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J. H. Longwell, *Director*

# Environmental Physiology and Shelter Engineering

*With Special Reference to Domestic Animals*

## XXIII. The Effect of Humidity on Insensible Weight Loss, Total Vaporized Moisture, and Surface Temperature In Cattle

H. J. THOMPSON, D. M. WORSTELL AND SAMUEL BRODY

*Missouri Agricultural Experiment Station and the United States Department of Agriculture Cooperating*
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### INTRODUCTION

This is the third progress report in a preliminary survey of effects of relative humidity at various temperatures on physiological reactions of European- and Indian-evolved (Brahman) cattle. The first (Bul. 521*) reported data on the effect of humidity on feed and water consumption, milk production and composition, and body weight; the second (Bul. 522) on heat production, rectal temperature, and cardiorespiratory activities. This report is on insensible weight loss, total moisture vaporization and hair and skin temperatures.

Humidity is expressed in different ways. Considerable space is devoted to its clarification in the two preceding reports. Relative humidity is used here. Relative humidity is the percentage ratio of water vapor present in the given air to the maximum vapor it can hold.

Methods and significance of measuring insensible weight loss** were reported in detail in Buls. 451 and 479. Total moisture vaporization was obtained by deducting metabolic weight loss (reported in Bul. 522) from the insensible weight loss**. Methods of measuring surface temperatures with the radiometer (hair) and touch thermocouple (skin) have also been reported (Buls. 481 and 489).

*Unless otherwise noted "Bul." refers to University of Missouri Agricultural Experiment Station *Research* Bulletin. Research bulletins referred to in this publication are:

451 — Air Temperature vs Insensible Weight Loss, 1948-49
479 — Air Temperature vs Insensible Weight Loss, 1949-50
481 — Air Temperature vs Hair and Skin Temperature, 1948-49
489 — Air Temperature vs Hair and Skin Temperature, 1949-50
521 — Humidity vs Feed Consumption and Milk Production, 1950-51
522 — Humidity vs Metabolism and Cardiorespiratory activities, 1950-51

**"Metabolic weight loss" is the *difference* between the weights of carbon dioxide and methane produced and oxygen consumed, $(CO_2 + CH_4) - O_2$. "Insensible weight loss" is the *sum* of the weight of moisture vaporized and the metabolic weight loss, $H_2O + [(CO_2 + CH_4) - O_2]$.

The animals, their feed consumption and milk production, environmental temperatures, and humidity schedules were given in Bul. 521 (Table 1). For the periods of "low temperatures" (12° to 40°F, 48 to 86% relative humidity) six lactating Jersey and six lactating Holstein cows were used; for the "high temperatures" (75°, 85°, 95° and 100°F, and 35 to 90% relative humidity) both lactating (3 Holsteins, 3 Brown Swiss, 2 Jerseys) and non-lactating (2 Jerseys and 2 Brahmans) cows were used. Control periods of 50°F (for low temperatures) or 65°F (for the higher temperatures) at 65 percent relative humidity were interspersed between the increases (or decreases) in experimental temperature.

In addition to the average laboratory air temperature and humidity calendars given in Bul. 521 (Table 1), Tables 1 and 2 in this bulletin

TABLE 1 -- AVERAGE AIR TEMPERATURE AND RELATIVE HUMIDITY (Winter 1950-51)

| Period | | For Entire Period | | During Insensible Loss Measurements | | During Surface Temperature Measurements | |
|---|---|---|---|---|---|---|---|
| From | To | °F | % R.H. | °F | % R.H. | °F | % R.H. |
| | | **For the Chamber Housing 6 Lactating Jerseys** | | | | | |
| Oct. 13 | Oct. 20 | 50 | 58-c | 52 | 58 | 50 | 60 |
| Oct. 20 | Nov. 3 | 40 | 56 | 40 | 62 | 41 | 56 |
| Nov. 3 | Nov. 17 | 40 | 58-1 | 41 | 57 | 39 | 46 |
| Nov. 17 | Dec. 1 | 40 | 86-h | 43 | 77 | 41 | 79 |
| Dec. 1 | Dec. 15 | 50 | 70-c | 52 | 70 | 51 | 63 |
| Dec. 15 | Dec. 29 | 12 | 66 | -- | -- | 11 | 62 |
| Dec. 29 | Jan. 12 | 12 | 84-h | 12 | 73 | 13 | 92 |
| Jan. 12 | Jan. 26 | 11 | 62-1 | 18 | 59 | 10 | 56 |
| Jan. 26 | Feb. 9 | 50 | 62-c | 50 | 70 | 50 | 62 |
| | | **For the Chamber Housing 6 Lactating Holsteins** | | | | | |
| Oct. 13 | Oct. 20 | 52 | 66-c | 53 | 67 | 54 | 62 |
| Oct. 20 | Nov. 3 | 40 | 64 | 42 | 69 | 44 | 65 |
| Nov. 3 | Nov. 17 | 40 | 74-h | 42 | 69 | 43 | 84 |
| Nov. 17 | Dec. 1 | 40 | 48-1 | 42 | 54 | 38 | 44 |
| Dec. 1 | Dec. 15 | 50 | 66-c | 50 | 66 | 49 | 64 |
| Dec. 15 | Dec. 29 | 15 | 70 | 10 | 61 | 13 | 63 |
| Dec. 29 | Jan. 12 | 14 | 65-1 | 13 | 66 | 13 | 64 |
| Jan. 12 | Jan. 26 | 17 | 84-h | 18 | 62 | 15 | 86 |
| Jan. 26 | Feb. 9 | 51 | 67-c | 52 | 66 | 52 | 68 |

Control conditions, designated by "c" refer to 50°F (or 65°F) and 65% relative humidity. The period of high and low relative humidity shown on the charts are designated by "h" and "1" respectively.

TABLE 2 -- AVERAGE AIR TEMPERATURE AND RELATIVE HUMIDITY (Summer 1951)

| Period | | For Entire Period | | During Insensible Loss Measurements | | During Surface Temperature Measurements | |
|---|---|---|---|---|---|---|---|
| From | To | °F | % R.H. | °F | % R.H. | °F | % R.H. |
| For the Chamber Housing 2 Lactating Jerseys, 2 Dry Jerseys and 2 Dry Brahmans | | | | | | | |
| Feb. 23 | Mar. 9 | 65 | 67-c | 64 | 47 | 65 | 64 |
| Mar. 9 | Mar. 23 | 75 | 38-1 | 73 | 27 | 74 | 36 |
| Mar. 23 | Apr. 6 | 76 | 75-h | 72 | 89 | 75 | 82 |
| Apr. 6 | Apr. 13 | 66 | 70-c | 66 | 68 | 65 | 68 |
| Apr. 13 | Apr. 27 | 84 | 40-1 | 83 | 40 | 86 | 38 |
| Apr. 27 | May 11 | 85 | 87-h | 86 | 88 | 85 | 84 |
| May 11 | May 25 | 65 | 67-c | 67 | 62 | 65 | 62 |
| May 25 | June 3 | 93 | 47-1 | 97 | 40 | 96 | 38 |
| June 3 | June 4 | 96 | 81-h | 93 | 85 | 96 | 82 |
| June 7 | June 8 | 93 | 40 | -- | -- | 95 | 60 |
| June 8 | June 22 | 66 | 67-c | 65 | 63 | 65 | 64 |
| June 24 | June 27 | 100 | 35-1 | 97 | 45 | 101 | 32 |
| June 28 | June 29 | 100 | 75-h | 100 | 78 | 100 | 72 |
| June 29 | July 20 | 66 | 63-c | 64 | 69 | 66 | 66 |
| For the Chamber Housing 3 Lactating Holsteins and 3 Lactating Brown Swiss | | | | | | | |
| Feb. 23 | Mar. 9 | 65 | 69-c | 67 | 46 | 65 | 64 |
| Mar. 9 | Mar. 23 | 75 | 39-1 | 75 | 29 | 75 | 36 |
| Mar. 23 | Apr. 6 | 76 | 78-h | 75 | 85 | 76 | 86 |
| Apr. 6 | Apr. 13 | 66 | 71-c | 66 | 67 | 65 | 68 |
| Apr. 13 | Apr. 27 | 85 | 44-1 | 86 | 40 | 85 | 44 |
| Apr. 27 | May 11 | 85 | 90-h | 88 | 85 | 85 | 86 |
| May 11 | May 25 | 65 | 71-c | 68 | 60 | 65 | 70 |
| May 25 | June 3 | 94 | 45-1 | 95 | 40 | 96 | 42 |
| June 3 | June 4 | 94 | 80-h | 94 | 83 | 96 | 84 |
| June 6 | June 7 | 94 | 60 | -- | -- | 95 | 60 |
| June 8 | June 29 | 66 | 66-c | 64 | 72 | 66 | 62 |
| July 1 | July 4 | 100 | 40-1 | 99 | 38 | 101 | 36 |
| July 4 | July 5 | 100 | 65-h | 98 | 59 | 102 | 62 |
| July 6 | July 29 | 66 | 62-c | 67 | 80 | 66 | 68 |

