UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE
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Research Bulletin 180

GROWTH AND DEVELOPMENT

With Special Reference to Domestic Animals

XXVI. The Energy Increment of Standing Over Lying and the Cost of Getting Up and Lying Down in Growing Ruminants (Cattle and Sheep): Comparison of Pulse Rate, Respiration Rate, Tidal Air, and Minute Volume of Pulmonary Ventilation During Lying and Standing.

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CONTENTS

FOREWORD

The special investigation on the growth and development is a cooperative enterprise in which the departments of Animal Husbandry, Dairy Husbandry, Agricultural Chemistry, and Poultry Husbandry have each contributed a substantial part. The plans for the investigation in the beginning were inaugurated by a committee including F. B. Mumford, A. C. Ragsdale, E. A. Trowbridge, H. L. Kempster, A. G. Hogan. Samuel Brody served as Chairman of this committee and has been chiefly responsible for the execution of the plans, interpretation of results and the preparation of the publications resulting from this enterprise.

The investigation has been made possible through a grant by the Herman Frasch Foundation represented by Dr. R. W. Thatcher, who has given valuable advice from the beginning of the investigation.

F. B. Mumford, *Director Agricultural Experiment Station*

ACKNOWLEDGMENTS.—Much of the laborious work involved in measuring the metabolism and computing the results was done by the following undergraduate student assistants: Harold Kaufman, William Harrison and Virgil Herring.

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ABSTRACT.—Data are presented for energy metabolism, pulse rate, respiration rate, tidal air, and minute volume of pulmonary ventilation in cattle (and metabolism only of sheep) during lying and standing. The extra energy expended during standing as compared to lying under the same conditions is 9% for cattle and sheep populations, and 13% for an unusually heavy steer weighing over 2000 pounds. The above values do not include the energy expended for standing up from the lying position or lying down from the standing position. In the case of cows weighing about 350 kilos the combined energy of standing up and lying down is of the order of 2.5 kilo-calories per 100 kilos of live weight. The pulse rate during standing is about 2% above that during lying; the respiration rate during standing is about 11% *below* that during lying, while the tidal air is about 25% *above* that during lying. The minute volume of pulmonary ventilation during standing is about 10% above that during lying. The data which include about 2000 metabolism measurements on 34 animals (2 Guernsey cows, 13 Jersey cows, 11 Holstein cows, 1 Hereford cow, 1 Hereford steer, 2 Holstein calves, 2 Hereford calves, and 2 Dorset sheep) were analyzed statistically and the results indicate that the differences between most of the cardiorespiratory activities during standing and lying are outside of the limits of error of these measurements. The metabolism measurements were made on well-trained animals by the closed-circuit oxygen-consumption method, with the oxygen spirometer attached to the respiratory system of the animal by means of a rubber sleeve.

I. INTRODUCTION

The total energy expended by an animal is, of course, the sum of the energies expended for each of the constituent processes, as for example: basal metabolism ("the maintenance requirement of net energy" of the resting animal in the lying position); heat increment of standing; energy expense for getting up and lying down; energy expenses for other movements such as walking, running, etc.; energy expenses incident to the reproductive processes, including gestation and lactation. The preceding reports were

This bulletin contains parts of the data included in a dissertation by Warren C. Hall.

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concerned with the *basal* and *resting* metabolism in growing animals: this report is concerned with the energy increment of standing over lying, and the energy expenses of getting up and lying down. Incidentally, data are also presented for pulse rate, respiration rate, tidal air, and minute volume of pulmonary ventilation during standing and lying.

II. LITERATURE

It would not be profitable to go into the details of the literature on this problem, partly because the results are very conflicting, but mainly because such reviews have recently been published by Forbes, Kriss, and associates, and by Benedict and Ritzman. A few quotations from these authors on their results, and on their reviews will serve as a brief summary of the problem, and as an introduction to the literature.

The literature, up to 1927, as it relates to cattle is summarized by Forbes and associates as follows:

"The quantitative determination of the comparative energy metabolism during standing and lying, either by direct or indirect calorimetry, presents many difficulties, and the results obtained by different investigators vary widely, in accord with differences in fundamental conceptions involved, and under the influence of different conditions of experimentation, especially as to size of animal and plane of nutrition. Thus, Hagemann, in two experiments with steers, reported increases of 28 per cent and 30 per cent in the total heat production of standing as compared with lying. Dahm, working in Zuntz's laboratory, and by Zuntz's method, found an increase of only 8 per cent in the respiratory excretion of carbon dioxide by a young bull, when standing as compared with lying. Klein studied the respiratory exchange of a steer, during standing and lying, by means of a tracheal cannula, and found an increase of 20.7 per cent in the heat production of standing as compared with lying. Armsby and Fries calculated that in 37 published experiments with steers the increase in the directly determined heat production during standing as compared with lying varied from a minimum of 28.3 per cent to a maximum of 64.5 per cent, averaging 41.4 per cent; and they stated that a considerable number of other experiments, unpublished at that time, gave similar results. Armsby and Fries also reported results of six experiments with a steer in which the carbon dioxide and water vapor, as well as the heat produced, were determined separately for intervals of standing and lying, and showed increases in carbon dioxide elimination during standing as compared with lying varying from 20.4 to 35.1 per cent, with corresponding increases in heat production varying between 32.3 and 40.0 per cent.

"In all of the experiments referred to above the animals received feed.

"Recently Fries and Kriss pointed out certain instrumental errors and imperfections in the method used by Armsby and Fries to separate the directly measured heat production between intervals of standing and lying, especially in feeding periods, and by an indirect computation concluded that a fasting cow, weighing 400 kg., gave off while standing 26.3 Calories more per hour than while lying, this increase being equal to 9.8 per cent of the total heat producton.

"This figure was derived from observations on a single cow, but under conditions regarded at the time as unusually favorable. In the light of the present paper, however, which is based upon much more extensive data, and improved technic and computations, the problem presented by the instrumental lag, in the study by Fries and Kriss, appears not to have been successfully handled; and it seems imperative, therefore, to reconsider the whole subject."

Accordingly, Forbes and associates of the Pennsylvania Institute of Animal Nutrition then described a new method for measuring the heat increment of standing for overcoming the instrumental lag. They used for this purpose their customary respiration calorimeter on two steers. The new method consisted in sampling and analyzing for CO_2 the outgoing air at 15-minute intervals; plotting the results against time of standing or lying, and determining from the resulting curve the CO_2 production when the time curve reached a constant value of CO_2 production. The heat increment of standing was then computed from the resulting data. They summarize their findings by this new method as follows:

"The determination of the energy expenditure of cattle in the standing compared with the lying position, as a basis for the computation of the heat production to a standard day as to standing and lying, has been reconsidered in the light of new evidence of the extent of the experimental lag, affecting the measurements of CO_2 and heat in the use of the respiration calorimeter.

"A steer weighing 468 kgs. produced 10.8 liters more CO_2 per hour (2.31 liters per 100 kg. live weight) during standing than during lying. On the basis of a determined heat-CO_2 ratio of 6.55, the increase of heat production for standing as compared with lying was 70.7 Calories per head, or 15.1 Calories per 100 kg. live weight, per hour."

The following comment by Benedict and Ritzman (referring apparently to the older work at Pennsylvania) may be pertinent in this connection:

"The Pennsylvania investigators computed that the basal katabolism of their cattle per square meter of body surface, when the cattle were standing for the entire 24 hours, was 1,365 calories or 401 calories greater than when the animal was lying 24 hours. The increment due to the standing position is thus 41 per cent. The difference of approximately 41 per cent between the metabolism in the lying and standing positions is, in accordance with the latest published and corrected computations from the Pennsylvania institute, very large, for the more recent figures of Fries and Kriss would imply a difference of approximately 9 per cent. The standards of Fries and Kriss are derived from a series of experiments with one especially satisfactory animal, cow 874, which gave off 4.9162 calories per minute while standing and 4.4771 calories per minute while lying. The difference is 0.4391 calorie, which represents a decrease in the heat-production with a change in body position from standing to lying of about 9 per cent. Our own data regarding the difference in metabolism in the two positions are, as already stated (see p. 202), not extensive enough to permit of drawing definite conclusions, but on the basis of our results it seems highly probable that the correction factor might in general be nearer 20 than 9 per cent, with a probable influence of the length of time since food was withheld."

The findings of Benedict and Ritzman on the heat increment of standing in steers are summarized in their 1927 paper as follows (p. 238):

"A difference from 20 to 30 per cent between the metabolism in the lying and in the standing position was noted on days with feed. In some instances this difference diminished during fasting and practically disappeared after the second or third day, but in other instances it persisted even to the fourth or fifth day."

Ritzman and Benedict (1931, p. 17), on the basis of unpublished data, state that

"With dry cows the difference between standing and lying varies immensely (i. e., from 10 to 40 per cent) on feed days, but on fasting the difference diminished after several days to less than 10 per cent, and in some cases showed a tendency to disappear entirely."

They explain the influence of fasting on the heat increment of standing as follows:

"Since cattle tend to be somewhat restless in standing while being regularly fed, but become more or less inert and lifeless on prolonged fast, it seems reasonable to conclude that the excess in energy production in standing over lying is largely due to restlessness and apart from the requirements of supporting the body."

Ritzman and Benedict also quote from one of their preceding reports to the effect that "with steers a difference of about 17 per cent was found, although variations up to 30 per cent did occur also on days when the animals were regularly fed."

As regards the heat increment of standing in sheep, the following averages from Ritzman and Benedict (1931, p. 16) summarize their findings:

Body Wt. Kgs.	Hours Without Food	Percentage increase in Metabolism due to Standing
53.1	18	13
51.3	42	32
55.8	50	8
48.1	24	35
45.4	48	18
37.9	26-37	11
34.7	26-37	12

The two high values (32 and 35 per cent) were obtained on animals that were very active while standing.

The above quotations cover the literature on the energy increment of standing in cattle and sheep, and they indicate that our knowledge of this subject is rather incomplete.

We shall not attempt to review the literature on this problem as it relates to humans except to note that Benedict and Johnson report that the energy metabolism in young women standing quietly is 9 per cent above that for sitting quietly. This finding is of interest to us because we found a similar heat increment of standing for *well-trained* cattle. Mention need also be made that Benedict and Murschhouser found that the manner of standing exerts an influence on the metabolic rate in humans.

