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Environmental Physiology

With Special Reference to Domestic Animals

XXVII. Influence of Wind on Heat Exchange and Body Temperature Regulation in Jersey, Holstein, Brown Swiss, and Brahman Cattle

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XXVII. Influence of Wind on Heat Exchange and Body Temperature Regulation in Jersey, Holstein, Brown Swiss, and Brahman Cattle

H. H. Kibler and Samuel Brody

Preceding bulletins in this series*[1] reported data on the effects of changes in temperature and humidity on cattle. This is one of several survey bulletins reporting the influence on cattle of wind or air velocity at various air temperature. One research bulletin[2] presented data on feed, water consumption, milk production, and body weight. A thesis by R. G. Yeck[3] presented data on insensible weight loss and total evaporative cooling. Another research bulletin[4] presented data on surface temperature, insensible weight loss, and total evaporative cooling of the same animals. Another,[5] to be reported by H. J. Thompson, will describe the equipment used in controlling air velocity and other environmental factors. This bulletin presents data on the effect of wind on respiration rate, pulse rate, pulmonary ventilation rate, rectal temperature, heat production, evaporative cooling from the respiratory tract, evaporative cooling from the outer surface, and total non-evaporative cooling.

INTERRELATIONS BETWEEN CLIMATIC FACTORS

In the experiments to determine the physiological effects of climate, the temperature, humidity, and air velocity were varied in turn. However, it is desirable to know the response to combinations of all three factors. Environments may have the same physiologically effective temperature despite quite different relations between temperature, humidity, and wind.

The comfort zone worked out by air conditioning engineers for man is based on his subjective feeling of comfort when exposed to

*References are listed at the end of the bulletin. A list of bulletins in the Environmental Physiology and Shelter Engineering series published up to 1952 is included in Mo. Agr. Exp. Sta. Res. Bul. 497.

various combinations of dry-bulb temperature, humidity, and air velocity. If a criterion of comfort based on measurements instead of feelings could be established, it would be possible to determine a "comfort zone" for cattle. In the preceding report,[6] it was shown that the "thermoneutrality" zone for lactating dairy cows was between 40° and 60° F. Undoubtedly cattle are comfortable within these narrow limits where their heat production is minimal.* It seems probable, however, that their "comfort zone" extends beyond these limits. The rectal temperature does not rise at environmental temperatures below 70° to 80° F,[7,8] and feed consumption and milk production[9,10] apparently do not decrease before this rise occurs. These facts indicate that rectal temperature measurements should be given considerable weight in determining the upper limits of the "comfort zone." At lower temperatures, rectal temperature may not be as good an index of comfort, since heat production rises and milk production may be depressed before rectal temperature falls below normal values.

Although still somewhat tentative because of unmeasured areas, the shaded section of Figure 1 shows the zone of normal rectal temperature for lactating Jersey, Holstein, and Brown Swiss cows. These data include measurements made during earlier temperature and humidity experiments in which the air velocity was constant at about 0.5 mph. The present data — indicated by the short dashed lines to the right of the shaded zone — show that wind at velocities of 7 to 10 mph enabled the different breeds to maintain normal body temperature during exposure to heat stress that would normally have caused a rise in body temperature. Wind tends to widen the "comfort zone" at high air temperatures below rectal temperature where cooling is beneficial but it tends, as will be shown later, to narrow the "comfort zone" at low temperature, where cooling is detrimental.

An analysis of the relation between wind and heat loss from cows is complicated by the interaction of several factors. Convective cooling rises with increasing air velocity but, in so doing, lowers the temperature of the outer surface of the animal, causing decreases in the losses by radiation, conduction, and outer surface vaporization. The convective cooling of the outer surface also reduces evaporative cooling from the respiratory tract by reducing respiration rate and pulmonary ventilation rate. These relations will be discussed in greater detail in connection with the presentation of the data.

The relation between wind and heat loss by convection is quite involved (even when considered separately from radiation and vapori-

*Minimal for conditions of normal rectal temperature. Heat production is depressed still lower when continued exposure to hot conditions increases rectal temperature.

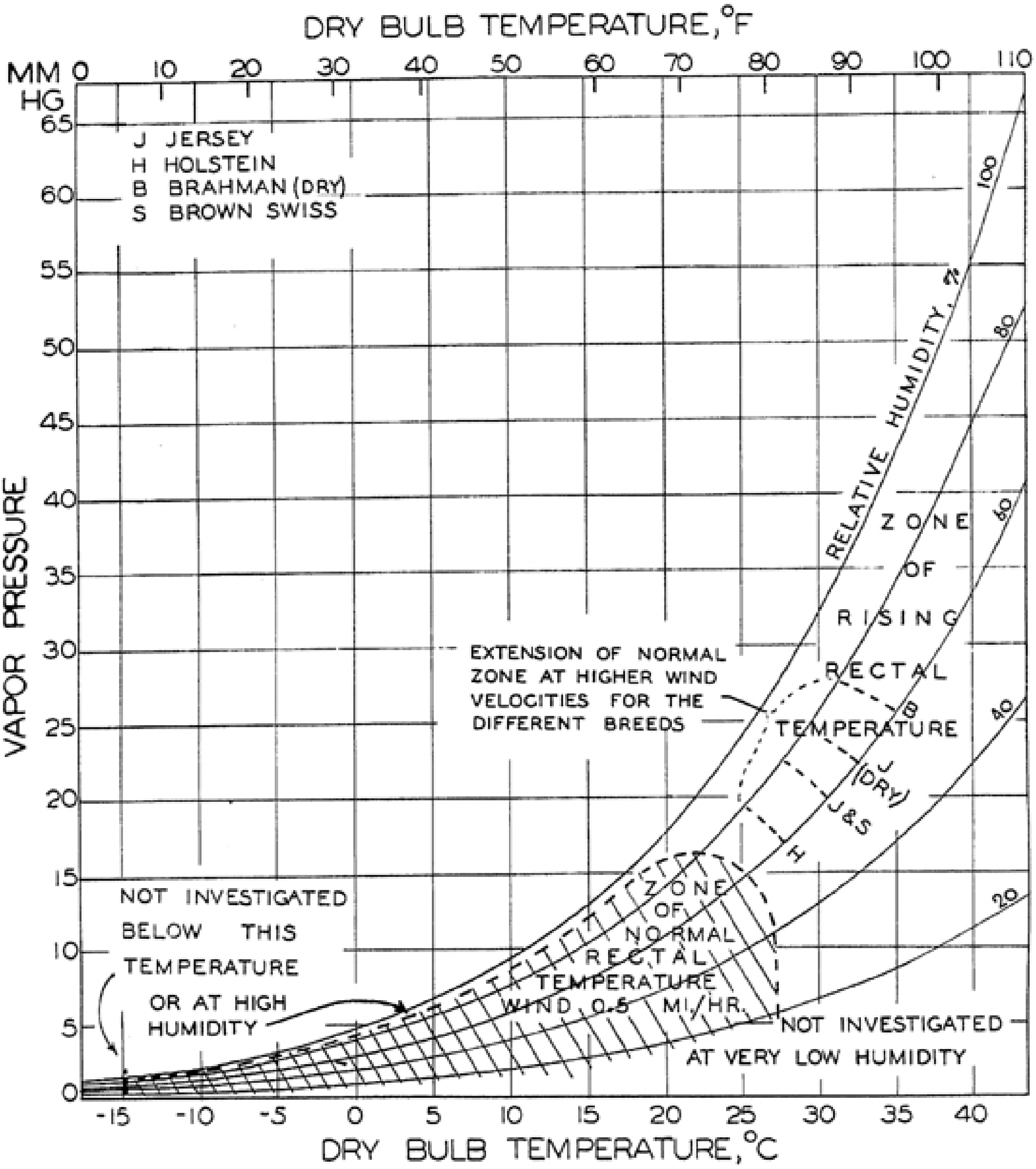

Fig. 1 — The zone of normal rectal temperature in dairy cows as affected by environmental temperature, humidity and air velocity. Dairy cows which were kept in an air conditioned chamber where the air velocity was 0.5 miles per hour maintained normal rectal temperatures during continuous exposure (24 hours a day for periods up to 2 weeks) to the range of environmental temperatures and humidities included in the shaded area of Fig. 1. By increasing the air velocity up to 6 to 10 miles per hour they were able to maintain normal body temperature during exposure to even more severe conditions, as indicated by the four dashed lines to the right of the shaded area. Additional data are needed to establish the exact boundaries for all conditions especially for extremely high and low relative humidity, and for temperatures below 5°F (-15°C).

zation) if all the environmental and physiological factors are considered.[11] Gagge and associates,[12] using men as subjects, expressed this relation by the equation

$$C = .65\ A_D\ \ V\ (T_S - T_A)$$

where C is the loss by convection in kg.-cal/hr., AD is the Du Bois area in square inches, V is the velocity of the air in ft./min., T_S is the skin temperature in °F, and T_A is the air temperature in degrees F. In their experiments, they were unable to determine from the data whether the use of V or $\sqrt{V}$ gave the better fitting equation. The applicability of the equation to cows cannot be determined from the data in this bulletin, as the heat losses by convection cannot be separated from the losses by radiation and conduction.

EXPERIMENT

During the winter of 1951-52, physiological measurements were made on 12 cows at three wind velocities: "low" (0.4 to 0.5 mph), "medium" (3 to 6 mph), and "high" (7 to 10 mph) at temperatures of 50° and 17° F as shown in Table 1A. Two weeks were given to each of the six experimental conditions. The "low" air velocity was at the level used in all preceding experiments on the effects of temperature and humidity.

During the summer of 1952, another group of 12 cows, including 5 of the animals used in the first winter experiment and 7 others, was similarly measured at the same three air velocities, but at temperatures of 65°, 80°, and 95° F as shown in Table 1B. The experimental periods at 95° were limited to two days but were carried on for two weeks at the other temperatures, as in the winter experiment. The average relative humidity varied from about 60 to 70 percent in both experiments.

Each group consisted of three lactating Holstein and three Brown Swiss cows in one chamber, and two lactating Jersey, two dry Jersey, and two dry Brahman cows in a second chamber.

With the exception of the use of a stethoscope instead of a manual palpation for counting pulse rate, the apparatus (open-circuit respiratory exchange) and methods were the same as previously described.[1,13,7]

TABLE 1A. -- SCHEDULE OF TESTS AND EXPERIMENTAL CONDITIONS
(Oct. 26, 1951 - Feb. 14, 1952)

JERSEY	BRAHMAN	HOLSTEIN	BROWN SWISS
548: 858 lbs.	209: 1068 lbs. (dry)	178: 1184 lbs.	9: 1110 lbs.
549: 833 lbs.	189: 992 lbs. (dry)	132: 1252 lbs.	41: 1114 lbs.
999: 902 lbs. (dry)		184: 1142 lbs.	47: 997 lbs.
264: 787 lbs. (dry)			

Period Air Velocity mi/hr	Chamber Temperature, °F		Relative Humidity %		No. of Days	No. of Tests		Period Dates		Period Air Velocity mi/hr	Chamber Temperature, °F		Relative Humidity %		No. of Days	No. of Tests	
	Period	Test*	Period	Test*		Metabolism*	Other+	From 3 PM	To 3 PM		Period	Test*	Period	Test*		Metabolism*	Other+
0.4	50	51	69	68	13	2	6	Oct. 26	Nov. 8	0.4	51	50	72	65	13	2	6
4.2	51	52	66	62	14	3	8	Nov. 8	Nov. 22	4.5	51	52	67	60	14	3	8
6.0	50	52	65	54	14	3	9	Nov. 22	Dec. 6	0.4	50	50	58	62	14	3	10
0.4	50	50	52	64	14	3	9	Dec. 6	Dec. 20	8.1	50	50	68	49	14	3	9
0.4	31	--	57	--	14	-	-	Dec. 20	Jan. 3	0.4	30	--	63	--	14	-	-
3.8	15	15	61	63	14	3	9	Jan. 3	Jan. 17	3.4	18	18	60	59	14	3	7
7.6	17	21	62	53	14	3	9	Jan. 17	Jan. 31	0.5	19	20	56	60	14	3	9
0.5	19	20	55	58	14	3	7	Jan. 31	Feb. 14	10.0	18	24	61	55	14	3	7

*Refers to conditions during metabolism tests which were made three times each period between 1 and 3 PM.
+Refers to measurements of pulse rate, respiration rate and rectal temperature which were made between 1 and 3 PM.

TABLE 1B. -- SCHEDULE OF TESTS* AND EXPERIMENTAL CONDITIONS
(Feb. 23 - May 29, 1952)

JERSEY	BRAHMAN	HOLSTEIN	BROWN SWISS
994: 814 lbs.	209: 1077 lbs. (dry)	144: 1295 lbs.	22: 1284 lbs.
205: 964 lbs.	189: 1029 lbs. (dry)	154: 1356 lbs.	23: 1375 lbs.
548: 865 lbs. (dry)		118: 1282 lbs.	47: 1031 lbs.
549: 872 lbs. (dry)			

Period Air Velocity mi/hr	Chamber Temperature, °F		Relative Humidity %		No. of Days	No. of Tests		Period Dates		Period Air Velocity mi/hr	Chamber Temperature, °F		Relative Humidity %		No. of Days	No. of Tests	
	Period	Test*	Period	Test*		Metabolism*	Other+	From 3 PM	To 3 PM		Period	Test*	Period	Test*		Metabolism*	Other+
0.5	66	63	69	65	12	2	8	Feb. 23	Mar. 6	0.4	64	69	71	66	12	2	8
6.2	66	67	64	64	14	3	9	Mar. 6	Mar. 20	8.8	66	67	60	56	14	3	9
0.4	64	67	65	64	7	1	4	Mar. 20	Mar. 27	6.4 }	66	67	64	65	14	3	10
8.5 }	66	67	60	59	7	3	8	Mar. 27	Apr. 3	4.8 }							
8.5 }					7			Apr. 3	Apr. 10	0.4	64	65	65	62	7	1	3
7.7	80	80	64	62	14	3	8	Apr. 10	Apr. 24	4.5	80	80	66	67	14	3	8
4.7	80	80	64	65	14	3	10	Apr. 24	May 8	8.7	80	81	62	61	14	3	10
0.4	80	80	64	63	10	2	4	May 8	May 18	0.4 }	80	80	63	60	12	2	6
0.4	94	95	63	60	2	2	2	May 18	May 20	0.4 }							
0.4	89	--	64	--	2	-	-	May 20	May 22	8.8	95	95	62	59	2	2	2
0.4	80	--	62	--	3	-	-	May 22	May 25	0.4	78	--	63	--	3	-	-
8.9	95	95	58	59	2	2	2	May 25	May 27	0.4	80	--	71	--	2	-	2
0.4	76	--	72	--	2	-	2	May 27	May 29	0.4	94	95	62	64	2	2	2

*Refers to conditions during the metabolism tests which were made between 1 and 3 PM.
+Respiration rate, rectal temperature and pulse rate measurements made between 1 and 3 PM.

