SEPTEMBER, 1949 RESEARCH BULLETIN 449

UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE

AGRICULTURAL EXPERIMENT STATION

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Environmental Physiology

With Special Reference to Domestic Animals

VI. Influence of Temperature, 50° to 0° F and 50° to 95° F, on Milk Production, Feed and Water Consumption and Body Weight in Jersey and Holstein Cows

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Missouri Agricultural Experiment Station and the United States Department of Agriculture Cooperating, Assisted by the Office of Naval Research.

(Publication authorized September 3, 1949)

COLUMBIA, MISSOURI

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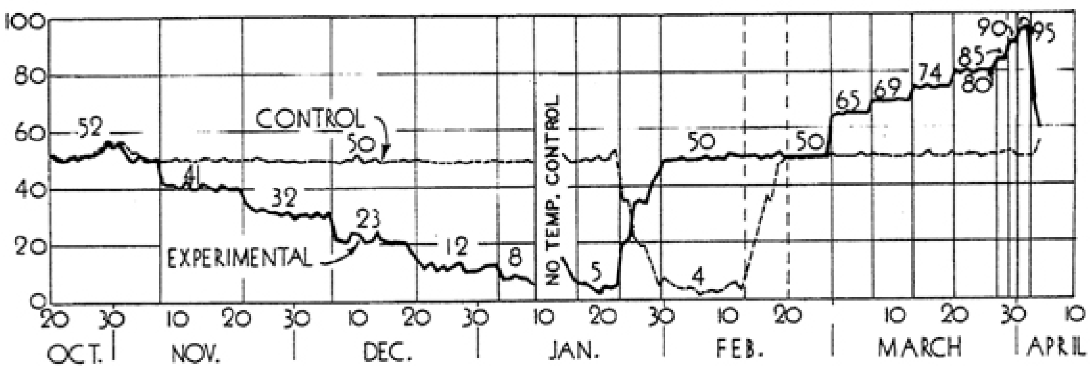

Fig. 1.—The temperature calendar.

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ORIENTATION

This report on data obtained during the winter of 1948-49 is a continuation of Missouri Research Bulletins 425 and 436 reporting similar data obtained during the summer of 1948. Laboratory, methods, and personnel were the same in the two periods, but the cows, temperature range, and temperature sequence were different.

During the *Summer, 1948* period the temperature of the *Experimental* group chamber was raised from 50 to 105°F. During the *Winter, 1948-49* period the temperature of the *Experimental* group chamber was: 1) gradually lowered from 50 to 4°F; 2) rapidly brought back to 50° F; and 3) raised from 50 to 95°F. During the same period the temperature of the *Control* group chamber was held constant at the 50°F level except for a four-week period, when it was lowered rapidly and maintained at 4°F for two weeks (to bring out the effect of low temperature on unacclimatized cows), then brought back to 50°F. The relative humidity ranged between 60 and 80 per cent in both chambers. The temperature calendar is shown graphically in Fig. 1 and numerically in Table 1.

As in the preceding experiment, each group of cows consisted of three lactating Jerseys, two lactating Holsteins, and one non-lactating, non-pregnant,

This is a part of a broad cooperative investigation between the Departments of Dairy Husbandry and Agricultural Engineering, of the Missouri Agricultural Experiment Station, University of Missouri, and the Bureau of Plant Industry, Soils and Agricultural Engineering, United States Department of Agriculture.

Acknowledgment is made to the Office of Naval Research (Ecology Branch) for financial assistance under Contract N7onr-292, Task Order IV, and to the Bureaus of Dairy Industry and Animal Industry of the Agricultural Research Administration, United States Department of Agriculture, for counsel.

H. J. Thompson, Resident Agricultural Engineer, and D. M. Worstell, Resident Statistician, represent the Bureau of Plant Industry, Soils, and Agricultural Engineering.

TABLE 1--TEMPERATURE CALENDAR

(October 1948, to April 1949)

Temperature Level (Average Air Temp., °F)		Relative Humidity, %		From	To (and including)
Experimental	Control	Experimental	Control		
52	53	71	69	October 25*	November 7
41	50	65	60	November 8	November 21
32	50	70	63	November 22	December 5
23	50	79	66	December 6	December 19
12	49	85	61	December 20	January 2
8.5	49	88	55	January 3	January 9
Power failure No temperature control (range $7-45^{\circ}\pm$)	($50^{\circ}\pm$)	85	67	January 10	January 16
5	50	83	53	January 17	January 23
Increased to 50†	Decreased to 5†	53	65	January 24	January 30
50	4	58	77	January 31	February 13
50	Increased to 50†	65	69	February 14	February 20
50	50	60	69	February 21	February 27
65	50	65	60	February 28	March 6
69	50	68	61	March 7	March 13
74	50.5	60	55	March 14	March 20
80	50.5	58	64	March 21	March 27
84	51	60	64	March 28*	March 29
90	51	60	65	March 30	March 31
94.5	50	46	64	April 1	April 2
70	50	60	63	April 3	
60	56	60	65	April 4	

* Up to and including March 21 the temperature changes were made in the mornings (about 8 a.m.); after March 21, the changes were made in the afternoon (3:00-4:00 p.m.) before the dates shown.
† Increased or decreased by 5 or 10° temperature intervals

Holstein. The position of the cows—Experimental and "matched" Controls—is shown in Fig. 2. The "history" of these cows is listed in Table 2.

No change in the feeding arrangement nor in the handling of the cows was made over the previous experiment. Alfalfa hay was fed *ad libitum*. Grain (the grain mix, including cod liver oil supplement, was as reported in Table 3 of Res. Bul. 425) and beet pulp were fed twice daily. Water (tempera-

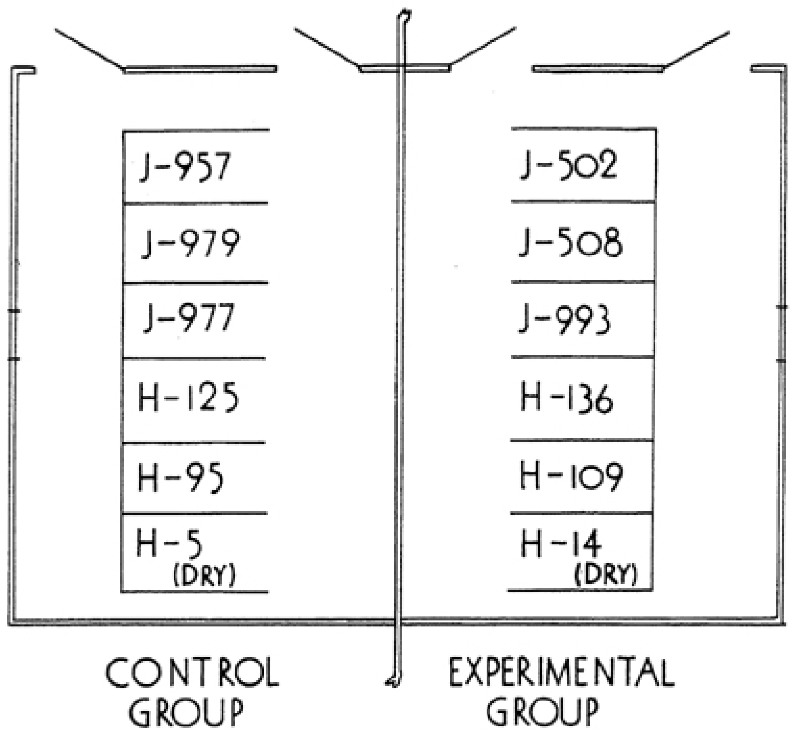

Fig. 2.—Diagram of position and pairing of the cows in the Climatic Laboratory; "J" stands for Jersey and "H" for Holstein cows.

ture ranged from 40 to 60°F depending on the chamber temperature) was available at all times in drinking cups.

The milk yields of the cows on this *Winter, 1948-49* experiment were considerably below those of the *Summer, 1948* experiment because the cows were more advanced in their stages of lactation and gestation. This is important because the depressing effect of unfavorable, especially high, temperature is much greater on high- than on low-milking cows. Therefore, the lesser effect produced on the cows during this winter period may have been due in part to the lower milk yield. Because of the low milk yield and advanced stage of lactation, little can be said concerning the effect of the high temperatures on milk production during the last phase of this winter experiment when the temperature was raised from 50 to 95°F.

