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LETTER OF TRANSMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY,
Washington, D. C., January 7, 1911.

SIR: I have the honor to transmit herewith and to recommend for publication as a bulletin of this bureau a manuscript entitled "The Influence of Type and of Age upon the Utilization of Feed by Cattle," by Dr. Henry Prentiss Armsby and Mr. J. August Fries. The paper describes work done during a period of three years in cooperation between this bureau and the Institute of Animal Nutrition of The Pennsylvania State College.

Two steer calves were selected as the subjects of this investigation, one a purebred typical beef animal of one of the well-known beef breeds, the other a "scrub" of mixed breeding. Exhaustive feeding trials were carried out with these animals, including twenty-four experiments with the respiration calorimeter. Finally the steers were subjected to a slaughter test whereby the quality of the meat and the relative size of the various cuts were accurately determined. The work is therefore important alike to the practical feeder and the agricultural scientist.

Respectfully,

A. D. MELVIN,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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THE INFLUENCE OF TYPE AND OF AGE UPON THE UTILIZATION OF FEED BY CATTLE.

INTRODUCTION.

It is a fact of common knowledge that marked differences exist between individual animals as regards the returns which they yield for the feed consumed. In the case of beef cattle especially it is easy to cite from the experimental records of the past numerous instances in which, quite aside from any differences in the quality of the product, the actual gain in weight per pound of feed consumed has varied considerably with different animals under like conditions. It is true that it is almost equally easy to cite experiments which have failed to show any such differences in this respect between typical beef animals and "scrubs" as was confidently anticipated by their projectors, but nevertheless differences in the type and individuality of animals are admittedly of great importance. The tendency has been to ascribe such differences to physiological causes. A common statement is that a good feeder has a greater digestive power than a poor one, although fairly numerous experiments have failed to show any marked differences in the percentage digestibility of the same feeding stuffs by animals of different types. What is really meant by such a statement usually is that the power of assimilation of the one animal is superior to that of the other; that is, it has been assumed that the advantage of the better type of animal lay in its ability to produce more flesh or fat from a unit of feed than could the poorer one.

The existence of such differences in the metabolic processes of individuals of the same species, however, does not seem especially probable. It is difficult to see, for example, how one steer could manufacture more fat than another from a unit weight of a carbohydrate. Moreover, an observed superiority in the amount of gain in live weight made may be conceived to arise from other causes, as, for example, from a difference in the maintenance requirement or in the chemical composition of the increase or from the ability of the one animal to consume a larger amount of feed than the other, while, of course, differences in selling price depend to a very large extent upon the conformation of the animal and the quality of the meat. Nevertheless, we are not warranted in ignoring the possibility that an improved animal or breed may have actually become a more efficient mechanism for converting digested food into tissue, and if such differences do exist, it is obviously of the highest importance, both from the scientific and the practical standpoints, that their existence and their extent be determined. On the one hand, if considerable, they would render futile any attempt to express with scientific accuracy the nutritive values of feeding stuffs, as, indeed, some writers claim to be the case. On the other hand, their practical importance is manifest, not merely in relation to the selection of animals for meat production but especially in their bearing on the problem of the improvement of the breeds of meat-producing animals.

The object of the investigation here reported was to test this question by using two animals of markedly dissimilar type and determining their digestive power for the same feeding stuffs and the proportion of the energy of the latter which they were able to use for maintenance or for productive purposes, respectively.

It has also been commonly taught, and seems to be generally accepted by animal husbandmen as an established fact, that young growing animals not only make relatively larger gains than more mature ones, but likewise more economical gains. While it is true, as Waters [1] has pointed out, that most feeding experiments have exaggerated the differences between young and mature cattle in these respects through failure to take account of the marked influence of the condition of fatness upon the rate and cost of gain, it is, nevertheless, a well-established fact that a given gain in live weight is, other things being equal, obtained more rapidly and with less feed in young than in old animals.

Certainly a large share of this difference, however, is due to the well-known variation in the character of the increase, as has been previously discussed by one of us.[2] The young animal has a remarkable power of storing up protein in the tissues of the body, and the increase in weight of such an animal consists to a great extent of protein tissue with its accompanying large amount of water. As the age of the animal increases, its capacity to store up protein diminishes, at first rapidly and then more slowly, while the storage of fat tends to increase. As a result, a unit of gain made by a young animal contains a relatively low percentage of dry matter, which itself has a relatively low energy value. On the other hand, the gain in weight made by a mature animal consists largely of adipose tissue with a low water content and a high energy value, so that a unit of increase in a mature fattening animal may represent the storage of six to eight times as much energy as an equal gain in weight by a very young animal. It is obvious that to produce a unit of increase in weight must require very different amounts of food in the two cases.

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[1] "Limitations of Baby Beef Production," Thirty-ninth Annual Report Missouri State Board of Agriculture, 1907, pp. 114–166.

[2] Armsby. U. S. Department of Agriculture, Bureau of Animal Industry, Bulletin 108, pp. 11–33.

The energy of the growth process in the young animal is such a striking phenomenon, however, and the feeder is so accustomed to thinking in terms of live weight that the impression has been created that somehow the rapid increase in weight and bulk by the young animal is, in part at least, the result of a greater intrinsic capacity for utilizing its feed. It has been supposed, in other words, that the actual physiological processes involved in the increase of weight are in the growing animal, by virtue of its power of growth, performed more economically than in the mature animal and consequently that a larger percentage of the energy of the food is stored in the form of gain in the younger animal.

It is clear that the truth of this supposition can not be tested by experiments in which only the gain in live weight is ascertained but that it is necessary to know also the make-up of the increase or the amount of energy which it contains. One object of the present investigation was to make comparisons of this sort upon the same animals at different ages, but this object was only partially attained.

GENERAL PLAN OF INVESTIGATION.

Two steer calves were selected as the subjects of investigation. One of these was a purebred Aberdeen-Angus of typical beef form, while the other was a "scrub" containing considerable Jersey blood and possessing the dairy rather than the beef form. These animals were about 8½ and 11 months old, respectively, at the beginning of the investigation in October, 1904, and were under nearly continuous observation for over 2½ years. During this time, with the exception of certain of the periods in which the balance of matter and energy was determined by means of the respiration calorimeter, they were fed an ordinary growing ration, and while maintained in a thrifty condition were at no time fattened. The feeding stuffs used were of the same kind for both animals in all the periods, and the different grains used were mixed throughout in the same proportions for each steer. The live weights of the animals were taken at least once weekly, as well as on three consecutive days at the end of each month, and they were systematically measured and photographed every three months.

At intervals during this time the digestibility of the total ration and the nitrogen balance were determined for each animal. It was originally intended to make these determinations once in three months, but this proved to be impracticable. In all, four such trials were made in addition to those included in the respiration calorimeter experiments mentioned in the next paragraph, viz, in December, 1904, July, 1905, November, 1905, and June, 1906. On subsequent pages these will be designated as "digestion and metabolism trials."

During each of the three winters covered by the investigation four experiments were made on each animal by means of the respiration calorimeter in order to determine the percentage availability of the energy of the feeds consumed. During the first winter, that of 1904–5, the feeding stuffs used differed from those employed during the ordinary feeding. In the succeeding two winters the grain feeds used were the same, only the amounts differing. The respiration calorimeter experiments, of course, included determinations of the digestibility of the rations and of the nitrogen balances of the animals. They will be designated, for the sake of brevity, as "calorimeter experiments."

For the convenience of the reader, the report of the work is divided into three parts.

Part I consists of a general account of the investigation, summarizing and discussing the principal results, but omitting the details of the respiration calorimeter experiments and of the digestion and metabolism trials.

Part II records the details of the respiration calorimeter experiments and of the digestion and metabolism trials the general results of which are discussed in Part I.

Part III contains the necessary information regarding the technic of the investigation, this being omitted in Parts I and II in order to avoid cumbering the pages and distracting the attention of the reader from the main line of thought.

After the close of the investigation in the spring of 1907 the animals were put on pasture during the summer, were fattened in the fall, and finally used for a demonstration in slaughtering and meat cutting, the weights of the different cuts being recorded.

GENERAL CONCLUSIONS.

The principal results of the investigation outlined in the foregoing paragraphs may be briefly summarized as follows:

The respiration calorimeter experiments failed to show that either the type or age of the steers exerted any material influence upon the percentage digestibility of the feeding stuffs or upon the proportion of their energy which was metabolized. As regards the percentage of the metabolizable energy which was available either for maintenance or for production, slight differences were observed in favor of the purebred steer and, in case of the grain, of the older as compared with the younger animal, but it is questionable whether they were large enough to be of practical significance.

On the limited grain ration of the periods outside the respiration calorimeter experiments, the scrub steer consumed relatively more hay than did the purebred animal, made an equal gain in live weight per head, and a materially greater one per unit of weight, and consumed somewhat less total air-dry feed per unit of gain.

This apparent discrepancy between the results of the respiration-calorimeter experiments and those of the remainder of the investigation appears to have been due chiefly to a difference in the composition of the increase in live weight in the two animals. The nitrogen balances show a notably greater tendency toward a storage of protein by the scrub than by the purebred steer, while the respiration-calorimeter experiments, on the other hand, show a materially greater gain of fat by the latter than by the former. In other words, the gain in weight by the scrub as compared with that by the purebred steer consisted more largely of protein with its accompanying water and to a smaller extent of fat, and therefore represented a materially smaller storage of feed energy. A similar conclusion was indicated by the results of the block test. From the data obtained for the available energy of the rations it is estimated that a kilogram of gain in live weight by the purebred steer was equivalent on the average to the storage of 40 per cent more energy than in the case of the scrub.

The energy requirement of the scrub steer for maintenance, computed to the same live weight, averaged 18.7 per cent higher than that of the purebred steer. Accordingly, the latter was able to use a relatively larger proportion of the total energy of his ration for the production of gain. A distinct influence of age upon the maintenance requirement was observed between the ages of 14 and 39 months, the requirement decreasing relatively as the animals matured.

In those of the respiration calorimeter experiments in which a heavy grain ration was fed, it was found that the purebred steer had a notably greater feeding capacity than the scrub steer—that is, he could be fed larger rations of grain, which he utilized to the same degree as did the scrub.

While, then, our results fail to show any material differences between the physiological processes of food utilization in the two animals, they also show clearly an economic superiority of the purebred over the scrub steer, due, first, to his relatively smaller maintenance requirement, and, second, to his ability to consume a larger surplus of feed above that requirement. Both these factors tend to make the actual production of human food in the form of meat and fat per unit of total feed consumed by the animal notably greater by the purebred animal. In these experiments this difference was masked by the inferior quality of the increase made by the scrub steer, so that on the basis of live weight alone the latter appears superior to the purebred animal.

Contrary to the conclusions drawn by us from earlier experiments, it was found that the availability of the energy of the grains used was substantially the same above and below the point of maintenance, and that in both cases the energy values as determined by the respiration calorimeter agreed well with those computed from the chemical composition by the use of Kellner's well-known factors. In the case of the hay, on the contrary, the availability below the point of maintenance was considerably greater than the result computed by means of Kellner's factors for the percentage utilization above maintenance.

In the case of the purebred animal especially, and to a less degree in that of the scrub, rations containing less available energy and notably less digestible protein than the amounts called for by the current feeding standards for growing cattle, produced entirely satisfactory gains in live weight.

ACKNOWLEDGMENTS.

The execution of an investigation covering over 30 months and including, in addition to the usual records of feed, live weight, etc., and numerous measurements and photographs of the animals, 32 digestion and metabolism trials and 24 experiments with the respiration calorimeter, together with the great variety of analytical and clerical work which these all imply, necessarily calls for a considerable staff of assistants. The personnel of this staff underwent considerable changes during the progress of the research, only one of those connected with the work at its inception remaining until the close (Mr. Braman). Moreover, the chemical analyses, as well as the computations and clerical work, incident to the calorimeter experiments and the digestion trials were necessarily performed to a large extent after the completion of the experiments themselves, so that an assistant was often engaged in analyses or computations for experiments in whose immediate execution he had not taken part and otherwise performed work of quite varied nature at different times. In all, aside from a few temporary assistants, 14 persons have had more or less part in the work, viz, in alphabetical order, Messrs. W. W. Braman, J. W. Calvin, T. M. Carpenter, F. W. Christensen, D. C. Cochrane, W. F. Frisbie, N. C. Hamner, R. C. Jones, R. A. Licthenthaeler, W. H. McIntire, N. G. Miller, J. H. Parkins, F. S. Putney, and R. E. Stallings.

For the reasons just indicated, it is impossible even to attempt any statement of the exact part taken by individuals or to make acknowledgments for the specific work done by each person. This is all the more true because the most important factor in whatever success the investigation has attained, and one which by its nature is incapable of such partition, is the loyalty and zeal which all concerned have shown in the execution of the plan of the investigation and in securing the greatest attainable accuracy of details. A

scientific investigation of any considerable scope necessarily requires a large amount of routine work any serious defects in which must inevitably render futile the most carefully laid plans. "Team work" is as essential in scientific investigation as on the athletic field, and the ungrudging cooperation of all the assistants in these laborious experiments can not be too emphatically acknowledged. Specific mention should also be made of the valuable advice and cooperation of Dr. William Frear, chemist, and Mr. M. S. McDowell, first assistant chemist of the experiment station, in the execution of the chemical analyses, and of the services of the late William C. Patterson, superintendent of grounds and buildings, in charge of the experiment station farm, to whom we are indebted for the necessary labor and facilities for the experimental feeding and care of the animals.

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PART I. GENERAL ACCOUNT OF THE INVESTIGATION.

THE ANIMALS.

Since one object of the investigation was to study the influence of the type of animal upon the utilization of the feed, as complete a description as possible of the animals used is essential to enable the reader to judge of the significance of the results. The animals selected were the following:

Steer A, Aberdeen-Angus, Maggie's Baron 2d, 69524. Sire, Bella's Baron, 46381; dam, Maggie of Douglass, 40511. Dropped January 16, 1904. Bred by the Pennsylvania State College.

Steer B, scrub. Sire, probably a scrub; dam, a high-grade Jersey. Dropped about November 7, 1903. Bred by W. I. Thompson, jr., State College, Pa. Purchased July, 1904.

As already stated, the animals were photographed at intervals of approximately three months, a side, front, and rear view being taken in each instance. The negatives are preserved as part of the records of the investigation. All these photographs were taken with the same lens and at the same distance from the subject, so that they are strictly comparable. Plates I, II, and III contain reproductions of photographs taken on October 8, 1904, October 15, 1906, and February 20, 1907, selected as illustrations of the whole series. The pictures show quite clearly that steer A (Aberdeen-Angus) was of the recognized beef form, while steer B (scrub) appears as distinctly to have belonged to the dairy type.

MEASUREMENTS.

Measurements of the animals were made monthly. The results are recorded in Table I of the appendix, and those relating to length of body, shoulder height, chest girth, and thickness at paunch are represented graphically on figures 1, 2, 3, and 4.

The method employed for measuring the animals was imperfect, and for this or other reasons it is evident that the results were not very accurate, as is indicated by the irregularities of the figures. While differences in the thickness of the animal's coat and variations in the state of fatness may have affected the results, they can hardly account for the considerable fluctuations shown. The following general conclusions, however, appear to be justified.

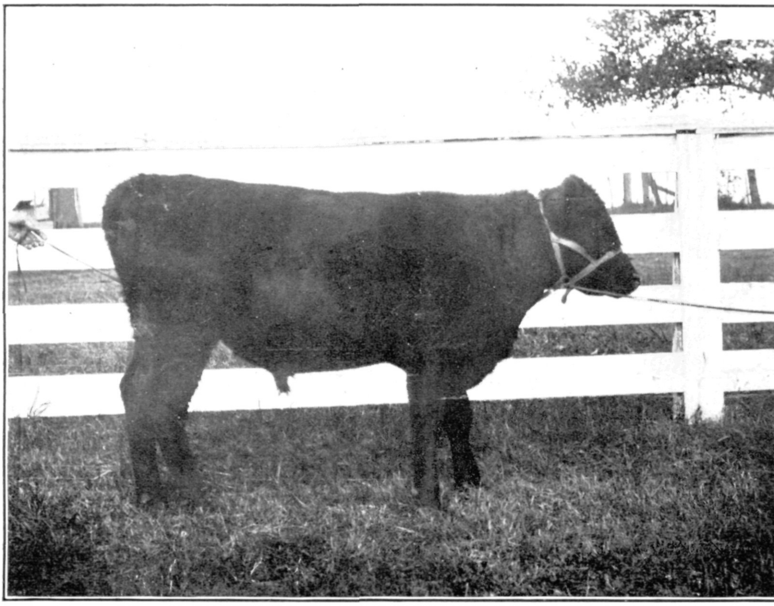

FIG. 1.—THE PUREBRED STEER AT 9 MONTHS OLD, OCTOBER 8, 1904.

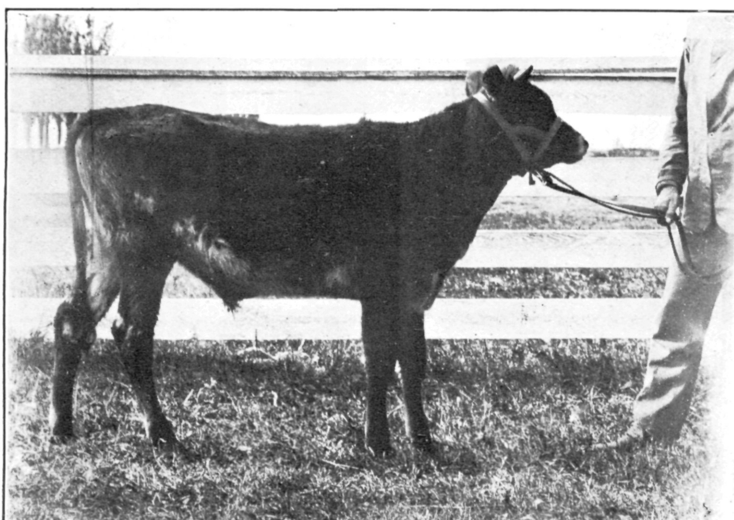

FIG. 2.—THE SCRUB STEER AT 11 MONTHS OLD, OCTOBER 8, 1904.

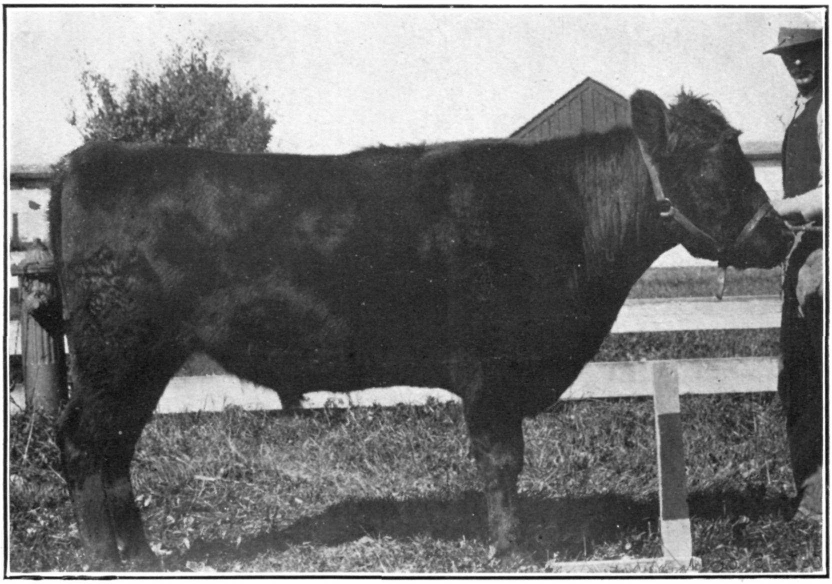

Fig. 1.—The Purebred Steer at 2 Years and 9 Months Old, October 15, 1906.

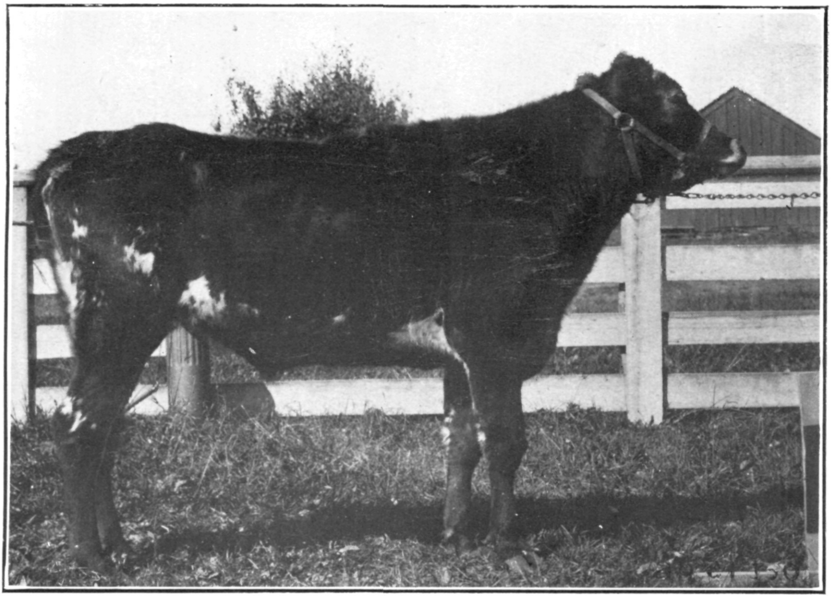

Fig. 2.—The Scrub Steer at 2 Years and 11 Months Old, October 15, 1906.

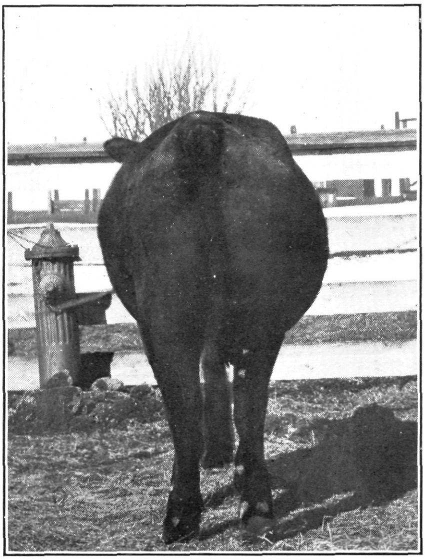

FIG. 1.—THE PUREBRED STEER.

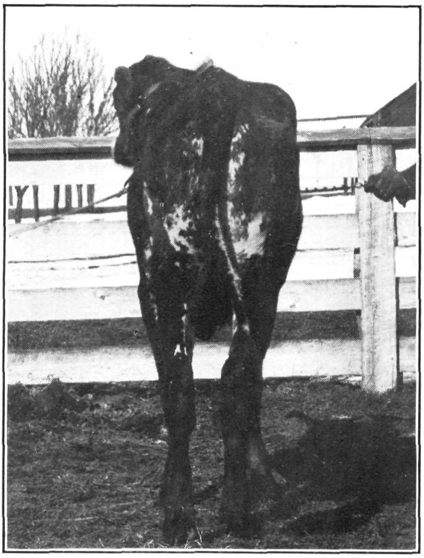

FIG. 2.—THE SCRUB STEER.

REAR VIEW OF THE STEERS ON FEBRUARY 20, 1907.

Length of body.—After the irregularities of the first six months, it appears that both animals gained in length at a similar rate for a time. After about November, 1905, however, the growth in length of steer A was much less rapid, while that of steer B continued at

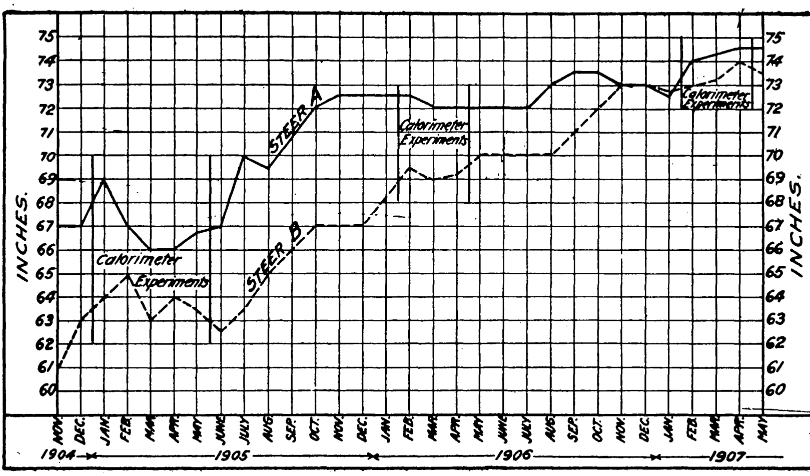

FIG. 1.—Length of body of steers at monthly periods from November, 1904, to May, 1907.

about the same rate as heretofore, so that this animal finally overtook steer A.

Shoulder height.—At the beginning of the experiment both steers were of about the same height. Steer B, however, increased his height much more rapidly than did steer A. In both the rate of

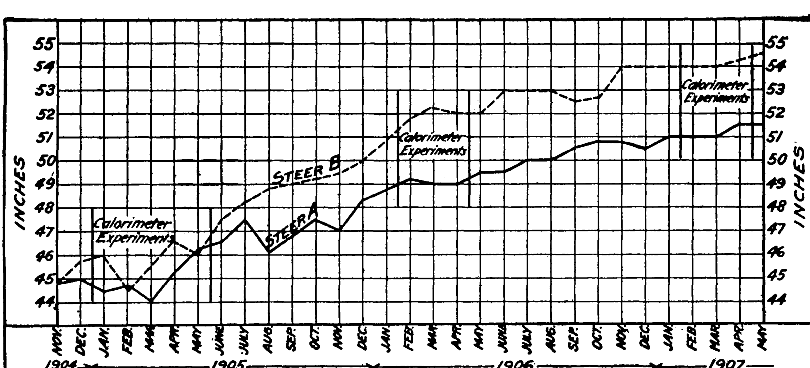

FIG. 2.—Height at shoulder of steers at monthly periods from November, 1904, to May, 1907.

increase appears to have diminished as the animals grew older, but this effect is rather more marked with steer B than with steer A.

