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Environmental Physiology

With Special Reference to Domestic Animals

IX. Milk Production and Feed and Water Consumption Responses of Brahman, Jersey, and Holstein Cows to Changes in Temperature, 50° to 105° F. and 50° to 8° F.

A. C. RAGSDALE, H. J. THOMPSON, D. M. WORSTELL, AND SAMUEL BRODY

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ORIENTATION

This bulletin continues reporting data on the influence of temperature on Jersey and Holstein cows (see Missouri Research Bulletins 425, 436 and 449). In addition, it reports observations on Texas-bred Brahman[1] cows for comparing the relative effects of changing temperature on European-evolved (*Bos Taurus*) and Indian-evolved (*Bos Indicus*) cattle.

The names *Brahman* and *Zebu* as used in this country are synonymous with Indian-evolved cattle of the sub-species *Bos Indicus*, including the well-known Indian dairy breeds[2] Sahiwal and Sindhi, and the dual purpose or draft breeds Tharparkar; Hariana; Guzerat (Kankrej); Nelore (Ongole); and Gyr (Katihawar). Most of the Indian-evolved cattle in the United States are of Gyr (Red Brahman) and Guzerat (Grey Brahman). There are other, variously colored, Indian cattle breeds in India[3,4]. The cows used by us in this project were gray "Barzee Brahman." Plate A shows one of Mr. Gates' Brahman cows[1] in the Climatic Laboratory at 100°F, and Plate B a herd of Brahmans on Mr. Gates' ranch.

These animals have a hump, evidently a nutrient storage organ to tide over periods of famine and drouth. Under famine conditions hump fat is oxidized furnishing energy and its weight in water. They have longer and better legs than European-evolved cattle and are, therefore, faster walkers (see Plate B) and therefore, more suited for range conditions. Their excess skin in the form of pendulous dewlap, ears, navel flap and sheath gives Brahmans an extra large surface area per unit weight for heat dissipation.

[1]Grateful acknowledgments are made to Mr. J. V. Gates, Poteet, Texas, for furnishing the Barzee Brahman cows. For details about these cows see "Barzee Brahmans," The Zebu Journal, p. 16, May, 1950.

[2]Kartha, K. P. R., "Milk Record of Cattle in Approved Dairy Farms of India," The Imperial Council in Agric. Res., Misc. Buls. 36, 37 and 52, Delhi, India, 1941 and 1942.

[3]Ware, F., "Survey of Important Cattle Breeds in India," *Id.*, Misc. Buls. 47 and 54, 1941.

[4]Schneider, B. H., "Cattle of India," The Cattleman, July 1949.

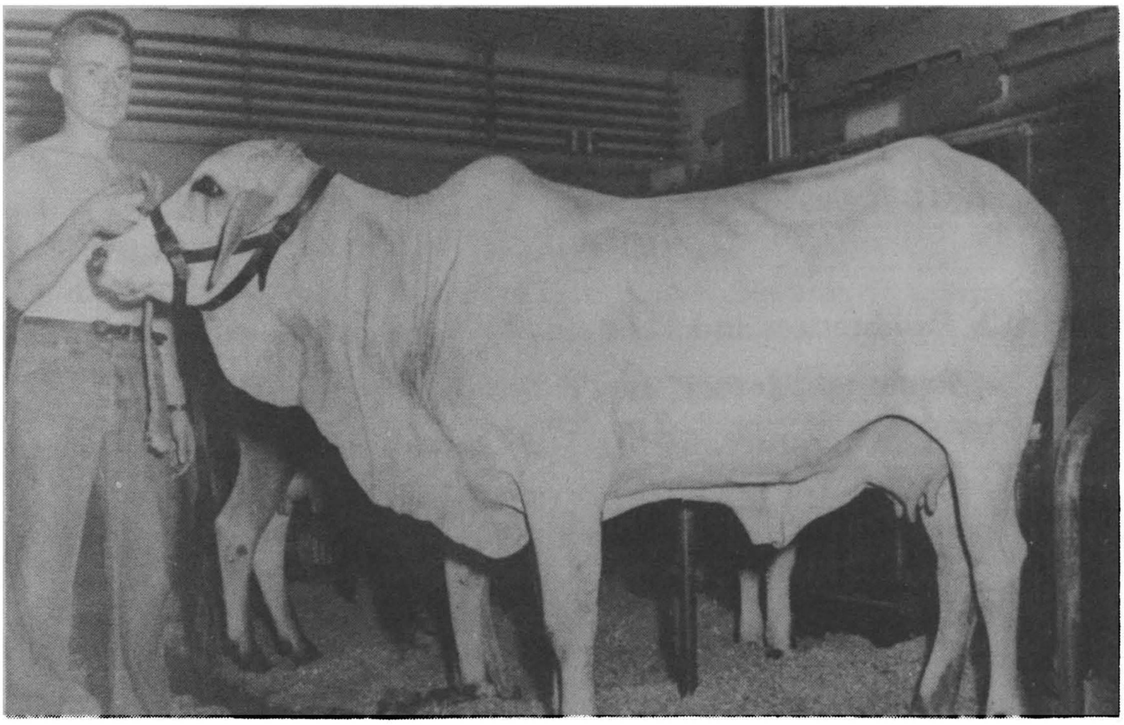


Plate A.—Photograph of Brahman 190 in the Experimental chamber at 100°F and 60 per cent relative humidity. Note the pendulous dewlap, ears, and navel flap.

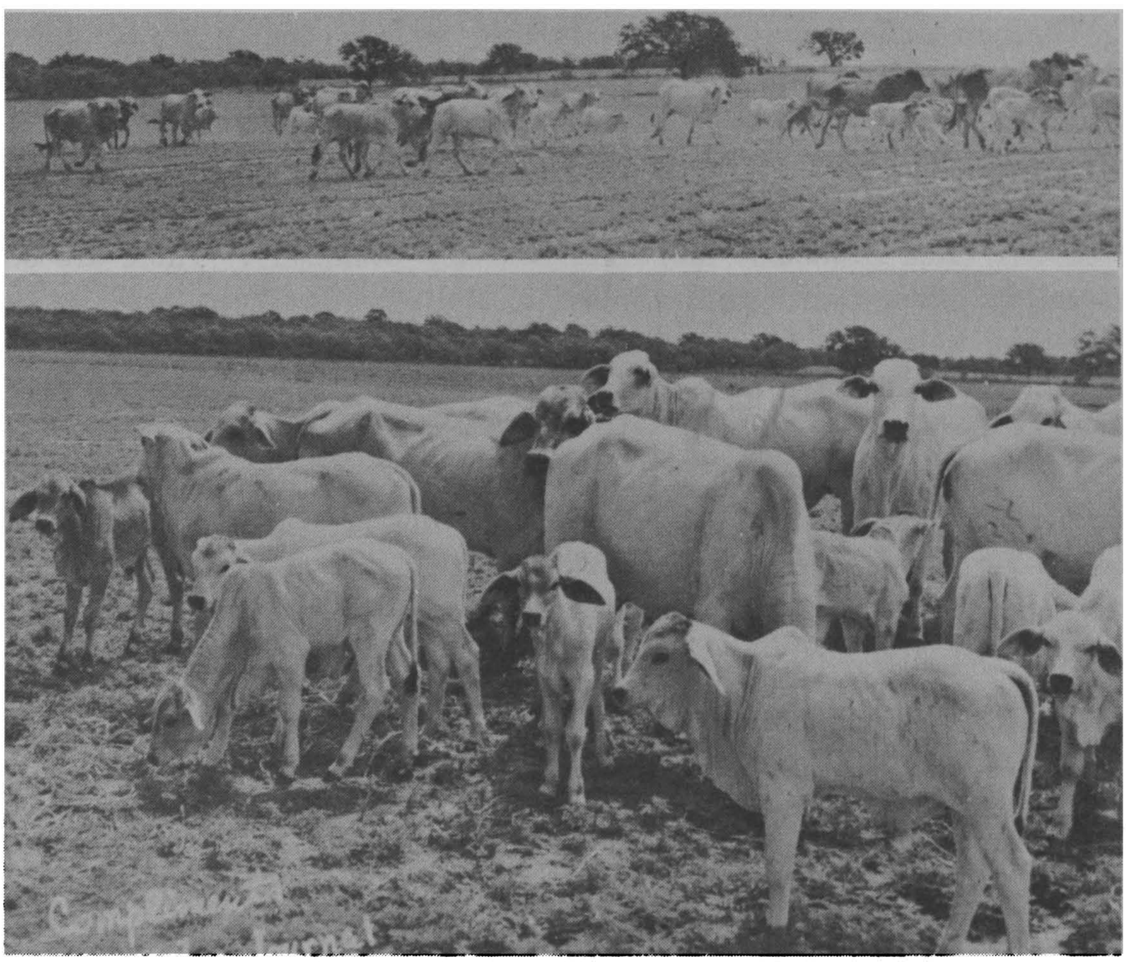


Plate B.—A herd of Brahmans on Mr. Gates' Ranch. We are grateful to Mr. Gates for furnishing us with these photographs. Note the difference in gait between these and the European-evolved cattle.

The short, sleek, usually gray or red, fine, glossy hair is a fair reflector of sunlight. The skin, black or chocolate color regardless of hair color, protects the animal from ultra-violet radiations. White glossy hair and dark skin is, of course, an ideal arrangement for protection against solar radiations, visible and ultra-violet.

Schneider[4] remarked that Brahman cattle can be seen dripping sweat over the dewlaps from sweat glands along the shoulder vein and on the neck. We are not familiar with definite sweating data, although at temperatures above 85° F yellow stripes appeared on the shoulder and neck down the dewlap, like tracks of dried sweat. The skin, however, felt dry. On several occasions—possibly depending on slight fluctuations in humidity and/or metabolic rate—we observed at 100°F moisture on the hump; and also moisture dripping down the legs from areas between the udder and legs. But we also observed this in Brown Swiss cows. Brahmans undoubtedly withstand oppressively humid heat much better than European cattle; while European cattle rest in the shade or stand in water in very hot weather, Brahman cattle graze busily[4]. Sweating may or may not be the major factor in this difference; this is as yet an unsolved problem in body temperature regulation.[5]

The Brahman's tough hide (no thicker, however, than that of European-evolved cattle) and ability to move irritated skin areas by highly developed panniculus muscle attachments protects against insect penetration. At any rate, it resists parasites, especially ticks and flies, and is not seriously affected by tick fever, rinderpest, hoof-and-mouth disease, and related afflictions.[4]

One reason for including Indian-evolved non-dairy cattle in a study of European-evolved dairy cattle is that an understanding of the factors that keep Indian cattle comfortable in oppressively hot climates may give a clue for selecting and developing European cattle that have similar factors, as witness the success of the King Ranch in the development of the heat-resistant Santa Gertrudis beef cattle. A second reason is that deepest insights are often obtained by apparently *theoretical* or *comparative* studies as, for example, the insight obtained into human nutrition by comparative studies of the nutrition of rats, dogs, guinea pigs, and chickens. Milk production is an end-product of countless intermediate and associated physiologic reactions each of which is influenced by climatic factors and shelter conditions. An understanding of the effect of climatic and shelter conditions on the component factors in the milk-producing complex is most likely to lead to rational adjustment of shelter to highest productivity.

This report includes two separate experiments: one during the summer of 1949 in which the Experimental cows were exposed to increasing temperatures from 50° up to 105°F, and another during the winter of 1949 in which the

[5]Findlay, J. D. & Yang, S. H., "Capillary distribution in cow skin," Nature *161*, 1012, 1948; also numerous footnote reference on page 291, in Brody, S., "Bioenergetics and Growth," Reinhold, New York, 1945.

Experimental cows were exposed to decreasing temperatures from 50° down to 8°F. The Control cows were maintained at 50°F during both periods. Details of the temperature schedules are given in Table 1 and Fig. 1. Two cows of each of the three breeds — Jersey, Holstein, Brahman — were used in each chamber, Experimental and Control, in both of the tests. The same Brahman

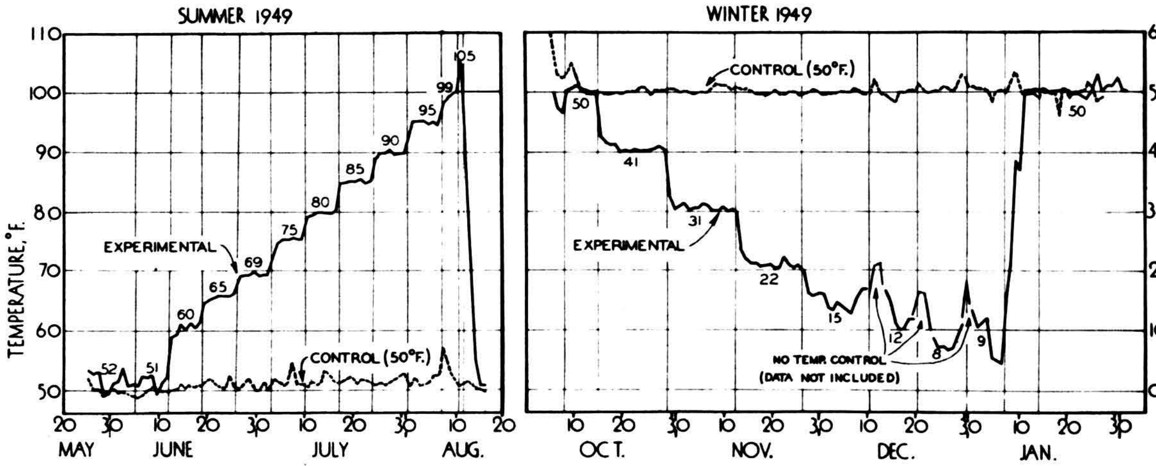


Fig. 1.—Time and temperature schedule. See Table 1 for numerical details.