Literature: There are several interesting references on the influence of cold weather on cattle. In 1907, Waters,[1] at the Missouri Station, reported that beef cattle did better when wintered outdoors than when conventionally housed. Dice,[2] at the North Dakota Station, reported that dairy cattle wintered outdoors produced as well as when conventionally housed, and the feed cost of maintenance was not substantially increased by the lower outdoor temperature. Jor-

[1]Waters, H. J., "Fattening cattle for market," Univ. Missouri Agr. Exp. Sta. Bul. 76, 1907.

[2]Dice, J. R., "The influence of stable temperature on the production and feed requirements of dairy cows," J. Dairy Sci., *23*, 61, 1940.

TABLE 2. - HISTORY OF THE COWS

Cow No.	Birth Date	Approximate Age, Years Oct. 1, 1948	Date of Last Calving	Number of Previous Lactations	Date of Last Breeding	Body Weight Lbs. Oct. 26, 1948	Average During October, 1948	
							Milk, lbs/day	Butterfat, %
Experimental Group								
Jersey 502	Sept. 6, 1944	4	May 17, 1948	1	July 14, 1948	820	16.6	6.2
Jersey 508	Dec. 14, 1944	3 3/4	June 22, 1948	1	Sept. 12, 1948	850	14.0	8.2
Jersey 933	Nov. 21, 1938	9 3/4	May 14, 1948	7	Sept. 6, 1948	840	18.8	6.5
Holstein 136	Oct. 23, 1944	4	June 19, 1948	1	Jan. 31, 1949	1220	33.6	3.8
Holstein 109	Sept. 3, 1943	5	May 9, 1948	1	July 10, 1948	1200	36.0	3.8
Holstein 14 (dry)	Dec. 8, 1939	9 3/4	Feb. 7, 1947	4	Farrow	1450		
Control Group								
Jersey 957	Jan. 24, 1941	8 3/4	May 14, 1948	4	Aug. 13, 1948	870	15.7	6.1
Jersey 979	Feb. 5, 1943	4 2/3	April 15, 1948	2	July 5, 1948	840	15.9	5.6
Jersey 977	Dec. 26, 1942	6 3/4	July 14, 1948	3	Sept. 13, 1948	910	17.2	5.6
Holstein 125	May 31, 1944	4 1/3	Aug. 24, 1948	2	March 8, 1949	1230	40.2	3.4
Holstein 95	April 9, 1943	5 1/2	May 13, 1948	2	Aug. 5, 1948	1170	29.4	3.6
Holstein 5 (dry)	July 20, 1939	9	May 6, 1947	5	Farrow	1400		

dan[3] suggested that dairy cows produced from 55 to 85 per cent more heat than was needed for maintenance of body temperature, and Armsby,[4] who pioneered heat-production measurements in cattle, saw no reason why a cow "might not be subjected to comparatively low temperatures without increasing metabolism for the sake of heat production solely."

Animals wintering outdoors respond to approaching cold weather by developing highly insulating coats of fur[5] and subcutaneous fat. Moreover, by driving the blood from the surface on declining temperature, the skin itself becomes an excellent insulator. Incidental to their productive, or even maintenance processes, farm animals consume large quantities of feed associated with high heat production, thus keeping the animal warm in cold weather, and making it unnecessary for the body to increase the oxidation of its tissues for maintaining normal body temperature.

Matching Cows: Some bodily properties, such as blood acidity (pH), remain remarkably constant; all individuals within the species—and perhaps all mammalian species—have at all times virtually the same pH. Other processes, such as those here reported on, are remarkably variable or labile. Unless they be identical twins in the same stages of lactation and gestation, no two cows produce the same amount of milk, or decline in milk production or in feed and water consumption at the same rate with advancing stages of lactation and gestation; and the individual variations in these respects are very great, indeed. Hence, while the Experimental and Control cows were matched with regard to obvious characteristics, such as body weight, stage of lactation, etc., the similarity between the matched animals with regard to rate of decline in milk yield with advancing stages of lactation and gestation is not and cannot be known. The comparisons between the results on the Experimental and Control here presented are, therefore, necessarily not strictly quantitative.

We observed (Missouri Res. Bul. 436) particularly dramatic individual differences in water consumption with increasing temperatures. One cow, J-212, increased her water consumption four-fold on increasing ambient temperature from 50 to 100°F, while other cows during the same temperature interval increased their consumption of water slightly or even reduced it (dry cow). Moreover, water consumption tends to vary with feed intake, milk yield, and body size (which in different species, from mice to elephants, is said to vary with the 0.88 power of body weight[6]).

It is evident then, that the comparison and interpretation of the results obtained on the Experimental and Control cows is not as simple as first appears.

It should be noted that our matched cows were not *pair-fed* in the sense of reducing the feed supply of the Control cows, which had the greater appetite,

[3]Jordan, W. H., "The feeding of animals," New York, p. 310, 1908.
[4]Armsby, H. P., "The nutrition of farm animals," New York, p. 454, 1917.
[5]See, for example, Mayer A., and Nichita, G., "Variation saisonnieres du metabolisme du lapin et modification de la fourrure," Ann. de physichochim, biol., 5, 621, 1929.
[6]Adolph, E. F., Science, *109*, 579, June 10, 1949.

to the level consumed by the matched Experimental cows. This, of course, introduced a serious ambiguity in the interpretation of the results in that the level of feed intake affects the levels of all other processes, including milk yield, water consumption, heat production, pulse rate, respiration rate, body temperature, and so on. So that we do not really know how much feed consumption as such and how much other factors associated with increasing temperature affected each of these reactions. The reason for not pair-feeding is that it was desired to know the effect of temperature on feed consumption. It seems that unless we used identical twins in the same stages of gestation and lactation, we could not avoid many indeterminate factors which affect differently the matched cows. For instance, the mere housing under the confined conditions of the Climatic Laboratory, regardless of the temperature employed, exerts an unfavorable effect on the cows, especially the large cows. However, we plan to use the paired-feeding method, to eliminate feed as an influencing factor, at the first opportunity. This discussion emphasizes the fact that the data from the present research are valuable for the general trends they furnish rather than for statistically quantitative analysis.

DATA

Because of the aforelisted great individual variations and complex interdependencies, we present in text Figs. 3 to 7 trends, semi-quantitative *pictures* (rather than quantitative "laws") of the relative slopes of the Experimental and Control cows. Average *numerical values* for the results obtained on the Experimental and matched Control animals at each temperature level are given in Tables 3 to 8 in the appendix.

Milk Yield and Butterfat Percentage: Fig. 3 shows milk yield and fat percentage as percentages of the initial levels (50°F equals 100 per cent), supplemented in the appendix by Tables 3 to 5 giving the absolute average numerical milk yields for each temperature level of the Experimental cows and also of the matched Control cows for the same time interval.

A conspicuous feature of the *Control* cows in Fig. 3 is the *increase* in fat percentage and *decrease* in milk yield during the period when the ambient temperature dropped to 4°F (from the normal Control level of 50°F). In the *Experimental* cows the rise in fat percentage and the decline in milk yield with declining temperature are less precipitous due, no doubt, to the gradualness of the lowering of the temperature, thereby permitting acclimatization, for example, by growing hair, and so on.

It appears from Fig. 3 that the Experimental Jerseys show relatively greater declines in milk yield and rise in fat percentage with declining temperatures than the Holsteins. While the large cows (Holsteins) are more sensitive than the smaller (Jerseys) to *high temperatures* (Missouri Res. Bul. 425), the small cows are more sensitive to the *low temperatures*. Similar trends (not shown) to those of total milk yield were obtained on FCM (fat-corrected milk to 4 per cent) and butterfat, lbs., for both groups of cows.