DISCUSSION OF RESULTS

While the data have been obtained primarily to study the effects of air velocity, they also provide valuable replications for preceding experiments on temperature. Breed comparisons of the effects of air velocity and temperature are presented in Figures 1 to 10. Figures 3 A, 5, 6 A, 7 A, and 10, especially, bring out the effects of changing air velocity at constant temperature, and Figures 3 B, 4, 6 B, 7 B, 8, and 9 emphasize the effects of changing temperature at constant air velocity. The data on individual cows are presented in Tables 2 to 6 in the Appendix.

Not many statistical tests were made because of the small volume of data and few animals of each breed. Unmeasured effects of the stages of lactation and gestation, and other factors such as acclimitization lags may have influenced the results.

Rectal Temperature: The rectal temperature is the best available index of an animal's ability to maintain a balance between heat production and heat dissipation. However, as it is a local measurement, it may reflect local rather than general conditions. It may be reasoned, therefore, that when a cow is exposed to wind, its rectal temperature reflects local surface chilling. In this experiment, the measurements were made with ordinary veterinary thermometers. As local surface effects would presumably diminish with increased depth of insertion, it is hoped that this experiment can be repeated, using a thermometer suitable for deeper insertion, such as the thermistor resistance thermometer previously described.[8]

Figure 2 shows the relative effects of the three air velocities on rectal temperature at five air temperatures. At 17° F air temperature, high wind velocity lowered the rectal temperature below its value at low velocity by about ½° F in the Jerseys and 1° F in the non-lactating Brahmans. No appreciable change occurred in the Brown Swiss and Holsteins. At 50° and 65°, the effects of wind were relatively negligible and not too consistent. At 80° and 95°, the cows which developed the highest rectal temperatures at low wind velocities were cooled the most by high wind velocity. This lowering of rectal temperature in degrees Fahrenheit amounted to about 1½° at 80° and over 2° at 95° in the lactating Holsteins, ¾° at 80° and 1° at 95° in the lactating Brown Swiss, ½° at 80° and 1½° at 95° in the lactating Jerseys, and ½° at 80° and ¾° at 95° in the non-lactating Jerseys. The non-lactating Brahmans were not affected by changes of wind velocity at these temperatures.

Statistical tests indicated that the effects of wind on rectal temperature were significant or highly significant in the Brahmans and

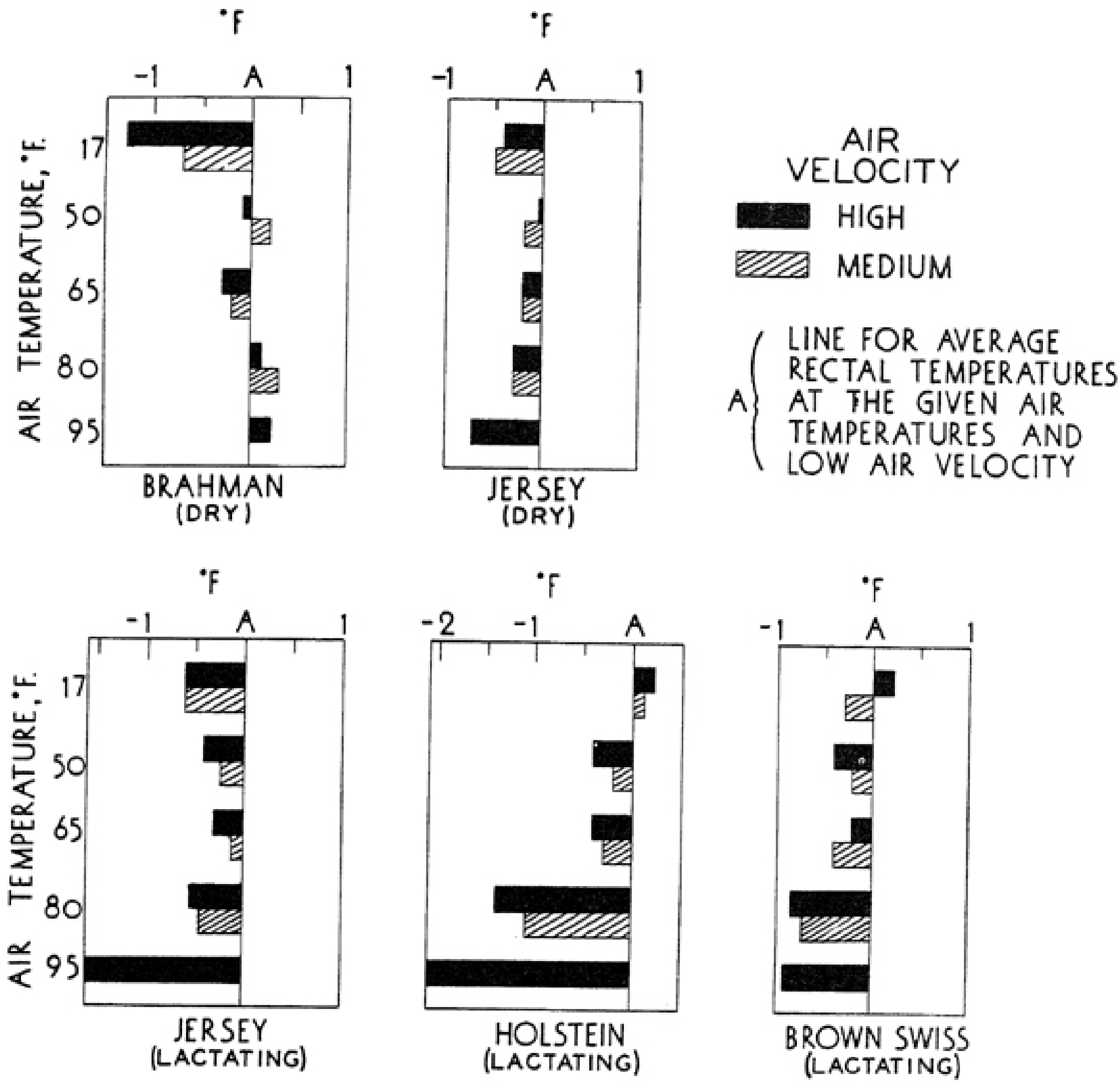

Fig. 2 — Influence of high (6 to 10 miles per hour) and medium (3 to 6 miles per hour) air velocities on rectal temperature as indicated by the deviations from the mean rectal temperature at low air velocity (0.4 to 0.5 mile per hour) at the given air temperatures.

Jerseys at air temperature 17° F and in Jerseys, Holsteins, and Brown Swiss at the 80° F air temperature. The data for 95° were not tested statistically because of the few observations, but as shown in Figure 2, the cooling effect of high wind was greater at 95° than at 80° for the European breeds.

Heat Production: As reported in a preceding bulletin,[6] dairy cows produced minimal heat while maintaining normal rectal temperatures at environmental temperatures between 40° and 60° F. Above this thermoneutrality zone, the rectal temperature rose and the heat production declined. Below this range, the heat production increased, preventing a fall in rectal temperature. All of these measurements were made at an air velocity of 0.5 mph.

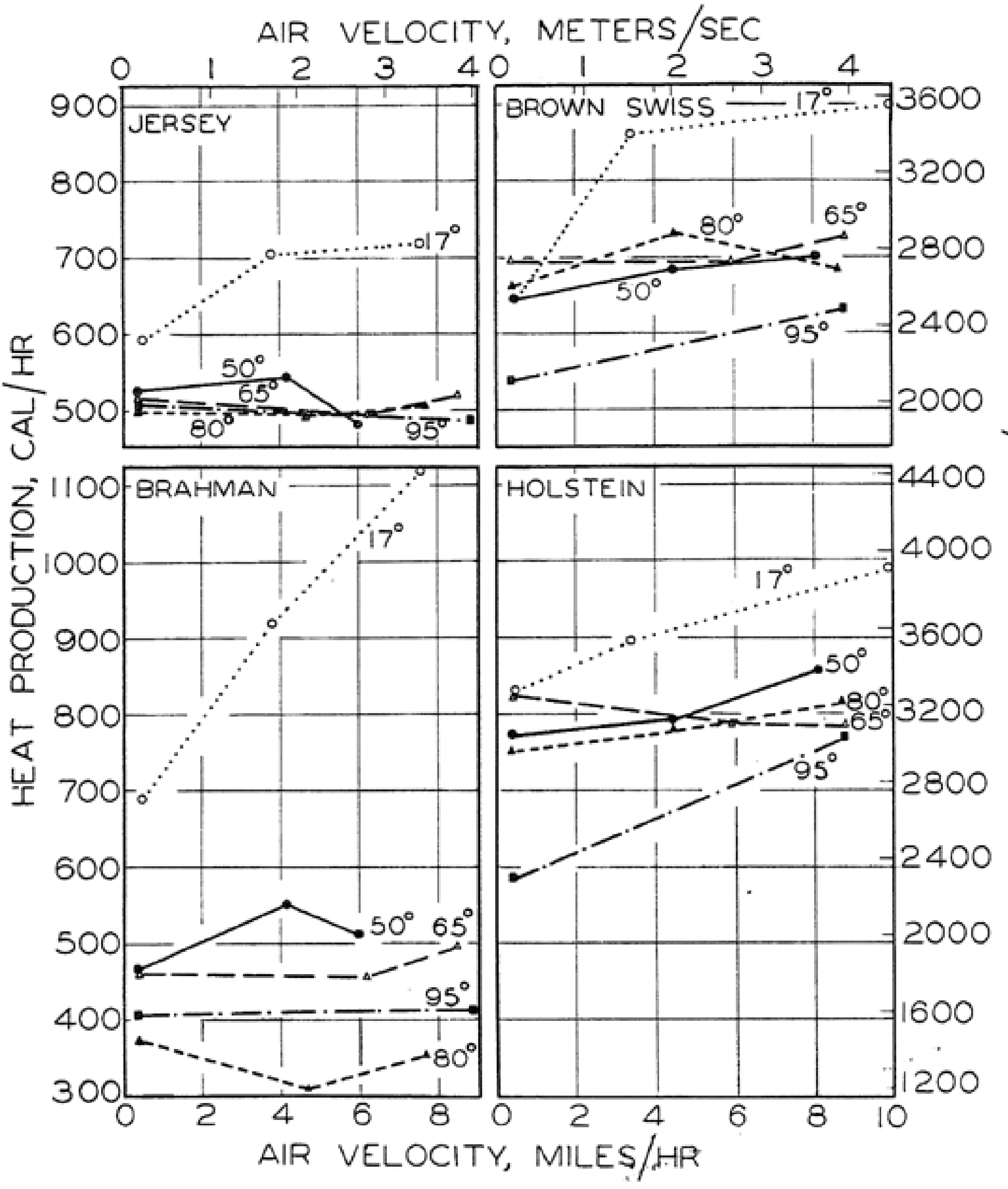

Fig. 3A — Influence of air velocity on heat production at five air temperatures.

Figure 3 confirms these responses for the low (0.5 mph) air velocity and shows that changes in wind velocity have no effect on heat production in the thermoneutrality zone.* In addition it shows that the depression of heat production in the Brown Swiss and Holstein cows at 95° F was greater at low than at high wind velocity. In the

*The higher heat production in the Brown Swiss and the Holsteins at 65° F than at 50° F resulted from a change of experimental animals. Those brought into the experiment at 65° F weighed about 130 pounds more per animal than those used at 50° F.