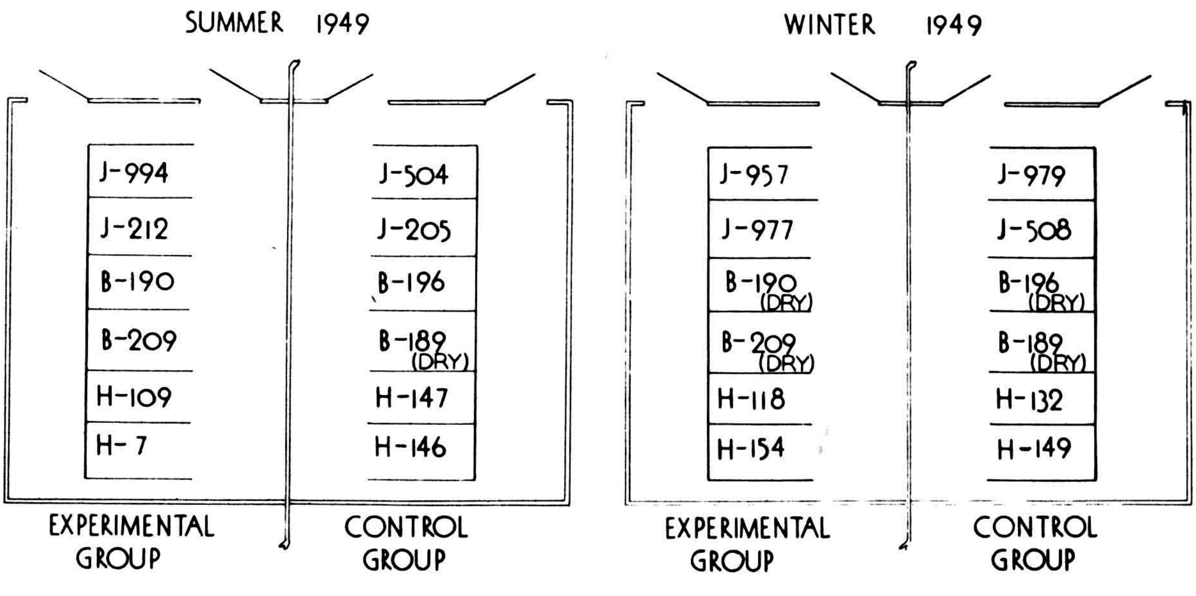


Fig. 2.—Arrangement and pairing of the cows in the laboratory. "B" stands for Brahman, "J" for Jersey, and "H" for Holstein. See Table 2 for the vital statistics of these cows.

cows were used for increasing and decreasing temperature, but the Jersey and Holsteins were different in the two periods. With the exception of one Control, Brahman 189, all cows were lactating during the summer, the period of rising temperature; and with the exception of the Brahmans, all cows were lactating during the winter, the period of declining temperature. Fig. 2 shows the arrangement of the cows in the laboratory, and Table 2 gives vital statistics.

No great changes were made over the preceding experiments in handling or feeding except that the alfalfa hay was grated and the left-over hay was

TABLE 1.--TEMPERATURE CALENDAR

Chamber Temp. °F Experimental	Control	Relative Humidity, % Experimental	Control	From	To (and including)
		Summer 1949			
Training Period at 50°F		66	68	May 23	June 4
51	50	67	70	June 5	June 11
60	50	71	69	June 12	June 18
65	51	73	67	June 19	June 25
69	51	76	67	June 26	July 2
75	52	70	68	July 3	July 9
80	51	65	64	July 10	July 16
85	51	64	64	July 17	July 23
90	51	66	64	July 24	July 30
95	51	57	66	July 31	August 6
99	53	62	62	August 7	August 11 (4a.m.)
105	51	59	63	August 11 (4a.m. to 4p.m.)	
decreased from 95 to 70 (av. 80)	51	64	62	August 12	
decreased from 70 to 50 (av. 55)	50	62	63	August 13	
51	49	66	66	August 14	August 15
All temperature changes up to August 11 were made about 4:30 p.m. of the last day of each experimental period.					
		Winter 1949			
Training Period at 50°F		67	64	October 4	October 7
50	52	66	64	October 8	October 14
41	50	57	65	October 15	October 28
31	50	60	69	October 29	November 11
22	50	60	70	November 12	November 25
15	50	63	69	November 26	December 9
range 21-16*	51	66	72	December 10	December 12
12	50	68	71	December 13	December 19
range 12-16*	51*	63	68	December 20	December 22
8	51	66	60	December 23	December 29
18*	51	64	62	December 30	
9	50	66	68	December 31	January 6
increased from 8 to 50 (av. 38)	51	68	62	January 7	January 13
50	50	67	68	January 14	February 1†
All temperature changes were made at 3:00 p.m. of the last day of each experimental period.					

* No temperature control due to power failure or had to be turned off due to repairs. Range given is between average daily temperatures. Data for these periods of "no temperature control" not included in tables or in charts.

† Control cows removed from chamber January 27 after 3:00 p.m.

air-dried for several days before weighing and deducted from the amount offered. Beet pulp (on a dry basis, 2 lbs. daily) and grain (grain mix, including cod liver oil supplement, was the same as reported in Table 3 of Res. Bul. 425) were fed twice daily. As in the preceding periods, the amount of grain fed the Jersey and Holsteins was based on milk production with, however, a daily minimum of four pounds. During the summer period of rising temperature the Brahman cows received 4 lbs. grain except B-209 which received 5 lbs.; 5 lbs. was fed all Brahmans during the winter period of declining temperature. Water was available at all times in individual drinking cups. In measuring water consumption, both drinking frequency and quantity were automatically recorded as explained below.

Experimental Design:—One may think of many experimental designs, including long-exposure trend method; long-exposure reversal method; short-exposure trend method; short-exposure reversal method; rapid rising or declining temperature by abrupt steps at given intervals; slow continuous rising or declining temperatures; rising temperature sequence (as from 0° up to 105°F); declining temperature sequence (as from 105° down to 0°F); identical-twin controls for the experimental animals (thus eliminating differences in physiological reactions associated with hereditary differences[6]); ordinary

TABLE 2.--HISTORY OF THE COWS

Cow No.	Birth Date	Date of Last Calving	Number of Previous Lactations	Date of Last Breeding	Beginning of Experiment: Approx. Age, Yrs.	Beginning of Experiment: Approx. Body Weight, Lbs.	Average During Months of May or September: Milk, lbs/day	Average During Months of May or September: Butterfat, %
				Summer 1949				
Experimental								
Jersey 994	Oct. 20, 1943	Feb. 19, 1949	3	Oct. 8, 1949	5 2/3	770	32.5	4.9
Jersey 212	Jan. 17, 1945	Mar. 2, 1949	2	July 6, 1949	4 1/2	990	34.0	4.2
Brahman 190	Jan. 25, 1947	Apr. 25, 1949	0	Sept. 17, 1949	2 1/2	750	*	
Brahman 209	May 6, 1947	Apr. 30, 1949	0	Sept. 17, 1949	2	710	*	
Holstein 109	Sept. 3, 1943	Apr. 21, 1949	2	Oct. 3, 1949	5 3/4	1250	36.3	3.3
Holstein 7	July 30, 1939	Feb. 26, 1949	6	---------	10	1270	47.7	3.0
Control								
Jersey 504	Sept. 15, 1944	Jan. 16, 1949	2	Apr. 4, 1949	4 3/4	840	30.0	4.6
Jersey 205	Oct. 7, 1944	Mar. 10, 1949	2	May 10, 1949	4 2/3	950	38.2	3.8
Brahman 196	Mar. 21, 1947	May 7, 1949	0	Aug. 8, 1949	2 1/4	880	*	
Brahman 189	Feb. 13, 1947	Apr. 27, 1949	0	Nov. 25, 1949	2 1/3	710	dry†	
Holstein 147	July 30, 1945	Feb. 23, 1949	1	Apr. 29, 1949	4	1180	36.9	3.7
Holstein 146	July 28, 1945	Feb. 10, 1949	1	May 4, 1949	4	1010	47.7	3.0
				Winter 1949				
Experimental								
Jersey 957	Jan. 24, 1941	May 31, 1949	5	Feb. 16, 1950	8 3/4	840	23.6	4.1
Jersey 977	Dec. 26, 1942	June 29, 1949	4	Aug. 31, 1949	6 3/4	920	19.8	6.4
Brahman 190	Jan. 25, 1947	Apr. 25, 1949	1	Sept. 17, 1949	3	850	dry	
Brahman 209	May 6, 1947	Apr. 30, 1949	1	Sept. 17, 1949	2 1/3	820	dry	
Holstein 118	Dec. 13, 1943	Aug. 18, 1949	2	Feb. 8, 1950	5 3/4	1200	38.8	3.5
Holstein 154	Dec. 25, 1945	June 25, 1949	1	Dec. 10, 1949	3 3/4	1200	39.1	3.3
Control								
Jersey 979	Feb. 5, 1943	Apr. 14, 1949	3	Aug. 1, 1949	6 2/3	870	19.6	4.5
Jersey 508	Dec. 14, 1944	June 25, 1949	2	Aug. 24, 1949	4 3/4	890	22.1	4.6
Brahman 196	Mar. 21, 1947	May 7, 1949	1	Aug. 8, 1949	2 1/2	940	dry	
Brahman 189	Feb. 13, 1947	Apr. 27, 1949	1	Nov. 25, 1949	2 2/3	800	dry	
Holstein 132	Sept. 14, 1944	Aug. 5, 1949	2	Jan. 30, 1950	5	1190	41.4	3.3
Holstein 149	Aug. 23, 1945	July 6, 1949	1	Sept. 9, 1949	4	1130	38.8	4.4

* Not milked before placed in the Laboratory.
† Milked only ten days after placed in Laboratory.

matched-control cows (involving hereditary differences between Experimental and Control cows); no controls but rely on published breed data for the average declines in milk yield with the advances in the periods of lactation and gestation supplemented for guidance by data obtained on occasional reverting to the initial or reference temperature. There are advantages and disadvantages in each of these methods, some of which are obvious, such as the relative advantages of the use of identical twins as controls for the experimental animals, over the use of ordinary matched cows (as explained on

[6]Hutt, F. B., J. Heredity, *21*, 339, 1930 stated: "A feeding experiment repeated upon each animal, using one twin and the other twin as control, would probably yield more conclusive results than if a dozen animals of greater genetic heterogeneity and of different ages were used for the same test."

page 7, Res. Bul. 449)[7]. In the observations here reported we used the same long-exposure trend methods and ordinary "matched-cow" controls as we did for the 1948 data reported in Res. Bul. 425 and 449.

We chose the continuous design in preference to the reversal plan for this investigation because cows change rapidly *physiologically* with the advance in: a) the period of lactation; b) the period of gestation; c) acclimatization (or deterioration); and the reversal system is too expensive in *time* as it takes nearly twice as long to obtain data on the same animals for the effects of a given temperature range by the reversal as by the simple trend method.

The physiological effects of advances in the periods of lactation and gestation, especially on milk yield, are generally known. Acclimatization effects are at present under investigation. But it is agreed that exposure of an animal to a temperature outside of certain limits may profoundly affect the neuro-endocrine system. For instance, increasing the environmental temperature from 34° to 95°F, reduced the thyroid activity of rats by 80 per cent (from 9.5 to 1.7 micrograms thyroxine production per day)[8]. It is generally known that the rate of adrenalin production is also affected by temperature changes although according to a different time schedule. Increasing temperature from 65° to 88°F, gradually reduced the metabolic rate of rats—over a considerable period of time, *over three weeks*—by about 20 per cent (from 620 to 510 Cal/sq.m/day)[9]. Thyroid and adrenal activity are only two effects in a complexly interrelated neuro-endocrine-enzyme system which is re-equilibrated, readjusted, or acclimatized to changes in temperature, over variable time periods. There are undoubtedly other changes. We are exploring the possibility of using radioiodine for measuring directly the effect of various temperatures on thyroid activity, as the thyroid seems to be a limiting link—perhaps the most important one—in the acclimatization chain.

Since writing the preceding reports several interesting papers came to light on the effect of temperature on animals, which do not, however, call for

[7]It is rather difficult to get identical twins because the total monozygous twinning frequency is only about 2.5% and of females only 0.6% (G. Bonnier, Acta Agricultura Suecana *1*, 139, 1946). Yet the Ruakura Animal Research Station, New Zealand Department of Agriculture, Wellington, 1950, reports (1949-50 Annual Report) that it has 208 sets of apparently identical twins for the study of the interaction of environment and inheritance with special reference to the effects of widely differing levels of nutrition. Data are also reported showing remarkably similar behavior patterns (grazing, lying, loafing, walking) and production (weight gains) of the twins. There is a large literature on twinning in cattle ranging from Lillie's pioneer work on "free martins" (J. Exp. Zool., *23*, 37-451 & Biol. Bul. *44*, 47-48, 1923) to the recent fine review by A. Hansson on "Identical twins in cattle" in Heredity (British Journal) *2*, part 1, 1, 1948.

[8]Dempsey, E. W. & Astwood, E. B., "The rate of thyroid hormone secretion at various environmental temperatures." Endocrinology, *32*, 809, 1943.

[9]Gelineo, S., "Influence du milieu thermique d' adaptation sur la thermogenese des homeothermes." Ann. Physiol. Physiochim. biol. *10*, 1083, 1934, cited on p. 285, of S. Brody's "Bioenergetics and Growth," Reinhold, 1945. Similar results on rabbits were recently published in Jugoslavian by Gelineo, Proc. Jugoslav. Acad. Sc. CXCII, Belgrad, 1949.

comment in this connection, beyond their listing[10], to indicate their general nature.

DATA

Milk Data:—Fig. 3 based on Tables 3 and 4 shows the milk and butterfat yields as percentages of the initial levels at 50°F, represented as 100 per cent. The initial temperature level was the same, 50°F, for both the rising and declining temperatures. (For Tables 3 to 8, see page 25.)

The left half of Fig. 3 represents the Experimental group and the right half the Control (50°F) group of cows. The left column of the Experimental group of charts shows that rising temperature, from the initial level of 50°F up to 105°F, had much less effect on the tropically-evolved Brahman than on the European-evolved Jersey and Holstein cows. The milk yield began to decline appreciably at about 75°F in European and 95°F in Indian cattle. The percentage decline in milk yield is greatest in the Holstein cows; less in the Jerseys; least in the Brahmans. The smaller effect of rising temperature on milk production in the Brahmans is due in part to their superior body-temperature regulation (such as the pendulous dewlap which furnishes a high surface to mass ratio) and in part to lower milk yield and, therefore, to lower sensitiveness to unfavorable conditions with regard to milk production.

Fig. 3 shows that reducing temperature from the initial level of 50°F down to 8°F depressed the milk production but slightly.

Body Weight:—The upper curves in Fig. 3 show no effect of *rising* temperature on the body weight of the Brahmans, but decided depression in body weight beginning with 80°F in the Jersey and Holstein cows. Although declining temperature from 50°F down to 8°F tended to slightly increase body weight in the Jerseys and Brahmans, the Control cows also showed an increase for this same time interval.