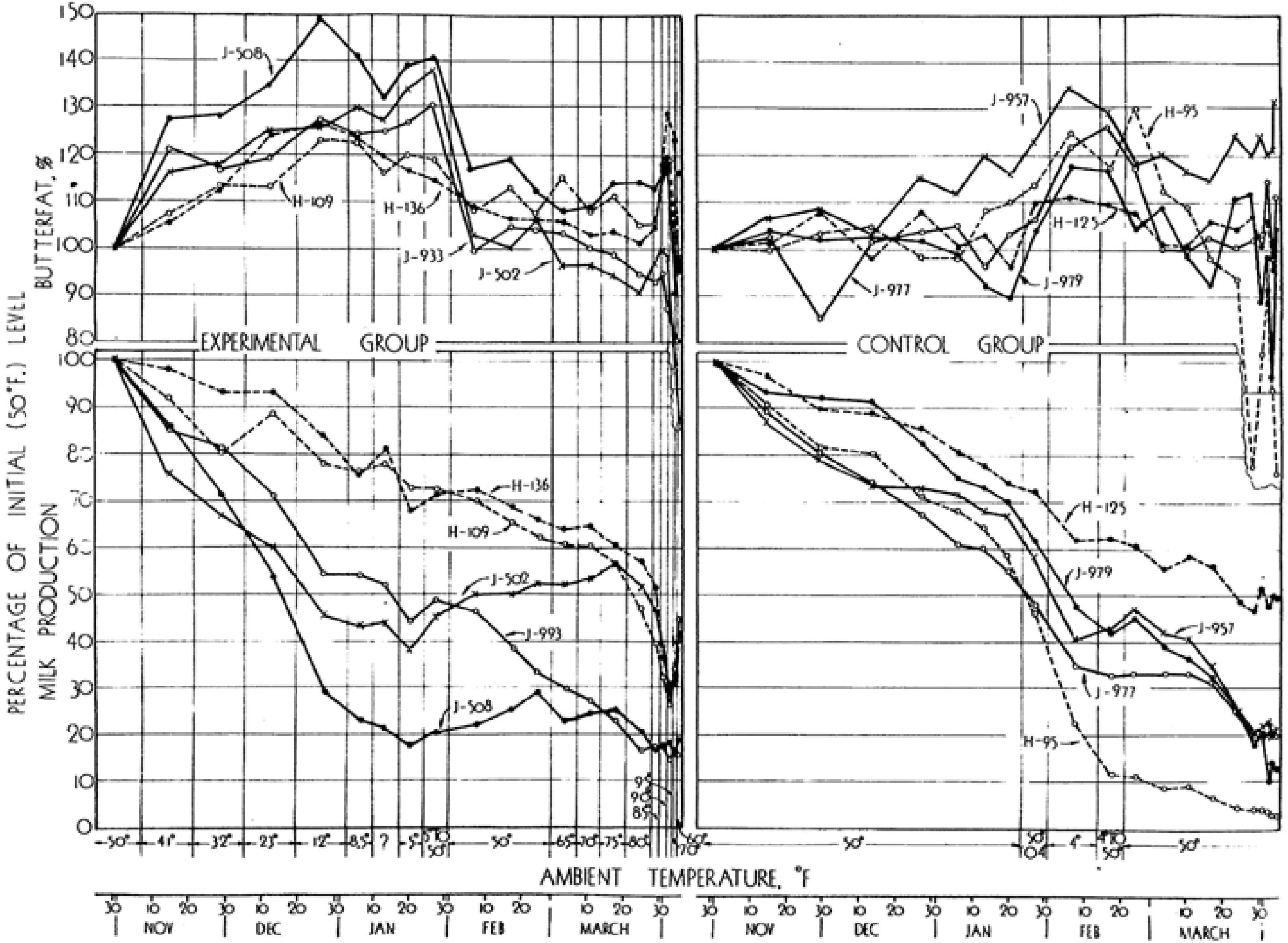

Fig. 3.—Milk production and butterfat percentage of the Control (right) and Experimental (left) Groups of cows in terms of the initial (50°F) values as 100 per cent. Note greater sensitiveness of the Jerseys (continuous line) to declining temperatures and Holsteins (broken lines) to rising temperatures; sharp rise in butterfat per cent in Control cows on declining temperatures; increased milk yield in J-502 and J-508 after the temperature was brought back to 50°F. The FCM curves (plotted as percentages of the initial level) are not shown because their shape is virtually identical with the milk curves.

Summarizing, the fat percentage rises with decreasing temperature from 50°F to 4°F and returns to the normal level on increasing temperature from 4 to 50°F; it tends to rise again on increasing temperature above 85°F. The *fat percentage rise* is associated in part with *milk yield decline* regardless of the causative factors, high or low temperature.

Body Weight: There appears to be no significant difference in body weight during the three months when the Experimental cows were subjected to lowering temperatures. (Fig. 4). A conspicuous feature of the Experimental Group in Fig. 4 is the sharp decline in body weight following 80°F. It appears that the larger the animal the more sensitive it is to rising environmental temperature.

Numerical data on the two groups for each temperature level are presented in the appendix in Table 6.

Feed Consumption Data: The hay consumption curves (in terms of percentage of the initial level) are shown in the middle segment of Fig. 4; the total TDN as percentage of initial level, and TDN per 100 lbs. live weight, are presented in Fig. 5. Numerical values of TDN are in Table 7 in the appendix.

The hay consumption data show a dramatic rise in the *Control* cows during the brief exposure to the 4°F temperature. The rise in feed consumption in the *Experimental* cows (temperature lowered *gradually* to 4°F) did not show such an impressive rise, which is somewhat puzzling, but may be attributed to an acclimatization tendency to gradually lowered temperatures. The relatively greater rise in hay consumption of the *Control* cows over the *Experimental* cows during March is, of course, associated with the rise in ambient temperature (from 65 to 95°F) in the Experimental chamber which depressed the feed consumption and body weight. The lower curves in Fig. 5 show that the ratios of TDN consumption per 100 lbs. live weight do not rise during March in the Control cows, indicating that the absolute rise in feed consumption is associated with increasing body weight due to advancing stage of gestation.

Water Consumption Data: Their outstanding feature during the Summer 1948 experiment was great individual variability with rising temperature as illustrated by the four-fold rise in water consumption from 50 to 100°F in J-212 and decline in H-106 (Missouri Res. Bul. 436). The present winter data, however, as illustrated in the upper curves of Fig. 4, in Fig. 6, and in Table 8 (in the appendix) show that below 50°F the water consumption tends to parallel the feed consumption; above 50° it rises up to 80°F followed by a decline with a further rise in temperature to 95°F.

The decline in water consumption with increasing temperature above 80°F shown in Fig. 4 is apparently the resultant of: a) decline in hay consumption (the water to hay consumption ratio tends to be approximately constant as demonstrated in the upper curves of Fig. 6); b) decline in milk production (milk contains about 87 per cent water); c) as well as rise in homeothermic need for water because of its cooling properties.