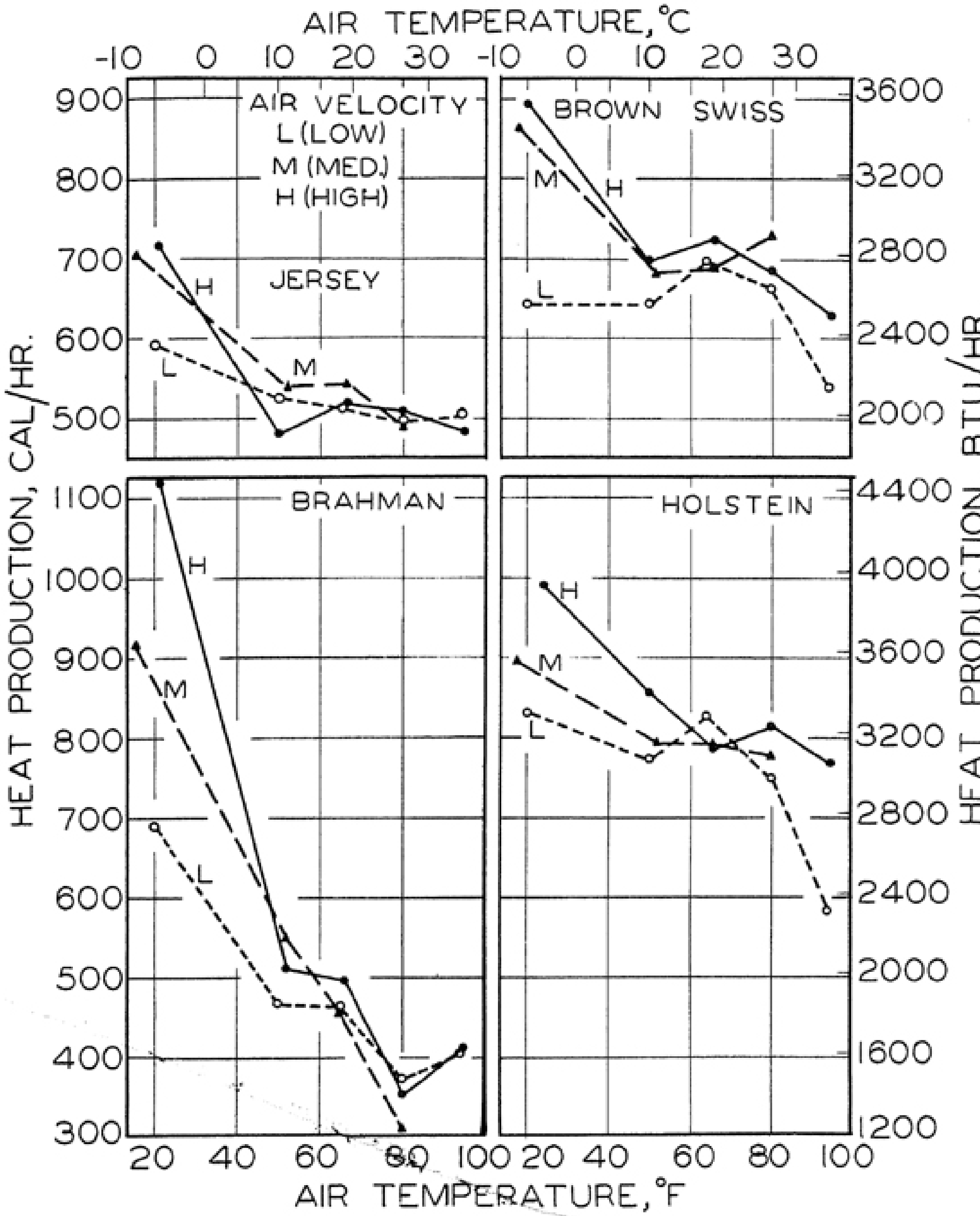

Fig. 3B — Influence of temperature on heat production at three air velocities.

Brahman and Jersey cows, changes in wind velocity had very little effect at 95° F.

On lowering the temperature from 50° to 17° F at low air velocity, the heat production in the non-lactating Brahmans increased about 40 percent (Figure 3B), confirming the influence of low temperature on heat production as reported in preceding bulletins. While holding the temperature at 17° F, an additional increase of 60 percent occurred when the air velocity was increased from 0.5 to 7.6 mph (Figure 3A). Similar but less pronounced increases in heat production occurred in the other cows on lowering the temperature and increasing the wind velocity. The low cold tolerance of the non-lactating Brahmans apparently was related to their low heat production. In the thermoneutrality zone they produced 10 percent less heat per animal than the non-lactating Jerseys which they outweighed by 20 percent.

It is rather disturbing that the increases in heat production at 17° F were not noticeably reflected in the feed and water consumption, milk

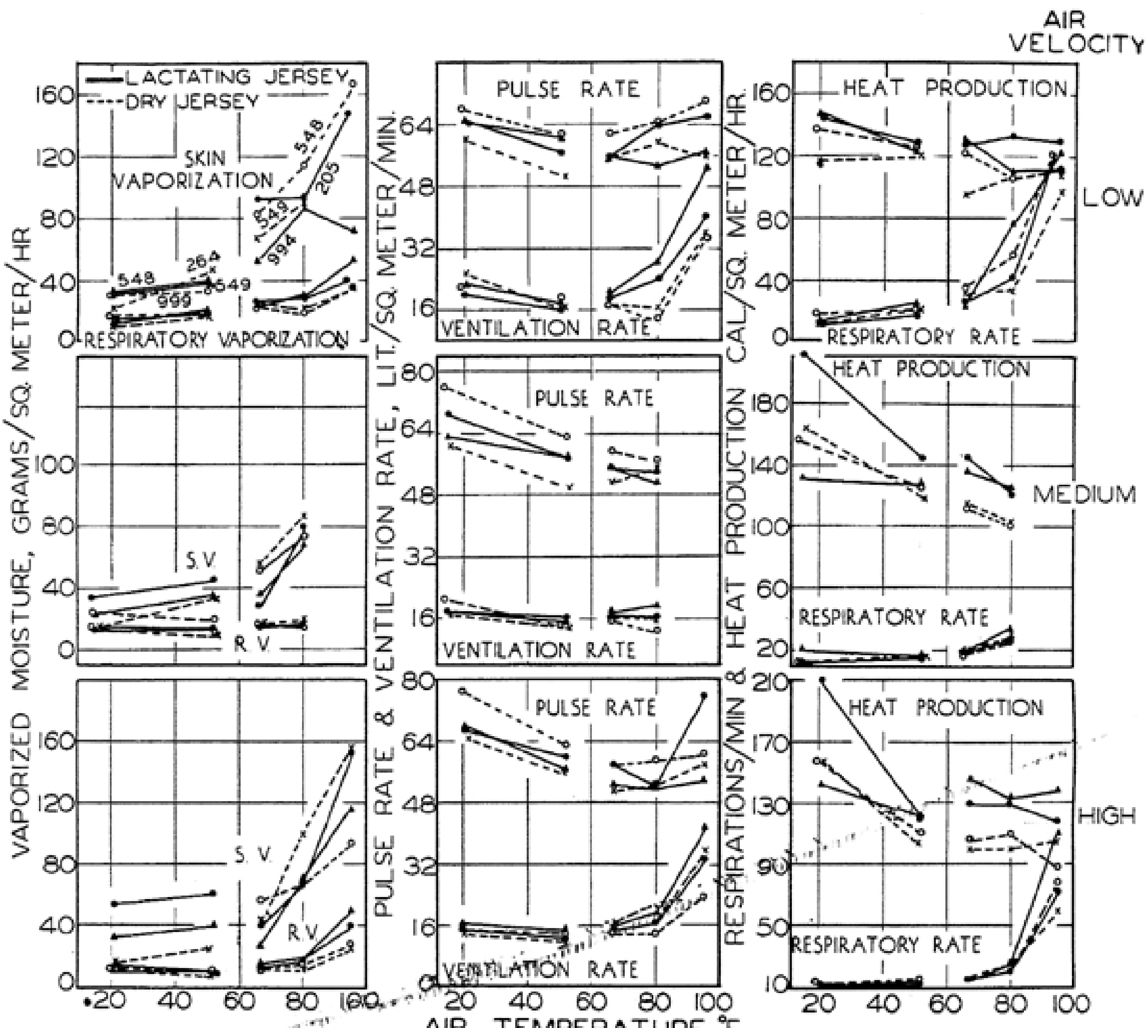

Fig. 4 — Relative responses of 2 lactating and 2 non-lactating Jersey cows to changes in air temperature (bottom scales) and to three levels of air velocity (see low, medium, high notation at right side). Skin vaporization and respiratory vaporization, gm/m²/hr are shown plotted to the same scale in the left-hand column; pulse rate per minute and pulmonary ventilation rate, lit/m²/min are shown in the middle column; and respirations/min and heat production Cal/m²/hr are shown in the right-hand column. The symbols corresponding to the cow numbers shown in the upper left-hand section were used in all sections. Because of space limitations it was necessary to abbreviate skin vaporization and surface vaporization in the two lower left-hand sections. The data indicate that individual differences in this small group tended to mask the effects of lactation.

production and body weight data previously reported.[2] There can be no completely satisfactory explanation for the discrepancy until more data have been accumulated. A partial explanation may be provided by the special conditions of the experiment. The cold stress affecting the heat production measurements was more severe than the average

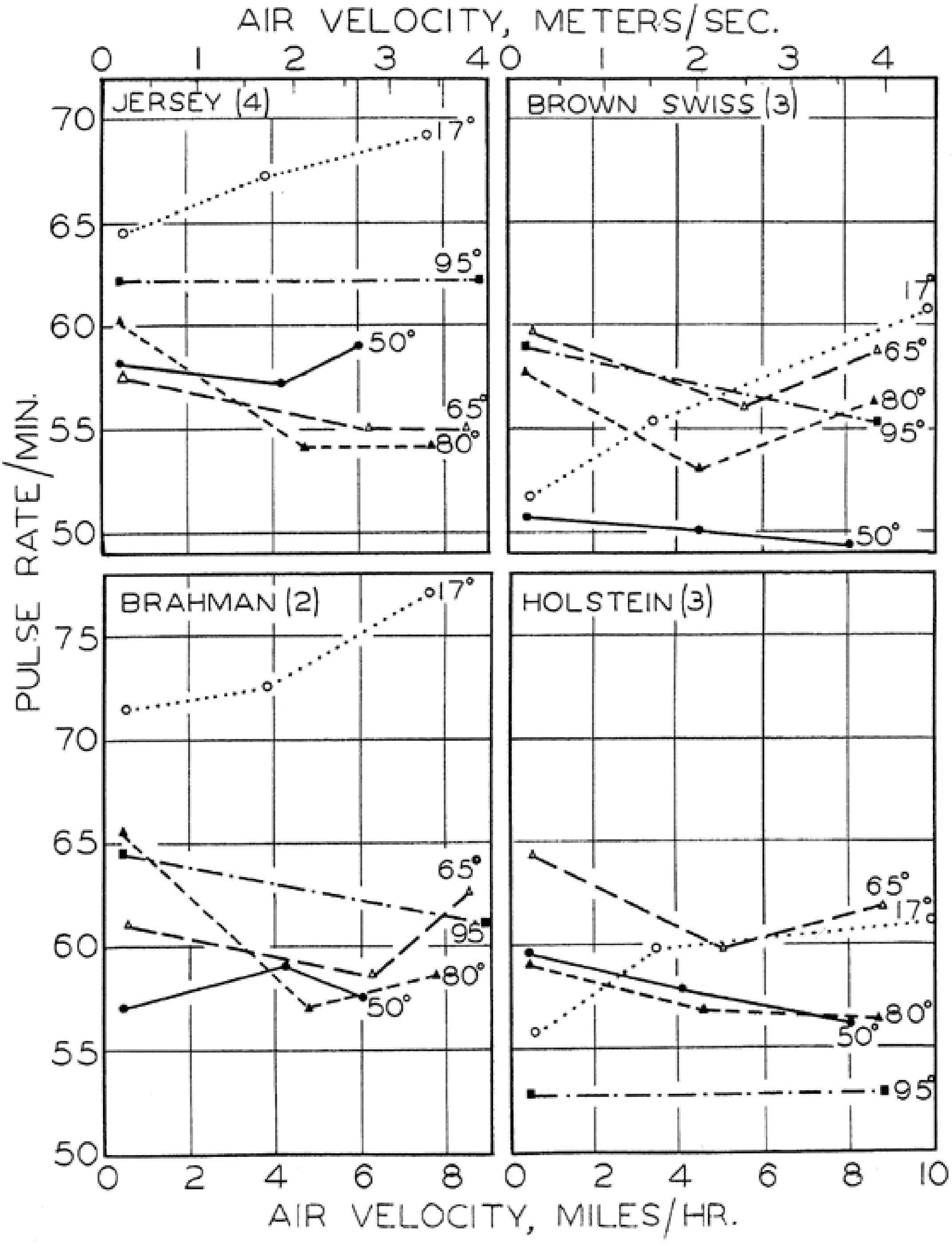

Fig. 5 — Influence of air velocity on pulse rate at five air temperatures.

cold stress over the 24-hour period affecting the milk production, feed and water consumption, and body weight. During the metabolism measurements, the animals stood up under overhead fans where they received the maximum intensity of wind over the greater part of their bodies. Over the 24-hour period, on the other hand, they were lying down part of the time at greater distances from the fan on warm bedding, with less surface exposed to the wind. Also, the fans were turned off a total of 4 hours a day during feeding and milking.

As the Jersey averages in Figure 3 include both lactating and non-lactating animals, a comparison of the various responses of the lactating and non-lactating animals in Figure 4 might be instructive. Heat production is given in the right hand sections. No definite conclusion can be reached on the influence of lactation on heat production in relation to wind velocity as the variations between individual cows tend to mask the effects of lactation.

Pulse Rate: At about 17° F air temperature, increasing the air velocity from 0.5 to 10 mph caused statistically significant increases of 4 to 6 beats per minute in the Brahman and Jersey cows, and highly significant increases of 5 to 9 beats per minute in the Holstein and Brown Swiss cows. At 0.5 mph air velocity at this temperature, the mean pulse rates by breeds were: Brahman, 72; Jersey, 65; Holstein, 56; Brown Swiss, 52. The lesser increase in pulse rate with increasing air velocity in the smaller breeds may be attributed to their higher mean rates at low temperature. Having shown greater response to decreasing temperature, the smaller breeds apparently possessed less reserve for response to increased wind. At temperatures from 50° to 95° F, the pulse rate varied irregularly with air velocity. The pulse rate is undoubtedly more susceptible to disturbing influences than the other measurements. Under the conditions of the experiment we could not isolate the animals from all disturbing influences.

Respiration Rate, Pulmonary Ventilation Rate, and Respiratory Evaporative Cooling: These three functions are closely interrelated in the dissipation of heat from the respiratory tract. Increasing wind velocity which lowers surface temperature also lowers deeper body temperature under some conditions, depressing respiratory activity by nervous reflex action, and thereby decreasing respiratory evaporative cooling. These relations are brought out in the following charts.