Feed Consumption:—This was plotted in Fig. 4, based on Tables 5 and 6, in terms of percentage of the original, 50°F, level. The decline in feed consumption during the period of rising temperature parallels and reflects the decline in milk production shown in Fig. 3. The decline in feed consumption begins at 75° to 80°F in the Jersey and Holstein cows, and 90° to 95°F in the Brahmans. With the exception of Holstein 118, *declining temperature*

[10]Bonsma, J. C., "Ecological Animal Husbandry Research Conference in Agriculture in Australia," and "The influence of climate on animal production and its effect on human nutrition." Printed in the Union of South Africa by the Government Printer, Pretoria, 1949. Bonsma, "Breeding cattle for increased adaptability to tropical and subtropical environments," J. Agr. Sc. *39*, 204-221, 1949. Wilson, W. O., "Effects of high temperatures on chickens." Poultry Science, *27*, 813, and *28*, 581, 1949. Robinson, K. W. & Lee, D. H. K., "Effect of the nutritional plane upon the reactions of animals to heat." J. Animal Sc., *6*, 182, 1947. Lee, D. H. K. & Phillips, R. W., "Assessment of the adaptability of livestock to climatic stress." *Id.* 7, 391, 1948. Heitman, H., Hughes, E. H., & Kelly, C. F., "The effects of air temperature and relative humidity on the physiological well being of swine." *Id.* *8*, 171, and 641, 1949. Arrillaga, C. G., "Effect of temperature and humidity on acclimatization of cattle in the tropics. *Id.* *8*, 637, 1948.

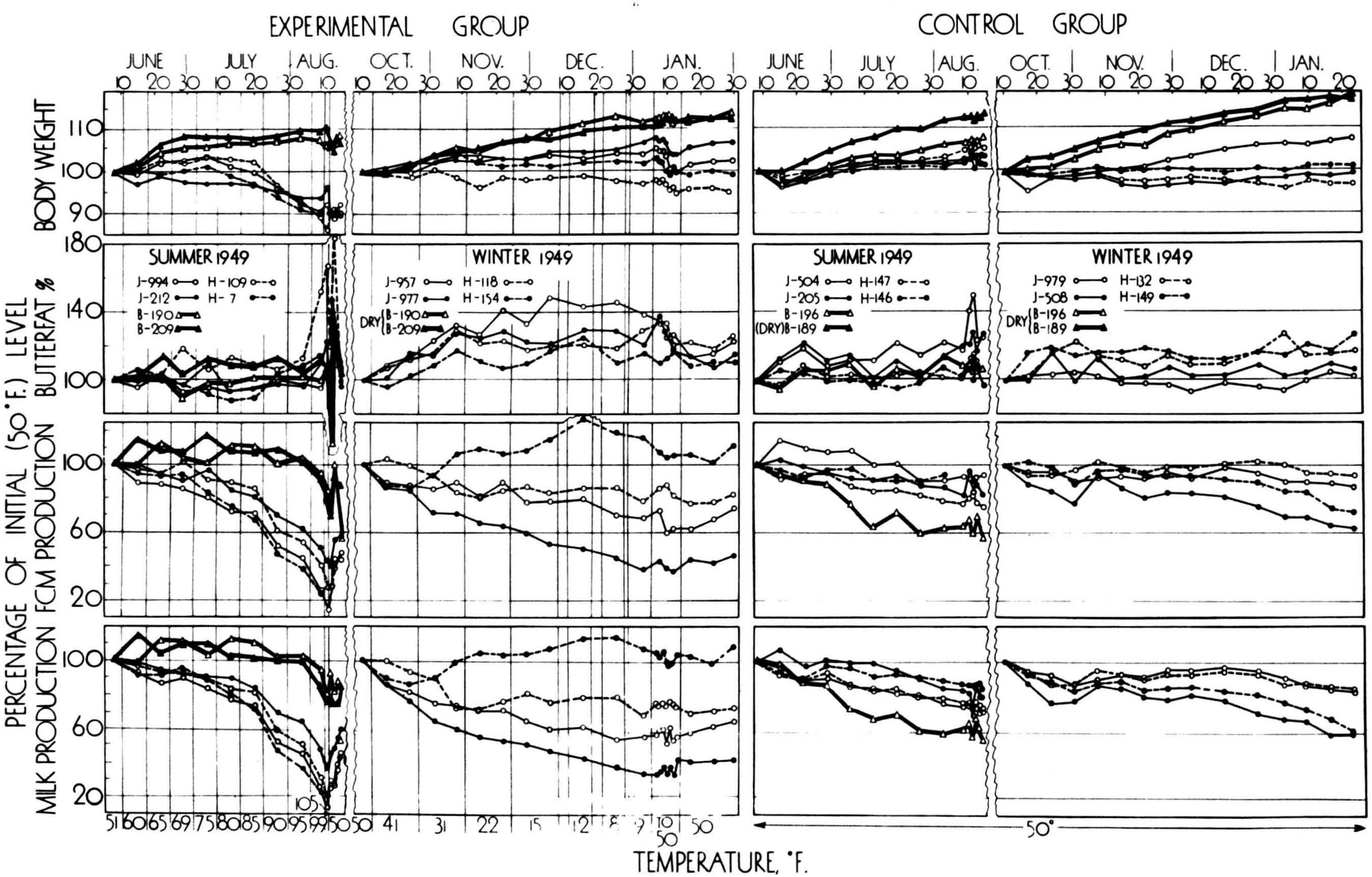


Fig. 3.—Milk and FCM (4% fat milk equivalent) production, fat percentage, and body weight as functions of rising temperature from 50° up to 105°F (left set of curves), declining temperature from 50° down to 8°F (second set from left), and constant temperatures of 50°F for Control cows (third and fourth sets from left) for the same time intervals. All data are presented in terms of percentages of the initial, 50°F, levels. The narrow intervals without temperature designations in the Winter period represent power failure and absence of temperature control.

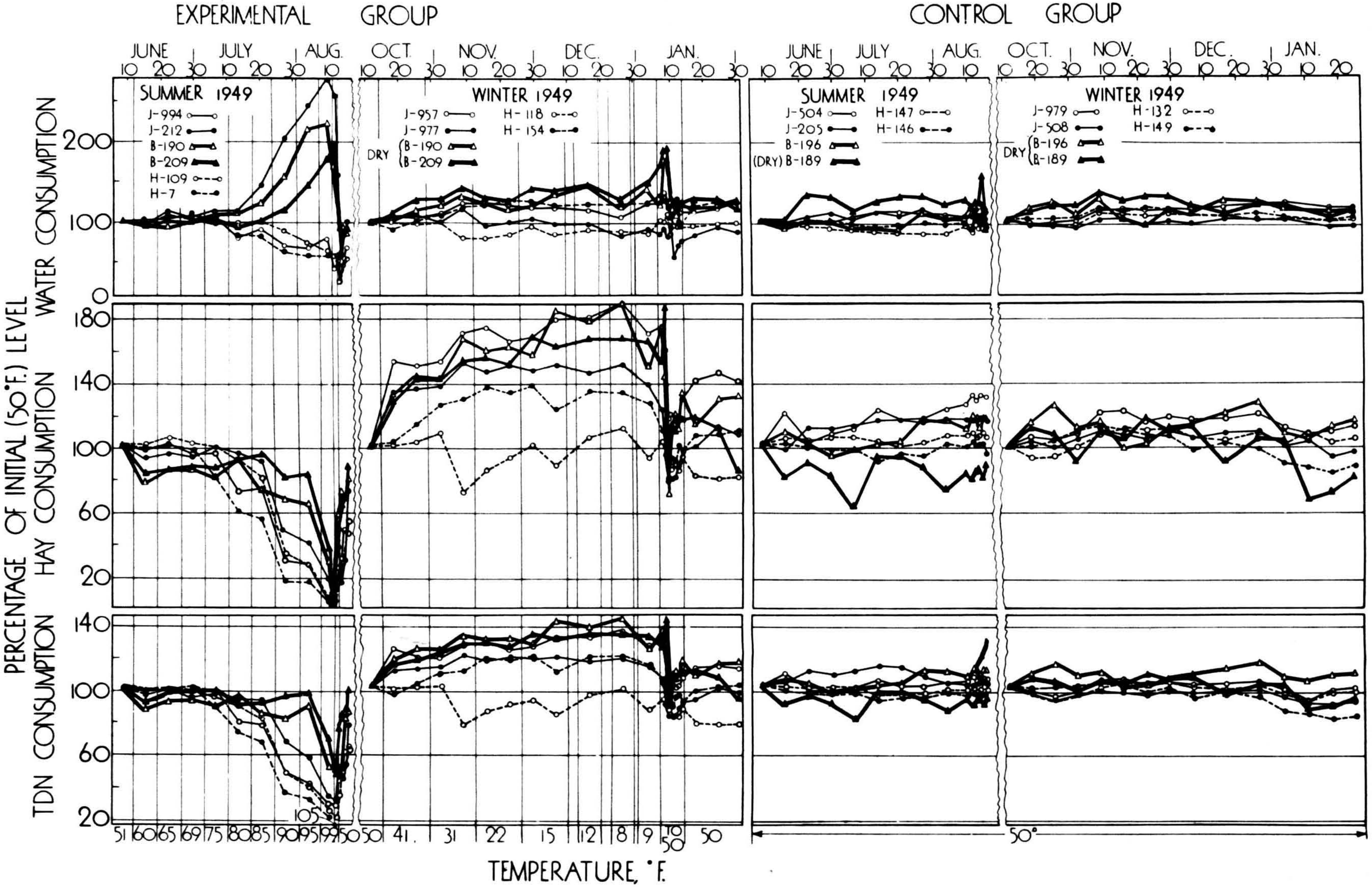


Fig. 4.—TDN, hay, and water consumption data presented in the same manner as the data in Fig. 3.

from 50° down to 8°F increased hay consumption 40 to 80 per cent above the initial 50° level. (The TDN consumption did not increase as much as the hay consumption because the grain allotment was in proportion to the milk yield.) Note the sudden drop in feed consumption with increasing temperature from 8° to 50°F. This harmonizes with the assumption that appetite behaves as if it were a temperature-regulating mechanism[11]; feed consumption

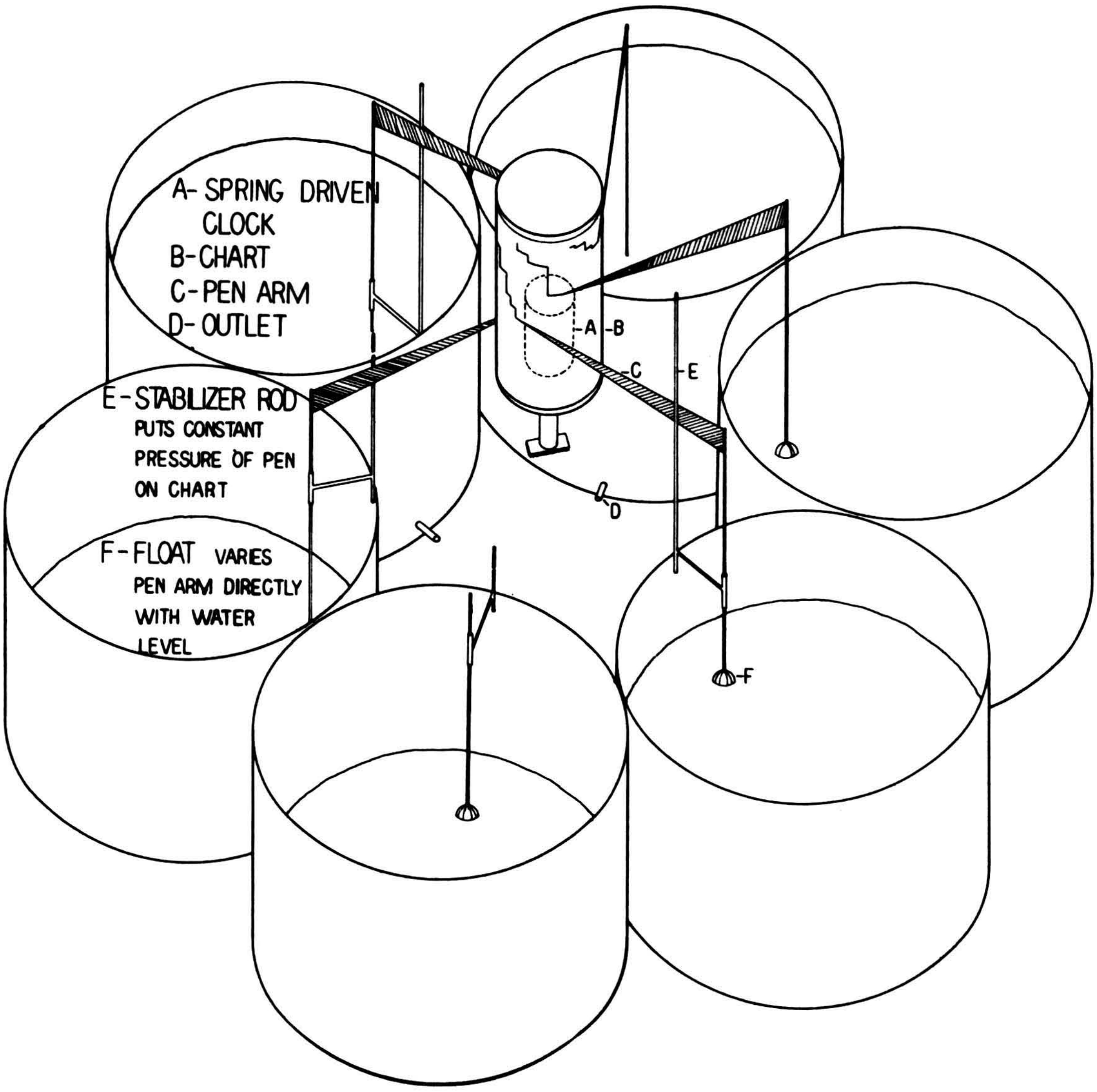


Fig. 5.—Schematic diagram of water consumption recorder. Various colored inks were used for recording on the clock kymograph the water consumed by each of the six individual animals. Total consumption for 12 animals during the 24-hour period was checked by a commercial one-half-inch water meter when tanks were manually filled to the standard level. No consumption was allowed during the filling interval of about 20 minutes.

is associated with extra heat production, therefore decreasing temperature should increase feed consumption so as to help keep warm; and increasing temperature should decrease feed consumption so as to help keep cool, and this is precisely what happens.

