	A—Cooling to 50° F. delayed as indicated		B—Held at 50° F. for 4, 3, 2, 1 and 0 hours—then cooled to 40° F.		C—Held 22 hours at 40° F.		D—Held 46 hours at 40° F.	
	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time
0 hours	0	0	— 1.4	— 9.3	+ 3.6	— .6	+ 3.6	+ 7.9
1 hour	0	— 4.1	0	—13.2	+ 21.4	— 7.4	+ 35.7	— .9
2 hours	+ 27.1	— 5.7	+ 28.6	—14.0	+ 75.0	— 9.3	+ 71.4	— .6
3 hours	+ 78.6	—11.5	+100.0	—15.8	+128.6	—12.5	+164.3	— 7.1
4 hours	+192.8	—21.3	+192.8	—23.2	+257.1	—16.9	+321.4	—11.8

is just past the production of the second generation of every original cell.

In the case of night's milk where the milk was held from 13 to 17 hours at 50° F. before cooling to 40° F., the fresh milk cooled at once

TABLE 7. PERCENTAGE INCREASES OR DECREASES IN AVERAGE BACTERIAL COUNTS AND PERCENTAGE INCREASES OR DECREASES IN AVERAGE REDUCTION TIMES IN MILKS HELD 1 TO 4 HOURS BEFORE COOLING TO 50° F., OVER THOSE IN SAMPLES COOLED AT ONCE GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

NIGHT'S MILK								
Cooling delayed	A—Cooling to 50° F. delayed as indicated		B—Held at 50° F. for 17, 16, 15, 14 and 13 hours—then cooled to 40° F.		C—Held 22 hours at 40° F.		D—Held 46 hours at 40° F.	
	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time
0 hours	0	0	+ 5.7	—10.2	0	— 1.3	+ 27.1	+ 2.4
1 hour	0	— 4.1	+ 28.6	—11.7	+ 39.3	— 4.9	+ 92.8	— 6.6
2 hours	+ 27.1	— 5.7	+ 60.7	—16.1	+ 85.7	— 9.9	+178.6	—13.7
3 hours	+ 78.6	—11.5	+178.6	—21.1	+192.8	—19.4	+328.6	—22.4
4 hours	+192.8	—21.3	+292.8	—26.6	+392.8	—27.3	+650.	—27.1

shows an increase of only 27 percent, while the milk whose cooling was delayed four hours, held 13 hours at 50° F. and then cooled to and held at 40° F. for 46 hours shows a 650 percent increase which, theoretically, would imply the growth of nearly three complete generations.

In tables 8 and 9 are shown percentage increases of bacterial counts over what they would have been had the milk been cooled at once and held as indicated under A, B, C and D. It plainly indicates in another way the advantages of rapid cooling over delayed cooling.

It should be pointed out that the use of the term "percentage increase" in connection with bacterial counts is of service only if one is

TABLE 8. PERCENTAGE INCREASES IN AVERAGE BACTERIAL COUNTS AND PERCENTAGE DECREASES IN AVERAGE REDUCTION TIMES OVER THOSE IN FRESH MILKS COOLED AT ONCE TO 50° F. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

MORNING'S MILK								
Cooling delayed	A—Cooling to 50° F. delayed as indicated		B—Held at 50° F. for 4, 3, 2, 1 and 0 hours—then cooled to 40° F.		C—Held 22 hours at 40° F.		D—Held 46 hours at 40° F.	
	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time
0 hours	0	0	0	0	0	0	0	0
1 hour	0	-4.1	+ 1.4	-4.3	+ 17.2	-6.8	+ 31.0	-8.2
2 hours	+ 27.1	-5.7	+ 30.4	-5.2	+ 69.0	-8.7	+ 65.5	-7.9
3 hours	+ 78.6	-11.5	+102.9	-7.1	+120.7	-11.9	+155.2	-13.9
4 hours	+192.8	-21.3	+197.1	-15.5	+244.8	-16.3	+306.9	-18.3

comparing counts within a series having the same initial count. This is true because, as has before been noted, the counts increase at a logarithmic rate (*i. e.*, 6, 12, 24, 48, etc.). For example, with an initial count of 6,000 per cc. a 1,500 percent increase would bring the count to

TABLE 9. PERCENTAGE INCREASES IN AVERAGE BACTERIAL COUNTS AND PERCENTAGE DECREASES IN AVERAGE REDUCTION TIMES OVER THOSE IN FRESH MILKS COOLED AT ONCE TO 50° F. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

NIGHT'S MILK								
Cooling delayed	A—Cooling to 50° F. delayed as indicated		B—Held at 50° F. for 17, 16, 15, 14 and 13 hours—then cooled to 40° F.		C—Held 22 hours at 40° F.		D—Held 46 hours at 40° F.	
	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time
0 hours	0	0	0	0	0	0	0	0
1 hour	0	-4.1	+ 21.6	-1.6	+ 39.3	-3.7	+ 51.7	-8.8
2 hours	+ 27.1	-5.7	+ 52.0	-6.5	+ 85.7	-8.8	+119.1	-15.7
3 hours	+ 78.6	-11.5	+153.5	-12.1	+192.8	-18.4	+237.1	-24.2
4 hours	+192.8	-21.3	+271.6	-18.3	+392.8	-26.4	+489.9	-28.8

96,000 per cc., while a 1,500 percent increase with an initial count of 48,000 per cc. would bring the count to 768,000 per cc. However, the fourth generation would have appeared in either case. This well illustrates the value and importance of a low initial count and why it is desirable to prolong generation time by every practicable means.

AVERAGE BACTERIAL COUNTS OF MILKS WHOSE INITIAL COUNTS WERE
10,000 PER CC. OR LESS

It was thought that it would be worth while to examine averages
from milks which had initial bacterial counts of 10,000 per cc. or less.

**TABLE 10. AVERAGE (GEOMETRIC MEAN) BACTERIAL COUNTS AND AVERAGE REDUCTION TIMES
OF MILKS WHOSE INITIAL COUNTS WERE 10,000 PER CC. OR UNDER AND WHICH
WERE INITIALLY COOLED TO 50° F. GROUPED ACCORDING TO THE LENGTH OF
TIME COOLING WAS DELAYED**

MORNING'S MILK

Cooling delayed	A—Cooling to 50° F. delayed as indicated			B—Held at 50° F. for 4, 3, 2, 1 and 0 hours—then cooled to 40° F.			C—Held 22 hours at 40° F.			D—Held 46 hours at 40° F.		
	Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time	
		Hrs.	Min.		Hrs.	Min.		Hrs.	Min.		Hrs.	Min.
0 hours	6,000	12	48	5,700	10	51	6,700	11	48	6,600	13	27
1 hour	5,500	11	45	6,000	10	15	6,900	11	30	7,500	12	7
2 hours	7,200	11	46	6,900	10	6	10,000	11	36	8,500	12	34
3 hours	8,900	11	9	9,500	9	51	10,200	10	54	10,400	11	55
4 hours	12,800	9	51	12,800	9	36	14,000	10	28	14,700	11	21

In tables 10 and 11 such counts, on morning's and night's milk re-
spectively, are so grouped according to the length of time cooling was
delayed. It will be noticed that although all the milks had been handled

**TABLE 11. AVERAGE (GEOMETRIC MEAN) BACTERIAL COUNTS AND AVERAGE REDUCTION TIMES
OF MILKS WHOSE INITIAL COUNTS WERE 10,000 PER CC. OR UNDER AND WHICH
WERE INITIALLY COOLED TO 50° F. GROUPED ACCORDING TO THE LENGTH OF
TIME COOLING WAS DELAYED**

NIGHT'S MILK

Cooling delayed	A—Cooling to 50° F. delayed as indicated			B—Held at 50° F. for 17, 16, 15, 14 and 13 hours— then cooled to 40° F.			C—Held 22 hours at 40° F.			D—Held 46 hours at 40° F.		
	Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time	
		Hrs.	Min.		Hrs.	Min.		Hrs.	Min.		Hrs.	Min.
0 hours	6,000	12	48	5,900	10	57	5,500	12	15	6,000	12	51
1 hour	5,500	11	45	6,700	10	36	6,300	12	1	6,700	12	19
2 hours	7,200	11	46	7,100	10	10	8,300	11	10	7,900	11	12
3 hours	8,900	11	9	9,500	10	1	10,900	10	49	11,700	10	25
4 hours	12,800	9	51	15,700	9	33	14,700	10	6	16,500	9	58

under conditions as nearly identical as possible, the counts did not in-
crease as rapidly as in the total averages. They did, however, show the
same trends as far as the effects of delayed cooling were concerned. A
possible explanation for this condition is that there probably exist in

low count milk a maximum of flora originating in the udder and a minimum of that derived from utensil contamination. It might be expected that any germicidal effect which might be present would be more potent towards the udder flora than towards organisms normally found as a result of utensil contamination. However perhaps too small a number of cases was studied to warrant generalization.

These figures, presented graphically in chart 2, afford an easy comparison. In tables 12 and 13 will be found the same figures as in

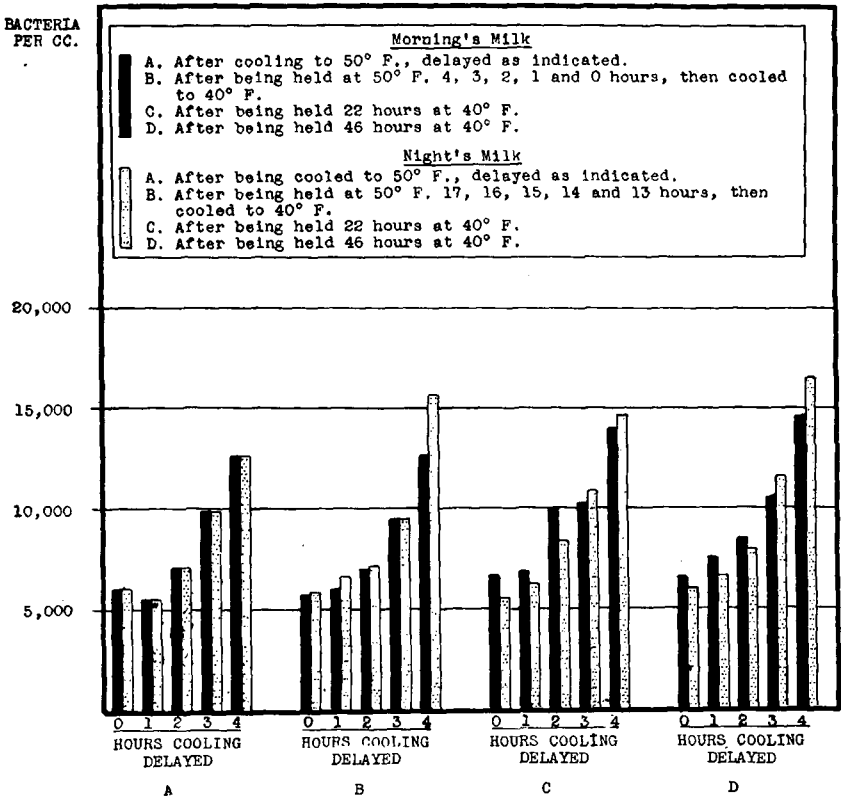


CHART 2. Study 1—Trial 1. Average bacterial counts initially 10,000 per cc. or less

tables 10 and 11, and in addition the minimum and maximum bacterial counts are shown. They are grouped according to holding conditions (time and temperature). The range is rather restricted as might be expected. In tables 14 and 15 will be found the percentage increases in bacterial counts over those in fresh milk cooled at once. The same trends will be noticed as for the total averages except that the increases are smaller, indicating a slowing down of bacterial activity and, there-

fore, fewer generations. In tables 16 and 17 appear the percentage increases in bacterial counts over what they would have been had the milk been cooled at once and held as indicated under A, B, C and D.

TABLE 12. AVERAGE (GEOMETRIC MEAN), MINIMUM AND MAXIMUM BACTERIAL COUNTS; AVERAGE, MAXIMUM AND MINIMUM REDUCTION TIMES OF MILKS WHOSE FIRST COOLING TO 50° F. WAS DELAYED AS INDICATED AND WHOSE INITIAL COUNTS WERE 10,000 PER CC. OR LESS. GROUPED ACCORDING TO HOLDING CONDITIONS (TIME AND TEMPERATURE)

MORNING'S MILK

Holding conditions (time and temp.)	Bacterial counts			Reduction times					
	Average (Geo. mean)	Minimum	Maximum	Average		Maximum		Minimum	
				Hrs.	Min.	Hrs.	Min.	Hrs.	Min.
Cooling delayed 0 hours									
A	6,000	3,400	9,300	12	48	13	15	12	..
B	5,700	3,200	9,400	10	51	12	30	9	30
C	6,700	4,700	10,500	11	48	14	30	9	45
D	6,600	3,800	11,100	13	27	16	52	11	..
Cooling delayed 1 hour									
A	5,500	2,600	9,100	11	45	12	15	11	30
B	6,000	3,800	9,300	10	15	12	..	9	..
C	6,900	5,300	10,300	11	30	14	..	10	..
D	7,500	5,200	10,700	12	7	14	52	9	..
Cooling delayed 2 hours									
A	7,200	4,700	10,000	11	46	13	15	10	45
B	6,900	4,800	10,300	10	6	11	15	8	45
C	10,000	7,100	11,400	11	36	13	52	10	..
D	8,500	7,500	10,000	12	34	15	..	11	..
Cooling delayed 3 hours									
A	8,900	5,000	11,400	11	9	13	15	9	45
B	9,500	5,600	15,000	9	51	10	30	9	..
C	10,200	5,600	13,500	10	54	12	45	9	45
D	10,400	6,900	13,500	11	55	14	57	9	52
Cooling delayed 4 hours									
A	12,800	6,300	18,600	9	51	11	15	9	..
B	12,800	6,300	18,600	9	36	11	15	9	..
C	14,000	8,600	20,800	10	28	11	45	9	15
D	14,700	10,600	19,100	11	21	13	..	9	22

HOLDING CONDITIONS

A—Cooling to 50° F. delayed as indicated.

B—Held at 50° F. for 4, 3, 2, 1 and 0 hours—then cooled to 40° F.

C—Held 22 hours at 40° F.

D—Held 46 hours at 40° F.

AVERAGE REDUCTION TIMES

It seemed desirable to determine the effect of the various cooling practices upon the methylene blue reduction time because this method is so commonly used at dairy plants and elsewhere as a quality test.

As has already been pointed out (1), the longer cooling is delayed the less will be the reduction time. This seems to hold true in every case. It should be said, however, that in the case of morning's milk

TABLE 13. AVERAGE (GEOMETRIC MEAN), MINIMUM AND MAXIMUM BACTERIAL COUNTS; AVERAGE, MAXIMUM AND MINIMUM REDUCTION TIMES OF MILKS WHOSE FIRST COOLING TO 50° F. WAS DELAYED AS INDICATED AND WHOSE INITIAL COUNTS WERE 10,000 PER CC. OR LESS. GROUPED ACCORDING TO HOLDING CONDITIONS (TIME AND TEMPERATURE)

NIGHT'S MILK

Holding conditions (time and temp.)	Bacterial counts			Reduction times					
	Average (Geo. mean)	Minimum	Maximum	Average		Maximum		Minimum	
				Hrs.	Min.	Hrs.	Min.	Hrs.	Min.
Cooling delayed 0 hours									
A	6,000	3,400	9,300	12	48	13	15	12	..
B	5,900	3,100	11,100	10	57	11	45	9	45
C	5,500	2,600	13,300	12	15	15	15	11	..
D	6,000	1,800	13,500	12	51	14	15	11	30
Cooling delayed 1 hour									
A	5,500	2,600	9,100	11	45	12	15	11	30
B	6,700	2,900	12,300	10	36	11	30	9	30
C	6,300	2,700	15,500	12	1	14	45	10	30
D	6,700	2,400	14,400	12	19	14	30	11	7
Cooling delayed 2 hours									
A	7,200	4,700	10,000	11	46	13	15	11	..
B	7,100	3,100	11,600	10	10	11	..	9	15
C	8,300	4,900	12,800	11	10	13	15	8	52
D	7,900	4,700	13,900	11	12	12	15	9	52
Cooling delayed 3 hours									
A	8,900	5,000	11,400	11	9	13	15	9	45
B	9,500	5,000	13,400	10	1	11	..	9	..
C	10,900	8,400	15,000	10	49	12	52	8	52
D	11,700	7,800	17,000	10	25	12	..	9	15
Cooling delayed 4 hours									
A	12,800	6,300	18,300	9	51	11	15	9	..
B	15,700	12,200	19,400	9	33	10	45	8	30
C	14,700	8,200	18,000	10	6	11	7	9	22
D	16,500	9,700	21,500	9	58	11	7	9	15

HOLDING CONDITIONS

A—Cooling to 50° F. delayed as indicated.

B—Held at 50° F. for 17, 16, 15, 14 and 13 hours—then cooled to 40° F.

C—Held 22 hours at 40° F.