III. METHODS

With the exception of the measurements reported by Dahm and Klein from Zuntz' laboratory (cited by Forbes, *et al* above) the published reports on this problem were made with the aid of respiration chambers or respiration-calorimeter chambers. By this method, the investigator has no control over the animal. Besides, as pointed out by Fries and Kriss, and Forbes and Kriss, there is a serious instrumental lag inherent in this method so that the results of the standing and lying metabolism can not be differentiated clearly. This necessitates making complicated corrections, with possibility of introducing computational errors.

The mask method used by us, on the other hand, obviates these difficulties. The method is described in detail on pp. 6 to 14, Missouri Research Bulletin 143. There is practically no instrumental lag by this method and consequently no corrections need be made; the animals are under nearly full control of the investigator, as they are trained to stand up or to lie down at the wish of the operator; the periods are short so that usually the animals do not get tired or restless; the method is simple so that hundreds of records can be taken and the averages arrived at statistically.

Our measurements were taken regularly about three times a week for a period of six months (February to July inclusive, 1932). The measurements were made in the morning, before the morning feeding (about 8 hours following the preceding evening's feeding in dairy cows, and about 12 hours after the preceding feeding in the other animals). On one day the lying measurement (15-minute record) was made first, followed by the standing measurement (15-minute record): then on the following morning, the standing measurement was made first followed by the lying measurement.

The lying measurements were made in the habitual haunches position as described in the preceding reports of this series. The standing measurements were made while the animal's neck was supported by a customary cattle stanchion. This kept the animal in place in its habitual manner. There was nothing unusual, uncomfortable, or strained for the animal.

As the animal was rested before the beginning of a measurement, the given measurement therefore represents strictly the metabolism either of standing or of lying, and exclusive of the energy expense of the act of getting up and lying down.

The energy of getting up and lying down was measured separately as follows: First, a usual 15-minute lying record was obtained. While the animal's respiratory system continues to be connected to the oxygen spirometer, the animal rises to the standing position and then lies down again within the period of about a minute. The animal continues in the lying position for 15 or 30 minutes longer, and the graphic record continues to be made. The energy of the entire cycle—standing up and lying down—is then computed from these graphic records, as will be explained presently.

In order to determine the influence of fasting and feeding on the heat increment of standing, a number of animals were fasted for from 2 to 6 days, and the measurements carried out in the usual manner.

IV. RESULTS

Table 1 contains all our data in the form of breed or group averages for the entire six-month period of observation.

Table 2 contains the statistical constants of the measurements for the dairy cows only.

A. Energy Metabolism

Metabolism measurements were made to evaluate the heat increment of standing over lying when the animals were on their usual diets, and while fasting; also to evaluate the energy expense of standing up and lying down.

1. The Heat Increments of Standing over Lying. (a) *"Resting" Metabolism*:—As previously noted, resting metabolism refers to the heat production while the animal is resting and before the morning feeding, which is 8 to 12 hours after the preceding evening's feeding. The animals are thus not in post-absorptive condition, as it requires 48 to 72 hours of fasting in ruminants to reach this condition. We assume indeed that under normal conditions of feeding as practiced on commercial farms, the specific dynamic action is approximately constant from hour to hour during the entire 24 hours, and the "resting metabolism" thus includes this constant specific dynamic action of the diet.

From Table 1, it is seen that the average heat increment of standing over lying, under customary conditions of feeding (that is, under conditions of "resting" metabolism) is 8.4% for Guernsey cows, 9.1% for Jersey cows, 8.8% for Holstein cows, 7.2% for a Hereford cow, 13.1% for the heavy Hereford steer (weighing over 2000 pounds), 9.1% for the Holstein calves, 6.1% for the Hereford calves, and 8.9% for the Dorset sheep.

Table 1.—Group Averages

Breed, Group and Sex	No. Anim. in Group	Total No. Meas.	Ave. Age Anim. Mos.	Ave. Wt. Anim. Kgs.	Ave. Surface Area Sq. M.	Ave. Rest. Met. Cals./Day Lying (2)	Ave. Rest. Met. Cals./Day Standing	Ave. Heat Increments of Standing over Lying Cals./Day Total (1)	Per 100 kg.	Per Sq. M.	Per cent. (1)/(2)	Pulse Rate L.	Pulse Rate S.	Pulse Rate Diff. %	Resp. Rate L.	Resp. Rate S.	Tidal Air (S. T. P.) L. Liters	Tidal Air (S. T. P.) S. Liters	Ventil. Rate (S. T. P.) L. Liters/Minute	Ventil. Rate (S. T. P.) S. Liters/Minute
Guernsey Cows	2	115	36	410	4.36	10209	11068	859	2.10	197	8.41	69	71	2.9	30	29	3.1	3.7	93	107
Jersey Cows	13	701	31	403	4.32	9615	16496	881	2.19	204	9.16	74	75	1.3	30	27	2.7	3.4	82	92
Holstein Cows	11	607	30	514	4.94	12262	13342	1080	2.10	210	8.81	71	73	2.8	30	27	3.4	4.2	104	114
Hereford Cows	1	64	40	422	4.43	9300	9972	672	1.59	152	7.20	57	58	1.8	30	29	3.4	3.8	102	109
Hereford Steer	1	65	40	875	5.78	12864	14547	1683	2.13	291	13.10	59	61	3.4	29	27	4.2	5.0	121	135
Holstein Heifer Calves	2	199	4.7	164	2.61	5708	6226	518	3.15	198	9.07	72	75	4.2	35	31	1.7	2.0	59	61
Hereford Heifer Calves	2	187	4.5	144	2.43	4959	5262	303	2.10	125	6.11	76	78	2.6	34	32	1.4	1.5	46	49
Dorset Ewes	2	51	24	63	1.34	2059	2242	183	2.81	141	8.92	--	--	--	--	--	---	---	---	---

Table 2.—Statistical Constants for Weight, Daily Metabolism, Pulse Rate, Respiration Rate, Tidal Air, and Ventilation Rate During Standing and Lying for Jersey and Holstein Cows

	Position	Holsteins Mean	Holsteins Stand. Devia.	Holsteins Coeff. of Varia.	Holsteins Per cent S over L	Jerseys Mean	Jerseys Stand. Devia.	Jerseys Coeff. of Varia.	Jerseys Per cent S over L	Per cent Holsteins over Jerseys
Wt. Kgs.		516.1 ± 1.400	51.6	9.998	------	404.9 ± 1.069	40.2	9.930	------	27.50
Metab. Cals. Per Day	S	13205.2 ± 61.429	2256.8	17.09	8.96	10528.0 ± 61.502	2310.5	21.95	8.70	25.43
	L	12118.8 ± 58.342	2143.4	17.68	------	9685.3 ± 53.246	2000.4	20.65	------	25.13
Pulse Rate Per Min.	S	72.5 ± 0.199	6.64	9.16	2.84	75.3 ± 0.164	5.96	7.92	1.62	------
	L	70.5 ± 0.202	6.74	9.56	------	74.1 ± 0.169	6.19	8.35	------	------
Respirations Per Min.	S	26.05 ± 0.208	7.07	27.10	−12.99*	26.64 ± 0.194	7.10	26.64	−10.57	------
	L	29.94 ± 0.183	6.22	20.80	------	29.79 ± 0.179	6.55	21.99	------	------
Tidal Air Liters	S	4.23 ± 0.002	0.666	15.72	26.74	3.42 ± 0.002	0.568	16.59	27.86	23.60
	L	3.34 ± 0.002	0.556	16.66	------	2.68 ± 0.002	0.577	21.54	------	24.68
Ventil. Rate Lit./M.	S	109.30 ± 0.687	23.39	21.40	7.96	90.25 ± 0.680	22.45	24.87	11.86	21.10
	L	101.24 ± 0.660	22.46	22.18	------	80.68 ± 0.700	20.67	25.62	------	25.48

Average Age of Holsteins 30 Months—range 22-43 months.
Average Age of Jerseys 31 Months—range 23-45 months.
All measurements were made under customary dairy-barn conditions before the regular morning feeding, which is about 8 hours following the preceding evening feeding and while the animals were very quiet.

The probable error of the mean = $0.6745 \times \sigma/\sqrt{n}$

The standard deviation, σ, = $\sqrt{\Sigma fd^2/n}$

Coefficient of variation = $100\, x\sigma/m$

Percentage increment of standing (S) over lying (L) is the difference between S and L, divided by L, and multiplied by 100.

*In this and all succeeding tables, negative percentage difference indicates value lower for standing than for lying.

To indicate the nature of the distribution of individual measurements, the data for the dairy cows are shown in Fig. 1 in the form of a conventional frequency polygon representing the frequency distribution of variations of the percentage heat increments of standing over lying.

The chart shows that occasionally the standing metabolism was lower than the lying metabolism; but this must be due to some experimental error, or to the fact that the animal was uncomfortable in the lying position. The latter is particularly true of animals in advanced stages of gestation, or in their flush of lactation. The animals are then visibly uncomfortable while lying, trying to shift their position so as to avoid pressure on the abdomen, or on the mammary glands. They are correspondingly more comfortable in the standing position. The high heat increments of standing are due to similar causes, when the animals are more restless in the standing position (as when the body is too heavy for the legs as in case of steer 815) shifting their weight, etc., and correspondingly more quiet in the lying position.

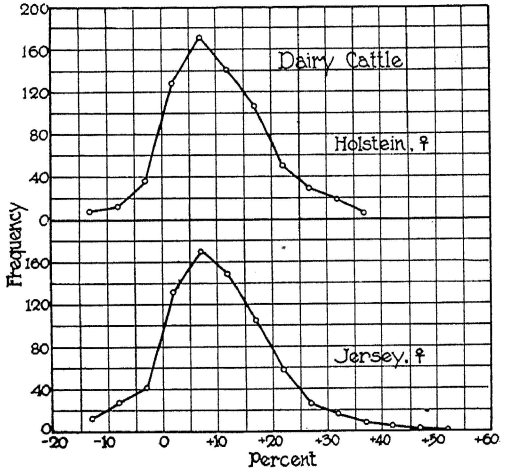

Fig. 1.—Frequency Distribution of Percentage Increase Standing Over Lying Energy Metabolism.