Control conditions, designated by "c" refer to 50°F (or 65°F) and 65% relative humidity. The periods of high and low relative humidity shown on the charts are designated by "h" and "l" respectively.

show temperatures of the workroom at the time the insensible weight losses were measured. Temperature of the chamber air surrounding the cows at the time surface temperatures were measured also is indicated. Differences between workroom and chamber air temperatures and relative humidities may explain some of the variability in the data.

Since the relative humidities were not exactly the same at all temperature levels (Tables 1 and 2), reactions of individual animals were plotted against time as in Fig. 2; against environmental temperature as in Fig. 3; or against certain parts of the body as in Fig. 6. The "high humidity" and "low humidity" points were then separately connnected (except Fig. 1). The relative effects of high and low relative humidities can, therefore, be determined by comparing the reaction levels and slopes in the charts. At environmental temperatures 40°F and 12°F the approximate "low humidity" was 60 percent and "high humidity" 80 percent; at temperatures 75°F and above, "low humidity" was approximately 40 percent and "high humidity" 85 percent.

## DATA AND DISCUSSION

### Insensible Weight Loss and Total Moisture Vaporization

Heat from the body is dissipated by vaporization and by non-evaporative methods — radiation, convection, and conduction. The lower the environmental temperature (i.e. the greater the thermal gradient between the body and environment) the greater the proportion of body-heat dissipation by radiation and convection, and the less by vaporization. Rising environmental temperature (decreasing the thermal gradient) shifts the heat dissipation from non-evaporative to evaporative cooling until, finally, when the environmental and body surface temperature coincide, all heat is dissipated by vaporization. To illustrate the shift from non-evaporative to evaporative cooling, it is recalled that the average evaporative heat dissipation in dairy cattle is around 10 percent of the heat production at 10°F; 50 percent at 70°F (21°C), and 100 percent at 105°F (41°C).

At the relatively low temperatures of 12° and 40°F, when little skin moisture was produced by the animals and less than half of the total heat produced was dissipated by vaporization, no effect of humidity on vaporization was observed (Fig. 1) under the given low humidity range. A striking feature of Fig. 1 is the parallelism between curves representing vaporized moisture per animal, per unit surface area, per unit heat production, and even per unit of insensible weight loss. Note also the similarity between slopes of the time curves for Holsteins and Jerseys, regardless of temperature or humidity. Fig. 2 shows that at

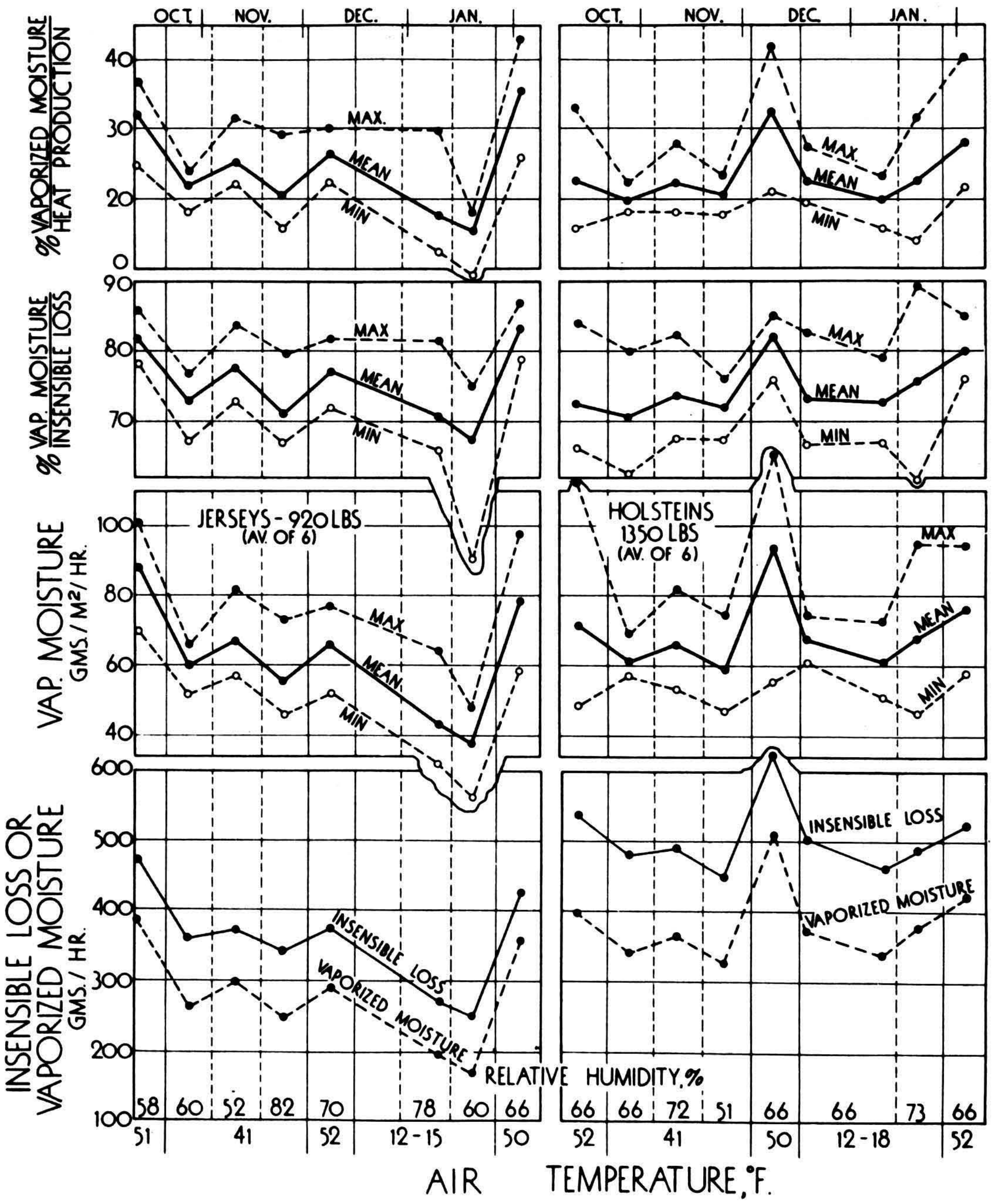



Fig. 1—Insensible weight loss and total moisture vaporization at 40° F and below appear to be unaffected by humidity but are affected by changing temperature. The values for metabolic weight loss and for heat production were taken from Missouri Res. Bul. 522. The latent heat of vaporization is assumed to be 580 Calories per kilogram of moisture.

temperatures above 75°F, when over half of the heat dissipation was by moisture vaporization, and especially at 85°F when about 70 percent of the heat produced was dissipated by vaporization, increase in relative humidity depressed the rate of evaporative cooling in spite of the higher skin temperatures of the cows. At chamber temperature 100°F, when almost all of the heat produced was dissipated by vaporization, the difference between effects of the two levels of humidity on moisture vaporization declined.