D—Held 46 hours at 40° F.

which was held at 50 F. for 0 hours before cooling to and maintaining at 40° F., the average reduction time was greater after holding for 46 hours than when sampled fresh (table 2). This is one rather notable inconsistency. For example, in a sample of fresh morning's milk cooled

at once, a bacterial count of 14,000 per cc. was observed and a reduction time of 10 hours and 34 minutes. After being held at 50° F. for four hours and then cooled to and held at 40° F. for 46 hours, the average bacterial count had increased very slightly to 14,500 per cc., while the

TABLE 14. PERCENTAGE INCREASES OR DECREASES IN AVERAGE BACTERIAL COUNTS AND PERCENTAGE DECREASES OR INCREASES IN AVERAGE REDUCTION TIMES IN MILKS HELD 1 TO 4 HOURS BEFORE COOLING TO 50° F., OVER THOSE IN SAMPLES COOLED AT ONCE, IN MILKS HAVING INITIAL BACTERIAL COUNTS OF 10,000 PER CC. OR LESS. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

MORNING'S MILK

Cooling delayed	A—Cooling to 50° F. delayed as indicated		B—Held at 50° F. for 4, 3, 2, 1 and 0 hours—then cooled to 40° F.		C—Held 22 hours at 40° F.		D—Held 46 hours at 40° F.	
	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time
0 hours	0	0	— 5.	—15.2	+ 11.7	— 7.8	+ 10.	+ 5.1
1 hour	— 8.3	— 8.2	0	—19.9	+ 15.	—10.2	+ 25.	— 5.3
2 hours	+ 20.	— 8.1	+ 15.	—21.1	+ 66.7	— 9.4	+ 41.7	— 1.8
3 hours	+ 48.3	—12.9	+ 58.3	—23.	+ 70.	—14.8	+ 73.3	— 6.9
4 hours	+113.3	—23.	+113.3	—25.	+133.3	—18.2	+145.	—11.3

reduction time had also increased somewhat to 11 hours and 24 minutes. In the fresh milk whose cooling was delayed four hours a bacterial count of 41,000 per cc. was obtained and a reduction time of 8 hours

TABLE 15. PERCENTAGE INCREASES OR DECREASES IN AVERAGE BACTERIAL COUNTS AND PERCENTAGE DECREASES OR INCREASES IN AVERAGE REDUCTION TIMES IN MILKS HELD 1 TO 4 HOURS BEFORE COOLING TO 50° F., OVER THOSE IN SAMPLES COOLED AT ONCE, IN MILKS HAVING INITIAL BACTERIAL COUNTS OF 10,000 PER CC. OR LESS. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

NIGHT'S MILK

Cooling delayed	A—Cooling to 50° F. delayed as indicated		B—Held at 50° F. for 17, 16, 15, 14 and 13 hours—then cooled to 40° F.		C—Held 22 hours at 40° F.		D—Held 46 hours at 40° F.	
	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time
0 hours	0	0	— 1.7	—14.4	— 8.3	— 4.3	0	+ 0.4
1 hour	— 8.3	— 8.2	+ 11.7	—17.2	+ 5.	— 6.1	+ 11.7	— 3.8
2 hours	+ 20.	— 8.1	+ 18.3	—20.6	+ 38.3	—12.8	+ 31.7	—12.5
3 hours	+ 48.3	—12.9	+ 58.3	—21.7	+ 81.7	—15.5	+ 95.	—18.6
4 hours	+113.3	—23.	+161.7	—25.4	+145.	—21.1	+175.	—22.1

and 19 minutes, while when this same milk was cooled to and held at 40° F. for 46 hours the bacterial count increased to 59,000 per cc. and the reduction time to 9 hours and 19 minutes.

In the night's milk which has been held longer at 50° F. the increased bacterial activity which has been encouraged at this temperature tended to modify some of the effect of the colder temperature upon the mechanism of the methylene blue test (table 3). For example, the

TABLE 16. PERCENTAGE INCREASES OR DECREASES IN AVERAGE BACTERIAL COUNTS AND PERCENTAGE DECREASES IN AVERAGE REDUCTION TIMES OVER THOSE IN FRESH MILKS COOLED AT ONCE TO 50° F., IN THOSE SAMPLES WHOSE INITIAL BACTERIAL COUNTS WERE 10,000 PER CC. OR LESS. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

MORNING'S MILK

Cooling delayed	A—Cooling to 50° F. delayed as indicated		B—Held at 50° F. for 4, 3, 2, 1 and 0 hours—then cooled to 40° F.		C—Held 22 hours at 40° F.		D—Held 46 hours at 40° F.	
	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time
0 hours	0	0	0	0	0	0	0	0
1 hour	— 8.3	— 8.2	+ 5.3	— 5.5	+ 3.	— 2.5	+ 13.6	— 9.9
2 hours	+ 20.	— 8.1	+ 21.	— 6.9	+ 49.2	— 1.7	+ 28.8	— 6.6
3 hours	+ 48.3	—12.9	+ 66.7	— 9.2	+ 52.2	— 7.6	+ 57.6	—11.4
4 hours	+113.3	—23.	+104.6	—11.5	+109.	—11.3	+122.7	—15.6

fresh milk cooled at once had a bacterial count of 14,000 per cc. and a reduction time of 10 hours and 34 minutes, whereas after being held for 17 hours at 50° F., and then cooled to and held at 40° F. for 46 hours, a bacterial count of 17,800 per cc. was found and a reduction time of 10

TABLE 17. PERCENTAGE INCREASES OR DECREASES IN AVERAGE BACTERIAL COUNTS AND PERCENTAGE DECREASES IN AVERAGE REDUCTION TIMES OVER THOSE IN FRESH MILKS COOLED AT ONCE TO 50° F., IN THOSE SAMPLES WHOSE INITIAL BACTERIAL COUNTS WERE 10,000 PER CC. OR LESS. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

NIGHT'S MILK

Cooling delayed	A—Cooling to 50° F. delayed as indicated		B—Held at 50° F. for 17, 16, 15, 14 and 13 hours—then cooled to 40° F.		C—Held 22 hours at 40° F.		D—Held 46 hours at 40° F.	
	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time
0 hours	0	0	0	0	0	0	0	0
1 hour	— 8.3	— 8.2	+ 13.6	— 3.2	+ 14.5	— 1.9	+ 11.7	— 4.2
2 hours	+ 20.	— 8.1	+ 20.8	— 7.2	+ 50.9	— 8.8	+ 31.7	—12.8
3 hours	+ 48.3	—12.9	+ 61.	— 8.5	+ 98.2	—11.7	+ 95.	—18.9
4 hours	+113.4	—23.	+166.1	—12.8	+167.3	—17.5	+175.	—22.4

hours and 49 minutes. In the fresh milk whose cooling was delayed four hours a bacterial count of 41,000 per cc. was found and a reduction time of 8 hours and 19 minutes. The same milk held at 50° F. for 13 hours before cooling to and holding at 40° F. for 46 hours had a

bacterial count of 105,000 per cc. and a reduction time of 7 hours and 42 minutes. The difference between the night's milk and the morning's milk is apparently due to the longer holding period at 50° F.

It is interesting to note that 50° F. is commonly thought to be a good temperature at which to hold milk. It would seem from these

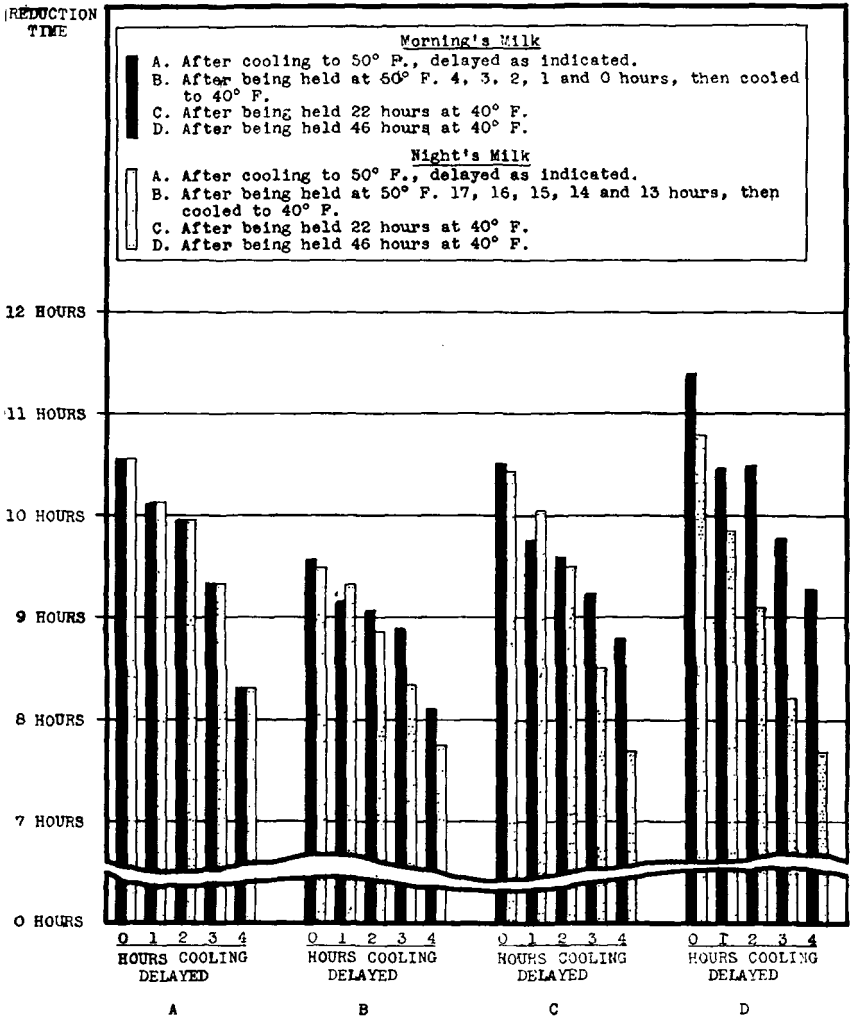


CHART 3. Study 1—Trial 1. Average reduction times

figures that however desirable this temperature may be it certainly is not ideal and that if producers are to be educated to produce better milk the advisability of the use of lower temperatures must be stressed.

These figures are shown graphically in chart 3. In tables 4 and 5 will be found the same averages as in tables 2 and 3, re-grouped accord-

ing to holding conditions (time and temperatures), as well as the maximum and minimum reduction times. The advantages of quick cooling are again manifested. In tables 6 and 7 will be found the percentage increases in reduction times over those in fresh milk cooled at once. It should be noted that the longer holding period at 50° F. (night's milk) causes measurable damage and lessens the reduction times but that the quickly cooled milk is damaged by far the least. In tables 8 and 9 are shown the percentage decreases in reduction times over what they would have been had the milk been cooled at once and held as indicated under A, B, C and D.

AVERAGE REDUCTION TIMES OF MILKS WHOSE INITIAL COUNTS WERE
10,000 PER CC. OR LESS

Tables 10 and 11 display the reduction times grouped according to the length of time cooling was delayed. Here the milks, after being held 46 hours at 40° F., have a longer reduction time than the fresh samples, both the low count milk and in the total averages. It should be noted that a temperature of 50° F. does not disturb the mechanism of the methylene blue test as much as the lower temperature of 40° F. Another fact to be noted is that morning's milk whose cooling had been delayed four hours, held 0 hours at 50° F., then cooled to and held at 40° F. for 46 hours, suffers much less, as measured by the reduction time, than does the night's milk whose cooling had been delayed four hours, held at 50° F. for 13 hours, then cooled to and held at 40° F. for 46 hours. This difference is perhaps a little more pronounced in the low count than in the total averages.

These figures are shown grouped in another way in tables 12 and 13, also graphically in chart 4. In tables 14 and 15 are shown the percentage decreases or increases in reduction times over those in fresh milk cooled at once. The trends are the same as in the total averages. The differences exist, but are not very significant. In some respects the reduction test may be more delicate than the plate count in detecting decreases in real quality. In tables 16 and 17 are shown the percentage decreases in reduction times over what they would have been had the milks been cooled at once and held as indicated under A, B, C and D. Again the differences in percentage are not significantly smaller than those for the total averages. It should again be noted that milk cooled at once to 50° F. and later cooled to and held at 40° F. suffers but slightly.

TRIAL 2

The samples used in this trial were handled exactly as were the samples in trial 1, except they were initially cooled to 60° F. Sixteen lots of milk were used, involving 640 separate plate counts and 640 separate reduction time determinations.

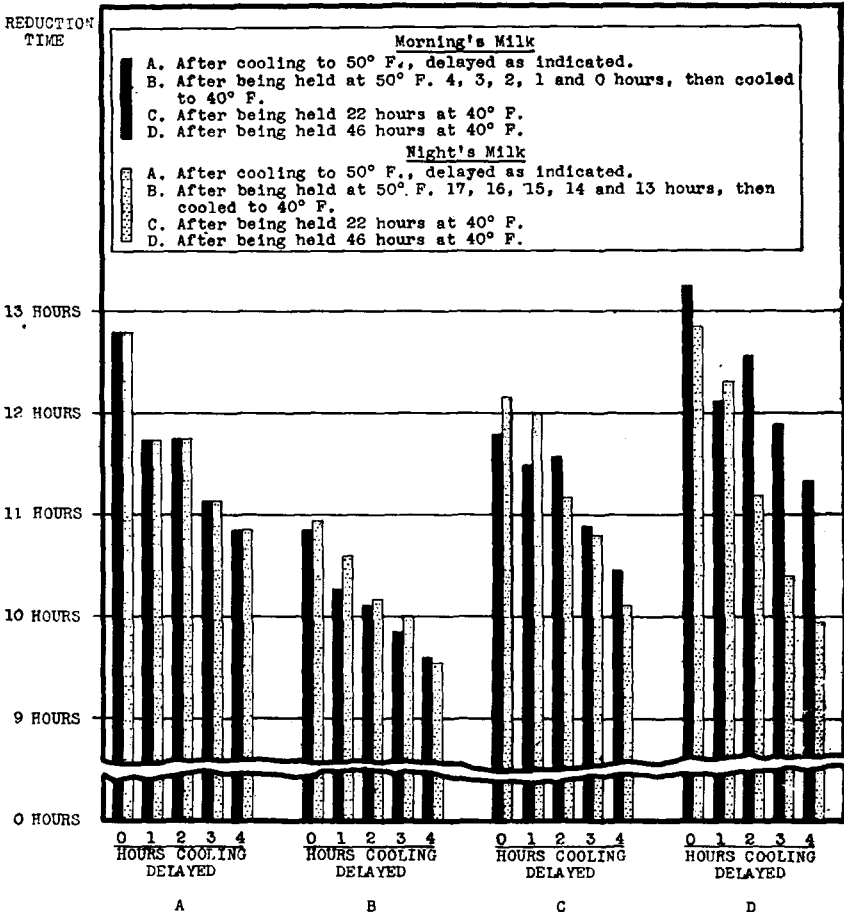


CHART 4. Study 1—Trial 1. Average reduction times on milks whose bacterial counts were initially 10,000 per cc. or less

AVERAGE BACTERIAL COUNTS

In table 18 will be found the average (geometric mean) bacterial counts on morning's milk, grouped according to the length of time cooling had been delayed. It will be noticed that any possible germicidal effect was quickly dissipated after holding at 60° F. for any considerable period; that quickly cooled milk, held at 60° F. for four hours,

then cooled to and held at 40° F. for 46 hours, increased in a bacterial count from 13,000 per cc. to only 20,700 per cc. (less than one generation), while milk whose cooling had been delayed four hours, held 0 hours at 60° F., then cooled to and held at 40° F. for 46 hours,

TABLE 18. AVERAGE (GEOMETRIC MEAN) BACTERIAL COUNTS AND AVERAGE REDUCTION TIME OF MILKS INITIALLY COOLED TO 60° F. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

MORNING'S MILK

Cooling delayed	A—Cooling to 60° F. delayed as indicated			B—Held at 60° F. for 4, 3, 2, 1 and 0 hours—then cooled to 40° F.			C—Held 22 hours at 40° F.		D—Held 46 hours at 40° F.			
	Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time	
		Hrs.	Min.		Hrs.	Min.		Hrs.	Min.		Hrs.	Min.
0 hours	13,100	9	28	13,400	9	15	16,500	9	13	20,700	9	38
1 hour	14,400	8	39	17,700	8	41	21,700	8	58	26,700	9	1
2 hours	20,300	7	51	23,300	8	8	28,000	8	9	43,200	8	11
3 hours	28,000	7	17	33,600	7	34	43,200	8	2	59,600	7	43
4 hours	46,000	6	48	46,400	6	56	56,900	7	42	86,100	7	35

increased greatly to 86,100 per cc. (or between two and three generations). Again to be noted is the fact that the morning's milk cooled at once, although held four hours at 60° F. before cooling to 40° F.,

TABLE 19. AVERAGE (GEOMETRIC MEAN) BACTERIAL COUNTS AND AVERAGE REDUCTION TIMES OF MILKS INITIALLY COOLED TO 60° F. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

NIGHT'S MILK

Cooling delayed	A—Cooling to 60° F. delayed as indicated			B—Held at 60° F. for 17, 16, 15, 14 and 13 hours—then cooled to 40° F.			C—Held 22 hours at 40° F.		D—Held 46 hours at 40° F.			
	Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time	
		Hrs.	Min.		Hrs.	Min.		Hrs.	Min.		Hrs.	Min.
0 hours	13,100	9	28	29,900	6	58	51,900	7	23	92,500	7	22
1 hour	14,400	8	39	54,500	6	18	84,400	6	51	131,000	6	55
2 hours	20,300	7	51	82,400	5	49	137,000	6	15	227,000	6	9
3 hours	28,000	7	17	131,000	5	24	222,000	5	41	394,000	5	31
4 hours	46,400	6	48	189,000	4	59	328,000	5	5	569,000	5	19

showed a lower bacterial count than the milk whose cooling was delayed four hours and held 0 hours at 60° F. before further cooling to 40° F.