Chest girth.—Steer B was inferior in chest girth to steer A, but his growth in this respect was fully as rapid as that of the latter. After about July, 1906, however, the rate for steer B falls off much more rapidly than that for steer A.

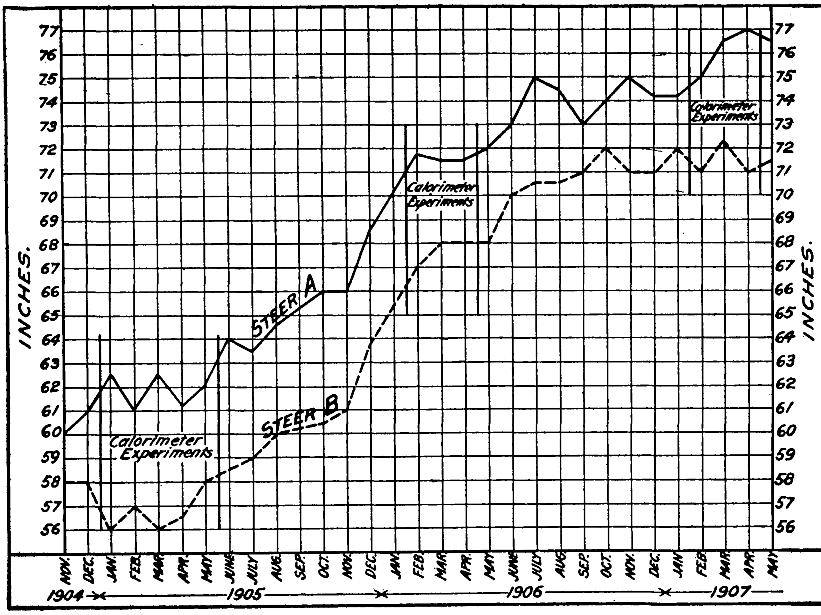

FIG. 3.—Chest girth of steers at monthly periods from November, 1904, to May, 1907.

It is plain from these comparisons that the increase in weight of steer A was due much more largely than that of steer B to an increase

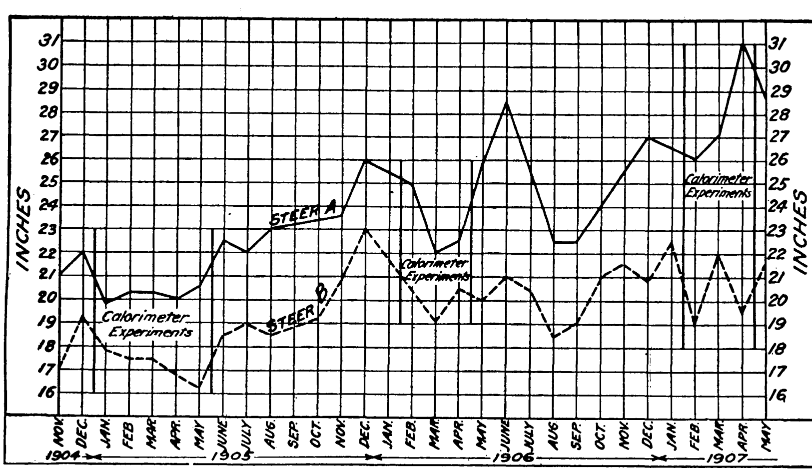

FIG. 4.—Thickness at paunch of steers at monthly periods from November, 1904, to May, 1907.

in the size of body, particularly in cross section. Steer B, on the other hand, gained more markedly in length and height.

LIVE WEIGHTS.

The live weights taken are recorded in Table II of the appendix and are represented graphically in figure 5, which shows the average live weights at the beginning of each month as recorded in Table IIa of the appendix. A comparison of these results shows that steer A steadily increased in live weight with but partial interruption by the calorimeter experiments. Steer B, on the other hand, shows a perceptibly slower rate of increase after the first year, while his growth, measured by live weight, was much more affected by the limited rations of the calorimeter experiments. A comparison of these results with those of the measurements and with the photographs taken shows that steer A made his gains of weight largely by increase in

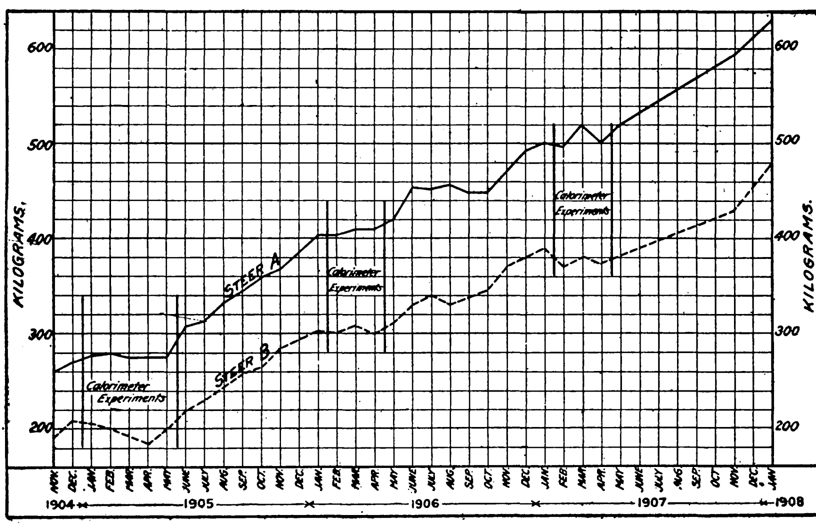

FIG. 5.—Live weights of steers, monthly, from November, 1904, to January, 1908.

depth and width of body, while the growth of steer B was much more "rangy."

It does not appear from the foregoing that the introduction of a period of light or insufficient feeding each year permanently affected the growth of the animals. It is true that steer B made little or no gain on the light rations of the calorimeter experiments, although steer A still showed some increase. The calorimeter experiments, amounting in all to about nine months, were largely lost time so far as gain in weight was concerned, but with the return to liberal rations, the gain apparently proceeded without any serious check, while the increase in size of the animal appears to have been much less affected than the increase in weight.

On December 4, 1906, the actual ages of the two animals were: Steer A, 34.5 months; steer B, 37 months. The periods during which actual productive feeding was carried on, however, amounted (omitting the period July 4–28, 1906, in which no gain was made) to 17.7 months for steer A and 16.6 months for steer B,[1] so that what we might call their virtual ages and the corresponding live weights at the close of the feeding, were:

Steer A, 26.2 months old; live weight, 1,089 pounds.
Steer B, 27.5 months old; live weight, 834 pounds.

The weight of steer A was at least fairly good for an unfattened animal at that age.

After December 4, 1906, there followed another experimental period of low feeding, during which, however, steer A gained materially (about 73 pounds). Following this the animals were on pasture for about six months, making their weights and virtual ages, October 28, 1908:

Steer A, 32 months old; live weight, 1,307 pounds.
Steer B, 33 months old; live weight, 943 pounds.

Two months later, January 4, 1908, they weighed after fattening: Steer A, 1,392 pounds; steer B, 1,063 pounds.

At most, the periods of maintenance and submaintenance seem only to have rendered the rate of gain in weight slightly less rapid, but not to have prevented the final attainment of a fairly satisfactory weight nor the production of a good quality of beef. It is also to be noted that up to the close of the records the animals were still increasing both in weight and size, showing that they had not yet completed their growth and indicating that the effect of scanty feeding is to delay rather than to diminish growth. This conclusion is entirely in harmony with the very interesting results upon the growth of animals under adverse conditions reported by Waters.[2]

BLOCK TEST.

As previously noted, both the animals were used for a demonstration in slaughtering and meat cutting, the work being conducted by Mr. W. H. Tomhave. The animals were killed on January 4, 1908. Steer B was not as well fattened as steer A, being rated as "common," while steer A was graded as "prime." Table 1 shows the total dressed weight and the weights of the several wholesale cuts expressed as percentages of the live weight and of the dressed weight, respectively.

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[1] Compare Table 52, p. 78.
[2] Society for the Promotion of Agricultural Science. Proceedings, 1908, pp. 71-96.

TABLE 1.—*Weights and percentages of wholesale cuts.*

Cuts.	Steer A (Aberdeen-Angus).			Steer B (scrub).		
	Weight of cuts.	Live weight.	Dressed weight.	Weight of cuts.	Live weight.	Dressed weight.
	Pounds.	*Per cent.*	*Per cent.*	*Pounds.*	*Per cent.*	*Per cent.*
Round	182.50	13.08	21.79	130.50	12.25	22.50
Loin	146.25	10.49	17.46	95.25	8.94	16.42
Suet	33.75	2.43	4.03	10.25	.96	1.77
Flank	43.50	3.12	5.20	20.00	1.88	3.45
Ribs	82.00	5.88	9.79	59.00	5.53	10.12
Chuck	249.50	17.90	29.79	195.00	18.31	33.62
Plate	99.75	7.15	11.94	70.25	6.59	12.12
Total	837.25	60.05	100.00	580.25	54.48	100.00

These results show the considerably higher percentage of dressed weight in the case of steer A which is characteristic of the beef animal, and likewise the predominance of the loin cut over the less valuable cuts in the forequarter in the beef animal as compared with the scrub.

The following comparison of the marketable meat of the retail cuts likewise shows that the proportion of the more valuable cuts was notably greater in steer A than in steer B:

TABLE 2.—*Marketable meat in retail cuts.*

Cuts.	Steer A (Aberdeen-Angus).			Steer B (scrub).		
	Weight.	Dressed weight.	Marketable meat.	Weight.	Dressed weight.	Marketable meat.
	Pounds.	*Per cent.*	*Per cent.*	*Pounds.*	*Per cent.*	*Per cent.*
Round steak, rump, sirloin steak, porterhouse steak, and prime ribs	337.00	40.25	44.24	222.25	38.32	42.46
All other cuts	424.75	50.74	55.76	301.25	52.14	57.54

The evidence of the block as well as of scales and tape line confirms that of the eye in characterizing steer A as a beef animal as contrasted with steer B.

THE RESPIRATION CALORIMETER EXPERIMENTS.

In studying the records of the animals just described while under experiment it will be convenient to consider first the results obtained in the respiration calorimeter experiments, taking up subsequently the records of the intermediate feeding periods and of the digestion and metabolism trials included in them.

PLAN OF RESPIRATION CALORIMETER EXPERIMENTS.

As stated in the introduction, the prime object of the investigation was to compare the total metabolism of the two animals at different ages when fed upon rations made as nearly comparable as possible for the purpose, especially, of determining whether the age or type of animal exerted any perceptible influence upon the percentage availability or percentage utilization of the energy of the ration, using these terms in the senses defined in our previous publications.

The income and outgo of matter and of energy was accordingly determined for each animal by means of the respiration calorimeter during January to April, 1905, 1906, and 1907 on four different rations, making 24 experiments in all. The general plan for each year was the same, being substantially that followed in the experiments upon the energy values of red-clover hay and corn meal reported in a previous bulletin.[1] In two periods upon hay alone different amounts were fed, one ration being intended to be slightly and the other considerably below the maintenance requirement. A comparison of these two periods served to determine the availability of the energy of the hay. In a third period grain was added to the smaller of the two hay rations in amount estimated to be nearly sufficient to reach the maintenance point, thus affording data for computing the availability of the energy of the grain. Finally, in a fourth period, as heavy a grain ration as was thought practicable was fed in conjunction with the same amount of hay, so that a comparison of the third and fourth periods would show the percentage utilization of the energy of the grain. As will appear in the following pages, the actual chronological order of the experiments differed from that just stated.

With a view to securing, in addition to the main results sought, data as to the energy values of individual feeding stuffs, the attempt was made in the experiments of 1905 to substitute wheat bran for the mixture of grains used up to that time, while timothy hay was employed in place of mixed hay on account of its being a more definite material. The substitution of bran for the mixed grain proved unfortunate in some respects. The animals did not appear to relish it and the amounts eaten were relatively small, even in the periods of heaviest feeding. It is possible that these facts may in some degree account for the irregularity of the results in that year.

In the respiration-calorimeter experiments of the two succeeding winters, therefore, the attempt to determine the energy values of single grains was abandoned and the same mixture of grains employed as was used in the intermediate periods up to April 12, 1906 (compare p. 60), viz:

	Parts, by weight.
Wheat bran	1
Corn meal	3
Old process linseed meal	3

[1] Bulletin 74, Bureau of Animal Industry.

Timothy hay was continued as the coarse feed. While this change in the grain disturbs the comparison between the three years as regards the influence of age, it does not affect the comparison of the two animals with each other. Table 3 shows the rations fed.

TABLE 3.—*Daily rations in respiration calorimeter experiments.*

Experiment.	Steer A.				Steer B.			
	Timothy hay.	Wheat bran.	Corn meal.	Old-process linseed meal.	Timothy hay	Wheat bran.	Corn meal.	Old-process linseed meal
Experiments of 1905.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Period I	2,250	1,600	....	....	2,000	1,200	....	....
Period II	2,250	3,000	....	....	2,000	2,000	....	....
Period III	2,250	....	....	....	2,000	....	....	....
Period IV	4,000	....	....	....	3,000	....	....	....
Experiments of 1906.								
Period I	3,000	300	900	900	2,800	200	600	600
Period II	3,000	700	2,100	2,100	2,800	357	1,072	1,071
Period III	3,000	....	....	....	2,800	....	....	....
Period IV	5,000	....	....	....	4,300	....	....	....
Experiments of 1907.								
Period I	3,400	335	1,000	1,000	3,200	235	700	700
Period II	3,400	800	2,400	2,400	3,200	450	1,350	1,350
Period III	3,400	....	....	....	3,200	....	....	....
Period IV	5,600	....	....	....	5,300	....	....	....

RELATIVE DIGESTIVE POWER.

As stated in the introduction, differences in the productive capacity of animals have been somewhat commonly ascribed to differences in digestive power. Do the results of this investigation support that view? The term "digestibility" has not infrequently been loosely used as equivalent to the total effect of the food upon growth, fattening, milk production, etc. In scientific usage, however, the conception of digestibility is, of course, entirely distinct from that of nutritive effect. The percentage digestibility means simply the proportion of the feeding stuff which the digestive organs of the animal are able to bring into solution and transmit to the blood for the various uses of the body. The nutritive effect obtained depends upon how good use the tissues of the body can make of materials thus supplied to them by the digestive organs. Digestibility is commonly determined by measuring the difference between feed and feces, the latter being regarded as consisting of the indigestible portion of the feed. While this is not strictly true in the case of farm animals it is sufficiently so for many purposes, while the difference does represent the net contribution of the feed to the nutrition of the body. In the present discussion the term "digested matter" is used as equivalent to "feed minus feces."

In comparing the digestive powers of two animals it is obviously necessary that they should receive identical rations, since feeds differ among themselves in digestibility. This condition is strictly fulfilled only in those of the calorimeter experiments in which hay was fed alone, and these will be first considered.

DIGESTIBILITY OF HAY.

The hay used was, as previously stated, nearly pure timothy (*Phleum pratense*). Analyses of duplicate samples taken at the beginning of each season's experiments showed the dry matter of the hay to have had the composition recorded in Table 4. Examination of subsequent samples taken as the hay was weighed out for feeding fully confirmed the accuracy of the sampling.

TABLE 4.—*Composition of timothy hay*[1]—*water-free.*

Component.	1905	1906	1907
	Per cent.	*Per cent.*	*Per cent*
Ash	4.87	5.86	5.01
Protein[2]	5.08	6.72	6.90
Nonprotein[2]	.39	.83	.24
Crude fiber	38.14	33.02	31.15
Nitrogen-free extract	49.51	51.01	54.55
Ether extract	2.01	2.56	2.15
Total dry matter	100.00	100.00	100.00
Organic matter	95.13	94.14	94.99
Total nitrogen	.894	1.251	1.155
Protein nitrogen	.812	1.075	1.104
Carbon	46.849	[3] 46.803	[3] 46.943
Hydrogen	6.302	[3] 6.570	[3] 5.779
	Calories.	*Calories.*	*Calories.*
Energy per gram[4]	4.4309	4.5159	[2] 4.5053

[1] Average of two general samples.
[2] Computed from nitrogen, using the factors stated in Part III, page 203.
[3] Average of four samples weighed out for the four periods.
[4] The word "calorie" in this bulletin signifies in every instance the large, or kilogram, calorie.

As stated, two different amounts of hay were fed each year, one being slightly below (in one instance slightly above) the maintenance requirement and the other considerably below it. They are designated here for convenience as maintenance and submaintenance rations without implying that the former was an exact maintenance ration. The results of the digestion trials, which are recorded in Part II of this bulletin, are summarized in Table 5.

TABLE 5.—*Percentage digestibility of timothy hay.*

Component.	Steer A.			Steer B.		
	Submaintenance.	Maintenance.	True average.	Submaintenance	Maintenance.	True average.
Experiments of 1905.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Ash	36.6	36.4	36.5	37.7	27.8	31.9
Protein [1]	23.2	8.5	14.4	10.1	....	3.0
Crude fiber	54.6	50.8	52.2	55.8	54.7	55.1
Nitrogen-free extract	59.0	57.5	58.0	60.0	61.4	60.8
Ether extract	44.5	45.1	44.9	46.3	53.1	50.5
Total dry matter	54.6	51.9	52.8	54.9	55.0	54.9
Organic matter	55.3	52.6	53.6	55.6	56.1	55.9
Total nitrogen	36.2	24.8	29.3	20.6	24.3	22.9
Carbon	51.4	49.1	49.9	51.9	52.3	52.2
Organic hydrogen	58.6	45.2	50.2	35.9	55.6	55.7
Energy	50.9	48.6	49.5	49.9	51.5	50.8
Experiments of 1906.						
Ash	48.7	42.9	45.0	42.3	42.7	42.5
Protein [1]	31.8	35.4	34.1	35.3	36.1	35.8
Crude fiber	54.0	52.1	52.8	58.2	55.7	56.7
Nitrogen-free extract	58.9	57.3	57.9	59.8	58.1	58.8
Ether extract	47.6	49.1	48.6	43.4	52.4	49.1
Total dry matter	54.7	53.1	53.7	56.4	54.9	55.5
Organic matter	55.1	53.7	54.2	57.3	55.6	56.3
Total nitrogen	37.9	42.1	40.6	40.9	42.7	42.0
Carbon	53.0	51.0	51.7	54.4	52.1	53.0
Organic hydrogen	54.5	53.2	53.7	55.9	52.2	53.6
Energy	51.8	50.1	50.7	53.6	52.0	52.6
Experiments of 1907.						
Ash	39.7	38.4	38.9	37.5	40.1	39.1
Protein [1]	40.9	45.5	43.8	43.0	44.0	43.6
Crude fiber	63.1	62.6	62.8	64.1	61.7	62.6
Nitrogen-free extract	67.0	65.5	66.1	65.5	64.9	65.1
Ether extract	47.3	48.4	48.0	44.4	50.7	48.4
Total dry matter	62.6	61.6	62.0	62.0	61.0	61.4
Organic matter	63.8	62.9	63.2	63.3	62.2	62.6
Total nitrogen	48.4	49.6	49.1	50.2	48.2	48.9
Carbon	60.5	59.6	59.9	59.8	59.2	59.4
Organic hydrogen	62.0	61.7	61.8	62.5	61.7	62.0
Energy	59.2	58.2	58.6	58.4	57.6	57.9

[1] Nonprotein assumed to be entirely digestible. Computed from nitrogen, using the factors stated in Part III, page 203.

INFLUENCE OF AMOUNT OF HAY CONSUMED ON DIGESTIBILITY.

A comparison of the submaintenance and maintenance periods shows that the digestibility of the crude fiber was less in every instance, and that of the nitrogen-free extract in every case but one (that of steer B in the experiments of 1905) upon the heavier of the two rations. Since these two ingredients make up the bulk of the organic matter of the hay, the percentage digestibility found for the organic matter and for the total dry matter is likewise less on the heavier ration, with the exception noted; and the same is also true of the total carbon and the total energy. The differences are not large, their extreme range being:

	Per cent.
Crude fiber	0.5–3.8
Nitrogen-free extract	.6–1.7
Dry matter	1.0–2.7
Organic matter	1.1–2.7
Carbon	.6–2.3
Energy	.8–2.3

In some cases the differences are decidedly less than the probable experimental error, while in no case are they considerable; but, nevertheless, their general uniformity of direction seems to indicate clearly a real, although slight, effect of increasing quantity in diminishing the percentage digestibility.

On the other hand, in four cases out of six the digestibility of the protein as here computed (i. e., assuming the nonprotein to be entirely digestible) was greater in the heavier ration, and the same is true of the total nitrogen, although the cases are not identical with those under protein.[1] The ether extract in all cases showed a higher digestibility in the heavier rations. The differences in digestibility of these ingredients are of about the same order of magnitude as those noted in the previous paragraph, except in the case of the ether extract in the experiments of 1907, where the difference was decidedly greater with steer B. It is not impossible that these apparent differences in the digestibility of nitrogenous materials and of ether extract may be due to a relatively lower amount of metabolic products in the feces from the heavier rations, while the method here adopted for computing the digestibility of the protein is not free from error. It was not found practicable, however, in these experiments to enter into any of the very interesting questions regarding the true as compared with the apparent digestibility of these nutrients.

COMPARISON OF ANIMALS.

In making a comparison of the digestive powers of the two animals, the possible influence of differences in the amount of hay consumed must be borne in mind. Obviously, too, since the animals differed in weight, this is a question of relative and not of absolute consumption. Table 6 shows the average of the last six weighings of each animal in each period, the actual consumption of dry matter per head, and the same calculated per 500 kilograms live weight, first in direct proportion to the weight and, second, in proportion to the two-thirds power of the live weight. The latter, however, would appear to be the proper basis of comparison, since it may be assumed that the efficiency of the digestive and resorptive organs would be proportional to their internal surface rather than to their cubic capacity.

[1] The results upon protein in the experiments of 1905 are obviously of questionable value.

TABLE 6.—*Dry matter of hay eaten.*

Experiments.	Steer A.				Steer B.			
	Live weight.	Dry matter of hay.			Live weight.	Dry matter of hay.		
		Per head.	Per 500 kilos.			Per head.	Per 500 kilos.	
			W.	$W^{\frac{2}{3}}$.			W.	$W^{\frac{2}{3}}$.
Experiments of 1905.	*Kilos.*	*Grams.*	*Grams.*	*Grams.*	*Kilos.*	*Grams.*	*Grams.*	*Grams.*
Submaintenance (Period III)	268.8	2,001	3,722	3,026	194.1	1,774	4,570	3,334
Maintenance (Period IV)	277.5	3,493	6,294	5,172	189.6	2,610	6,884	4,980
Experiments of 1906.								
Submaintenance (Period III)	399.1	2,647	3,316	3,076	296.2	2,470	4,169	3,501
Maintenance (Period IV)	406.6	4,425	5,442	5,079	308.6	3,805	6,162	5,249
Experiments of 1907.								
Submaintenance (Period III)	507.3	2,974	2,931	2,945	373.7	2,798	3,744	3,398
Maintenance (Period IV)	514.2	4,892	4,757	4,801	384.9	4,630	6,015	5,513

From Table 6 it appears that, with the exception of the maintenance ration of 1905, steer B consumed in every case relatively more hay than steer A, so that any effect of the quantity of hay consumed would be to lower the digestibility by steer B. We actually find, on the contrary, a distinct tendency toward a higher digestibility by steer B in the first two years. This is true of the total dry matter, the organic matter, the crude fiber, the nitrogen-free extract, the carbon, and the energy, with but a single exception (the energy of the submaintenance ration in 1905). The differences show a range very similar to that observed in regard to the influence of quantity but are in the opposite direction, that is, while in five cases out of six steer B consumed relatively more dry matter than steer A, the percentage digestibility is greater on the part of steer B. The actual range of the differences is:

	Per cent.
Crude fiber	1.2–4.2
Nitrogen-free extract	.9–3.9
Dry matter	.3–3.1
Organic matter	.3–3.5
Carbon	.5–3.2
Energy	1.9–2.9

In the third season, 1907, on the contrary, steer A seems to have overtaken steer B as regards digestive power, the differences being in every case slightly in favor of steer A, although they are mostly fractions of 1 per cent, the results being practically identical. The results upon total nitrogen, protein, and ether extract are irregular and lead to no conclusions.

INFLUENCE OF AGE OF ANIMALS.

The percentage digestibility appears to have increased from year to year in these experiments. A strict comparison is not possible, however, since the composition of the hay consumed was not identical in the three seasons. The hay of 1905 was low in nitrogen and high in crude fiber and had a correspondingly low digestibility. That of 1906 was of better quality, containing considerably less fiber, and shows a notably higher percentage digestibility of the total nitrogen and of the protein, but only a slight gain in that of the crude fiber and nitrogen-free extract. The hay of 1907 contained almost the same percentage of total nitrogen as that of the previous season but a larger proportion of true protein, and the digestibility of the latter again showed a marked increase. The most striking difference, however, is the notable increase in the percentage digestibility of the nonnitrogenous ingredients in 1907 as compared with 1906. This is true both of the crude fiber, the nitrogen-free extract, the total carbon, and the energy, as well as of the dry matter and total organic matter. While some of this difference may be due to the lower crude fiber content of the hay, it seems questionable whether it can all be ascribed to this cause. The figures at least suggest an influence of the age of the animal. If such is actually the explanation, the increase, as already noted, was apparently greater with steer A than with steer B, so that the digestive powers of the two animals appear practically equal in the third year.