An interesting observation was that the moisture vaporized at 65°F was 15 to 30 percent of the total water drunk. On increasing the temperature, this proportion increased to 75 percent (Fig. 4). The percentage ratio of vaporized moisture to water drunk varied greatly due, in part, to individual differences in the quantity of water spilled from water cups (see water consumption curves in Fig. 6, Bul. 521).

### Surface Temperature

In addition to the "main body temperature" (average of 6 measurements on the back, belly, right and left sides of body, neck, and rear) in preceding experiments (Buls. 481 and 489), 17 other spots (Fig. 5) were measured.

Figs. 6 to 9 show how surface temperatures of these spots change with changing environmental temperature. As inferred from the evaporative cooling data, skin temperatures were lower at the low humidity at environmental temperatures exceeding 75°F. Greater vaporization rates at low humidity levels evidently reduced skin temperature below that of the high humidity level.

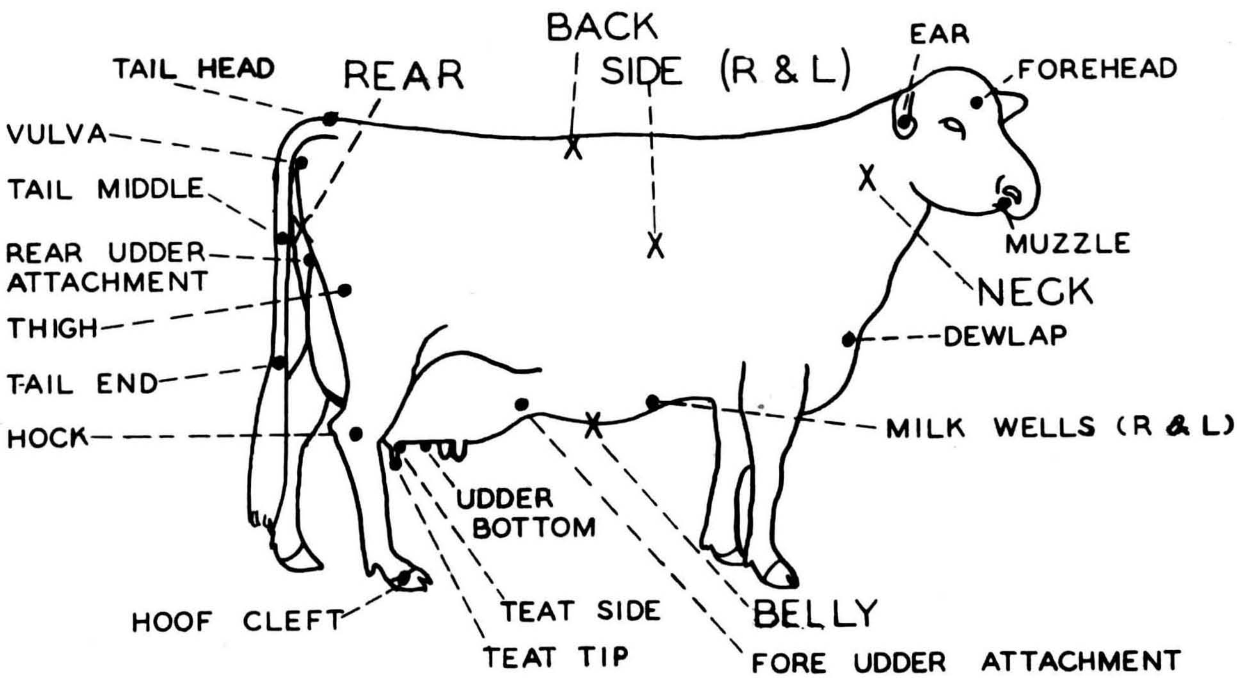



Fig. 5—Diagram showing approximate positions where skin temperatures were measured. The "X's" indicate spots averaged for what is designated as the "main body temperature" (cf. position is shown in Res. Bul. 481, Fig. 3). In Figs. 6 through 9 the temperature given for the "udder" is the average of three spots (udder bottom, rear and fore udder attachment); likewise, the milkwell is the average of the right and left milkwells. The temperature of the muzzle represents a wet surface in contrast to the temperature of the other parts which were "dry".

At the "low temperature", 12°-15°F, skin temperatures in Jerseys were slightly lower at the low than at the high humidity level; while in Holsteins the skin temperatures were higher at the low than at the high humidity level. Since the different parts of the body were all either consistently lower or higher, this difference between the two breeds cannot be explained by experimental error. What, then, is the explanation? Preceding reports on surface temperature (Buls. 481 and 489) showed a higher skin temperature in Jersey than in Holstein cows at temperatures below 50°F. Hair temperatures, however, were approximately the same or slightly lower in the Jerseys. Could this difference be explained by breed differences in skin thickness[1] and/or in the insulating properties of hair? Or could differences in body size explain this peculiarity by assuming that the smaller the animal the closer the skin to its center and, therefore, the higher its temperature?

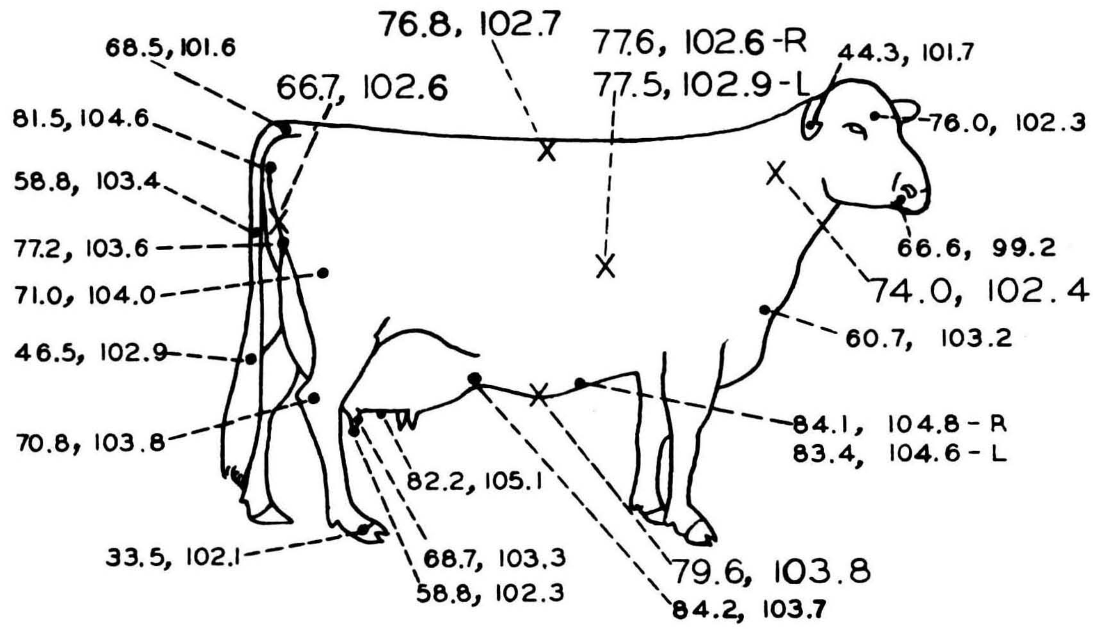
Figs. 6 to 8 show that, with the exception of the Brahman at 100°F, decreasing humidity at 85° and above decreased skin temperature in all cows. Another puzzling observation is shown in Fig. 9. Why does the Brahman heifer have a higher skin temperature than dry Brahman cow 209? This was thought to be due to B-209 being an "end" cow. She was in the stanchion next to the wall and so was exposed to a somewhat different environment on one side than the animals having cows flanking on both sides. Yet, J-549, S-48, and H-312 were also "end" cows and showed no difference in skin temperatures from others of the same breed. Neither was there a skin temperature difference between Jersey heifer 559 and Jersey cow 979 (dry). It, therefore, appears that the apparent skin temperature differences between the Brahman cow and heifer cannot be explained by difference in age or in position in the chamber. Data are insufficient for computing statistically significant differences.