The average bacterial counts of night's milk will be found in table 19. The figures are significant. Identical milks were used but while the quick cooled fresh milk, held 17 hours at 60° F. (equivalent

to holding over night on the farm), then cooled to and held at 40° F. for 46 hours, increased to 92,500 per cc., the milk whose cooling had been delayed four hours, held 13 hours at 60° F. then cooled to and held at 40° F. for 46 hours, exhibited a bacterial count of 569,000 per cc. Furthermore night's milk cooled at once to 60° F., although

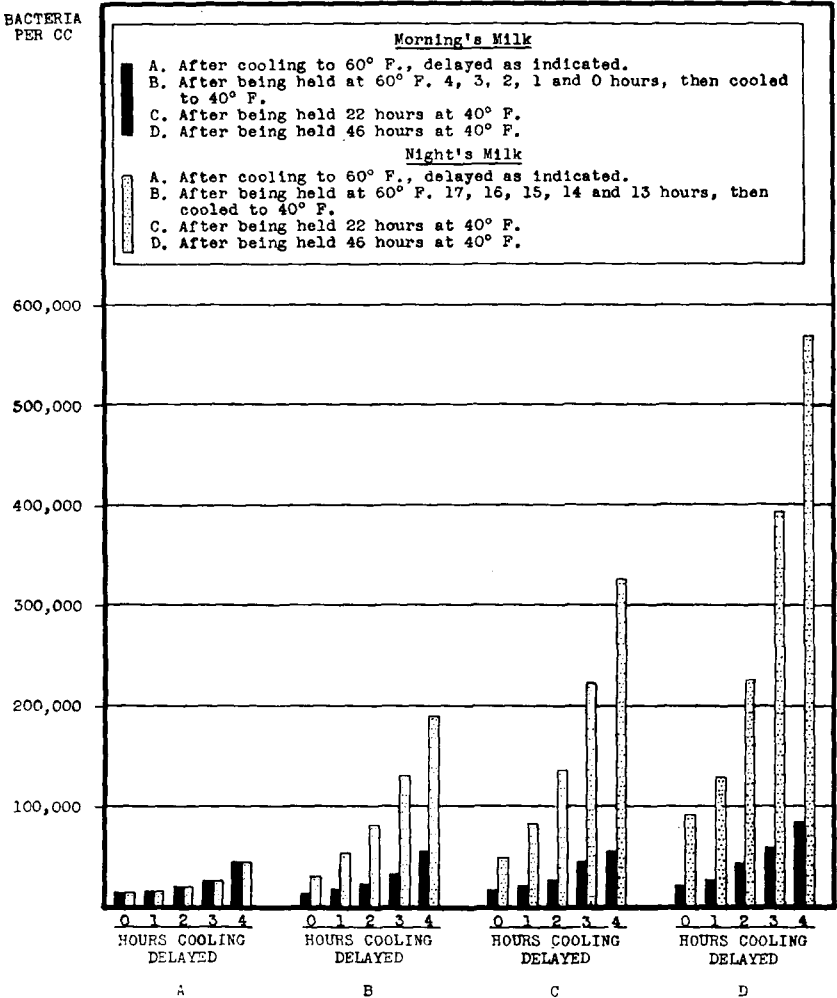


CHART 5. Study 1—Trial 2. Average bacterial counts

held 17 hours before cooling to 40° F., showed a lower bacterial count than did the sample whose cooling was delayed four hours and held 13 hours before cooling further to 40° F.

The same figures are compared graphically in chart 5. In tables 20 and 21 the same figures are re-grouped according to holding con-

ditions (time and temperature) and the minimum and maximum counts are shown. A rather wide range of counts was used.

Tables 22 and 23 show percentage increases in bacterial counts over those in fresh milk cooled at once. In morning's milk cooled at

TABLE 20. AVERAGE (GEOMETRIC MEAN), MINIMUM AND MAXIMUM BACTERIAL COUNTS; AVERAGE, MAXIMUM AND MINIMUM REDUCTION TIMES OF MILKS WHOSE FIRST COOLING TO 60° F. WAS DELAYED AS INDICATED. GROUPED ACCORDING TO HOLDING CONDITIONS (TIME AND TEMPERATURE)

MORNING'S MILK

Holding conditions (time and temp.)	Bacterial counts			Reduction times					
	Average (Geo. mean)	Minimum	Maximum	Average		Maximum		Minimum	
				Hrs.	Min.	Hrs.	Min.	Hrs.	Min.
Cooling delayed 0 hours									
A	13,100	1,450	99,500	9	28	21	15	6	15
B	13,400	2,200	95,800	9	15	19	30	6	15
C	16,500	1,250	160,000	9	13	14	52	6	..
D	20,700	2,100	380,000	8	38	15	7	4	45
Cooling delayed 1 hour									
A	14,400	1,900	102,000	8	39	20	15	5	30
B	17,700	2,000	104,000	8	41	16	..	5	..
C	21,700	1,800	274,000	8	58	15	15	4	15
D	26,700	2,500	600,000	9	1	15	..	3	..
Cooling delayed 2 hours									
A	20,300	2,400	148,000	7	51	13	7	4	..
B	23,300	2,900	179,000	8	8	15	7	4	15
C	28,000	3,400	548,000	8	9	13	50	3	..
D	43,200	3,600	2,340,000	8	11	11	45	1	30
Cooling delayed 3 hours									
A	28,000	2,900	358,000	7	17	11	7	3	..
B	33,600	3,500	284,000	7	34	15	15	3	..
C	43,200	3,500	754,000	8	2	15	30	2	30
D	59,600	4,800	2,740,000	7	43	12	45	1	15
Cooling delayed 4 hours									
A	46,400	5,800	416,000	6	48	11	..	2	30
B	46,400	5,800	416,000	6	56	11	..	2	30
C	56,900	4,400	1,380,000	7	42	15	7	1	45
D	86,100	4,600	3,880,000	7	35	12	37	1	15

HOLDING CONDITIONS

A—Cooling to 60° F. delayed as indicated.

B—Held at 60° F. for 4, 3, 2 1 and 0 hours—then cooled to 40° F.

C—Held 22 hours at 40° F.

D—Held 46 hours at 40° F.

once the increase after 46 hours is only 58 percent, whereas the milk whose cooling was delayed four hours shows a bacterial increase of 557 percent (or nearly three generations) after being held the 46 hours at 40° F. In night's milk the quick cooled sample has increased in 46

hours at 40° F., 606 percent (or nearly three generations), while when cooling was delayed four hours and the milk was held under the same conditions the count increased 4,243 percent (or between five and six generations). The ratio of increment is about the same in night's and

TABLE 21. AVERAGE (GEOMETRIC MEAN), MINIMUM AND MAXIMUM BACTERIAL COUNTS; AVERAGE, MAXIMUM AND MINIMUM REDUCTION TIMES OF MILKS WHOSE FIRST COOLING TO 60° F. WAS DELAYED AS INDICATED. GROUPED ACCORDING TO HOLDING CONDITIONS (TIME AND TEMPERATURE)

NIGHT'S MILK									
Holding conditions (time and temp.)	Bacterial counts			Reduction times					
	Average (Geo. mean)	Minimum	Maximum	Average		Maximum		Minimum	
				Hrs.	Min.	Hrs.	Min.	Hrs.	Min.
Cooling delayed 0 hours									
A	13,100	1,450	99,500	9	28	21	15	6	15
B	29,900	2,550	620,000	6	58	10	37	2	45
C	51,900	2,300	3,850,000	7	23	11	15	2	..
D	92,500	5,650	4,600,000	7	22	13	30	1	15
Cooling delayed 1 hour									
A	14,400	1,900	102,000	8	39	20	15	5	30
B	54,500	5,500	1,430,000	6	18	10	..	2	..
C	84,400	5,200	3,450,000	6	51	11	..	1	30
D	131,000	7,300	7,300,000	6	55	11	15	1	..
Cooling delayed 2 hours									
A	20,300	2,400	148,000	7	51	13	7	4	..
B	82,400	11,100	2,040,000	5	49	9	30	1	45
C	137,000	6,600	5,300,000	6	15	10	15	1	..
D	227,000	13,500	7,850,000	6	9	12	30	1	..
Cooling delayed 3 hours									
A	28,000	2,900	299,000	7	17	11	7	3	..
B	131,000	13,800	3,050,000	5	24	10	..	1	30
C	222,000	15,800	4,800,000	5	41	9	45	1	15
D	394,000	25,300	10,500,000	5	31	12	45
Cooling delayed 4 hours									
A	46,400	5,800	416,000	6	48	11	..	2	30
B	189,000	26,200	3,800,000	4	59	9	..	1	15
C	328,000	23,000	10,700,000	5	5	9	30	1	15
D	569,000	38,500	27,600,000	5	19	10	15	..	45

HOLDING CONDITIONS

A—Cooling to 60° F. delayed as indicated.

B—Held at 60° F. for 17, 16, 15, 14 and 13 hours—then cooled to 40° F.

C—Held 22 hours at 40° F.

D—Held 46 hours at 40° F.

morning's milk but percentage gains and generation times are significantly different. This change in the night's milk seems almost entirely due to prolonged holding at the rather dangerous temperature of 60° F., which produced gross gains in bacterial population.

TABLE 22. PERCENTAGE INCREASES IN AVERAGE BACTERIAL COUNTS AND PERCENTAGE INCREASES OR DECREASES IN AVERAGE REDUCTION TIMES OVER THOSE IN FRESH MILKS COOLED AT ONCE TO 60° F. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

MORNING'S MILK

Cooling delayed	A—Cooling to 60° F. delayed as indicated		B—Held at 60° F. for 4, 3, 2, 1 and 0 hours—then cooled to 40° F.		C—Held 22 hours at 40° F.		D—Held 46 hours at 40° F.	
	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time
0 hours	0	0	+ 2.3	— 2.3	+ 26.	— 2.6	+ 58.	+ 1.8
1 hour	+ 9.9	— 8.6	+ 35.1	— 8.3	+ 65.6	— 5.3	+103.8	— 4.8
2 hours	+ 55.	—17.1	+ 77.9	—14.1	+113.7	—13.9	+229.8	—13.6
3 hours	+113.7	—23.1	+156.5	—20.1	+229.8	—15.1	+355.	—18.5
4 hours	+254.2	—28.2	+254.2	—26.8	+334.4	—18.7	+557.2	—19.9

TABLE 23. PERCENTAGE INCREASES IN AVERAGE BACTERIAL COUNTS AND PERCENTAGE DECREASES IN AVERAGE REDUCTION TIMES OVER THOSE IN FRESH MILKS COOLED AT ONCE TO 60° F. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

NIGHT'S MILK

Cooling delayed	A—Cooling to 60° F. delayed as indicated		B—Held at 60° F. for 17, 16, 15, 14 and 13 hours—then cooled to 40° F.		C—Held 22 hours at 40° F.		D—Held 46 hours at 40° F.	
	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time
0 hours	0	0	+ 128.2	—26.4	+ 296.2	—22.	+ 606.1	—22.2
1 hour	+ 9.9	— 8.6	+ 316.	—33.4	+ 544.3	—27.6	+ 900.	—26.9
2 hours	+ 55.	—17.1	+ 529.	—38.6	+ 945.8	—34.	+1,632.8	—35.
3 hours	+113.7	—23.1	+ 900.	—43.	+1,594.6	—40.	+2,907.6	—41.7
4 hours	+254.2	—28.2	+1,342.7	—47.4	+2,403.8	—46.3	+4,243.5	—43.8

TABLE 24. PERCENTAGE INCREASES IN AVERAGE BACTERIAL COUNTS AND PERCENTAGE DECREASES IN AVERAGE REDUCTION TIMES IN MILKS HELD 1 TO 4 HOURS BEFORE COOLING TO 60° F., OVER THOSE IN SAMPLES COOLED AT ONCE. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

MORNING'S MILK

Cooling delayed	A—Cooling to 60° F. delayed as indicated		B—Held at 60° F. for 4, 3, 2, 1 and 0 hours—then cooled to 40° F.		C—Held 22 hours at 40° F.		D—Held 46 hours at 40° F.	
	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time
0 hours	0	0	0	0	0	0	0	0
1 hour	+ 9.9	— 8.6	+ 32.1	— 6.1	+ 31.5	— 2.7	+ 29.	— 6.4
2 hours	+ 55.	—17.1	+ 73.9	—12.1	+ 69.7	—11.6	+108.7	—15.
3 hours	+113.7	—23.1	+150.7	—18.2	+161.8	—12.8	+187.9	—19.9
4 hours	+254.2	—28.2	+246.3	—25.	+244.8	—16.4	+315.9	—21.3

TABLE 25. PERCENTAGE INCREASES IN AVERAGE BACTERIAL COUNTS AND PERCENTAGE DECREASES IN AVERAGE REDUCTION TIMES IN MILKS HELD 1 TO 4 HOURS BEFORE COOLING TO 60° F., OVER THOSE IN SAMPLES COOLED AT ONCE. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

NIGHT'S MILK

Cooling delayed	A—Cooling to 60° F. delayed as indicated		B—Held at 60° F. for 17, 16, 15, 14 and 13 hours—then cooled to 40° F.		C—Held 22 hours at 40° F.		D—Held 46 hours at 40° F.	
	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time
0 hours	0	0	0	0	0	0	0	0
1 hour	+ 9.9	- 8.6	+ 82.3	- 9.6	+ 62.6	- 7.2	+ 41.6	- 6.1
2 hours	+ 55.	-17.1	+175.6	-16.5	+164.	-15.3	+145.4	-16.5
3 hours	+113.7	-23.1	+338.1	-22.5	+327.7	-23.	+325.9	-25.1
4 hours	+254.2	-28.2	+532.1	-28.5	+532.	-31.2	+515.9	-27.8

TABLE 26. AVERAGE (GEOMETRIC MEAN) BACTERIAL COUNTS AND AVERAGE REDUCTION TIMES OF MILKS WHOSE INITIAL COUNTS WERE 10,000 PER CC. OR UNDER AND WHICH WERE INITIALLY COOLED TO 60° F. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

MORNING'S MILK

Cooling delayed	A—Cooling to 60° F. delayed as indicated			B—Held at 60° F. for 4, 3, 2, 1 and 0 hours—then cooled to 40° F.			C—Held 22 hours at 40° F.			D—Held 46 hours at 40° F.		
	Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time	
		Hrs.	Min.		Hrs.	Min.		Hrs.	Min.		Hrs.	Min.
0 hours	4,000	12	57	5,100	11	57	4,800	11	45	6,000	13	3
1 hour	4,900	11	51	6,700	11	4	6,000	11	52	7,400	12	25
2 hours	7,500	10	36	8,800	10	25	9,000	10	47	11,000	11	9
3 hours	9,700	9	40	12,000	10	44	12,000	10	54	15,000	10	36
4 hours	18,000	8	31	18,000	8	55	17,000	10	22	20,000	10	19

TABLE 27. AVERAGE (GEOMETRIC MEAN) BACTERIAL COUNTS AND AVERAGE REDUCTION TIMES OF MILKS WHOSE INITIAL COUNTS WERE 10,000 PER CC. OR UNDER AND WHICH WERE INITIALLY COOLED TO 60° F. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

NIGHT'S MILK

Cooling delayed	A—Cooling to 60° F. delayed as indicated			B—Held at 60° F. for 17, 16, 15, 14 and 13 hours—then cooled to 40° F.			C—Held 22 hours at 40° F.			D—Held 46 hours at 40° F.		
	Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time	
		Hrs.	Min.		Hrs.	Min.		Hrs.	Min.		Hrs.	Min.
0 hours	4,000	12	57	6,400	8	49	6,900	9	49	10,400	10	45
1 hour	4,900	11	51	10,900	8	21	10,900	9	24	14,300	10	22
2 hours	7,500	10	36	19,800	8	13	18,000	8	43	26,700	9	9
3 hours	9,700	9	40	33,600	7	33	35,200	8	24	53,300	8	42
4 hours	18,000	8	31	47,300	6	51	43,200	7	21	68,500	8	16

Tables 24 and 25 show percentage increases in bacterial counts over what they would have been had the milks been cooled at once, making it more clear that the real harm was due to a combination of delayed cooling and holding for prolonged periods at 60° F. It will be

TABLE 28. AVERAGE (GEOMETRIC MEAN), MINIMUM AND MAXIMUM BACTERIAL COUNTS; AVERAGE, MAXIMUM AND MINIMUM REDUCTION TIMES OF MILKS WHOSE FIRST COOLING TO 60° F. WAS DELAYED AS INDICATED AND WHOSE INITIAL COUNTS WERE 10,000 PER CC. OR LESS. GROUPED ACCORDING TO HOLDING CONDITIONS (TIME AND TEMPERATURE)

MORNING'S MILK

Holding conditions (time and temp.)	Bacterial counts			Reduction times					
	Average (Geo. mean)	Minimum	Maximum	Average		Maximum		Minimum	
				Hrs.	Min.	Hrs.	Min.	Hrs.	Min.
Cooling delayed 0 hours									
A	4,000	1,450	7,100	12	57	21	15	8	45
B	5,100	2,200	7,400	11	57	19	30	8	30
C	4,800	1,250	10,800	11	45	14	52	9	30
D	6,000	2,100	11,700	13	3	15	7	12	..
Cooling delayed 1 hour									
A	4,900	1,900	10,200	11	51	20	15	8	30
B	6,700	2,000	10,400	11	4	16	..	8	15
C	6,000	1,800	13,200	11	52	15	15	9	45
D	7,400	2,500	25,500	12	25	15	..	10	45
Cooling delayed 2 hours									
A	7,500	2,400	14,400	10	36	13	7	8	15
B	8,800	2,900	16,800	10	25	15	7	8	45
C	9,000	3,400	17,500	10	47	13	50	8	45
D	11,000	3,600	25,000	11	9	11	45	10	30
Cooling delayed 3 hours									
A	9,700	2,900	16,700	9	40	11	7	8	15
B	12,000	3,500	24,600	10	44	15	15	8	..
C	12,000	3,500	24,500	10	54	15	30	9	..
D	15,000	4,800	31,000	10	36	12	45	9	..
Cooling delayed 4 hours									
A	18,000	5,800	39,800	8	31	9	7	8	..
B	18,000	5,800	39,800	8	55	10	15	7	45
C	17,000	4,400	42,000	10	22	15	7	8	30
D	20,000	4,600	44,000	10	19	12	37	8	45

HOLDING CONDITIONS

A—Cooling to 60° F. delayed as indicated.