Figure 6A shows that increasing air velocity reduced the respiration rate, especially at high temperatures. At low air temperatures (17° for Jersey, Holsteins, and Brown Swiss, and up to 65° F for the Brahmans) the rates were below 14 per mnute and showed very slight changes with increased air velocity. Figure 7A shows closely parallel effects on pulmonary ventilation rate. The slight rise in respiratory

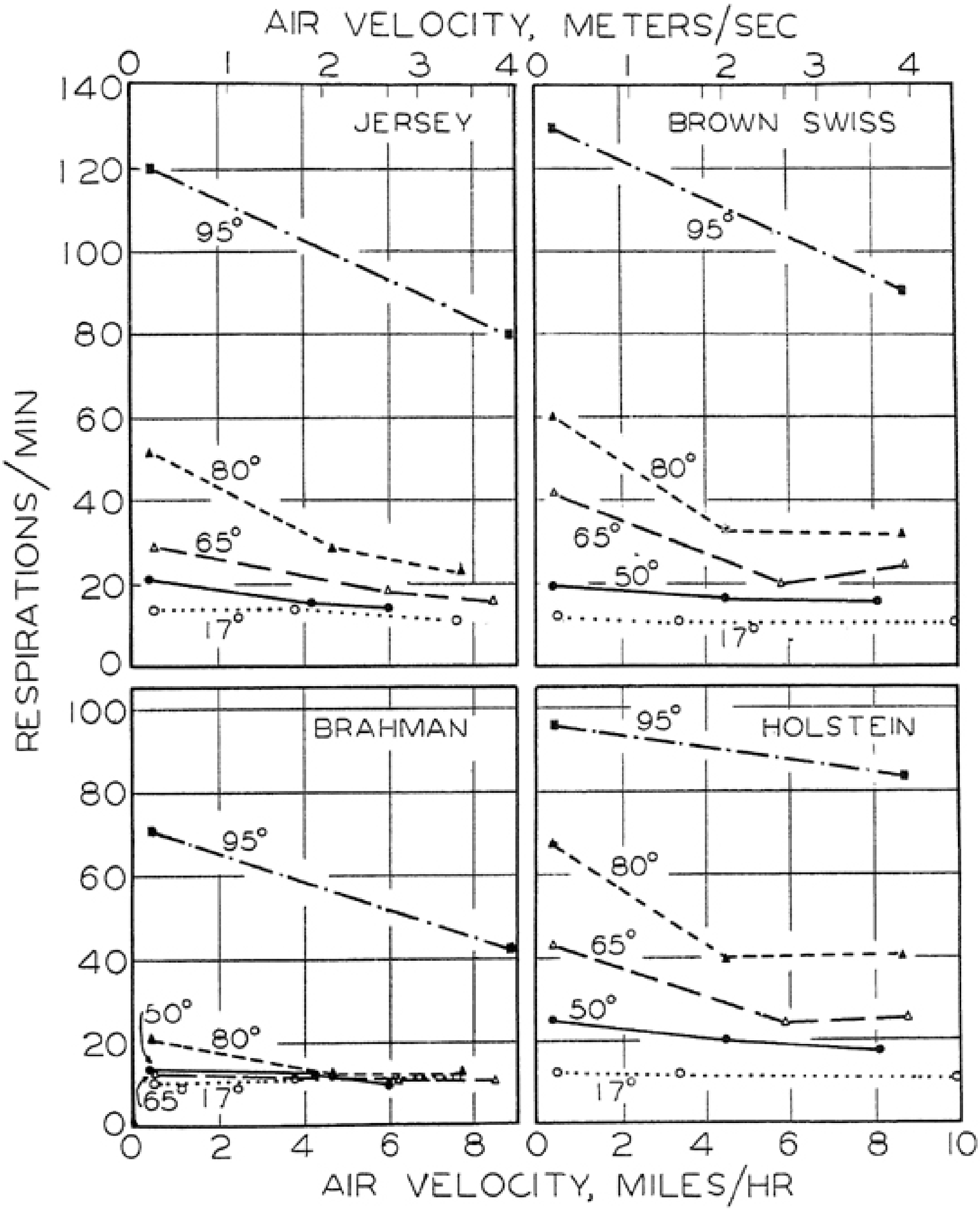

Fig. 6A — Influence of air velocity on respiration rate at five air temperatures.

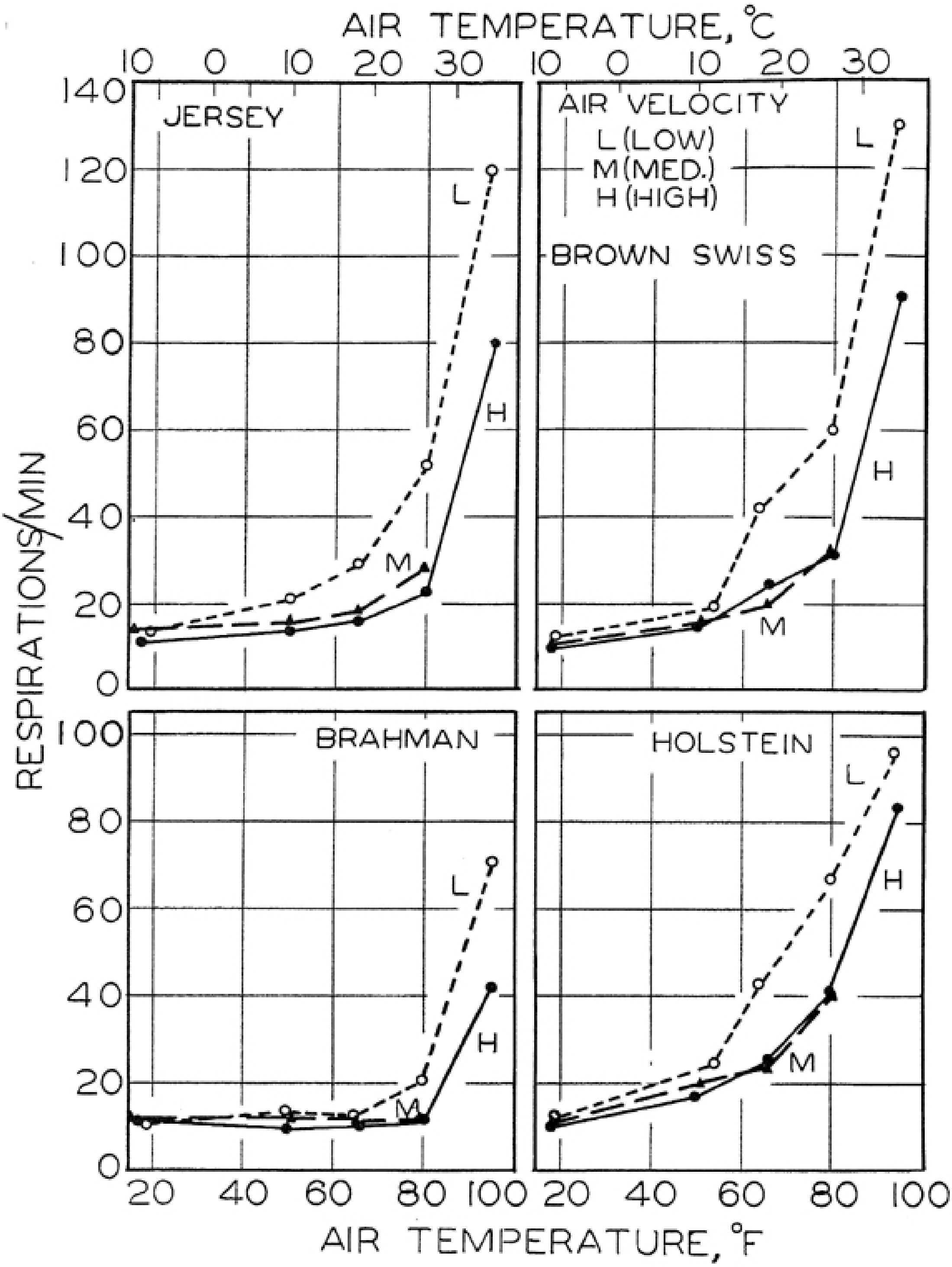

Fig. 6B — Influence of air temperature on respiration rate at three wind levels.

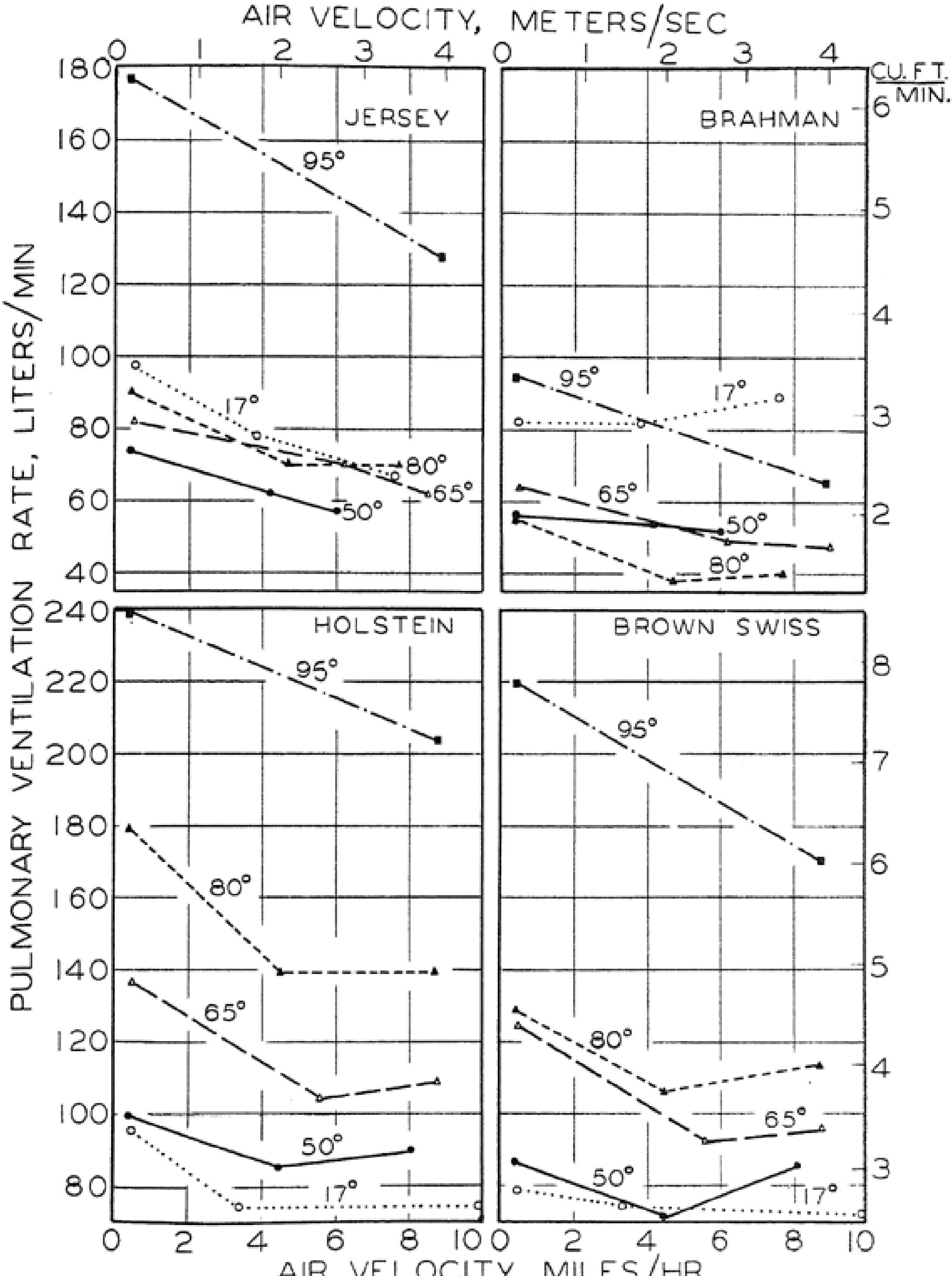

Fig. 7A — Influence of wind velocity on respiration volume at five temperature levels.