All the differences just discussed are relatively small and the experiments as a whole are in accord with those of numerous previous investigators in showing that individual differences in digestive power are of comparatively little significance. At any rate the results as regards the hay clearly fail to show any superiority in this respect on the part of the purebred over the scrub animal, or on the part of the young over the more mature animal.

DIGESTIBILITY OF GRAIN.

In the experiments of 1905 wheat bran constituted the exclusive grain ration. In the other two years the grain consisted of a mixture by weight of 1 part of bran, 3 of corn meal, and 3 of old process linseed meal. In 1905 two general samples of the bran were taken which agreed closely in composition with each other and also with subsequent samples taken in the course of the experiments. In the other two years each kind of grain was weighed out separately in the proportions given and the composition of the mixture computed, check analyses on the mixture agreeing substantially with the computed composition. Table 7 shows the average composition of the grain used in each season.

TABLE 7.—*Composition of grain—water-free.*

Component.	Wheat bran, 1905.	Mixed grain, 1906.	Mixed grain, 1907.
	Per cent.	*Per cent.*	*Per cent.*
Ash	7.52	4.10	4.14
Protein[1]	14.50	16.97	17.95
Nonprotein[1]	.49	3.43	2.22
Crude fiber	11.49	6.10	6.16
Nitrogen-free extract	61.88	62.89	64.38
Ether extract	4.12	6.51	5.15
	100.00	100.00	100.00
Organic matter	92.48	95.90	95.86
Total nitrogen	2.648	3.743	3.658
Protein nitrogen	2.544	3.013	3.185
Carbon	46.392	46.860	46.957
Hydrogen	6.768	6.965	6.082
Energy per gram	*Calories.* 4.5318	*Calories.* 4.6904	*Calories.* 4.6698

[1] Computed from nitrogen, using factors stated in Part III, page 203.

The digestibility of the grain must, of course, be estimated from that of the total ration by subtracting the amount computed to have been digested from the hay, and for well-known reasons the results of such a computation are subject to not inconsiderable errors. The first question which arises is what digestibility should be assumed for the hay in these experiments. On the one hand the hay portion of the mixed ration was substantially the same in amount as the hay fed in the submaintenance periods, so that it may seem that the coefficients obtained in those periods should be used. On the other hand, however, a considerable amount of grain was fed with the hay, so that the total amount of dry matter consumed was even greater than in the maintenance periods on hay. The matter is largely one of arbitrary choice, but fortunately the differences are not large. The experiments have been computed by the use of what may be called the true average digestibility. The amounts of each ingredient digested in the two experiments with the hay alone have been added and compared with the total amount of the same ingredient consumed, thus giving more weight to the maintenance than to the submaintenance periods. These averages are the ones recorded in Table 5, page 27. Two amounts of grain were fed each year along with practically the same quantity of hay. The detailed figures are given in Part II of this bulletin and the results as to percentage digestibility summarized in Table 8. For the sake of comparison there has been included in the table the percentage digestibility of the total crude fiber plus nitrogen-free extract, i. e., of the total nonnitrogenous organic matter other than ether extract.

TABLE 8.—*Percentage digestibility of grain.*

Components.	Steer A.			Steer B.		
	Light ration.	Heavy ration.	Average.	Light ration.	Heavy ration.	Average.
Experiments of 1905—Wheat bran.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Ash	44.3	53.6	49.0	20.3	44.7	32.5
Protein [1]	72.2	73.2	72.7	76.9	85.8	81.4
Crude fiber	2.9	22.7	12.8	11.0	12.9	12.0
Nitrogen-free extract	74.1	74.4	74.3	75.0	77.0	76.0
Ether extract	82.3	81.0	86.7	70.9	77.0	74.0
Total dry matter	64.9	67.2	66.1	64.9	68.1	66.5
Crude fiber+nitrogen-free extract	63.6	66.4	65.0	65.3	67.8	66.6
Organic matter	66.5	68.3	67.4	67.7	70.1	68.9
Total nitrogen	74.7	75.9	75.3	78.7	81.5	80.1
Carbon	68.7	68.3	68.5	69.2	70.8	70.0
Organic hydrogen	79.2	73.1	76.2	71.0	72.8	71.9
Energy	67.3	67.6	67.5	67.8	70.4	69.1
Experiments of 1906—Mixed grain.						
Ash	24.0	39.1	31.6	30.7	30.0	30.4
Protein [1]	78.9	66.2	72.6	81.2	71.0	76.0
Crude fiber	70.9	− 7.3	31.8	38.9	−56.9	− 9.0
Nitrogen-free extract	90.6	87.8	89.2	91.7	89.0	90.4
Ether extract	104.1	95.0	99.6	108.3	99.9	104.1
Total dry matter	85.6	77.1	81.4	85.3	75.5	80.4
Crude fiber+nitrogen-free extract	88.8	79.2	84.0	86.9	75.8	81.3
Organic matter	88.3	78.7	83.5	87.6	77.4	82.5
Total nitrogen	84.7	75.6	80.2	86.2	79.3	82.8
Carbon	86.4	76.9	81.7	86.6	76.8	81.7
Organic hydrogen	92.9	77.0	85.0	99.2	77.8	88.5
Energy	87.0	77.6	82.3	86.4	77.3	81.9
Experiments of 1907—Mixed grain.						
Ash	27.9	29.4	28.7	10.9	36.5	23.7
Protein [1]	73.9	73.0	73.4	81.7	78.8	80.3
Crude fiber	11.3	− 7.2	2.1	−13.9	17.6	1.9
Nitrogen-free extract	87.4	87.6	87.5	84.5	91.1	87.8
Ether extract	97.5	92.1	94.8	89.7	91.5	90.6
Total dry matter	78.4	77.2	77.8	75.2	82.3	78.8
Crude fiber+nitrogen-free extract	80.6	79.3	80.0	73.8	84.6	80.2
Organic matter	80.6	79.3	80.0	78.0	84.3	81.2
Total nitrogen	79.1	78.7	78.9	85.0	83.4	84.2
Carbon	78.7	77.9	78.3	75.9	83.4	79.6
Organic hydrogen	81.2	79.2	80.2	76.0	85.2	80.6
Energy	79.6	78.3	78.9	76.3	83.1	79.7

[1] Nonprotein assumed to be entirely digestible. Computed from nitrogen, using factors stated in Part III, page 203.

The negative coefficients for crude fiber shown in the foregoing table are familiar results of such computations of the digestibility of a grain ration and, of course, are to be interpreted as indicating that the grain diminished the digestibility of the crude fiber of the hay. These effects, even if small in themselves, when calculated upon the small absolute amount of crude fiber in the grain become relatively great. The results show the usual irregularities in the case of those ingredients which are present in relatively small amount and whose digestibility is most affected by the presence of metabolic products in the feces, viz, the ether extract and the protein.

INFLUENCE OF AMOUNT OF GRAIN CONSUMED ON DIGESTIBILITY.

The two following tables show the amount of dry matter contained in the total ration (grain plus hay) and in the grain consumed in each period per head and per 500 kilograms live weight computed as in the case of the hay in Table 6. It will be seen that the total consumption on the light ration, when computed in proportion to the surface of the animal, was very uniform. The additional amount consumed on the heavy ration ranged from about 22 to 34 per cent, except in the case of steer A in the last two experiments, where it rose to over 50 per cent.

TABLE 9.—*Dry matter of total ration (hay and grain) eaten.*

Ration.	Steer A.				Steer B.			
	Live weight.	Dry matter of ration.			Live weight.	Dry matter of ration.		
		Per head.	Per 500 kilos.			Per head.	Per 500 kilos.	
			W.	$W^{\frac{2}{3}}$.			W.	$W^{\frac{2}{3}}$.
Experiments of 1905—Bran.	*Kilos.*	*Grams.*	*Grams.*	*Grams.*	*Kilos.*	*Grams.*	*Grams.*	*Grams.*
Light ration (Period I)	270.7	3,348	6,184	5,049	198.6	2,803	7,057	5,188
Heavy ration (Period II)	279.1	4,579	8,204	6,763	196.9	3,582	9,098	6,666
Experiments of 1906—Mixed grain.								
Light ration (Period I)	404.0	4,400	5,446	5,073	298.0	3,628	6,087	5,123
Heavy ration (Period II)	420.7	6,804	8,085	7,634	309.6	4,583	7,402	6,306
Experiments of 1907—Mixed grain.								
Light ration (Period I)	498.6	4,931	4,945	4,941	372.6	4,157	5,571	5,055
Heavy ration (Period II)	518.7	7,708	7,430	7,521	386.4	5,451	7,054	6,471

TABLE 10.—*Dry matter of grain eaten.*

Ration.	Steer A.			Steer B.		
	Per head.	Per 500 kilos.		Per head.	Per 500 kilos.	
		W.	$W^{\frac{2}{3}}$.		W.	$W^{\frac{2}{3}}$.
Experiments of 1905—Bran.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Light ration (Period I)	1,370.2	2,531	2,066	1,032.5	2,600	1,911
Heavy ration (Period II)	2,583.2	4,628	3,816	1,802.6	4,578	3,355
Experiments of 1906—Mixed grain.						
Light ration (Period I)	1,792.0	2,218	2,066	1,194.7	2,005	1,687
Heavy ration (Period II)	4,172.9	4,959	4,682	2,129.0	3,439	2,930
Experiments of 1907—Mixed grain.						
Light ration (Period I)	1,996.2	2,003	2,001	1,397.8	1,876	1,700
Heavy ration (Period II)	4,759.0	4,588	4,644	2,676.9	3,464	3,178

The digestibility of the bran is seen to be greater on the heavier ration, with the exception of the ether extract, total carbon, and organic hydrogen in the case of steer A. The differences, however, are small and probably within the range of error of such experiments.

With the mixed grain fed in 1906 and 1907 the results are contradictory. In the first year the digestibility appears to have been decidedly less on the heavier ration, while in 1907, on the other hand, very little difference is noted in the case of steer A, and in the case of steer B a notably higher digestibility is shown for the heavier ration. There is no apparent error in the determination of the digestibility of the total ration, but it is not easy to form a judgment as to the range of possible error in the computation of the digestibility of the grain from that of the total ration. The figures for the digestibility of the light ration in 1906 seem abnormally high as compared with the average digestion coefficients of these feeding stuffs, from which an average percentage digestibility of about 81 for the total dry matter of the mixed grain may be computed. On the whole, the safest course seems to be to consider that the average of the coefficients for the light and heavy rations represents approximately the actual digestibility of the grain.

COMPARISON OF ANIMALS.

If we are justified in assuming, as just suggested, that the average figures for the two periods represent the true digestibility of the grain, very little difference appears between the two animals in this respect either in the case of the mixed grain or of the bran. If anything, the tendency is toward a slightly higher digestibility by steer B, but all the differences are much less than those found between the light and heavy rations.

INFLUENCE OF AGE OF ANIMALS.

No comparison in this respect is possible between the experiments of the first year and those of the succeeding two, since the feed was different. The digestibility in the experiments of 1907 was, on the average, less than that found in the experiments of 1906, although again the differences are smaller than those found between the light and heavy rations. If we are justified in suspecting that the results obtained for the light ration in the experiments of 1906 are too high, the difference between the two animals in the two years becomes insignificant.

PERCENTAGE OF ENERGY METABOLIZABLE.

By metabolizable energy is understood that portion of the total potential energy of the feed which is capable of conversion into kinetic energy in the body. Expressed in another way, it is the total potential energy of the feed minus the potential energy of the excreta, the latter including the feces, urine, and methane or other combustible gases. The determination of the percentage of the feed energy metabolized is precisely similar to the determination of the digestibility of the feed in being a determination by difference, the only distinction in this respect being that in the one case only one excretum (the feces) is taken account of, while in the other all the excreta are considered. The percentage of energy metabolizable may be computed either upon the total potential energy of the feed or upon the potential energy of the digested matter, the latter method of expression having the advantage for some purposes of eliminating the effect of variations in digestibility. The results for metabolizable energy are given in detail in Part II of this bulletin and are summarized here. As in the case of the determination of digestibility, it is necessary to consider first the results upon the hay, and with these as a basis to compute the corresponding results for the grain.

TIMOTHY HAY.

The percentage losses of potential energy in the feces are of course the complements of the percentage digestibility as already given. The percentage losses in the urine and methane and the percentage of energy metabolizable are shown in Table 11.

TABLE 11.—*Percentage losses and percentages of energy metabolizable—Timothy hay.*

	Per cent of total energy.			Per cent of "digested" energy.		
	Submaintenance.	Maintenance.	True average.	Submaintenance.	Maintenance.	True average.
Percentage losses of energy in urine.						
Experiments of 1905:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Steer A	3.64	2.86	3.14	7.15	5.88	6.35
Steer B	3.20	2.79	2.95	6.42	5.42	5.81
Average	3.42	2.83	3.05	6.79	5.65	6.08
Experiments of 1906:						
Steer A	3.44	3.40	3.42	6.64	6.74	6.74
Steer B	3.72	3.70	3.71	6.94	7.12	7.05
Average	3.58	3.55	3.57	6.79	6.93	6.90
Experiments of 1907:						
Steer A	4.52	4.40	4.45	7.64	7.56	7.60
Steer B	4.97	4.61	4.74	8.51	8.01	8.19
Average	4.75	4.51	4.60	8.08	7.79	7.90
Percentage losses of energy in methane.						
Experiments of 1905:						
Steer A	6.87	6.75	6.80	13.49	13.88	13.74
Steer B	7.76	6.78	7.17	15.56	13.17	14.12
Average	7.32	6.77	6.99	14.53	13.53	13.93
Experiments of 1906 (computed from digested carbohydrates):						
Steer A	6.97	6.68	6.78	13.46	13.34	13.38
Steer B	7.24	6.92	7.04	13.51	13.30	13.38
Average	7.11	6.80	6.91	13.49	13.32	13.38
Experiments of 1907:						
Steer A	8.17	7.90	8.00	13.81	13.57	13.65
Steer B	8.38	7.84	8.04	14.34	13.61	13.89
Average	8.28	7.87	8.02	14.08	13.59	13.77
Percentage of energy metabolizable.						
Experiments of 1905:						
Steer A	40.43	39.01	39.52	79.36	80.24	79.91
Steer B	38.92	41.88	40.70	78.02	81.41	80.07
Average	39.68	40.45	40.11	78.69	80.83	79.99
Experiments of 1906:						
Steer A	41.37	40.01	40.52	79.90	79.87	79.88
Steer B	42.65	41.38	41.88	79.55	79.58	79.57
Average	42.01	40.70	41.20	79.73	79.73	79 73
Experiments of 1907:						
Steer A	46.49	45.93	46.14	78.55	78.87	78.75
Steer B	45.07	45.13	45.11	77.15	78.38	77 92
Average	45.78	45.53	45.63	77.85	78.63	78.34

In consequence of the relatively smaller losses in the feces (i. e., the greater digestibility) observed in 1907, the percentage of the total energy of the hay which was metabolizable was higher than in the two previous years, the average percentages for both animals being:

Percentage of total energy metabolizable.

	Per cent.
Experiment of 1905	40.11
Experiment of 1906	41.20
Experiment of 1907	45.63

When the influence of varying digestibility is eliminated by computing the percentage of "digested" energy metabolizable, this difference practically disappears, the results being:

Percentage of "digested" energy metabolizable.

	Per cent.
Experiment of 1905	79.99
Experiment of 1906	79.73
Experiment of 1907	78.34

Computed in this way, the percentage of the "digested" energy which was metabolizable shows a slight decrease from year to year which is chiefly due to an increasing percentage loss in the urine. The latter, however, may be plausibly accounted for by the greater richness of the hay in protein, especially in 1907. If this explanation be accepted, the experiments fail to give any indication of an influence of the age of the animal upon the percentage of energy metabolizable.

But very little difference is apparent between the two animals as respects the percentage of energy metabolizable. Averaging the results on the two animals for the three years we have the following:

TABLE 12.—*Percentage of energy of timothy hay metabolizable—Average of 3 years.*

	Submaintenance ration.	Maintenance ration.	Average.
	Per cent.	*Per cent.*	*Per cent.*
Total energy:			
Steer A	42.76	41.65	42.06
Steer B	42.21	42.80	42.56
"Digested" energy:			
Steer A	79.27	79.66	79.51
Steer B	78.24	79.79	79.19

Neither does the amount of hay consumed appear to have had any material influence, except possibly in the case of steer B, where a slightly greater loss both in the urine and the methane is recorded in the submaintenance periods. The differences, however, hardly seem significant.

GRAIN.

The data for the grain, as already noted, must be computed by difference and therefore are subject, like the results of a digestion experiment, to relatively large errors. The percentage losses in urine and methane and the percentages of energy metabolizable are summarized in Table 13.

TABLE 13.—*Percentage losses and percentages of energy metabolizable—Grain.*

	Per cent of total energy.			Per cent of "digested" energy.		
	Submaintenance.	Maintenance.	Average.	Submaintenance.	Maintenance.	Average.
Percentage losses of energy in urine.						
Experiments of 1905—Bran:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Steer A	5.06	4.90	4.98	7.51	7.25	7.38
Steer B	5.52	6.04	5.78	8.14	8.57	8.36
Average	5.29	5.47	5.38	7.83	7.91	7.87
Experiments of 1906—Mixed grain:						
Steer A	7.62	6.13	6.88	8.76	7.90	8.33
Steer B	8.19	6.86	7.53	9.48	8.89	9.19
Average	7.91	6.50	7.21	9.12	8.40	8.76
Experiments of 1907—Mixed grain:						
Steer A	6.78	6.28	6.53	8.52	8.02	8.27
Steer B	7.79	7.53	7.66	10.21	9.06	9.64
Average	7.29	6.91	7.10	9.37	8.54	8.96
Percentage losses of energy in methane						
Experiments of 1905—Bran:						
Steer A	8.04	6.93	7.49	11.94	10.25	11.10
Steer B	7.18	7.56	7.37	10.58	10.73	10.66
Average	7.61	7.25	7.43	11.26	10.49	10.88
Experiments of 1906—Mixed grain: [1]						
Steer A	8.30	7.63	7.97	9.54	9.83	9.69
Steer B	8.11	7.30	7.71	9.38	9.44	9.41
Average	8.21	7.47	7.84	9.46	9.64	9.55
Experiments of 1907—Mixed grain:						
Steer A	8.52	7.29	7.91	10.70	9.31	10.01
Steer B	9.42	8.72	9.07	12.35	10.48	11.42
Average	8.97	8.01	8.49	11.53	9.90	10.72
Percentage of energy metabolizable.						
Experiments of 1905—Bran:						
Steer A	54.24	55.77	55.01	80.55	82.50	81.53
Steer B	55.13	56.85	55.99	81.24	80.70	80.97
Average	54.69	56.31	55.50	80.90	81.60	81.25
Experiments of 1906—Mixed grain:						
Steer A	71.08	63.86	67.47	81.70	82.27	81.99
Steer B	70.10	63.18	66.64	81.14	81.67	81.41
Average	70.59	63.52	67.06	81.42	81.97	81.70
Experiments of 1907—Mixed grain:						
Steer A	64.28	64.70	64.49	80.78	82.67	81.73
Steer B	59.08	66.88	62.98	77.44	80.46	78.95
Average	61.68	65.79	63.74	79.11	81.57	80.34

[1] Computed from digested carbohydrates.

The greater digestibility of the mixed grain used in the second and third years as compared with that of the bran fed during the first year of course raises the percentage of the total energy metabolizable in the two latter years, the average results for the two animals being:

Percentage of total energy metabolizable.

	Per cent.
Experiment of 1905 (wheat bran)	55.50
Experiment of 1906 (mixed grain)	67.06
Experiment of 1907 (mixed grain)	63.74

As between the second and third years, the lower digestibility of the grain observed in 1907, of course, lowers correspondingly the percentage of the total energy metabolized. When, however, we eliminate the influence of the digestibility, by computing the results upon the "digested" energy, we obtain almost uniform results for the three years. The slightly lower figure for the last year is due, as in the case of the hay, to a slightly greater relative loss in the urine.

Percentage of "digested" energy metabolizable.

	Per cent.
Experiment of 1905 (wheat bran)	81.25
Experiment of 1906 (mixed grain)	81.70
Experiment of 1907 (mixed grain)	80.34

The percentage of "digested" energy metabolizable appears to have been slightly greater on the heavy than on the light ration, the difference being due to somewhat smaller losses in the methane. It is questionable, however, whether any of these differences are sufficiently large to be significant.

On the average of the results of all three years, disregarding the differences of feed in the first year, steer A shows a slight superiority over steer B in the percentage of energy metabolizable. This difference is largely due, however, to the comparatively low result obtained for steer B on the light ration of 1907. Except for this, the differences are very small and doubtless within the limits of error.

TABLE 14.—*Percentage of energy of grain metabolizable—Average of 3 years.*

	Light ration.	Heavy ration.	Average.
Total energy:	*Per cent.*	*Per cent.*	*Per cent.*
Steer A	63.20	61.44	62.32
Steer B	61.44	62.30	61.87
"Digested" energy:			
Steer A	81.01	82.48	81.75
Steer B	79.94	80.94	80.44

On the whole, the results for metabolizable energy agree closely with those obtained regarding the digestibility of the feed and fail to indicate with certainty any effect of age or of individuality upon either. This is quite what would have been expected and, so far as digestibility is concerned, is in accord with the results of other investigators. The process of digestion might be called, in a broad way, a chemical process. In healthy animals under normal conditions and after they have passed the stage of extreme youth, we may assume that the digestive enzyms are secreted in quantity sufficient to secure complete action upon all the food ingredients consumed, unless these are taken in excessive quantities. Furthermore, it may be assumed that by the time cattle have reached the age of 8 or 10 months a normal bacteriological flora has been established in the digestive tract. Under these conditions digestion may be said to be a chemical and bacteriological rather than a physiological process. It is a sort of incubation of materials which have not yet, strictly speaking, entered into the substance of the body at all. Under such conditions there is little scope for any effect of age or of individuality.

AVAILABILITY OF METABOLIZABLE ENERGY.

The metabolizable energy of a feeding stuff is that portion of its total potential energy which is capable of conversion into the kinetic form in the body. It corresponds to the conception of "Physiologischer Wärmewert," or "Physiologischer Nutzeffekt," introduced by Rubner [1] in connection with his experiments upon the replacement values of nutrients, or to the fuel values of Atwater.[2] Upon the results of these earlier experiments Rubner based his celebrated law of isodynamic replacement. This law is in effect that, when fed in limited quantities, the several nutrients may be substituted as sources of energy for body substances previously katabolized, or may replace each other, in amounts inversely proportional to their physiological heat values, or metabolizable energy. The validity of this law was generally accepted and not only were the relative values of single nutrients and of human dietaries estimated upon the basis of their metabolizable energy, but it was attempted also to apply Rubner's factors to the digestible protein, carbohydrates, and fats, so-called, of stock feeds and extensive tables of the fuel values of the latter computed in this way have been published. Moreover, there was a natural tendency to overlook the limitation which Rubner set to his law and to apply it to productive as well as to maintenance rations.

It has been clearly demonstrated, however, that only under special conditions is the metabolizable energy, or fuel value, of a nutrient or feeding stuff the measure of its value to the organism. This was shown clearly by the early experiments of Zuntz and his associates, which antedate Rubner's results, while later investigations have fully confirmed the earlier ones, the difference being especially marked in the case of herbivorous animals. Zuntz and Hagemann [3] have demonstrated that this is the case with the horse, especially upon the coarse

[1] Zeitschrift für Biologie; **21**, 250 and 337.

[2] U. S. Dept. of Agr., Office of Experiment Stations Bul. 21; Conn, (Storrs) Experiment Station, 12th Report (1899), p. 71.

[3] Landw. Jahrb., **18**, 1; **23**, 125; **27**, Ergänzbd. III.

feeds; Kellner[1] has shown the same thing to hold true in the fattening of cattle; we[2] have demonstrated that it also holds in the case of maintenance and submaintenance rations of cattle; and Rubner[3] himself has shown that his earlier results were due to the comparatively low temperatures at which he experimented and constituted a special case of a general law.

Opinions are still more or less divided as to the cause of the phenomenon, but there is no dispute as to the fact. Only a part of the metabolizable energy of the food is ordinarily substituted for energy previously derived from the katabolism of protein and fat in the body or is recovered in the gain of flesh and fat made by the body on abundant feeding.

METHOD OF DETERMINING AVAILABILITY.

The relation between the amount of metabolizable energy supplied to the animal in its feed and the resulting effect upon the body may be determined by a comparison of two periods in which different amounts of the feeding stuff or ration in question are consumed. For example, in Periods III and IV of the experiments of 1905 two different amounts of the same timothy hay were fed. After making the necessary corrections as described in succeeding paragraphs and in the detailed account of the experiments, it was found that the metabolizable energy of the rations consumed by steer A and the gain of energy by the animal (a loss being regarded as a negative gain) were as follows:

	Metabolizable energy of ration.	Gain of energy by animal.
	Calories.	*Calories.*
Period IV	5,981.4	− 680.2
Period III	3,641.4	−2,096.1
Difference	2,340.0	1,415.9

The excess of 2,340 calories of metabolizable energy in Period IV as compared with Period III reduced the loss of potential energy from the body by only 1,415.9 calories. In other words, only 60.5 per cent of the additional metabolizable energy supplied in Period IV was substituted for energy previously derived from the katabolism of body substance, while the remainder was disposed of by an increase of 924.1 calories in the heat production of the steer, corresponding to Rubner's "specific dynamic effect," the heat production rising from 5,635.8 calories to 6,559.9 calories (corrected). It is customary in such a case to speak of the 1,415.9 calories as the available energy of

[1] Landw. Vers. Stat., **44**, 257; **47**, 275; **50**, 245; **53**, 1.