B—Held at 60° F. for 4, 3, 2, 1 and 0 hours—then cooled to 40° F.

C—Held 22 hours at 40° F.

D—Held 46 hours at 40° F.

further noted that in morning's milk the observable damage was caused by delayed cooling and that was not due to comparatively short holding period at 60° F., whereas in the night's milk the excess counts may be attributed to the longer holding period at 60° F.

AVERAGE BACTERIAL COUNTS OF MILKS WHOSE INITIAL COUNTS WERE
10,000 PER CC. OR LESS

Tables 26 to 33 inclusive show that the same trends are evidenced as were found in the case of the total counts. In fact the differences in

TABLE 29. AVERAGE (GEOMETRIC MEAN), MINIMUM AND MAXIMUM BACTERIAL COUNTS; AVERAGE, MAXIMUM AND MINIMUM REDUCTION TIMES OF MILKS WHOSE FIRST COOLING TO 60° F. WAS DELAYED AS INDICATED AND WHOSE INITIAL COUNTS WERE 10,000 PER CC. OR LESS. GROUPED ACCORDING TO HOLDING CONDITIONS (TIME AND TEMPERATURE)

NIGHT'S MILK

Holding conditions (time and temp.)	Bacterial counts			Reduction times					
	Average (Geo. mean)	Minimum	Maximum	Average		Maximum		Minimum	
				Hrs.	Min.	Hrs.	Min.	Hrs.	Min.
Cooling delayed 0 hours									
A	4,000	1,450	7,100	12	57	21	15	8	45
B	6,400	2,550	11,800	8	49	9	..	8	15
C	6,900	2,300	20,000	9	49	11	15	8	15
D	10,400	6,300	30,000	10	45	13	30	7	30
Cooling delayed 1 hour									
A	4,900	1,900	10,200	11	51	20	15	8	30
B	10,900	5,500	24,700	8	21	9	30	7	45
C	10,900	5,200	31,500	9	24	11	..	7	45
D	14,300	7,300	52,000	10	22	13	..	6	45
Cooling delayed 2 hours									
A	7,500	2,400	12,200	10	36	13	7	8	15
B	19,800	11,100	44,000	8	13	9	15	7	..
C	18,000	6,600	47,000	8	43	10	15	7	30
D	26,700	13,500	93,000	9	9	12	30	6	45
Cooling delayed 3 hours									
A	9,700	2,900	16,700	9	40	11	7	8	15
B	33,600	13,800	61,000	7	33	8	30	6	..
C	35,200	15,800	67,000	8	24	9	45	7	15
D	53,300	25,300	215,000	8	42	12	..	5	45
Cooling delayed 4 hours									
A	18,000	5,800	39,800	8	31	9	7	8	..
B	47,300	26,200	90,500	6	50	8	15	5	30
C	42,300	23,000	85,000	7	21	9	30	4	30
D	68,500	38,000	260,000	8	16	10	15	6	..

HOLDING CONDITIONS

A—Cooling to 60° F. delayed as indicated.

B—Held at 60° F. for 17, 16, 15 14, and 13 hours—then cooled to 40° F.

C—Held 22 hours at 40° F.

D—Held 46 hours at 40° F.

favor of low counts that were noted in the milks initially cooled to 50° F. are much less pronounced in this trial. The varying holding times at 60° F. seem quickly to stimulate bacterial activity and to

TABLE 30. PERCENTAGE INCREASES IN AVERAGE BACTERIAL COUNTS AND PERCENTAGE DECREASES OR INCREASES IN AVERAGE REDUCTION TIMES OVER THOSE IN FRESH MILKS COOLED AT ONCE TO 60° F., IN MILKS WHOSE INITIAL BACTERIAL COUNTS WERE 10,000 PER CC. OR LESS. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

MORNING'S MILK

Cooling delayed	A—Cooling to 60° F. delayed as indicated		B—Held at 60° F. for 4, 3, 2, 1 and 0 hours—then cooled to 40° F.		C—Held 22 hours at 40° F.		D—Held 46 hours at 40° F.	
	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time
0 hours	0	0	+ 27.5	- 7.7	+ 20.	- 9.3	+ 50.	+ 0.8
1 hour	+ 22.5	- 8.5	+ 67.5	-14.5	+ 50.	- 8.4	+ 85.	- 4.1
2 hours	+ 87.5	-18.1	+120.	-19.6	+125.	-16.7	+175.	-13.9
3 hours	+142.5	-25.4	+200.	-17.1	+200.	-15.8	+275.	-18.1
4 hours	+350.	-34.2	+350.	-31.1	+325.	-19.9	+400.	-20.3

TABLE 31. PERCENTAGE INCREASES IN AVERAGE BACTERIAL COUNTS AND PERCENTAGE DECREASES IN AVERAGE REDUCTION TIMES OVER THOSE IN FRESH MILKS COOLED AT ONCE TO 60° F., IN MILKS WHOSE INITIAL BACTERIAL COUNTS WERE 10,000 PER CC. OR LESS. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

NIGHT'S MILK

Cooling delayed	A—Cooling to 60° F. delayed as indicated		B—Held at 60° F. for 17, 16, 15, 14 and 13 hours then cooled to 40° F.		C—Held 22 hours at 40° F.		D—Held 46 hours at 40° F.	
	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time
0 hours	0	0	+ 60.	-31.9	+ 72.5	-24.2	+ 160.	-17.
1 hour	+ 22.5	- 8.5	+ 172.5	-35.5	+172.5	-27.5	+ 257.5	-19.9
2 hours	+ 87.5	-18.1	+ 395.	-36.5	+350.	-31.4	+ 567.5	-29.3
3 hours	+142.5	-25.4	+ 740.	-41.7	+780.	-35.1	+1,232.5	-32.8
4 hours	+350.	-34.2	+1,082.5	-47.1	+980.	-43.2	+1,612.5	-36.2

TABLE 32. PERCENTAGE INCREASES IN AVERAGE BACTERIAL COUNTS AND PERCENTAGE INCREASES OR DECREASES IN AVERAGE REDUCTION TIMES IN MILKS HELD 1 TO 4 HOURS BEFORE COOLING TO 60° F., OVER THOSE IN FRESH SAMPLES COOLED AT ONCE IN MILKS WHOSE INITIAL BACTERIAL COUNTS WERE 10,000 PER CC. OR LESS. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

MORNING'S MILK

Cooling delayed	A—Cooling to 60° F. delayed as indicated		B—Held at 60° F. for 4, 3, 2, 1 and 0 hours—then cooled to 40° F.		C—Held 22 hours at 40° F.		D—Held 46 hours at 40° F.	
	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time
0 hours	0	0	0	0	0	0	0	0
1 hour	+ 22.5	- 8.5	+ 31.4	- 7.4	+ 25.	+ 1.	+ 23.2	- 4.8
2 hours	+ 87.5	-18.1	+ 72.5	-12.8	+ 87.5	- 8.2	+ 83.3	-14.6
3 hours	+142.5	-25.4	+135.3	-10.2	+150.	- 7.2	+150.	-18.8
4 hours	+350.	-34.2	+252.9	-25.4	+254.2	-11.8	+233.3	-20.9

TABLE 33. PERCENTAGE INCREASES IN AVERAGE BACTERIAL COUNTS AND PERCENTAGE DECREASES IN AVERAGE REDUCTION TIMES IN MILKS HELD 1 TO 4 HOURS BEFORE COOLING TO 60° F., OVER THOSE IN FRESH SAMPLES COOLED AT ONCE, IN MILKS WHOSE INITIAL BACTERIAL COUNTS WERE 10,000 PER CC. OR LESS. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

NIGHT'S MILK

Cooling delayed	A—Cooling to 60° F. delayed as indicated		B—Held at 60° F. for 17, 16, 15, 14 and 13 hours—then cooled to 40° F.		C—Held 22 hours at 40° F.		D—Held 46 hours at 40° F.	
	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time
0 hours	0	0	0	0	0	0	0	0
1 hour	+ 22.5	— 8.5	+ 70.3	— 5.3	+ 58.	— 3.4	+ 37.5	— 3.6
2 hours	+ 87.5	—18.1	+209.4	— 6.8	+160.9	—11.2	+156.7	—14.9
3 hours	+142.5	—25.4	+425.	—14.4	+410.1	—14.4	+412.5	—19.1
4 hours	+350.	—34.2	+639.1	—22.3	+526.1	—25.1	+558.6	—23.1

counteract the effect of any germicidal agency that may be present. These figures are also graphically compared in chart 6.

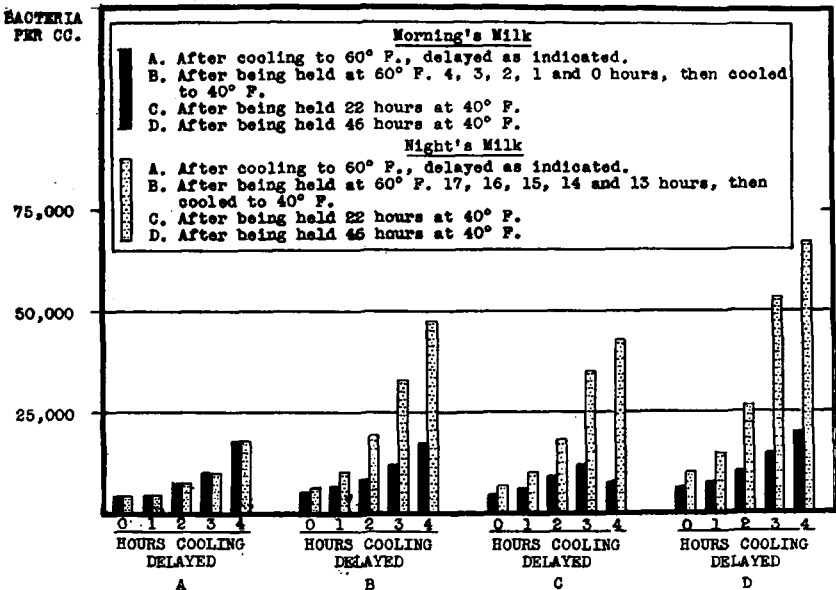


CHART 6. Study 1—Trial 2. Average bacterial counts, initially 10,000 per cc. or less

AVERAGE REDUCTION TIMES

In tables 18 and 19 will be found stated the average reduction times of both morning's and night's milks, arranged according to the length of time that cooling was delayed. In morning's milk, even though cooled to and held at 60° F. for periods up to four hours before cooling to and

holding at 40° F. for 22 and 46 hours, the reduction times generally increased, although decreasing to the length of time cooling was delayed under each holding condition. In night's milk the first condition does not hold. The longer holding periods at 60° F. (13 and 17 hours) counteract the influence which the lower temperature of 40° F. sometimes exerts on the mechanism of the methylene blue test, and they

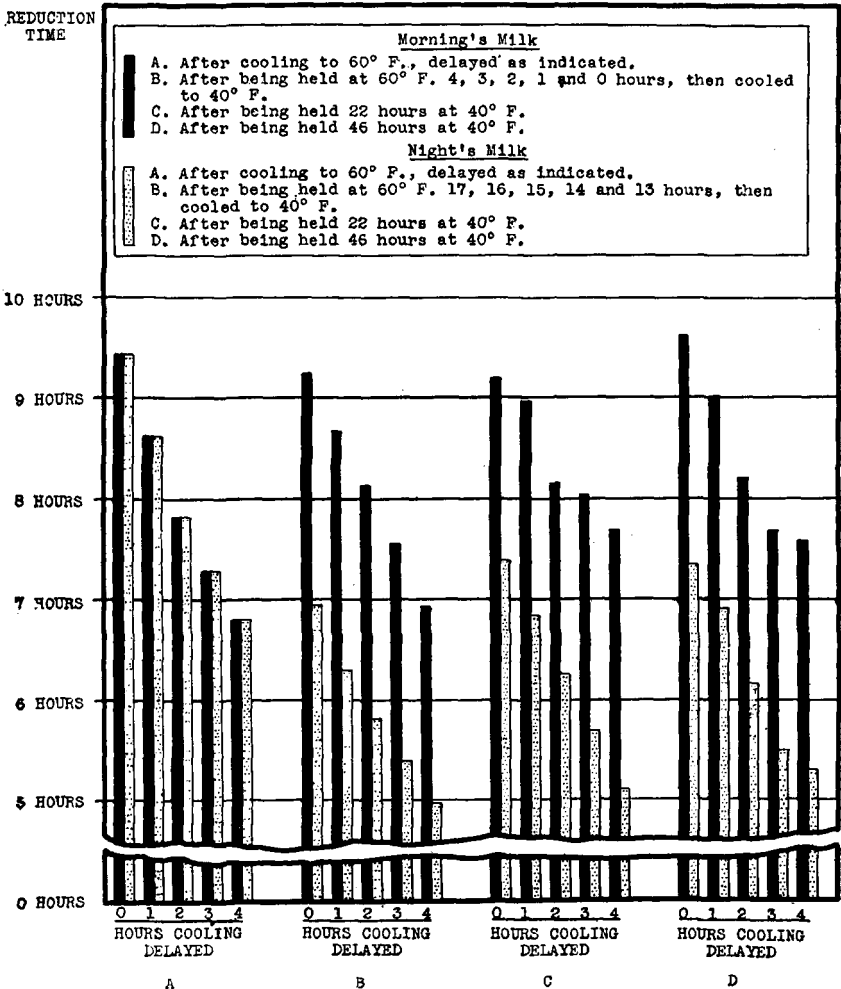


CHART 7. Study 1—Trial 1. Average reduction times

decrease as reasonably they might be expected to do as the bacterial counts increase. These figures are graphically compared in chart 7. Tables 20 and 21 contain the same figures re-grouped according to holding conditions and also contain the maximum and minimum reduction times.

Tables 22 and 23 contain the percentage increases in reduction times over those in the fresh milk cooled at once. The reduction times in quick cooled samples of morning's milk, held at 60° F. four hours, then cooled to and held at 40° F. for 46 hours, actually increased 1.8 percent because of the physical effect of the 40° F. temperature, while the four hours of delayed cooling, 0 hours at 60° F. and holding at 40° F. for 46 hours, decreased the reduction time 19.9 percent. In night's milk there is the same situation that was noted in the respect to the bacterial counts. The damage which is wrought is due to a combination of the effect of delayed cooling and the longer holding time at 60° F.

Tables 24 and 25 show percentage decreases in reduction times over what they would have been had the milks been cooled at once.

AVERAGE REDUCTION TIMES OF MILKS WHOSE INITIAL COUNTS WERE
10,000 PER CC. OR LESS

Tables 26 to 23 inclusive disclose very much the same trends as for the bacterial counts in this class. These figures are graphically compared in chart 8.

DISCUSSION OF STUDY I

Although the use of a thermometer at the weigh stand is a vital matter, obviously it can only indicate the temperature of the milk at weighing time. No clue is afforded as to how long it took to cool it to that temperature or how much time elapsed before the milk was first subjected to a low temperature. The work herein reported certainly indicates that it is just as important to know how long the milk was held before it was subjected to a low temperature as it is to know the temperature ultimately attained. For example, if milk is cooled at once to 50° F., even though it has been held as long as 17 hours before cooling to 40° F. at the receiving station, no very great damage has been done, as measured by the standard plate count or the methylene blue reduction test, whereas milk held for a shorter time at 50° F. before cooling to 40° F., but delayed in its original cooling, may be damaged. This trend is plainly evidenced in the work reported in trial 1. In trial 2, wherein the original cooling temperature was 60° F., the same trend is again unmistakably apparent.