[11]Brobeck, J. R., "Food intake as a mechanism of temperature regulation." Yale J. Biol. and Med. *20*, 545, 1948.

Water Consumption:—Each cow had access at all times to a water-cup fountain of the usual commercial design employed in dairy barns. Water was fed to the cups by gravity from individual cylindrical water tanks placed about ten feet above the cup levels. Automatic water recorders were installed to the individual cylindrical water tanks for each chamber as shown in Fig. 5. Measurements from these recorders (weekly clock kymograph charts) give total amount of water delivered to the water bowls per drink, per hour, per day; frequency of drinking; time of day and amount of each drink.

The upper segment of Fig. 4, based on Table 7, brings out striking individual and breed differences in water-consumption with rising environmental temperature. One Jersey and both Holsteins *decreased* their water consumption with increasing temperature; Jersey 212, on the other hand, and the two Brahmans *increased* their water consumption with increasing temperature. The unusual increase in water consumption of Jersey 212 was previously reported (charts on pages 9 and 12 and text pages 16 to 18, Res. Bul. 436; this cow did not waste more water than the other cows). Fig. 4 in the present report brings out the striking similarity of the water-drinking patterns of Jersey 212 and of the Brahmans, rather than of the other Jersey and Holstein cows. Is the similarity of the water *consumption* patterns of Jersey 212 and of the Brahmans associated with a common mechanism of water *loss,* such as greater "sweating" in the Brahmans and Jersey 212 than in the other cows, or are the similarities fortuitous, due to different water loss mechanism, such as greater vaporization rate in the Brahmans and greater urination rate in Jersey 212? Quantitative urination data along with quantitative water consumption data might, perhaps, furnish the answer.

The ratios of water consumption to hay consumption, to milk production, and to body weight shown in Fig. 6 substantiate the conclusions of the previous reports (Res. Bul. 436 and 449) that Jersey 212 is unique with regards to her increasing water consumption with increasing temperature. The rise in the ratios of water consumption to hay consumption and to milk production with increasing temperature, of course, also depends on the decline in hay or TDN consumption (upper segment Fig. 6) and milk production.

The slight increase in water consumption with declining temperatures shown in Fig. 4 is associated with increase in hay consumption with declining temperature, as indicated by the ratios of water to hay consumption in Fig. 6.

Figs. 7 to 9 bring out an intriguing aspect of the way rising temperature affects the water consumption *pattern.* These charts show: 1) the amounts of water consumed per drink and per day; 2) the time of drinking; 3) duration of non-drinking intervals; 4) the drinking frequency distribution; 5) the time intervals of drinking following feeding (feeding began at about 4:30 a.m. and 3 p.m.).

There are two relatively long non-drinking intervals, the longer one occurring at midnight and the shorter one at noon. These non-drink periods

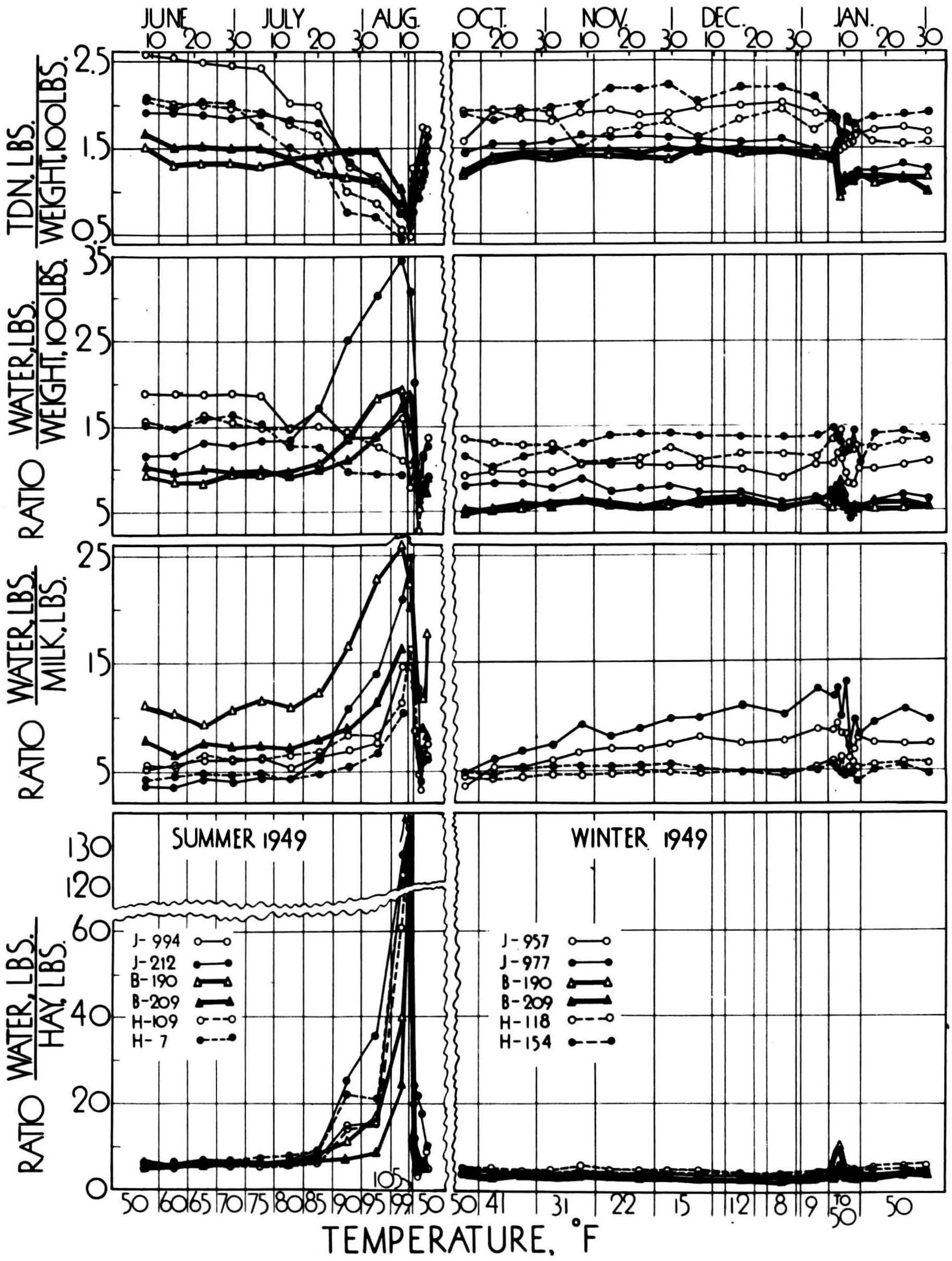
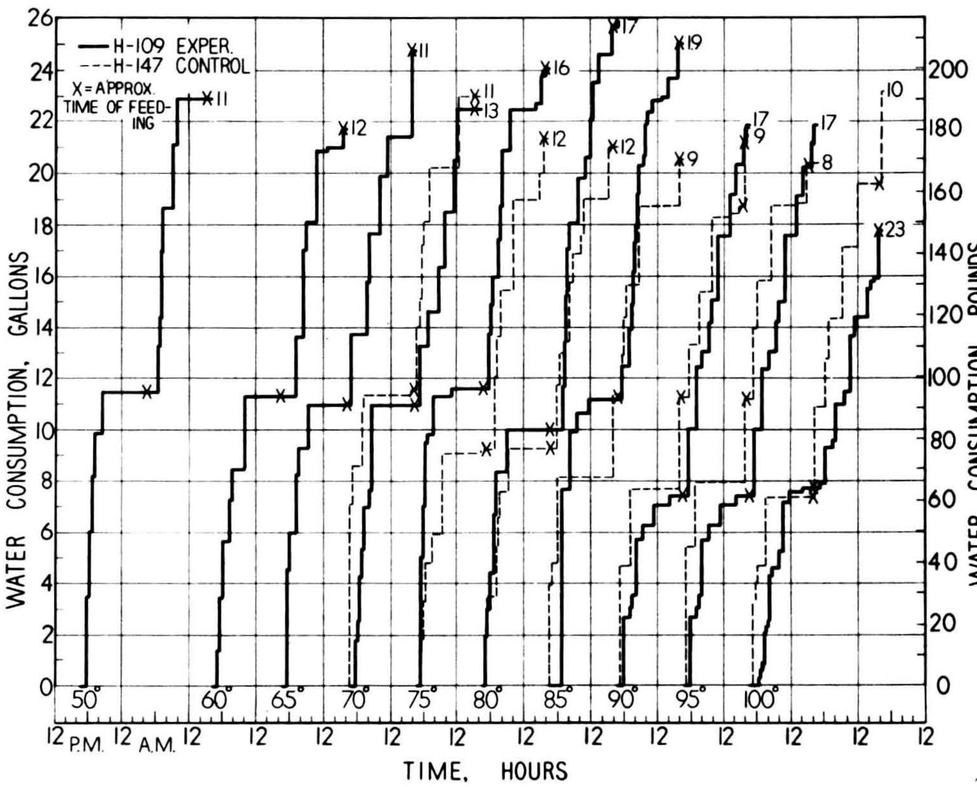


Fig. 6.—Ratios of water consumption to hay consumption, milk production, and body weight; and the ratio of TDN consumption to body weight. The ratio of water consumption to body weight brings out the difference between Jersey 212 and the other cows more dramatically than the absolute water consumption curve in Fig. 4. The rise in the ratios of water consumption and to milk production is proportional to the decline in milk production and hay consumption as well as to increase in water consumption. The narrow intervals without temperature designations in the winter period represent power failure and absence of temperature control. High values at 105°F for the ratio of water to hay consumption not shown are: J-994, 180; J-212, 469; B-209, 384; H-109, 1945.



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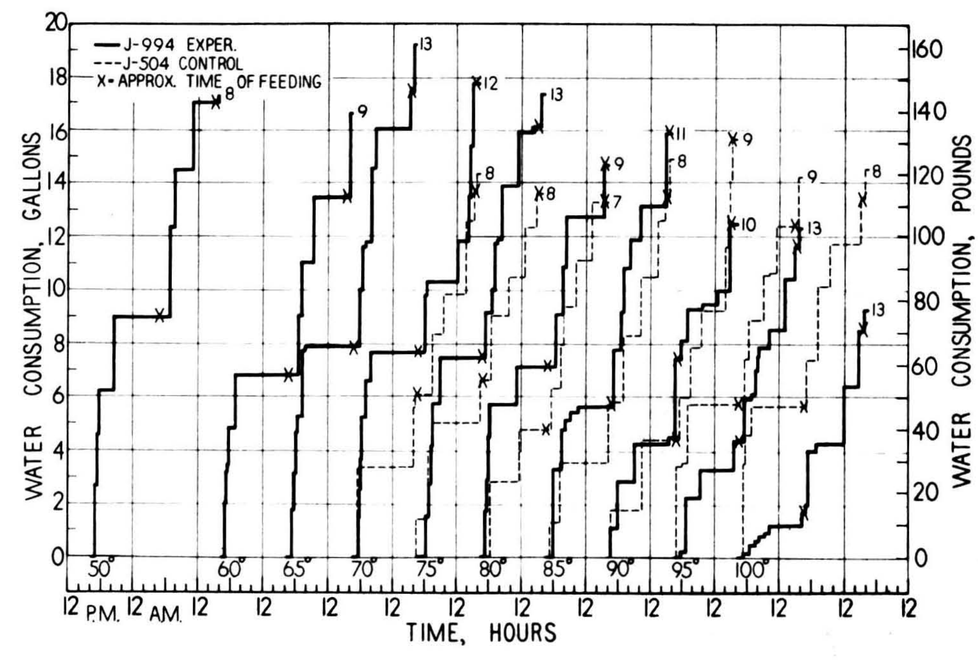
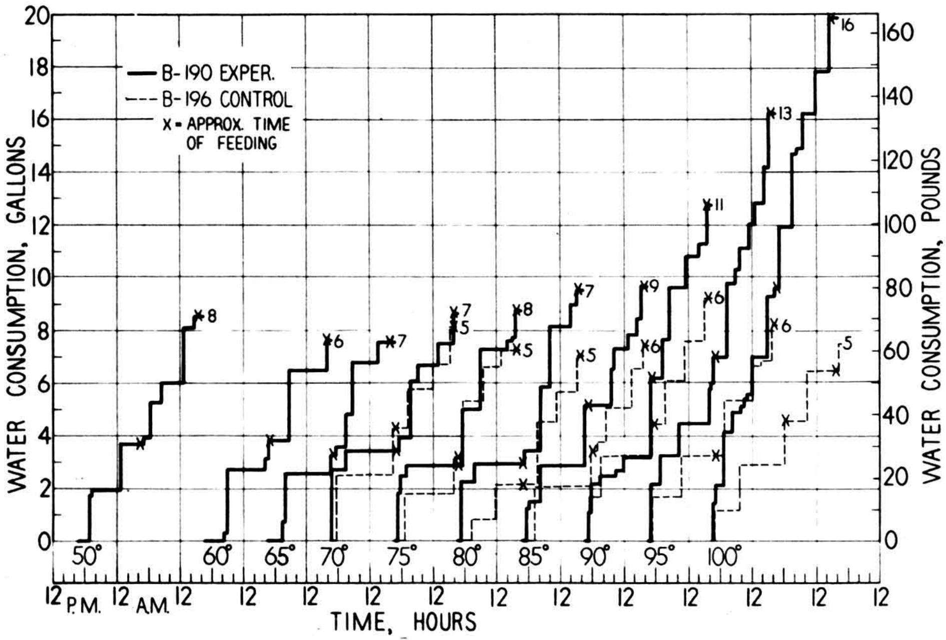
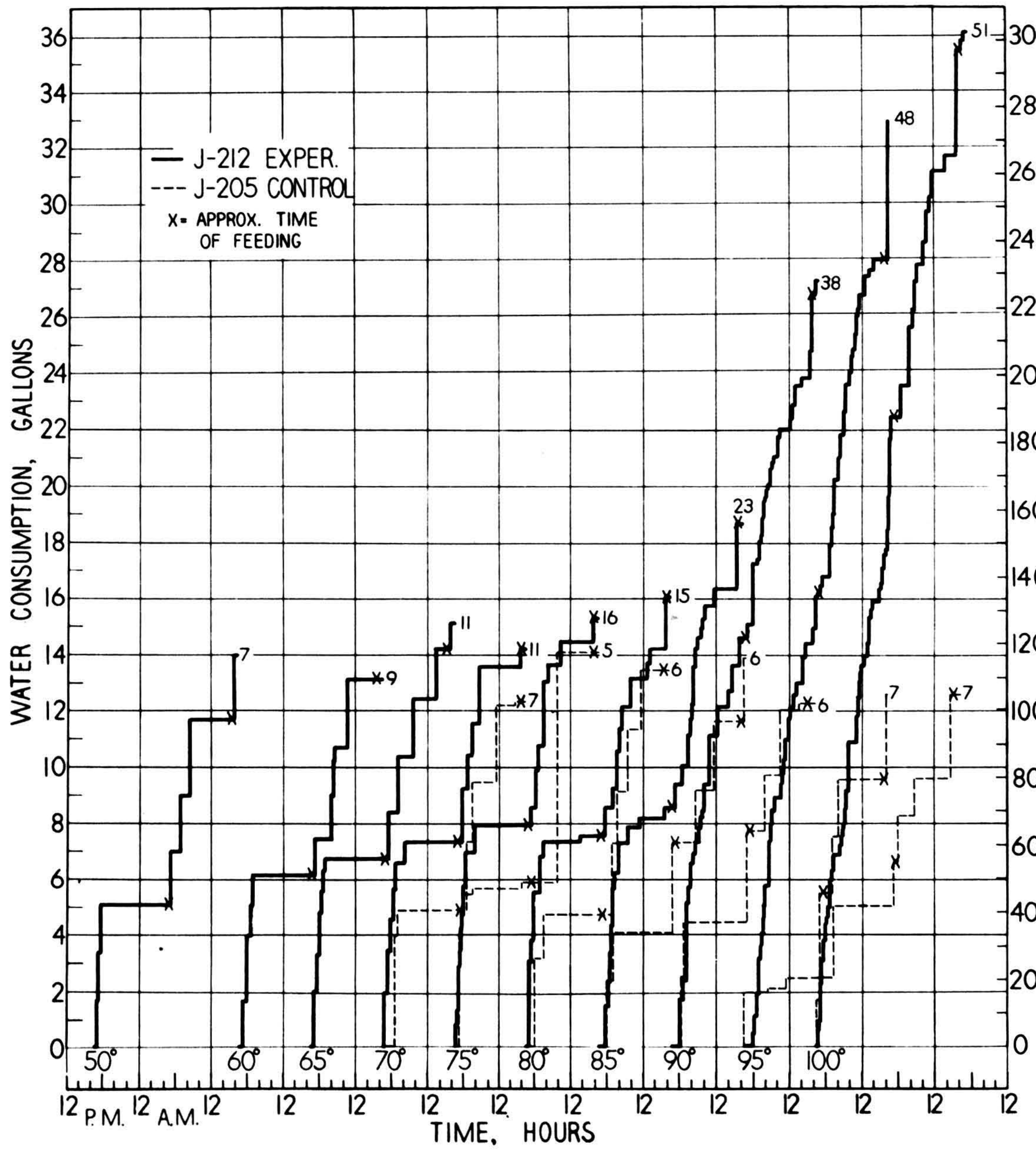