[2] Bureau of Animal Industry Bulletins 51, 74, and 101; Landw. Jahrb., **32**, 665; **34**, 861; **37**, 423.

[3] Gesetze des Energieverbrauchs bei der Ernährung, 1902.

the hay added to the basal ration of Period III and to say that 60.5 per cent of the metabolizable energy of the hay was available. Such a method of statement does not necessarily imply that the remaining 39.5 per cent served no useful function in the body, but simply asserts that the net result to the organism was the same as if 60.5 per cent of the metabolizable energy were substituted unit for unit for energy derived from the katabolism of body substance and as if the remaining 39.5 per cent were useless. What the experiment really shows is that a unit of metabolizable energy in the hay had only 60.5 per cent of the value of a unit of metabolizable energy in the body substance (chiefly fat) previously katabolized, but the first method of expression is both common and convenient and may be retained. A precisely similar computation might, of course, be made, based upon the total instead of the metabolizable energy of the rations.

CORRECTIONS.

In a determination of the availability of feed energy it is, of course, essential that the two periods compared be identical, except as to the amount of feed consumed. In practice it is impossible to secure exact identity, and certain corrections usually become necessary. These are, in the order of their importance, a correction for the influence of standing and lying, a correction for the difference in the live weight of the animal, and a correction for unavoidable variations in the amount of the basal ration consumed.

Correction for standing and lying.—The authors have shown in previous experiments that standing as compared with lying causes a very material increase in the metabolism of cattle. These results were fully confirmed in the present investigation. By averaging those portions of each period which seemed free from irregularities due to the change from the standing to the lying position, and vice versa, with its accompanying change in the rate of flow of water through the heat absorbers, and which also seemed free from accidental irregularities, the average rate per minute at which heat was emitted by the animal by means of radiation and conduction and brought out of the calorimeter in the water current was computed for the standing and lying positions separately. The method is described in detail in Part II of this bulletin, in connection with the experiments of 1905 (p. 118), and the results are given in full in connection with the experiments of each of the three years. The percentage excess of heat given off in the standing as compared with the lying position was found to be as shown in Table 15, the percentage being calculated upon the amount given off while lying. The figures of the table render it obvious that any considerable difference in the proportion of time spent standing or lying in the two periods to be compared would seriously distort the result.

TABLE 15.—*Percentage increase in heat emission due to standing.*

	Experiments of 1905.	Experiments of 1906.	Experiments of 1907.
	Per cent.	*Per cent.*	*Per cent*
Steer A:			
Period I	50.0	34.2	31.3
Period II	37.9	44.4	48.5
Period III	48.3	32.9	34.6
Period IV	36.3	41.6	37.2
Steer B:			
Period I	31.8	38.5	39.7
Period II	36.0	44.4	50.1
Period III	43.6	40.1	36.6
Period IV	36.9	42.0	46.4

In a recent article[1] Zuntz has called attention to the apparently smaller influence of standing and lying upon the metabolism of the sheep, as computed from experiments by Hagemann,[2] in which the difference in the heat production as computed from the respiratory exchange was only 8 per cent. Dahm,[3] working in Zuntz's laboratory and by his methods, likewise found an increase of only 8 per cent in the respiratory excretion of carbon dioxide by a young bull when standing as compared with that when lying. Zuntz points out that even with a uniform rate of heat production the heat emission would tend to be less in the lying posture, since less of the animal's surface is exposed for radiation and evaporation. Zuntz is inclined to attribute the discrepancy between our results and those of Hagemann and of Dahm to this effect, or, in other words, to assume in our experiments a storing up of heat, either in the body of the animal or in the platform beneath him, during the periods of lying.

That there would be a tendency in this direction is undeniable, but we do not believe that it is of sufficient magnitude to seriously affect our comparison of the metabolism standing and lying. While it is impracticable at this time to enter into a detailed discussion of the point, we hope to do so on another occasion, but attention may be called to the fact that in making the comparisons contained in Table 15 those portions of the experiments immediately preceding or following the change from the one position to the other were excluded.

The foregoing results refer only to that part of the heat which was given off by radiation and conduction and taken up by the water current in the heat absorbers. No similar results are available for that portion of the heat which was given off as latent heat of water vapor, since only the total elimination of this substance during each subperiod of 12 hours was determined. A comparison[4] of the proportion of the total heat evolved which was given off as latent heat of

[1] Medizinische Klinik, 1910.

[2] Arch. (Anat. u.) Physiol., 1899, Suppl., p. 111.

[3] Biochem. Ztsch., 28, 494.

[4] The details of the comparison will be found on pages 122–124 of Part II of this bulletin.

water vapor in the 96 subperiods of the three years, however, fails to afford any indication that this proportion was affected by the proportion of time spent standing or lying, although the latter varied quite widely. Consequently it has been assumed that the amount of heat given off as latent heat of water vapor is proportional to that given off by radiation and conduction. On this basis the heat production of each period has been corrected to what it would have been had the animal stood for 12 hours out of each 24. The method of computing the correction may be conveniently illustrated by the results on steer A in Period I of the experiments of 1905, for which the following data are recorded:

Heat emission per day:	
By radiation and conduction....calories..	5, 217. 6
As latent heat of water vapor....do....	3, 293. 8
Total....do....	8, 511. 4
Percentage of heat in water vapor....	38. 70
Time standing....minutes..	1, 137
Time lying....do....	303
Heat by radiation and conduction, per minute:	
Standing....calories..	3. 8260
Lying....do....	2. 5509
Difference....do....	1. 2751

If we multiply the difference between the heat emission per minute when standing and when lying by one-half the difference in the number of minutes standing and lying, we obtain a correction which in this case must be subtracted from the observed heat to obtain the heat computed to 12 hours standing, as follows:

$$1.2751 \times 417 = 531.7 \text{ calories.}$$
$$5{,}217.2 - 531.7 = 4{,}685.9 \text{ calories.}$$

Assuming that the percentage of the total heat emitted which was given off by radiation and conduction would have remained the same, viz, 61.30 per cent, the total heat emission would have been:

$$4{,}685.9 \div 0.6130 = 7{,}644.8 \text{ calories.}$$

The corrected heat emission as thus computed has been used in calculating the gain or loss of energy by the body. The balances of energy as thus corrected and the corresponding gains are recorded in Part II of this bulletin in connection with each of the three series of experiments (pp. 126, 157, and 184).

Correction for live weight.—The varying rations consumed caused greater or less changes in the live weights of the animals, which presumably caused corresponding changes in their maintenance requirements. It is evident, however, that if the steer weighs more in the second period than in the first some of the feed added in the second period will be used to supply his increased maintenance requirement, and in this way the comparison between the two periods will be disturbed. The method used for correcting this error may be conveniently illustrated by the results obtained with steer A in Periods III and IV in the experiments of 1905, which have already served (p. 40) to illustrate the general method of determining availability. The basis of the correction is the assumption that the maintenance requirement, as measured by the fasting katabolism, is approximately proportional to the two-thirds power of the live weight. This has been shown by various experimenters to be the case, not only with different animals of the same species but even with different species. According to Kellner, it is true, the increase in the maintenance requirement during fattening is in a somewhat more rapid proportion, but for the rather small changes in weight in these experiments and for the purpose of computing a correction simply the assumption is probably sufficiently accurate.

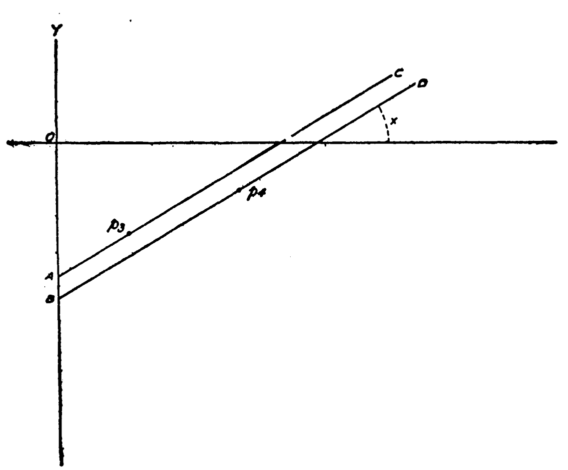


FIG. 6.—Correction for live weight.

In the periods selected as an illustration, the average of the last six weighings of steer A was: Period III, 268.8 kilograms; Period IV, 277.5 kilograms.

Assuming the fasting katabolism to be approximately proportional to the two-thirds power of the live weight, that of Period IV would be to that of Period III as 1 : 0.9781. In figure 6, in which the abscissas represent the metabolizable energy of the ration and the ordinates the gain of energy by the body, let the points p_3 and p_4 having the ordinates $x_3\,y_3$ and $x_4\,y_4$, respectively, represent the results obtained in Periods III and IV on the same animal. Through these points let there pass the parallel lines AC and BD, making with the axis of X the angle x, whose tangent would represent the percentage availability of the metabolizable energy of the hay. The distances OA and OB would then represent the fasting katabolism in the two periods and would be to each other as the two-thirds powers of the live weights. Letting $\frac{\text{OA}}{\text{OB}}=n$, and tang $x=m$, it may be shown that the value of m, that is, the availability of the metabolizable energy, is

$$m=\frac{y_3-ny_4}{x_3-nx_4}$$

Substituting the corresponding numerical values for steer A from Table 101, page 126, in Part II, viz,

$$x_3 = 3{,}641.4 \qquad y_3 = -2{,}096.1$$
$$x_4 = 6{,}115.3 \qquad y_4 = -\ \ 695.4$$
$$n = 0.9781$$

we find the percentage availability to be 60.51 per cent, as the following computation shows:

$$m = \frac{-2{,}096.1 - (0.9781 \times\ -695.4)}{3{,}641.4 - (0.9781 \times\ 6{,}115.3)} = 0.6051$$

Correction for variations in basal ration.—The availability of the energy of the grain is computed by comparison of a period in which both grain and hay were fed with a basal ration of hay alone. Such a comparison, of course, requires that the amount of hay consumed in each instance be the same, a condition which it is practically impossible to exactly fulfill.

The method of correction may be illustrated by the results upon steer A in Periods I and III of the experiments of 1905. The hay in Period I was intended to be the same in amount as in Period III, in which the basal ration was fed. On account of slight variations in the moisture content of the hay, however, the actual amounts of organic matter of hay consumed in the two periods varied slightly, so that the difference in metabolizable energy between the total rations of Periods I and III does not accurately represent the additional metabolizable energy derived from the bran. The total organic matter of the hay consumed was: In period III, 1,919.6 grams; in Period I, 1,894.3 grams; difference, 25.3 grams.

In the case of steer A, according to Table 94 of Part II (p. 116), the total organic matter of the hay contained, on the average of Periods III and IV, 1.853 calories of metabolizable energy per gram, of which 60.51 per cent, as just computed, was available. Applying these factors to the difference in the organic matter consumed in the hay, we may correct the results on Period I to what they would have been had the same amount of hay been consumed as in Period III, as follows:

	Organic matter of hay consumed.	Metabolizable energy of total ration (Table 101).	Gain by body (Table 101).
	Grams.	*Calories.*	*Calories.*
In Period I	1,894.3	6,889.1	−951.3
Correction for hay	+25.3	+46.9	+ 28.4
Period I, corrected	1,919.6	6,936.0	−922.9

The corrected results of Period I may then be compared with those of Period III, making a further correction for the difference in live weight in the same manner as in comparing Periods III and IV.

The average weight of the steer for the last six weighings of each of these periods was: Period III, 268.8 kilograms; Period I, 270.7 kilograms. The ratio of the fasting katabolism of Period III to that of Period I, represented by n in the previous formula, would therefore be:

$$n=\left(\frac{268.8}{270.7}\right)^{2/3}=0.9951$$

The corresponding values of x and y, after correction for the difference in the hay consumed, would be:

$$x_1=6{,}936.0 \qquad y_1=-\ 922.9$$
$$x_3=3{,}641.4 \qquad y_3=-2{,}096.1$$

Accordingly, the percentage availability, computed by the previous formula, is 36.11, the computation being as follows:

$$m=\frac{-2{,}096.1-(0.9951\times -922.9)}{3{,}641.4-(0.9951\times 6{,}936.0)}=0.3611$$

PERCENTAGE AVAILABILITY.

The availability of the metabolizable energy in the several experiments has been computed in the manner above illustrated. The data for the several corrections, as well as the details of the computation, are recorded in connection with the description of the individual calorimeter experiments in Part II and the final results are summarized in Table 16.

TABLE 16.—*Percentage availability of metabolizable energy.*

Ration.	1905		1906		1907	
	Steer A.	Steer B.	Steer A.	Steer B.	Steer A.	Steer B.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Timothy hay	60.51	55.21	71.49	60.86	57.05	56.50
Wheat bran:						
Periods II-III	58.74	51.98				
Periods I-III	36.11	53.10				
Periods II-I	84.13	50.55				
Mixed grain:						
Periods II-III			58.89	51.51	61.55	57.71
Periods I-III			74.02	41.12	58.18	58.73
Periods II-I			52.30	70.44	64.10	56.74

The foregoing results are also represented graphically in figures 7, 8, and 9, in which the abscissas represent the amounts of metabolizable energy in the several rations and the ordinates the corresponding gains of energy by the animal. The values for the several periods are those obtained after correcting for differences in live weight and in the amount of hay consumed. The percentage availability derived from a comparison of any two periods is equal, of course, to the tangent of the angle made by the corresponding line with the horizontal axis.

An inspection of the table and diagrams renders it evident that the results of the experiments of 1907, in which the closest agreement between the observed and computed heat production was obtained, are likewise the most consistent among themselves, while those of the two previous years show greater irregularities. The latter is especially the case with regard to the availability of the energy of

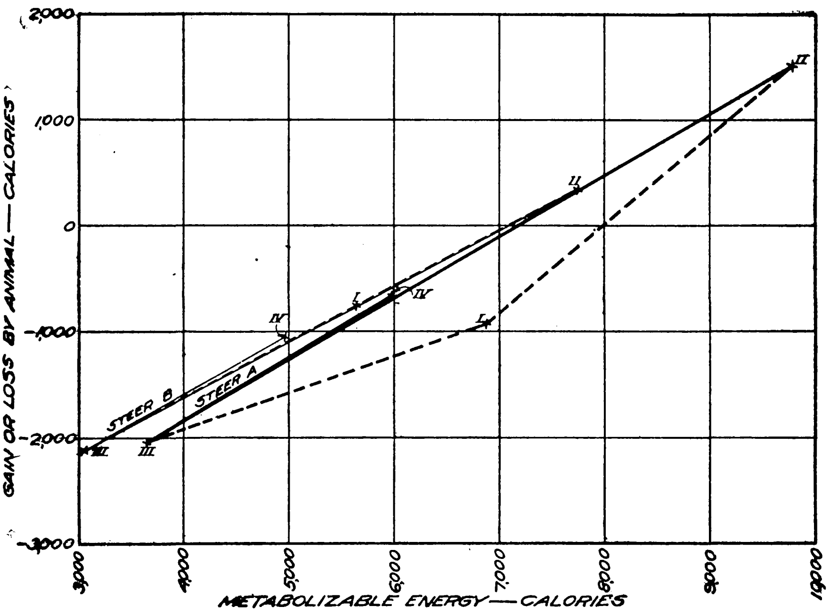


FIG. 7.—Availability of metabolizable energy, experiments of 1905.

the grain as computed respectively by a comparison of Periods I and III and of Periods II and I. On the other hand, if we regard Period III as the basal ration and compute the availability of the energy of the grain from a comparison of Periods II and III, the results in the three years are decidedly more concordant. Accordingly, in the figures the availability of the energy of the hay as shown by a comparison of Periods IV and III and that of the grain as computed by a comparison of Periods II and III are represented by full lines and the other results by broken lines.

AVAILABILITY ABOVE AND BELOW MAINTENANCE.

A computation of the availability by a comparison of Periods II and III assumes that the same percentage is available above and below the maintenance requirement. In previous publications [1] we have expressed the belief, based in part upon experimental results

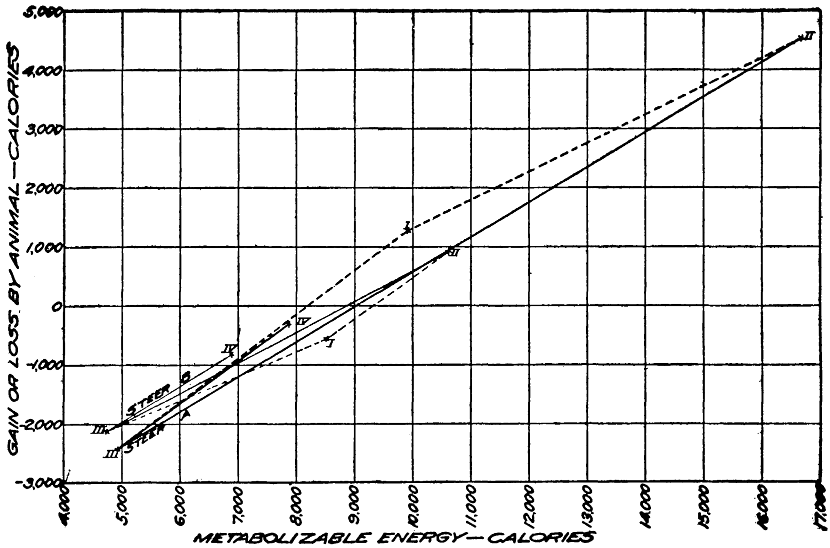


FIG. 8.—Availability of metabolizable energy, experiments of 1906.

and in part upon theoretical considerations, that this is not the case, but that the proportion of metabolizable energy capable of being

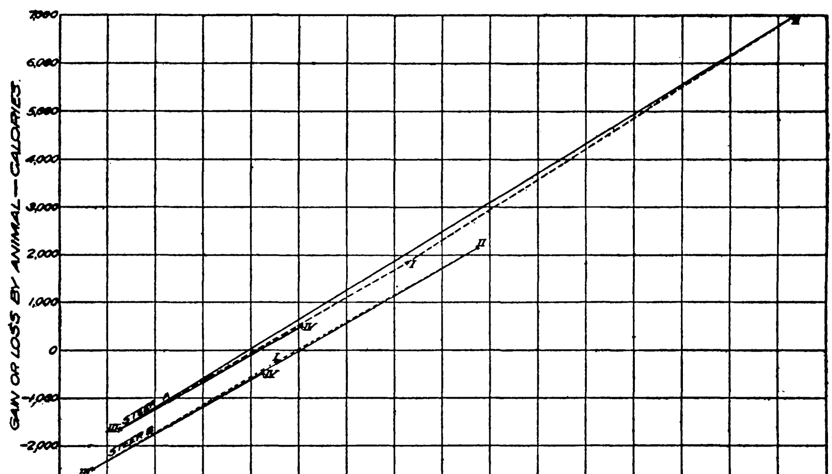


FIG. 9.—Availability of metabolizable energy, experiments of 1907.

stored up as gain after the maintenance requirement is satisfied is materially less than that available below the maintenance require-

[1] Bureau of Animal Industry Bul. 51, p. 64, and Bul. 74, pp. 42–44; "Principles of Animal Nutrition," pp. 444–446.

ment to diminish the loss of energy from the body. The results of the present series of experiments fail to support that view. The experiments upon hay alone were all upon quantities below the maintenance requirement, with the exception of steer A in Period IV of the experiments of 1907, and even in this case the ration was but slightly in excess of maintenance. In the case of the mixed rations of hay and grain, however, Period I, in which a light grain ration was added to the hay of the basal ration of Period III, was intended to be approximately a maintenance ration, while in Period II the amount of grain was increased so as to cause a material gain by the animals. As a matter of fact, the ration of Period I was less than the maintenance requirement of steer B in every case, while with steer A on the contrary it was somewhat above the maintenance requirement except in the experiments of 1905. If, now, it be true that the percentage availability is less above the maintenance requirement than below, then the availability computed from a comparison of Periods I and II should be less than that computed from a comparison of Periods I and III. In the experiments of 1907, in which, as noted, the results seem most concordant, the availability computed from Periods I and II is in one case greater than in the other case less than that computed from Periods I and III, the difference being relatively small in both cases. Both the figures of Table 16 and the graphic representation of the results appear to indicate clearly that in this series the percentage of the metabolizable energy of the grain which was available was substantially independent of whether the amounts consumed were above or below the maintenance requirement. In the other two years, in which the results are less satisfactory, the availability computed above the maintenance requirement, i. e., from Periods I and II, is in two cases greater and in two cases less than that computed below, but the differences are decidedly greater. In consideration of the greater weight attaching to the concordant results of the experiments of 1907, we are inclined to conclude that the percentage of the metabolizable energy of the grain available was substantially the same above and below the maintenance requirement and that the discrepancies in the earlier experiments are perhaps due to errors affecting particularly the results of Period I.

A reconsideration of the experimental evidence upon which we based our earlier view points to the same conclusion. In the experiments on timothy hay, reported in the first of the publications cited, only one period showed a gain of energy by the animal and this amounted to only 266 calories. Attention was called to this fact in the discussion of the results and it was specifically stated that much stress should not be laid upon the results of this period. In the experiments with corn meal in 1903, reported in the second of the publications cited, however, a gain of 3,525 calories was obtained in the period of heavy feeding, and from this we computed a percentage utilization of 53.28 as compared with a percentage availability below maintenance of 77.81. In this computation, however, we failed to take due account of the fact that in these experiments the proportion of time spent standing was notably greater in the period of heavy feeding (Period IV) than in the others, a fact which would tend to reduce the gain by the animal. In connection with the detailed description of the respiration calorimeter experiments in Part II of this bulletin, we have included a recalculation of the results, making the corrections for standing and lying, for live weight, and for differences in the amount of hay consumed in percisely the same manner as in the three series of experiments under discussion. In the experiments of 1903 the minimum ration of hay was given in Period II, the light grain ration (much below maintenance) in Period III and the heavy grain ration in Period IV. The final results for availability are as follows:

TABLE 17.—*Recalculated availability of metabolizable energy, 1903.*

	Per cent.
Red clover hay:	
Periods I–II	44.04
Corn meal:	
Light ration, Periods III–II	66.22
Heavy ration, Periods IV–II	69.12
Heavy ration, Periods IV–III	70.83

These figures, as well as the graphic representation of the results on figure 10, like those of the three series of 1905–1907, fail to give any evidence of a decreased availability above the point of maintenance as compared with that below.

SUMMARY OF AVAILABILITY.

If, then, we are justified in concluding that the percentage availability is the same above and below maintenance, it would seem that the most satisfactory measure of the availability of the energy of the grain in the experiments under discussion will be obtained by comparing the results of Period II, in which the maximum amount of grain was fed, with those of Period III upon hay alone, regarding the latter as the basal ration, since this comparison affords the widest range in the amount of grain consumed, thus presumably reducing the relative error. Upon this basis, we obtain the following comparison of the results upon the two animals in the three series of experiments:

TABLE 18.—*Summary of availability of metabolizable energy.*

	Steer A.	Steer B.
Timothy hay.		
Experiments of 1905	60.51	55.21
Experiments of 1906	71.49	60.86
Experiments of 1907	57.05	56.50
Wheat bran.		
Experiments of 1905	58.74	51.98
Mixed grain.		
Experiments of 1906	58.89	51.51
Experiments of 1907	61.55	57.71

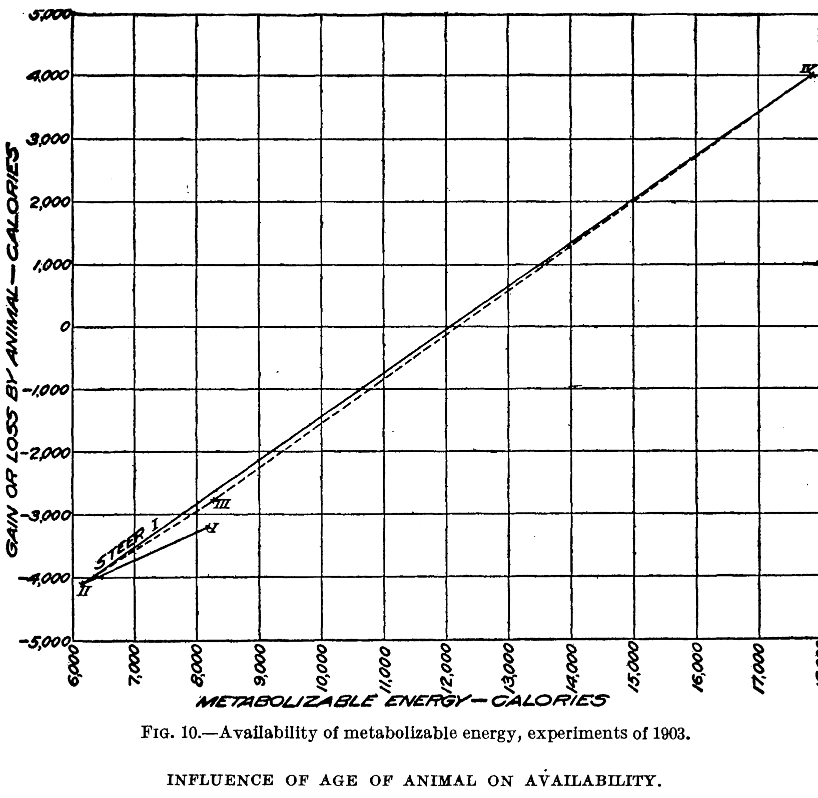


FIG. 10.—Availability of metabolizable energy, experiments of 1903.