Fig. 1 is useful in indicating that it is dangerous to draw conclusions concerning the heat increment of standing from one or two measurements. Statistical studies of populations offer a more certain approach to results on energy metabolism, as they do in most other biological problems, especially problems involving physiological processes.

Table 3 (at the end of this bulletin) presents more detailed information about the individual dairy cows under observation. Here are given the calendar months, live weights, ages, the lying and standing metabolism in Calories per day, percentage differences between lying and standing, average deviations from the mean values for lying and standing, and time of calving.

(*b*) *Fasting Metabolism*:—We next consider the influence of fasting on the heat increment of standing. This is important in view of the fact that Benedict and Ritzman report that "Since cattle tend to be somewhat restless in standing while being regularly fed, but become more or less inert and lifeless on prolonged fast, it seems reasonable to conclude that the excess in energy production in standing over lying is largely due to restlessness and apart from the requirements of supporting the body."

Unfortunately, we could not fast our well-trained dairy cows because they were either gestating or lactating and mostly on Advanced Registry tests. We were therefore obliged to confine our fasting experiments to the four calves (205, 206, 669, 670) and to the unusually heavy steer 815. The steer's body, as noted, seemed to be too heavy for his legs, so that he swayed his body and shifted his weight while standing. The consequences are that his heat-increment values of standing are not very consistent, depending on the way he felt about it at the given time.

The results of a few fasting experiments are presented in Table 4, but they will be most easily understood by presenting them in graphic form. Accordingly, the results are thus presented in Figs. 2 and 3.

In Fig. 2 we have the absolute values (Calories per day) plotted against time of fasting for the animals. The circles represent standing metabolism while the stars represent lying metabolism. In several cases the curves include the period of refeeding, beginning with the vertical broken line indicated on the chart.

Fig. 3 represents the same measurements but in terms of percentages of the heat increments of standing over lying.

The distribution of the data points, especially as shown in Fig. 3, is admittedly very irregular. But still the data serve for indicating as to whether or not feeding or fasting influences the energy cost of standing over lying. The fluctuations in the values appear to be fortuitous rather than systematic, thus leading to the conclusion that feeding or fasting exerts but slight, if any, influence on the heat increment of standing.

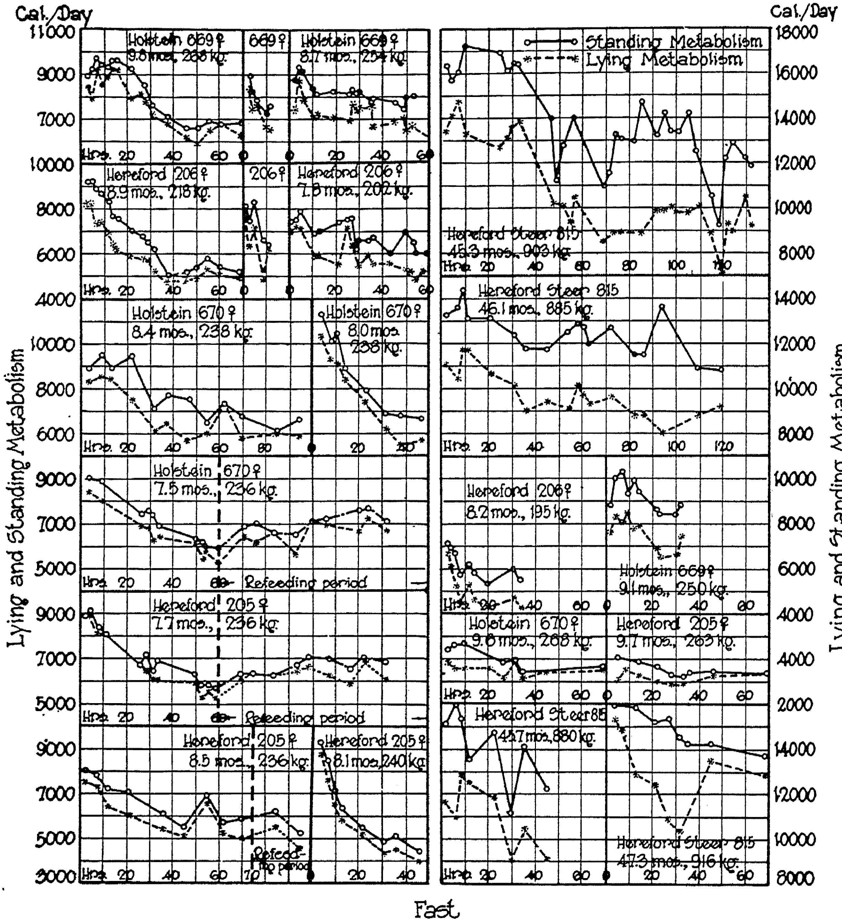

Fig. 2.—Comparison of Standing and Lying Energy Metabolism During Fasts.

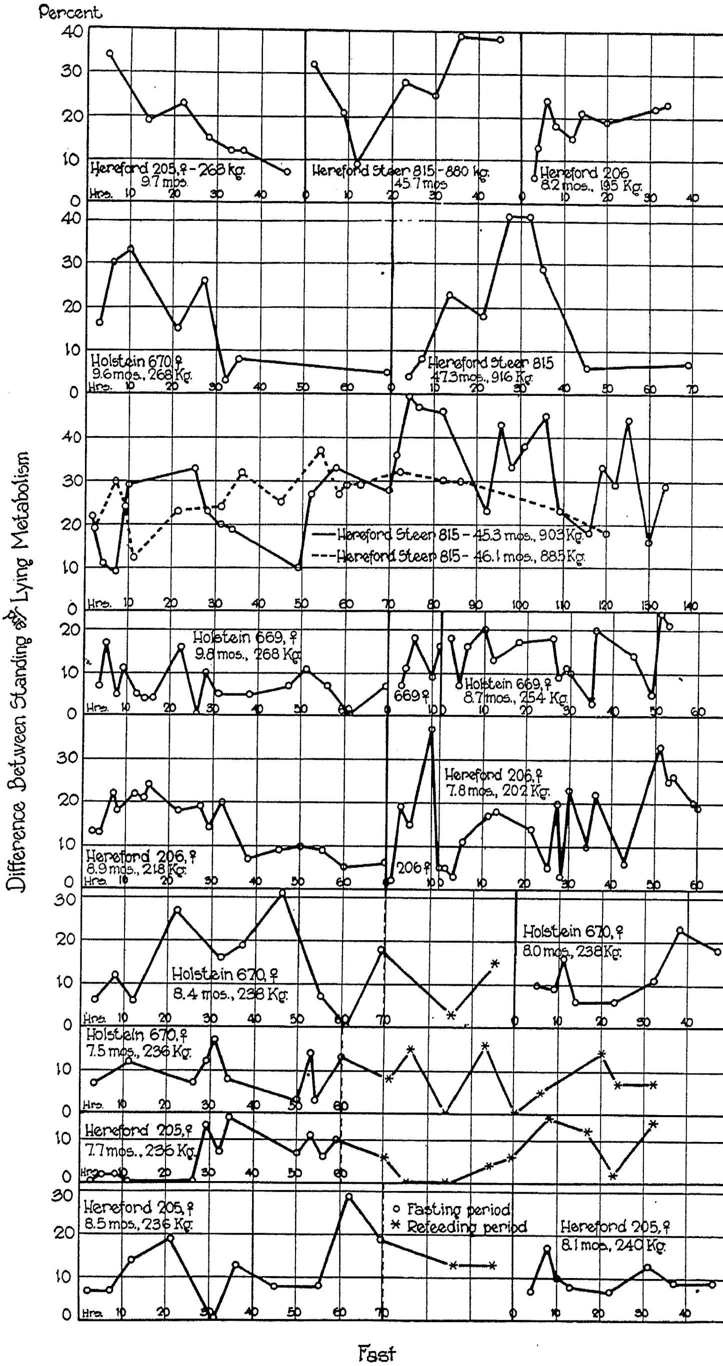

Fig. 3.—Percentage Differences of Standing and Lying Energy Metabolism During Fasts.