7b

Figs. 7a, b, c, and d.—The effect of increasing temperature on the water consumption pattern. Typical twenty-four-hour periods (4:30 p. m. to 4:30 p. m.) from each temperature level (from 50° to 100°F) are shown for an Experimental (heavy solid lines) Holstein 109 (7a); Jersey 994 (7b); Brahman 190 (7c); and Jersey 212 (7d). Their paired Controls (light broken lines) are shown for the same time period. The total water consumption for the 24-hour period is represented by the height of the vertical line; the water consumption per drink is represented by the total height of each segment; the number of drinks (represented by the number of vertical segments) is given by the numerical value given at the top of each segment. The horizontal segments represent non-drinking intervals. Compare the patterns of the Brahman (7c) and Jersey 212 (7d) with the other Jersey and Holstein (7a and b).


B-190 EXPER.
B-196 CONTROL
X = APPROX. TIME OF FEEDING
WATER CONSUMPTION, GALLONS
WATER CONSUMPTION, POUNDS
TIME, HOURS
12 P.M. 12 A.M.
50° 60° 65° 70° 75° 80° 85° 90° 95° 100°

7c


J-212 EXPER.
J-205 CONTROL
X = APPROX. TIME OF FEEDING
WATER CONSUMPTION, GALLONS
WATER CONSUMPTION, POUNDS
TIME, HOURS
12 P.M. 12 A.M.
50° 60° 65° 70° 75° 80° 85° 90° 95° 100°

7d

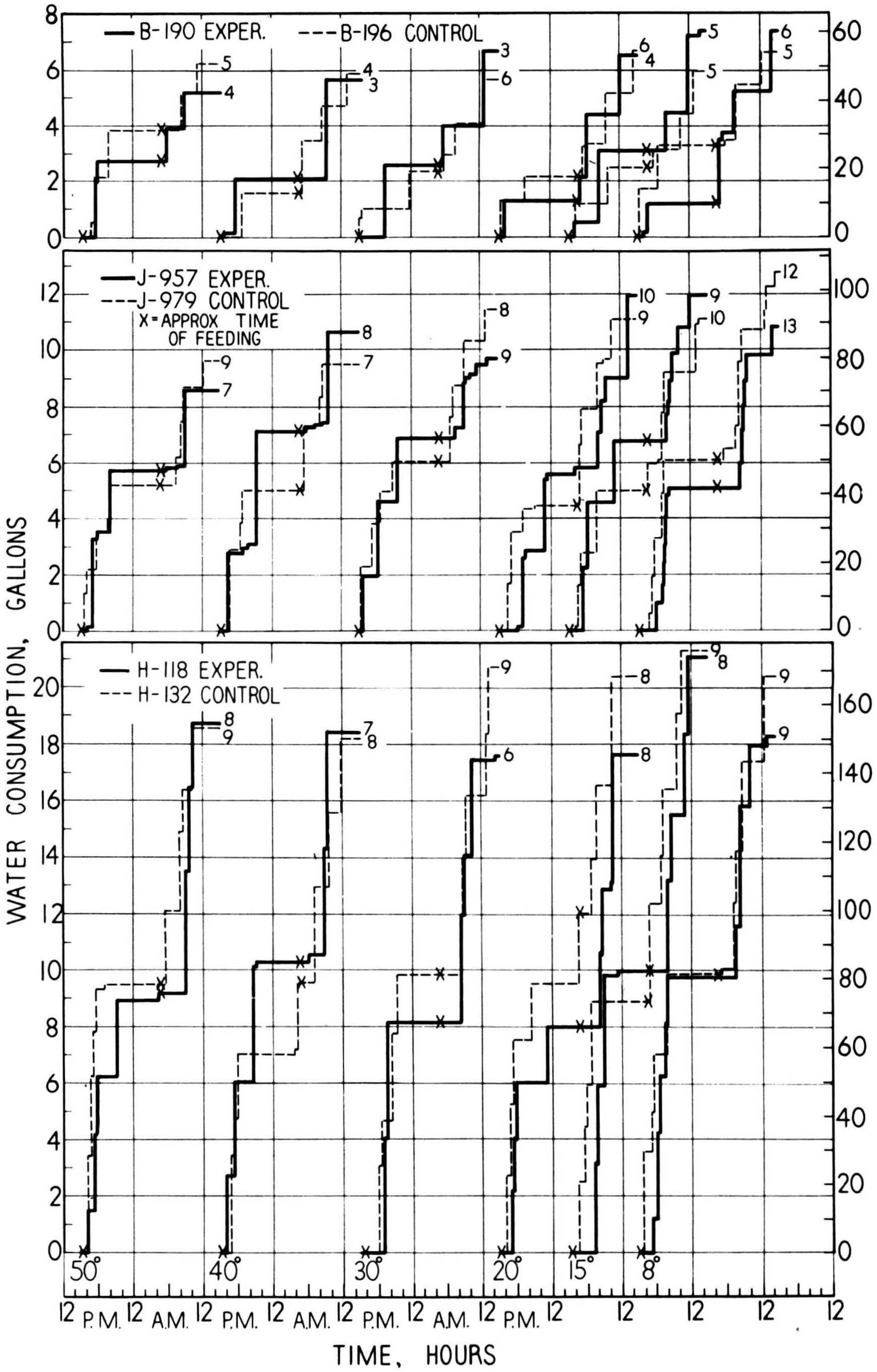


Fig. 8.—The water consumption pattern is apparently unchanged or changed but slightly by decreasing temperatures below 50°F. Like Fig. 7, typical 24-hour periods (3 p. m. to 3 p. m.) from each temperature level are shown for one cow of each breed. See legend to Fig. 7 for explanation.

indicate in a measure the changing activity of the cows with changing temperature. The chart shown in the upper section of Fig. 9 was prepared by averaging the length (in hours) of these non-drink periods. Increasing temperature reduced the length of the non-drink intervals to a greater extent

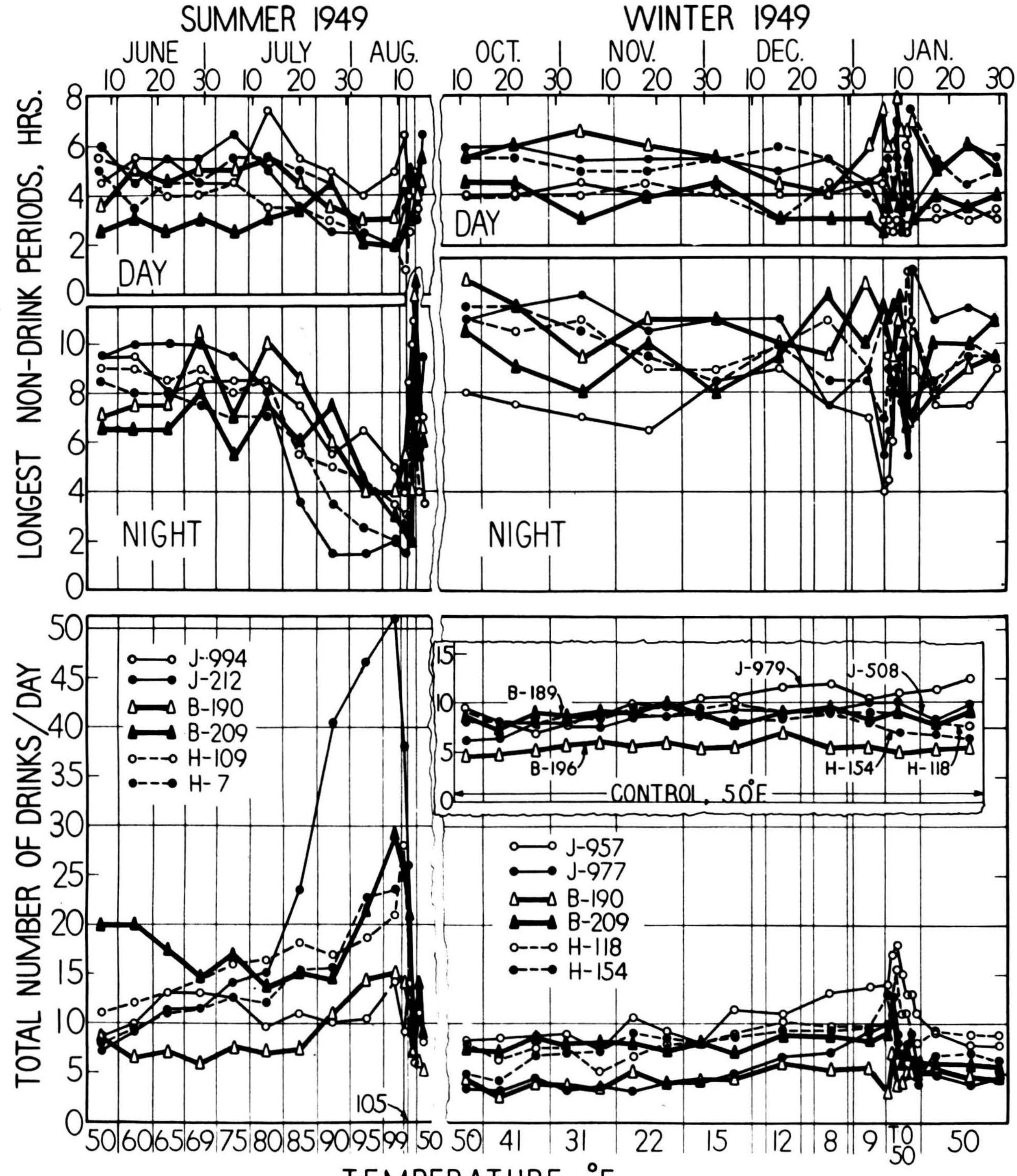


Fig. 9.—Duration of longest non-drink periods during night and day (upper sections) and drinking frequency (lower section) as function of time and temperature for the Experimental cows. The insert shows the drinking frequency for the Control cows during the Winter period. No change occurred in the non-drink periods for the Control cows. The narrow intervals without temperature designations in the Winter period represent power failure and absence of temperature control.

during the night than during the day, as might be expected from the greater disturbances (measurements) during the day (although no difference was observed between the week days and Sundays, when measurements were minimal).

The drinking frequency usually increased with increasing temperature above 50°F even in the cows that decreased their water consumption. Interestingly enough, the drinking frequency also tended to increase somewhat with decreasing temperature below 50°F, although for a different reason. The increasing drinking frequency with *rising* temperature above 50°F has a homeothermic significance, to help keep the body cool; the slight increasing drinking frequency with *declining* temperature is apparently associated with increasing hay consumption rather than with homeothermicity.

While the water-consumption *patterns* of Jersey 212 and of the Brahmans are similar, Figs. 7c and d and 9 show that the increase in absolute water consumption and in drinking frequency is greater in Jersey 212 than in the Brahmans.

TEMPERATURE OF MAXIMAL MILK PRODUCTION

Figs. 10 to 12, along with Fig. 3, bring out the fact that, under the given conditions, 40° to 70°F is the zone of maximal milk production for European-evolved cattle; and that increasing temperature above 70° depresses the milk yield much more severely than decreasing the temperature below 40°F. Our data are not sufficient to warrant greater exactness but it seems probable that the optimal temperature for milk production for European-evolved cattle is near 50°F. The corresponding temperature zone of maximal productivity for Indian-evolved cattle has not yet been determined, although it evidently embraces a higher temperature level, perhaps up to 90°F.