INFLUENCE OF AGE OF ANIMAL ON AVAILABILITY.

One of the objects of the investigation was to compare the percentage availability in the same animal at different ages. This purpose was largely frustrated, however, by the impossibility of obtaining hay of identical quality in the three years and likewise by the necessity of changing to a mixed-grain ration in order to secure the consumption of an adequate amount.

As noted in the discussion of the results upon digestibility, the hay used in 1905 was of decidedly poorer quality than that of the other two years, being low in protein and high in crude fiber. The latter fact, as has been well established by Kellner's investigations, tends to increase the expenditure of energy in digestion and assimilation, or, in other words, to diminish the percentage availability of the energy. Notwithstanding this, however, the availability found for the poorer hay, as compared with that observed with the better quality in 1907, was but 1.29 less in the case of steer B, and 3.46 greater with steer A. These results might be taken to indicate a relatively greater availability by the younger animal were it not for the rather unsatisfactory character of the experiments of 1905. The results on the hay in 1906 seem abnormally high, being greater for each animal than those for the grain.

In the case of the grain a comparison of the results in 1906 and 1907 upon practically identical mixtures shows a higher percentage availability in the case of the older animal, especially with steer B, although here, too, the differences are rather small. On the whole, while the results as regards the influence of age are indecisive, they afford little support to the belief in a greater ability of young animals to utilize the metabolizable energy of their feed.

INFLUENCE OF INDIVIDUALITY UPON AVAILABILITY.

It is not easy to form a judgment as to the probable error involved in the results of complicated experiments like the foregoing, and the significance of small differences may readily be exaggerated. In the experiments of 1907, which, as already pointed out, are the most satisfactory of the three series, there is a difference in the percentage availability of 3.84 in the case of the grain and 0.55 in that of the hay in favor of steer A as compared with steer B. These differences are small, and in the case of the hay especially seem practically negligible. They appear to gain somewhat in significance, however, from the fact that the differences observed in the earlier, even though less satisfactory series, are not only greater but also are uniformly in the same direction. Even including the less satisfactory comparisons contained in Table 16, this fact is true in 9 cases out of 12. Taking the results as a whole, therefore, they seem to indicate a small but distinct superiority of steer A over steer B as regards the availability of the metabolizable energy of the feed. This difference appears to be more marked in the earlier years, while as the animals matured steer B nearly or quite overtook steer A in this respect, so that it seems questionable whether the differences in the third year's experiments are of much significance.

As regards the explanation of such a difference, only speculations can be presented. It is not easy to conceive how any metabolic process or set of processes, such, for example, as are involved in the production of fat from carbohydrates, can be conducted more efficiently in one individual than in another. It would seem that if such a difference between individuals exists as is indicated by the foregoing results we must seek for its explanation in differences in the character of the body substance gained or katabolized. Upon this point, of course, respiration-calorimeter experiments afford but meager information. They show the total gain or loss of ash, nitrogenous matter, and fat (and glycogen), but reveal nothing as to the part of the body where they are deposited or katabolized, nor as to the exact nature of the material involved. It may not be without significance in this connection that, as shown on previous pages, the growth of steer A was more largely in body girth, while steer B increased relatively more rapidly in length and height, or that, as will appear later, steer A showed a tendency to fatten, while steer B inclined to gain relatively more nitrogenous material. In other words, the difference in availability may conceivably be related to the apparent difference in the nature of the gains or losses.

THE ENERGY REQUIREMENT FOR MAINTENANCE.

From the results of the two periods on hay alone in each year it is easy to compute, on the one hand, the amount by which it would have been necessary to increase the supply of metabolizable energy to prevent any loss of potential energy from the body, or, on the other hand, to calculate the amount of potential energy which would have been lost by the animal had the ration been reduced to zero.

Thus in the case of steer A in the experiments of 1907, for example, the metabolizable energy of the hay consumed daily in Period III was 6,234.5 calories, and on this ration the body lost daily 1,679.4 calories, while a comparison with Period IV (compare p. 51) shows an availability of the metabolizable energy of 57.05 per cent. Evidently, then, to prevent the loss from the body of 1,679.4 calories it would have been necessary to add to the daily ration sufficient hay to supply $1,679.4 \div 0.5705 = 2,943.7$ calories of metabolizable energy, making the total metabolizable energy of the daily ration $2,943.7 + 6,234.5 = 9,178.2$ calories.

If, on the other hand, the ration had been reduced to zero, the loss of energy per day by the animal would have been increased by $6,234.5 \times 0.5705 = 3,556.8$ calories and the total loss would have been $1,679.4 + 3,556.8 = 5,236.2$ calories.

A precisely similar computation may, of course, be made from the data of Period IV.

In figure 11, let the points A and B represent the results of Periods III and IV, plotted in the same manner as in figure 9, the metabolizable energy in the two periods being represented, respectively, by OE and OF and the gain or loss by the animal by EA and FB, while the line AB, intersecting the horizontal axis at C, represents the percentage availability. It is plain, then, that OC represents the amount of metabolizable energy required to reduce the loss from the body to zero, that is, for maintenance, while OD evidently represents the body loss that would have occurred if the supply of metabolizable energy had been reduced to zero. That is, OD represents the computed fasting katabolism,[1] or the amount of energy actually required for the necessary internal work of the body, while the value of OC shows the amount of metabolizable energy having this particular percentage of availability, viz, 57.05, which would have been required to reach equilibrium. In other words, the maintenance *ration*, expressed in terms of metabolizable energy, is variable depending upon the percentage availability of the energy, while the maintenance *requirement* expressed in terms of the computed fasting katabolism is constant for the same animal under the same external conditions. Any ration therefore which will supply available energy equal to OD will be a maintenance ration. Thus, if the metabolizable energy of a ration had an availability of 65 per cent, represented by the line DG, the maintenance requirement in terms of available energy would still be represented by OD, but the maintenance ration expressed in terms of metabolizable energy would equal not OC but OG. Plainly it is preferable, therefore, to express the maintenance requirement as a constant in terms of available energy.

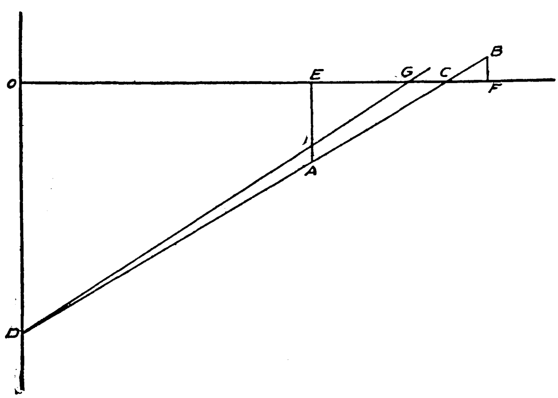


FIG. 11.—The maintenance requirement.

The computation of the maintenance requirements of the two animals in these experiments suffers from the more or less unsatisfactory nature of the results obtained with regard to the availability of the metabolizable energy of the hay in the first two years. In the experiments of 1906 in particular, the percentage availability of the energy of the hay appears to be too high. In the case of steer A especially the results are not only larger than those obtained in 1905 and in 1907, but are higher than the figures found for the availability of the mixed grain, a result which seems unlikely. The hay used was similar in composition and digestibility to that used in 1907 and the computation of the maintenance requirement has been made by assuming the availability of its energy to have been the same as that found for the corresponding animal in the year 1907.

[1] On the assumption, of course, that the experiment is made at or above the critical external temperature for the animal.

Computed on this assumption and in the manner shown in the foregoing example, the maintenance requirements of the two animals in the three series of experiments were as shown in Table 19. For the sake of ready comparison, the results have also been recalculated to a uniform weight of 500 kilograms in proportion to the two-thirds power of the live weight.

TABLE 19.—*Computed maintenance requirements in terms of available energy.*

	Steer A.	Steer B.
Per day and head:	*Calories.*	*Calories.*
Experiments of 1905	4,396	3,946
Experiments of 1906	5,228	4,801
Experiments of 1907	5,236	5,821
Per day and 500 kilos live weight:		
Experiments of 1905	6,649	7,532
Experiments of 1906	6,077	6,806
Experiments of 1907	5,186	6,931

The experiments of 1907, the results of which are the most satisfactory, show a marked difference between the two animals as regards the maintenance requirement, that of steer B being 33.7 per cent higher than that of steer A. The results obtained in 1905 and 1906 naturally have less weight, but nevertheless they show a difference in the same general direction. On the average of the three years' experiments the available energy required for maintenance per 500 kilograms live weight was: Steer A, 5,971 calories; steer B, 7,090 calories. Even omitting the relatively low result for steer A in 1907, the average for steer A is materially lower than that for steer B.

The correction of the results to a uniform time of 12 hours standing may be assumed to have approximately eliminated any difference in the maintenance requirement due to the influence of standing or lying. Steer B possessed the active, nervous temperament of the dairy type, while steer A showed the quiet, almost phlegmatic disposition of the typical beef animal. The figures appear to show that this difference in temperament, aside from any effect which it had upon the amount of time spent standing or lying, very materially affected the maintenance requirement. If such differences prove to be characteristic of the two types of animals, they will go far toward explaining the economic superiority of the beef type.

With the exception of steer B in 1907, the relative maintenance requirement shows a marked decrease from year to year. We may conjecture that this is due to lessened muscular activity with advancing maturity.

ENERGY VALUES OF FEEDING STUFFS.

In order to have a basis for estimating the available energy of the rations in periods not covered by the calorimeter experiments, it appears desirable to compute from the foregoing results the energy values of the feeds used, while it will be of interest also to compare the experimental results with those obtained by applying Kellner's factors to the digestible nutrients as computed from the results of the digestion experiments.

TIMOTHY HAY.

The total chemical energy of the hay in each of the three years is recorded in Table 4, page 26, while the average percentage of it which was metabolizable is shown in Table 12, page 36, the difference between the two animals in this respect being insignificant. The percentage availability of the metabolizable energy, as shown in Table 18, page 51, and in the subsequent discussion, appears to have been slightly greater by steer A than by steer B, but the differences seem too small to be of any importance in such a general comparison of rations as is attempted on subsequent pages. Accordingly, the average percentage availability by the two animals is made the basis of the computation. Furthermore, as noted in the discussion of the percentage availability, the results upon hay in the year 1906 are questionable. They have therefore been rejected in the following computation and the average result with the two animals in the experiments of 1907 has been used, as was the case in the computation of the maintenance requirement on page 55. The content of available energy therefore has been calculated from the metabolizable energy by the use of the following percentages of availability:

	Per cent.
Experiments of 1905	57.86
Experiments of 1906	56.78
Experiments of 1907	

Computed in this way, the energy values of the hay are:

TABLE 20.—*Energy values per gram of dry matter of timothy hay.*

	Experiments of—		
	1905	1906	1907
	Calories.	*Calories.*	*Calories.*
Digested energy	2.2243	2.3347	2.6266
Metabolizable energy	1.7782	1.8610	2.0567
Available energy	1.0288	1.0567	1.1678

WHEAT BRAN.

But one series of experiments, viz, that of 1905, was made upon wheat bran alone. As was the case with the hay, the percentage of the total energy metabolizable, as shown in Table 13, page 37, differed but slightly as between the two animals. The percentage availability of the metabolizable energy was 6.76 per cent greater with steer A than with steer B, but it may be questioned whether this difference is significant. The energy values of the wheat bran are as follows:

TABLE 21.—*Energy values per gram of dry matter of wheat bran.*

	Calories.
Digested energy	3.0942
Metabolizable energy	2.5149
Available energy:	
Steer A	1.4773
Steer B	1.3072
Average	1.3923

MIXED GRAIN.

The mixed grain in the experiments of 1906 and 1907 consisted, as previously stated, of 1 part by weight of wheat bran, 3 of corn meal, and 3 of old-process linseed meal. The energy values of the separate ingredients of this mixture were not determined, but only that of the mixture as a whole. Using the averages of the results obtained with the two animals for the percentage of the total energy digestible, metabolizable, and available, we have the following results:

TABLE 22.—*Energy values per gram of dry matter of mixed grain.*

	Experiments of— 1906	1907	Average of the 2 years.
	Calories.	*Calories.*	*Calories.*
Digested energy	3.8508	3.7032	3.7770
Metabolizable energy	3.1457	2.9758	3.0608
Available energy:			
Steer A	1.8525	1.8316	1.8421
Steer B	1.6204	1.7173	1.6689
Average	1.7365	1.7745	1.7555

COMPUTED ENERGY VALUES.

Applying to the average composition of the feeds used in the three experiments as shown in Tables 4 and 7, pages 26 and 31, the average of the coefficients for the two steers as recorded in Tables 5 and 8, pages 27 and 32, we obtain the figures of Table 23 for the so-called digestible nutrients computed in the customary way. The corn meal used in the investigations of 1903, reported in Bulletin No. 74 of this bureau, the availability of whose energy is recalculated on page 50, has also been included in the table.

TABLE 23.—*Digestible nutrients in dry matter of feeding stuffs.*

	Timothy hay. 1905	Timothy hay. 1906	Timothy hay. 1907	Wheat bran. 1905.	Mixed grain. 1906	Mixed grain. 1907	Mixed grain. Average.	Corn meal. 1903.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Protein	0.73	2.35	3.02	11.18	12.61	13.80	13.20	6.58
Nonprotein	.39	.83	.24	.49	3.43	2.22	2.83	.48
Carbohydrates [1]	49.89	47.89	55.33	47.95	57.05	56.50	56.78	80.39
Ether extract	.96	1.25	1.04	3.31	6.03	4.77	5.40	4.05
Total	51.97	52.32	59.63	62.93	79.12	77.29	78.21	91.50

[1] Sum of digestible crude fiber and digestible nitrogen-free extract.

From the results contained in Table 23, together with the percentage of total crude fiber contained in the several feeds, we may compute their production values according to Kellner by the use of the factors which he has worked out. These are:[1]

Production values per gram.

	Calories.
Digestible protein	2.24
Digestible starch and crude fiber	2.36
Digestible cane sugar	1.79
Digestible ether extract:	
In coarse fodders	4.50
In cereals and legumes and their by-products	5.00
In feeds containing over 5 per cent of fat	5.70

The factor for the protein is applied only to the true protein, the nonprotein being ignored in the computation. From the total energy thus computed there must be deducted in the case of hay, straw, and similar coarse fodders 1.36 calories and in the case of chaff and like materials 0.66 calories for each gram of total crude fiber present. In the case of concentrated feeds the total is multiplied by a percentage expressing the relative energy value of the digestible matter as compared with digestible starch or other pure nutrients, these percentages (Wertigkeit) being based on the results of experiments by Kellner which have not yet been published in full. As applied, for example, to the hay of the experiments of 1907, the computation would be as follows:

In 1 gram dry matter.

		Calories.
Digestible protein	0.0302×2.24=	0.0676
Digestible carbohydrates	.5533×2.36=	1.3058
Digestible ether extract	.0104×4.50=	.0468
		1.4202
Total crude fiber	.3115×1.36=	.4237
Production value		.9965

For the grains used in these experiments Kellner gives the following percentages by which the production values as obtained by computation from the digestible protein, carbohydrates, and fat are to be multiplied: Wheat bran, 77 per cent; corn meal, 100 per cent; linseed cake, 97 per cent. For a mixture of these in the proportion used in these experiments the average value would be 95 per cent. Kellner's production values attempt to show the amount of energy which will be stored up in the body of an animal as gain of flesh and fat when a unit of the feed is added to a ration already fully sufficient for maintenance.

[1] "Die Ernährung der Landwirtschaftl. Nutztiere," 5th ed., pp. 149 and 159.

TABLE 24.—*Comparison of observed and computed energy values per gram dry matter.*

Feed.	Observed available energy.	Computed production values.	Computed ÷observed.
	Calories.	*Calories.*	*Per cent.*
Timothy hay:			
Experiments of 1905	1.0288	0.7183	69.82
Experiments of 1906	1.0567	.7900	74.76
Experiments of 1907	1.1678	.9965	85.33
Average of American timothy hay [1]	....	.8525	....
Wheat bran:			
Experiments of 1905—			
Steer A	1.4773	....	....
Steer B	1.3072	....	....
Average	1.3923	1.1916	85.58
Mixed grains:			
Experiments of 1906—			
Steer A	1.8525	....	....
Steer B	1.6204	....	....
Average	1.7365	1.8314	105.47
Experiments of 1907—			
Steer A	1.8316	....	....
Steer B	1.7173	....	....
Average	1.7745	1.7870	100.70
Average of both years—			
Steer A	1.8421	....	....
Steer B	1.6689	....	....
Average	1.7555	1.8092	103.07
Corn meal:			
Experiments of 1903 [2]	2.3460	2.2471	95.78

[1] U. S. Department of Agriculture, Farmers' Bulletin 346, p. 15.
[2] Using corrected availability for Periods IV–II, Table 17.

As was shown on pages 47–50, our results indicate that in the case of the grain the availability was the same above and below the point of maintenance and the very good agreement between the observed and computed energy values shown by the foregoing table in the case of the mixed grain, especially in the experiments of 1907, appears entirely in harmony with this conclusion.

On the other hand, the results upon the hay show a marked discrepancy, the computed energy value ranging from 70 to 85 per cent of the observed. The observed results on the hay, however, represent substantially the availability of its energy below the point of maintenance and the comparison perhaps indicates that on the light hay rations used in these experiments the availability of the energy is greater than when, as in Kellner's experiments, the hay is added to a liberal basal ration and when, therefore, the volume of the contents of the alimentary canal is considerably greater. In other words, it seems not impossible that, as Kellner has suggested,[1] there may be an optimum volume of the contents of the digestive tract below which the expenditure of energy in the mechanical work

[1] "Die Ernährung der Landwirtschaftl. Nutztiere," 5th ed., p. 164.

of digestion is not materially affected by the amount of food consumed. It is hoped that subsequent experiments now in process of computation may throw some light upon this point.

It will be noted that the results obtained upon the bran in 1905 show almost as great a discrepancy as compared with the computed as do those obtained upon the hay. No obvious explanation of this difference presents itself, although it may be noted that all the rations in this series of experiments were comparatively light.

THE INTERMEDIATE FEEDING PERIODS.

The prime object of the respiration-calorimeter experiments was to compare the digestibility of the feeding stuffs and the percentage of their energy metabolizable, as well as the availability of the latter, by the two animals and in the successive seasons. For these purposes, especially the latter, it was necessary in some periods to give rations less in amount than the maintenance requirement. As already stated, there were four respiration-calorimeter periods each winter, covering in all, including preliminary and transition feeding, about three months. During three of these periods the animals were on rations either below or but little above the maintenance requirement. The ration of the remaining period was fairly comparable in kind and amount with the feeding during the remainder of the year, but this period was interpolated between two periods of low feeding and was too short (three to four weeks) to give the determination of the gain of live weight any material value. During about three months of each year, therefore, the live weight of the animals, especially of steer B, was either at a standstill or showed only a very moderate gain. During the remaining nine months of the year, designated as "intermediate feeding periods," the aim was to supply a ration which should be sufficient to produce normal growth but not such as to fatten the animals.

RATIONS CONSUMED.

At the outset of the investigation and up to April 12, 1906, inclusive, with the exception, as stated, of the respiration-calorimeter periods of 1905, the grain consisted of the same mixture which was employed in the respiration-calorimeter experiments of the second and third years, viz:

	Parts by weight.
Clear corn meal	3
Linseed meal	3
Wheat bran	1

From that time until July 31, 1906, inclusive, the grain mixture consisted of—

	Parts by weight.
Corn and cob meal	3
Linseed meal	1
Wheat bran	1

From August 1 to December 15, 1906, the use of linseed meal was discontinued, the grain ration consisting of—

	Parts by weight.
Corn and cob meal	2
Wheat bran	1

During the remainder of the investigation the animals were either upon the rations of the respiration calorimeter periods or those preliminary to them.

The coarse feed for the intermediate periods above referred to consisted during the winter of mixed clover and timothy hay, the timothy predominating. During the summer and fall of each year, viz, from July 16 to October 5, 1905, and from July 7 to November 30, 1906, the hay was replaced by the green soiling crops or ensilage which were being fed to the dairy herd.

Each animal received, per 1,000 pounds live weight, 7 pounds of the grain mixture, the amount of feed being based upon the average of three weighings of the animal at the end of each month. The amount of coarse fodder consumed was regulated by the appetite of the animal.

FEEDING RECORD.

The complete feeding records of the two animals, exclusive of the calorimeter periods, are contained in Table III of the appendix. The following summary, Table 25, shows the totals and averages for the periods into which the feeding naturally divides itself according to the kinds of feed consumed, and corresponding also to the grouping of the live weight results in Table 52, page 78. In those periods in which green soiling crops were fed, the air-dry weights consumed, as computed from the percentages given in Table III of the appendix, are recorded as being most nearly comparable with the gross weights of the other feeding stuffs. The percentage of air-dry matter in the soiling crops was determined, in connection with the observations on the dairy herd, upon a composite daily sample representing the entire period during which the given feed was used.

TABLE 25.—*Intermediate feeding periods—Feeding record per head.*

Date of feeding period.	Number of days.	Mixed hay.	Timothy hay.	Soiling crops, air-dry.	Wheat bran.	Corn meal.	Corn and cob meal.	Linseed meal.	Total air-dry feed.	Average air-dry feed per day.
Steer A.		*Kilos.*	*Kilos.*	*Kilos.*	*Kilos.*	*Kilos.*	*Kilos.*	*Kilos.*	*Kilos.*	*Kilos.*
Oct. 1 to Dec. 10, 1904	71	252.2	....	....	17.73	53.18	....	53.18	376.29	5.30
Apr. 2 to July 15, 1905	105	258.8	72.00	....	36.74	110.22	....	110.22	587.98	5.60
July 16 to Oct. 5, 1905	82	5.2	....	205.26	29.29	87.86	....	87.86	415.47	5.07
Oct. 6 to Dec. 3, 1905	59	131.7	79.83	....	20.86	62.58	....	62.58	357.55	6.06
Apr. 8 to July 6, 1906	90	478.6	....	....	53.09	6.00	153.26	57.09	748.04	8.31
July 7 to 31, 1906	25	....	....	47.40	12.00	....	36.00	12.00	107.40	4.30
Aug. 1 to Oct. 25, 1906	87	2.0	....	167.65	72.50	....	145.00	....	387.15	4.45
Oct. 26 to Dec. 15, 1906	50	190.6	....	55.94	34.66	....	69.32	....	350.52	7.01
Steer B.										
Oct. 1 to Dec. 10, 1904	71	252.2	....	....	12.49	37.47	....	37.47	339.63	4.78
May 7 to July 15, 1905	70	234.7	....	....	19.99	59.97	....	59.97	374.63	5.35
July 16 to Oct. 5, 1905	82	4.4	....	204.91	23.42	70.27	....	70.27	373.27	4.55
Oct. 6 to Dec. 3, 1905	59	133.6	70.88	....	16.34	49.02	....	49.02	318.86	5.40
Apr. 15 to July 6, 1906	83	386.3	....	....	36.35	....	109.04	36.35	568.04	6.84
July 7 to 31, 1906	25	....	....	47.00	11.16	....	33.48	11.16	102.80	4.11
Aug. 1 to Oct. 25, 1906	87	....	....	185.30	68.28	....	136.56	....	390.14	4.48
Oct. 26 to Dec. 15, 1906	50	160.6	....	55.94	33.47	....	66.94	....	316.95	6.34

Owing to his smaller size, steer B consumed somewhat less air-dry feed than did steer A. In proportion to his size, however, he consumed notably more. This is true in every case when the comparison is made per thousand pounds of live weight. If the comparison is made on the basis of the two-thirds power of the live weight (that is, approximately in proportion to the surface), only one exception to the rule occurs.

COMPOSITION OF FEEDING STUFFS.

Tables 26 and 27 contain the results of the analyses which were made of the feeding stuffs used in the intermediate feeding periods and in the digestion and metabolism experiments which were included in those periods. The results are grouped under the same dates shown in Table 25, the date at which the samples were taken being also shown. Details regarding the exact period covered by each sample, as well as other particulars, will be found in the notes appended to the tables. In a considerable number of instances only the loss of moisture on air drying and the nitrogen in the air-dry material were determined. To facilitate comparison of the results, the partial dryings have therefore been tabulated. In a few instances, due to an oversight, the moisture in the air-dry feeding stuff was not determined, and it has been necessary to assume a figure for it. These assumed percentages, as well as all the percentages affected by the assumption, are distinguished by being inclosed in brackets.