TABLE 4.—INFLUENCE OF FASTING ON ENERGY METABOLISM AND CARDIORESPIRATORY ACTIVITY DURING LYING AND STANDING

Time After Feeding Hrs.	Barn Temp. °C.	Met. Cals./Day Lying	Met. Cals./Day Stand.	Met. Cals./Day Diff. %	Pulse Rate L.	Pulse Rate S.	Pulse Rate Diff. %	Resp. Rate L.	Resp. Rate S.	Tidal Air (S. T. P.) L. Liters	Tidal Air (S. T. P.) S. Liters	Ventil. Rate (S. T. P.) L. Liters/Minute	Ventil. Rate (S. T. P.) S. Liters/Minute
Hereford Steer #815; Weight 885 kgs.; Age 46 Mos.; Date 9/24/32.													
1	18	11136	13286	19	66	68	3	27	25	4.8	5.4	130	136
6	20	10445	13594	30	66	66	0	30	26	4.2	5.1	126	133
8	20	11674	14438	24	62	64	3	29	26	4.2	5.3	121	139
11	20	11674	13056	12	64	66	3	24	22	3.6	5.0	86	111
20	15	10598	13056	23	58	62	7	21	20	4.2	4.9	89	97
30	19	10061	12442	24	60	64	7	28	22	3.9	4.5	109	99
35	18	8986	11827	32	56	60	7	24	20	3.6	4.8	86	96
44	18	9370	11750	25	46	50	9	21	20	4.2	4.8	88	96
53	22	9139	12518	37	48	50	4	22	22	3.8	5.3	84	116
57	22	10138	12902	27	48	52	8	23	23	3.5	5.3	81	121
58	22	9677	12672	31	46	48	4	23	24	3.7	4.3	86	104
61	22	9293	11981	29	50	50	0	25	22	3.7	3.7	93	82
71	20	9600	12672	32	52	54	4	24	22	3.7	3.5	64	78
83	22	8832	11520	30	48	50	4	23	25	3.2	4.4	74	110
86	18	8832	11520	30	46	46	0	21	19	4.9	4.7	102	89
92	20	8832	10906	23	48	50	4	18	15	3.9	5.4	70	81
Holstein Female #669; Weight 254 kgs.; Age 9 Mos.; Date 9/7/32.													
2	25	7392	8717	18	90	96	7	40	37	1.7	2.2	68	81
18	25	6950	8218	17	74	72	−3	33	42	1.8	2.2	59	92
23	26	6893	8141	18	80	84	5	36	34	1.7	2.0	61	68
25	26	7565	8314	9	82	86	5	38	29	2.2	2.3	84	67
26	26	7315	8141	11	80	88	10	32	29	1.9	2.2	61	64
28	26	7469	8218	10	74	78	5	31	33	2.0	2.3	62	76
32	23	7450	7699	3	84	82	−2	36	37	1.9	2.2	68	81
34	23	6605	7949	20	70	72	−3	29	30	1.7	2.0	49	60
42	25	6797	7718	14	66	64	−3	25	31	1.6	1.9	40	59
47	25	7046	7392	5	66	66	0	37	32	1.7	2.0	63	64
49	30	6374	7872	24	64	68	3	37	30	1.7	2.3	63	69
51	30	6624	8006	21	66	64	−3	35	28	1.7	2.5	67	70
Holstein Female #670; Weight 236 kgs.; Age 7 Mos.; Date 8/29/32.													
11	26	7949	8870	12	90	90	0	41	41	2.0	2.7	82	111
26	28	6912	7392	7	80	74	−8	43	43	1.6	1.3	69	56
29	28	6816	7642	12	80	72	−10	39	35	1.1	1.7	43	60
31	28	6240	7392	17	68	72	6	38	33	1.6	1.9	61	63
34	28	6413	6912	8	70	74	6	45	41	1.9	2.3	86	94
50	23	6125	6298	3	58	66	14	26	22	2.2	2.4	57	53
53	22	5414	6182	14	60	64	7	29	22	2.4	2.6	70	57
56	22	5837	6010	3	64	62	−3	30	29	2.2	2.6	66	75
59	22	5242	5914	13	62	64	3	25	27	2.1	2.5	53	68
Hereford Female #205; Weight 240 kgs.; Age 8 Mos.; Date 9/12/32.													
2	25	9696	10368	7	84	90	7	48	38	1.9	2.7	90	102
7	28	8064	9466	17	90	92	2	40	32	1.7	2.4	68	78
9	28	7488	8237	10	86	93	8	42	40	1.4	2.3	60	91
12	28	6835	7411	8	80	84	5	43	33	1.5	2.2	64	71
21	23	6163	6568	7	62	78	26	38	31	1.4	2.2	53	68
30	25	5261	5933	13	58	64	10	29	23	1.4	2.3	42	53
36	24	5549	6067	9	58	64	10	38	29	1.3	2.0	50	59
45	22	4934	5357	9	54	58	7	28	26	1.5	2.3	41	61
Hereford Female #206; Weight 203 kgs.; Age 8 Mos.; Date 9/7/32.													
4	25	7219	7469	3	100	110	10	52	45	1.4	1.7	73	77
5	25	7123	7891	11	92	98	7	45	47	1.9	2.2	86	103
12	22	5894	6893	17	90	86	−4	35	35	2.3	1.8	81	63
13	22	5894	6970	18	72	80	11	31	42	1.7	2.0	53	84
20	25	6451	7373	14	90	96	7	43	39	1.3	1.7	56	66
30	26	5295	6643	23	72	76	6	35	43	1.4	1.6	49	69
35	23	5914	6509	10	68	72	6	46	44	1.0	1.3	46	57
36	23	5491	6682	22	68	70	3	37	38	1.0	1.4	37	53
53	30	5242	6547	25	--	--	--	36	43	1.2	1.6	43	69
43	30	4819	6048	26	--	--	--	39	45	1.0	1.3	39	59
59	24	5050	6067	20	--	--	--	36	47	1.2	1.2	43	56
61	25	4954	5875	19	--	--	--	30	29	1.2	1.6	36	46

2. The Combined Energy Cost of Getting Up and Lying Down:—Having determined the energy increment of standing over lying, it then seemed logical to attempt to evaluate the energy of getting up and lying down. This was done as follows:

A graphic record was first made of the lying metabolism, as indicated in Fig. 4 by records I and II, and by lines A and B up to the point X. Without removing the mask, the animal then got up at point X, and lay down at point Y, and the making of the record continued. Line B was then drawn for record II, which is a continuation of, and is therefore parallel to, line A. The point P was then located on graphic record III, indicating the end of the lag period; that is, where the upper graphic record III becomes parallel to the lower graphic record I. Line C is drawn through this point P parallel to line B. The distance D between point P and line B then represents the extra oxygen used for getting up and lying down; from which the energy of getting up and lying down is computed in the usual manner.

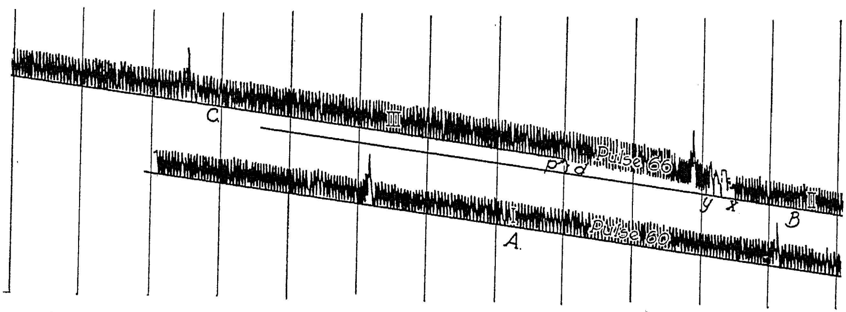

Fig. 4.—A Graphic Record and Measurements Used in Determining the Increase in Oxygen Consumption Due to Combined Acts of Getting Up and Lying Down. Record I is graphic record above line A. Record II is graphic record above line B. Record III is graphic record above line C.

The results obtained on two cows are shown in Table 5. The combined energy cost of getting up and lying down is seen to be, for these animals (age 2½ years, weight 330 to 390 kgs.) from 8 to 9 Calories; or 2.5 Calories per 100 kilograms of live weight.

For purposes of comparison, Table 5 also contains values for resting metabolism (Calories per minute) of the animals at the various trials and the lag period (minutes required to reach the original metabolic rate).

The above values represent the combined energy of getting up and lying down. We have also attempted to determine *separately* the energy expense of getting up and lying down. However, we decided not to publish the results as, separately, they come dangerously close to being within the limits of error of measuring metabolism in cattle; since for this purpose the reference base, corresponding to graphic record I in Fig. 4, has to be established at a different time than when the energy of lying down is measured, and metabolism in cattle made at different times can not be relied upon with certainty to agree to within 5%.

In order to determine what agreement might be expected for measurements made on the same animal on successive days under comparable conditions, the resting (lying) metabolism data of cows 428 to 829 given in Table 5 were analyzed statistically, with the results given in Table 6. It is there seen that the coefficients

TABLE 5.—COMBINED ENERGY EXPENSE OF GETTING UP AND LYING DOWN

	Guernsey Cow 428 Age 2.5 years, Wt. 330 kgs.				Jersey Cow 829 Age 2.5 years, Wt. 390 kgs.			
	Energy, getting up and lying down		Resting Metab. Cal/Min.	Lag Period Min.	Energy, getting up and lying down		Resting Metab. Cal/Min.	Lag Period Min.
Expt. No.	Total Cals.	Cal. per 100 kg.			Total Cals.	Cal. per 100 kg.		
1	7.8	2.4	6.1	5	8.5	2.2	8.5	7
2	8.6	2.6	6.0	7	14.9	3.8	8.5	7
3	12.5	3.8	5.9	9	10.5	2.7	8.3	8
4	8.3	2.5	6.3	6	13.0	3.3	8.7	6
5	8.5	2.6	7.0	6	9.6	2.5	9.4	5
6	7.2	2.2	6.1	9	11.5	3.0	8.7	5
7	8.8	2.7	6.3	9	7.2	1.8	8.9	6
8	4.3	1.3	5.6	6	7.0	2.8	9.0	5
9	4.3	1.3	6.3	5	5.6	1.4	9.2	8
10	10.4	3.2	6.1	6	12.6	3.2	8.7	7
11	5.9	1.8	5.9	6	8.8	2.3	8.8	6
12	11.0	3.3	5.5	10	7.8	2.0	8.6	5
13	10.1	3.1	5.7	7	7.4	1.8	8.2	7
14	7.2	2.2	6.1	5	8.8	2.3	8.9	6
15	7.8	2.4	6.2	5	10.6	2.7	9.5	6
16	4.3	1.3	6.1	3	8.1	2.1	9.0	7
17	5.1	1.5	6.1	7	8.2	2.1	9.2	3
18	13.4	4.1	6.1	6	10.1	2.6	9.4	6
19	7.4	2.2	6.4	5	7.4	1.8	9.3	5
20	11.0	3.3	6.4	5	8.7	2.3	9.8	6
21	8.6	2.6	6.1	6	5.3	1.4	9.7	6
22	5.8	1.9	6.5	4	6.2	1.6	8.6	9
23	5.6	1.7	5.6	5	7.3	1.8	8.5	8
24	7.0	2.1	5.9	5	7.2	1.8	9.4	7
25	7.5	2.3	5.9	5	8.5	2.2	9.4	5
26	6.1	1.8	5.9	4	7.8	2.0	8.7	6
27	6.7	2.0	5.9	5	10.6	2.7	9.5	8
28	5.9	1.8	6.4	5	4.5	1.2	9.6	4
29	7.4	2.2	6.2	6	9.6	2.5	9.7	3
Ave.	7.8	2.4	6.1	6	8.8	2.6	9.0	6

TABLE 6.—STATISTICAL CONSTANTS OF COWS 829 AND 428 FOR AUGUST AND SEPTEMBER

	COW 829						COW 428					
	Mean		Stand. Dev.		Coeff. of Varia.		Mean		Stand. Dev.		Coeff. of Varia.	
	Aug.	Sept.	Aug.	Sept.	Aug.	Sept.	Aug.	Sept.	Aug.	Sept.	Aug.	Sept.
Metabolism Cals./Day	12810	12582	699	335	5.5	2.7	9684	8650	597	312	6.2	3.6
Pulse Rate Per Min.	78.3	74.3	3.4	4.6	4.4	6.1	62.7	61.0	2.3	4.2	3.7	6.8
Respirations Per Min.	43.8	34.9	7.0	4.1	15.9	11.7	26.6	24.6	2.5	4.4	9.2	17.9
Tidal Air in cc.	2870	3115	55	99	1.9	3.2	3230	3540	479	89	14.8	2.5
Pulmonary Ventilation Liters /Min.	125	108	15.2	5.6	12.6	5.2	85	86	6.8	9.5	8.0	11.0

of variation of the metabolism data of cow 829, varied for the two sub periods from 5.5 in August to 2.7 in September. In the case of cow 428, the coefficient of variation was 6.2 in August and 3.6 in September. These two animals, it must be noted, are our best experimental subjects, and the greatest possible care was taken in securing these measurements. Table 2 shows that the coefficient of variation for the resting metabolism of the entire cow population for the entire 6-months period (including different stages of gestation, lactation, environmental temperature, and diet) is about 17.1 for the Holstein cattle and about 21 for the Jersey cattle.