Fig. 10 shows how temperature affects the ratios of milk production (also butterfat percentage, body weight, feed and water consumption) of the Experimental to the matched Control cows; Fig. 11 shows how temperature affects the efficiency of milk production, that is, the ratio of milk energy produced to TDN energy consumed, corrected for body weight loss (on the assumption that 2.18 lb. TDN is equivalent to one lb. loss in live weight); Fig. 12, compares the milk declines of the individual Experimental cows and their Controls from the initial 50°F temperature up to 105°F and 50°F down to 0°F for lactating Jerseys and Holsteins. Temperature effects on butterfat, body weight, feed and water consumption are also shown in Fig. 12.

All data in Fig. 12 are represented in terms of percentages of the levels at 50°F, as all measurements began at 50°F. Since parts of the changes in milk production and in related processes in time are associated with advances in the periods of lactation and gestation, the *light* curves for the Control animals are plotted along side the *heavy* curves for the Experimental animals. Note that Jersey 212 and 994 were used in both summer trials and that their curves for the successive years (and lactation periods) agree satisfactorily considering the differences in ages and in stages of lactation and gestation in the successive trials. Note that Holsteins 118 and 109 were used in the declining and rising temperature periods but for different lactation periods.

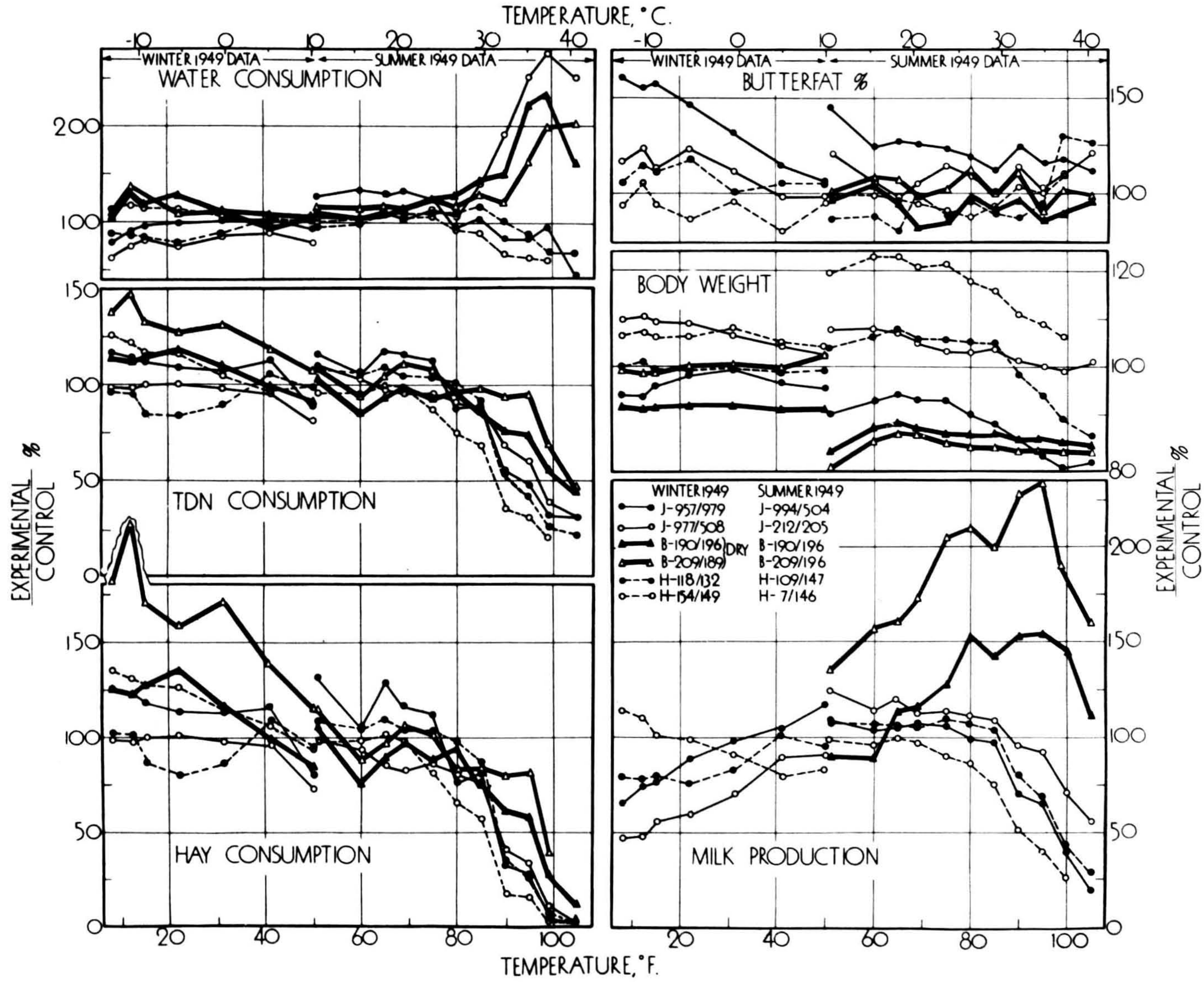


Fig. 10.—Ratios of Experimental to Control data during the period of *declining* temperatures (50° down to 8°F) and for the period of *rising* temperatures (50° up to 105°F). Compare to page 14, Res. Bul. 449. Since one of the Control Brahman cows was dry during the summer, the same lactating Control Brahman was used to compute the ratios on both Experimental Brahman cows. The increasing milk ratios in the Brahman cows with increasing temperature reflects the more rapid decrease in milk production of the Control cow rather than increase in milk production of the Experimental cows (compare to Fig. 3).

A major purpose of Fig. 12 is to find out how closely a cow can duplicate her record in successive years under the given conditions of rising temperature from 50° to 105°F. Fig. 12 shows that for the given temperatures the 1948 & 1949 milk-production curves are parallel but when the Control cows for the same *time* intervals are considered, it is found that the changes with advancing time (50° to 105°F) are much less for the 1949 data than for the 1948 data during the increasing temperatures. This is to be expected as the

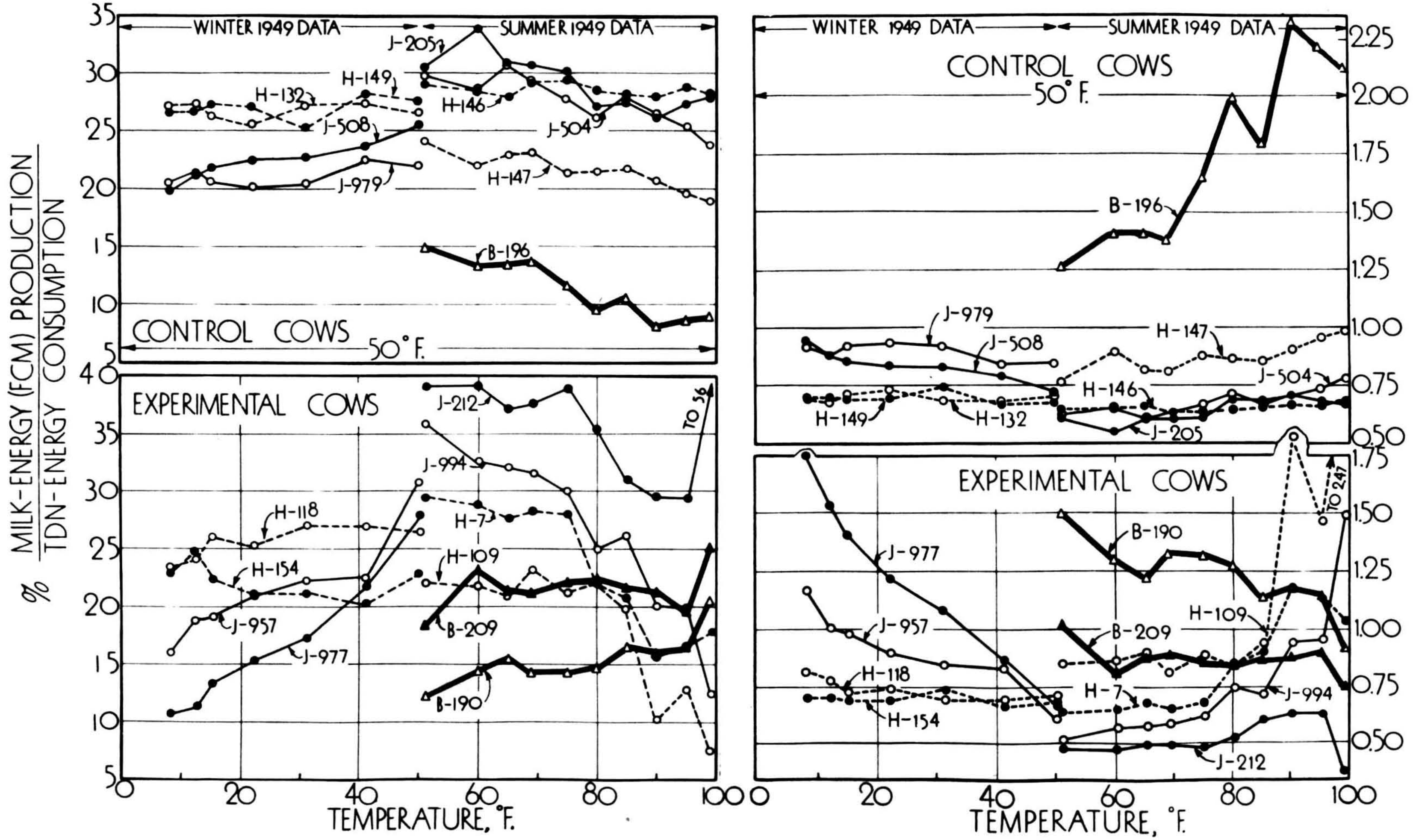


Fig. 11.—Effect of increasing environmental temperature from 8° to 105°F on the efficiency of milk production (ratio of FCM Calories produced to TDN Calories consumed, assuming that one lb. FCM is equivalent to 340 Calories and one lb. TDN to 1814 Calories) lower left section, and on the pounds TDN (total digestible nutrients) consumed per pound FCM produced, lower right section. The Control cows for the same time interval are shown in the upper sections to indicate the effect of advancing lactation and gestation on the efficiency of milk production. Above 80°F, the Jersey and Holstein Experimental cows were corrected for body weight loss by adding to the total TDN consumed a computed value obtained by multiplying 2.18 by weight loss in lbs.; for explanation, see pages 839-41 of Brody's "Bioenergetics and Growth."

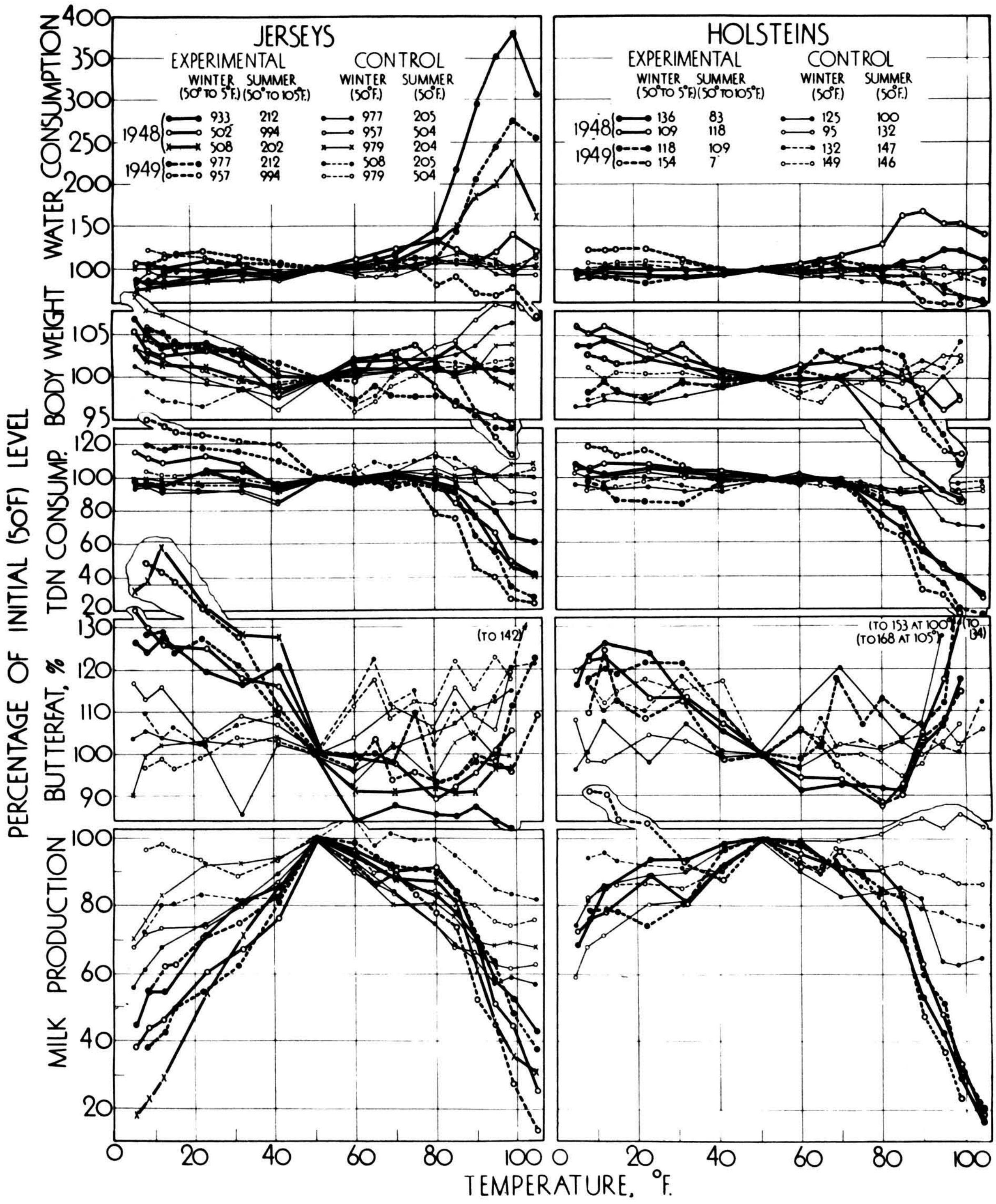


Fig. 12.—Summary chart of the 1948 (continuous lines) and 1949 (broken lines) data on lactating Jersey and Holstein cows, presented in terms of the initial temperature levels at 50°F, as function of rising temperatures from 50° up to 105°F (Summer), and of declining temperatures from 50°F down to about 5°F (Winter). The same symbols represent Experimental and their paired Control cows but the curves for the Experimental cows are heavy while for the Control cows they are light. Control H-100 was sick during the time interval corresponding to the 90°F temperature level (which accounts for her rapid decline in milk production and TDN consumption). For further details of the 1948 data, see Mo. Res. Buls. 425 and 449.

time intervals for most of the temperature levels during the 1948 period were twice as long as those for the 1949 period although more temperature levels were used in the 1949 test period. (The total time from 50° to 105°F for the 1948 period of rising temperatures was 154 days whereas the 1949 period was 68 days.) The time interval during the two winter periods (50° to 5°F) is very similar and covered the same total time period of 91 days. The effects of increasing temperatures may therefore have been somewhat greater in 1949 than in 1948 data because the more rapid changes in temperatures in 1949 did not permit as great an acclimatization to the higher temperatures as in 1948, and in part, perhaps, because the 1948 stages of lactation were somewhat more advanced.