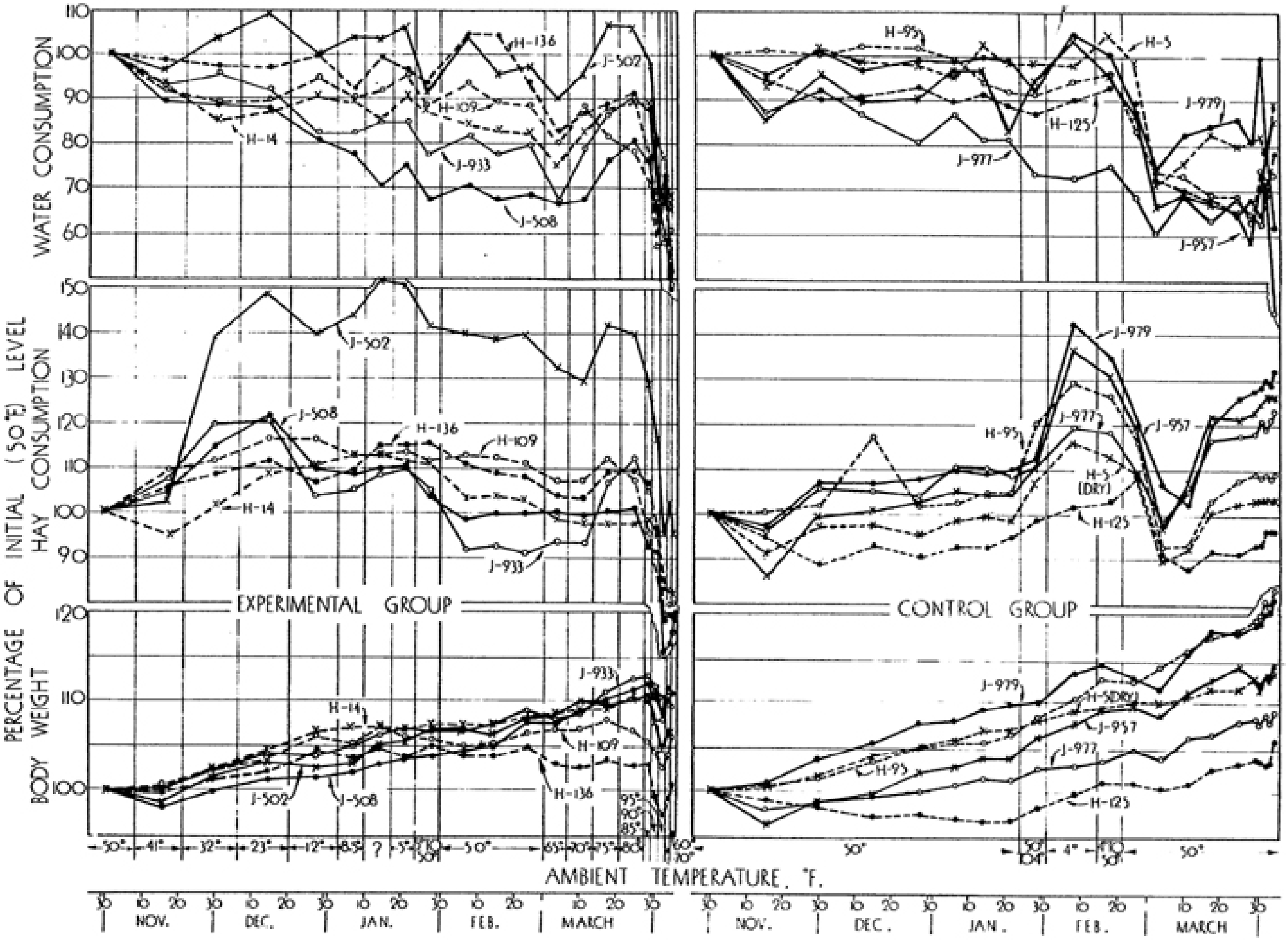

Fig. 4.—Body weight (lower segments), hay consumption (middle segment), and water consumption in the Control (right) and Experimental (left) groups of cows in terms of percentages of the initial (50°F) level. Note more rapid rise in body weight and feed consumption in Control cows on lowering temperature to 4°F. The increase in hay consumption in J-502 is only apparent due to a low initial value which has the effect of magnifying the actual consumption at the lower temperatures. Note the strong tendency for the water consumption to parallel the hay consumption; also the parallelism between body weight increase and hay consumption increase in the latter part of the experiment in the Control cows.

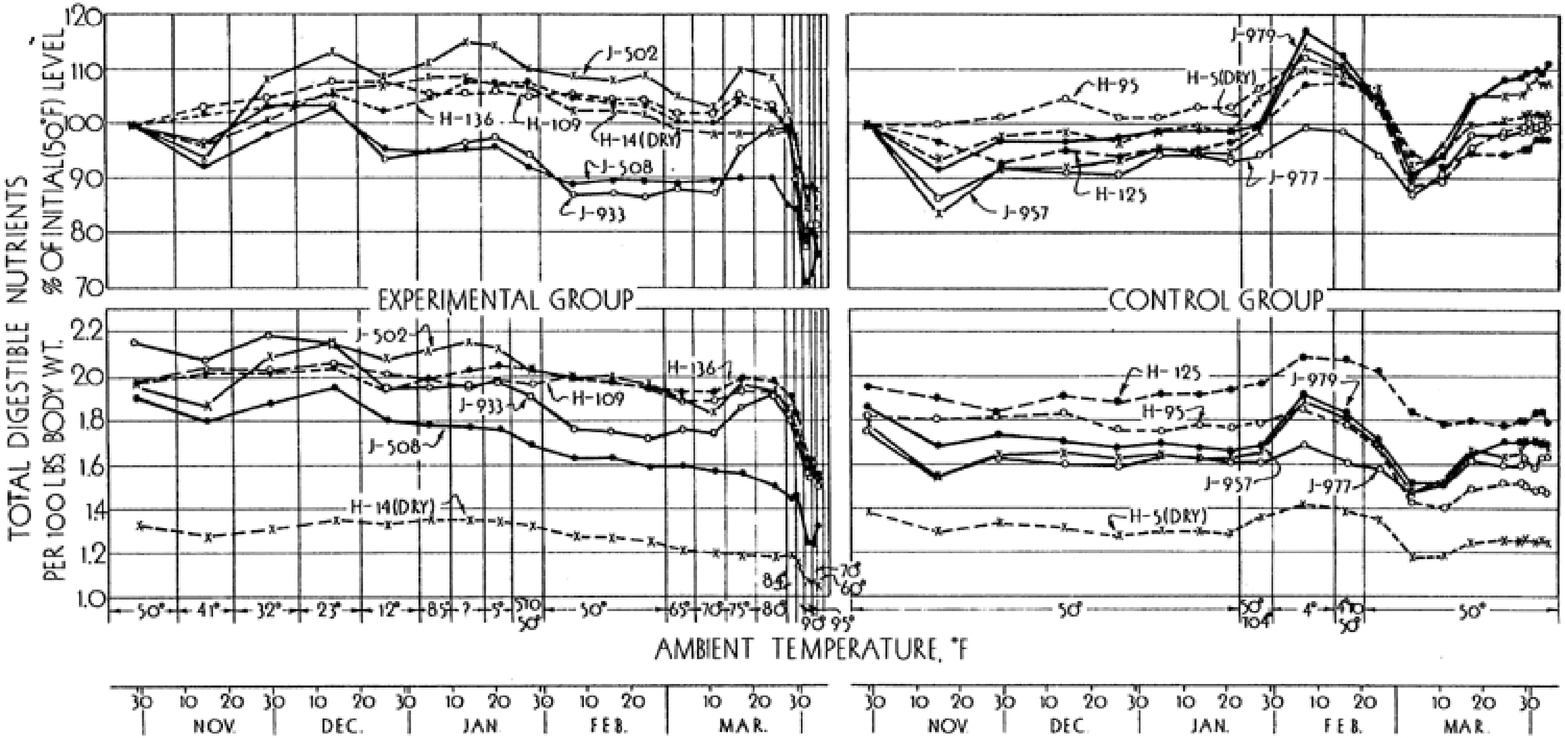

Fig. 5.—TDN consumption per animal and per 100 lbs. body weight as percentage of the initial (50°F) level. Note the sudden rise in TDN consumption in the Control cows during declining temperature. During the end of March the *total* TDN consumption per animal increased but not *per 100 lbs. body weight*, demonstrating that increase in TDN consumption per animal is due to increased body weight.