Hair temperature data (measured with radiometer), shown in Fig. 10, are similar to the skin temperature data (measured with the touch thermocuple) in that reducing humidity reduced the surface temperature at environmental temperatures above 75°F.

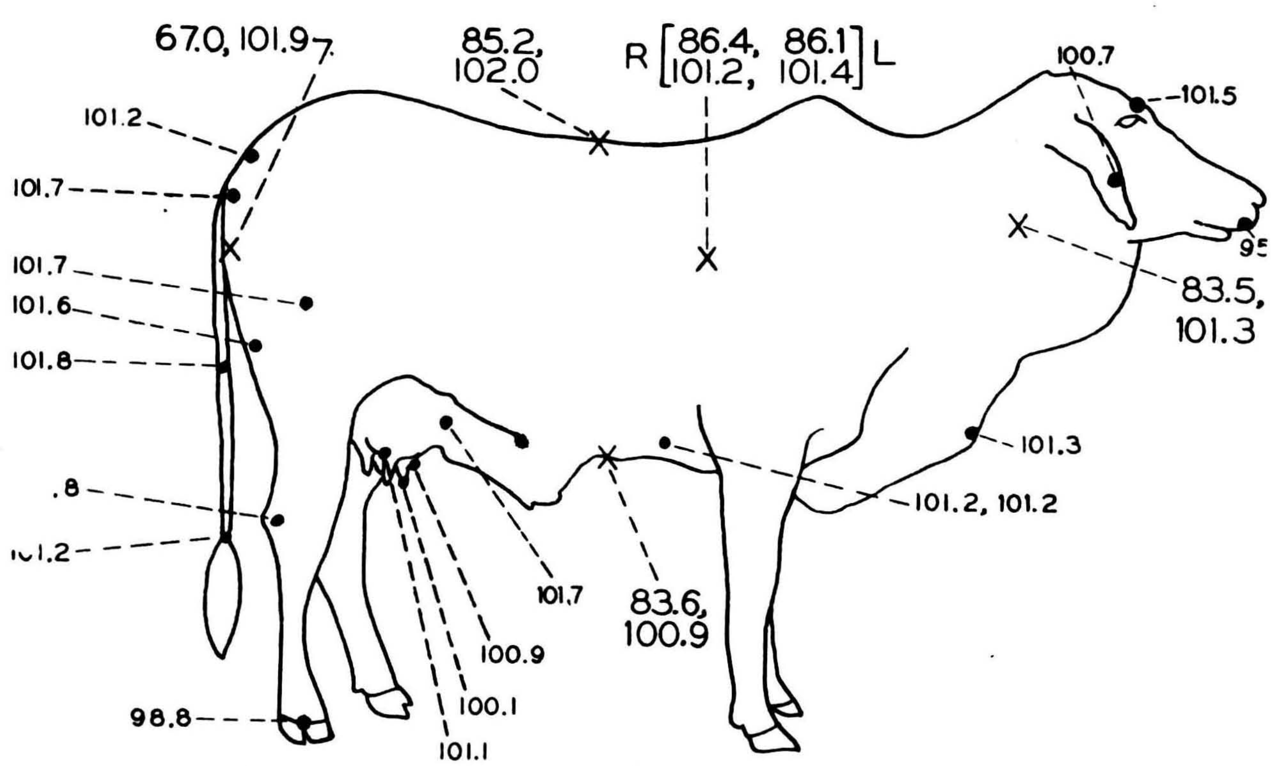
Fig. 10 brings out rather dramatically the differences in hair temperature levels of the jaw and leg, compared with that of the main body. In European cattle jaw temperature was higher than main body temperature below 75°F environmental temperature; increasing environmental temperature reduced the difference between hair temperature of the main body and the jaw; and at 95° and 100°F the difference disappeared. In Brahmans, however, the main body temperature remained lower than the jaw temperature throughout.

[1]Cf. McAdams, W. H., *Heat Transmission*, McGraw-Hill, p. 345.

## SKIN TEMPERATURE
## (TOUCH THERMOCOUPLE)




LOWEST @ 12.5° F., 88% R.H., JAN. 25,'51 -AVE. OF 6 HOLSTEIN COWS
HIGHEST @ 101.6°F., 65% R.H., JULY 5,'51 - AVE. OF 3 HOLSTEIN COWS




LOWEST @ 11.1°F., 65% R.H., DEC. 15, '49;
HIGHEST @ 101.9° F., 33% R.H., JUNE 26,'51 - BRAHMAN COW 209

Fig. 11—Highest and lowest skin temperature obtained on Holstein cows (upper diagram) for the indicated parts of the body. Note the lower skin temperatures for a given spot in the Brahman cow (lower section) at environmental temperature 102°F. The temperatures shown were the highest obtained regardless of humidity. The lowest points for the main body temperature of the Brahman were taken from a previous experiment (reported in part in Res. Bul. 489).

sult of higher skin temperature) at high humidity are physiologically detrimental, yet they facilitate non-evaporative cooling, particularly by convection.

## SUMMARY AND ABSTRACT

Tabular and/or graphic data are presented showing effects of high and low relative humidity on insensible weight loss, total vaporized moisture, and surface (hair and skin) temperatures on Jersey, Holstein, Brown Swiss, and Brahman cattle. Air temperatures used were 12°, 40°, 75°, 85°, 95°, and 100°F.

**Evaporative cooling:** At 12° and 40°F air temperatures there was no indication that increasing humidity affected vaporization rate. At temperatures of 75°, 85°, and 95°F there was a noticeable depression of vaporization with increasing humidity. Above 85°F air temperatures Holstein vaporization rates were somewhat lower than those of Brown Swiss. Effects of increasing humidity at 95° and 100°F were less on the smaller and lower-producing Jerseys. Individual differences and experimental variation in air temperatures may have masked some of the smaller effects of humidity. Brahman cows appeared to have dissipated a greater percentage of their total heat by evaporative cooling at high temperatures than European cattle. This was particularly true at high relative humidity levels.

**Surface temperature:** In addition to the "main-body temperatures" (average of 6 points) previously reported, this bulletin includes *thermocouple* measurements on *skin* temperature of 15 other parts of the body, including the ear, muzzle, teats, tail, and hock. *Hair* temperatures were measured with the Hardy *radiometer*. At 85°F and above, skin and hair temperatures of the cows were increased some on increasing relative humidity; at 12° and 40°F, however, there was no significant effect of relative humidity on skin temperature. At air temperatures above 85°F skin temperatures appeared lower in Brahmans than in European-evolved breeds.

The great differences in surface temperatures between different spots on the body at the lower air temperatures were one of the striking features of the data. Thus, at 12°F air temperature, skin temperature of the Jersey hoof cleft was about 30°F, that of the milkwell 85°F.