It is interesting to note that the variability of the various kinds of measurements shown in Table 2 fall into two classes. We have on one hand body weight and pulse rate with a variation of the order of 8 to 10%. On the other hand, we have oxygen consumption ("metabolism"), minute volume of pulmonary ventilation, tidal air, and respiration rate with a variability of 20 to 25%. The excess variability in the second class of measurements presumably represents variability due to environmental conditions. Dairymen are familiar with similar differences in variability as regards quantity of milk secretion, and percentage of fat in milk of cow populations. The variability of milk secretion (which is sensitive to environmental conditions) is between 20 and 25%; while of the percentage of fat in milk (not easily affected by environmental conditions), it is of the order of 8 to 10%. The situation as regards the variability in Table 6 differs from that in Table 2 in that in Table 6 the measurements were made on the same animal, and thus individual variability is entirely eliminated; and that the measurements were confined to relatively very short periods (12 days), thus eliminating largely variations due to environmental changes.

B. A Comparison of Cardiorespiratory Activities During Standing and Lying

There is, of course an intimate relation between respiration, circulation, and oxygen consumption (energy metabolism). The respiratory system takes in the oxygen, and the circulatory system transports it to the tissues for the needed energy production. It would then be reasonable to assume that on changing from the lying to the standing position, there would be parallel percentage increases in the time volumes of oxygen consumption, blood flow, and pulmonary ventilation. Boothby has indeed found such parallelism in men doing moderate, progressively increasing amounts of work. We were not in a position to measure the time rate of blood flow, but we have measured the pulse rate, which ordinarily coincides with the heart rate; and the graphic method of measuring oxygen consumption gave us, incidentally, records of the respiration rates, tidal air (amounts of air breathed out in normal expiration) and, therefrom, the time rate of pulmonary ventilation.

These results are presented in Tables 1 and 2 in summary form, and very briefly commented upon here.

1. **Pulse Rate:**—Tables 1 and 2 show that in dairy cows the average pulse rate is between 69 and 74 beats per minute during lying, and 71 to 75 during standing; in the beef cow, the average pulse rate during lying is 57, and during standing 58; in the beef steer, the increase is from 59 to 61. The percentage increase in pulse rate during standing is thus about one-fourth of the increase above lying in the case of metabolism. The pulse rate in the calves is somewhat higher than in the older animals.

In adult humans, the average basal pulse rate is 62 for males and 69 for females.

2. **Respiration Rate.**—Tables 1 and 2 show that the average respiration rates in dairy cows are about 30 during lying, and about 27 during standing, or an average **decrease** of about 10 per cent. (The respiration rate in adult humans is 15 to 20, twice as great in children, and 50 to 70 in new-born infants.) Table 3 shows, as might be expected, that the respiration rate tends to increase with increasing temperature.

3. **Tidal Air.**—The *decrease* in respiration rate during standing as compared to lying, is compensated by a corresponding *increase* in tidal air (volume of air breathed out, or taken in during each respiration). The tidal air is presented in terms of liters, corrected to standard temperature and pressure. The tidal air in dairy cows during lying is seen to be about 3.1 liters, and during standing, 3.8 liters. The tidal air of the large steer, 815, is 4.2 liters during lying, and 4.9 liters during standing. In the calves, it is 1.2 to 1.4 liters lying, and 1.3 to 1.7 standing.

In humans the average tidal air is said to be only 500 cc.

4. **Ventilation Rate.**—Tables 1 and 2 show that the volume of air expired (or inspired) per minute by dairy cows is about 91 liters while lying, and about 100 liters while standing. The increase for standing over lying is thus about 10%, which is of the same order of increase as for oxygen consumption. Table 3 shows, that the ventilation rate tends to increase with the approach of hot weather, as also the percentage difference between lying and standing.

The calves show but a very slight increase in ventilation rate during standing; this may indicate a more efficient cardiorespiratory apparatus in the young animals.

The above data refer to measurements made in the morning before the morning feeding, which is about 12 hours following the preceding feeding in non-lactating animals, and 8 hours following feeding in lactating animals. All measurements were made with the animals connected to the respiration apparatus.

On fasting, the cardiorespiratory activities naturally decrease as shown in Table 4. The greatest percentage decrease during fast occurs in the ventilation rate followed, in order, by respiration rate, pulse rate, oxygen consumption, and last by tidal air. Thus in a typical 72-hour fast on steer 815, the decreases from the beginning to the end of fast were, ventilation rate, 36% for standing and 39% for lying; respiration rate, 38% for standing and 35% for lying; pulse rate, 23% for standing and 26% for lying; oxygen consumption 21% for standing and 24% for lying; tidal air, 6% for standing and 15% for lying.

SUMMARY

Data are presented showing that the energy increments of standing over lying are, in round numbers, 9% for dairy cattle and sheep, 7% for a Hereford cow; 13% for a very heavy fat Hereford steer.

The above averages are based on a total of about 2000 measurements made on 34 animals (2 Guernsey cows, 13 Jersey cows, 11 Holstein cows, 1 Hereford cow, 1 Hereford steer, 2 Holstein calves, 2 Hereford calves, 2 Dorset ewes). The group averages for weight, age, metabolism, pulse rate, respiration rate, tidal air, and minute volume of pulmonary ventilation are given in Table 1. Statistical constants of these measurements for the Holstein and Jersey cattle are given in Tables 2 and 6.

The percentage increase in pulse rate on standing over lying is ⅓ to ¼ of the percentage increase in oxygen consumption. The respiration rate is *decreased* by 10 to 12% on standing as compared to lying; but this decrease in respiration rate is compensated by a proportional *increase* in the tidal air during standing, so that the increase in the volume of air exhaled per minute (minute volume of pulmonary ventilation) is of the same order as the increase in oxygen consumption.

The pulse rate in quietly resting cattle 8 to 14 hours after feeding is about 69 beats per minute; that is, it is of the same order as in

humans. The respiration rate in cattle under the given conditions of food supply, about 29 per minute, is much higher than in humans. The tidal air in cattle varies largely with live weight, but it is of the order of 3000 c.c. in medium sized cows, 4500 c.c., in a very heavy steer (weighing over 2000 pounds), and 1400 to 2000 cc. in 4-months old calves (as compared to about 500 cc. in humans). The minute volume of pulmonary ventilation varies directly with the oxygen consumption; it is from 82 to 92 liters per minute in Jersey cows, 93 to 107 liters per minute in Guernsey cows, 104 to 114 liters per minute in Holstein cows, 121 to 135 liters per minute in the large steer, and 46 to 61 liters per minute in 4-months old calves.

During fasting, all the cardiorespiratory activities decline. Thus in a 72-hour fast in the steer, the oxygen consumption declined by about 22%, the pulse rate by 24%, the respiration rate declined by 36%, the tidal air by 10%, and minute volume of ventilation by 37%. The percentage decline during fasting was least for the tidal air and greatest for respiration and ventilation rates. These, to our knowledge, are the first published data on the tidal air and minute volume of ventilation in farm animals.

The combined energy cost of getting up and lying down for medium sized cattle is of the order of 8 Calories (kilo calories) per animal, or 2.5 Calories per 100 kilos live weight. It appears that most of this energy is expended for getting up, and that little of it is expended for lying down.

The statistical analyses of the dairy cattle populations (Table 2) for the entire 6-month period of observation (including extreme range of temperatures and all stages of lactation and gestation) show that the body weight and pulse rate have a coefficient of variation which is of the same order (about 10%); while oxygen consumption (metabolism), ventilation rate, tidal air, and respiration rate also have a coefficient of variation of the same order (about 20%), but which is about double that for body weight and pulse rate. If, however, as shown in Table 6, the coefficients of variation are computed for short intervals (11 to 12 day periods) on the same individual, then the coefficients of variation are reduced to from 1/4 to 1/7 of that found for the entire population. Thus, the coefficient of variation for resting metabolism of the entire Jersey cow population for the entire 6-month interval is seen to be 22 (Table 2); while of the individual Jersey cow 829, it is only 5.5 for the 12 measurements in August, and 2.7 for the 12 measurements in September.

BIBLIOGRAPHY

Armsby, H. P., and Fries, J. A., *Influence of Standing or Lying Upon the Metabolism of Cattle.* Amer. J. Physiol., 1913, 31, 245.

Benedict, F. G., and Ritzman, E. G., *The Metabolism of the Fasting Steer.* Carnegie Institution of Washington, Public. 377, 1927; Über die den Energieumsatz bei schafen beeinflussenden Faktoren. Arch. Tierernahrung u. Tierzucht, Abt. B., 1931, I, 1.

Benedict, E. G., and Johnson, A., *The Energy Loss of Young Women During the Muscular Activity of Light Household Work.* Am. Philosophical Soc., 1919, lviii, 89.

Boothby, W. M., *A Determination of the Circulation Rate in Man at Rest and at Work.* Am. J. Physiol., 1915, 57, 383.