It is puzzling that (with the exception of Jersey 212) the water consumption increased with increasing temperature during 1948 and decreased during 1949. This may be due to the greater decrease in hay consumption during the 1949 period (the ratio of water to hay, shown in Fig. 6, is much greater in the 1949 than in the 1948 period).

While a large literature has grown up on the effect of environmental temperature on fat percentage in milk since Eckles' classic paper in 1909[12], the second segment from the bottom in Fig. 12 is the first report on the effect of controlled environmental temperature, 5° to 105°F, on fat percentage. The fat percentage undoubtedly rises with declining temperature from 50° or 60°F down to 0°F, and that the rise is much steeper in Jersey than in Holsteins. The fat percentage also tends to increase with declining milk yield above 80°F especially in the Holsteins.

SUMMARY AND ABSTRACT

Data are presented on the influence of rising temperature, 50° up to 105°F, and of declining temperatures, 50° down to 8°F, on milk production, butterfat percentage, feed and water consumption, and body weight of European-evolved (Jersey and Holstein) and Indian-evolved (Texas bred Brahman) cattle. Comparisons were made of the data obtained on the Experimental cows with data obtained on the matched Control cows housed at 50°F.

The optimal production in European-evolved cows appears to be about 50°F; milk yield begins to decline above 70°F and below 40°F; the decline with rising temperatures is earlier in the Holsteins than in the Jerseys; the decline with declining temperatures is earlier in the Jerseys, in fact, the Holsteins are affected very little, if any, by declining temperatures down to 8°F. The low-producing Brahman cows did not decline in milk production until 90° to 95°F. The butterfat percentage increased with declining temperatures below 40°F and with rising temperatures above 80°F. The feed consumption, like the milk production, decreased with rising temperatures above 70°F, and increased with declining temperatures below 40°F, even if the milk production did not decline. The Jersey and Holstein cows lost weight with rising temperatures above 75°F while the Brahmans maintained their weight. All animals gained weight with declining temperatures. With the exception of

[12] Eckles, C. H., "Jarhreszeitliche Schwankungen des Prozentischen Fettgehaltes in Kuhmilch." Milchwirtschaftliches Zentralbl., 5, 448, 1909.

Jersey 212 and the Brahmans, which had similar rising water consumption patterns, the cows either maintained or reduced their water consumption with increasing environmental temperature above 75°F. Several charts show intriguing peculiarities of the water-consumption pattern—total water consumption per day and per drink, number of drinks per day, lengths of non-drink periods during night and day, all as function of time and temperature. They all show that Jersey 212 differs from the other Jerseys and Holsteins, but resembles the Brahmans, in these respects.

A comparison is presented of the reactions of lactating Jersey and Holstein cows obtained during 1948 and 1949.

APPENDIX

TABLE 3.--AVERAGE MILK AND BUTTERFAT PRODUCTION FOR THE DIFFERENT TEMPERATURE LEVELS (SUMMER 1949)

Temperature Levels,* °F		Exper. J-994	Contr. J-504	Exper. J-212	Contr. J-205	Exper. B-190	Contr. B-196	Exper. B-209	Contr. B-189	Exper. H-109	Contr. H-147	Exper. H-7	Contr. H-146
Exper.	Contr.					Butterfat, %							
51	50	6.31	4.33	5.62	4.67‡	5.25	5.40	5.38	(dry)	3.19	3.70	3.29	3.33
60	50	6.05	4.84	5.61	5.31	5.40	5.12	5.52		3.16	3.60	3.49‡	3.53
65	51	6.53	5.10	5.63	5.73	5.33	5.70	6.12		3.27	4.03	3.36	3.47
69	51	5.91	4.71	5.48	5.24	4.67	5.68	5.55		3.78	3.78	3.20	3.34
75	52	6.06	4.88	6.19	5.38	5.10	5.92	6.03		3.41	3.83	3.04	3.35
80	51	5.85	4.86	5.23	4.78	5.12	5.21	5.81		3.61	3.77	2.91	3.29
85	51	5.95	5.31	5.31	5.25	5.26	5.76	5.78		3.47	3.83	2.96	3.18
90	51	6.27	5.01	5.52	4.85	5.33	5.52	6.07		3.41	3.89	3.42	3.28
95	51	6.18	5.35	5.47	5.33	5.33	6.18	5.55		3.59	3.78	3.57	3.58
99	53	6.04	5.13	6.27	5.65	5.21	5.87	5.99		4.88	3.74	3.78**	3.43
105	51	6.9	6.15	6.9	5.7	5.6	5.9	5.8		5.35	4.2		3.55
51	49	6.3	5.45	5.4	6.0	5.7†	5.8	5.55		3.5	3.95		3.25
						Milk Production, lb/day							
51	50	27.9	25.7	31.5	25.4‡	6.3	7.1	9.5		35.5	33.1	46.6	47.3
60	50	25.7	24.8	31.0	27.1	6.1	6.9	10.8	(dry)	34.6	30.8	42.7‡	44.4
65	51	24.1	23.0	29.7	24.8	7.0	6.2	9.9		33.1	29.8	42.6	42.8
69	51	24.9	23.3	28.9	25.7	7.0	6.0	10.4		32.6	31.0	44.7	46.1
75	52	23.2	21.9	28.6	25.2	6.4	5.1	10.4		31.3	28.5	41.2	45.8
80	51	21.5	21.7	28.2	25.3	7.0	4.6	9.7		29.8	27.7	37.6	43.4
85	51	20.5	21.0	26.4	24.2	6.9	4.8	9.6		29.0	27.9	33.1	44.1
90	51	14.5	20.6	22.0	22.9	6.4	4.2	9.5		21.0	26.3	21.8	42.8
95	51	12.6	19.4	19.9	21.5	6.4	4.0	9.5		18.0	26.0	17.0	42.3
99	53	7.4	19.0	15.1	21.2	5.9	4.2	8.1		11.2	25.2	10.6**	41.2
105	51	3.8	19.6	11.7	20.8	5.0	4.5	7.2		7.1	24.7		41.1
51	49	10.9	18.1	17.1	20.1	5.5	4.3	7.1		12.5	24.8		41.6
51	49	12.5	18.4	18.7	20.3	3.3†	3.8	8.1		16.3	24.0		40.1
						FCM, lb/day (Fat Corrected Milk to 4%)							
51	50	37.5	26.9	39.1	28.1‡	7.42	8.55	11.5		31.2	31.6	41.7	42.3
60	50	33.4	27.8	38.4	32.4	7.38	8.03	13.2		30.4	29.0	39.5‡	41.1
65	51	33.1	26.8	36.8	31.1	8.35	7.76	13.0		29.6	29.8	38.8	39.6
69	51	32.0	25.7	35.4	30.3	7.70	7.57	12.9		31.6	30.0	39.3	41.3
75	52	30.5	24.9	38.0	30.5	7.49	6.50	13.5		28.5	27.6	35.0	41.7
80	51	27.3	24.6	33.3	28.3	8.19	5.46	12.4		28.0	26.9	31.4	38.8
85	51	26.7	25.1	31.5	28.6	8.20	6.11	12.2		26.8	27.1	28.1	38.8
90	51	19.5	23.7	27.0	25.6	7.60	5.11	12.5		19.1	25.9	19.8	38.3
95	51	16.8	23.5	24.4	25.7	7.66	5.37	11.7		16.9	25.2	16.0	39.8
99	53	9.6	22.1	20.3	26.3	6.94	5.42	10.5		12.7	24.4	10.3**	37.5
105	51	5.4	26.1	16.8	26.1	6.20	5.78	9.14		8.6	25.4		38.6
51	49	16.8	22.3	22.6	26.4	4.14†	4.83	10.0		15.1	24.0		35.3

* Temperature levels are arranged in time sequence. See Table 1 for details.
** H-7 removed from laboratory at veterinarian's recommendation August 8, 5:45 p.m.
† One milking on Aug. 15, B-190
‡ Had mastitis (J-205 from May 30 to June 5, inclusive; H-7 on June 14 and 15)

TABLE 4.--AVERAGE MILK AND BUTTERFAT PRODUCTION FOR THE DIFFERENT TEMPERATURE LEVELS (WINTER 1949)

Temperature Levels,* °F Exper.	Contr.	Exper. J-957	Contr. J-979	Exper. J-977	Contr. J-508	Exper. H-118	Contr. H-132	Exper. H-154	Contr. H-149
				Butterfat, %					
50	52	5.06	4.74	5.82	5.88	3.35	3.16	3.46	3.62
41	50	5.62	4.86	6.34	6.42	3.67	3.49	3.43	4.26
31	50	6.50	4.91	7.10†	6.33	4.11‡	3.74	3.91	4.08
22	50	6.85	4.67	7.44	6.00	4.09‡	3.48	3.73	4.28
15	50	7.19	4.54	7.09	6.21	4.00	3.56	3.92	4.16
12	50	7.26	4.67	7.51	6.07	4.02	3.49	4.32	4.07
8	51	7.36	4.57	7.48	6.42	3.95	3.71	3.80	4.25
9	50	7.00	4.49	7.03	6.08	4.30‡	4.04	3.98	4.18
50	50	5.88	4.92	6.50	6.43	4.07	3.68	3.72	4.40
				Milk Production, lb/day					
50	52	18.3	15.6	15.1	16.7	36.2	38.0	29.6	35.7
41	50	15.2	14.6	12.2	13.7	34.9	34.5	26.0	32.3
31	50	13.6	13.9	9.4†	13.6	29.0‡	34.7	27.8	30.6
22	50	12.8	14.5	8.2	13.9	26.7‡	35.2	30.8	31.0
15	50	11.4	15.0	7.4	13.4	28.2	35.6	31.2	30.8
12	50	11.3	15.3	6.4	13.3	28.4	36.4	33.4	30.3
8	51	9.9	15.0	5.7	12.0	28.4	35.8	33.6	29.4
9	50	10.1	14.5	5.1	11.4	24.6‡	33.7	31.8	27.6
50	50	11.2	13.4	6.3	10.0	25.6	33.1	30.4	23.3
				FCM, lb/day (Fat Corrected Milk to 4%)					
50	52	21.3	17.2	19.2	21.5	32.9	23.4	27.4	33.6
41	50	18.8	16.6	16.4	18.6	33.3	31.9	23.7	33.8
31	50	18.7	15.8	13.8†	18.3	29.4‡	33.1	27.4	31.1
22	50	18.2	16.0	12.4	18.1	27.1‡	32.6	29.4	32.4
15	50	16.9	16.1	10.8	17.8	28.2	33.5	30.7	31.7
12	50	16.9	16.9	9.8	17.5	28.4	33.7	34.9	30.8
8	51	15.0	16.4	8.7	16.3	28.4	34.2	32.6	30.3
9	50	14.6	15.6	7.4	15.0	25.7‡	33.7	31.8	28.4
50	50	14.4	15.2	8.7	13.6	26.0	31.6	29.0	24.7

* Temperature levels arranged in time sequence. See Table 1 for details.
† Mastitis, Oct. 28
‡ Off feed due to digestive disturbance--Nov. 8 to 13 and Dec. 31

TABLE 5.--AVERAGE BODY WEIGHT AND FEED CONSUMPTION FOR THE DIFFERENT TEMPERATURE LEVELS (SUMMER 1949)

Temperature Levels,* °F Exper.	Contr.	Exper. J-994	Contr. J-504	Exper. J-212	Contr. J-205	Exper. B-190	Contr. B-196	Exper. B-209	Contr. B-189	Exper. H-109	Contr. H-147	Exper. H-7	Contr. H-146
						Body Weight, lb.							
51	50	758	846	988	918‡	743	882	710	712	1274	1228	1291	1081
60	50	755	812	961	890	753	864	726	711	1286	1208	1302‡	1058
65	51	776	823	977	899	777	882	756	726	1312	1218	1290	1051
69	51	781	838	966	920	787	901	772	745	1302	1234	1295	1072
75	52	787	849	964	932	787	918	769	757	1315	1244	1307	1077
80	51	771	856	966	936	793	924	768	768	1319	1253	1282	1088
85	51	758	858	960	936	795	923	763	779	1307	1243	1257	1087
90	51	729	858	945	932	796	934	769	781	1235	1255	1211	1092
95	51	704	864	929	929	803	947	780	796	1188	1265	1179	1085
99	53	688	866	929	934	801	948	779	800	1142	1284	1174**	1106
105	51	702	879	951	942	788	955	786	801	1105	1292		1122
51	49	691	876	898	941	806	955	767	799	1158	1297		1108
51	49	702	889	890	938	809	956	758	806	1154	1293		1114
						Hay Consumption, lb/day							
51	50	22.7	17.4	19.4	19.9‡	13.4	12.8	14.6	10.8	35.3	32.7	33.6	34.2
60	50	22.0	21.0	18.0	19.4	10.3	13.8	12.0	8.7	35.8	34.3	32.3‡	34.6
65	51	22.9	17.8	18.6	22.2	11.4	13.0	12.4	9.6	37.2	33.7	33.8	33.8
69	51	21.6	18.6	18.0	22.0	11.5	11.9	12.5	8.8	36.1	34.6	32.6	33.5
75	52	21.6	19.3	19.2	22.5	10.8	12.4	12.5	6.7	35.3	34.3	27.3	33.5
80	51	16.3	21.4	18.4	23.0	12.1	12.9	10.4	10.1	32.5	33.1	20.1	31.1
85	51	16.6	20.3	17.6	23.1	9.7	13.1	10.9	10.1	28.7	33.2	18.4	32.2
90	51	6.6	20.3	9.3	23.0	9.0	14.9	11.7	9.3	11.8	33.4	5.4	31.8
95	51	6.0	21.5	7.8	23.1	8.6	14.8	12.1	7.9	9.2	34.9	5.3	34.6
99	53	.9	22.0	2.5	23.3	3.8	14.1	5.4	9.0	2.1	34.8	.9**	33.9
105	51	.3	23.1	.6	22.9	1.6	15.2	.4	8.6	.1	35.3		34.9
51	49	11.1	22.8	5.6	23.5	9.1	15.1	9.9	8.8	13.6	35.5		34.6
51	49	10.6	22.9	13.7	23.2	10.7	15.0	12.8	9.5	18.8	34.6		32.4

TABLE 5.--AVERAGE BODY WEIGHT AND FEED CONSUMPTION FOR THE DIFFERENT TEMPERATURE LEVELS (SUMMER 1949) (cont'd.)