TABLE 26.—*Composition of feeding stuffs in intermediate feeding periods.*

Feed and period.	Date of sampling.	Air-dry matter in fresh substance.	In air-dry matter.		Dry matter in fresh substance.	In dry matter.							
			Dry matter.	Nitrogen.		Ash.	Protein.	Non-protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Total nitrogen.	Energy, calories per gram.
		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Mixed hay.													
Oct. 1 to Dec. 10, 1904	Nov. 26, 1904	......	......	......	......	8.09	12.88		28.25	50.78		2.060	......
	....do	......	......	......	......	7.92	13.20		28.30	50.58		2.112	......
	Nov. 28, 1904[1]	91.80	[89.79]	1.873	[82.42]	......	......	......	......	......	......	[2.086]	......
Apr. 2 to July 15, 1905	June 28, 1905[1]	92.50	90.99	2.020	84.25	6.69	12.25	1.22	30.39	46.09	3.36	2.220	4.5940
Oct. 6 to Dec. 3, 1905	Oct. 4, 1905	99.23(?)	......	1.210	......	......	......	......	......	......	......	......	......
	Oct. 31, 1905	90.70	95.22	1.640	86.36	6.32	9.06	1.28	29.88	51.08	2.38	1.722	......
	Nov. 6, 1905[1]	91.97	95.28	1.490	87.63	5.98	8.26	2.14	31.70	48.83	3.09	1.564	4.5005
Apr. 8 to July 6, 1906	Oct. 31, 1905[2]	......	......	......	......	......	......	......	......	......	......	......	......
	June 18, 1906[1]	98.04	88.44	1.803	86.71	7.12	11.14	1.20	30.04	47.91	2.59	2.039	4.4531
Oct. 26 to Dec. 15, 1906	June 18, 1906[2]	......	......	......	......	......	......	......	......	......	......	......	......
Wheat bran.													
Oct. 1 to Dec. 10, 1904	Oct. 1, 1904	92.10	[94.42]	2.475	[86.96]	[8.81]	[14.94]		[10.55]	[65.70]		[2.621]	......
	Nov. 29, 1904[1]	91.50	[94.42]	2.460	[86.39]	......	......	......	......	......	......	[2.606]	......
Apr. 2 to July 15, 1905	June 28, 1905[1]	98.00	90.51	2.397	88.70	7.02	12.54	2.12	10.13	63.02	5.17	2.648	4.5841
July 16 to Oct. 5, 1905	Aug. 2, 1905	97.26	......	2.515	......	......	......	......	......	......	......	......	......
Oct. 6 to Dec. 3, 1905	Oct. 13, 1905	Lost.	......	2.567	......	......	......	......	......	......	......	......	......
	Nov. 4, 1905[1]	91.84	95.45	2.705	87.66	7.08	13.38	2.32	9.70	63.58	3.94	2.840	4.5058
	Dec. 4, 1905	92.00	......	2.985	......	......	......	......	......	......	......	......	......
Apr. 8 to July 6, 1906	Oct. 13, 1905[3] Dec. 4, 1905	92.00	90.16	2.759	82.96	7.30	12.67	3.93	9.82	62.37	3.91	3.060	......
	Apr. 11, 1906	93.30	......	2.806	......	......	......	......	......	......	......	......	......
	June 11, 1906	92.60	......	2.743	......	......	......	......	......	......	......	......	......
	June 16, 1906[1]	96.00	90.16	2.716	86.56	7.56	14.56	2.15	9.65	61.07	5.01	3.012	4.5397
July 7 to 31, 1906	June 11, 1906[2]	......	......	......	......	......	......	......	......	......	......	......	......
Aug. 1 to Oct. 25, 1906	July 30, 1906	98.00	......	2.634	......	......	......	......	......	......	......	......	......
	Oct. 4, 1906	93.20	......	2.604	......	......	......	......	......	......	......	......	......
Oct. 26 to Dec. 15, 1906	Oct. 4, 1906[2]	......	......	......	......	......	......	......	......	......	......	......	......
Corn meal.													
Oct. 1 to Dec. 10, 1904	Oct. 1, 1904	92.80	[90.12]	1.450	[83.63]	[1.52]	[9.65]		[1.84]	[86.99]		[1.609]	......
	Nov. 29, 1904[1]	92.50	[90.12]	1.413	[83.36]	......	......	......	......	......	......	[1.568]	......
Apr. 2 to July 15, 1905	June 28, 1905[1]	96.80	89.91	1.337	87.03	1.48	8.22	0.61	2.40	83.69	3.60	1.487	4.4773
July 16 to Oct. 5, 1905	Aug. 2, 1905	96.33	......	1.475	......	......	......	......	......	......	......	......	......

[1] Sample for digestion and metabolism. [2] See above. [3] Composite sample.

TABLE 26.—*Composition of feeding stuffs in intermediate feeding periods*—Continued.

Feed and period	Date of sampling.	Air-dry matter in fresh substance.	In air-dry matter.		Dry matter in fresh substance.	In dry matter.							
			Dry matter.	Nitrogen.		Ash.	Protein.	Non-protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Total nitrogen.	Energy, calories per gram.
Corn meal—Continued.		*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
	Oct. 13, 1905[1]	92.00	....	1.440	....	....	....	....	....	....	....	....	....
Oct. 6 to Dec. 3, 1905	Nov. 4, 1905[2]	91.25	95.38	1.490	87.03	1.39	8.99	0.30	2.27	84.14	2.91	1.562	4.4077
	Dec. 4, 1905[1]	88.83	....	1.495	....	....	....	....	....	....	....	....	....
	Oct. 13, 1905 / Dec. 4, 1905[3]	....	92.58	1.487	....	1.83	9.21	0.34	2.23	82.91	3.48	1.606	....
Apr. 8 to July 6, 1906	Apr. 11, 1906[5]	93.50		1.375									
	June 11, 1906[5]	91.50	....	1.398	....	....	....	....	....	....	....	....	....
	June 16, 1906[2,5]	93.30	90.37	1.336	86.13	1.76	8.54	0.26	8.41	77.14	3.89	1.478	4.5233
July 7 to 31, 1906	June 11, 1906[4]	....	....	....	....	....	....	....	....	....	....	....	....
Aug. 1 to Oct. 25, 1906	July 30, 1906[5]	81.00	....	1.071	....	....	....	....	....	....	....	....	....
	Oct. 4, 1906[5]	94.60	....	1.258	....	....	....	....	....	....	....	....	....
Oct. 26 to Dec. 15, 1906	do.[4]	....	....	....	....	....	....	....	....	....	....	....	....
Linseed meal.													
Oct. 1 to Dec. 10, 1904	Oct. 1, 1904	94.40	[94.64]	5.235	[89.34]	[5.78]	[30.46]		[9.39]	[54.37]		[5.540]	....
	Nov. 29, 1904[2]	93.50	[94.64]	5.383	[88.49]	....	....	....	....	....	....	....	....
Apr. 2 to July 15, 1905	June 28, 1905[2]	[0]	90.85	5.060	[90.85]	5.67	27.21	2.93	9.46	47.07	7.66	5.570	4.9244
July 16 to Oct. 5, 1905	Aug. 2, 1905	98.00	....	5.490	....	....	....	....	....	....	....	....	....
	Oct. 13, 1905	95.00	....	5.995	....	....	....	....	....	....	....	....	....
Oct. 6 to Dec. 3, 1905	Nov. 4, 1905	95.77	94.52	5.925	90.52	4.91	29.87	3.58	8.00	52.15	1.49	6.192	4.7838
	Dec. 4, 1905	94.00	....	5.885	....	....	....	....	....	....	....	....	....
	Oct. 13, 1905 / Dec. 4, 1905[3]	....	92.07	5.861	....	4.94	27.98	6.02	9.43	44.25	7.38	6.366	....
Apr. 8 to July 6, 1906	Apr. 11, 1906	97.20		5.391									
	June 11, 1906	96.30	....	5.278	....	....	....	....	....	....	....	....	....
	June 16, 1906[2]	96.30	91.44	5.626	88.05	5.62	26.05	6.66	9.09	44.56	8.02	6.153	4.9642
July 7 to 31, 1906	June 11, 1906[4]	....	....	....	....	....	....	....	....	....	....	....	....

[1] See below.
[2] Sample for digestion and metabolism trial.
[3] Composite sample.
[4] See above.
[5] Corn and cob meal.

TABLE 27.—*Composition of green forage used in intermediate feeding periods.*

Date.	Feedstuff.	Air-dry matter in fresh substance.	Nitrogen in air-dry substance.
1905.		*Per cent.*	*Per cent.*
July 16 to 28	Alfalfa	25.74	2.70
July 29 to Aug. 8	Soy beans	20.75	2.11
Aug. 9 to 14	Cowpeas	14.26	2.75
Aug. 15 to 31	Kafir corn and cowpeas	16.57	1.37
Sept. 1 to 5	Alfalfa	25.60	3.11
Sept. 6 to 20	Cowpeas	15.70	2.88
Sept. 21 to Oct. 3	Corn fodder	12.00	1.83
Oct. 4 to 5	Clover and grass	62.50	2.34
1906.			
July 7 to 8	Clover and timothy	48.80	1.40
July 9 to 16	Oats and peas	12.19	2.58
July 17 to 20	Alfalfa	27.37	2.66
July 21 to Aug. 3	Silage (mixed grasses)	30.20	2.00
Aug. 4 to 21	Corn fodder	16.79	....
Aug. 22 to 28	Alfalfa	20.71	2.75
Aug. 29 to Sept. 2	Cowpeas	17.16	2.59
Sept. 3 to 7	Alfalfa	28.36	2.55
Sept. 8 to 21	Kafir corn and cowpeas	13.34	1.84
Sept. 22 to 30	Corn fodder	No sample.	No sample.
Oct. 1 to 4	Grass	No sample.	No sample.
Oct. 5 to 9	Alfalfa	20.52	2.67
Oct. 10 to 12	Corn fodder	No sample.	No sample.
Oct. 13 to 25	Corn silage	No sample.	No sample.

NOTES ON COMPOSITION OF FEEDING STUFFS.

October 1 to December 10, 1904: During October and November long hay was fed. On November 26, 1904, a portion of the same hay was cut for the digestion trials of December 1 to 10 and duplicate samples were taken in which the composition of the dry matter was determined. The average of these two analyses is regarded as representing the composition of the dry matter of the hay used in the digestion trial and also of that previously fed. On November 28, when the feeds were weighed out for the digestion trial, a second sample was taken in which only the loss in air drying and the nitrogen were determined. The percentage of moisture in the air-dry matter has been computed on the assumption that the nitrogen content was the same as the average of the two previous samples.

In the samples of grain taken during this period the determination of the moisture in the air-dry material was overlooked. The percentage given in the table is estimated from that found in similar samples in these and previous experiments.

April 2 to July 15, 1905: From April 2 to 26, steer A was fed timothy hay from the stock used for the preceding respiration-calorimeter experiments. A sample of the mixed hay used during the remainder of this time was taken on June 28, 1905, when feed was weighed out for the digestion and metabolism trial, and the same is true of the sampling of the grain.

October 6 to December 3, 1905: On October 4, hay, consisting chiefly of timothy, was weighed out and used until October 30. Beginning October 31, another lot of mixed hay containing but little clover was used, a considerable quantity being cut and mixed. This hay is represented by the samples of October 31 and November 6, 1905, the latter being taken when the feed was weighed out for the digestion trial. This hay was used up to December 3.

On October 13 and November 4, 1905, samples of the grain were taken, both samples being of the same lot, the second being taken at the time when feeds were weighed out for the digestion trials. Another set of samples of the same lot was taken December 4. The samples of October 13 and December 4 were subsequently united and an analysis made of the composite sample.

April 8 to July 6, 1906: Mixed hay, represented by the sample of October 31, 1905, was fed to both steers up to May 18, 1906, inclusive. The hay subsequently fed is represented by the sample of June 6, 1906, taken when the feed was weighed out for the digestion trial. The grain fed to steer A up to April 11 is represented by the composite of the samples taken October 13, 1905, and December 4, 1905.

The samples of April 11 and June 11, 1906, represent the mixed grain fed between April 12 and June 20, 1906, while subsequent to June 20 the grain used is represented by the samples of June 16, 1906, taken when the feed was weighed out for the digestion trial.

July 7 to 31, 1906: The grain fed during this time was the same as that represented by the sample of June 11, 1906, in the previous period.

August 1 to October 25, 1906: The grain is represented by the samples of July 30 and October 4, 1906, in which air-dry matter and nitrogen only were determined. The first sample was taken from the lot fed from August 1 to October 3, and the second sample from that fed from October 4 to October 25, 1906.

October 26 to December, 1906: Hay was fed from the lot represented by the sample of June 18, 1906, in the previous period, and the grain was the same as that represented by the samples of October 4, 1906, in the previous period.

For convenience of comparison the average composition of the feeding stuffs used in the calorimeter experiments is given in Table 28.

TABLE 28.—*Composition of feeding stuffs used in calorimeter experiments.*

Component.	Timothy hay.			Wheat bran.			Corn meal.		Linseed meal.	
	1904–5 [1]	1905–6 [1]	1906–7 [1]	1904–5 [1]	1905–6 [2]	1906–7 [2]	1905–6 [2]	1906–7 [2]	1905–6 [2]	1906–7 [2]
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Ash	4.87	5.86	5.01	7.52	6.92	7.08	1.52	1.49	5.76	5.81
Protein [3]	5.08	6.72	6.90	14.50	14.22	13.40	9.20	9.92	25.65	27.48
Nonprotein [3]	.39	.83	.24	.49	2.62	3.10	.63	.34	6.50	3.80
Crude fiber	38.14	33.02	31.15	11.49	9.60	10.23	2.13	2.14	8.88	8.83
Nitrogen-free extract	49.51	51.01	54.55	61.88	61.90	62.20	81.26	82.07	44.85	47.44
Ether extract	2.01	2.56	2.15	4.12	4.74	3.99	5.26	4.04	8.36	6.64
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Total nitrogen	.894	1.251	1.155	2.648	3.053	3.012	1.668	1.725	6.047	5.807
Protein nitrogen	.812	1.075	1.104	2.544	2.495	2.351	1.534	1.653	4.664	4.998

[1] Average of two "general samples."
[2] Average of samples for Periods I and II.
[3] Computed from nitrogen, using the factors stated in Part III, page 203.

DIGESTION AND METABOLISM TRIALS.

As was stated in the introduction, four digestion and metabolism trials were made in the course of the intermediate feeding periods. The trials were made simultaneously upon the two animals, in the building containing the respiration calorimeter, upon the following dates:

TABLE 29.—*Dates of digestion and metabolism trials.*

Year.	Preliminary period.	Excreta collected.
1904	Nov. 1 to 30	Dec. 1 to 10,
1905	July 1 to 5	July 6 to 15.
1905	Nov. 8 to 12	Nov. 13 to 22.
1906	June 20 to 26	June 27 to July 6.

The purpose of these trials was to secure such data as was possible regarding the actual amounts of digestible matter and of metabolizable energy consumed by the steers during the several periods of the feeding and also to determine by means of the nitrogen balance the rate of growth of nitrogenous tissue in the two steers at different ages.

To secure the first of these objects, the attempt was made to have the rations in the digestion trials representative of those consumed during the intervening time. While, however, they corresponded quite closely in most cases with those of the previous two to four weeks, the variations in the hay eaten during the several periods were not inconsiderable. Consequently, it is not possible to apply the coefficients of digestibility obtained in the digestion trials directly to the average mixed rations of the corresponding periods. Nevertheless, as will appear, the results of the digestion trials may be made the basis of a fairly accurate computation of the metabolizable energy of the rations actually consumed. On the other hand, the results of these trials afford no sufficient basis for a comparison of the digestive powers of the two animals, nor of those of the same animal at different ages.

The details of these digestion and metabolism trials are recorded in Part II, pages 187 to 199. The total digestible nutrients, including the "digested" energy, in each trial were as shown in the following table:

TABLE 30.—*Digested nutrients in digestion and metabolism trials.*

Component.	Steer A.				Steer B.			
	Dec. 1 to 10, 1904.	July 6 to 15, 1905.	Nov. 13 to 22, 1905.	June 27 to July 6, 1906.	Dec. 1 to 10, 1904.	July 6 to 15, 1905.	Nov. 13 to 22, 1905.	June 27 to July 6, 1906.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Protein[1]	216.7	403.0	406.6	450.4	260.6	349.0	363.1	380.9
Nonprotein[1]		70.0	109.5	106.6		61.5	103.1	81.2
Crude fiber	354.8	327.4	620.4	812.0	394.8	448.5	615.7	659.8
Nitrogen-free extract	1,345.6	1,957.4	2,157.1	2,990.0	1,338.4	1,796.2	1,982.7	2,254.8
Ether extract		157.6	107.5	194.7		141.8	101.7	141.6
Total organic matter	1,917.1	2,915.4	3,401.1	4,553.7	1,993.8	2,797.0	3,166.3	3,518.3
Ash	32.8	96.5	85.9	191.4	87.9	112.5	84.2	146.1
Total dry matter	1,949.9	3,011.9	3,487.0	4,745.1	2,081.7	2,909.5	3,250.5	3,664.4
Total nitrogen	45.6	85.1	89.6	100.1	45.6	73.4	79.2	82.1
	Calories.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Energy	....	13,756.6	15,609.9	21,024.7	....	13,290.8	14,565.7	16,063.2
True protein, estimating nonprotein at average of other 3 trials	151.2	....	....	....	197.0	....	....	....

[1] Computed from nitrogen, using the factors stated in Part III, page 203.

NITROGEN AND ENERGY BALANCES.

The nitrogen balances of the four trials are tabulated in Part II, pages 197–199. With the exception of the first trial (Dec. 1 to 10, 1904), determinations of energy were made in the feed and feces, while the energy of the urine was also determined in the first, second, and fourth trials. The results of the determinations on the feeds and feces are tabulated in Part II in connection with the analyses of those materials. Table 31 contains the results on the urine:

TABLE 31.—*Energy per gram of urine.*

Date of experiment.	Steer A.	Steer B.
	Calories per gram.	*Calories per gram.*
Dec. 1 to 10, 1904	0.2271	0.2713
July 6 to 15, 1905	.1265	.2615
June 27 to July 6, 1906	.2949	.3010

The ration of November 13 to 22, 1905, did not differ widely from that of June 27 to July 6, 1906, and the energy of the urine in the former trial may be computed from that found in the latter, in proportion to the urinary nitrogen, without serious error.

Applying these figures to the weights of urine excreted, as shown in the detailed records of the experiments in Part II, upon the assumption that the energy content of the spilled urine and washings was proportional to its nitrogen content, gives the following results for the total energy of the urine:

TABLE 32.—*Total energy of daily urine.*

Date of experiment.	Steer A.	Steer B.
	Calories.	*Calories.*
Dec. 1 to 10, 1904	1,238	1,412
July 6 to 15, 1905	1,088	1,028
Nov. 13 to 22, 1905	[1] 1,363	[1] 1,266
June 27 to July 6, 1906	1,599	1,361

[1] Computed from nitrogen.

The production of methane in the digestion trials can be computed approximately from the total amount of carbohydrates digested. On the average of the respiration-calorimeter experiments of 1905 and of 1907 (compare p. 142) there were excreted 3.65 grams of carbon in the form of methane for each 100 grams of carbohydrates (nitrogen-free extract plus crude fiber) digested. Applying this factor to these experiments we can compute approximately the loss of potential energy in methane with the following results:

TABLE 33.—*Approximate daily loss of energy in methane.*

Date of experiment.	Steer A.	Steer B.
	Calories.	*Calories.*
Dec. 1 to 10, 1904	1,106	1,128
July 6 to 15, 1905	1,487	1,461
Nov. 13 to 22, 1905	1,807	1,691
June 27 to July 6, 1906	2,474	1,897

Combining the foregoing figures and estimates for the urine and methane with the data as to energy contained in the detailed report of the digestion trials in Part II, we may add to the nitrogen balance in each case a partial energy balance showing the approximate amount of metabolizable energy contained in the ration in each trial. The energy of the estimated hair and brushings is computed from the estimated nitrogen, the average for the three series of respiration-calorimeter experiments being 65.9 calories per gram nitrogen. The results of this computation are as follows, those figures depending upon estimates being distinguished by brackets:

TABLE 34.—*Nitrogen and partial energy balances in digestion trials.*

	Steer A.				Steer B.			
	Nitrogen.		Energy.		Nitrogen.		Energy.	
	Income.	Outgo.	Income.	Outgo.	Income.	Outgo.	Income.	Outgo.
Dec. 1 to 10, 1904.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Mixed hay	62.5		[13,507]		62.5		[13,507]	
Wheat bran	5.8		[997]		4.1		[707]	
Corn meal	10.2		[2,818]		7.2		[2,000]	
Linseed meal	37.3		[3,294]		26.5		[2,337]	
Uneaten feed		31.6		[4,682]		13.7		[1,935]
Feces		44.0		[7,229]		41.0		[7,384]
Urine		78.5		1,238		69.8		1,412
Hair and brushings (estimated)		[1.4]		[92]		[1.2]		[79]
Methane				[1,106]				[1,128]
Nitrogen balance	39.7				25.4			
Metabolizable energy				6,269				6,613
Total	155.5	155.5	20,616	20,616	125.7	125.7	18,551	18,551
July 6 to 15, 1905.								
Mixed hay	52.3		10,827		52.3		10,827	
Wheat bran	8.5		1,464		6.7		1,159	
Corn meal	14.0		4,208		11.1		3,332	
Linseed meal	53.5		4,832		42.3		3,825	
Feces		43.2		7,574		39.0		5,852
Urine		79.1		1,088		65.9		1,028
Hair and brushings (estimated)		[1.5]		[99]		[1.2]		[79]
Methane				[1,487]				[1,461]
Nitrogen balance		4.4				6.3		
Metabolizable energy				11,083				10,723
Total	128.2	128.2	21,331	21,331	112.4	112.4	19,143	19,143
Nov. 13 to 22, 1905.								
Mixed hay	47.2		13,566		49.3		14,197	
Wheat bran	9.0		1,422		7.1		1,126	
Corn meal	14.7		4,143		11.6		3,280	
New process linseed meal	60.5		4,677		47.9		3,703	
Feces		41.8		8,198		36.7		7,740
Urine		85.0		[1,363]		72.4		[1,266]
Hair and brushings		[1.7]		[112]		[1.4]		[92]
Methane				[1,807]				[1,691]
Nitrogen balance		2.9				5.4		
Metabolizable energy				12,328				11,517
Total	131.4	131.4	23,808	23,808	115.9	115.9	22,306	22,306
June 27 to July 6, 1906.								
Mixed hay	90.5		19,769		72.1		15,753	
Wheat bran	16.6		2,495		12.0		1,808	
Corn-and-cob meal	24.2		7,421		17.6		5,376	
Linseed meal	34.4		2,776		24.9		2,011	
Feces		65.6		11,436		44.5		8,884
Urine		99.7		1,599		77.9		1,361
Hair and brushings		[1.9]		[125]		[1.6]		[105]
Methane				[2,474]				[1,897]
Nitrogen balance	1.5					2.6		
Metabolizable energy				16,827				12,701
Total	167.2	167.2	32,461	32,461	126.6	126.6	24,948	24,948

PROTEIN AND ENERGY CONTENT OF RATIONS FOR ENTIRE PERIODS.

As stated in the foregoing paragraphs, the rations consumed in the digestion and metabolism trials did not correspond exactly with the average of those consumed in the corresponding feeding periods. The differences do not appear to be great enough, however, in most cases to prevent the computation of a correction which shall give at least a reasonably accurate result for the protein and energy content of the rations of the entire periods.

Protein.—The mixed grain in the respiration-calorimeter experiments of 1906 and 1907 contained on the average 17.46 per cent of protein, which had a percentage digestibility of 75.6, making the average percentage of digestible protein in the dry matter 13.2 per cent.

Computed from the composition of the separate feeds, the mixed grain of the last digestion trial contained 13.25 per cent of protein. If we assume the same percentage digestibility for this as for that of the other three periods, viz, 75.6, this is equivalent to 10.02 per cent digestible protein in the dry matter.

The average percentage digestibility of the protein of the hay in the respiration-calorimeter experiments of 1907 was 43.7 per cent. The mixed hay of the general feeding, however, contained considerably more protein, the percentage ranging from 8.26 to 12.25 as compared with 6.90 in the timothy hay. We may presume that along with this higher proportion of protein there went a higher percentage digestibility. The experiments afford no means of computing it separately, but we have arbitrarily assumed a digestibility of 50 per cent.

Tabulating the foregoing results, we have the following:

TABLE 35.—*Digestible protein in dry matter of feeds in intermediate feeding periods.*

Date of experiment.	Hay.	Mixed grain.
	Per cent.	Per cent.
Oct. 1 to Dec. 10, 1905	[1] 5.79	13.20 (Oct. 1, 1905 to Dec. 3, 1905)
Apr. 2 to July 15, 1905	6.13	
Oct. 6 to Dec. 3, 1905	4.13	
Apr. 8 to July 16, 1906	5.57	10.02

[1] Assuming an average percentage of 1.46 nonprotein.

Energy.—For the purpose of computing corrections for the energy values, factors may be derived from the results of the respiration-calorimeter experiments.

The hay used in the general feeding was mixed clover and timothy, while that of the respiration-calorimeter experiments was timothy alone. The chemical composition of the former, however, except for the higher percentage of protein, corresponded fairly well with that of the timothy hay of the respiration-calorimeter experiments of 1907, especially as regards the percentage of crude fiber, and the energy results for the two animals in that year have been used in computing the factor for the correction.

The grains in the first three digestion and metabolism trials were substantially the same as in the respiration calorimeter experiments of 1906 and 1907 as appears from a comparison of their chemical composition as shown in Tables 26 and 28, and accordingly we may apply to the mixture the average results for steers A and B in the two years. In the fourth trial (June 27 to July 6, 1906) the proportions of the single grains were different and corn-and-cob meal was used in place of corn meal. Probably these changes would result in a somewhat lower percentage availability, but simply for use as a correction we may tentatively assume the same factors.