Dahm, K., *Die Bedeutung des mechanischen teils der verdauungsarbeit für den Stoffwechsel des Rindes.* Bioc. Z., 1910, 28, 457.

Forbes, E. B., Kriss, M., Braman, W. W., *et al. The Influence of Position of Cattle, as to Standing and Lying, on the Rate of Metabolism.* J. Agric. Res., 1927, 35, 947.

Fries, J. A., and Kriss, M., *Metabolism of Cattle During Standing and Lying.* Am. J. Physiol., 1924, lxxi, 60.

Hagemann, O., *Das Respirations-Calorimeter in Bonn und Einige Untersuchungen mit demselben bei zwei Rindern und einem Pferde.* Landw. Jahrb., 1911, 41 (Ergänzbd. 1), 61, 128.

Heide, R. von der Klein, and Zunt, N., *Respirations und Stoffwechselversuche am Rinde über den Nährwert der Kartoffelschlempe und ihrer ausgangsmaterialien.* Landw. Jahrb., 1913, 44, 765.

Pearce, R. G., *The Cardiorespiratory Mechanism in Health and Disease.* Arch. Int. Med., 1921, 27, 139.

Read, J. M., *Correlation of Basal Metabolic Rate With Pulse Rate and Pulse Pressure.* J. Am. Med. Assn., 1922, 78, 1887.

Ritzman, E. G, and Benedict, F. G., *The Energy Metabolism of Sheep* Univ. New Hampshire, Agric Expt. Sta, Tech. Bull. 43, 1930; *The Heat Production of Sheep Under Varying Conditions.* Id., Tech. Bull. 45, 1931.

Suttliff, W. D., and Holt, E., *The Age Curve of Pulse Rate Under Basal Conditions.* Arch. Int. Med., 1925, 35, 224.

Table 3.—Monthly Averages of "Resting" Energy Metabolism During Standing and Lying in Individual Cattle. Data on the Pulse Rate, Respiration Rate, Tidal Air, and Minute Volume of Pulmonary Ventilation.

		"Resting" Met. Cal./day					Pulse Rate			Resp. Rate			Tidal Air (Lit., S. T. P.)			Ventilation Rate (Liters, S. T. P.)		
Month	Live Wt. Kgs.	Lying	Ave. Dev. %	Stand.	Ave. Dev. %	Diff. %	L.	S.	Diff. %	L.	S.	Diff. %	L.	S.	Diff. %	L.	S.	Diff. %
Guernsey Female #427, Medium Milker; Average Age 43 Months.																		
Feb.	476	12240	6	13603	5	11	72	74	3	27	19	−10	3.4	4.2	24	102	114	12
Mar.*	480	10799	7	11673	5	8	67	69	3	28	23	−18	3.1	3.9	26	87	90	4
Apr.	430	11342	8	12268	9	8	63	66	5	26	27	4	3.8	4.3	15	98	117	19
May	432	11809	5	12626	5	7	63	64	2	27	29	7	3.7	4.3	18	99	126	27
June	434	11562	4	12545	4	9	57	59	4	30	34	13	3.4	3.9	15	101	131	30
July	426	11965	8	12822	8	7	57	60	5	33	39	18	3.8	4.1	19	125	161	29
Guernsey Female #428, Medium Milker; Average Age 29 Months																		
Feb.	384	8223	6	8777	4	7	77	80	4	36	30	−17	2.5	3.2	25	91	95	4
Mar.	406	8420	6	9155	5	9	76	79	4	32	26	−19	2.5	3.3	31	80	85	6
Apr.*	414	7925	11	8686	8	10	80	84	5	31	26	−16	2.4	3.1	28	75	80	7
May	358	9878	7	10732	6	9	80	83	4	26	23	−12	3.0	3.7	24	78	85	9
June	340	8842	6	9888	8	12	67	72	8	29	29	0	3.0	3.5	17	86	100	17
July	338	9499	4	10043	4	6	64	65	2	28	33	18	3.2	3.2	0	90	104	16
Holstein Female #591, Good Milker; Average Age 39 Months.																		
Feb.	509	14062	10	16082	7	14												
Mar.	527	15696	6	17193	4	10	78	82	5	30	28	−6	4.3	5.0	17	126	138	10
Apr.	550	16457	4	17579	8	7	77	80	4	29	27	−6	4.4	5.1	17	126	139	10
May	540	15206	4	16569	4	9	78	79	2	32	27	−16	4.4	4.9	11	141	132	−7
June	554	15067	5	15936	6	6	76	80	5	37	34	−9	4.1	4.3	6	152	146	−4
July*	545	15094	8	16083	5	7	77	80	5	40	39	−3	4.0	4.6	15	161	179	11
Holstein Female #592, Medium Milker; Average Age 36 Months.																		
Feb.	494	14930	9	15606	5	5	64	66	3	30	28	−5	3.4	5.8	68	102	120	19
Mar.	504	14967	6	16140	4	8	66	69	6	27	26	−4	3.8	4.4	17	103	116	12
Apr.	510	13295	5	14601	5	10	63	68	9	27	25	−6	3.7	4.3	18	99	110	11
May	499	13810	3	14344	3	4	62	64	2	29	28	−3	3.6	4.1	12	106	116	9
June	544	13351	8	13960	3	5	61	63	5	37	36	−4	3.3	4.0	19	124	142	14
July	508	14065	4	14690	5	4	65	65	−.8	42	43	2	3.1	3.6	15	131	154	18

*Calved

Holstein Female #593, Good Milker; Average Age 33 Months.																		
Feb.	532	13517	6	15347	11	14	70	72	3	34	28	−18	4.0	5.0	25	137	141	3
Mar.	533	14923	5	16632	8	12	69	71	3	29	25	−14	3.9	4.8	24	113	120	7
Apr.	543	15295	6	16209	6	6	71	73	3	29	25	−14	4.1	5.5	34	120	139	16
May	532	15331	3	16507	3	8	68	69	2	28	27	−4	4.0	4.9	21	113	132	17
June	515	13137	4	14798	4	13	63	65	3	35	34	−3	3.8	4.6	21	133	158	19
July	523	12945	3	14536	3	12	--	--	-	--	--	-	---	---	--	---	---	--
Holstein Female #594, Good Milker; Average Age 31 Months.																		
Feb.	556	13413	7	14153	6	6	68	69	2	29	24	−17	3.2	4.2	31	92	101	−10
Mar.*	542	14432	3	16287	6	13	74	76	3	29	24	−19	2.8	3.9	39	82	93	14
Apr.	493	15025	5	16491	6	10	77	80	4	31	25	−18	3.3	4.5	36	103	114	11
May	490	14874	2	15961	2	7	69	70	3	31	28	−10	3.6	4.5	25	112	125	11
June	494	15172	6	16292	7	7	64	65	2	40	40	0	3.2	3.8	19	129	151	16
July	479	13010	3	14408	5	11	55	57	4	44	42	−5	2.8	3.3	18	122	140	15
Holstein Female #597, Good Milker; Average Age 30 Months.																		
Feb.	464	9379	5	10133	4	8	76	78	2	25	20	−20	3.1	4.2	35	76	84	9
Mar.	484	9744	7	10912	5	12	74	74	0	24	18	−25	3.3	4.5	36	79	83	5
Apr.	508	10958	5	11660	7	6	77	79	2	27	21	−25	3.3	4.5	36	90	94	4
May	528	11684	4	12337	4	6	81	81	0	27	24	−11	3.3	3.8	15	89	92	3
June*	405	11770	2	12730	3	8	79	79	0	36	39	8	3.0	3.3	10	107	128	20
July	379	10929	4	12120	6	11	71	73	2	30	29	−3	3.5	4.2	20	104	121	16
Holstein Female #599, Good Milker; Average Age 29 Months.																		
Feb.	503	9609	8	10910	5	14	71	72	1	25	24	−4	3.3	4.0	21	82	97	17
Mar.	527	10786	8	11545	8	7	72	73	1	27	23	−15	3.1	4.5	45	82	104	26
Apr.	552	11754	5	12672	6	8	76	72	3	26	22	−15	3.4	4.1	21	89	90	2
May	575	12569	7	13256	6	6	80	82	3	26	25	−4	3.3	4.0	21	87	99	14
June*	465	11175	9	12178	10	9	76	77	1	32	28	−13	2.8	3.4	21	89	96	7
July	437	10974	8	12437	6	13	64	65	2	34	32	−6	3.0	3.6	20	102	114	12
Holstein Female #600, Medium Milker; Average Age 28 Months.																		
Feb.	474	9634	5	10569	5	10	69	71	3	32	26	−19	3.0	3.5	17	95	91	−5
Mar.	497	10270	8	11565	8	13	71	74	4	31	26	−16	2.8	3.7	32	87	96	10
Apr.	520	10335	6	11659	7	13	72	77	7	32	26	−19	3.0	4.0	33	96	105	10
May	537	11821	3	12918	4	9	79	80	1	33	30	−9	3.0	3.6	20	99	107	8
June*	431	12384	2	13052	5	5	82	82	0	32	27	−16	2.8	3.7	32	90	100	10
July	396	11230	6	12749	4	14	71	72	1	33	33	0	3.4	3.9	15	111	128	15

*Calved.