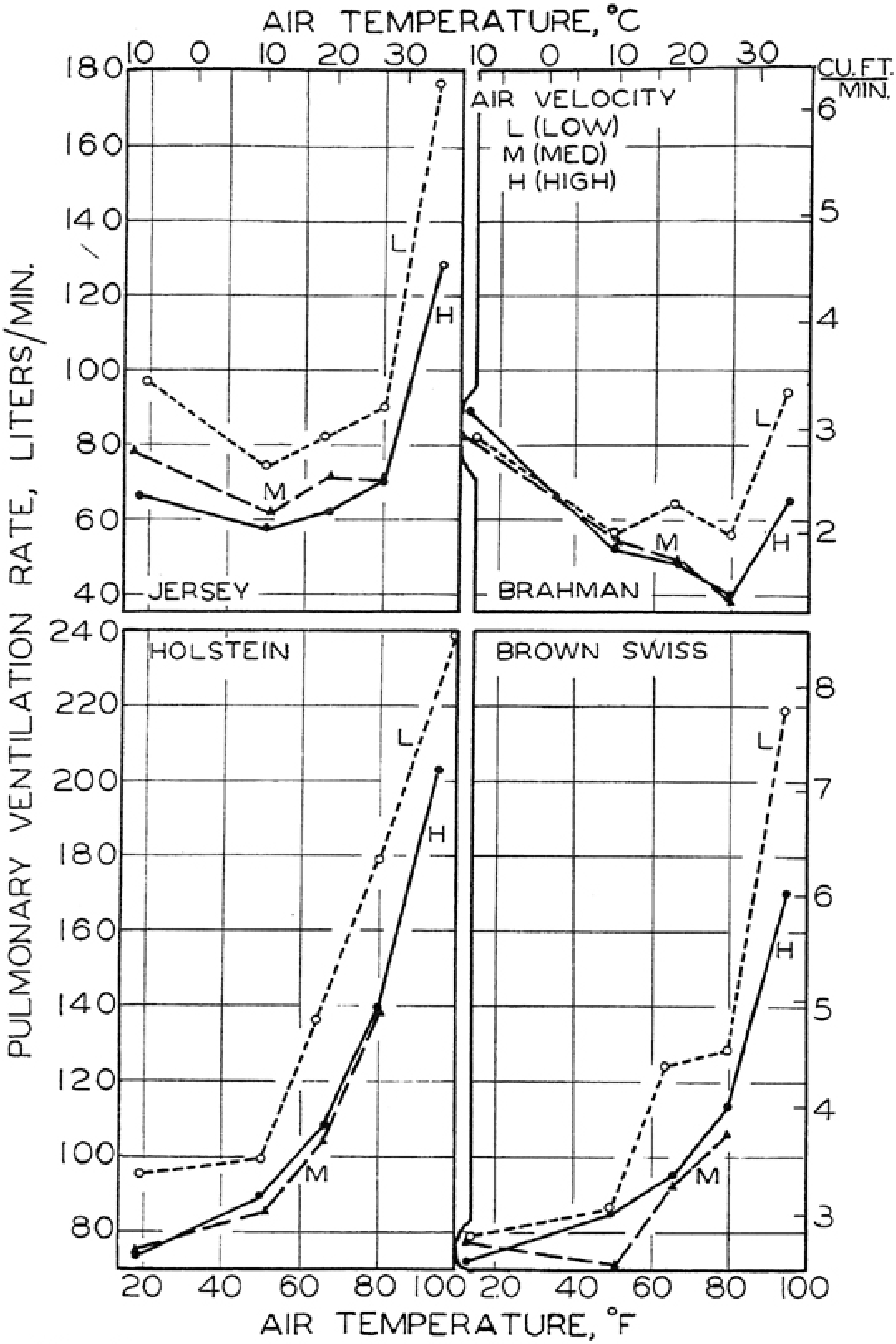

Fig. 7B — Influence of air temperature on respiratory volume at three wind levels.

activity in the Brahmans at 17° F with rising air velocity was, no doubt, associated with their greatly increased heat production. It is noticeable that at temperatures below 95° F the changes in respiration rate, and especially pulmonary ventilation rate, caused by increasing air velocity were greater between 0.4 and 5 mph than between 5 and 9 mph.

Figure 8 shows the decrease in respiratory vaporization with increasing air velocity, resulting from the reduction in respiratory activity just discussed. For the range of temperatures from 17° to 95° F, the values at high and medium velocity averaged about 30 percent below those at low velocity, except in the Brahmans at 17° F. It will be recalled, however, that the respiratory activity of the Brahmans at 17° F was also greater at high than at low velocity, explaining the increase in evaporative cooling.

The effects of changes in temperature and air velocity on respiratory activity in cattle are apparently modified considerably by acclimatization. Previously reported data[6] showed decreases of 40 to 50 percent in respiration rate as the temperature was lowered from 50° to 5° F over a period of several weeks. Graf and Peterson,[14] on the other hand, found that the respiration rate in a group of cattle housed at 45° F was not changed when they were taken outside and exposed for 1 hour to temperatures between −16° and +16° F. The mean rate was 21 in both instances. Their animals, unlike ours, did not have time to become adjusted to the cold. They reported shivering and greatly increased activity in their cows. This might easily explain the higher respiration rates of their animals. Figure 6B shows that in the present data the respiration rates fell below 14 per minute at temperatures between 15° and 20° F.

Figure 7B shows a continuous rise in pulmonary ventilation rate with increasing environmental temperature in the Holsteins and Brown Swiss. In the Jerseys and Brahmans, however, the rates were higher at the high and low temperatures, with lower values between 50° and 80° F.

Evaporative Cooling from the Skin: Figure 9 shows that vaporization from the skin increased with rising temperature but tended to decrease with rising air velocity. The only possible explanation for the decrease in vaporization with rising air velocity is that less moisture reached the surface of the convectively cooled skin —probably because of a slower diffusion rate brought about by diminished blood flow through constricted skin capillaries or, less likely, because of decreased sweat gland activity. As the vaporization from the skin was not measured directly, as was respiratory vaporization, but was computed by

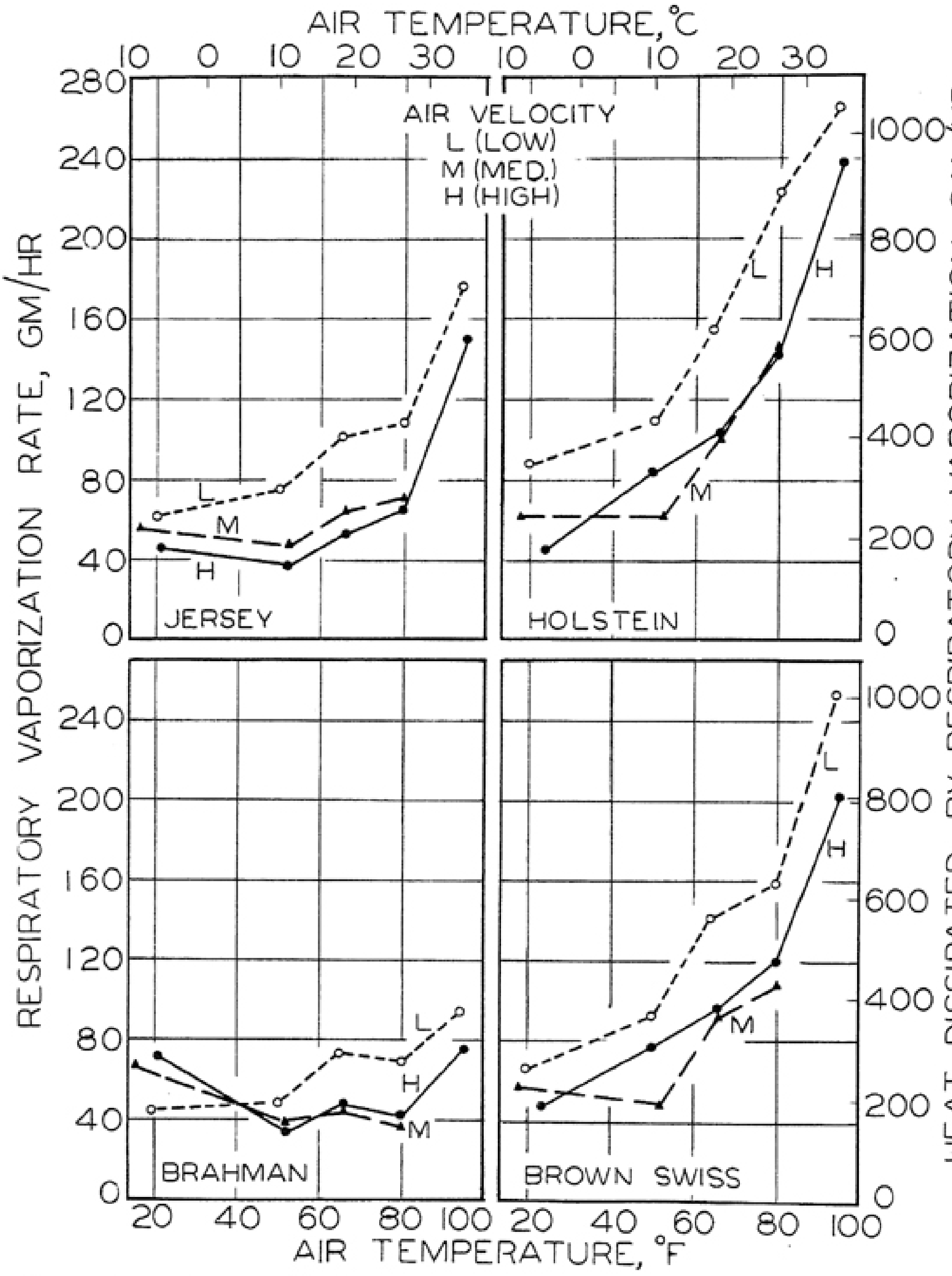

Fig. 8 — Influence of air temperature on respiratory vaporization rate at five temperatures.

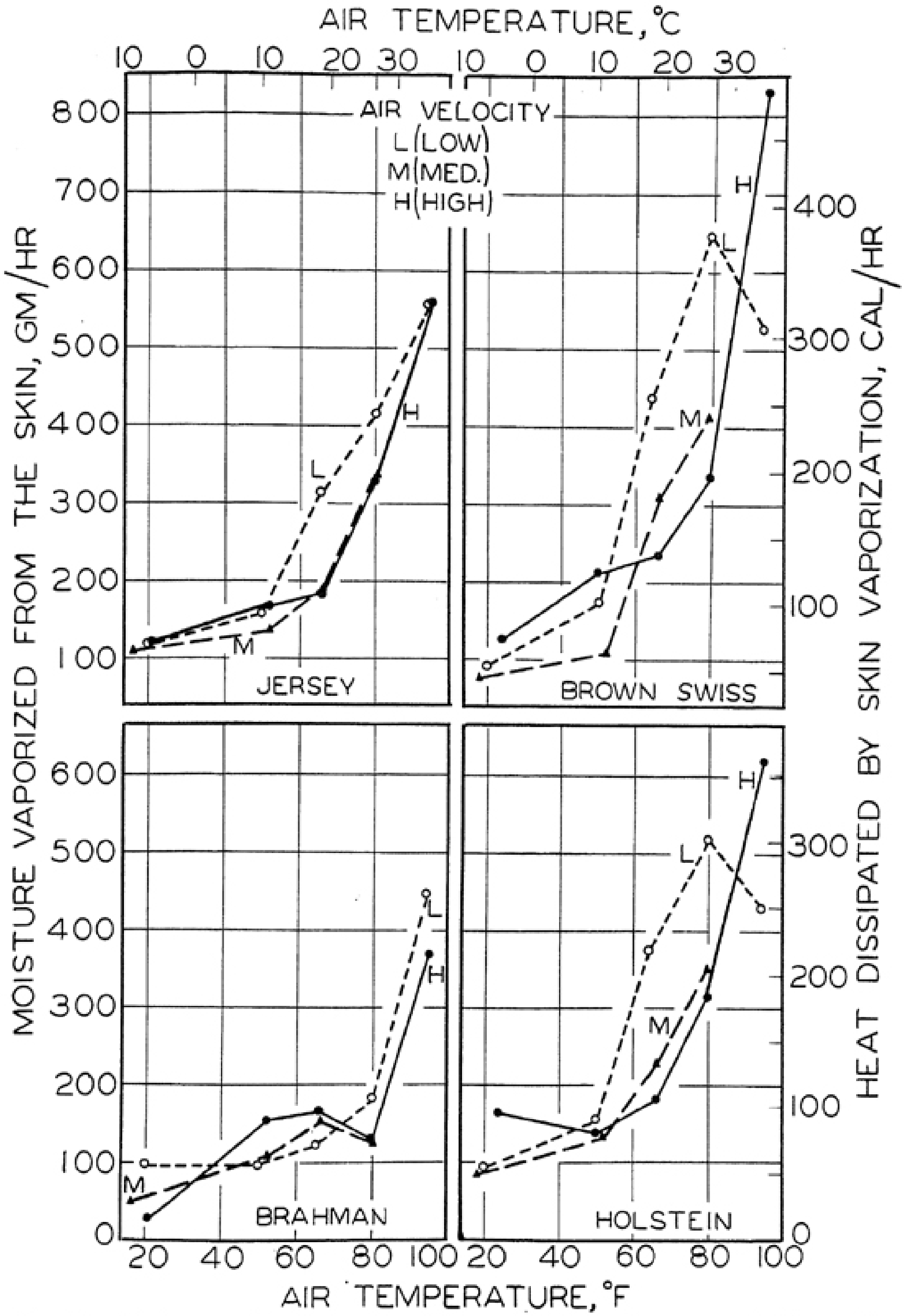

Fig. 9 — Influence of air temperature on outer surface vaporization rate at five temperatures.