In the course of this study and others, several series were found in which the bacterial counts decreased, not only from hour to hour of

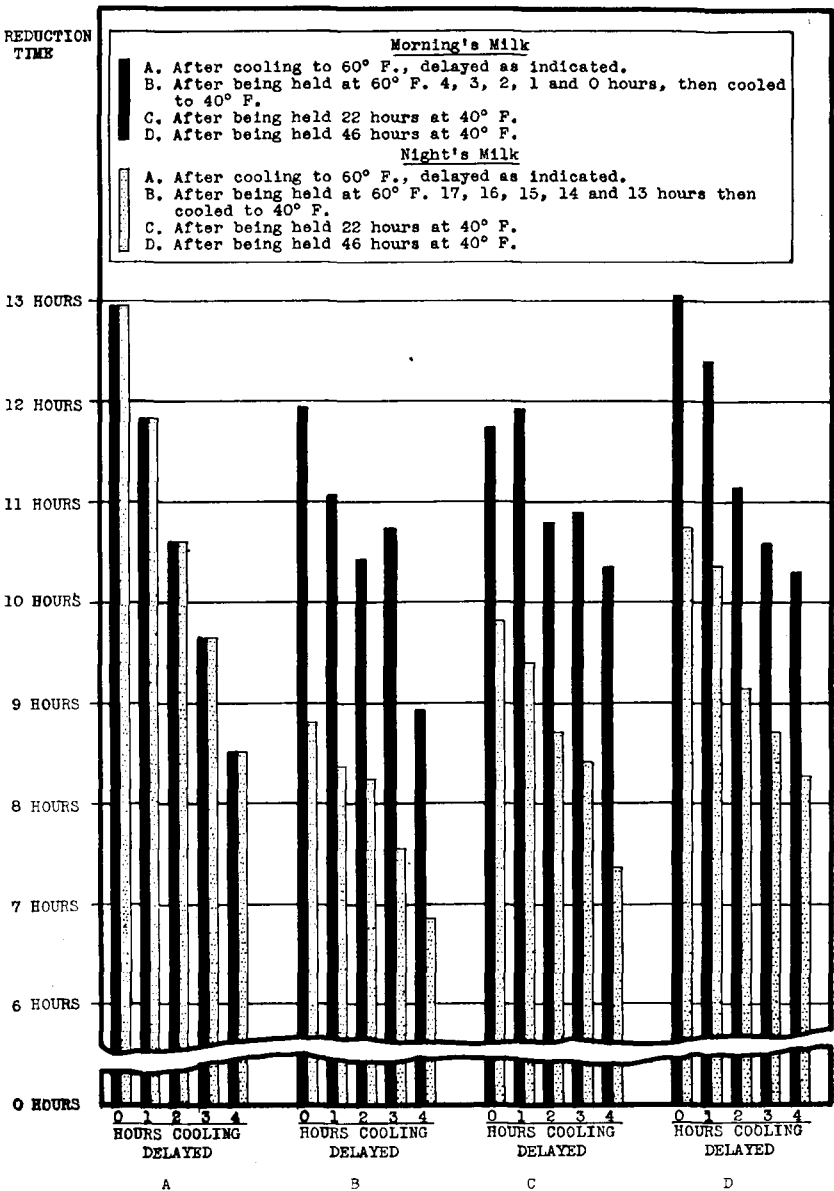


CHART 8. Study 1—Trial 1. Average reduction times on milks whose initial bacterial counts were 10,000 per cc. or less

delayed cooling but from one holding period to another. This happened more frequently with the low count than with the high count milks. However in no case did it appear that as much as four hours delayed

cooling resulted in a count lower than the initial one. The great majority of cases—as shown by the averages—were found to suffer progressively for each hour of delayed cooling.

STUDY 2

In this study three different methods of handling were used on identical milks in order to note what effect they would have on the quality of the milk, as measured by the standard plate count and the methylene blue reduction time. Twelve different lots of milk were used, some hand milked, some machine milked, some good and some not so good. A total of 180 separate plate counts and 180 separate reduction time determinations were made in duplicate.

TRIAL I

These samples were cooled, after delays of 0, 1, 2, 3 and 4 hours to 60° F.; sub-sampled for plating and reduction time determination, immediately after each of the five samples had been cooled; held at 60° F. for 8 hours and again sub-sampled; cooled to and held at 40° F. for 24 hours; and, finally, sub-sampled for making the two tests.

TABLE 34. AVERAGE (GEOMETRIC MEAN), BACTERIAL COUNTS AND AVERAGE REDUCTION TIMES OF ALL MILKS INITIALLY COOLED TO 60° F. WHICH WERE LATER COOLED TO AND HELD AT 40° F. AS INDICATED. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

Cooling delayed	A—Cooling to 60° F. delayed as indicated			B—Held at 60° F. eight hours—then cooled to 40° F.			C—held 24 hours at 40° F.		
	Average bacterial count (Geo. mean)	Average reduction time Hrs.	Min.	Average bacterial count (Geo. mean)	Average reduction time Hrs.	Min.	Average bacterial count (Geo. mean)	Average reduction time Hrs.	Min.
0 hours	18,900	10	58	21,700	10	29	24,900	10	33
1 hour	19,800	10	19	34,300	9	52	40,400	10	6
2 hours	29,900	9	39	59,600	8	44	59,600	8	6
3 hours	45,200	8	22	114,000	7	12	107,000	7	11
4 hours	90,300	7	19	180,000	6	59	207,000	6	48

AVERAGE BACTERIAL COUNTS

These counts are arranged in table 34 according to the length of time cooling was delayed. It should be noted that there is a count of 19,000 per cc. in the fresh milk cooled at once to 60° F.; the sample whose cooling was delayed four hours has a count of 90,000 per cc.; after being held eight hours at 60° F. the quickly cooled milk has increased only to about 22,000 per cc., while the sample delayed four hours has been about doubled to 180,000 per cc.; after being cooled to

and held at 40° F. for 24 hours the quick cooled milk has increased only to 25,000 per cc., while the four-hour delayed sample has increased to 207,000 per cc. In table 35 the same counts are shown, arranged according to holding conditions (time and temperature) and the minimum and maximum counts are stated, thus showing the range of counts.

TABLE 35. AVERAGE (GEOMETRIC MEAN), MINIMUM AND MAXIMUM BACTERIAL COUNTS; AVERAGE, MAXIMUM AND MINIMUM REDUCTION TIMES OF MILKS INITIALLY COOLED TO AND HELD AT 60° F.; LATER COOLED TO AND HELD AT 40° F. AS INDICATED. GROUPED ACCORDING TO HOLDING CONDITIONS (TIME AND TEMPERATURE)

Holding conditions (time and temp.)	Bacterial counts			Reduction times					
	Average (Geo. mean)	Minimum	Maximum	Average		Maximum		Minimum	
				Hrs.	Min.	Hrs.	Min.	Hrs.	Min.
Cooling delayed 0 hours									
A	18,900	2,200	261,000	10	58	23	37	3	..
B	21,700	2,000	1,540,000	10	29	26	..	3	15
C	24,900	2,200	2,900,000	10	33	25	..	2	45
Cooling delayed 1 hour									
A	19,800	1,600	380,000	10	19	24	7	2	15
B	34,300	2,500	3,350,000	9	52	26	..	1	45
C	40,400	2,700	5,680,000	10	6	25	..	1	30
Cooling delayed 2 hours									
A	29,900	3,500	640,000	9	39	23	45	1	45
B	59,600	4,900	4,000,000	8	44	23	22	1	15
C	59,600	6,000	5,840,000	8	6	19	30	1	15
Cooling delayed 3 hours									
A	45,200	5,600	866,000	8	22	22	45	1	30
B	114,000	7,700	14,300,000	7	12	18	22	1	..
C	107,000	6,000	16,800,000	7	11	19	30	1	..
Cooling delayed 4 hours									
A	90,300	6,100	7,500,000	7	19	19	22	..	45
B	180,000	14,100	23,100,000	6	59	20	..	1	7
C	207,000	13,300	20,800,000	6	48	19	37	..	45

HOLDING CONDITIONS

A—Cooling to 60° F. delayed as indicated.

B—Held at 60° F. 8 hours—then cooled to 40° F.

C—Held 24 hours at 40° F.

Table 36 shows the percentage increases in bacterial counts over those in fresh milk cooled at once. It is interesting to note that the quickly cooled sample has increased only 15 percent after eight hours at 60° F., and after being held 24 hours at 40° F., only 32 percent, while the sample whose cooling was delayed four hours increased 378 percent in fresh milk, 852 percent after being held eight hours at 60° F. and

TABLE 36. PERCENTAGE INCREASES IN AVERAGE BACTERIAL COUNTS AND PERCENTAGE DECREASES IN AVERAGE REDUCTION TIMES OVER THOSE IN FRESH MILK COOLED AT ONCE. SAMPLES INITIALLY COOLED TO 60° F.; LATER COOLED TO AND HELD AT 40° F. AS INDICATED. GROUPED ACCORDING TO LENGTH OF TIME COOLING WAS DELAYED

Cooling delayed	A—Cooling to 60° F. delayed as indicated		B—Held at 60° F. 8 hours—then cooled to 40° F.		C—Held 24 hours at 40° F.	
	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time
0 hours	0	0	+ 14.8	— 4.4	+ 31.7	— 3.8
1 hour	+ 4.8	— 5.9	+ 81.5	—10.	+113.8	— 7.9
2 hours	+ 58.2	—12.	+215.3	—20.4	+215.3	—26.
3 hours	+139.2	—23.7	+503.2	—34.3	+466.1	—34.5
4 hours	+377.8	—33.3	+852.4	—36.3	+995.2	—38.

995 percent after being cooled to and held at 40° F. for 24 hours. It is reasonable to suppose that the damage, above that caused by delayed cooling, should be charged to the comparatively short holding time at 60° F.

In table 37 are set forth the percentage increases in bacterial counts over what they would have been had the samples been cooled at once.

TABLE 37. PERCENTAGE INCREASES IN BACTERIAL COUNTS AND PERCENTAGE DECREASES IN REDUCTION TIMES OVER THOSE IN SAMPLES COOLED AT ONCE. SAMPLES INITIALLY COOLED TO 60° F., LATER COOLED TO AND HELD AT 40° F. AS INDICATED. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

Cooling delayed	A—Cooling to 60° F. delayed as indicated		B—Held at 60° F. 8 hours—then cooled to 40° F.		C—Held 24 hours at 40° F.	
	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time
0 hours	0	0	0	0	0	0
1 hour	+ 4.8	— 5.9	+ 58.1	— 5.9	+ 62.2	— 4.3
2 hours	+ 58.2	—12.	+174.6	—16.7	+139.4	—23.1
3 hours	+139.2	—23.7	+425.3	—31.3	+329.7	—31.9
4 hours	+377.8	—33.3	+729.5	—33.4	+731.3	—35.5

TABLE 38. AVERAGE (GEOMETRIC MEAN) BACTERIAL COUNTS AND AVERAGE REDUCTION TIMES OF MILKS WHOSE INITIAL COUNTS WERE 10,000 PER CC. OR LESS, WHICH WERE INITIALLY COOLED TO 60° F. AND LATER COOLED TO 40° F. AS INDICATED. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

Cooling delayed	A—Cooling to 60° F. delayed as indicated			B—Held at 60° F. eight hours—then cooled to 40° F.			C—held 24 hours at 40° F.		
	Average bacterial count	Average reduction time		Average bacterial count	Average reduction time		Average bacterial count	Average reduction time	
	(Geo. mean)	Hrs.	Min.	(Geo. mean)	Hrs.	Min.	(Geo. mean)	Hrs.	Min.
0 hours	4,700	15	14	4,000	15	20	3,800	15	10
1 hour	4,500	14	41	6,400	15	6	6,200	14	52
2 hours	7,500	14	..	12,800	13	17	9,500	12	12
3 hours	12,800	12	22	21,000	10	41	14,000	10	44
4 hours	20,300	10	52	35,000	10	40	33,000	10	16

TABLE 39. AVERAGE (GEOMETRIC MEAN) MINIMUM AND MAXIMUM BACTERIAL COUNTS; AVERAGE, MAXIMUM AND MINIMUM REDUCTION TIMES OF MILKS INITIALLY COOLED TO 60° F., LATER COOLED TO AND HELD AT 40° F. AS INDICATED, IN THOSE SAMPLES WHOSE INITIAL BACTERIAL COUNTS WERE 10,000 PER CC. OR LESS. GROUPED ACCORDING TO HOLDING CONDITIONS (TIME AND TEMPERATURE)

Holding conditions (time and temp.)	Bacterial counts			Reduction times					
	Average (Geo. mean)	Minimum	Maximum	Average		Maximum		Minimum	
				Hrs.	Min.	Hrs.	Min.	Hrs.	Min.
Cooling delayed 0 hours									
A	4,700	2,200	9,700	15	14	23	37	9	30
B	4,000	2,000	8,400	15	20	26	..	8	30
C	3,800	2,200	7,700	15	10	25	..	9	30
Cooling delayed 1 hour									
A	4,500	1,600	11,400	14	41	24	7	10	7
B	6,400	2,500	14,300	15	6	26	..	8	30
C	6,200	2,700	15,700	14	52	25	..	8	30
Cooling delayed 2 hours									
A	7,500	3,500	15,200	14	..	23	45	9	..
B	12,800	4,900	24,100	13	17	23	22	8	..
C	9,500	6,000	14,900	12	12	19	30	7	30
Cooling delayed 3 hours									
A	12,800	5,600	39,200	12	22	22	45	7	45
B	21,000	9,100	67,000	10	41	18	22	7	..
C	14,000	6,000	33,300	10	44	19	30	6	15
Cooling delayed 4 hours									
A	20,300	6,100	55,000	10	52	19	22	7	15
B	35,000	14,100	75,600	10	40	20	..	6	30
C	33,000	13,300	70,000	10	16	19	37	6	..

HOLDING CONDITIONS

- A—Cooling to 60° F. delayed as indicated.
 B—Held to 60° F. eight hours—then cooled to 40° F.
 C—Held 24 hours at 40° F.

TABLE 40. PERCENTAGE INCREASES OR DECREASES IN AVERAGE BACTERIAL COUNTS AND PERCENTAGE DECREASES OR INCREASES IN AVERAGE REDUCTION TIMES OVER THOSE IN FRESH MILKS COOLED AT ONCE, IN THOSE SAMPLES WHOSE INITIAL BACTERIAL COUNTS WERE 10,000 PER CC. OR LESS. SAMPLES INITIALLY COOLED TO AND HELD AT 60° F., LATER COOLED TO AND HELD AT 40° F. AS INDICATED. GROUPED ACCORDING TO LENGTH OF TIME COOLING WAS DELAYED

Cooling delayed	A—Cooling to 60° F. delayed as indicated		B—Held at 60° F. 8 hours—then cooled to 40° F.		C—Held 24 hours at 40° F.	
	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time
0 hours	0	0	— 14.9	+ 0.6	— 19.1	— 0.4
1 hour	— 4.3	— 3.6	+ 36.2	— 0.9	+ 31.9	— 2.4
2 hours	+ 59.6	— 8.1	+172.3	—12.8	+102.1	—19.9
3 hours	+172.3	—18.8	+346.8	—29.9	+197.9	—29.5
4 hours	+331.9	—28.7	+644.7	—29.9	+602.1	—32.6

These figures naturally discount to some extent the effects of holding and throw into relief the effects of delayed cooling.

AVERAGE BACTERIAL COUNTS INITIALLY 10,000 PER CC. OR LESS

Here again, as in table 38, the advantages are slightly in favor of the low count milk, especially in milks cooled at once and, also, an actual decrease occurred after 24 hours holding at 40° F. Table 39 shows the same figures re-grouped according to holding conditions (time and

TABLE 41. PERCENTAGE INCREASES OR DECREASES IN AVERAGE BACTERIAL COUNTS AND PERCENTAGE DECREASES IN AVERAGE REDUCTION TIMES OVER THOSE IN SAMPLES COOLED AT ONCE, IN THOSE SAMPLES WHOSE INITIAL BACTERIAL COUNTS WERE 10,000 PER CC. OR LESS. SAMPLES INITIALLY COOLED TO 60° F., LATER COOLED TO AND HELD AT 40° F. AS INDICATED. GROUPED ACCORDING TO LENGTH OF TIME COOLING WAS DELAYED

Cooling delayed	A—Cooling to 60° F. delayed as indicated		B—Held at 60° F. 8 hours —then cooled to 40° F.		C—Held 24 hours at 40° F.	
	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time
0 hours	0	0	0	0	0	0
1 hour	— 4.3	— 3.6	+ 60.	— 1.5	+ 63.2	— 2.
2 hours	+ 59.6	— 8.1	+220.	—13.4	+150.	—20.
3 hours	+172.3	—18.8	+425.	—30.3	+268.4	—29.2
4 hours	+331.9	—28.7	+775.	—30.4	+768.4	—32.3

temperature) and also shows the minimum and maximum bacterial counts.

Table 40 sets forth the percentage increases or decreases in bacterial counts over those in the fresh milks cooled at once. The point is that the quick cooled milk held 8 hours at 60° F., then cooled to and held at 40° F. for 24 hours, shows an actual decrease of 19 percent, whereas the samples whose cooling was delayed 4 hours, held 8 hours at 60° F., then cooled to and held at 40° F. for 24 hours, have increased 602 percent in bacterial content. The same trends prevail as for the total averages.

Table 41 shows percentage increases in bacterial counts over what they would have been had the samples been cooled at once. This reveals the increment chargeable to delayed cooling. The same trends are noted as in the total averages.