TABLE 3.—MONTHLY AVERAGES OF "RESTING" ENERGY METABOLISM DURING STANDING AND LYING IN INDIVIDUAL CATTLE. DATA ON THE PULSE RATE, RESPIRATION RATE, TIDAL AIR, AND MINUTE VOLUME OF PULMONARY VENTILATION. (Continued)

		"Resting" Met. Cal./day					Pulse Rate			Resp. Rate			Tidal Air (Lit., S. T. P.)			Ventilation Rate (Liters, S. T. P.)		
Month	Live Wt. Kgs.	Lying	Ave. Dev. %	Stand.	Ave. Dev. %	Diff. %	L.	S.	Diff. %	L.	S.	Diff. %	L.	S.	Diff. %	L.	S.	Diff. %
				Holstein Female #601, Medium Milker; Average Age 28 Months.														
Feb.	504	8515	4	10176	6	20	63	66	5	24	22	−8	3.3	4.3	30	79	94	19
Mar.	522	10829	9	12196	12	13	67	69	3	28	23	−18	3.3	4.1	24	93	95	3
Apr.	551	11767	5	13055	4	11	66	68	3	32	27	−16	3.1	3.7	19	89	101	2
May	574	12488	5	13290	5	6	70	72	3	32	34	6	3.1	3.7	19	99	124	25
June	588	13213	6	13772	6	4	70	72	3	36	37	3	2.9	3.5	21	106	129	22
July*	490	12189	9	12699	8	4	68	69	2	35	33	−6	2.9	3.1	7	102	104	2
				Holstein Female #602, Medium Milker; Average Age 26 Months.														
Feb.	493	9370	5	10387	5	11	65	69	6	27	19	−30	3.0	4.5	50	81	86	6
Mar.	523	10226	4	10897	3	7	69	70	1	28	20	−29	3.2	4.7	47	89	94	5
Apr.	550	10471	6	12119	8	16	71	72	1	31	22	−29	3.2	4.5	41	100	100	0
May	571	11100	5	12270	5	11	71	73	3	31	24	−23	3.0	4.4	47	94	105	12
June	586	12046	5	12806	5	6	72	74	3	38	25	−34	3.1	4.4	42	117	111	−6
July*	588	12714	3	13798	4	9	76	79	4	38	28	−26	2.9	4.3	48	110	120	9
				Holstein Female #603, Dry; Average Age 25 Months.														
Feb.	466	9845	5	10834	5	10	65	67	3	25	24	−3	3.5	4.3	23	88	100	16
Mar.	499	11046	7	12509	8	13	67	69	3	25	20	−20	3.5	4.3	23	88	85	−4
Apr.	529	11459	5	12502	6	9	69	71	3	28	26	−7	3.3	3.9	18	92	102	10
May	560	12518	5	13008	6	4	73	74	1	32	27	−16	3.4	3.9	15	107	107	0
June	575	12758	7	13529	6	6	70	71	1	33	28	−15	3.3	3.8	15	110	105	−4
July	598	13424	5	14476	3	8	80	81	1	36	37	3	2.9	3.5	21	106	129	22
				Holstein Female #604, Dry; Average Age 24 Months.														
Feb.	447	9162	4	9953	5	9	67	71	6	20	18	−9	4.0	5.0	25	81	91	13
Mar.	459	9544	7	9987	5	5	67	69	3	19	16	−19	4.0	5.3	33	78	83	7
Apr.	478	9225	8	10137	9	10	64	67	4	22	19	−13	3.8	5.1	34	85	98	16
May	504	9851	5	10912	4	11	65	68	5	26	23	−12	3.8	4.5	18	96	101	5
June	524	10143	5	11059	5	9	67	70	4	27	23	−15	3.5	4.5	29	97	106	10
July	538	11309	6	12639	6	12	68	71	5	32	28	−14	3.8	4.6	21	123	128	84

Jersey Female #819, Good Milker; Average Age 42 Months.

Feb.	472	11684	8	13226	12	13	76	75	−1	30	26	−14	3.4	4.1	21	101	104	4
Mar.*	482	11844	9	13200	11	11	80	82	2	32	26	−18	2.9	4.0	38	92	103	12
Apr.	436	12073	11	13901	10	15	72	74	3	24	23	−5	3.8	4.8	26	93	112	20
May	421	11981	7	14011	7	17	71	72	2	25	24	−6	3.7	4.4	19	92	103	12
June	400	11737	5	13358	7	14	64	66	3	30	31	5	3.3	4.1	24	98	128	31
July	405	11589	4	13452	5	16	59	61	3	40	42	3	2.9	3.7	28	117	156	33

Jersey Female #821, Medium Milker; Average Age 40 Months.

Feb.	465	12012	10	12787	14	7	77	78	1	46	34	−27	2.7	3.6	33	125	121	−3
Mar.	472	13584	5	15254	5	12	77	79	2	40	31	−22	2.5	3.7	48	101	116	15
Apr.	478	12595	5	13962	9	11	78	81	4	42	32	−23	2.4	3.4	42	102	108	6
May	458	11438	5	13910	5	22	73	75	3	32	25	−23	2.5	3.5	40	80	88	10
June*	475	11443	8	13171	9	15	75	77	3	36	33	−9	2.3	3.2	39	83	107	29
July	419	10913	6	12219	5	12	67	68	2	37	40	9	2.4	2.7	13	89	108	22

Jersey Female #882, Poor Milker; Average Age 36 Months.

Feb.	398	11251	6	12275	6	9	71	74	4	36	30	−17	2.9	3.9	34	105	117	11
Mar.	406	10665	4	11620	4	9	73	76	4	30	22	−27	3.3	4.4	33	99	96	−3
Apr.	423	8744	10	9901	8	13	73	73	0	27	21	−21	2.9	4.0	38	77	83	8
May	429	8971	10	9768	8	9	74	74	0	26	25	−4	3.0	3.8	27	79	95	20
June	425	7515	10	8326	7	11	64	64	0	28	25	−9	2.8	3.6	29	79	91	15
July	433	9436	5	10263	7	9	70	70	0	33	29	−10	3.0	3.7	23	99	107	9

Jersey Female #823, Medium Milker; Average Age 35 Months.

Feb.	365	12633	12	13517	7	7	79	82	4	37	30	−19	3.0	4.0	33	111	120	9
Mar.	372	13094	5	13657	5	4	76	79	4	37	27	−27	2.9	3.8	31	108	102	−6
Apr.	383	11750	7	12256	8	4	73	75	3	36	29	−14	3.1	4.3	39	112	125	12
May	384	11170	6	12338	6	10	72	73	1	34	29	−15	2.7	4.1	41	93	119	27
June	392	10949	7	11465	8	5	68	70	3	37	35	−7	2.7	3.4	26	101	118	18
July	394	10337	7	11236	5	9	66	68	3	36	40	11	2.4	2.7	13	87	108	24

Jersey Female #827, Good Milker; Average Age 30 Months.

Feb.	407	8097	7	9139	6	13	81	82	2	34	29	−16	2.3	2.6	13	77	75	−2
Mar.	421	10037	7	11025	9	10	83	85	2	34	29	−16	2.2	2.8	27	77	80	5
Apr.*	429	10879	8	11462	9	6	83	86	3	35	31	−12	2.1	2.6	24	71	80	12
May	388	11167	9	12556	15	12	84	85	2	33	28	−14	2.6	3.1	19	87	88	1
June	375	11387	5	12477	12	10	76	77	2	40	41	2	2.4	2.7	13	98	110	12
July	374	11319	10	12296	11	9	--	--	-	--	--	----	---	---	--	-----	---	--

*Calved.

TABLE 3.—MONTHLY AVERAGES OF "RESTING" ENERGY METABOLISM DURING STANDING AND LYING IN INDIVIDUAL CATTLE. DATA ON THE PULSE RATE, RESPIRATION RATE, TIDAL AIR, AND MINUTE VOLUME OF PULMONARY VENTILATION. (Continued)

		"Resting" Met. Cal./day					Pulse Rate			Resp. Rate			Tidal Air (Lit., S. T. P.)			Ventilation Rate (Liters, S. T. P.)		
Month	Live Wt. Kgs.	Lying	Ave. Dev. %	Stand.	Ave. Dev. %	Diff. %	L.	S.	Diff. %	L.	S.	Diff. %	L.	S.	Diff. %	L.	S.	Diff. %
Jersey Female #828, Dry; Average Age 29 Months.																		
Feb.	372	7756	9	9542	13	23	67	70	5	24	22	−8	2.8	3.6	29	67	79	18
Mar.	388	8640	10	9683	6	12	69	70	1	23	21	−9	2.8	3.6	29	64	75	17
Apr.	409	7641	10	8486	4	11	73	75	3	22	25	14	2.6	3.4	31	60	84	39
May	423	8856	9	9446	5	7	77	77	0	23	26	13	2.8	3.5	25	64	91	42
June	433	8423	8	9440	7	12	74	76	3	24	25	4	2.8	3.2	14	67	80	18
July	443	10575	7	11133	6	5	77	77	0	28	29	4	2.8	3.1	11	79	90	13
Jersey Female #829, Good Milker; Average Age 28 Months.																		
Feb.	408	8781	5	9766	6	11	73	73	0	28	23	−18	2.7	3.3	22	76	77	1
Mar.	422	9427	3	10090	4	7	75	78	4	30	23	−23	2.5	3.5	40	76	81	7
Apr.	442	8951	7	9676	9	8	80	80	0	29	25	−14	2.5	3.4	36	74	85	16
May*	463	10034	5	10617	6	6	82	82	0	29	27	−7	2.5	3.1	24	74	85	15
June	405	11645	6	12240	11	5	84	82	−2	35	36	3	3.1	3.4	10	110	123	12
July	385	11821	4	12358	4	5	74	70	−5	40	38	−5	3.0	3.3	10	119	126	6
Jersey Female #831, Dry; Average Age 27 Months.																		
Feb.	379	7955	3	8762	8	10	72	72	0	29	22	−24	2.8	3.6	29	82	80	−2
Mar.	397	9346	7	9669	6	4	78	77	−1	29	23	−21	2.9	3.9	34	84	89	5
Apr.	415	7949	9	8354	11	5	78	77	−1	27	23	−15	2.5	3.4	36	68	78	14
May	431	8914	7	8969	5	1	79	77	−3	29	24	−17	2.6	3.4	31	76	82	8
June	451	9454	7	9638	4	2	80	76	−5	29	29	0	2.6	3.3	27	77	97	26
July	468	10870	5	10973	6	1	82	82	0	33	32	−2	2.8	3.3	18	91	107	18
Jersey Female #833, Medium Milker; Average Age 27 Months.																		
Feb.	363	8075	3	9018	8	12	70	74	6	27	24	−11	3.1	4.1	32	83	98	18
Mar.	385	9629	8	9874	7	3	75	77	3	24	23	−4	3.0	3.5	17	71	81	14
Apr.	403	9059	11	9848	10	9	76	77	1	27	27	0	3.0	3.6	20	81	98	21
May	419	9365	8	10154	9	8	77	79	3	25	26	4	3.1	3.5	13	77	91	18
June*	380	10193	6	11541	6	13	73	75	3	32	34	6	2.5	3.2	28	81	109	34
July	360	10411	6	11573	5	11	69	72	4	37	40	8	2.6	2.7	4	95	108	13