Temperature Levels,* °F		Exper. J-994	Contr. J-504	Exper. J-212	Contr. J-205	Exper. B-190	Contr. B-196	Exper. B-209	Contr. B-189	Exper. H-109	Contr. H-147	Exper. H-7	Contr. H-146
Exper.	Contr.	Total Digestible Nutrients (TDN) lb/day (Computed with aid of F.B. Morrison's "Feeds and Feeding," 1948)											
51	50	19.6	16.9	18.8	17.2‡	11.2	10.8	11.8	9.9	26.6	24.6	26.6	27.6
60	50	19.2	18.3	18.4	17.9	9.6	11.4	10.7	8.8	26.1	24.7	25.7‡	27.1
65	51	19.3	16.4	18.4	19.0	10.2	11.0	11.4	9.3	26.5	24.4	26.4	26.7
69	51	19.0	16.4	17.6	18.5	10.2	10.4	11.5	8.9	25.6	24.5	26.1	26.5
75	52	19.0	16.8	18.2	19.0	9.9	10.7	11.5	7.8	25.2	24.3	23.4	26.7
80	51	15.5	17.6	17.6	19.6	10.5	10.9	10.4	9.5	23.6	23.5	19.2	25.5
85	51	15.0	16.9	17.2	19.4	9.3	11.0	10.6	9.5	21.5	23.4	17.6	25.9
90	51	9.2	16.9	12.5	18.3	9.0	11.9	11.1	9.1	12.5	23.5	9.1	25.7
95	51	8.2	17.3	10.6	17.6	8.8	11.9	11.2	8.4	10.2	24.2	8.2	26.7
99	53	5.6	17.4	6.8	17.7	6.4	11.5	7.9	9.1	6.2	24.2	5.3**	26.0
105	51	5.3	17.9	5.5	17.5	5.2	12.1	5.4	8.8	5.2	24.4		26.5
51	49	11.9	17.8	9.9	17.8	9.0	12.0	10.2	8.8	13.9	24.5		26.4
51	49	12.0	17.8	14.3	17.6	9.8	12.0	11.6	9.2	16.9	24.1		25.2

* Temperature levels are arranged in time sequence. See Table 1 for details.
‡ Had mastitis (J-205 from May 30 to June 5, inclusive; H-7 on June 14 and 15)
** H-7 removed from laboratory at veterinarian's recommendation August 8, 5:45 p.m.

TABLE 6.--AVERAGE BODY WEIGHT AND FEED CONSUMPTION FOR THE DIFFERENT TEMPERATURE LEVELS (WINTER 1949)

Temperature Levels,* °F		Exper. J-957	Contr. J-979	Exper. J-977	Contr. J-508	Exper. B-190	Contr. B-196	Exper. B-209	Contr. B-189	Exper. H-118	Contr. H-132	Exper. H-154	Contr. H-149
Exper.	Contr.	Body Weight, lb.											
50	52	828	868	908	890	863	947	824	808	1205	1213	1182	1132
41	50	829	861	924	884	868	955	829	835	1192	1208	1186	1127
31	50	855	863	934†	876	903	987	859	860	1200‡	1208	1231	1140
22	50	858	875	937	859	918	1003	877	882	1175‡	1187	1207	1135
15	50	858	895	946	864	939	1033	891	902	1187	1194	1204	1138
12	50	856	914	955	866	962	1058	903	917	1199	1188	1211	1131
8	51	866	921	959	875	977	1069	912	922	1182	1183	1216	1146
9	50	866	925	975	879	966	1083	915	942	1172‡	1167	1211	1134
50	50	850	933	970	885	980	1110	931	951	1154	1178	1184	1149
		Hay Consumption, lb/day											
50	52	13.0	16.2	13.4	18.6	9.4	11.2	9.6	8.4	28.6	28.7	28.0	28.2
41	50	19.8	17.0	18.0	18.8	13.3	13.5	12.6	9.1	29.0	26.7	30.3	28.6
31	50	21.1	18.6	19.4†	19.9	14.7	12.8	14.3	8.3	25.5‡	29.8	35.6	31.2
22	50	22.1	19.3	19.8	19.7	15.1	11.2	14.7	9.3	25.3‡	31.4	37.8	29.9
15	50	22.6	19.1	19.9	19.9	16.0	12.6	15.8	9.3	26.8	31.2	36.6	28.6
12	50	23.4	19.1	19.5	20.1	16.6	13.6	16.0	7.6	30.1	29.7	37.6	28.7
8	51	24.5	19.5	20.1	20.4	17.7	14.3	16.0	8.8	31.7	31.1	37.3	27.8
9	50	22.2	18.1	18.5	18.8	14.1	12.1	15.8	8.6	26.4‡	28.8	35.6	25.0
50	50	18.6	18.0	14.2	17.6	11.7	12.9	10.2	6.4	23.0	29.7	30.2	24.0
		Total Digestible Nutrients (TDN) lb/ day (Computed with aid of F.B. Morrison's "Feeds and Feeding," 1948)											
50	52	13.0	14.6	12.9	15.8	9.9	10.8	10.0	9.4	23.3	23.6	22.5	22.8
41	50	15.6	13.9	14.2	14.8	11.9	12.0	11.5	9.8	23.1	21.9	22.0	22.6
31	50	15.8	14.5	14.9†	15.2	12.6	11.6	12.4	9.4	20.4‡	22.8	24.4	23.2
22	50	16.3	14.9	15.2	15.1	12.8	10.8	12.6	9.8	20.1‡	24.0	26.3	22.5
15	50	16.6	14.8	15.2	15.2	13.2	11.5	13.1	9.9	20.3	23.9	25.7	21.8
12	50	17.0	14.8	15.0	15.3	13.6	12.0	13.2	9.0	22.0	23.2	26.6	21.7
8	51	17.5	15.0	15.3	15.4	14.1	12.4	13.2	9.6	22.9	23.8	26.8	21.3
9	50	16.4	14.3	14.5	14.6	12.2	11.3	13.1	9.5	20.0‡	22.5	25.5	19.3
50	50	14.6	14.2	12.3	14.0	11.1	11.7	10.3	8.4	17.9	22.7	22.3	18.3

* Temperature levels arranged in time sequence. See Table 1 for details.
† Mastitis, Oct. 28
‡ Off feed due to digestive disturbance--Nov. 8 to 13 and Dec. 31

TABLE 7.--AVERAGE FREQUENCY AND AMOUNT OF WATER CONSUMED FOR THE DIFFERENT TEMPERATURE LEVELS (SUMMER 1949)

Temperature Levels,* °F Exper.	Contr.	Exper. J-994	Contr. J-504	Exper. J-212	Contr. J-205	Exper. B-190	Contr. B-196	Exper. B-209	Contr. B-189	Exper. H-109	Contr. H-147	Exper. H-7	Contr. H-146
		Water Consumption, gal/day											
51	50	17.2	13.6	13.8	13.2†	8.3	7.9	8.9	4.4	23.8	24.9	23.6	23.3
60	50	17.0	12.8	13.4	13.0	7.6	7.4	8.4	4.4	22.9	23.6	23.1†	22.4
65	51	17.5	13.7	15.4	13.9	7.7	8.0	9.1	5.8	25.8	23.2	24.7	23.3
69	51	17.8	13.5	14.8	14.4	8.8	7.9	9.0	5.7	24.2	22.8	25.5	23.5
75	52	17.5	14.2	15.5	13.6	8.9	7.3	9.1	4.9	23.5	21.7	24.0	22.5
80	51	13.7	14.8	15.5	14.6	9.1	7.3	8.3	5.4	23.5	21.6	19.9	21.6
85	51	15.5	15.0	19.8	14.2	10.1	7.2	9.1	5.7	23.7	20.5	19.1	22.0
90	51	12.0	14.7	28.5	15.0	12.7	8.6	10.2	5.7	21.2	20.9	14.4	22.6
95	51	11.6	14.4	33.6	13.5	17.6	8.0	12.9	5.2	18.0	20.8	13.6	22.2
99	53	13.2	14.1	38.2	13.9	18.4	8.0	15.9	5.5	15.3	23.0	13.4**	22.8
105	51	6.7	15.6	34.9	13.9	13.8	8.6	17.5	5.1	14.0	21.1		20.5
51	49	9.2	16.2	12.2	12.8	7.6	8.2	7.6	6.8	10.4	22.2		23.3
51	49	11.5	13.8	13.7	14.6	7.0	9.2	8.1	3.8	12.6	23.7		21.6
		Total Number of Drinks Per Day											
51	50	8.6		7.1		8.5		19.8		11.0		7.9	
60	50	9.9		9.1		6.4		19.9		12.1		9.4†	
65	51	13.0		11.3		7.0		17.3		13.0		11.1	
69	51	13.0	8.5	11.4	7.5	5.9	5.6	14.7	5.0	14.4	13.0	11.4	12.0
75	52	12.4	9.0	14.1	7.0	7.6	5.6	16.9	5.4	15.9	13.0	12.6	12.4
80	51	9.7	7.0	15.1	6.3	6.9	5.0	13.6	5.7	16.4	11.1	12.1	10.1
85	51	10.9	8.0	23.4	6.6	7.3	6.0	15.1	5.7	18.1	8.4	15.4	8.9
90	51	10.1	10.2	40.4	7.8	10.9	6.5	14.7	5.0	16.9	9.5	15.6	10.5
95	51	10.4	9.1	46.6	7.3	14.3	5.1	21.4	4.9	18.6	8.9	22.7	10.0
99	53	14.2	7.2	51.0	7.2	15.0	5.2	29.2	5.0	20.8	12.0	23.5**	9.0
105	51	9	10	38	6	14	7	25	6	28	10		10
51	49	11	7	12	7	6	5	14	5	11	8		8
51	49	9	7	9	6	5	5	9	5	8	10		7

* Temperature levels are arranged in time sequence. See Table 1 for details.
† Had mastitis June 14 and 15.
** H-7 removed from laboratory at veterinarian's recommendation August 8, 5:45 p.m.

TABLE 8.--AVERAGE FREQUENCY AND AMOUNT OF WATER CONSUMED FOR THE DIFFERENT TEMPERATURE LEVELS (WINTER 1949)

Temperature Levels,* °F Exper.	Contr.	Exper. J-957	Contr. J-979	Exper. J-977	Contr. J-508	Exper. B-190	Contr. B-196	Exper. B-209	Contr. B-189	Exper. H-118	Contr. H-132	Exper. H-154	Contr. H-149
		Water Consumption, gal/day											
50	52	9.2	9.9	8.9	11.4	5.4	5.2	4.7	4.5	19.3	19.0	16.6	16.1
41	50	9.7	9.4	9.4	10.7	5.7	6.1	5.5	5.2	18.5	18.1	15.6	16.2
31	50	10.5	10.4	9.4†	10.9	6.6	6.0	6.2	5.6	16.9**	19.3	18.6	17.5
22	50	11.1	11.2	8.5	11.1	6.4	5.0	6.2	5.7	15.6**	20.3	20.4	17.8
15	50	10.8	11.3	8.8	11.0	6.7	5.7	6.5	5.5	16.9	20.2	20.2	17.5
12	50	10.4	11.6	8.5	11.5	7.7	5.9	6.7	4.9	17.1	19.9	20.1	16.9
8	51	9.5	11.9	7.1	11.5	6.3	5.9	5.9	5.3	16.8	19.1	20.1	17.6
9	50	11.0	12.0	7.8	11.5	7.5	5.4	6.9	5.3	16.2**	19.6	20.2	16.8
50	50	10.5	11.9	7.7	10.5	6.4	6.4	5.7	4.8	18.2	18.9	20.0	16.3
		Total Number of Drinks Per Day											
50	52	8.3	9.3	3.3	6.1	4.3	4.6	7.4	8.6	7.9	9.0	4.9	8.0
41	50	8.6	7.0	3.7	7.2	3.2	4.8	7.8	8.1	6.8	7.9	5.4	8.0
31	50	8.1	8.3	3.4†	7.6	3.6	5.8	7.9	8.9	6.2**	8.4	7.0	8.5
22	50	9.9	9.7	3.6	8.6	4.5	5.8	7.6	9.4	7.2**	8.8	8.8	9.5
15	50	9.6	10.5	4.4	9.2	4.4	5.4	7.5	8.5	8.5	9.6	8.4	8.4
12	50	11.0	11.7	6.7	9.1	6.0	6.9	8.9	9.0	10.0	9.1	9.3	8.3
8	51	13.2	11.9	7.2	9.3	5.3	5.4	8.8	9.6	9.7	9.0	9.3	8.9
9	50	13.8	10.4	9.2	10.0	5.6	5.4	8.4	8.4	9.8**	9.0	9.6	8.0
50	50	8.3	12.8	4.4	9.1	4.9	5.5	5.9	8.5	9.0	7.8	6.8	6.5

* Temperature levels arranged in time sequence. See Table 1 for details.
† Mastitis, Oct. 28.
** Off feed due to digestive disturbance--Nov. 8 to 13 and Dec. 31.