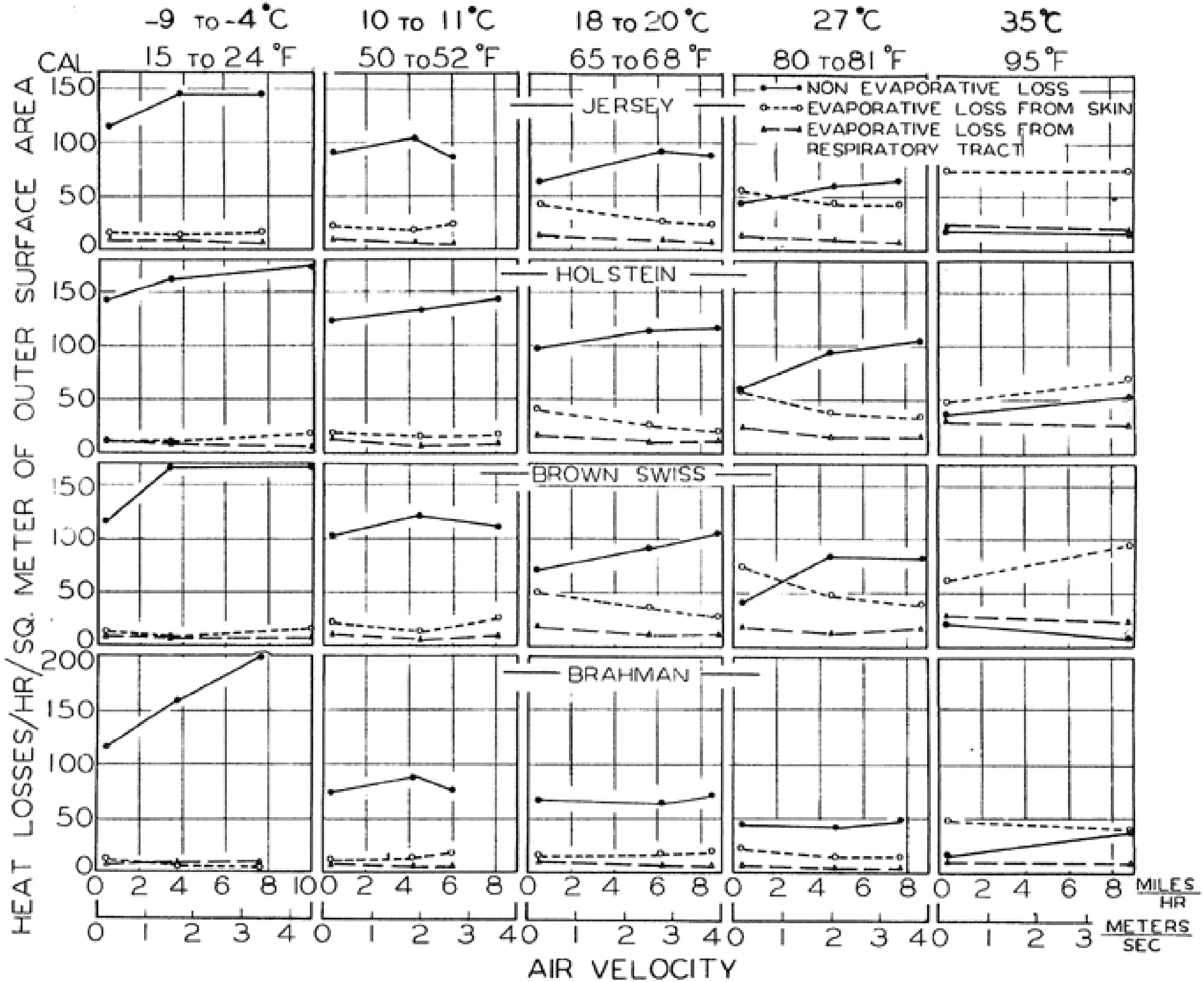

Fig. 10 — Influence of air velocity on evaporative cooling from the respiratory tract, evaporative cooling from the outer body surface, and total non-evaporative cooling, at five temperatures.

difference[1,3,4] and hence affected by cumulative errors, additional data are needed before a more detailed analysis is justified.

Non-evaporative Heat Loss: The effects of changing wind velocity and temperature on the evaporative and non-evaporative losses are summarized in Figure 10 and Tables 5 and 6. The non-evaporative losses, indicated by solid lines, decrease with rising temperature, but generally increase with rising air velocity. Opposing effects of air velocity and temperature on the components of the non-evaporative loss (convection, radiation, and conduction) accounted for this difference. Increasing air velocity increases the convective heat loss (as indicated in Equation 1), but, at the same time, lowers the skin temperature and thereby decreases the radiation and conduction losses. Increasing temperature, on the other hand, decreases the temperature gradient between the animal and its environment and thereby decreases the heat losses in all three non-evaporative components. As an example of the opposing effects of temperature and wind, Figure 10 shows that the non-evaporative heat loss in the Holsteins decreased from about 150 to 50 Cal./M^2/hr. as the temperature was increased from about 20° to 95° F; in contrast to an increase from 50 to 100 Cal./M^2/hr. as the wind velocity was increased from 0.5 to 9 mph at the 80° F temperature level.

SUMMARY

Data are presented on the influence of changing wind or air velocity (0.5 to 10 mph) at temperatures of 17°, 50°, 65°, 80° and 95° F on respiration rate, pulse rate, pulmonary ventilation rate, rectal temperature, heat production, evaporative cooling from the respiratory tract, and related values on outer surface evaporative and total non-evaporative cooling in Jersey, Holstein, Brown Swiss, and Brahman cattle.

Increasing wind or air velocity from 0.5 to 10 mph was found to increase the heat dissipation in cattle at 17° F environmental temperature (as indicated by increased heat production). Similar increases in air velocity at 50° and 65° F had little effect on total heat dissipation; the non-evaporative heat losses were generally greater, but they were balanced by smaller heat losses by vaporization from the respiratory tract and skin. Heat production in Holstein and Brown Swiss cattle was depressed less by 80° F temperature at high wind velocity than at low wind velocity. At 95° F, wind velocities of 8 to 9 mph cooled the individual Jersey, Holstein and Brown Swiss cows which had developed high rectal temperatures sufficiently to allow their metabolism to proceed at more normal (less depressed) levels. This was accompanied by less depression of feed consumption and milk production.

At 17° F, air velocities of 8 to 10 mph increased the heat loss in Holstein, Jersey and Brown Swiss cows to the extent that they increased their heat production by 20 to 35 percent while maintaining normal rectal temperature. Under similar conditions, Brahman cows increased their heat production by 60 percent but were unable to prevent a fall in rectal temperature of about 1° F.

At an environmental temperature of 95° F, the individual Holsteins, Brown Swiss and Jerseys which developed high rectal temperatures at 0.5 mph air velocity were benefited by air velocities of 8 and 9 mph. The lowering of rectal temperatures, in degrees Fahrenheit, amounted to about 1½° at 80° and over 2° at 95° in the lactating Holsteins; ¾° at 80° and 1° at 95° in the lactating Brown Swiss; ½° at 80° and 1½° at 95° in the lactating Jerseys, and ½° at 80° and ¾° at 95° in the non-lactating Jerseys. The non-lactating Brahmans maintained approximately normal rectal temperature at all air velocities at 80° and 95°.

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TABLE 2 -- INFLUENCE OF AIR MOVEMENT ON THE HEAT PRODUCTION, PULMONARY VENTILATION AND METABOLIC WEIGHT LOSS RATES IN INDIVIDUAL DAIRY COWS AT FIVE TEMPERATURE LEVELS

Air Temperature, °F	15° - 19°			50° - 51°			Air Temperature, °F	64° - 67°			80°			94° - 95°	
Air Velocity*	L	M	H	L	M	H	Air Velocity*	L	M	H	L	M	H	L	H
							Heat Production, Calories per hour								
Jersey							Jersey								
548	625	551	602	518	532	508	548+	520	482	460	468	448	480	495	393
549	604	878	874	532	608	498	549+	414	496	436	480	462	442	489	477
999+	638	714	727	550	547	494	994	542	554	592	447	510	540	450	543
264+	497	674	660	487	477	420	205	572	644	574	591	544	574	582	513
Brahman							Brahman								
209	734	930	1254	488	611	612	209	530	460	596	399	296++	332	399	420
189	642	906	986	444	487	403	189	393	448	392	342	320	370	408	399
Holstein							Holstein								
178	956	900	891	759	792	976	144	730	710	796	666	724	754	660	795
132	792	852	898	723	800	754	154	920	830	752	963	824	866	498	732
184	744	930	1182	840	779	838	118	826	822	800	615	784	822	588	774
Brown Swiss							Brown Swiss								
9	624	862	792	688	754	698	22	696	672	642	621	756	702	558	672
41	666	831	780	592	656	672	23	788	796	914**	717	838	726	---	660
47	640	894	1120	654	634	725	47	614	610	618	651	602	618	516	555
							Pulmonary Ventilation Rate, liters per minute, S.T.P.								
Jersey							Jersey								
548	96	73	73	76	64	61	548+	77	65	60	62	57	59	156	101
549	82	71	65	67	66	55	549+	82	71	61	77	71	71	162	98
999+	102	97	69	82	66	62	994	85	68	65	117	78	77	212	166
264+	108	70	61	68	54	49	205	86	80	63	104	72	72	179	147
Brahman							Brahman								
209	81	91	110	63	66	62	209	68	54	55	59	34++	36	107	68
189	83	72	68	50	41	41	189	60	44	41	54	43	45	80	62
Holstein							Holstein								
178	111	74	111	103	91	97	144	143	97	108	167	157	138	242	208
132	77	64	77	138	83	80	154	140	104	113	205	137	155	260	212
184	97	83	97	111	82	91	118	124	110	103	164	124	124	216	190

TABLE 2 -- CONTINUED

Air Temperature, °F	15° - 19°			50° - 51°			Air Temperature, °F	64° - 67°			80°			94° - 95°	
Air Velocity*	L	M	H	L	M	H	Air Velocity*	L	M	H	L	M	H	L	H
Brown Swiss							**Brown Swiss**								
9	76	77	76	90	84	88	22	121	96	98	115	103	111	240	166
41	74	78	74	89	68	85	23	142	101	105**	183	132	145	254	223
47	85	76	85	80	62	83	47	110	80	82	86	82	82	163	122
							Metabolic Weight Loss, grams per hour								
Jersey							**Jersey**								
548	85	71	69	89	74	63	548+	62	76	49	37	52	40	68	46
549	74	46	57	89	74	66	549+	67	57	59	69	67	53	37	54
999+	79	86	73	73	82	72	994	60	68	53	62	64	78	51	72
264+	53	74	54	74	55	54	205	66	57	88	73	68	72	37	53
Brahman							**Brahman**								
209	88	82	102	72	66	73	209	56	53	44	38	16++	2	47	33
189	51	59	50	42	46	45	189	43	49	39	32	35	33	37	29
Holstein							**Holstein**								
178	104	127	91	85	82	117	144	77	77	70	74	104	57	91	91
132	93	101	82	106	111	126	154	57	78	78	125	121	105	138	63
184	119	127	68	117	94	110	118	79	109	83	88	85	78	122	66
Brown Swiss							**Brown Swiss**								
9	75	88	64	86	70	99	22	77	50	79	52	79	94	144	99
41	72	91	69	69	51	67	23	33	71	55**	70	63	70	---	58
47	64	107	105	79	62	92	47	66	73	60	55	57	54	73	57

*L indicates low; M, medium; and H, high air velocity. For the actual values in miles per hour for the different conditions, see Table 1.

+Dry cows.

**Sick with bad knees.

++Poor appetite for several days.

TABLE 3 -- INFLUENCE OF AIR MOVEMENT ON OXYGEN CONSUMPTION, CARBON DIOXIDE AND METHANE PRODUCTION IN INDIVIDUAL DAIRY COWS AT FIVE TEMPERATURE LEVELS

Air Temperature, °F	15° - 19°			50° - 51°			Air Temperature, °F	64° - 67°			80°			94° - 95°	
Air Velocity*	L	M	H	L	M	H	Air Velocity*	L	M	H	L	M	H	L	H
							Oxygen Consumption, liters per hour, S.T.P.								
Jersey							Jersey								
548	124	110	121	102	106	101	548+	103	95	92	95	89	97	98	78
549	120	181	179	106	121	103	549+	82	99	87	95	92	89	100	95
999+	128	142	145	109	109	98	994	108	110	119	89	101	107	90	109
264+	100	136	134	96	95	84	205	114	130	114	117	109	114	119	103
Brahman							Brahman								
209	146	188	254	98	122	122	209	107	92	122	81	61++	66	80	86
189	131	185	204	89	98	80	189	79	90	80	68	64	75	83	81
Holstein							Holstein								
178	191	179	191	153	158	192	144	149	143	171	134	143	154	131	158
132	160	169	160	144	159	149	154	189	168	154	191	164	173	98	149
184	149	185	149	167	154	167	118	167	145	160	122	158	166	116	157
Brown Swiss							Brown Swiss								
9	125	175	125	137	156	139	22	139	137	127	125	151	140	111	133
41	133	166	133	142	133	135	23	164	161	188**	144	166	146	---	134
47	129	179	129	130	127	145	47	123	121	124	132	116	125	102	112
							Carbon Dioxide Production, liters per hour, S.T.P.								
Jersey							Jersey								
548	129	112	119	115	111	109	548+	103	104	89	86	89	89	102	77
549	121	151	155	118	121	112	549+	86	98	90	101	98	88	89	95
999+	129	143	138	112	116	99	994	106	110	110	94	103	114	89	110
264+	98	131	121	104	94	86	205	113	120	124	119	110	116	103	98
Brahman							Brahman								
209	145	172	230	103	119	122	209	103	89	108	76	50++	48	79	77
189	118	160	170	83	92	79	189	77	88	76	64	62	70	77	71
Holstein							Holstein								
178	186	187	170	149	152	191	144	142	139	155	131	151	137	138	156
132	158	167	168	153	166	166	154	161	157	145	193	175	174	136	135
184	162	191	206	172	155	172	118	156	157	155	130	153	155	142	143

TABLE 3 -- CONTINUED

Air Temperature, °F	15° - 19°			50° - 51°			Air Temperature, °F	64° - 67°			80°			94° - 95°	
Air Velocity*	L	M	H	L	M	H	Air Velocity*	L	M	H	L	M	H	L	H
Brown Swiss							Brown Swiss								
9	125	166	145	137	144	146	22	136	122	128	116	145	143	143	140
41	128	162	146	117	119	128	23	132	148	160**	137	149	137	---	122
47	121	179	201	129	120	146	47	120	122	118	121	111	115	109	107
Methane Production, liters per hour, S.T.P.															
Jersey							Jersey								
548	10	10	10	11	8	11	548+	7	8	5	4	4	4	8	7
549	9	9	10	11	11	7	549+	20	5	7	7	6	8	5	2
999+	10	8	10	10	13	8	994	5	11	9	4	5	8	5	15
264+	3	13	8	9	7	6	205	9	9	8	7	10	8	4	8
Brahman							Brahman								
209	14	16	14	10	7	9	209	7	11	6	5	5++	1	7	5
189	7	10	9	6	6	4	189	5	5	4	2	4	2	5	7
Holstein							Holstein								
178	12	17	13	15	11	19	144	13	8	11	8	13	9	7	13
132	14	19	13	14	14	16	154	12	11	10	23	13	11	13	13
184	17	18	10	20	11	13	118	14	8	9	7	13	13	10	10
Brown Swiss							Brown Swiss								
9	10	14	10	14	11	12	22	10	7	10	3	11	16	28	17
41	13	11	8	8	9	10	23	8	11	11**	7	7	11	---	11
47	13	12	10	14	8	14	47	7	7	5	7	5	8	6	7

*L indicates low; M, medium; and H, high air velocity. For the actual values in miles per hour for the different conditions, see Table 1.