The factors to be used for correcting the energy results, then, as derived from Tables 18, 20, and 22, pages 51, 56, and 57, are as follows:

TABLE 36.—*Estimated energy values of feeds in intermediate periods.*

Feed.	Metabolizable energy per gram of dry matter.	Percentage availability of metabolizable energy.	Available energy per gram of dry matter.
	Calories.	*Per cent.*	*Calories.*
Mixed hay	2.057	56.78	1.168
Mixed grain	3.061	57.43	1.756

Applying the foregoing factors to the differences between the hay and grain consumed in the metabolism trials and in the whole periods, we may make the following computations of the protein and energy values of the rations consumed in the several periods.

OCTOBER 1 TO DECEMBER 10, 1904.

The average feed consumption for the entire period, computed from the data contained in Tables 25 and 26, pages 62 and 63, as compared with that of the digestion trial of December 1 to 10, 1904, is shown in the following table:

TABLE 37.—*Comparison of feed consumed per day.*

Feed.	Steer A.				Steer B.			
	Whole period, Oct. 1 to Dec. 10, 1904.		Metabolism trial, Dec. 1 to 10, 1904.		Whole period, Oct. 1 to Dec. 10, 1904.		Metabolism trial, Dec. 1 to 10, 1904.	
	Fresh weight.	Dry matter.	Fresh weight.	Dry matter.	Fresh weight.	Dry matter.	Fresh weight.	Dry matter.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Wheat bran	250	217	254	219	176	153	180	156
Corn meal	749	626	761	634	528	442	540	450
Linseed meal	749	669	761	673	528	472	540	478
Total grain	1,748	1,512	1,776	1,526	1,232	1,067	1,260	1,084
Mixed hay	3,552	2,928	2,492	1,954	3,552	2,928	3,120	2,563

The succeeding table shows the excess or deficiency of the grain and hay consumed in the whole period as compared with the corresponding quantities in the digestion trial, and the equivalent amounts of digestible protein and of metabolizable energy computed by the use of the factors contained in Tables 35 and 36. These corrections, added to the digestible protein and metabolizable energy found in the metabolism trial give the approximate amounts of the same ingredients in the average ration of the whole period.

TABLE 38.—*Digestible protein and metabolizable energy in entire period.*

	Steer A.			Steer B.		
	Dry matter.	Digestible protein.	Metabolizable energy.	Dry matter.	Digestible protein.	Metabolizable energy.
	Grams.	*Grams.*	*Calories.*	*Grams.*	*Grams.*	*Calories.*
Difference in grain	− 13	− 1.7	− 40	− 17	− 2.2	− 52
Difference in hay	+974	+ 56.4	+2,003	+365	+ 21.1	+ 751
Total correction	....	+ 54.7	+1,963	....	+ 18.9	+ 699
Found in metabolism trial	....	151.2	6,269	....	197.0	6,613
Computed for whole period	....	205.9	8,232	....	215.9	7,312

In this instance, the rations of the digestion trial differed quite widely as regards the ratio of hay to grain from the average ration of the period, while the results obtained, as noted, were questionable, especially as regards the nitrogen balance. (Compare pp. 192 and 197.) It will probably be more accurate, therefore, to compute the digestible protein and the energy values directly from the average daily feed consumed during the period by applying to the total dry matter of the grain and hay eaten as shown in Table 37 the same factors used above. The following are the results of this computation:

TABLE 39.—*Computed digestible protein and energy per day in entire period.*

	Steer A.	Steer B.
Digestible protein ... grams	374.4	315.7
Metabolizable energy ... calories	10,651	9,289
Available energy ... do	6,075	5,294

APRIL 2[1] TO JULY 15, 1905.

A comparison of the average daily feed consumed, as computed from Tables 25 and 26, with the amounts eaten during the metabolism trial of July 6 to 15, 1905, shows much smaller differences than in the period previously considered.

[1] May 2 for steer B.

TABLE 40.—*Comparison of feed consumed per day.*

Feed.	Steer A.				Steer B.			
	Whole period, Apr. 2 to July 15, 1905.		Metabolism trial, July 6 to 15, 1905.		Whole period, May 2 to July 15, 1905.		Metabolism trial, July 6 to 15, 1905.	
	Fresh weight.	Dry matter.	Fresh weight.	Dry matter.	Fresh weight.	Dry matter.	Fresh weight.	Dry matter.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Wheat bran	350	310	360	319	286	254	285	253
Corn meal	1,050	914	1,080	940	857	746	855	744
Linseed meal	1,050	954	1,080	981	857	779	855	777
Total grain	2,450	2,178	2,520	2,240	2,000	1,779	1,995	1,774
Mixed hay	3,150	2,654	2,800	2,357	3,353	2,825	2,800	2,357

Correcting the results of the metabolism trial for the differences in the dry matter of grain and hay consumed as compared with the whole period, in the same manner as in the previous case, the following results are obtained:

TABLE 41.—*Digestible protein and metabolizable energy per day in entire period.*

	Steer A.			Steer B.		
	Dry matter.	Digestible protein.	Metabolizable energy.	Dry matter.	Digestible protein.	Metabolizable energy.
	Grams.	*Grams.*	*Calories.*	*Grams.*	*Grams.*	*Calories.*
Difference in grain	− 62	− 8.2	−190	+ 5	+ 0.7	+ 15
Difference in hay	+297	+18.2	+611	+468	+28.7	+963
Total correction	....	+10.0	+421	....	+29.4	+978
Found in metabolism trial	....	403.0	11,083	....	349.0	10,723
Computed for whole period	....	413.0	11,504	....	378.4	11,701

As a check upon the results of Table 41, the digestible protein and metabolizable energy has also been computed from the average amounts of dry matter consumed per day during the whole period with the following results:

TABLE 42.—*Computed digestible protein and metabolizable energy per day in entire period.*

	Steer A.	Steer B.
Digestible protein:		
From hay .... grams	162.7	173.2
From grain .... do	287.5	234.8
Total .... do	450.2	308.0
Metabolizable energy:		
From hay .... calories	5,460	5,811
From grain .... do	6,667	5,446
Total .... do	12,127	11,257

The fairly good agreement of the results obtained by these two methods indicates the absence of any serious error.

The difference between the percentage availability of the hay and that of the mixed grain, as shown in Table 36, is so small that for these approximate computations we may apply the average of the two results, viz, 57.11 per cent, to the total metabolizable energy of the whole ration. Computed in this way the available energy of the ration of this period as computed, on the one hand, from the corrected results of the metabolism trial, and, on the other hand, from the total dry matter consumed, is as follows: From digestion trial—Steer A, 6,570 calories; steer B, 6,682 calories. From dry matter eaten—Steer A, 6,925 calories; steer B, 6,428 calories.

OCTOBER 6 TO DECEMBER 3, 1905.

Comparing the feed consumed in the entire period with that eaten in the digestion trial of November 13 to 22, 1905, we obtain the following results:

TABLE 43.—*Comparison of feed consumed per day.*

Feed.	Steer A.				Steer B.			
	Whole period, Oct. 6 to Dec. 3, 1905.		Metabolism trial, Nov. 13 to 22, 1905.		Whole period, Oct. 6 to Dec. 3, 1905.		Metabolism trial, Nov. 13 to 22, 1905.	
	Fresh weight.	Dry matter.	Fresh weight.	Dry matter.	Fresh weight.	Dry matter.	Fresh weight.	Dry matter.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Wheat bran	354	310	360	316	277	243	285	250
Corn meal	1,061	923	1,080	940	831	723	855	744
Linseed meal	1,061	960	1,080	978	831	752	855	774
Total grain	2,476	2,193	2,520	2,234	1,939	1,718	1,995	1,768
Hay	3,585	3,119	3,440	3,014	3,466	3,016	3,600	3,155

The metabolizable energy computed from the results of the metabolism trials by correcting for differences in the amounts of hay and grain consumed and that computed directly from the average dry matter eaten during the entire period are as follows:

TABLE 44.—*Digestible protein and metabolizable energy per day in entire period.*

	Steer A.			Steer B.		
	Dry matter.	Digestible protein.	Metabolizable energy.	Dry matter.	Digestible protein.	Metabolizable energy.
	Grams.	*Grams.*	*Calories.*	*Grams.*	*Grams.*	*Calories.*
Difference in grain	− 41	−5.3	−126	− 50	− 6.6	−153
Difference in hay	+105	+4.3	+216	−139	− 5.7	−286
Total correction	....	−1.0	+ 90	....	−12.3	−439
Found in metabolism trial	....	406.6	12,328	....	363.1	11,517
Computed for whole period	....	405.6	12,418	....	350.8	11,078

TABLE 45.—*Computed digestible protein and metabolizable energy per day in entire period.*

	Steer A.	Steer B.
Digestible protein:		
From hay....grams..	128.8	124.6
From grain....do....	289.5	226.8
Total....do....	418.3	351.4
Metabolizable energy:		
From hay....calories..	6,417	6,204
From grain....do....	6,713	5,259
Total....do....	13,130	11,463

The corresponding available energy, computed as before, is: From digestion trial—Steer A, 7,092 calories; steer B, 6,327 calories. From dry matter eaten—Steer A, 7,499 calories; steer B, 6,546 calories.

APRIL 8[1] TO JULY 6, 1906.

In this period, as already noted, the ingredients of the mixed grain differed from those in the previous periods, corn-and-cob meal taking the place of corn meal, and the proportions of the single grains in the mixture being different. In the absence of any direct determinations of the energy values of the new grain mixture, however, we have used those employed in the previous three periods for the other mixtures. Tabulated as before, the comparison of the whole period with the digestion trial of June 27 to July 6, 1905, gives the results contained in the following tables:

TABLE 46.—*Comparison of feed consumed per day.*

Feed.	Steer A.				Steer B.			
	Whole period, Apr. 8 to July 6, 1906.		Metabolism trial, June 27 to July 6, 1906.		Whole period, Apr. 15 to July 6, 1906.		Metabolism trial, June 27 to July 6, 1906.	
	Fresh weight.	Dry matter.	Fresh weight.	Dry matter.	Fresh weight.	Dry matter.	Fresh weight.	Dry matter.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Wheat bran..........	590	511	635	550	438	379	460	398
Corn-and-cob meal...	[2] 1,770	1,525	1,905	1,641	1,314	1,132	1,380	1,189
Linseed meal........	634	558	635	559	438	386	460	405
Total grain.....	2,994	2,594	3,175	2,750	2,190	1,897	2,300	1,992
Mixed hay...........	5,318	4,611	5,120	4,439	4,654	4,036	4,080	3,538

[1] April 15 for steer B.

[2] Includes 67 grams corn meal.

TABLE 47.—*Digestible protein and metabolizable energy per day in entire period.*

	Steer A.			Steer B.		
	Dry matter.	Digestible protein.	Metabolizable energy.	Dry matter.	Digestible protein.	Metabolizable energy.
	Grams.	*Grams.*	*Calories.*	*Grams.*	*Grams.*	*Calories.*
Difference in grain	−156	− 15.6	− 474	− 95	− 9.5	− 291
Difference in hay	+172	+ 9.6	+ 354	+498	+ 27.7	+ 1,024
Total correction	....	− 6.0	− 120	....	+ 18.2	+ 733
Found in metabolism trial	....	450.4	16,827	....	380.9	12,701
Computed for whole period	....	444.4	16,707	....	399.1	13,434

TABLE 48.—*Computed digestible protein and metabolizable energy per day for entire period.*

	Steer A.	Steer B.
Digestible protein:		
From hay .... grams	256.8	224.8
From grain .... do	259.9	190.1
Total .... do	516.7	414.9
Metabolizable energy:		
From hay .... calories	9,485	8,302
From grain .... do	7,940	5,807
Total .... do	17,425	14,109

The available energy, computed as before, is: From digestion trial—Steer A, 9,542 calories; steer B, 7,673 calories. From dry matter eaten—Steer A, 9,952 calories; steer B, 8,058 calories.

OCTOBER 26 TO DECEMBER 15, 1906.

No digestion and metabolism trials were made during this period. We are compelled, therefore, to compute the digestible protein and the available energy of the average daily ration from the total amounts consumed by the use of average factors.

The average daily ration which was consumed during this period is shown in the table below. The mixed hay, wheat bran, and corn-and-cob meal are assumed to have contained the same percentage of dry matter as in the previous period and the air-dry corn silage to contain 90 per cent of dry matter.

TABLE 49.—*Average feed consumed per day.*

Feed.	Steer A.		Steer B.	
	Fresh weight.	Dry matter.	Fresh weight.	Dry matter.
	Grams.	*Grams.*	*Grams.*	*Grams.*
Mixed hay	3,812	3,305	3,212	2,785
Corn silage (air-dry weight)	1,118	963	1,118	963
Wheat bran	693	600	669	579
Corn-and-cob meal	1,386	1,247	1,339	1,205

For the wheat bran we may assume the same protein and energy values as were found in the respiration-calorimeter experiments of 1905, and for the mixed hay the averages used in computing the last previous period, as follows:

Digestible protein:		
Wheat bran	per cent	11.18
Mixed hay	do	5.57
Available energy per gram of dry matter:		
Wheat bran	calories	1.392
Mixed hay	do	1.168

No determinations of the available energy of corn-and-cob meal are on record. A calculation based on the composition as shown in Table 26, using Jordan's coefficients of digestibility and Kellner's factors for energy and assuming a "Wertigkeit" of 90 per cent, gives the following approximate values: Digestible protein, 3.93 per cent; available energy per gram dry matter, 1.76 calories.

For the silage, we have used the digestible protein and available energy computed for average American corn silage in Farmers' Bulletin 346 of the United States Department of Agriculture, viz, digestible protein in dry matter, 4.73 per cent; available energy per gram of dry matter, 1.426 calories.

Using these estimates, the average daily ration as stated above contained:

TABLE 50.—*Computed digestible protein and metabolizable energy per day for entire period.*

Feed.	Steer A.		Steer B.	
	Digestible protein.	Available energy.	Digestible protein.	Available energy.
	Grams.	*Calories.*	*Grams.*	*Calories.*
Mixed hay	184.1	3,861	155.1	3,253
Corn silage	45.6	1,373	45.6	1,373
Wheat bran	67.1	835	67.7	806
Corn-and-cob meal	49.0	2,195	47.4	2,121
	345.8	8,264	315.8	7,553

SUMMARY OF AVERAGE RATIONS IN THE INTERMEDIATE FEEDING PERIODS.

The foregoing computations of the digestible protein and available energy of the average daily rations in the several periods of the general feeding are summarized in the following table:

TABLE 51.—*Summary of average daily rations per head.*

Periods.	Steer A.		Steer B.	
	Digestible protein.	Available energy.	Digestible protein.	Available energy.
	Grams.	*Calories.*	*Grams.*	*Calories.*
Oct. 1 to Dec. 10, 1904	374.4	6,075	315.7	5,294
Apr. 2 to July 15, 1905	413.0	6,570		
May 2 to July 15, 1905			378.4	6,682
Oct. 6 to Dec. 3, 1905	405.6	7,092	350.8	6,327
Apr. 8 to July 6, 1906	444.4	9,542		
Apr. 15 to July 6, 1906			399.1	7,673
Oct. 26 to Dec. 15, 1906	345.8	8,264	315.8	7,553

NUTRITIVE EFFECT OF RATIONS.

GAINS IN LIVE WEIGHT.

The following table shows the live weights most nearly corresponding to the beginning and end of each of the periods into which the intermediate feeding was divided, as shown in Table 25. The weights, except where otherwise noted, are the average of three or five consecutive daily weighings, regarded as representing the average weight on the middle day. Dates have been selected on which such averages could be taken and, therefore, they do not in all cases correspond exactly with those of Table 25 showing the feed consumed. The differences in this respect are so small, however, that we may safely compare the daily averages of feed consumed and gains made without fearing the introduction of any sensible error.

TABLE 52.—*Gains in live weight in intermediate feeding periods.*

Periods.	Number of days.	Initial weight of steer.	Final weight of steer.	Total gain.	Gain per day.	Daily gain per 1,000 mean weight.
Steer A.		*Kilos.*	*Kilos.*	*Kilos.*	*Kilos.*	*Kilos.*
Oct. 1 to Dec. 11, 1904	71	246.5	280.7	34.2	0.482	1.828
Mar. 31 to July 13, 1905	104	277.0	314.3	37.3	.359	1.262
July 13 to Sept. 28, 1905	77	314.3	360.0	45.7	.594	1.762
Sept. 28 to Nov. 28, 1905	61	360.0	387.3	27.3	.448	1.199
Apr. 6 to July 4, 1906	89	403.2	456.1	52.9	.594	1.382
July 4 to July 28, 1906	24	456.1	[1] 456.6	.5	.021	.046
July 28 to Oct. 27, 1906	91	[1] 456.6	[1] 466.8	10.2	.112	.243
Oct. 27 to Dec. 4, 1906	39	[1] 466.8	495.1	28.3	.726	1.509
Apr. 30 to Oct. 28, 1907	181	527.8	[1] 594.2	66.4	.367	.654
Oct. 28 to Jan. 4, 1908	68	[1] 594.2	[1] 632.8	38.6	.568	.926
Totals and means:						
Oct. 1, 1904 to Dec. 4, 1906	555			236.4	.426	1.149
Oct. 1, 1904, to Jan. 4, 1908	825			341.4	.414	.942
Steer B.						
Oct. 1 to Dec 11, 1904	71	171.0	215.0	44.0	.620	3.213
May 5 to July 13, 1905	69	195.0	233.6	38.6	.559	2.608
July 13 to Sept. 28, 1905	77	233.6	263.5	29.9	.388	1.561
Sept. 28 to Nov. 28, 1905	61	263.5	296.8	33.3	.546	1.949
Apr. 13 to July 4, 1906	82	307.9	343.1	35.2	.429	1.318
July 4 to July 28, 1906	24	343.1	[1] 335.4	—7.7	—.321	—.946
July 28 to Oct. 27, 1906	91	[1] 335.4	[1] 363.2	27.8	.305	.873
Oct. 27 to Dec. 4, 1906	39	[1] 363.2	379.2	16.0	.410	1.105
Apr. 26 to Oct. 28, 1907	185	384.1	[1] 428.6	44.5	.241	.593
Oct. 28 to Jan. 4, 1908	68	[1] 428.6	[1] 483.1	54.5	.801	1.757
Totals and means:						
Oct. 1, 1904, to Dec. 4, 1906	514			217.1	.422	1.875
Oct. 1, 1904, to Jan. 4, 1908	767			316.1	.412	1.260

[1] Single weighing.

In five periods out of nine, omitting the doubtful period of July 4 to 28, 1906, steer B shows a somewhat greater gain per head and a notably greater gain per 1,000 kilograms live weight than steer A, but taking the experiments as a whole, little difference appears in the average daily gain in live weight per head. The average daily gain per 1,000 kilograms up to December 4, 1906, which terminates that portion of the intermediate feeding for which exact feeding records were kept, is 63 per cent greater by steer B than by steer A. If we include in the comparison the summer pasturage in

1907 and the period of fattening during the succeeding winter, the difference is reduced to 34 per cent.

FEED CONSUMED PER UNIT OF GAIN.

The feed consumed in the foregoing periods is recorded in Table 25, but the amount of air-dry matter eaten may be repeated here for readier comparison with the gains in live weight. Table 53 shows the average daily consumption of air-dry feed per head and also the amount eaten per 1,000 kilograms live weight, computed both directly in proportion to the weight and in proportion to the two-thirds power of the live weight, i. e., to the surface.

TABLE 53.—*Air-dry feed eaten.*

Periods.	Feed consumed per day.			Feed consumed per kilogram gain in live weight.
	Per head.	Per 1,000 kilograms average live weight.		
		W.	$W^{\frac{2}{3}}$.	
Steer A.	*Kilos.*	*Kilos.*	*Kilos.*	*Kilos.*
Oct. 1 to Dec. 11, 1904	5.30	20.11	12.89	11.00
Mar. 31 to July 13, 1905	5.60	18.84	12.55	15.52
July 13 to Sept. 28, 1905	5.07	14.35	9.99	8.15
Sept. 28 to Nov. 28, 1905	6.06	16.32	11.76	13.62
Apr. 6 to July 4, 1906	8.31	19.34	14.59	13.99
July 4 to 28, 1906	4.30	9.40	7.24	[204.30]
July 28 to Oct. 27, 1906	4.45	9.64	7.45	39.73
Oct. 27 to Dec. 4, 1906	7.01	14.57	11.42	9.66
Average	5.85	15.73	11.31	13.68
Steer B.				
Oct. 1 to Dec. 11, 1904	4.78	24.51	14.17	7.63
May 5 to July 13, 1905	5.35	24.34	14.59	9.60
July 13 to Sept. 28, 1905	4.55	17.44	10.96	10.96
Sept. 28 to Nov. 28, 1905	5.40	19.31	12.63	9.91
Apr. 13 to July 4, 1906	6.84	21.10	14.52	16.01
July 4 to 28, 1906	4.11	11.81	8.26	....
July 28 to Oct. 27, 1906	4.48	12.83	9.03	14.69
Oct. 27 to Dec. 4, 1906	6.34	17.08	12.27	15.46
Average	5.28	18.98	12.34	12.37

The greater consumption of coarse feed by steer B on the limited grain ration has already been noted and is reflected in the foregoing table. While the air-dry matter consumed per head is greater in the case of steer A, the consumption is relatively greater by steer B, whether calculated in proportion to the weight or surface, with a single exception in the latter case. Accompanying this greater consumption of feed by steer B we find (omitting the doubtful period, July 4 to 28, 1906) that in four cases out of the seven, steer B produced a unit of gain in live weight on less air-dry feed than did steer A, the average of the whole time being decidedly in favor of the former animal. Judged merely from the standpoint of the increase in live weight therefore, steer B appears to have been on the whole a more economical producer than steer A up to December 4, 1906. On pasture during the following summer, however, steer

A gained 50 per cent faster per head than did steer B and a little more rapidly per 1,000 kilograms live weight. Steer A reached a greater final weight than steer B, because he started the experiment with the advantage of weight in his favor. He had more internal machinery to work with, but the figures do not indicate that the machinery worked any more efficiently in the production of increase in live weight. Whatever advantage, if any, steer A had over steer B in the economical production of live weight in relation to total feed consumed apparently manifested itself in the earlier periods of his life before the beginning of this investigation.

THE PRODUCTION OF PROTEIN TISSUE.

The four respiration calorimeter experiments each winter necessarily included determinations of the nitrogen balance. In one of these four periods (Period II) the ration was largely in excess of the maintenance requirement, while in the experiments of 1906 and 1907, the rations of steer A in Period I likewise proved to be materially above maintenance. We may therefore presume that in these periods the animals made a normal gain of protein, since the protein supply in the ration was fairly liberal. In addition to these periods, the digestion trials made on each animal during the intermediate feeding periods included determinations of income and outgo of nitrogen, so that in all we have nine nitrogen balances for steer A and seven for steer B, exclusive of those on maintenance or submaintenance rations. The dates of these trials and the rations consumed are brought together for convenience, in the following table:

TABLE 54.—*List of nitrogen balances.*

Date of trial.	Steer A—Daily ration. Hay.	Wheat bran.	Corn meal.	Linseed meal.
	Grams.	*Grams.*	*Grams.*	*Grams.*
Dec. 1 to 10, 1904	[1] 3,629	254	761	761
Feb. 9 to 18, 1905	[2] 2,250	3,000	....	....
July 6 to 15, 1905	[1] 2,800	360	1,080	1,080
Nov. 13 to 22, 1905	[1] 3,440	360	1,080	1,080
Jan. 18 to 27, 1906	[2] 3,000	300	900	900
Feb. 15 to 24, 1906	[2] 3,000	700	2,100	2,100
June 27 to July 6, 1906	[1] 5,120	635	[3] 1,905	635
Jan. 31 to Feb. 9, 1907	3,400	335	1,000	1,000
Feb. 28 to Mar 9, 1907	[2] 3,400	800	2,400	2,400

Date of trial.	Steer B—Daily ration. Hay.	Wheat bran.	Corn meal.	Linseed meal.
	Grams.	*Grams.*	*Grams.*	*Grams.*
Dec. 2 to 10, 1904	[1] 3,629	180	540	540
Apr. 27 to May 6, 1905	[2] 2,000	2,000	....	....
July 6 to 15, 1905	[1] 2,800	285	855	855
Nov. 13 to 22, 1905	[1] 3,600	285	855	855
Feb. 23 to Mar. 3, 1906	[2] 2,800	357	1,072	1,071
June 27 to July 6, 1906	[1] 4,080	460	[3] 1,380	460
Mar. 7 to 16, 1907	[2] 3,200	450	1,350	1,350

[1] Mixed clover and timothy hay. [2] Timothy hay. [3] Corn-and-cob meal.

The succeeding table summarizes the daily gain or loss of nitrogen by the animals in the foregoing periods, as shown by the detailed records of Part II, and the corresponding amounts of protein, obtained by multiplication of the nitrogen by the factor 6.0, while the protein has also been computed per 1,000 kilograms in direct proportion to the live weight.