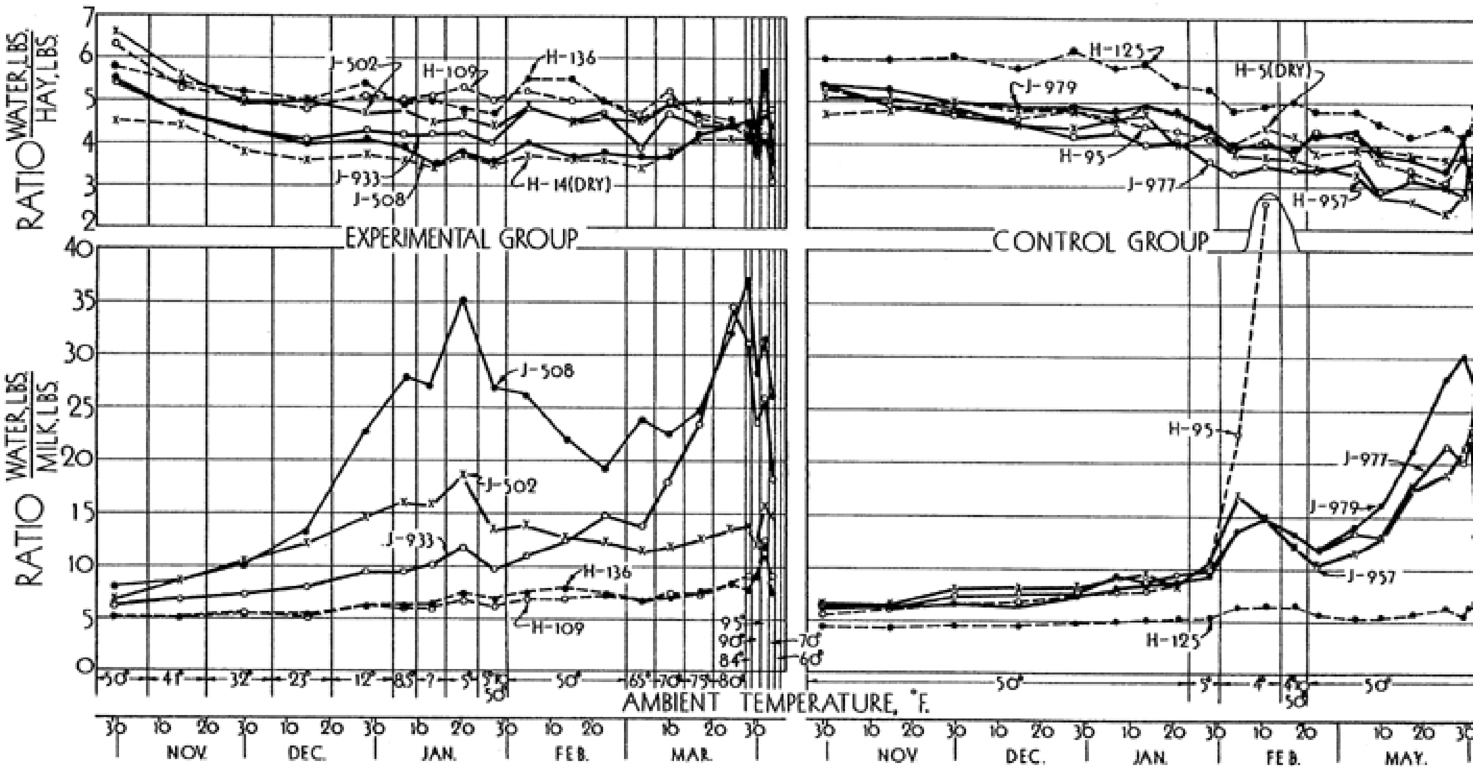

Fig. 6.—Ratios of water consumption to hay consumption (upper segment) and to milk production (lower segment) for both the Experimental (left) and Control (right) cows. The changes in the water to milk ratio at the low temperatures usually parallel, and are presumably caused by, changes in the feed consumption. In the Control cows, the increase in the water to milk ratio during March apparently reflects the low milk production and increased feed consumption associated with increased body weight.

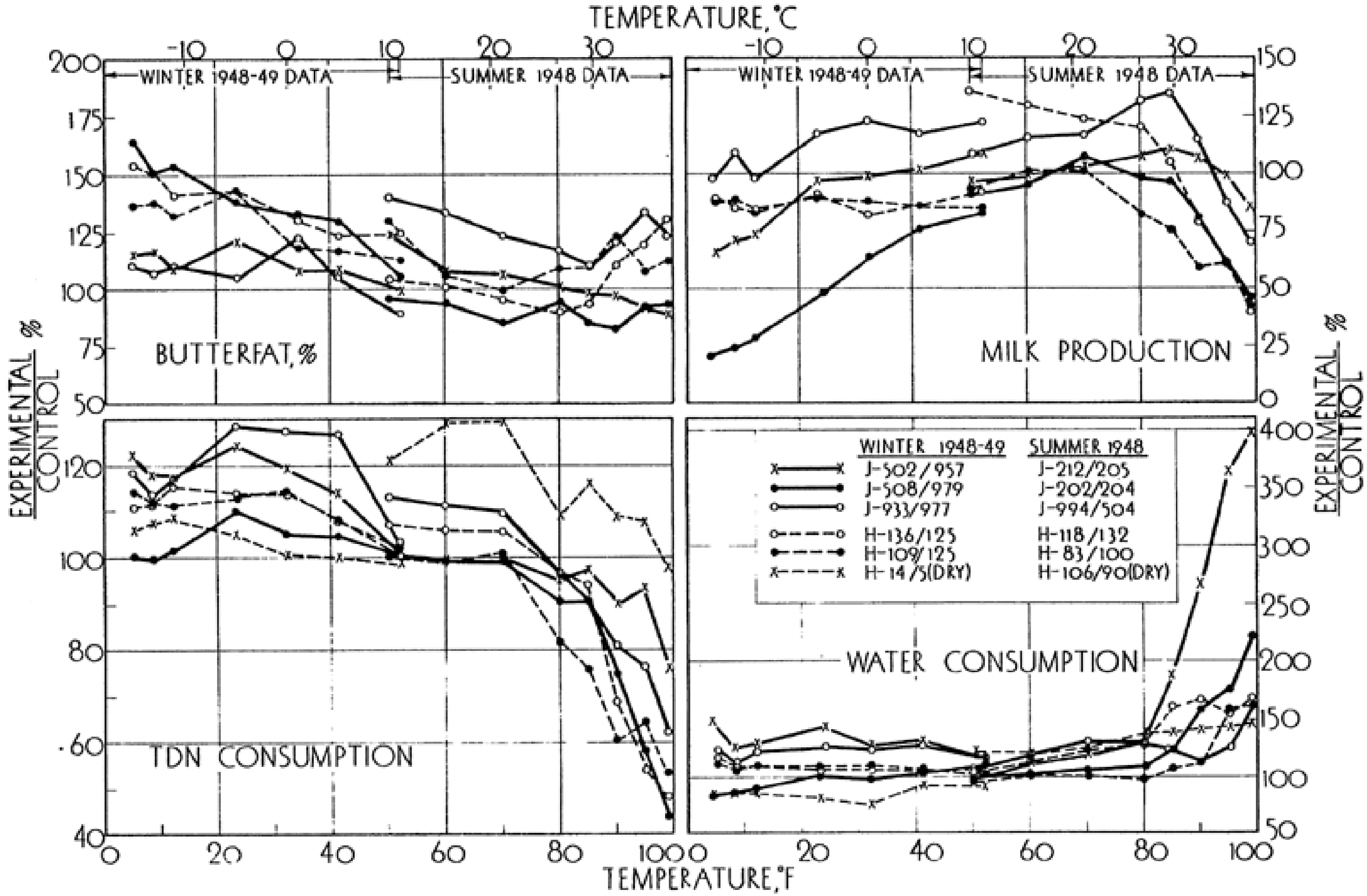

Fig. 7.—Changes in total milk yield, its butterfat per cent, feed (TDN) and water consumption in terms of ratios of the values obtained on the Experimental cows to their matched Controls. The curves from 50°F *down* to 0°F represent the effects of *declining* temperatures (Winter, 1948-49); from 50° *up* to 100°F, the effects of *rising* temperatures (Summer, 1948). Due to the abnormally rapid decline in milk production in Control Cow H-95, it was believed that H-125 would be a more typical Control for comparing H-109 (Experimental cow). H-100 was sick during the 95°F temperature period, and consequently the comparison for this time interval is not representative of H-83.