# APPENDIX

TABLE 3 -- INSENSIBLE LOSS AND EVAPORATIVE LOSS IN HOLSTEIN CATTLE
(February 23 to July 20, 1951)

| Temperature °F | | Relative | Number of | Body | Insensible Loss | Vaporized Moisture* | | % Vaporized Moisture, Cal. |
|---|---|---|---|---|---|---|---|---|
| Dry Bulb | Wet Bulb | Humidity % | Obser-vations | Weight Kg. | grams per hour | grams per hr. | gms/sq.m. per hr. | Total Heat Production*, Cal. |
| | | | | Holstein 315 | | | | |
| 69.0 | 57.0 | 48 | 2 | 502 | 465 | 365 | 75 | 31 |
| 72.0 | 54.5 | 29 | 2 | 490 | 732 | 639 | 133 | 61 |
| 75.0 | 72.0 | 87 | 3 | 493 | 662 | 614 | 127 | 56 |
| 66.0 | 59.0 | 66 | 2 | 484 | 472 | 411 | 86 | 36 |
| 86.5 | 69.0 | 41 | 3 | 491 | 973 | 934 | 194 | 88 |
| 88.0 | 84.0 | 86 | 3 | 479 | 620 | 548 | 115 | 54 |
| 69.0 | 59.5 | 57 | 1 | 481 | 550 | 473 | 99 | 43 |
| 95.0 | 75.0 | 40 | 2 | 478 | 910 | 814 | 171 | 68 |
| 95.0 | 90.0 | 82 | 2 | 466 | 713 | 614 | 131 | 68 |
| 63.5 | 57.5 | 70 | 1 | 476 | 560 | 478 | 101 | 51 |
| 98.0 | 76.0 | 37 | 1 | 462 | 860 | 776 | 167 | 82 |
| 99.0 | 86.0 | 59 | 1 | 452 | 755 | 714 | 155 | 69 |
| 67.0 | 63.0 | 80 | 1 | 482 | 320 | 229 | 48 | 24 |
| | | | | Holstein 317 | | | | |
| 67.0 | 55.0 | 46 | 2 | 486 | 610 | 546 | 114 | 48 |
| 75.5 | 57.0 | 30 | 3 | 535 | 847 | 759 | 150 | 69 |
| 76.0 | 72.5 | 85 | 3 | 533 | 693 | 606 | 120 | 49 |
| 65.0 | 58.0 | 67 | 1 | 524 | 320 | 241 | 48 | 22 |
| 85.0 | 68.0 | 42 | 4 | 527 | 952 | 870 | 174 | 78 |
| 88.0 | 83.5 | 84 | 3 | 507 | 673 | 635 | 129 | 77 |
| 66.5 | 57.0 | 56 | 2 | 522 | 550 | 489 | 98 | 44 |
| 95.5 | 77.0 | 43 | 2 | 500 | 1160 | 1091 | 224 | 109 |
| 93.5 | 88.5 | 83 | 1 | 483 | 850 | 795 | 166 | 89 |
| 63.0 | 57.0 | 68 | 1 | 521 | 410 | 322 | 65 | 30 |
| 98.5 | 76.5 | 37 | 1 | 511 | 1040 | 966 | 196 | 82 |
| 96.5 | 82.5 | 56 | 1 | 486 | 895 | 837 | 175 | 72 |
| 67.0 | 62.5 | 78 | 1 | 532 | 300 | 234 | 46 | 21 |
| | | | | Holstein 314 | | | | |
| 66.5 | 54.0 | 44 | 4 | 517 | 536 | 475 | 96 | 37 |
| 78.5 | 58.0 | 30 | 1 | 521 | 560 | 488 | 98 | 46 |
| 74.5 | 70.5 | 83 | 3 | 522 | 543 | 431 | 86 | 32 |
| 65.0 | 58.5 | 68 | 1 | 517 | 270 | 190 | 38 | 17 |
| 86.0 | 68.0 | 40 | 4 | 522 | 948 | 854 | 171 | 62 |
| 88.0 | 83.5 | 84 | 3 | 504 | 643 | 588 | 120 | 66 |
| 68.0 | 60.0 | 62 | 1 | 506 | 490 | 414 | 84 | 34 |
| 96.0 | 75.5 | 38 | 2 | 506 | 1115 | 1072 | 219 | 104 |
| 90.0 | 87.0 | 89 | 1 | 477 | 960 | 949 | 200 | 86 |
| 64.5 | 59.5 | 74 | 1 | 523 | 435 | 376 | 75 | 33 |
| 100.0 | 78.0 | 39 | 1 | 507 | 830 | 754 | 154 | 56 |
| 95.0 | 81.0 | 54 | 1 | 487 | 620 | 593 | 124 | 52 |
| 65.5 | 62.0 | 82 | 1 | 521 | 410 | 326 | 65 | 24 |

*Metabolic weight loss and heat production from Table 6, Missouri Research Bulletin 522; surface area in square meters equal 0.15 x (weight in Kg.)$^{0.56}$ (see S. Brody, "Bioenergetics and Growth", Reinhold, 1945, page 360). Vaporized moisture was converted to calories by multiplying grams of moisture by 0.58.

TABLE 4 -- INSENSIBLE LOSS AND EVAPORATIVE LOSS IN BRAHMAN CATTLE
(February 23 to July 20, 1951)

| Temperature °F Dry Bulb | Temperature °F Wet Bulb | Relative Humidity % | Number of Observations | Body Weight kg. | Insensible Loss grams per hour | Vaporized Moisture* grams per hr. | Vaporized Moisture* gms/sq.m. per hr. | % Vaporized Moisture, Cal. / Total Heat Production,* Cal. |
|---|---|---|---|---|---|---|---|---|
| | | | | | Brahman 3 | | | |
| 63.0 | 52.0 | 47 | 5 | 321 | 301 | 240 | 56 | 34 |
| 73.5 | 55.0 | 29 | 4 | 331 | 371 | 313 | 72 | 50 |
| 73.0 | 71.0 | 91 | 1 | 328 | 325 | 274 | 64 | 34 |
| 67.0 | 60.5 | 69 | 1 | 350 | 260 | 190 | 42 | 25 |
| 82.0 | 66.0 | 43 | 4 | 354 | 356 | 311 | 69 | 40 |
| 87.0 | 83.0 | 85 | 3 | 358 | 525 | 494 | 109 | 72 |
| 67.0 | 59.0 | 62 | 6 | 370 | 317 | 262 | 57 | 31 |
| 96.0 | 77.5 | 45 | 2 | 379 | 780 | 748 | 160 | 83 |
| 91.0 | 88.0 | 89 | 1 | 368 | 590 | 554 | 121 | 72 |
| 65.0 | 57.5 | 64 | 1 | 397 | 340 | 283 | 59 | 34 |
| 99.0 | 80.0 | 43 | 1 | 404 | 865 | 818 | 169 | 91 |
| 100.0 | 93.5 | 78 | 1 | 381 | 505 | 506# | 108 | 71 |
| 64.0 | 58.0 | 70 | 1 | 400 | 240 | 205 | 43 | 25 |
| | | | | | Brahman 209 | | | |
| 63.0 | 53.0 | 51 | 6 | 416 | 363 | 311 | 63 | 37 |
| 74.0 | 54.0 | 24 | 4 | 432 | 341 | 298 | 59 | 43 |
| 69.0 | 66.5 | 88 | 1 | 439 | 375 | 306 | 60 | 37 |
| 65.0 | 58.0 | 66 | 2 | 440 | 300 | 247 | 49 | 29 |
| 84.0 | 66.5 | 40 | 4 | 447 | 610 | 573 | 112 | 72 |
| 86.0 | 83.5 | 90 | 3 | 453 | 543 | 489 | 95 | 61 |
| 67.0 | 58.0 | 58 | 4 | 462 | 342 | 270 | 52 | 30 |
| 99.5 | 77.5 | 37 | 2 | 468 | 795 | 745 | 142 | 82 |
| 94.0 | 89.0 | 82 | 1 | 467 | 730 | 697 | 133 | 98 |
| 64.0 | 55.5 | 58 | 1 | 471 | 280 | 259 | 49 | 30 |
| 97.0 | 78.0 | 42 | 1 | 478 | 690 | 648 | 122 | 76 |
| 99.0 | 93.0 | 79 | 1 | 461 | 700 | 666 | 128 | 104 |
| 64.0 | 58.0 | 70 | 1 | 479 | 225 | 194 | 36 | 25 |

*Metabolic weight loss and heat production from Table 5, Missouri Research Bulletin 522; surface area of Brahman cows assumed to be 12% greater than for Jersey or Holstein cows (see p. 14, Missouri Research Bulletin 464). Vaporized moisture was converted to calories by multiplying grams of moisture by 0.58.