+Dry cows.

**Sick with bad knees.

++Poor appetite for several days.

TABLE 4 -- INFLUENCE OF AIR MOVEMENT ON RESPIRATION RATE, PULSE RATE, AND RECTAL TEMPERATURE IN INDIVIDUAL DAIRY COWS AT FIVE TEMPERATURE LEVELS

Air Temperature, °F	15° - 19°			50° - 51°			Air Temperature, °F	64° - 67°			80°			94° - 95°	
Air Velocity*	L	M	H	L	M	H	Air Velocity*	L	M	H	L	M	H	L	H
							Respiration Rate per minute								
Jersey							Jersey								
548	14	20	11	25	17	15	548+	35	17	16	56	25	20	134	78
549	11	12	11	17	14	12	549+	32	20	17	33	29	26	97	60
999+	18	12	12	20	15	14	994	24	18	15	77	34	26	123	110
264+	12	12	11	21	16	15	205	26	18	16	42	27	20	122	72
Brahman							Brahman								
209	11	13	13	14	12	10	209	15	13	12	25	13++	14	75	46
189	10	10	10	12	12	9	189	10	9	9	16	10	10	66	38
Holstein							Holstein								
178	13	12	11	25	22	18	144	38	19	22	61	38	35	90	76
132	11	11	10	23	17	17	154	51	32	30	86	50	54	116	98
184	13	11	11	27	21	17	118	40	21	24	55	32	32	82	76
Brown Swiss							Brown Swiss								
9	12	11	10	20	17	16	22	44	21	26	57	28	31	138	78
41	12	12	12	19	17	15	23	43	21	27**	69	41	40	133	108
47	13	10	10	18	15	15	47	39	18	20	54	29	25	118	86
							Pulse Rate per minute								
Jersey							Jersey								
548	65	63	68	61	58	57	548+	62	59	58	65	57	59	70	61
549	65	69	67	57	58	60	549+	56	51	51	59	55	53	56	58
999+	68	76	77	62	63	63	994	56	55	53	53	51	52	57	54
264+	60	61	65	51	50	56	205	56	55	58	64	54	53	66	76
Brahman							Brahman								
209	73	71	78	60	62	62	209	62	59	66	66	62++	67	67	62
189	70	74	76	53	56	53	189	60	58	57	65	52	50	62	60
Holstein							Holstein								
178	53	56	58	57	54	56	144	57	52	55	56	54	51	46	52
132	56	61	62	60	57	55	154	68	62	64	59	56	58	53	52
184	58	62	63	61	62	57	118	68	65	66	62	60	60	59	54
Brown Swiss							Brown Swiss								
9	58	54	58	51	50	48	22	53	50	52	55	50	54	59	58
41	61	54	61	48	46	46	23	70	66	71**	64	58	63	64	58
47	63	58	63	54	54	54	47	56	52	53	54	51	52	54	50

TABLE 4 -- CONTINUED

Air Temperature, °F	15° - 19°			50° - 51°			Air Temperature, °F	64° - 67°			80°			94° - 95°	
Air Velocity*	L	M	H	L	M	H	Air Velocity*	L	M	H	L	M	H	L	H
							Rectal Temperature, °F								
Jersey							Jersey								
548	101.2	100.4	100.9	100.6	100.2	100.5	548+	100.9	100.8	100.8	100.9	100.9	100.8	101.8	101.2
549	101.2	100.8	100.4	100.4	100.4	99.7	549+	100.6	100.4	100.3	100.9	100.4	100.5	102.0	101.2
999+	101.3	100.7	101.1	100.9	100.5	100.5	994	100.8	100.7	100.5	101.1	100.8	100.8	105.6	103.3
264+	101.0	100.8	100.6	100.7	100.7	101.2	205	100.8	100.7	100.5	101.2	100.8	100.6	103.1	102.2
Brahman							Brahman								
209	101.2	100.2	100.0	100.1	100.2	99.7	209	101.0	100.7	100.4	100.8	101.2++	101.4	101.1	101.1
189	101.3	100.9	99.8	100.8	100.9	100.9	189	101.1	101.0	101.0	101.4	101.5	101.1	101.3	101.6
Holstein							Holstein								
178	100.5	100.2	100.9	100.6	100.2	100.3	144	101.1	100.9	100.7	101.2	101.0	100.7	105.2	102.0
132	100.1	100.9	100.8	100.5	100.5	100.0	154	101.2	101.0	100.9	103.3	101.2	101.0	106.1	104.9
184	100.9	100.6	100.4	100.6	100.4	100.3	118	101.1	100.4	100.5	101.8	100.7	100.4	105.0	102.9
Brown Swiss							Brown Swiss								
9	100.3	100.0	100.6	100.5	100.1	99.7	22	100.8	100.4	100.6	101.2	100.7	100.5	102.4	101.6
41	100.4	99.8	100.6	100.2	100.0	99.6	23	101.1	100.7	101.0**	101.8	100.8	100.9	105.4	104.4
47	100.5	100.6	100.5	100.0	100.0	100.0	47	100.9	100.3	100.6	101.3	100.5	100.3	102.8	101.8

*L indicates low; M, medium; and H, high air velocity. For the actual values in miles per hour for the different conditions, see Table 1.

+Dry cows.

**Sick with bad knees.

++Poor appetite for several days.

TABLE 5A. -- INFLUENCE OF AIR VELOCITY ON THE RELATIVE HEAT LOSSES BY EVAPORATIVE AND NON-EVAPORATIVE PROCESSES, AND ON THE RELATIVE EVAPORATIVE WEIGHT LOSSES FROM THE RESPIRATORY TRACK AND SKIN IN JERSEY AND BRAHMAN CATTLE.

(Oct. 26, 1951 - Feb. 14, 1952)

Dry Bulb Temperature °F	Air Velocity Miles per Hour	Evaporative Weight Loss Per Hour: From Respiratory Tract: gm. per cow	gm. per m²	% of total vaporization	From Skin: gm. per cow	gm. per m²	% of total vaporization	Heat Dissipation Per Hour: Evaporative: Respiratory: Cal per cow	Cal per m²	Skin: Cal per cow	Cal per m²	Non-Evaporative: Total: Cal per cow	Cal per m²	Heat Dissipation Relative to Total Heat Production: Evaporative: Respiratory (Percent)	Skin (Percent)	Non-Evaporative: Total (Percent)
Jersey 999																
50	0.4	79	18	35	144	33	65	46	10	84	19	420	95	9	15	76
52	4.2	48	11	38	80	18	62	28	6	46	10	473	108	5	9	86
52	6.0	43	10	--	---	---	--	25	6	---	--	---	---	5	--	--
19	0.5	77	17	36	137	30	64	45	10	79	17	514	111	7	12	81
14	3.8	62	14	29	152	33	71	36	8	88	19	590	129	5	12	83
20	7.6	51	11	44	66	14	56	30	6	38	8	659	143	4	5	91
Jersey 264																
51	0.4	68	17	27	188	46	73	39	10	109	27	338	83	8	22	70
53	4.2	38	9	23	127	32	77	22	5	74	17	381	95	5	15	80
51	6.0	29	7	23	97	24	77	17	4	56	14	347	86	4	13	83
20	0.5	43	10	34	84	20	66	25	6	49	12	423	101	5	10	85
16	3.8	56	14	53	50	12	47	32	8	29	7	613	149	5	4	91
22	7.6	42	10	44	54	13	56	24	6	31	8	604	144	4	5	91
Jersey 548																
50	0.4	86	20	34	168	40	66	50	12	97	23	371	88	10	19	71
52	4.2	52	12	27	142	34	73	30	7	82	20	420	100	6	15	79
52	6.0	42	10	20	163	39	80	24	6	95	23	389	93	5	19	76
20	0.5	66	16	33	132	31	67	38	9	77	18	510	121	6	12	82
15	3.8	50	12	35	94	22	65	29	7	54	13	468	111	5	10	85
21	7.6	43	10	24	135	32	76	25	6	78	19	499	118	4	13	83

TABLE 5A -- CONTINUED

Dry Bulb Temperature °F	Air Velocity Miles per Hour	Evaporative Weight Loss Per Hour: From Respiratory Tract, gm. per cow	From Respiratory Tract, gm. per m^2	From Respiratory Tract, % of total vaporization	From Skin, gm. per cow	From Skin, gm. per m^2	From Skin, % of total vaporization	Heat Dissipation Per Hour: Evaporative, Respiratory, Cal per cow	Evaporative, Respiratory, Cal per m^2	Evaporative, Skin, Cal per cow	Evaporative, Skin, Cal per m^2	Non-Evaporative, Total, Cal per cow	Non-Evaporative, Total, Cal per m^2	Heat Dissipation Relative to Total Heat Production (Percent): Evaporative, Respiratory	Evaporative, Skin	Non-Evaporative, Total
								Jersey 549								
50	0.4	69	17	33	137	33	67	40	10	79	19	413	99	8	15	77
52	4.2	50	12	21	186	44	79	29	7	108	26	471	113	5	18	77
52	6.0	34	8	12	250	60	88	20	5	145	35	333	80	4	29	67
21	0.5	59	14	35	110	26	65	34	8	64	15	506	122	6	11	83
15	3.8	54	13	29	135	33	71	31	8	78	19	768	186	4	9	87
21	7.6	46	11	17	222	53	83	27	6	129	31	718	173	3	15	82
								Brahman 209								
50	0.4	52	10	41	76	14	59	30	6	44	8	414	77	6	9	85
52	4.2	44	8	33	90	17	67	26	5	52	10	533	99	4	9	87
51	6.0	43	8	25	127	24	75	25	5	74	14	513	95	4	12	84
20	0.5	43	8	45	52	10	55	25	5	30	6	679	128	3	4	93
14	3.8	74	14	65	39	7	35	43	8	23	4	864	160	5	2	93
19	7.6	96	18	86	15	3	14	56	10	9	2	1190	223	4	1	95
								Brahman 189								
50	0.4	46	9	28	116	22	72	27	5	67	13	350	67	6	15	79
53	4.2	34	7	22	122	24	78	20	4	71	14	396	77	4	15	81
51	6.0	26	5	13	177	34	87	15	3	103	20	285	54	4	26	70
21	0.5	47	9	25	142	27	75	27	5	82	16	532	102	4	13	83
15	3.8	57	11	50	57	11	50	33	6	33	6	840	157	4	4	92
22	7.6	48	9	56	37	7	44	28	5	22	4	936	177	3	2	95

TABLE 5B. -- INFLUENCE OF AIR VELOCITY ON THE RELATIVE HEAT LOSSES BY EVAPORATIVE AND NON-EVAPORATIVE PROCESSES, AND ON THE RELATIVE EVAPORATIVE WEIGHT LOSSES FROM THE RESPIRATORY TRACT AND SKIN IN HOLSTEIN AND BROWN SWISS CATTLE.
(Oct. 26, 1951 - Feb. 14, 1952)

		Evaporative Weight Loss Per Hour						Heat Dissipation Per Hour						Heat Dissipation Relative to Total Heat Production		
		From Respiratory Tract			From Skin			Evaporative				Non-Evaporative		Evaporative		Non-Evaporative
								Respiratory		Skin		Total				
Dry Bulb Temperature °F	Air Velocity Miles per Hour	gm. per cow	gm. per m^2	% of total vaporization	gm. per cow	gm. per m^2	% of total vaporization	Cal per cow	Cal per m^2	Cal per cow	Cal per m^2	Cal per cow	Cal per m^2	Respiratory Percent	Skin Percent	Total Percent
Holstein 178																
50	0.4	100	20	28	257	51	72	58	11	149	30	552	109	8	20	72
51	4.5	64	13	30	149	29	70	37	7	86	17	668	131	5	11	84
49	8.1	92	18	29	229	45	71	53	10	133	26	790	154	5	14	81
20	0.5	98	19	44	123	24	56	57	11	71	14	828	162	6	7	87
18	3.4	70	14	34	135	27	66	41	8	78	16	781	154	5	8	87
26	10.0	43	8	20	170	33	80	25	5	99	19	767	151	3	11	86
Holstein 132																
50	0.4	94	18	34	179	34	66	54	10	104	20	565	109	7	15	78
52	4.5	56	11	34	108	21	66	32	6	63	12	705	136	4	8	88
50	8.1	70	15	45	87	17	55	41	8	50	10	663	129	5	7	88
20	0.4	73	14	36	129	25	64	42	8	75	14	675	131	5	10	85
17	3.4	52	10	37	89	17	63	30	6	52	10	770	150	4	6	90
24	10.0	42	8	21	156	30	79	24	5	90	17	783	152	3	10	87
Holstein 184																
50	0.4	136	27	83	27	5	17	79	16	16	3	745	150	9	2	89
51	4.5	63	13	31	141	28	69	36	7	82	16	661	133	5	10	85
51	8.1	86	17	47	96	19	53	50	10	56	11	732	148	6	7	87
20	0.4	91	18	78	25	5	22	53	11	14	3	677	136	7	2	91
19	3.4	64	13	77	19	4	23	37	8	11	2	882	178	4	1	95
23	10.0	49	10	23	160	32	77	28	6	93	19	1061	215	2	8	90