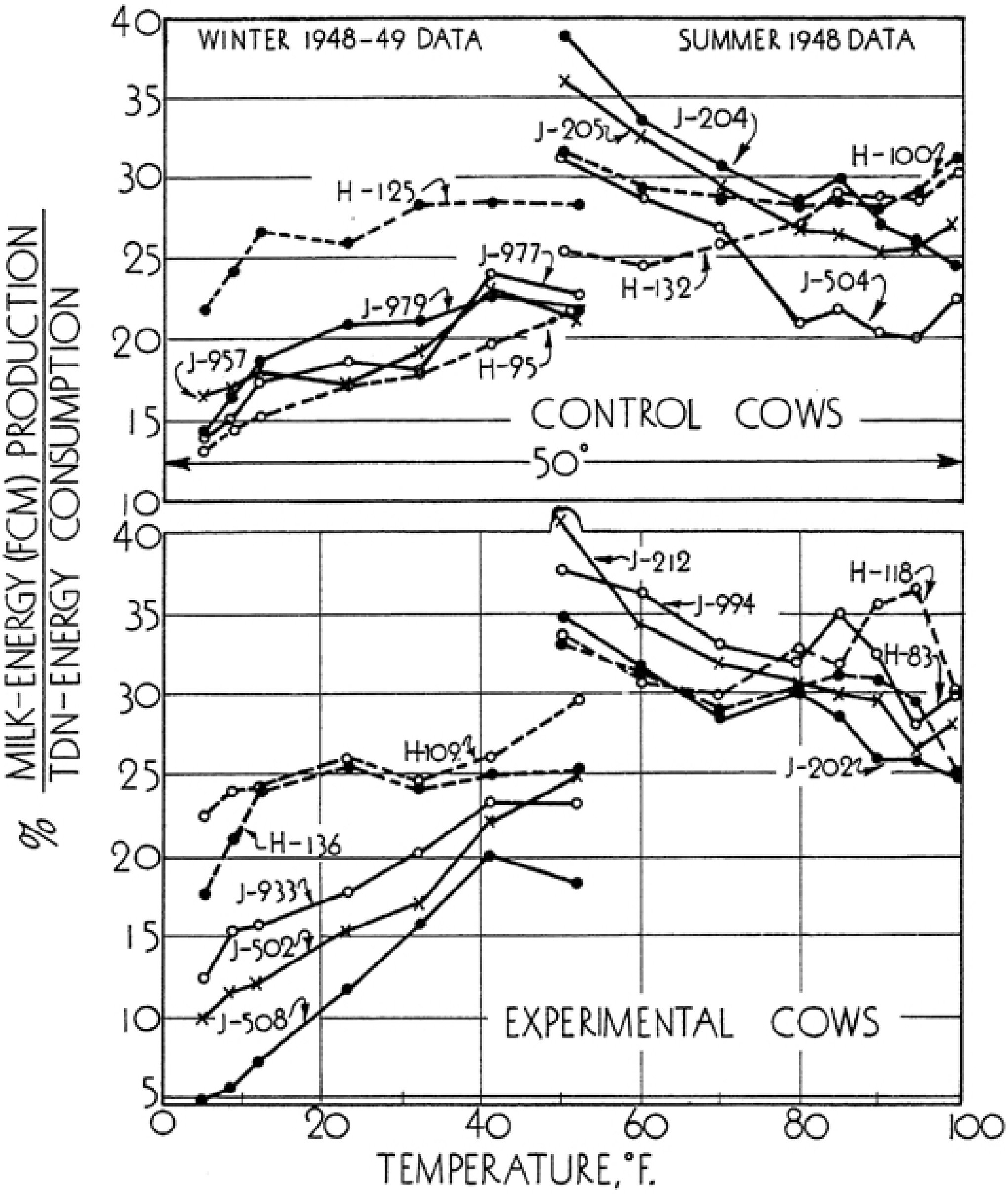

Fig. 8.—Effect of environmental temperature, 0 to 100°F (50 to 0°F, Winter, 1948-49 data; 50 to 100°F, Summer, 1948 data), on the economy or efficiency of milk production represented by the ratio of FCM Calories to TDN Calories consumed (assuming that one lb. FCM is equivalent to 340 Calories and one lb. TDN to 1814 Calories). The similarity in shape between the Control curves (upper segment) and Experimental (lower segment) indicates that the advance of the stages of lactation and gestation exerted a profound influence on the shapes of the curve. There were, no doubt, changes in body composition as well as in body weight in both groups of cows during the periods. Hence, the changes in economy or efficiency indicated by the curves as functions of temperature are more apparent than real. The summer cows began the test in earlier stages of lactation and gestation and produced much more milk than the winter cows (see data in Missouri Res. Bul. 425), hence the higher ratios for the summer cows. The rise in the ratio of the Experimental animals at the higher temperatures is probably an artifice resulting from the increased spilling of saliva and water over the left-over hay, which was not then dried before weighing; therefore, the consumed hay appeared to be less than the actual consumption. Consequently, the ratios of milk energy produced to TDN consumed at the higher temperatures are apparently higher than actually occurred.

Comparison of Data Obtained During Declining and Rising Temperature Periods: Fig. 7 shows a comparison of data (milk, butterfat per cent, TDN, water consumption) obtained during increasing temperatures from 50 to 105°F (*Summer, 1948*) and declining temperatures from 50° down to about 0°F (*Winter, 1948-49*) in terms of the ratios of the values obtained on the Experimental Group (varying temperatures) to the values of the Control Cows (constant temperature at 50°F) for the same time intervals.

From Fig. 7 (upper left section) it appears that the lowest butterfat percentage occurs between 60 and 80°F and increases with both rising and, especially, with declining temperatures.

The milk yield (upper right-hand section) appears to be maximal and at greatest economy (as inferred from Figs. 7 and 8) around 50°F. However, the picture might have appeared different if the initial temperature had been other than 50°F. At temperatures higher and lower than 50°F milk yield appears to decrease, beginning a drastic decline at 80°F. The depressing effect on milk yield with increasing temperature is evidently much greater than with decreasing temperature. The Jerseys appear to be less affected than the Holsteins by rising temperatures while the Holsteins are less affected than the Jerseys by declining temperatures.

The effect of high temperatures on TDN consumption (lower left-hand section Fig. 7) is more pronounced than the effect on low temperatures. As in the case of milk production, the Holsteins (except the dry Holstein) appear more affected by the high temperatures while the Jerseys are more affected by low temperatures. Here, too, the critical high temperature appears to be 80°F.

The critical temperature for water consumption (lower right-hand section Fig. 7) is also at 80°F, following which individual variations begin to become striking. At temperatures below 80°F, the water consumption parallels the feed consumption as demonstrated by Fig. 5.

From these ratios it appears that the optimal temperature for milk production is around 50°F but, of course, this is a first rough approximation which needs to be tested by many experiments. There is no question but that the critical high temperature for milk and butterfat production, and for feed and water consumption is 80°F. There does not appear to be a sharp critical low temperature; the decline is gradual, with the Jersey cows being more affected by falling temperatures (below 50°F) than the Holsteins. These critical temperatures are for acclimatized cows that have been exposed to gradually increasing or decreasing temperatures for relatively long periods. For cows not thus acclimatized, the effects of the critical temperatures are more striking as indicated by the data on the Control cows in this *Winter* experiment and in the *Summer, 1948* experiment (Missouri Res. Bul. 425).

SUMMARY AND ABSTRACT

Data are presented on the influence of ambient temperature, 4° to 95°F, on milk production, fat percentage, feed and water consumption, and body weight of twelve dairy cows, six in each, "Control" and "Experimental" chamber of the Climatic Laboratory. Lowering of temperature from 50° to 4°F increased feed consumption and butterfat percentage, but decreased somewhat the milk yield; rising temperature from 80° to 95°F depressed milk production, feed consumption, and body weight. Water consumption tends to parallel feed consumption, but, with great individual differences, tends to increase with increasing temperatures above 80°F. The effects of sudden lowering of temperature (from 50° to 4°F) on the Control or unacclimatized cows was found to be much more striking than on the Experimental or acclimatized cows.

The optimal temperature zone—quantity and efficiency—for milk production appears to be not far from 50°F, a statement that has to be substantiated. The critical high temperature is apparently 80°F; whereas no critical low temperature is evident, a gradual effect was observed. Rising temperatures are more detrimental to the Holstein cows and declining temperatures to Jersey cows. The effect of lowering temperatures below 50°F is much less for both breeds than the effect of rising temperatures above 50°F.