#Higher values for vaporized moisture than for insensible weight loss indicate negative values for metobolic weight loss. Although these values may have resulted from differences in time and place between the insensible weight loss and metabolism measurements, these are reasonable values for short periods under the given conditions, which would be compensated over longer periods.

TABLE 5 -- INSENSIBLE LOSS AND EVAPORATIVE LOSS IN JERSEY CATTLE
(February 23 to July 20, 1951)

| Temperature °F Dry Bulb | Temperature °F Wet Bulb | Relative Humidity % | Number of Observations | Body Weight kg. | Insensible Loss grams per hour | Vaporized Moisture* grams per hr. | Vaporized Moisture* gms/sq.m. per hr. | % Vaporized Moisture, Cal. / Total Heat Production,* Cal. |
|---|---|---|---|---|---|---|---|---|
| | | | | **Jersey 999 (Lactating)** | | | | |
| 65.5 | 53.5 | 44 | 6 | 450 | 412 | 332 | 72 | 32 |
| 73.0 | 54.0 | 27 | 4 | 434 | 558 | 507 | 113 | 46 |
| 74.0 | 72.0 | 91 | 1 | 419 | 510 | 463 | 105 | 45 |
| 65.0 | 58.5 | 68 | 2 | 414 | 442 | 389 | 89 | 34 |
| 83.0 | 66.0 | 40 | 3 | 414 | 908 | 840 | 192 | 80 |
| 86.0 | 83.0 | 88 | 4 | 386 | 493 | 447 | 106 | 56 |
| 67.0 | 59.0 | 62 | 3 | 405 | 500 | 445 | 103 | 46 |
| 97.0 | 77.0 | 40 | 2 | 387 | 810 | 765 | 181 | 86 |
| 92.0 | 88.0 | 85 | 1 | 363 | 840 | 869# | 214 | 89 |
| 65.0 | 57.5 | 64 | 1 | 379 | 410 | 354 | 85 | 36 |
| 97.5 | 79.0 | 44 | 1 | 398 | 830 | 765 | 178 | 79 |
| 99.5 | 92.5 | 77 | 1 | 343 | 850 | 865# | 219 | 102 |
| 64.0 | 58.0 | 69 | 1 | 362 | 270 | 175 | 43 | 23 |
| | | | | **Jersey 549 (Lactating)** | | | | |
| 65.5 | 54.5 | 49 | 5 | 383 | 436 | 388 | 92 | 43 |
| 71.5 | 53.0 | 27 | 4 | 378 | 518 | 456 | 109 | 58 |
| 72.0 | 69.0 | 86 | 2 | 376 | 460 | 401 | 97 | 46 |
| 67.5 | 61.0 | 68 | 1 | 384 | 400 | 335 | 80 | 36 |
| 84.0 | 67.0 | 40 | 4 | 394 | 946 | 884 | 207 | 98 |
| 36.0 | 83.0 | 88 | 3 | 371 | 535 | 496 | 120 | 67 |
| 67.0 | 59.0 | 62 | 4 | 391 | 472 | 429 | 101 | 48 |
| 97.0 | 76.0 | 37 | 2 | 392 | 770 | 720 | 169 | 80 |
| 95.0 | 89.5 | 80 | 1 | 369 | 870 | 856 | 208 | 95 |
| 64.5 | 56.0 | 58 | 1 | 399 | 310 | 243 | 57 | 31 |
| 97.0 | 80.0 | 47 | 1 | 403 | 1030 | 983 | 228 | 96 |
| 100.0 | 92.0 | 73 | 1 | 364 | 610 | 599 | 147 | 63 |
| 64.0 | 58.0 | 70 | 1 | 392 | 340 | 282 | 66 | 32 |
| | | | | **Jersey 559 (Dry)** | | | | |
| 65.0 | 53.0 | 44 | 4 | 298 | 320 | 259 | 71 | 42 |
| 72.0 | 54.5 | 30 | 4 | 302 | 340 | 305 | 83 | 57 |
| 72.0 | 69.0 | 86 | 2 | 315 | 358 | 322 | 86 | 47 |
| 66.0 | 60.0 | 71 | 1 | 317 | 275 | 240 | 64 | 37 |
| 82.5 | 66.0 | 41 | 4 | 327 | 514 | 463 | 121 | 63 |
| 86.0 | 83.5 | 89 | 3 | 329 | 433 | 380 | 99 | 52 |
| 67.0 | 60.0 | 67 | 5 | 342 | 329 | 283 | 72 | 39 |
| 95.5 | 76.5 | 42 | 1 | 351 | 740 | 709 | 178 | 86 |
| 97.0 | 92.0 | 83 | 1 | 341 | 520 | 506 | 129 | 70 |
| 68.0 | 62.0 | 72 | 1 | 358 | 300 | 253 | 63 | 35 |
| 96.0 | 81.5 | 54 | 1 | 371 | 800 | 751 | 182 | 91 |
| 64.0 | 58.0 | 69 | 1 | 366 | 300 | 265 | 65 | 41 |
| | | | | **Jersey 979 (Dry)** | | | | |
| 64.0 | 53.0 | 48 | 6 | 442 | 485 | 418 | 92 | 48 |
| 74.5 | 55.0 | 26 | 4 | 444 | 486 | 410 | 90 | 51 |
| 73.5 | 71.0 | 90 | 1 | 445 | 475 | 416 | 91 | 42 |
| 65.0 | 58.5 | 68 | 2 | 448 | 342 | 289 | 63 | 32 |
| 84.0 | 66.0 | 38 | 4 | 456 | 786 | 726 | 157 | 69 |
| 86.0 | 83.5 | 91 | 3 | 448 | 537 | 489 | 107 | 56 |
| 67.0 | 58.0 | 58 | 3 | 463 | 445 | 387 | 83 | 37 |
| 99.0 | 77.5 | 38 | 2 | 465 | 955 | 897 | 192 | 92 |
| 93.0 | 89.0 | 85 | 1 | 440 | 700 | 689 | 152 | 85 |
| 65.0 | 57.5 | 64 | 1 | 466 | 295 | 226 | 48 | 24 |
| 97.0 | 78.0 | 43 | 1 | 459 | 805 | 761 | 164 | 86 |
| 64.0 | 58.0 | 70 | 1 | 434 | 240 | 173 | 38 | 22 |

*Metabolic weight loss and heat production from Table 5, Missouri Research Bulletin 522; surface area in square meters equals 0.15 x (weight in Kg.)$^{0.56}$ (see S. Brody, "Bioenergetics and Growth", Reinhold, 1945, page 360). Vaporized moisture was converted to calories by multiplying grams of moisture by 0.58.

#Higher values of vaporized moisture than for insensible weight loss indicate negative values for metabolic weight loss. Although these values may have resulted from differences in time and place between the insensible weight loss and metabolism measurements, these are reasonable values for short periods under the given conditions, which would be compensated over longer periods.