TABLE 5B -- CONTINUED

Dry Bulb Temperature °F	Air Velocity Miles per Hour	Evaporative Weight Loss Per Hour: From Respiratory Tract: gm. per cow	gm. per m²	% of total vaporization	From Skin: gm. per cow	gm. per m²	% of total vaporization	Heat Dissipation Per Hour: Evaporative: Respiratory: Cal per cow	Cal per m²	Skin: Cal per cow	Cal per m²	Non-Evaporative: Total: Cal per cow	Cal per m²	Heat Dissipation Relative to Total Heat Production (Percent): Evaporative: Respiratory	Skin	Non-Evaporative: Total
							Brown Swiss 9									
50	0.4	98	20	28	251	51	72	57	12	146	30	486	99	8	21	71
52	4.5	56	11	34	109	22	66	32	6	63	13	658	132	4	9	87
49	8.1	86	17	23	280	57	77	50	10	162	33	486	98	7	23	70
20	0.4	61	13	37	106	22	63	35	7	61	13	527	108	6	10	84
18	3.4	57	12	52	52	11	48	33	7	30	6	799	164	4	3	93
25	10.0	41	8	22	143	29	78	24	5	83	17	685	140	3	11	86
							Brown Swiss 41									
50	0.4	99	20	43	129	26	57	57	12	75	15	460	94	10	12	78
52	4.5	45	9	26	129	26	74	26	5	75	15	555	112	4	11	85
51	8.1	74	15	28	192	39	72	43	9	111	23	518	105	6	17	77
16	0.4	65	13	41	93	19	59	38	8	54	11	574	116	6	8	86
19	3.4	54	11	43	72	15	57	31	6	42	9	758	153	4	5	91
24	10.0	48	10	26	140	28	74	28	6	81	16	671	134	4	10	86
							Brown Swiss 47									
50	0.4	82	18	37	138	30	63	48	10	80	17	525	113	7	12	81
51	4.5	44	9	29	107	23	71	26	6	62	13	546	117	4	10	86
50	8.1	71	15	30	165	35	70	41	9	96	20	588	126	6	13	81
20	0.4	71	15	50	70	15	50	41	9	41	9	558	120	7	6	87
19	3.4	58	12	59	40	9	41	34	7	23	5	837	180	4	3	93
24	10.0	51	11	35	96	21	65	30	7	56	12	1035	223	3	5	92

TABLE 6A. -- INFLUENCE OF AIR VELOCITY ON THE RELATIVE HEAT LOSSES BY EVAPORATIVE AND NON-EVAPORATIVE PROCESSES, AND ON THE RELATIVE EVAPORATIVE WEIGHT LOSSES FROM THE RESPIRATORY TRACT AND SKIN IN JERSEY AND BRAHMAN CATTLE
(Feb. 21 - May 29, 1952)

		Evaporative Weight Loss per Hour						Heat Dissipation Per Hour						Heat Dissipation Relative to Total Heat Production		
		From Respiratory Tract			From Skin			Evaporative				Non-Evaporative		Evaporative		Non-Evaporative
								Respiratory		Skin		Total				
Dry Bulb Temperature °F	Air Velocity Miles per Hour	gm. per cow	gm. per m^2	% of total vaporization	gm. per cow	gm. per m^2	% of total vaporization	Cal per cow	Cal per m^2	Cal per cow	Cal per m^2	Cal per cow	Cal per m^2	Respiratory Percent	Skin Percent	Total Percent
Jersey 548																
65	0.5	96	22	22	350	82	78	56	13	203	48	261	61	11	39	50
66	6.2	63	15	23	215	50	77	37	9	125	29	320	75	8	26	66
67	8.5	49	11	17	240	55	83	28	6	139	32	293	67	6	30	64
80	0.4	80	18	14	506	115	86	46	10	293	67	129	29	10	62	28
80	4.7	60	14	16	323	73	84	35	8	187	42	226	51	8	42	50
80	7.7	61	14	17	291	66	83	35	8	169	38	276	63	7	35	58
95	0.4	157	35	18	740	167	82	91	20	429	97	-25	-6	18	87	-5
95	8.9	119	27	22	413	93	78	69	16	240	54	84	19	18	61	21
Jersey 994																
65	0.5	94	23	31	205	50	69	54	13	119	29	369	90	10	22	68
66	6.2	56	14	29	136	33	71	32	8	79	19	443	108	6	14	80
67	8.5	56	14	32	118	29	68	32	8	68	17	492	121	5	12	83
80	0.5	124	31	26	349	86	74	72	18	202	50	173	42	16	46	38
80	4.7	69	17	21	267	66	79	40	10	155	38	315	78	8	30	62
80	7.7	79	19	22	288	71	78	46	11	167	41	327	81	9	31	60
95	0.4	210	53	43	279	70	57	122	31	162	41	166	42	27	36	37
95	8.9	196	50	30	457	116	70	114	29	265	67	164	42	21	49	30
Jersey 205																
65	0.5	109	24	21	409	91	79	63	14	237	53	272	61	11	41	48
66	6.2	68	15	29	165	37	71	39	9	96	21	509	114	6	15	79
67	8.5	54	12	23	178	40	77	31	7	103	23	440	99	5	18	77
80	0.4	135	30	25	402	91	75	78	17	233	53	280	63	13	40	47
80	4.7	74	17	18	345	78	82	43	10	200	45	301	68	8	37	55
80	7.7	71	16	19	300	67	81	41	9	174	39	359	81	7	30	63
93	0.4	179	40	21	654	147	79	104	23	379	85	99	22	18	65	17
95	8.9	172	39	20	670	152	80	100	23	389	88	24	5	19	76	5

TABLE 6A -- CONTINUED

Dry Bulb Temperature °F	Air Velocity Miles per Hour	Evaporative Weight Loss per Hour: From Respiratory Tract: gm. per cow	From Respiratory Tract: gm. per m²	From Respiratory Tract: % of total vaporization	From Skin: gm. per cow	From Skin: gm. per m²	From Skin: % of total vaporization	Heat Dissipation Per Hour: Evaporative: Respiratory: Cal per cow	Respiratory: Cal per m²	Skin: Cal per cow	Skin: Cal per m²	Non-Evaporative: Total: Cal per cow	Total: Cal per m²	Heat Dissipation Relative to Total Heat Production: Evaporative: Respiratory (Percent)	Evaporative: Skin (Percent)	Non-Evaporative: Total (Percent)
								Jersey 549								
65	0.5	106	25	27	289	67	73	61	14	168	39	185	43	15	41	44
67	6.2	69	16	22	239	56	78	40	9	139	32	317	74	8	28	64
67	8.5	52	12	22	187	43	78	30	7	108	25	298	68	7	25	68
80	0.4	93	21	19	405	90	81	54	12	235	52	191	42	11	49	40
80	4.7	75	17	16	389	87	84	44	10	226	50	192	43	10	49	41
80	7.7	50	11	10	440	99	90	29	6	255	57	158	36	7	57	36
95	0.4	158	35	--	---	---	--	92	20	---	--	---	---	19	--	--
95	8.9	113	25	14	708	156	86	66	15	411	90	1	.2	14	86	.2
								Brahman 209								
64	0.5	79	15	38	131	24	62	46	9	76	14	408	76	9	14	77
66	6.2	44	8	20	177	33	80	26	5	103	19	332	62	6	22	72
66	8.5	60	11	27	162	30	73	35	6	94	17	467	87	6	16	78
80	0.4	74	14	34	143	27	66	43	8	83	16	273	52	11	21	68
80	4.7	31	6	30	73	14	70	18	4	42	8	236	47	6	14	80
80	7.7	45	9	28	117	23	72	26	5	68	13	238	46	8	20	72
95	0.4	105	20	23	343	65	77	61	12	199	38	139	26	15	50	35
95	8.9	78	15	18	359	68	82	45	9	208	39	167	31	11	49	40
								Brahman 189								
65	0.5	67	13	37	114	22	63	39	8	66	13	288	55	10	17	73
66	6.2	44	8	26	127	24	74	26	5	74	14	349	66	6	16	78
67	8.5	35	7	17	166	31	83	20	4	96	18	275	52	5	25	70
80	0.4	61	11	22	217	41	78	35	6	126	24	181	34	10	37	53
80	4.7	41	8	19	174	33	81	24	5	101	19	195	37	7	32	61
80	7.7	38	7	21	139	26	79	22	4	81	15	267	50	6	22	72
95	0.4	84	16	13	549	102	87	49	9	318	59	41	6	12	78	10
95	8.9	73	14	16	378	70	84	42	8	219	41	137	25	11	55	34

TABLE 6B. -- INFLUENCE OF AIR VELOCITY ON THE RELATIVE HEAT LOSSES BY EVAPORATION AND NON-EVAPORATIVE PROCESSES, AND ON THE RELATIVE EVAPORATIVE WEIGHT LOSSES FROM THE RESPIRATORY TRACT AND SKIN IN HOLSTEIN AND BROWN SWISS CATTLE.
(Feb. 21 - May 29, 1952)

Day Bulb Temperature °F	Air Velocity Miles per Hour	Evaporative Weight Loss Per Hour						Heat Dissipation Per Hour						Heat Dissipation Relative to Total Heat Production		
		From Respiratory Tract			From Skin			Evaporative				Non-Evaporative		Evaporative		Non-Evaporative
								Respiratory		Skin		Total				
		gm. per cow	gm. per m²	% of total vaporization	gm. per cow	gm. per m²	% of total vaporization	Cal per cow	Cal per m²	Cal per cow	Cal per m²	Cal per cow	Cal per m²	Respiratory	Skin	Total
														Percent		
								Holstein 144								
68	0.4	154	29	31	344	65	69	89	17	200	38	441	83	12	28	60
67	5.6	81	16	28	207	40	72	47	9	120	23	543	105	7	17	76
67	8.8	97	19	27	268	52	73	56	11	155	30	584	112	7	20	73
80	0.4	208	41	26	593	116	74	121	24	344	67	201	39	18	52	30
80	4.5	161	31	49	170	33	51	93	18	99	19	533	103	13	14	73
81	8.7	138	27	40	204	40	60	80	16	118	23	556	108	11	16	73
95	0.4	257	51	30	587	117	70	149	30	340	68	170	34	23	51	26
95	8.8	252	50	28	637	126	72	146	29	369	73	279	55	18	46	35
								Holstein 154								
68	0.4	164	30	26	478	88	74	95	17	277	51	548	101	10	30	60
67	5.6	112	21	28	290	54	72	65	12	168	31	597	111	8	20	72
67	8.8	108	20	35	197	36	65	63	12	114	21	575	106	8	15	77
80	0.4	258	48	34	507	94	66	150	29	294	54	519	97	16	30	54
80	4.5	141	26	20	551	102	80	82	15	320	59	423	78	10	39	51
81	8.7	167	31	27	453	84	73	97	18	263	49	506	94	11	30	59
95	0.4	278	53	44	359	69	56	161	31	208	40	129	25	32	42	26
95	8.8	243	46	25	744	141	75	141	27	432	82	160	30	19	59	22
								Holstein 118								
67	0.4	148	28	34	293	56	66	86	16	170	32	570	108	10	21	69
67	5.6	109	21	37	188	36	63	63	12	109	21	650	125	8	13	79
67	8.8	104	20	58	76	15	42	60	12	44	9	696	134	7	6	87
80	0.4	204	40	31	458	90	69	118	23	266	52	231	45	19	43	38
80	4.5	133	26	29	327	63	71	77	15	190	36	517	100	10	24	66
81	8.7	124	24	30	295	57	70	72	14	171	33	579	113	9	21	70
95	0.4	261	52	43	342	69	57	151	30	198	40	238	48	26	34	40
95	8.8	218	44	31	481	96	69	126	26	279	56	369	74	16	36	48

TABLE 6B -- CONTINUED

Day Bulb Temperature °F	Air Velocity Miles per Hour	Evaporative Weight Loss Per Hour: From Respiratory Tract gm. per cow	gm. per m^2	% of total vaporization	From Skin gm. per cow	gm. per m^2	% of total vaporization	Heat Dissipation Per Hour: Evaporative: Respiratory Cal per cow	Cal per m^2	Skin Cal per cow	Cal per m^2	Non-Evaporative: Total Cal per cow	Cal per m^2	Heat Dissipation Relative to Total Heat Production (Percent): Evaporative Respiratory	Evaporative Skin	Non-Evaporative Total
								Brown Swiss 22								
68	0.4	129	25	21	493	93	79	75	14	286	54	335	63	11	41	48
67	5.6	85	16	16	445	85	84	49	9	258	49	365	70	7	39	54
67	8.8	93	18	30	218	42	70	54	10	126	24	462	88	8	20	72
80	0.4	140	27	17	665	128	83	81	16	386	74	154	30	13	62	25
80	4.5	106	20	20	436	83	80	61	12	253	48	442	85	8	34	58
81	8.7	115	22	27	311	60	73	67	13	180	35	455	87	10	25	65
96	0.4	264	51	33	547	106	67	153	30	317	61	88	17	27	57	16
95	8.8	190	37	16	991	191	84	110	22	580	111	-13	-3	16	86	-2
								Brown Swiss 23								
67	0.4	174	32	27	473	87	73	101	19	274	50	413	76	13	35	52
67	5.6	111	21	31	250	47	69	64	12	145	27	587	110	8	18	74
67	8.8	125	23	30	295	55	70	72	13	171	32	670	124	8	19	73
80	0.4	227	43	23	743	141	77	132	25	431	82	154	29	18	60	22
80	4.5	135	26	19	562	107	81	78	15	326	62	434	82	9	39	52
81	8.7	160	30	27	433	82	73	93	17	251	48	382	72	13	34	53
95	0.4	312	61	37	538	104	63	181	35	312	60	---	---	--	--	--
96	8.8	275	52	23	917	174	77	160	30	532	101	-31	-6	24	81	-5
								Brown Swiss 47								
67	0.4	119	25	25	352	75	75	69	14	204	44	341	72	11	33	56
67	5.6	79	17	25	233	50	75	46	10	135	29	429	91	8	22	70
67	8.8	74	16	28	191	41	72	43	9	111	24	464	99	7	18	75
80	0.4	106	22	17	529	112	83	61	13	307	65	283	60	9	47	44
80	4.5	82	17	25	244	52	75	48	10	142	30	413	87	8	24	68
81	8.7	82	17	24	262	56	76	48	10	152	33	418	89	8	24	68
96	0.4	184	39	27	493	105	73	107	23	286	61	123	26	21	55	24
95	8.8	140	30	19	578	124	81	81	17	335	72	139	30	15	60	25