AVERAGE REDUCTION TIMES

The average reduction times grouped according to the length of time cooling was delayed appear in table 34. It is noticeable that de-

layed cooling is responsible for most of the damage done. It again seems doubtful whether the picture of what has happened or is likely to happen as a result of holding at a low temperature is entirely accurate. For example, the reduction time in fresh milk, whose cooling was delayed four hours, had not lessened as far as reduction time was concerned, after holding for eight hours at 60° F. and holding to and holding at 40° F. for 24 hours, any more than in the case of the fresh milk cooled at once and handled in the same way, whereas the bacterial count on the samples held four hours before cooling increased from 90,000 per cc. 207,000 per cc. and the quickly cooled milk from 19,000 per cc. to only 25,000 per cc. under the same conditions.

Tables 35 shows the same figures re-grouped according to holding conditions (time and temperature) as well as the maximum and minimum reduction times.

Table 36 shows the percentage decreases or increases in reduction times over those in fresh milk cooled at once, grouped according to the length of time cooling was delayed. Again, the major damage had evidently been caused by delayed cooling, although it should be pointed out that had the milks been cooled to and held at 50° F. or even 60° F. throughout the trial the outcome presumably would have been different. The 24-hour holding period at 40° F. which followed the 8-hour holding period at 60° F., apparently did much to mitigate the harm done during those eight hours as far as any influence exerted upon the mechanism of the methylene blue test is concerned; hence this fact should be kept in mind when one scans this table.

Table 37 shows percentage decreases in reduction times over what they would have been had the milk been cooled at once. They discount the results due to the holding period and throw into relief the damage by delayed cooling.

AVERAGE REDUCTION TIMES OF SAMPLES WHOSE INITIAL BACTERIAL
COUNTS WERE 10,000 PER CC. OR LESS

Tables 38, 39, 40 and 41 disclose about the same trends as are shown in the tables of total averages. Of course the initial reduction times are large and the extreme damage which may be debited against delayed cooling and holding periods is not great.

TRIAL 2

These samples were cooled, after delays of 0, 1, 2, 3 and 4 hours, to 40° F.; sub-sampled for plating and methylene blue reduction time

determination immediately after each of the five samples had been cooled to 40° F.; held at 40° F. 24 hours and sub-sampled as before; warmed to and held at 60° F. for 8 hours; and, finally, sub-sampled as before.

AVERAGE BACTERIAL COUNTS

Some interesting relationships are displayed in table 42. For example, the fresh sample cooled at once displayed a bacterial count of about 17,000 per cc.; after 24 hours at 40° F. it had decreased to 14,000 per cc.; and after 8 hours at 60° F. it had increased to about 39,000 per cc. The sample whose cooling was delayed 4 hours had a count of 84,000 per cc.; after being held 24 hours at 40° F. the count had in-

TABLE 42. AVERAGE (GEOMETRIC MEAN), BACTERIAL COUNTS AND AVERAGE REDUCTION TIMES OF ALL MILKS INITIALLY COOLED TO 40° F. AND LATER WARMED TO AND HELD AT 60° F. AS INDICATED. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

Cooling delayed	A—Cooling to 40° F. delayed as indicated			B—Held at 40° F. 24 hours—then warmed to 60° F.			C—Held eight hours at 60° F.		
	Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time	
		Hrs.	Min.		Hrs.	Min.		Hrs.	Min.
0 hours	16,900	11	46	14,000	12	59	38,600	8	30
1 hour	18,500	10	59	20,700	12	24	92,500	7	46
2 hours	24,900	10	11	35,200	11	24	165,000	6	18
3 hours	36,900	9	2	51,900	10	22	343,000	5	8
4 hours	84,400	7	44	102,000	8	28	735,000	4	24

creased slightly to 102,000 per cc., but after being held 8 hours longer at 60° F. the count had increased to 735,000 per cc. In the first instance it had only a little more than doubled, while in the latter case it had increased about nine times. The significant point is that exactly the same milks were used in trial 2 as were used in trial 1. They were studied for the same length of time (32 hours). They were both held for the same length of time at 60° F. (8 hours) and at 40° F. (24 hours), but the milks as handled in trial 1 were in much better condition, measured by the standard plate count and methylene blue reduction test, than were the milks as handled in trial 2. A possible explanation for this is that in trial 1, where the milks were first cooled to and held at 60° F. for 8 hours, some germicidal agency possibly exercised a suppressing influence on bacterial development and before this influence had fully spent itself the samples were further cooled to and held at 40° F. for 24 hours. Although bacterial development had gained some

headway while the samples were being held at 60° F., this tendency to increase was checked by lowering the temperature to 40° F. In other words, the effect was prolonged and spread out. In trial 2, where the samples were cooled to and held at 40° F. for 24 hours and then warmed to and held at 60° F. for 8 hours longer, the potency of any germicidal agency present had largely been dissipated during the 24 hours when the milk was held at a low temperature so that its effects

TABLE 43. AVERAGE (GEOMETRIC MEAN), MINIMUM AND MAXIMUM BACTERIAL COUNTS; AVERAGE, MAXIMUM AND MINIMUM REDUCTION TIMES OF MILKS INITIALLY COOLED TO AND HELD AT 40° F., LATER WARMED TO AND HELD AT 60° F. AS INDICATED. GROUPED ACCORDING TO HOLDING CONDITIONS (TIME AND TEMPERATURE)

Holding conditions (time and temp.)	Bacterial counts			Reduction times					
	Average (Geo. mean)	Minimum	Maximum	Average		Maximum		Minimum	
				Hrs.	Min.	Hrs.	Min.	Hrs.	Min.
Cooling delayed 0 hours									
A	16,900	2,000	256,000	11	46	25	52	3	..
B	14,000	1,500	472,000	12	59	29	7	3	45
C	38,600	3,500	2,900,000	8	30	18	45	1	15
Cooling delayed 1 hour									
A	18,500	1,800	318,000	10	59	24	15	2	15
B	20,700	2,500	1,570,000	12	24	27	52	3	15
C	92,500	12,500	7,800,000	7	46	18	45	1	..
Cooling delayed 2 hours									
A	24,900	1,900	447,000	10	11	24	7	2	..
B	35,200	3,600	6,540,000	11	24	28	37	1	30
C	165,000	10,500	10,400,000	6	18	17	22	..	45
Cooling delayed 3 hours									
A	36,900	4,400	765,000	9	2	22	30	1	15
B	51,900	2,300	7,200,000	10	22	25	37	1	..
C	343,000	31,000	21,000,000	5	8	10	45	..	30
Cooling delayed 4 hours									
A	84,400	7,500	8,570,000	7	44	21	30	1	..
B	102,000	8,800	8,700,000	8	28	24	45	1	..
C	735,000	55,000	129,000,000	4	24	9	30	..	30

HOLDING CONDITIONS

A—Cooling to 40° F. delayed as indicated.

B—Held at 40° F. 24 hours—then warmed to 60° F.

C—Held eight hours at 60° F.

were indistinguishable from those of other factors. On the other hand, perhaps the organisms present were preparing themselves for more normal increase when more favorable conditions appeared. Therefore, when the samples were finally warmed to 60° F. there was very little to

interfere with the normal increased bacterial development expected at that temperature.

The results so far shown would indicate that it is very much better for the milk to hold it at 60° F. for a time and then to cool to and hold at 40° F., than it would be to allow already properly cooled milk

TABLE 44. PERCENTAGE INCREASES OR DECREASES IN AVERAGE BACTERIAL COUNTS AND PERCENTAGE DECREASES OR INCREASES IN AVERAGE REDUCTION TIMES OVER THOSE IN FRESH MILKS COOLED AT ONCE. SAMPLES INITIALLY COOLED TO 40° F., LATER WARMED TO AND HELD AT 60° F. AS INDICATED. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

Cooling delayed	A—Cooling to 40° F. delayed as indicated		B—Held at 40° F. 24 hours—then warmed to 60° F.		C—Held 8 hours at 60° F.	
	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time
0 hours	0	0	— 17.2	+10.3	+ 128.4	—27.8
1 hour	+ 9.5	— 6.6	+ 22.5	+ 5.4	+ 447.3	—34.
2 hours	+ 47.3	—13.4	+108.3	— 3.1	+ 876.3	—46.4
3 hours	+118.3	—23.2	+207.1	—11.9	+1,929.6	—56.4
4 hours	+399.4	—34.3	+503.6	—28.	+4,249.1	—62.6

to warm to 60° F. It must not be forgotten, however, that in both trials 1 and 2 delayed cooling gets in its deadly work just the same.

In table 43 the same figures are re-grouped according to holding conditions (time and temperature) and, in addition, the minimum and maximum counts are shown. Table 44 shows the percentage bac-

TABLE 45. PERCENTAGE INCREASES IN AVERAGE BACTERIAL COUNTS AND PERCENTAGE DECREASES IN AVERAGE REDUCTION TIMES OVER THOSE IN SAMPLES COOLED AT ONCE. SAMPLES INITIALLY COOLED TO 40° F., LATER WARMED TO AND HELD AT 60° F. AS INDICATED. GROUPED ACCORDING TO LENGTH OF TIME COOLING WAS DELAYED

Cooling delayed	A—Cooling to 40° F. delayed as indicated		B—Held at 40° F. 24 hours—then warmed to 60° F.		C—Held 24 hours at 60° F.	
	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time
0 hours	0	0	0	0	0	0
1 hour	+ 9.5	— 6.6	+ 47.8	— 4.5	+ 139.6	— 8.6
2 hours	+ 47.3	—13.4	+151.4	—12.2	+ 327.5	—25.9
3 hours	+118.3	—23.2	+270.7	—20.2	+ 788.6	—39.6
4 hours	+399.4	—34.3	+628.6	—34.8	+1,804.1	—48.2

terial increases over those in fresh milk cooled at once. The same trends are indicated as in tables 42 and 43. It is of interest to note here the percentage increases in table 36, trial 1. In table 45 are found the percentage increases in bacterial counts over what they would have been had the milk been cooled at once.

TABLE 46. AVERAGE (GEOMETRIC MEAN) BACTERIAL COUNTS AND AVERAGE REDUCTION TIMES IN MILKS WHOSE INITIAL BACTERIAL COUNTS WERE 10,000 PER CC. OR LESS; WHICH WERE INITIALLY COOLED TO 40° F., AND LATER WARMED TO AND HELD AT 60° F. AS INDICATED. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

Cooling delayed	A—Cooling to 40° F. delayed as indicated			B—Held at 40° F. 24 hours—then warmed to 60° F.			C—Held 8 hours at 60° F.		
	Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time	
		Hrs.	Min.		Hrs.	Min.		Hrs.	Min.
0 hours	4,900	16	40	4,000	18	21	6,000	11	37
1 hour	4,900	15	50	5,100	17	36	17,200	11	35
2 hours	6,300	15	9	7,400	16	50	28,000	9	34
3 hours	11,000	13	44	8,900	15	35	68,600	7	22
4 hours	24,000	11	40	20,000	12	46	120,000	6	15

TABLE 47. AVERAGE (GEOMETRIC MEAN), MINIMUM AND MAXIMUM BACTERIAL COUNTS; AVERAGE, MAXIMUM AND MINIMUM REDUCTION TIMES OF MILKS INITIALLY COOLED TO AND HELD AT 40° F., LATER WARMED TO AND HELD AT 60° F. AS INDICATED; IN THOSE SAMPLES HAVING INITIAL BACTERIAL COUNTS OF 10,000 PER CC. OR LESS. GROUPED ACCORDING TO HOLDING CONDITIONS (TIME AND TEMPERATURE)

Holding conditions (time and temp.)	Bacterial counts			Reduction times					
	Average (Geo. mean)	Minimum	Maximum	Average		Maximum		Minimum	
				Hrs.	Min.	Hrs.	Min.	Hrs.	Min.
Cooling delayed 0 hours									
A	4,900	2,000	9,700	16	40	25	52	10	45
B	4,000	1,500	9,600	18	21	29	7	11	22
C	6,000	3,500	8,500	11	37	18	45	8	7
Cooling delayed 1 hour									
A	4,900	1,800	11,700	15	50	24	15	10	..
B	5,100	2,500	10,200	17	36	27	52	11	..
C	17,200	8,600	34,000	11	35	18	45	7	30
Cooling delayed 2 hours									
A	6,300	1,900	18,100	15	9	24	7	9	..
B	7,400	3,600	14,200	16	50	28	37	10	15
C	28,000	10,500	75,400	9	34	17	22	7	30
Cooling delayed 3 hours									
A	10,500	4,400	24,600	13	44	22	30	7	45
B	8,900	2,300	20,300	15	35	25	37	8	37
C	68,600	31,000	181,000	7	22	10	45	4	30
Cooling delayed 4 hours									
A	23,800	7,500	56,200	11	40	21	30	6	30
B	20,000	8,800	36,800	12	46	24	45	7	30
C	120,000	55,000	255,000	6	15	9	30	4	15

HOLDING CONDITIONS

- A—Cooling to 40° F. delayed as indicated.
 B—Held at 40° F. 24 hours—then warmed to 60° F.
 C—Held eight hours at 60° F.

AVERAGE BACTERIAL COUNTS, INITIALLY 10,000 PER CC. OR LESS

Table 46 is concerned with the average bacterial counts on all samples whose initial counts were 10,000 per cc. or less. They are grouped according to the length of time cooling was delayed. Again the low count milk suffered less than the others. The quickly cooled

TABLE 48. PERCENTAGE INCREASES OR DECREASES IN AVERAGE BACTERIAL COUNTS AND PERCENTAGE INCREASES OR DECREASES IN AVERAGE REDUCTION TIMES OVER THOSE IN FRESH MILKS COOLED AT ONCE, IN THOSE SAMPLES WHOSE INITIAL BACTERIAL COUNTS WERE 10,000 PER CC. OR LESS. SAMPLES INITIALLY COOLED TO AND HELD AT 40° F., LATER WARMED TO AND HELD AT 60° F. AS INDICATED. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

Cooling delayed	A—Cooling to 40° F. delayed as indicated		B—Held at 40° F. 24 hours—then warmed to 60° F.		C—Held 8 hours at 60° F.	
	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time
0 hours	0	0	— 8.4	—10.1	+ 22.4	—30.3
1 hour	0	— 5.	+ 4.1	+ 5.6	+ 251.	—30.5
2 hours	+ 28.6	— 9.1	+ 51.	+ 1.	+ 471.4	—42.6
3 hours	+124.5	—17.6	+ 81.6	— 6.5	+1,300.	—55.8
4 hours	+389.8	—30.	+308.2	—23.4	+2,349.	—62.5

milks suffer relatively little and the item of quick cooling may mean the difference between receiving a bonus or losing it. The figures again emphasize the danger of allowing milk, even low initial count milk, to warm up once it has been properly cooled.

Tables 47, 48 and 49 show no trends not indicated in the preceding tables.

TABLE 49. PERCENTAGE INCREASES IN AVERAGE BACTERIAL COUNTS AND PERCENTAGE DECREASES IN AVERAGE REDUCTION TIMES OVER THOSE IN SAMPLES COOLED AT ONCE, IN THOSE SAMPLES WHOSE INITIAL BACTERIAL COUNTS WERE 10,000 PER CC. OR LESS. SAMPLES INITIALLY COOLED TO 40° F., LATER WARMED TO AND HELD AT 60° F. AS INDICATED. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

Cooling delayed	A—Cooling to 40° F. delayed as indicated		B—Held at 40° F. 24 hours—then warmed to 60° F.		C—Held 8 hours at 60° F.	
	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time
0 hours	0	0	0	0	0	0
1 hour	0	— 5.	+ 27.5	— 4.1	+ 186.7	— 0.3
2 hours	+ 28.6	— 9.1	+ 85.	— 8.3	+ 366.7	—17.6
3 hours	+124.5	—17.6	+122.5	—15.1	+1,043.3	—36.6
4 hours	+389.8	—30.	+400.	—30.4	+1,900.	—46.2

AVERAGE REDUCTION TIMES

These averages are shown in table 42 grouped according to the length of time cooling was delayed. It is interesting to note that in the

samples initially cooled to and held at 40° F. for 24 hours, the reduction time in each case has increased over those in the fresh milk by an hour or more, while the bacterial counts in the same samples, except in the milk cooled at once, have slightly increased. In general, the same trends are noted as for the bacterial counts for this trial.

Table 43 shows the same figures re-grouped according to holding conditions (time and temperature) as well as the maximum and minimum reduction times. Table 44 shows the percentage decreases or increases in reduction times over those in fresh milk cooled at once and table 45 the percentage decreases in reduction times over what they would have been had the samples been cooled at once. It is worth noting that with each holding condition the reduction time of the sample which had been held 4 hours before cooling decreased about 4 hours over the samples which had been cooled at once.

AVERAGE REDUCTION TIMES FOR SAMPLES WHOSE INITIAL BACTERIAL
COUNTS WERE 10,000 PER CC. OR LESS

These figures are shown in tables 46, 47, 48 and 49 and indicate the same trends heretofore been noted but the fact is emphasized that low count milks, as might be expected, suffer least from adverse conditions.

TRIAL 3

After delays of 0, 1, 2, 3 and 4 hours the milks were initially cooled to and held at 40° F. throughout the trial. They were sub-sampled for purposes of making plate count and reduction time determinations at the end of the initial cooling period, and at the end of 24 hours and 32 hours. The milk used in all three trials was identical.