APPENDIX

TABLE 3--AVERAGE MILK PRODUCTION, LBS./DAY, FOR THE DIFFERENT TEMPERATURE LEVELS

Temperature Levels, °F Exper.	Temperature Levels, °F Contr.	Exper. J-502	Contr. J-957	Exper. J-508	Contr. J-979	Exper. J-933	Contr. J-977	Exper. H-136	Contr. H-125	Exper. H-109	Contr. H-95
52	53	16.6	14.0	13.2	15.7	18.5	15.0	34.2	39.8	36.8	26.6
41	50	12.6	12.2	11.3	14.7	15.8	13.4	33.6	38.7	33.8	24.2
32	50	11.1	11.1	9.4	14.5	15.0	12.1	31.9	35.8	29.6	21.7
23	50	10.0	10.3	7.1	14.4	13.1	11.1	31.9	35.4	32.6	21.4
12	49	7.6	10.2	3.8	13.0	10.0	10.1	28.7	34.1	28.7	18.9
8.5	49	7.2	10.0	3.0	11.8	10.0	9.1	25.9	32.5	28.0	18.0
No Temp. Contr.		7.3	9.5	2.8	11.5	9.6	9.0	27.8	30.9	28.7	17.1
5	50	6.3	9.4	2.3	11.0	8.2	8.3	23.3	29.5	26.6	15.6
5-50	50-5	7.5	8.2	2.7	9.7	9.0	7.2	24.4	28.7	26.6	12.3
50	4	8.3	5.7	2.9	7.5	8.5	5.2	24.7	24.6	25.8	6.0
50	4-50	8.3	6.0	3.3	6.6	7.1	4.9	23.5	24.8	24.0	3.1
50	50	8.7	6.6	3.8	7.1	6.1	5.0	22.5	24.1	22.9	2.9
65	50	8.7	5.9	3.0	6.1	5.5	5.0	21.9	22.3	22.4	2.3
69	50	8.9	5.7	3.2	5.7	5.0	5.0	22.2	23.3	22.2	2.4
74	50.5	9.4	4.9	3.3	5.1	4.2	4.7	20.8	22.4	20.9	1.7
80	50.5	8.6	3.5	2.7	3.9	3.0	3.7	19.5	19.4	17.3	1.2
84	51	7.8	2.9	2.2	2.8	3.2	2.9	17.6	18.6	14.4	1.0
90	51	6.6	3.1	2.3	3.2	3.2	3.0	12.5	20.4	11.8	1.0
94.5	50	4.7	3.2	2.4	1.6	2.6	3.4	10.3	19.0	9.6	.9
70	50	5.1	2.8	2.1	2.2	3.0	3.1	11.4	20.1	12.5	.7
60	56	6.8	2.9	2.5	2.0	2.9	3.0	14.2	19.8	16.6	.6

TABLE 4--AVERAGE BUTTERFAT, %, FOR THE DIFFERENT TEMPERATURE LEVELS

Temperature Levels, °F		Exper. J-502	Contr. J-957	Exper. J-508	Contr. J-979	Exper. J-933	Contr. J-977	Exper. H-136	Contr. H-125	Exper. H-109	Contr. H-95
Exper.	Contr.										
52	53	5.61	5.59	5.37	5.06	5.37	5.96	3.73	3.28	4.09	3.65
41	50	6.52	5.97	6.86	5.27	6.50	6.11	3.93	3.32	4.12	3.64
32	50	6.62	6.08	6.90	5.16	6.26	5.07	4.19	3.53	4.64	3.77
23	50	7.01	5.76	7.23	5.20	6.40	6.05	4.63	3.22	4.64	3.82
12	49	7.06	6.45	8.00	5.15	6.84	6.17	4.71	3.54	5.03	3.59
8.5	49	7.31	6.27	7.59	5.00	6.67	6.25	4.60	3.30	5.00	3.60
No Temp.	Contr.	7.14	6.70	7.11	4.68	6.70	5.75	4.46	3.38	4.74	3.95
5	50	7.51	6.50	7.47	4.54	6.80	6.15	4.34	3.16	4.90	4.02
5-50	50-5	7.72	6.88	7.56	5.28	7.01	6.35	4.27	3.61	4.85	4.15
50	4	5.76	7.54	6.24	5.95	5.34	7.25	4.07	3.65	4.43	4.55
50	4-50	5.62	7.21	6.32	5.92	5.62	7.51	3.97	3.59	4.62	4.28
50	50	5.96	6.61	6.02	5.28	5.58	6.99	3.96	3.54	4.39	4.74
65	50	5.41	6.72	5.80	5.52	5.55	5.97	3.94	3.29	4.70	4.10
69	50	5.41	6.52	5.83	5.00	5.36	5.94	3.83	3.41	4.40	3.98
74	50.5	5.29	6.42	6.11	4.68	5.31	6.10	3.86	3.30	4.54	3.58
80	50.5	5.09	6.94	6.13	5.61	5.08	5.97	3.77	3.42	4.29	3.42
84	51	5.45	6.76	6.06	5.66	5.00	6.04	3.90	3.51	4.30	1.95
90	51	5.58	6.92	6.24	4.50	5.07	6.14	4.38	3.29	4.80	2.84
94.5	50	5.50	6.72	6.42	4.98	4.68	6.82	4.80	3.30	4.86	3.34
70	50	4.20	6.74	4.87	3.69	4.33	5.84	4.59	3.14	4.15	2.55
60	56	3.53	7.35	6.24	5.24	4.30	6.64	3.63	3.39	3.90	1.90

TABLE 5--AVERAGE F C M, LBS./DAY, FOR THE DIFFERENT TEMPERATURE LEVELS

(FCM is fat corrected milk to 4%)

Temperature Levels, °F		Exper. J-502	Contr. J-957	Exper. J-508	Contr. J-979	Exper. J-933	Contr. J-977	Exper. H-136	Contr. H-125	Exper. H-109	Contr. H-95
Exper.	Contr.										
52	53	20.6	17.4	16.0	18.3	22.4	19.5	32.7	35.6	37.4	25.0
41	50	17.3	15.9	16.2	17.6	21.7	17.6	33.1	34.6	34.3	22.7
32	50	15.4	14.6	13.5	17.1	20.2	14.1	32.9	33.1	32.3	21.0
23	50	14.5	13.1	10.5	17.0	17.8	14.4	34.8	31.2	35.5	20.8
12	49	11.1	13.9	6.1	15.3	14.2	13.4	31.7	31.5	33.0	17.8
8.5	49	10.8	13.4	4.6	13.6	14.0	12.1	28.2	29.1	32.2	16.9
No Temp.	Contr.	10.7	13.3	4.1	12.7	13.5	11.4	29.9	28.1	31.7	17.1
5	50	9.6	12.9	3.5	11.8	11.6	11.0	24.3	26.0	30.2	15.6
5-50	50-5	11.7	11.8	4.2	11.6	13.0	9.8	25.5	27.0	29.8	12.7
50	4	10.5	8.7	3.9	9.8	10.2	7.7	25.1	23.1	27.3	6.5
50	4-50	10.3	8.9	4.4	8.5	8.8	7.5	23.5	23.3	26.2	3.2
50	50	11.3	9.2	4.9	8.5	7.6	7.2	22.5	22.3	24.3	3.2
65	50	10.5	8.3	3.8	7.5	6.8	6.5	21.6	20.0	24.8	2.3
69	50	10.8	7.8	4.1	6.6	6.0	6.4	21.5	21.2	23.5	2.4
74	50.5	11.2	6.7	4.3	5.6	5.0	6.2	20.5	20.0	22.5	1.6
80	50.5	10.0	5.0	3.6	4.8	3.5	4.8	18.9	17.7	18.1	1.1
84	51	9.4	4.1	2.9	3.5	3.7	3.8	17.3	17.2	15.0	.7
90	51	8.2	4.4	3.1	3.4	3.7	3.9	13.2	18.3	13.2	.8
94.5	50	5.8	4.5	3.3	1.8	2.9	4.8	11.5	17.0	10.9	.8
70	50	5.3	3.9	2.4	1.8	3.1	3.9	12.4	17.4	12.9	.6
60	56	6.3	4.4	3.3	2.4	3.0	4.2	13.3	18.0	16.4	.4