Jersey Female #834, Dry; Average Age 26 Months.																		
Feb.	327	7012	8	7588	4	8	70	70	0	30	25	−17	2.5	2.9	16	74	72	−3
Mar.	341	7144	4	7612	4	7	71	72	1	27	22	−19	2.6	3.2	23	69	70	2
Apr.	358	6966	9	7050	8	1	71	74	4	28	24	−14	2.4	2.9	21	66	71	7
May	377	7903	6	8193	6	4	75	77	3	28	26	−7	2.6	3.1	19	72	80	12
June	387	7830	12	8233	7	5	75	75	0	28	32	14	2.6	2.9	12	74	92	25
July	402	9365	5	10483	7	12	79	81	3	35	36	3	2.0	2.3	15	71	83	17
Jersey Female #835, Dry; Average Age 25 Months.																		
Feb.	337	7192	5	7619	5	6	68	70	3	24	18	−25	2.7	3.8	41	65	68	6
Mar.	347	7414	5	7847	7	6	69	70	1	24	18	−25	2.5	3.2	28	60	57	−4
Apr.	366	7187	8	7215	7	1	66	70	6	22	20	−9	2.5	3.3	32	56	65	17
May	375	7662	7	7863	6	3	72	72	0	23	22	−4	2.6	3.2	23	59	70	19
June	390	7283	9	7648	7	5	74	72	−3	24	23	−4	2.6	3.0	15	63	70	11
July	406	8874	6	9275	3	5	75	75	0	26	27	4	2.5	3.1	24	65	83	27
Jersey Female #836, Dry; Average Age 25 Months.																		
Feb.	338	7656	5	8194	7	7	70	70	0	18	17	−7	3.5	4.0	14	63	67	6
Mar.	347	7942	7	9153	9	15	71	73	3	19	16	−15	3.1	4.0	29	59	64	8
Apr.	363	8140	6	8751	8	8	73	75	3	21	19	−12	3.1	3.9	26	67	74	10
May	380	8855	7	9784	6	11	71	72	1	21	20	−6	3.1	3.5	13	65	68	5
June	392	13233	6	13896	5	5	75	77	3	24	25	6	2.7	3.0	11	64	74	15
July	410	9393	7	10287	7	10	79	81	3	26	28	5	2.5	2.8	12	66	77	17
Jersey Female #837, Dry; Average Age 25 Months.																		
Feb.	353	6758	4	7642	5	13	71	73	3	23	20	−13	2.7	3.7	37	63	75	19
Mar.	368	7196	8	8106	7	13	72	72	0	24	17	−29	2.8	4.0	43	67	67	0
Apr.	389	7712	7	8723	8	13	76	76	0	26	20	−23	2.7	3.6	33	69	72	4
May	405	7951	4	9013	3	13	75	77	3	27	21	−22	2.6	3.4	31	70	70	0
June	419	8344	5	9493	4	14	73	75	3	30	23	−23	2.8	3.7	32	84	85	1
July	433	8879	5	10172	3	15	79	79	0	34	29	−15	2.6	3.6	38	88	105	21
Hereford Steer #815; Average Age 40 Months.																		
Dec.	842	11566	7	13701	11	19	58	58	0	28	27	−4	3.9	4.7	21	108	127	17
Jan.	864	10752	7	12339	8	15	59	61	3	27	26	−4	4.4	4.9	11	119	128	8
Feb.	871	10642	16	11707	9	10	55	59	7	25	25	0	4.8	5.3	10	119	134	12
Mar.	887	13261	7	15014	5	13	55	57	4	29	27	−7	4.2	4.8	14	122	130	6
Apr.	892	13173	7	14242	7	8	56	58	4	27	27	0	4.0	4.4	10	109	119	10
May	882	13305	5	15225	4	14	57	60	5	25	25	0	4.6	5.3	15	115	132	15
June	882	15078	8	16793	8	11	65	65	0	34	32	−6	4.4	5.2	18	149	168	13
July	878	13683	7	15520	5	13	64	65	2	31	30	−3	4.0	4.7	18	124	142	15
Aug.	880	12481	6	16269	4	30	65	69	6	31	28	−10	3.9	4.9	26	122	136	11

*Calved.

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		"Resting" Met. Cal./day					Pulse Rate			Resp. Rate			Tidal Air (Lit., S. T. P.)			Ventilation Rate (Liters, S. T. P.)		
Month	Live Wt. Kgs.	Lying	Ave. Dev. %	Stand.	Ave. Dev. %	Diff. %	L.	S.	Diff. %	L.	S.	Diff. %	L.	S.	Diff. %	L.	S.	Diff. %
					Hereford Female #816, Dry; Average Age 40 Months.													
Dec.	381	6912	28	7649	27	11	54	54	0	31	29	−7	3.0	3.3	10	92	96	4
Jan.	382	6690	13	7048	10	5	53	54	2	23	23	0	3.6	3.9	8	82	91	11
Feb.	391	5831	9	6202	11	6	52	52	0	21	20	−5	4.5	4.7	4	94	93	−1
Mar.	402	8243	6	8762	5	6	50	51	2	23	23	0	3.9	4.2	8	89	97	10
Apr.	420	10290	5	10847	1	5	52	54	4	30	30	0	3.4	3.8	12	103	113	10
May	444	11251	5	11645	8	4	59	60	2	34	33	−3	3.5	3.8	9	119	126	6
June	481	13809	8	14484	5	5	60	64	7	43	36	−16	2.9	3.5	20	126	127	1
July*	474	12256	12	13741	10	12	--	--	-	--	--	---	---	---	--	---	---	--
Aug.	460	11301	7	12683	6	12	72	74	3	35	34	−3	3.2	3.8	19	112	130	16
						Hereford Female #205; Born 1/12/32.												
Feb.	54	2380	17	2510	19	6	--	--	-	21	19	−10	0.7	0.9	29	15	16	10
Mar.	80	3865	6	3856	5	0	81	83	3	21	22	5	0.8	0.8	0	16	18	12
Apr.	102	4122	6	4122	7	0	79	80	1	24	23	−4	1.0	1.0	0	23	23	0
May	128	4544	8	5003	11	10	79	82	4	28	24	−14	1.4	1.6	14	38	38	0
June	160	5750	4	6095	4	6	76	78	3	36	31	−14	1.5	1.8	20	55	55	0
July	186	6162	5	6690	3	9	75	77	3	41	36	−12	1.7	2.0	18	70	71	1
Aug.	195	6172	6	6818	7	11	83	88	6	44	39	−11	1.6	2.1	31	72	84	16
Sept.	231	6259	5	7142	5	14	65	66	2	36	28	−22	1.9	2.8	47	69	78	18
Oct.	253	6183	5	6963	7	13	78	83	6	39	31	−21	2.3	3.0	30	91	92	1
						Hereford Female #206; Born 1/16/32.												
Feb.	52	2316	10	2383	14	3	73	73	0	33	43	30	0.4	0.4	0	14	17	27
Mar.	70	3342	15	3555	13	6	84	87	4	32	31	−3	0.8	0.9	13	26	27	5
Apr.	93	4755	4	4766	5	0	75	78	4	36	33	−8	0.9	1.0	11	31	32	5
May	118	4246	7	4461	6	5	72	74	3	35	35	0	1.0	1.1	10	35	39	10
June	134	4547	6	4654	6	2	73	75	3	40	36	−10	1.2	1.4	17	49	49	0
July	152	5603	5	5934	8	6	71	77	9	42	43	2	1.3	1.3	0	53	55	3
Aug.	162	5507	5	6011	4	9	70	70	0	36	34	−6	1.6	1.8	13	59	60	1
Sept.	188	6393	10	6781	10	6	78	79	1	27	31	15	1.7	1.9	12	47	58	25
Oct.	229	7102	7	7975	8	12	76	76	0	36	36	0	1.8	1.9	1	65	70	8

Holstein Female #669; Born 12/20/31.

Feb.	69	3115	13	3304	13	6	--	--	-	--	--	--	---	---	--	--	--	--
Mar.	92	4465	11	4609	10	3	73	75	3	33	33	0	1.0	1.0	0	32	34	7
Apr.	119	5785	4	5873	6	2	73	75	3	34	32	−6	1.2	1.3	8	42	41	−2
May	151	5860	7	6074	8	4	73	73	0	35	31	−11	1.5	1.5	0	51	48	−6
June	177	6181	4	6624	4	7	73	73	0	39	37	−5	1.6	1.6	0	61	60	−2
July	199	6466	5	6947	4	7	74	76	3	38	33	−13	1.7	1.9	12	63	63	0
Aug.	212	6544	4	7035	6	8	75	76	−1	37	33	−11	1.9	2.1	11	69	68	−1
Sept.	238	7189	5	8295	6	15	71	81	14	35	29	−17	1.9	2.6	37	67	75	12
Oct.	283	7906	6	8657	3	9	--	--	--	34	27	−21	2.0	2.3	15	68	62	−9

Holstein Female #670; Born 1/16/32.

Feb.	58	2691	13	2779	12	3	--	--	-	--	--	--	---	---	--	--	--	--
Mar.	80	3473	9	3668	8	6	67	72	8	24	23	−4	0.7	1.0	43	18	24	36
Apr.	100	4354	8	4408	7	1	65	66	2	26	24	−8	0.9	1.1	22	24	26	8
May	123	4752	15	5218	14	10	78	79	1	30	25	−17	1.4	1.6	14	43	41	5
June	155	6153	4	6497	5	6	73	76	4	37	32	−14	1.4	1.6	14	53	52	−2
July	186	6602	5	7669	6	16	74	74	0	45	38	−16	1.7	2.2	29	78	82	6
Aug.	200	6701	8	7603	9	14	76	78	3	43	40	−7	2.2	2.5	14	95	100	5
Sept.	238	7373	6	8300	6	13	62	64	3	35	29	−17	2.3	3.1	35	79	90	13
Oct.	261	7125	3	8509	3	19	78	82	5	37	32	−14	2.6	3.3	27	95	106	11

*Calved.