AVERAGE BACTERIAL COUNTS

The bacterial counts of these samples are grouped in table 50 according to the length of time cooling was delayed. Again the best milk is that which was cooled at once at 40° F. and held at that temperature throughout the trial. As disclosed by these figures, the greatest damage done to this milk may fairly be charged to delayed cooling and not to holding conditions. In the other two trials the responsibility seemed to be divided.

Table 51 shows the figures re-grouped according to holding conditions (time and temperature) and as well the minimum and maximum

TABLE 50. AVERAGE (GEOMETRIC MEAN) BACTERIAL COUNTS AND AVERAGE REDUCTION TIMES OF ALL MILKS INITIALLY COOLED TO AND HELD AT 40° F. THROUGHOUT THE TRIAL AS INDICATED. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

Cooling delayed	A—Cooling to 40° F. delayed as indicated			B—Held 24 hours at 40° F.			C—Held 32 hours at 40° F.		
	Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time	
		Hrs.	Min.		Hrs.	Min.		Hrs.	Min.
0 hours	16,900	11	46	14,000	12	59	10,200	12	8
1 hour	18,500	10	59	20,700	12	24	13,400	11	39
2 hours	24,900	10	11	35,200	11	24	23,800	11	16
3 hours	36,900	9	2	51,900	10	22	40,400	10	11
4 hours	84,400	7	44	102,000	8	28	84,400	8	58

TABLE 51. AVERAGE (GEOMETRIC MEAN), MINIMUM AND MAXIMUM BACTERIAL COUNTS; AVERAGE, MAXIMUM AND MINIMUM REDUCTION TIMES OF MILKS INITIALLY COOLED TO AND HELD AT 40° F. AS INDICATED. GROUPED ACCORDING TO HOLDING CONDITIONS (TIME AND TEMPERATURE)

Holding conditions (time and temp.)	Bacterial counts			Reduction times					
	Average (Geo. mean)	Minimum	Maximum	Average		Maximum		Minimum	
				Hrs.	Min.	Hrs.	Min.	Hrs.	Min.
Cooling delayed 0 hours									
A	16,900	2,000	256,000	11	46	25	52	3	..
B	14,000	1,500	472,000	12	59	29	7	3	45
C	10,200	900	650,000	12	8	24	15	3	..
Cooling delayed 1 hour									
A	18,500	1,800	318,000	10	59	24	15	2	15
B	20,700	2,500	1,570,000	12	24	27	52	3	15
C	13,400	1,100	2,720,000	11	39	24	15	3	..
Cooling delayed 2 hours									
A	24,900	1,900	447,000	10	11	24	7	2	..
B	35,200	3,600	6,540,000	11	24	28	37	1	30
C	23,800	2,300	3,900,000	11	16	24	30	2	45
Cooling delayed 3 hours									
A	36,900	4,400	765,000	9	2	22	30	1	15
B	51,900	2,300	7,200,000	10	22	25	37	1	..
C	40,400	3,200	4,160,000	10	11	20	30	1	45
Cooling delayed 4 hours									
A	84,400	7,500	8,570,000	7	44	21	30	1	..
B	102,000	8,800	8,700,000	8	28	24	45	1	..
C	84,400	5,700	6,450,000	8	58	19	15	1	45

HOLDING CONDITIONS

A—Cooling to 40° F. delayed as indicated.

B—Held 24 hours at 40° F.

C—Held 32 hours at 40° F.

bacterial counts. The figures being thus grouped enable one the more readily to compare any influence which holding conditions may exert. Table 52 shows percentage increases over those in fresh milks cooled

TABLE 52. PERCENTAGE INCREASES OR DECREASES IN AVERAGE BACTERIAL COUNTS AND PERCENTAGE DECREASES OR INCREASES IN AVERAGE REDUCTION TIMES OVER THOSE IN FRESH MILKS COOLED AT ONCE. SAMPLES INITIALLY COOLED TO AND HELD AT 40° F. AS INDICATED. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

Cooling delayed	A—Cooling to 40° F. delayed as indicated		B—Held 24 hours at 40° F.		C—Held 32 hours at 40° F.	
	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time
0 hours	0	0	- 17.2	+10.3	- 39.6	+ 3.1
1 hour	+ 9.5	- 6.6	+ 22.4	+ 5.4	- 20.7	- 1.
2 hours	+ 47.3	-13.4	+108.3	- 3.1	+ 40.8	- 4.2
3 hours	+118.3	-23.2	+207.1	-11.9	+139.	-13.4
4 hours	+399.4	-34.3	+503.6	-28.	+399.4	-23.8

at once. The same trends are indicated but show in another way for this grouping the superiority of quickly cooled milks. Table 53 sets forth the percentage increases in bacterial counts over what they would have been had the samples been cooled at once.

TABLE 53. PERCENTAGE INCREASES IN AVERAGE BACTERIAL COUNTS AND PERCENTAGE DECREASES IN AVERAGE REDUCTION TIMES OVER THOSE SAMPLES COOLED AT ONCE. SAMPLES COOLED TO AND HELD AT 40° F. AS INDICATED. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

Cooling delayed	A—Cooling to 40° F. delayed as indicated		B—Held 24 hours at 40° F.		C—Held 32 hours at 40° F.	
	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time
0 hours	0	0	0	0	0	0
1 hour	+ 9.5	- 6.6	+ 47.8	- 4.5	+ 31.4	- 4.
2 hours	+ 47.3	-13.4	+151.4	-12.2	+133.3	- 7.1
3 hours	+118.3	-23.2	+270.7	-20.2	+296.1	-16.1
4 hours	+399.4	-34.3	+628.6	-34.8	+727.4	-26.1

AVERAGE BACTERIAL COUNTS, INITIALLY 10,000 PER CC. OR LESS

Tables 54, 55, 56 and 57 indicate the same trends as do the total averages; however, everything favors the low count milk.

AVERAGE REDUCTION TIMES

Table 50 contains these averages grouped according to the length of time cooling was delayed. They exhibit a longer reduction time after

TABLE 54. AVERAGE (GEOMETRIC MEAN) BACTERIAL COUNTS AND AVERAGE REDUCTION TIMES OF MILKS WHOSE INITIAL BACTERIAL COUNTS WERE 10,000 PER CC. OR LESS, WHICH WERE INITIALLY COOLED TO AND HELD AT 40° F. AS INDICATED. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

Cooling delayed	A—Cooling to 40° F. delayed as indicated			B—Held 24 hours at 40° F.			C—Held 32 hours at 40° F.		
	Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time		Average bacterial count (Geo. mean)	Average reduction time	
		Hrs.	Min.		Hrs.	Min.		Hrs.	Min.
0 hours	4,900	16	40	4,000	18	21	3,300	16	34
1 hour	4,900	15	50	5,100	17	36	3,300	16	4
2 hours	6,300	15	9	7,400	16	50	4,900	15	59
3 hours	11,000	13	44	8,900	15	35	7,700	14	20
4 hours	24,000	11	40	20,000	12	46	18,000	12	59

TABLE 55. AVERAGE (GEOMETRIC MEAN), MINIMUM AND MAXIMUM BACTERIAL COUNTS; AVERAGE, MAXIMUM AND MINIMUM REDUCTION TIMES OF MILKS INITIALLY COOLED TO AND HELD AT 40° F. AS INDICATED, IN THOSE SAMPLES WHOSE INITIAL BACTERIAL COUNTS WERE 10,000 PER CC. OR LESS. GROUPED ACCORDING TO HOLDING CONDITIONS (TIME AND TEMPERATURE)

Holding conditions (time and temp.)	Bacterial counts			Reduction times					
	Average (Geo. mean)	Minimum	Maximum	Average		Maximum		Minimum	
				Hrs.	Min.	Hrs.	Min.	Hrs.	Min.
Cooling delayed 0 hours									
A	4,900	2,000	9,700	16	40	25	52	10	15
B	4,000	1,500	9,600	18	21	29	7	11	22
C	3,300	900	8,700	16	34	24	15	17	45
Cooling delayed 1 hour									
A	4,900	1,800	11,700	15	50	24	15	10	..
B	5,100	2,500	10,200	17	36	27	52	11	..
C	3,300	1,100	8,100	16	4	24	15	9	45
Cooling delayed 2 hours									
A	6,300	1,900	18,100	15	9	24	7	9	..
B	7,400	3,600	14,200	16	50	28	37	10	15
C	4,900	2,300	12,400	15	59	24	30	9	30
Cooling delayed 3 hours									
A	11,000	4,400	24,600	13	44	22	30	7	45
B	8,900	2,300	20,300	15	35	25	37	8	37
C	7,700	3,200	23,000	14	20	20	30	9	15
Cooling delayed 4 hours									
A	24,000	7,500	56,200	11	40	21	30	6	30
B	20,000	8,800	36,800	12	46	24	45	7	30
C	18,000	5,700	47,600	12	59	19	15	6	15

HOLDING CONDITIONS

A—Cooling to 40° F. delayed as indicated.

B—Held 24 hours at 40° F.

C—Held 32 hours at 40° F.

22 hours at 40° F. than when fresh, although the reduction decreases, as always, with the length of time cooling was delayed. The table again shows the inconsistencies of the reduction test as influenced by low holding temperatures. This seems to be a well established

TABLE 56. PERCENTAGE INCREASES OR DECREASES IN AVERAGE BACTERIAL COUNTS AND PERCENTAGE INCREASES OR DECREASES IN AVERAGE REDUCTION TIMES OVER THOSE IN FRESH MILKS COOLED AT ONCE, IN THOSE SAMPLES WHOSE INITIAL BACTERIAL COUNTS WERE 10,000 PER CC. OR LESS. SAMPLES INITIALLY COOLED TO AND HELD AT 40° F. AS INDICATED. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

Cooling delayed	A—Cooling to 40° F. delayed as indicated		B—Held 24 hours at 40° F.		C—Held 32 hours at 40° F	
	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time
0 hours	0	0	— 18.4	+10.1	— 32.6	— 0.6
1 hour	0	— 5.	+ 4.1	+ 5.6	— 32.6	— 3.6
2 hours	+ 28.6	— 9.1	+ 51.	+ 1.	0	— 4.1
3 hours	+124.5	—17.6	+ 81.6	— 6.5	+ 57.1	—14.
4 hours	+389.8	—30.	+308.2	—23.4	+267.3	—22.1

phenomena since it occurs in nearly every case thus far studied at this Station.

It should be pointed out that milk suffers less, as disclosed by this test, in quick cooled milk held 32 hours than does the fresh milk held 4 hours before cooling. It seems a case of telling the truth but not

TABLE 57. PERCENTAGE INCREASES IN AVERAGE BACTERIAL COUNTS AND PERCENTAGE DECREASES IN AVERAGE REDUCTION TIMES OVER THOSE IN SAMPLES COOLED AT ONCE, IN THOSE SAMPLES WHOSE INITIAL BACTERIAL COUNTS WERE 10,000 PER CC. OR LESS. SAMPLES INITIALLY COOLED TO AND HELD AT 40° F. AS INDICATED. GROUPED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

Cooling delayed	A—Cooling to 40° F. delayed as indicated		B—Held 24 hours at 40° F.		C—Held 32 hours at 40° F	
	Bacterial count	Reduction time	Bacterial count	Reduction time	Bacterial count	Reduction time
0 hours	0	0	0	0	0	0
1 hour	0	— 5.	+ 27.5	— 4.1	0	— 3.
2 hours	+ 28.6	— 9.1	+ 85.	— 8.3	+ 48.5	— 3.5
3 hours	+124.5	—17.6	+122.5	—15.8	+133.5	—13.5
4 hours	+389.8	—30.	+400.	—30.4	+445.5	—21.6

the whole truth. It would be foolish to claim that the quality of milk improves by holding, for it probably is never any better than at the moment it leaves the cow, but it is fair to infer from these figures that milk suffers less when quickly cooled to 40° F. and held at that tem-

perature for 32 hours than when cooling is delayed for 4 hours. Frequently it will mean the difference between making or not making the grade.

Table 51 shows the average reduction times re-grouped according to holding conditions (time and temperature) and allows an easier com-

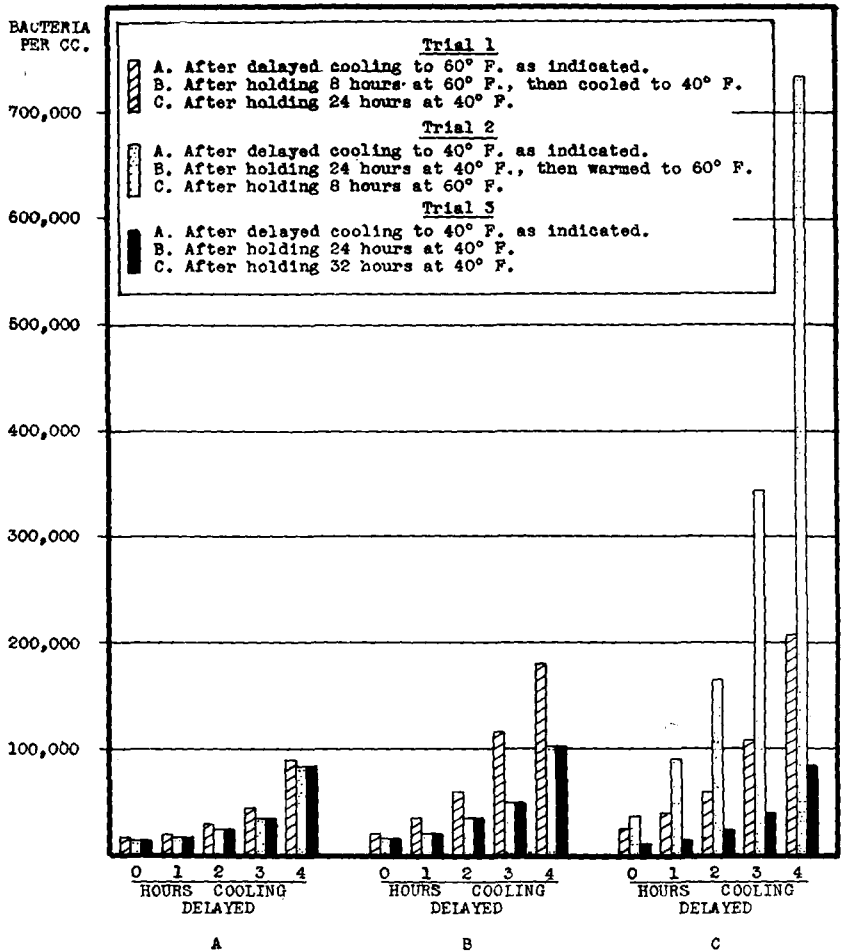


CHART 9. Study 2. Average (geometric mean) bacterial counts

parison of what happens under the three holding conditions A, B and C. It also shows the maximum and minimum reduction times. Table 52 gives the percentage decreases or increases in reduction times over those in fresh milks cooled at once and table 53 the percentage decreases in reduction times over what they would have been had the samples been cooled at once.

AVERAGE REDUCTION TIMES OF SAMPLES WHOSE INITIAL BACTERIAL COUNTS WERE 10,000 PER CC. OR LESS

Tables 54, 55, 56 and 57 afford the same information for this grouping as are given in similar tables for the total averages. The total average bacterial counts for all three trials are compared graphically in

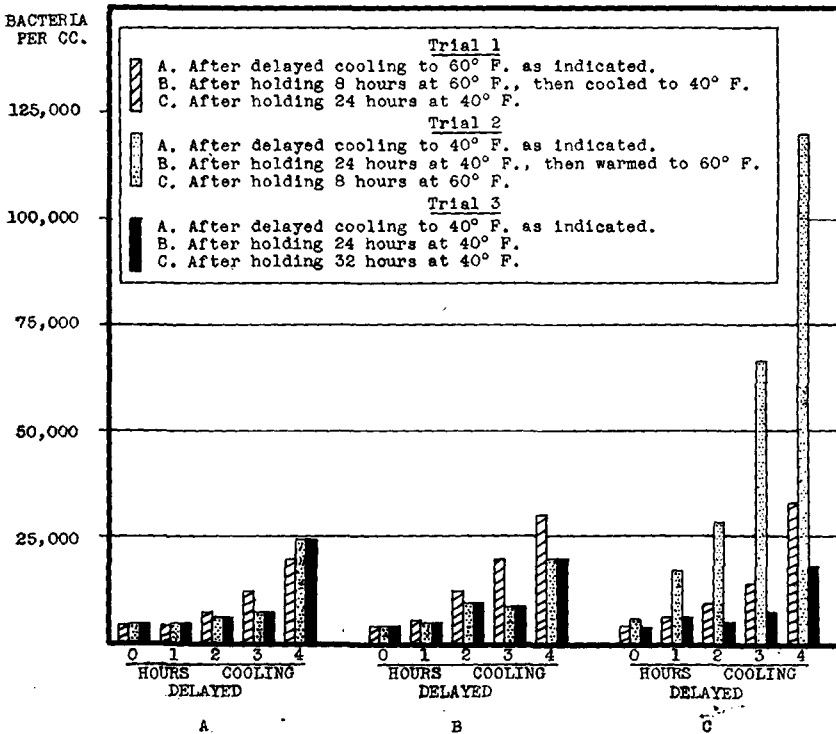


CHART 10. Study 2. Average (geometric mean) bacterial counts, initially 10,000 per cc. or less

chart 9, the bacterial counts, initially 10,000 per cc. or less, in chart 10, the total average reduction times for all three trials in chart 11 and the average reduction times on samples whose initial bacterial counts were 10,000 per cc. or less in chart 12.