TABLE 6--AVERAGE BODY WEIGHT, LBS., FOR THE DIFFERENT TEMPERATURE LEVELS

Temperature Levels, °F Exper.	Temperature Levels, °F Contr.	Exper. J-502	Contr. J-957	Exper. J-508	Contr. J-979	Exper. J-933	Contr. J-977	Exper. H-136	Contr. H-125	Exper. H-109	Contr. H-95	Exper. H-14	Contr. H-5
52	53	797	864	854	844	835	908	1221	1207	1200	1180	1441	1400
41	50	786	832	837	852	836	887	1219	1195	1208	1188	1443	1404
32	50	809	854	852	874	855	896	1236	1184	1227	1198	1477	1424
23	50	822	861	863	890	868	903	1247	1172	1244	1220	1507	1454
12	49	817	882	866	909	866	907	1275	1176	1272	1238	1537	1468
8.5	49	821	889	871	911	877	913	1266	1168	1263	1244	1544	1480
No Temp. Contr.		838	896	879	922	886	921	1278	1166	1285	1244	1543	1495
5	50	839	896	884	926	893	920	1266	1167	1272	1254	1541	1496
5-50	50-5	852	916	886	928	891	931	1282	1185	1270	1277	1548	1512
50	4	850	929	891	956	891	934	1269	1205	1259	1301	1547	1526
50	4-50	847	943	896	964	896	939	1268	1219	1261	1329	1546	1531
50	50	861	947	918	952	909	951	1279	1218	1276	1326	1560	1540
65	50	863	936	918	940	901	942	1256	1209	1281	1344	1563	1539
69	50	876	958	929	975	908	962	1251	1215	1282	1365	1572	1548
74	50.5	872	972	940	996	926	965	1263	1236	1294	1386	1574	1561
80	50.5	878	985	950	994	939	978	1254	1244	1279	1393	1589	1560
84	51	881	974	956	1002	942	982	1257	1250	1266	1408	1582	1578
90	51	857	962	942	1004	932	976	1211	1248	1252	1412	1598	1571
94.5	50	833	976	928	1013	900	986	1187	1243	1230	1432	1583	1579
70	50	849	971	951	1014	923	978	1210	1246	1248	1426	1591	1573
60	56	849	986	947	1027	913	987	1230	1275	1272	1447	1597	1586

TABLE 7--AVERAGE TOTAL DIGESTIBLE NUTRIENTS, LBS./DAY, FOR THE DIFFERENT TEMPERATURE LEVELS

(Computed with the aid of F. B. Morrison's "Feeds and Feeding", 1948)

Temperature Levels, °F		Exper. J-502	Contr. J-957	Exper. J-508	Contr. J-979	Exper. J-933	Contr. J-977	Exper. H-136	Contr. H-125	Exper. H-109	Contr. H-95	Exper. H-14	Contr. H-5
Exper.	Contr.												
52	53	15.6	15.4	16.3	15.7	18.0	15.9	24.1	23.5	23.7	21.5	19.1	19.5
41	50	14.7	12.9	15.1	14.4	17.4	13.7	24.6	22.7	24.6	21.5	18.4	18.3
32	50	16.9	14.1	16.0	15.2	18.7	14.6	25.0	21.8	24.9	21.8	19.3	19.1
23	50	17.7	14.2	16.8	15.2	18.7	14.5	25.5	22.4	25.6	22.5	20.3	19.2
12	49	17.0	14.4	15.6	15.3	16.9	14.4	24.7	22.1	25.6	21.8	20.5	18.8
8.5	49	17.4	14.7	15.5	15.5	17.1	15.0	25.2	22.4	25.1	21.8	20.8	19.3
No Temp. Contr.		18.0	14.6	15.6	15.5	17.4	15.0	26.0	22.4	25.1	22.2	20.8	19.4
5	50	17.9	14.6	15.6	15.5	17.6	14.8	26.0	22.7	25.2	22.2	20.6	19.3
5-50	50-5	17.2	15.2	15.0	15.7	17.0	15.0	26.0	23.3	24.9	22.9	20.5	20.5
50	4	17.0	17.6	14.5	18.4	15.7	15.8	25.3	25.2	25.1	24.1	19.6	21.6
50	4-50	16.9	17.1	14.6	17.7	15.7	15.7	25.1	25.3	24.8	23.7	19.6	21.3
50	50	17.0	16.0	14.6	16.4	15.6	15.0	25.0	24.7	24.8	22.3	19.5	20.8
65	50	16.4	13.9	14.6	14.3	15.9	13.9	24.3	22.2	24.2	19.2	18.9	18.1
69	50	16.1	14.8	14.6	14.8	15.8	14.5	24.2	21.7	24.2	19.3	18.8	18.4
74	50.5	17.2	16.2	14.7	16.4	17.2	15.6	25.1	22.3	25.0	20.6	18.8	19.5
80	50.5	17.0	16.2	14.7	17.0	17.9	15.6	24.8	22.2	24.6	21.2	18.8	19.7
84	51	16.0	16.3	13.9	17.1	17.0	15.7	24.0	22.5	23.5	21.4	18.9	19.9
90	51	15.0	16.5	13.8	17.2	16.2	16.0	22.2	22.5	21.7	21.3	18.7	19.9
94.5	50	13.2	16.7	11.6	17.3	14.0	15.8	19.2	22.9	19.0	21.4	16.9	19.9
70	50	13.8	16.6	11.8	17.2	14.7	16.0	19.4	22.9	19.4	21.3	16.9	19.9
60	56	13.2	16.6	12.5	17.5	13.7	16.2	19.2	22.9	19.4	21.4	16.8	19.9
Range, lbs./day, for the entire period for:													
Hay Consumption:		16-26	16-25	13-24	17-26	16-25	17-22	23-26	25-33	23-24	25-35	21-30	24-31
Digestible Protein:		2.5-3.5	2.4-3.4	3.1-2.2	2.6-3.6	2.6-3.6	2.6-3.1	3.7-5.1	4.2-4.9	3.6-5.0	3.7-4.7	3.2-4.0	3.5-4.2
Grain Consumption:		7-5	6-4	7-4	7-5	8-6	7-5	9-8	10	10-8	9-7	6	6

TABLE 8--AVERAGE WATER CONSUMPTION, GAL./DAY, FOR THE DIFFERENT TEMPERATURE LEVELS

Temperature Levels, °F Exper.	Temperature Levels, °F Contr.	Exper. J-502	Contr. J-957	Exper. J-508	Contr. J-979	Exper. J-933	Contr. J-977	Exper. H-136	Contr. H-125	Exper. H-109	Contr. H-95	Exper. H-14 (Dry)	Contr. H-5 (Dry)
52	53	13.3	11.3	12.9	11.6	13.7	11.5	21.4	20.7	22.4	17.1	14.1	15.2
41	50	12.8	9.7	11.5	11.1	12.8	10.0	21.1	19.6	20.6	17.3	13.2	14.2
32	50	13.8	10.8	11.4	11.5	13.1	10.6	20.8	18.7	20.0	17.2	12.0	15.5
23	50	14.5	10.1	11.3	11.2	12.6	10.0	20.7	18.8	20.1	17.5	12.3	15.0
12	49	13.3	10.2	10.4	11.5	11.3	9.3	21.3	19.3	21.2	17.1	12.8	14.9
8.5	49	13.8	10.9	10.0	11.5	11.3	10.0	19.7	18.6	20.2	16.6	12.6	14.5
No Temp. Contr.		13.8	10.9	9.1	11.6	11.6	9.4	21.2	19.0	20.6	16.1	12.0	15.6
5	50	14.1	9.4	9.7	11.5	11.6	9.4	20.6	18.5	21.4	15.8	12.8	15.0
5-50	50-5	12.2	10.7	8.7	10.7	10.6	8.5	20.1	18.0	19.9	15.7	12.3	15.0
50	4	13.8	11.7	9.1	12.2	11.2	8.4	22.3	18.7	21.0	16.2	11.9	14.9
50	4-50	12.7	10.8	8.7	11.7	10.6	8.7	22.3	19.3	20.0	16.5	11.7	16.0
50	50	12.9	9.8	8.8	10.2	10.9	7.9	20.1	18.6	19.8	14.3	11.6	15.0
65	50	12.0	7.5	8.6	8.7	9.2	7.0	17.7	15.1	18.0	12.8	10.6	10.9
69	50	12.7	7.9	8.7	9.6	10.8	8.0	18.6	14.5	19.8	12.6	11.6	11.6
74	50.5	14.2	7.6	9.8	9.8	11.8	7.3	19.0	14.2	18.3	11.8	12.4	12.6
80	50.5	14.1	7.4	10.4	10.0	12.4	7.9	19.5	13.3	17.5	11.7	12.6	12.3
84	51	13.0	6.6	9.8	9.4	12.0	7.5	16.4	14.1	15.8	10.8	12.6	12.4
90	51	9.6	8.0	7.8	11.6	9.1	7.2	13.8	13.5	12.8	12.8	11.4	12.5
94.5	50	8.9	9.0	9.1	9.2	8.1	9.1	15.6	14.4	13.0	12.4	10.8	11.8
70	50	9.1	9.7	6.6	7.2	6.6	4.9	10.2	16.2	13.6	12.6	9.2	13.6