TABLE 6 -- INSENSIBLE LOSS AND EVAPORATIVE LOSS IN BROWN SWISS CATTLE
(February 23 to July 20, 1951)

| Temperature °F Dry Bulb | Temperature °F Wet Bulb | Relative Humidity % | Number of Observations | Body Weight kg. | Insensible Loss grams per hour | Vaporized Moisture* grams per hr. | Vaporized Moisture* gms/sq.m. per hr. | % Vaporized Moisture, Cal. / Total Heat Production*, Cal. |
|---|---|---|---|---|---|---|---|---|
| | | | | Brown Swiss 48 | | | | |
| 66.0 | 56.5 | 55 | 2 | 532 | 512 | 462 | 92 | 36 |
| 75.0 | 55.0 | 25 | 2 | 514 | 748 | 680 | 138 | 56 |
| 76.0 | 73.0 | 87 | 3 | 517 | 662 | 622 | 125 | 53 |
| 66.0 | 60.0 | 71 | 2 | 505 | 658 | 593 | 121 | 42 |
| 86.0 | 68.0 | 39 | 4 | 507 | 998 | 903 | 184 | 75 |
| 87.5 | 83.5 | 84 | 4 | 486 | 839 | 804 | 168 | 75 |
| 67.0 | 58.0 | 58 | 2 | 489 | 615 | 548 | 114 | 48 |
| 95.0 | 75.0 | 39 | 1 | 484 | 1270 | 1192 | 249 | 104 |
| 97.0 | 90.0 | 76 | 1 | 494 | 777 | 734 | 152 | 71 |
| 66.0 | 61.0 | 76 | 1 | 528 | 745 | 653 | 130 | 57 |
| 100.0 | 79.0 | 39 | 1 | 483 | 1190 | 1144 | 240 | 102 |
| 100.0 | 89.0 | 65 | 1 | 460 | 845 | 835 | 180 | 85 |
| 67.0 | 64.0 | 84 | 1 | 519 | 350 | 282 | 57 | 27 |
| | | | | Brown Swiss 47 | | | | |
| 69.0 | 55.0 | 40 | 2 | 436 | 638 | 577 | 128 | 53 |
| 75.0 | 57.0 | 32 | 2 | 440 | 715 | 620 | 137 | 63 |
| 74.0 | 71.0 | 85 | 3 | 440 | 557 | 495 | 109 | 48 |
| 65.5 | 59.0 | 68 | 2 | 444 | 490 | 407 | 89 | 42 |
| 86.5 | 69.0 | 41 | 4 | 450 | 910 | 831 | 181 | 76 |
| 87.5 | 84.0 | 87 | 2 | 436 | 808 | 761 | 169 | 91 |
| 68.0 | 60.5 | 66 | 2 | 452 | 440 | 378 | 82 | 35 |
| 95.0 | 75.0 | 39 | 2 | 442 | 1108 | 1042 | 229 | 88 |
| 90.0 | 86.5 | 87 | 1 | 417 | 800 | 792 | 180 | 67 |
| 65.0 | 59.5 | 74 | 1 | 465 | 340 | 282 | 60 | 28 |
| 99.0 | 78.0 | 39 | 1 | 448 | 1195 | 1132 | 247 | 114 |
| 96.0 | 82.0 | 55 | 1 | 409 | 845 | 831 | 191 | 77 |
| 67.0 | 63.0 | 79 | 1 | 455 | 315 | 243 | 52 | 24 |
| | | | | Brown Swiss 22 | | | | |
| 67.0 | 55.0 | 46 | 1 | 521 | 450 | 385 | 77 | 32 |
| 75.5 | 56.5 | 28 | 2 | 510 | 348 | 275 | 56 | 28 |
| 75.0 | 71.0 | 83 | 3 | 507 | 392 | 316 | 64 | 27 |
| 66.0 | 59.5 | 68 | 2 | 508 | 365 | 296 | 60 | 29 |
| 86.0 | 68.5 | 40 | 4 | 504 | 865 | 815 | 167 | 70 |
| 88.0 | 84.0 | 85 | 3 | 495 | 693 | 653 | 135 | 67 |
| 70.0 | 61.0 | 60 | 1 | 516 | 590 | 541 | 109 | 49 |
| 95.0 | 75.0 | 40 | 2 | 501 | 1145 | 1122 | 230 | 96 |
| 95.0 | 90.0 | 83 | 2 | 500 | 910 | 905 | 186 | 102 |
| 63.0 | 57.0 | 70 | 1 | 522 | 410 | 319 | 64 | 26 |
| 100.0 | 79.0 | 39 | 1 | 503 | 1135 | 1040 | 213 | 85 |
| 99.5 | 89.0 | 66 | 1 | 481 | 775 | 847# | 178 | 62 |
| 66.5 | 63.0 | 81 | 1 | 511 | 380 | 282 | 57 | 21 |

*Metabolic weight loss and heat production from Table 6, Missouri Research Bulletin 522; surface area in square meters equals 0.15 x (weight in Kg.)$^{0.56}$ (see S. Brody, "Bioenergetics and Growth", Reinhold, 1945, page 360). Vaporized moisture was converted to calories by multiplying grams of moisture by 0.58.

#Higher values for vaporized moisture than for insensible weight loss indicate negative values for metabolic weight loss. Although these values may have resulted from differences in time and place between the insensible weight loss and metabolism measurements, these are reasonable values for short periods under the given conditions, which would be compensated over longer periods.

TABLE 7 -- EFFECT OF HUMIDITY AT TEMPERATURE LEVELS 40° AND 15° ON THE SKIN AND HAIR TEMPERATURES, °F, OF HOLSTEIN AND JERSEY COWS
(Winter 1950-51)

| Relative Humidity % | Thermocouple Chamber Air | Thermocouple Cow Skin* | Thermocouple No. of Obs. | Radiometer Chamber Surface | Radiometer Cow Surface* | Radiometer Jaw | Radiometer Leg | Radiometer No. of Obs. | Dates of Measurement |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Holstein Cows (average of 6) | | | | | |
| 62 | 53.8 | ---- | 0 | 55.8 | 84.7 | 86.6 | 80.1 | 12 | Oct. 12 & 17 |
| 65 | 44.0 | 88.6 | 6 | 46.8 | 81.0 | 83.9 | 87.2 | 12 | Oct. 24 & 31 |
| 84 | 42.6 | 90.0 | 12 | 46.8 | 81.4 | 82.7 | 68.1 | 12 | Nov. 14 & 17 |
| 44 | 38.1 | 88.0 | 6 | 43.7 | 76.5 | 78.0 | 60.8 | 6 | Nov. 21 |
| 64 | 49.0 | 86.7 | 9 | 52.4 | 81.1 | 81.9 | 74.4 | 12 | Dec. 7 & 13 |
| 63 | 12.7 | 82.6 | 6 | 18.4 | 59.7 | 65.8 | 40.1 | 6 | Dec. 26 |
| 64 | 12.8 | 84.2 | 6 | 16.8 | 60.1 | 64.3 | 35.3 | 6 | Jan. 11 |
| 86 | 15.0 | 78.6 | 12 | 21.3 | 64.0 | 66.2 | 39.7 | 18 | Jan. 16, 23 & 25 |
| 68 | 51.5 | 89.1 | 6 | 52.9 | 81.9 | 81.2 | 74.5 | 12 | Feb. 2 & 7 |
| | | | | Jersey Cows (average of 6) | | | | | |
| 60 | 50.2 | ---- | 0 | 52.6 | 82.6 | 86.6 | 76.4 | 12 | Oct. 11 & 19 |
| 56 | 41.0 | 81.5 | 6 | 43.9 | 76.3 | 82.4 | 60.8 | 12 | Oct. 26 & Nov. 3 |
| 46 | 38.6 | 89.9 | 9 | 41.2 | 74.4 | 79.0 | 63.4 | 9 | Nov. 15 & 16 |
| 79 | 41.0 | 89.3 | 10 | 44.0 | 75.9 | 80.6 | 69.5 | 10 | Nov. 22 & 28 |
| 63 | 51.2 | 92.6 | 12 | 52.9 | 78.0 | 82.5 | 75.2 | 12 | Dec. 6 & 14 |
| 62 | 11.4 | 82.1 | 3 | 16.6 | 53.4 | 64.6 | 32.6 | 6 | Dec. 19 |
| 92 | 12.8 | 84.6 | 6 | 14.6 | 56.8 | 63.2 | 31.0 | 6 | Jan. 8 & 9 |
| 56 | 10.1 | 83.3 | 12 | 16.4 | 55.5 | 62.4 | 36.9 | 12 | Jan. 15 & 24 |
| 62 | 50.5 | 89.3 | 12 | 52.0 | 78.1 | 80.7 | 75.8 | 12 | Feb. 1 & 15 |

*Each observation consists of an average of six spot measurements; back, belly, right and left sides of body, neck and rear.