DISCUSSION OF STUDY 2

Charts 9, 10, 11 and 12 display and compare graphically the figures gathered in trials 1, 2 and 3. They give an interesting picture of what happen to plate counts and to methylene blue reduction times under the conditions described. The charts indicate, better than the figures, that

REDUCTION
TIME

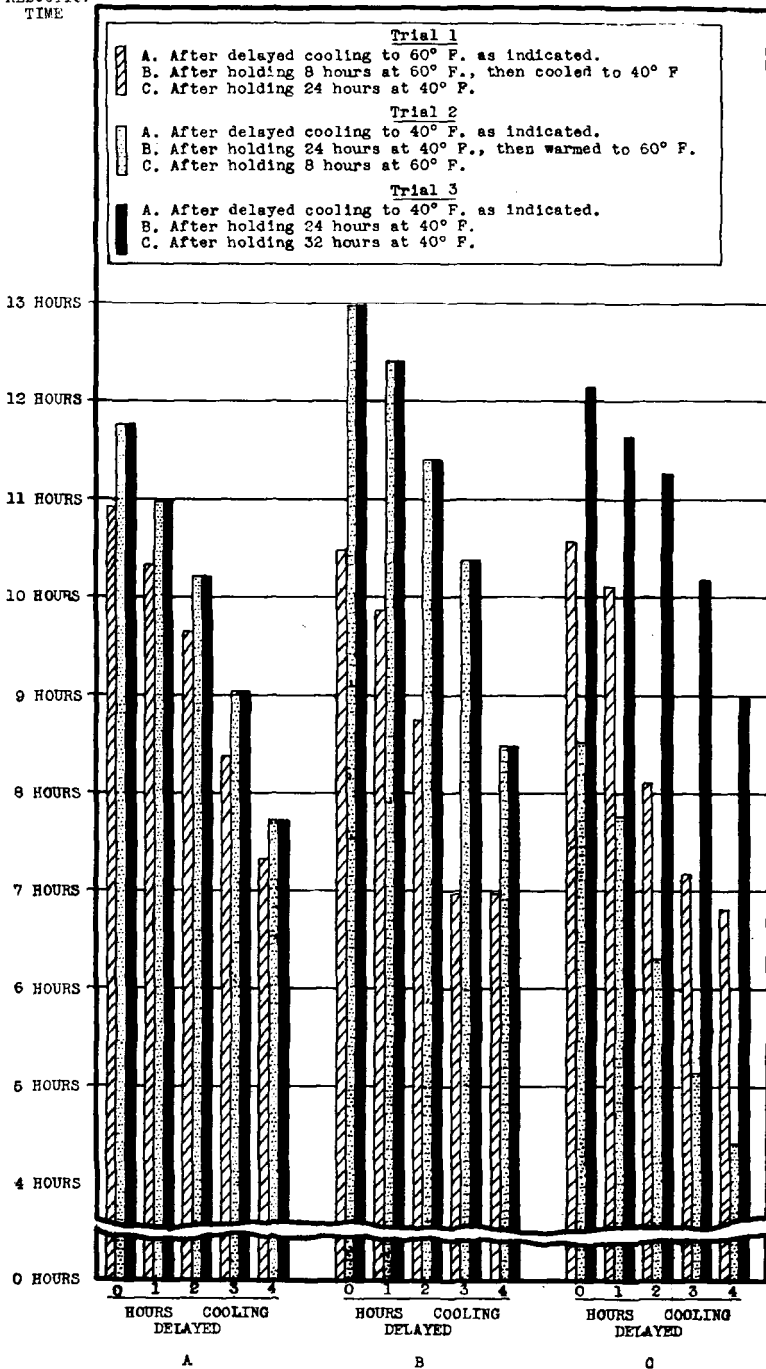


CHART 11. Study 2. Average reduction times

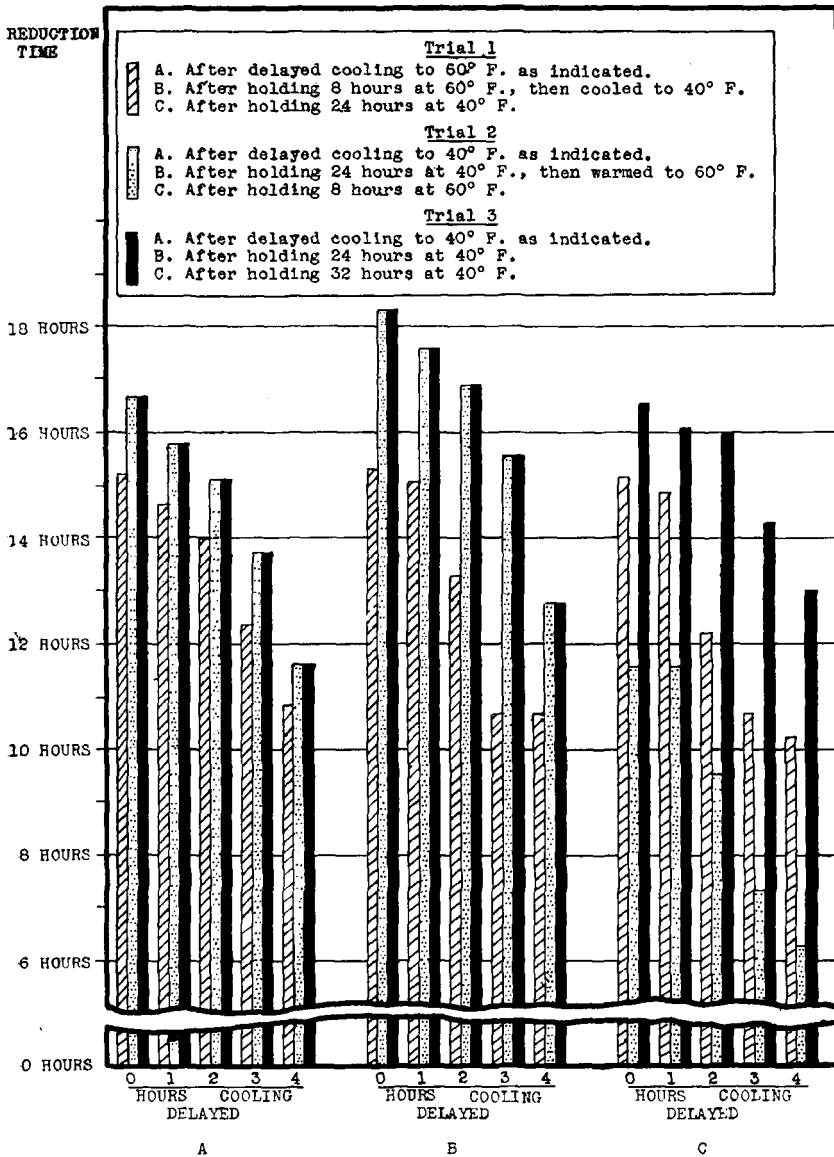


CHART 12. Study 2. Average reduction times on milks whose initial bacterial counts were 10,000 per cc. or less

the trends are very much the same for the low count samples as for the total averages.

An examination of the figures for trial 1 alone would perhaps justify the conclusion that cooling to and holding at 60° F. for 8 hours rather freely stimulates bacterial activity and that there is no direct evi-

dence of the existence of a germicidal agency. However, from the figures for trial 2 is obtained an entirely different view. Here a part of the same milk, cooled immediately to 40° F., held at that temperature for 24 hours and then warmed to and held at 60° F. for 8 hours, stimulates bacterial activity far more than was the case under the conditions of trial 1 where the samples were held at 60° F. for the first 8 hours. The conclusion would seem justified that some factor other than low temperature is involved. Probably the most plausible conclusion would be that in trial 1 the presence of a germicidal agency has exercised a suppressing influence in the fresh milk which inhibits growth at a temperature which ordinarily might be expected to accelerate it. It should be pointed out, however, that although normal growth is somewhat suppressed under the conditions of trial 1, a measurable impetus is given to bacterial activity by cooling to and holding at as warm a temperature as 60° F. for the first 8 hours and that, again, the quickly cooled samples are better than are those where cooling had been delayed. This increased bacterial activity seems to have been effectively checked by lowering the temperature to 40° F. but of course damage already done can not be obviated.

In trial 2 the effect of any germicidal agency which may be present is so attenuated by cooling the milk to and holding at 40° F. for 24 hours that it loses much of its potency; therefore, when the milk is warmed to and held at 60° F. for 8 hours, bacterial activity can quickly respond to this favorable temperature with little inhibitory influence to hold it back.

In trial 3, wherein a part of the same milk which is involved in the other two trials was cooled to and held at 40° F. for the entire 32 hours, the results were highly satisfactory. However, even here, the difference between quickly cooled milk and milk held 4 hours before cooling is noticeable. How much of the difference is due to unfavorable growing temperature, how much to other growth factors and how much to the presence of a germicidal agency matters little. The point is that promptly cooling milk to and continuously holding it at a temperature of 40° F. or lower accomplishes about all that proper cooling can. When digression from this procedure occurs it is at the expense of the present and future quality of the milk.

STUDY 3

During the studies herein reported and others (both reported and unreported) considerable data were accumulated concerning the direct

effect of the delayed cooling of milk upon both the bacterial count and the reduction time.

The results from 137 separate lots of milk were assembled and the average (geometric mean) bacterial counts and the average reduction times obtained. This involved 685 bacterial counts and 685 reduction times. The percentage increases in bacterial counts and the percentage decreases in reduction times, over those in fresh milk cooled at once, are also shown. These figures are collected in table 58. The average bacterial counts are shown graphically in chart 13, the average reduction times in chart 14.

TABLE 58. SHOWING THE INFLUENCE OF DELAYED COOLING UPON THE AVERAGE (GEOMETRIC MEAN) BACTERIAL COUNTS AND AVERAGE REDUCTION TIMES OF 685 SAMPLES OF MISCELLANEOUS MILK. ARRANGED ACCORDING TO THE LENGTH OF TIME COOLING WAS DELAYED

Cooling delayed	Bacterial counts		Reduction times		
	Average (Geo. mean)	% Increases	Hrs. Average	Min.	% Decreases
0 hours	22,200	0	9	3	0
1 hour	23,800	+ 7.2	8	28	— 6.4
2 hours	31,000	+ 39.7	7	52	—13.1
3 hours	43,200	+ 95.5	7	10	—20.8
4 hours	67,000	+200.	6	21	—30.

In the various lots of milk are samples procured during every month of the year; samples of varying bacterial flora; produced under good and bad sanitary conditions; hand and machine-drawn milk, etc. In fact, they should afford a good cross section of the kind of milk brought into the average country receiving plant. They have the inherent weakness of all averages in that they exactly fit no individual case. They do, however, show a definite and unmistakable trend.

It would seem that the reduction test is more sensitive from the first to changes in the milk when fresh than is the plate count. One explanation which may be advanced is that the reduction of methylene blue is said to be dependent, to a certain extent at any rate, upon the oxygen consumption inherent to bacterial growth (9), and that this growth probably is taking place continuously whether the individual cells are separated, and therefore capable of being counted, or whether they are merely in the process of becoming separated, and therefore are incapable of being counted.

Practical growth measurement is dependent upon complete division and separation of the individual cell into two cells; hence it is hardly

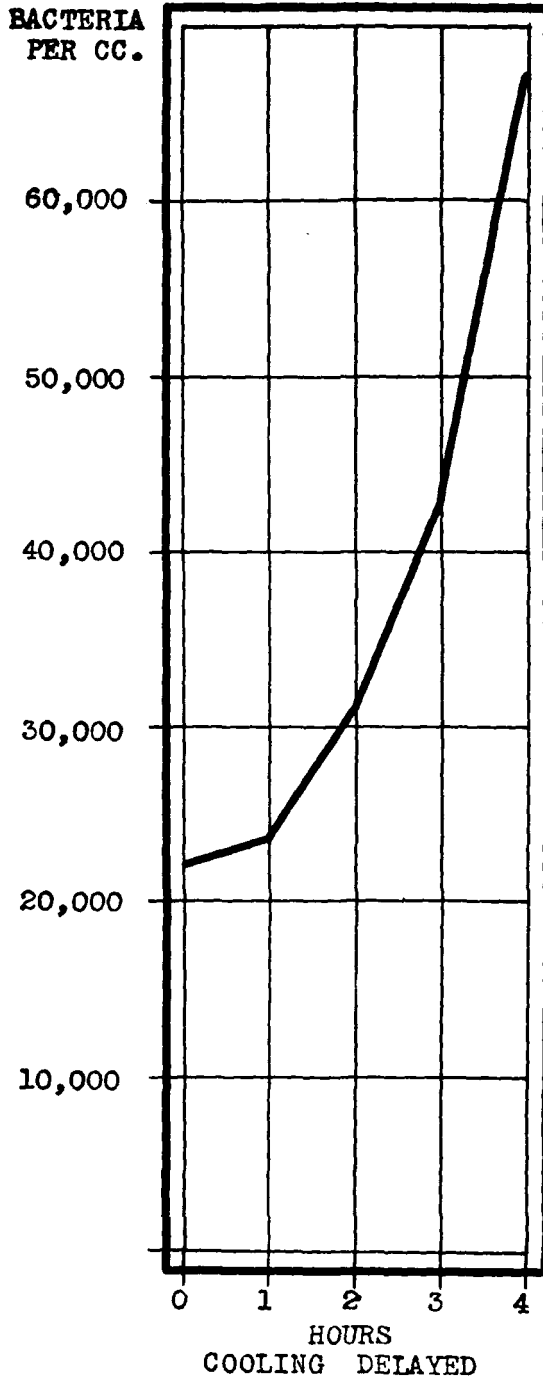


CHART 13. *Study 3.* Average (geometric mean) bacterial counts of 685 samples miscellaneous milk. Arranged according to the length of time cooling was delayed

REDUCTION
TIME

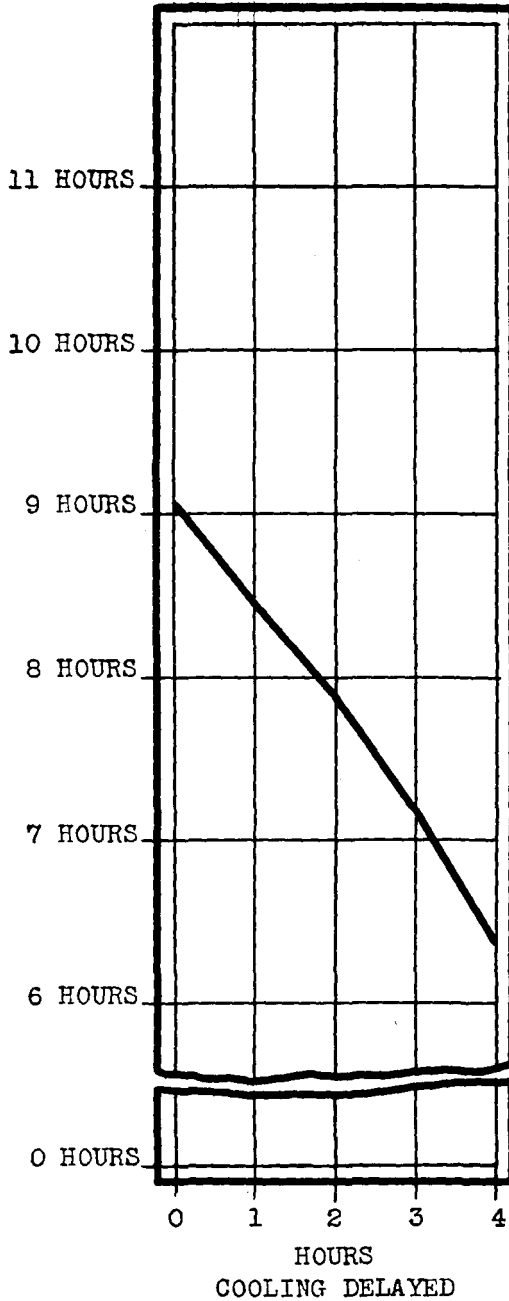


CHART 14. Study 3. Average reduction times of 685 samples miscellaneous milk. Arranged according to the length of time cooling was delayed

tenable to maintain that because there is not a measurable increase in cells (perhaps a decrease), nothing is happening within the cell which may influence the reduction time or future bacterial growth. Be that as it may, the clear conclusion which may be drawn from the survey of the figures herein presented is that fresh milk which is not subjected to a cooling influence suffers progressively for every hour of delay in the application of a low temperature.

CONCLUSIONS

1. Cooling milk immediately to 50° F. is a fairly satisfactory procedure, even when it is held over night.
2. Cooling morning's milk immediately to 60° F. is a fairly satisfactory procedure.
3. Cooling night's milk to 60° F. is an unsatisfactory procedure.
4. Allowing milk to become warm once it has been properly cooled to 40° F. or below, is an unsatisfactory procedure.
5. Cooling milk immediately to and holding at a temperature of 40° F. or below seems to produce the best results in respect to its quality, both present and future.
6. Fresh milk, unsubjected to any cooling influence, suffers progressively for every hour of such delay.
7. The lower the initial temperature used the better.

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