TABLE 8 -- EFFECT OF HUMIDITY AT TEMPERATURE LEVELS 75°, 85°, 95° AND 100°F ON THE SKIN AND HAIR TEMPERATURES, °F, OF JERSEY AND BRAHMAN COWS (Summer 1951)

| Relative | Thermocouple | | | Radiometer | | | |
|---|---|---|---|---|---|---|---|
| Humidity % | Chamber Air | Cow Skin* | No. of Obs. | Chamber Surface | Cow Surface* | No. of Obs. | Dates of Measurements |
| | | | Jersey Cows (average of 4) | | | | |
| 64 | 64.9 | 92.0 | 4 | 66.4 | 87.6 | 4 | Mar. 7 |
| 36 | 73.6 | 93.6 | 8 | 75.2 | 90.8 | 8 | Mar. 16 & 19 |
| 82 | 74.8 | 93.3 | 8 | 76.4 | 92.6 | 8 | Apr. 2 & 4 |
| 68 | 64.9 | 91.2 | 4 | 67.7 | 89.1 | 4 | Apr. 10 |
| 38 | 85.6 | 96.7 | 4 | 86.0 | 95.9 | 8 | Apr. 18 |
| 84 | 85.4 | 98.2 | 8 | 86.5 | 96.9 | 8 | May 1 & 8 |
| 62 | 64.9 | 89.8 | 12 | 67.5 | 88.7 | 12 | May 15, 21, 22 & 24 |
| 38 | 95.7 | 100.2 | 4 | 95.8 | 99.2 | 4 | May 29 |
| 82 | 96.4 | 101.3 | 4 | 97.2 | 100.8 | 4 | June 4 |
| 60 | 94.7 | 99.1 | 4 | 95.5 | 98.6 | 4 | June 7 |
| 64 | 64.5 | 88.6 | 4 | 66.6 | 87.1 | 4 | June 13 |
| 32 | 101.2 | 101.6 | 4 | 101.3 | 100.6 | 4 | June 26 |
| 72 | 99.8 | 101.9 | 4 | 100.2 | 101.4 | 4 | June 29 |
| 66 | 66.3 | 89.2 | 4 | 68.6 | 87.6 | 8 | July 9 & 10 |
| | | | Brahman Cows (average of 2) | | | | |
| 64 | 64.7 | 91.6 | 2 | 66.8 | 87.8 | 2 | Mar. 7 |
| 36 | 73.5 | 93.8 | 4 | 75.4 | 92.8 | 4 | Mar. 16 & 19 |
| 82 | 75.0 | 93.8 | 4 | 76.9 | 95.1 | 4 | Apr. 2 & 4 |
| 68 | 64.8 | 90.2 | 2 | 67.8 | 90.0 | 2 | Apr. 10 |
| 38 | 86.0 | 97.5 | 2 | 86.4 | 97.7 | 4 | Apr. 18 |
| 84 | 85.2 | 97.6 | 4 | 86.8 | 97.9 | 4 | May 1 & 8 |
| 62 | 64.8 | 89.6 | 6 | 68.0 | 90.2 | 6 | May 15, 21, 22 & 24 |
| 38 | 95.7 | 100.4 | 2 | 95.6 | 99.6 | 4 | May 29 |
| 82 | 96.5 | 100.9 | 2 | 97.7 | 101.0 | 2 | June 4 |
| 60 | 94.7 | 98.2 | 2 | 95.5 | 98.7 | 2 | June 7 |
| 64 | 64.6 | 88.5 | 2 | 66.8 | 88.0 | 2 | June 13 |
| 32 | 101.7 | 101.7 | 2 | 101.2 | 101.0 | 2 | June 26 |
| 72 | 99.7 | 100.4 | 2 | 100.2 | 100.8 | 2 | June 29 |
| 66 | 66.4 | 89.3 | 2 | 69.0 | 89.2 | 4 | July 10 |

*Each observation consists of an average of six spot measurements; back, belly, right and left sides of body, neck and rear.

TABLE 9 -- EFFECT OF HUMIDITY AT TEMPERATURE LEVELS 75°, 85°, 95° AND 100°F ON THE SKIN AND HAIR TEMPERATURES, °F, OF HOLSTEIN AND BROWN SWISS COWS (Summer 1951)

| Relative Humidity % | Thermocouple Chamber Air | Thermocouple Cow Skin* | Thermocouple No. of Obs. | Radiometer Chamber Surface | Radiometer Cow Surface* | Radiometer No. of Obs. | Dates of Measurement |
|---|---|---|---|---|---|---|---|
| | | | Holstein Cows (average of 3) | | | | |
| 64 | 64.9 | 91.6 | 3 | 66.5 | 87.3 | 3 | Mar. 6 |
| 36 | 75.0 | 93.1 | 6 | 75.6 | 91.0 | 6 | Mar. 15 & 20 |
| 86 | 75.6 | 93.9 | 3 | 76.6 | 92.3 | 3 | Apr. 3 |
| 68 | 65.4 | 90.4 | 3 | 67.1 | 87.6 | 3 | Apr. 9 |
| 44 | 84.5 | 96.2 | 3 | 84.9 | 95.3 | 3 | Apr. 19 |
| 86 | 85.1 | 97.9 | 6 | 86.2 | 95.8 | 6 | Apr. 30 & May 7 |
| 70 | 65.1 | 89.8 | 3 | 68.2 | 86.9 | 3 | May 22 & 23 |
| 42 | 96.3 | 100.2 | 6 | 96.0 | 99.2 | 6 | May 28 & June 1 |
| 84 | 96.5 | 101.7 | 2 | 97.0 | 100.8 | 3 | June 4 |
| 60 | 95.0 | ---- | 0 | 95.5 | 98.6 | 3 | June 7 |
| 62 | 65.7 | 89.0 | 3 | 68.4 | 87.8 | 3 | June 14 |
| 36 | 100.6 | 101.3 | 3 | 99.5 | 100.8 | 3 | July 3 |
| 62 | 101.6 | 102.8 | 3 | 100.6 | 102.0 | 3 | July 5 |
| 68 | 66.2 | 90.1 | 3 | 67.9 | 88.9 | 3 | July 16 |
| | | | Brown Swiss (average of 3) | | | | |
| 64 | 65.2 | 92.3 | 3 | 66.7 | 85.7 | 3 | Mar. 6 |
| 36 | 75.2 | 93.6 | 6 | 75.6 | 90.0 | 6 | Mar. 15 & 20 |
| 86 | 75.9 | 94.1 | 3 | 76.8 | 91.9 | 3 | Apr. 3 |
| 68 | 65.4 | 91.1 | 3 | 67.1 | 88.4 | 3 | Apr. 9 |
| 44 | 84.6 | 96.3 | 3 | 85.1 | 95.3 | 3 | Apr. 19 |
| 86 | 85.0 | 98.0 | 6 | 86.4 | 96.6 | 6 | Apr. 3 & May 7 |
| 70 | 65.4 | 89.5 | 3 | 68.2 | 88.1 | 3 | May 22 & 23 |
| 42 | 96.2 | 100.4 | 6 | 95.6 | 99.5 | 6 | May 28 & June 1 |
| 84 | 96.4 | 101.7 | 3 | 96.7 | 100.9 | 3 | June 4 |
| 60 | 95.0 | ---- | 0 | 95.5 | 98.8 | 3 | June 7 |
| 62 | 66.1 | 89.4 | 3 | 68.4 | 88.9 | 3 | June 14 |
| 36 | 100.7 | 101.3 | 3 | 99.0 | 101.0 | 3 | July 3 |
| 62 | 101.5 | 102.7 | 3 | 100.2 | 102.1 | 3 | July 5 |
| 68 | 65.9 | 89.6 | 3 | 68.3 | 89.1 | 3 | July 16 |

*Each observation consists of an average of six spot measurements; back, belly, right and left sides of body, neck and rear.