TABLE 55.—*Gains of nitrogen and protein.*

Date of trial.	Age of steer.	Average live weight.	Gains of nitrogen.	Equivalent protein—Per head.	Equivalent protein—Per 1,000 kilos live weight.
Steer A.	*Months.*	*Kilos.*	*Grams.*	*Grams.*	*Grams.*
Dec. 1 to 10, 1904	11	278.3	− 39.7	− 238.2	− 856.0
Feb. 9 to 18, 1905	13	279.1	+ 1.8	+ 10.8	+ 38.7
July 6 to 15, 1905	18	312.3	+ 4.4	+ 26.4	+ 84.5
Nov. 13 to 22, 1905	22	379.3	+ 2.9	+ 17.4	+ 45.9
Jan. 18 to 27, 1906	24	404.0	+ 3.2	+ 19.2	+ 47.5
Feb. 15 to 24, 1906	25	420.7	− 5.7	− 34.2	− 81.3
June 27 to July 6, 1906	30½	451.4	− 1.5	− 9.0	− 19.9
Jan. 31 to Feb. 9, 1907	36½	498.6	+ 1.1	+ 6.6	+ 13.2
Feb. 28 to Mar. 9, 1907	38½	518.7	+ 3.6	+ 21.6	+ 41.6
Steer B.					
Dec. 2 to 10, 1904	13	215.5	− 25.4	− 152.4	− 707.1
Apr. 27 to May 6, 1905	15	196.9	+ 11.6	+ 69.6	+ 353.5
July 6 to 15, 1905	20	232.4	+ 6.3	+ 37.8	+ 162.6
Nov. 13 to 22, 1905	24	288.0	+ 5.4	+ 32.4	+ 112.5
Feb. 23 to Mar. 3, 1906	28	309.6	− 1.2	− 7.2	− 23.3
June 27 to July 6, 1906	32	340.9	+ 2.6	+ 15.6	+ 45.8
Mar. 7 to 16, 1907	40	386.4	+ 9.6	+ 57.6	+ 149.1

It is evident from the foregoing table that the results as regards protein are decidedly irregular. Those obtained in the first digestion trial (Dec. 1 to 10, 1904), as already noted, are plainly erroneous, owing in part to the abnormally low consumption of feed during those trials and in part probably to some undetected error. In the digestion trial of June 27 to July 6, 1906, as pointed out on page 198, some extraneous cause seems to have affected the protein katabolism, causing a marked increase during the 10 days on which the nitrogen balance was determined. It seems probable, therefore, that the gain of nitrogen shown by the tables is lower in this trial than properly corresponds to the feed consumed. We are unable to account for the negative nitrogen balances in the respiration calorimeter experiments of February 15 to 24 and February 24 to March 2, 1906.

Omitting the first digestion trial and accepting the results of the others as they stand, figure 12 shows the gain of protein in grams per 1,000 kilograms live weight. With the exception of the apparently abnormal gain by steer B in the trial from April 27 to May 6, 1905, the results on the two animals, notwithstanding their apparently capricious character, show a rather striking parallelism, falling to a minimum in the trial of February, 1906, and rising to approximately the original level in the last trial. The cause of this behavior is not obvious. It does not seem to be directly related to the protein supply in the feed. Table 56 shows the digestible protein of the rations per head and also computed per 1,000 kilograms in proportion to the live weight. The minimum protein requirement for the maintenance of the nitrogen equilibrium of cattle may be estimated at not far from 500 grams per 1,000 kilograms live weight. Subtracting this amount from the digestible protein per 1,000 kilograms gives, in the fifth column of the table, the amount of protein available for the production of gain of flesh, while the sixth, or last, column shows the percentage of this surplus actually stored up in the body of the animal according to the figures of Table 55.

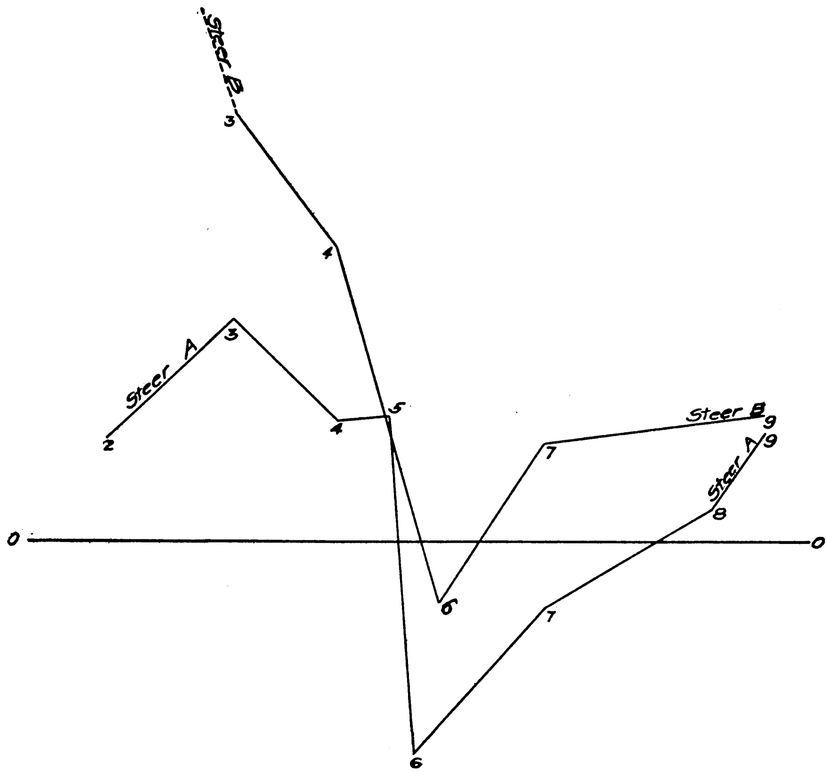


FIG. 12.—Gain of protein per 1,000 kilograms live weight.

TABLE 56.—*Digested protein of rations in digestion and metabolism trials.*

Date of trial.	Age of steer.	Per head.	Per 1,000 kilos live weight.		Percentage of surplus stored in body.
			Total.	Surplus after deducting maintenance.	
Steer A.	*Months.*	*Grams.*	*Grams.*	*Grams.*	*Per cent.*
Feb. 9 to 18, 1905	13	293.1	1,050.2	550.2	7.0[illegible]
July 6 to 15, 1905	18	403.0	1,290.3	790.3	10.67
Nov. 13 to 22, 1905	22	406.6	1,072.0	572.0	8.02
Jan. 18 to 27, 1906	24	315.8	781.7	281.7	16.86
Feb. 15 to 24, 1906	25	530.5	1,261.0	761.0	− 10.68
June 27 to July 6, 1906	30½	450.4	997.8	497.8	− 4.00
Jan. 31 to Feb. 9, 1907	36½	353.9	709.8	209.8	6.29
Feb. 28 to Mar. 9, 1907	38½	725.4	1,398.3	898.3	4.63
Steer B.					
Apr. 27 to May 6, 1905	15	218.3	1,108.7	608.7	58.08
July 6 to 15, 1905	20	349.0	1,501.7	1,001.7	16.22
Nov. 13 to 22, 1905	24	363.1	1,260.7	760.7	14.79
Feb. 23 to Mar. 3, 1906	28	318.1	1,027.4	527.4	− 4.42
June 27 to July 6, 1906	32	380.9	1,117.3	617.3	7.42
Mar. 7 to 16, 1907	40	467.9	1,211.0	711.0	20.97

Figure 13 shows graphically the surplus protein supply per 1,000 kilograms live weight in each period. A comparison with figure 12, representing the gains of protein, shows no obvious relation between the two.

The results recorded in the last column of Table 56 as to the percentage of the surplus protein retained in the body are expressed

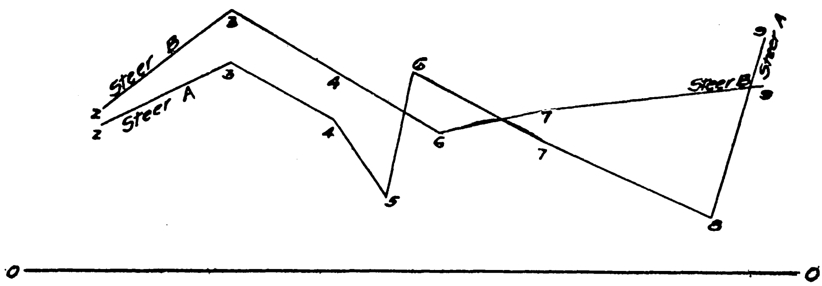


FIG. 13.—Surplus protein per 1,000 kilograms live weight.

graphically in figure 14. The percentage retention in the case of steer A in the trial of January 18 to 27, 1906, is relatively high. No corresponding result is available on steer B for the reason that the energy of his total ration in that period was below the maintenance requirement, and a material loss of fat from the body of the animal took

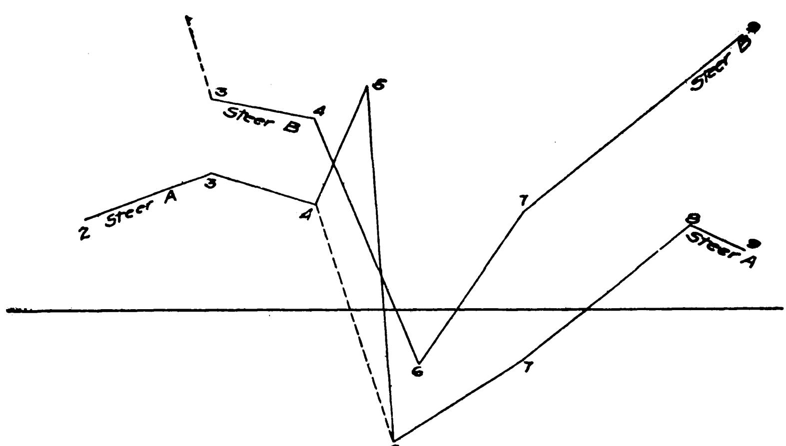


FIG. 14.—Percentage of surplus protein retained in body.

place. If we disregard this one result for steer A and consider the broken line in the diagram to represent the course of his protein gains between the trials of November, 1905, and February, 1906, we find the same general parallelism between the results on the two animals as in the case of the absolute gains. The rations fed were lower in protein than was intended. The computed surplus of protein above the estimated maintenance requirement is in most cases greater with steer B than with steer A, but the fact that in the case of the former animal a higher percentage of this larger supply was retained would not indicate that the somewhat more liberal supply of protein in the feed of steer B was the cause of his greater gain, nor that the protein supply was the limiting factor of the gain of protein tissue by steer A.

We may say, then, that the relative gain of protein by the animals and the percentage of the surplus feed protein which was retained in the body run, in general, parallel in the two animals, but that steer B was superior to steer A in both respects. In spite of some irregularity in the results, therefore, they seem to indicate quite clearly that steer B possessed a greater tendency to growth of protein tissue than did steer A.

ENERGY STORAGE—CHARACTER OF GAIN IN LIVE WEIGHT.

It has been shown on pages 78 to 80 that steer B made relatively greater gains in live weight than did steer A and required on the average a smaller weight of air-dry feed to produce a unit of gain. The differences in the character of the growth of the two animals, however, as revealed by the measurements and photographs taken and confirmed by the results of the block test would prepare one to expect that a unit gain in live weight might differ widely at different times and with the two animals, both as to chemical composition and as to the amount of energy storage which it represented, and therefore as to its value as human food. The comparisons now to be presented appear to confirm this expectation.

RELATIVE GAIN OF PROTEIN.

It has been shown in some detail in preceding paragraphs that steer B showed a distinctly greater tendency toward gain of protein tissue than did steer A. A gain of protein, however, represents the storage of much less energy than that of a corresponding weight of fat, and, moreover, a gain of protein implies the deposition along with it of three or four times its weight of water. The tendency of the apparently greater ability of steer B to store up protein, therefore, would be to make his gain in live weight relatively more rapid than that of steer A on equivalent rations. Part of this difference may be plausibly accounted for by his greater increase in length and height with the accompanying increase in those structural tissues such as bones, ligaments, tendons, skin, etc., which consist largely of protein.

PROPORTION OF FAT TO PROTEIN IN INCREASE.

In the respiration calorimeter experiments we have data as to the proportions of protein and fat gained. A comparison of the record shows that in every case in which there was a gain of both protein and fat the ratio of the former to the latter was notably smaller with steer A than with steer B. This is also shown by the following tabulation, in which the composition of the ash-free increase is computed from the data contained in Part II, assuming fresh lean meat to contain 3.55 per cent nitrogen. The table includes also two cases of a negative nitrogen balance, illustrating the greater gain of fat by steer A in these cases also.

TABLE 57.—*Computed composition of ash-free gain.*

	Steer A.				Steer B.			
	Weight.		Per cent.		Weight.		Per cent.	
	Flesh.	Fat.	Flesh.	Fat.	Flesh.	Fat.	Flesh.	Fat.
Experiments of 1905.	*Grams.*	*Grams.*	*Per cent.*	*Per cent.*	*Grams.*	*Grams.*	*Per cent.*	*Per cent.*
Period II	50.7	112.5	31.06	68.94	326.8	54.6	85.69	14.31
Experiments of 1906.								
Period I	90.1	135.0	40.03	59.97	....	....	....	....
Period II	−160.6	469.2	....	....	− 33.8	122.6	....	....
Experiments of 1907.								
Period I	31.0	175.7	15.00	85.00	....	....	....	....
Period II	101.4	657.3	13.36	86.64	270.4	243.8	52.59	47.41
Period IV	− 42.3	70.3	....	....	− 67.6	23.9	....	....

The corresponding energy content of one kilogram of the ash-free gain, computed by the use of the customary factors, is as follows:

TABLE 58.—*Energy content of 1 kilogram of ash-free gain.*

	Steer A.	Steer B.
Experiments of 1905.	*Calories.*	*Calories.*
Period II	6,926	2,399
Experiments of 1906.		
Period I	6,183	....
Experiments of 1907.		
Period I	8,257	....
Period II	8,393	5,143

It is of course true that the foregoing comparisons are probably affected by the total amount of feed eaten. In the corresponding periods steer A consumed heavier rations than steer B, and this would tend to increase the production of fat relatively to that of protein tissue. The results are cited as indications rather than proofs of the difference in the character of the gains in the two animals. It is to be noted, however, that in the experiments of 1907 the ration of steer A in Period I and that of steer B in Period II were approximately equal in amount, and in this case the energy content of 1 kilogram of gain is notably greater with steer A.

Another indication of the greater proportion of fat in the gain made by steer A was obtained in connection with the block test. In the fattening preliminary to this test it was impossible to bring steer B into as good condition as steer A, the latter being graded as "prime," while steer B was graded as "common." Steer B produced somewhat less internal fat than steer A, and his subcutaneous fat tissue was much less fully developed. In technical phrasing, his carcass was not well covered. The following table illustrates these differences:

TABLE 59.—*Proportion of fat in carcasses.*

Animals.	Live weight.	Dressed weight.	Per cent of live weight.		
			Suet in loin.	Paunch and intestinal fat.	Pluck fat.
	Pounds.	*Pounds.*	*Per cent.*	*Per cent.*	*Per cent.*
Steer A	1,395	837.75	2.426	0.910	5.02
Steer B	1,065	580.25	.962	.658	4.60

The lean meat of both steers was "marbled," but that of steer A to a much greater extent than that of steer B. It was not possible to analyze the carcasses of the two animals, but samples of the lean meat of the porterhouse and round of each animal were analyzed by Mr. W. W. Braman,[1] with the following results, the energy being computed in the same manner as before. The results show a marked difference in the energy content of the lean meat of the two animals.

TABLE 60.—*Composition of fresh lean meat.*

	Porterhouse cut.		Round cut.	
	Steer A.	Steer B.	Steer A.	Steer B.
Total nitrogen ... per cent	3.407	3.488	3.496	3.616
Fat ... do	12.71	6.72	6.66	3.34
Energy per kilogram ... calories	2,372	1,831	1,829	1,554

ENERGY CONTENT OF GAIN IN LIVE WEIGHT.

The foregoing results agree in indicating that a unit of gain in live weight by steer A contained more potential energy than in the case of steer B. The data contained in Table 51 regarding the available energy of the average daily rations consumed afford a further test of this supposition.

The available energy of a feeding stuff or ration, in the sense in which the term is here used, signifies that portion of its total energy

[1] "The Influence of Fattening upon the Composition of the Lean Meat of Cattle," thesis for the degree of M. S., 1908.

which can be used on the one hand to prevent a loss of the stored-up energy of the body or, on the other hand, when supplied in excess of the maintenance requirement, is stored up as gain of flesh and fat. If, then, from the available energy of the rations as recorded in Table 51, we deduct the available energy required for maintenance, the remainder will represent the amount of energy capable of being stored up in the body as the potential energy of protein and fat. In the following table this computation has been made. The maintenance requirements are those computed on page 55, viz, per 500 kilograms live weight, for steer A, 5,971 calories, and for steer B, 7,090 calories. The actual maintenance requirement per day in each case has been computed in proportion to the two-thirds power of the live weight on the basis of the average live weight for the period as shown in the first column of the table. Dividing the estimated daily gain of energy by the average daily gain in live weight gives in the last column the total energy content of 1 kilogram of gain.

TABLE 61.—*Energy content of gain in live weight.*

Date of trial.	Average live weight.[1]	Available energy per day.	Estimated maintenance requirement.	Estimated gain of energy.	Average daily gain in weight.	Energy in 1 kilogram gain.
Steer A.	*Kilos.*	*Calories.*	*Calories.*	*Calories.*	*Kilos.*	*Calories.*
Oct. 1 to Dec. 10, 1904	263.6	6,075	3,897	2,178	0.482	4,519
Apr. 2 to July 15, 1905	295.7	6,570	4,207	2,363	.359	6,583
Oct. 6 to Dec. 3, 1905	373.7	7,092	4,918	2,174	.448	4,853
Apr. 8 to July 6, 1906	429.7	9,542	5,397	4,145	.594	6,978
Oct. 26 to Dec. 15, 1906	481.0	8,264	5,818	2,446	[2] .726	3,369
Steer B.						
Oct. 1 to Dec. 10, 1904	193.0	5,294	3,760	1,534	.620	2,474
May 2 to July 15, 1905	214.3	6,682	4,030	2,652	.559	4,744
Oct. 6 to Dec. 3, 1905	280.2	6,327	4,819	1,508	.546	2,762
Apr. 15 to July 6, 1906	325.5	7,673	5,326	2,347	.429	5,471
Oct. 26 to Dec. 15, 1906	371.2	7,553	5,813	1,740	[2] .410	4,244

[1] Average of initial and final weights as recorded in Table 52 for the period corresponding most nearly to the feeding period.
[2] Initial weight in this period is from a single weighing.

The data of Table 61, as well as the graphic representation of the results in figure 15, show that with the exception of the last period, in which the true gain of weight is somewhat uncertain, steer A appeared notably superior to steer B as regards the energy content of a unit of gain. We can hardly err in ascribing this difference largely to the greater proportion of protein and accompanying water which appears to have characterized the gain made by steer B.

Another interesting point brought out by these results is an apparent seasonal variation in the energy content of the gain, it being greatest in the spring months and least in the fall months.

None of the foregoing results can, of course, be interpreted as constituting a quantitative determination of the composition or energy value of the gains in live weight. Taken together, however, they seem to be fairly conclusive as to the qualitative nature of the difference in this respect between the two animals and to furnish an adequate explanation of the apparent discrepancy between the results of the determinations of digestibility and availability of the feed, on the one hand, and the relatively greater gain of live weight by steer B on the other hand.

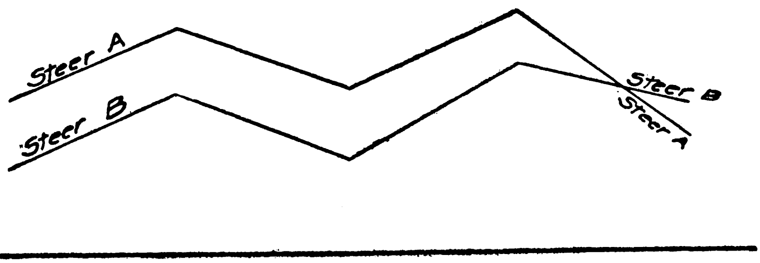


FIG. 15.—Energy content of 1 kilogram gain in live weight.

FEED REQUIREMENTS FOR GROWTH.

It is of interest to compare the rations consumed and the gains made by these two steers with the accepted feed requirements of such animals as formulated in the current tables of "feeding standards" for growing cattle. The most recent and generally accepted of these are Kellner's [1] which are expressed in terms of digestible protein and "starch values," 1 kilogram starch value being equivalent to 2,356 calories of energy value. Kellner's standards are as follows, the starch values being reduced to their equivalents in energy value expressed in "therms." [2]

TABLE 62.—*Kellner's feeding standards for growing cattle.*

Age in months.	Average live weight per head.	Requirements per 1,000 kilos live weight.	
		Digestible protein.	Energy values.
Dairy breeds.	*Kilos.*	*Kilos.*	*Therms.*
3 to 6	140	2.80	35.81
6 to 12	240	2.30	27.10
12 to 18	320	1.80	21.20
18 to 24	400	1.30	18.85
Beef breeds.			
3 to 6	150	3.50	38.88
6 to 12	250	2.80	31.81
12 to 18	350	2.20	23.56
18 to 24	430	1.50	21.20

[1] "Die Ernährung der landwirtschaftl. Nutztiere.," 5th ed., p. 615.
[2] A therm equals 1,000 kilogram calories.

The live weight of steer A at the beginning of the investigation corresponded with the weight assumed by Kellner for animals of the same age, being, if anything, a trifle higher, but the weight of steer B was considerably less. The later weights of the two steers can not be compared with those predicated by Kellner for the corresponding ages on account of the respiration calorimeter experiments, covering about three months of each year, during which light rations were fed and little or no growth made. We may, however, compare our results with those expected to be obtained by the use of Kellner's standards by computing the average daily rate of gain in the intermediate feeding periods. From Kellner's figures, as given in Table 62, the expected gain per day and head may be computed as follows:

	Dairy breeds.	Beef breeds.
	Kilos.	*Kilos.*
Between 4½ and 9 months	0.392	0.392
Between 9 and 15 months	.437	.564
Between 15 and 21 months	.437	.437

The actual average daily gains by our steers, as shown in Table 52, for the periods for which the protein and energy content of the rations are computed in Table 51, are shown also in Table 63, which likewise includes what was called on page 22 the virtual age of the animals, that is, the age exclusive of the respiration calorimeter experiments.

TABLE 63.—*Average daily gains in live weight.*

Periods.	Steer A.		Steer B.	
	Virtual age.	Average daily gain.	Virtual age.	Average daily gain.
	Months.	*Kilos.*	*Months.*	*Kilos.*
Oct. 1 to Dec. 10, 1904	8.5–10.9	0.482	10.9–13.2	0.620
Apr. 2 to July 15, 1905	10.9–14.4	.359		
May 2 to July 15, 1905			13.2–15.4	.559
Oct. 6 to Dec. 3, 1905	17.0–19.0	.448	18.1–20.2	.546
Apr. 8 to July 6, 1906	19.0–22.0	.594		
Apr. 15 to July 6, 1906			20.2–23.1	.429
Oct. 26 to Dec. 15, 1906	25.0–26.2	.726	26.2–27.5	.410

On the average of the foregoing feeding periods, aggregating 17.7 months for steer A and 16.6 months for steer B, the average daily gains per head were, respectively, 0.426 kilogram and 0.422 kilogram, equivalent to an average of about 0.935 pound. The figures show clearly that the rate of gain during the feeding periods, outside of the respiration calorimeter experiments on limited rations, was fully as great as that predicated by Kellner for similar animals and would be very satisfactory in practice for animals not being fattened.

The rations shown in Table 51, computed to 1,000 kilograms live weight in direct proportion to the latter, are as follows:

TABLE 64.—*Average rations per 1,000 kilograms live weight.*

Steer A.			Steer B.		
Virtual age in months.	Digestible protein.	Energy values.	Virtual age in months.	Digestible protein.	Energy values.
	Kilos.	*Therms.*		*Kilos.*	*Therms.*
8.5 to 10.9	1.42	23.05	10.9 to 13.2	1.64	27.43
10.9 to 14.4	1.40	22.22	13.2 to 15.6	1.77	31.18
17.0 to 19.0	1.09	18.98	18.1 to 20.2	1.25	22.58
19.0 to 22.0	1.03	22.20	20.2 to 23.1	1.23	23.57
25.0 to 26.2	0.72	17.18	26.2 to 27.5	0.85	20.35

ENERGY VALUES.

The rations of steer B contained in the earlier periods of the experiments somewhat less energy value than the standards for dairy breeds call for and a somewhat larger amount during the later periods. The differences, however, are not very marked. Steer A, as already noted, consumed relatively less feed than steer B and consequently the energy value of his rations is notably less in the earlier periods than that called for by the standards for beef breeds and somewhat less in the later periods. On these rations both steers made on the whole quite similar gains per head, which, as already noted, were entirely satisfactory from a practical standpoint. Steer B being the lighter animal, his gains were relatively greater, although, as has already been shown, this greater relative gain seems to have had a lower energy value per unit. Steer A, on the other hand, seems to have had a relatively low maintenance requirement and possibly the average beef animal would require more feed for this purpose than did steer A. On the whole, the results upon these two animals indicate that for simple growth without material fattening, Kellner's standards as regards energy might be somewhat reduced.

PROTEIN SUPPLY.

As regards the protein supply, we find a striking contrast between our rations and the accepted standards. Our two steers made entirely satisfactory gains on rations whose digestible protein ranged in the case of steer B from 70 to 95 per cent of the formulated requirements of the dairy breeds, and in the case of steer A from 50 to 70 per cent of those of the beef breeds. The difference is greatest at the earliest ages and gradually diminishes. One of us [1] has previously called attention to the fact that the protein supply called for by the current feeding standards for growing cattle is greatly in excess of the sum of the maintenance requirement and the amount

[1] Armsby: Bureau of Animal Industry, Bulletin 108, pp. 27–29 and pp. 57–65.

actually stored up in the body, and that we have no recorded determinations of the minimum protein demands of such animals. The quantities of digestible protein consumed by the two steers in this investigation, although less than those called for by the standards, were still considerably in excess of the amounts calculated in the publication referred to, but, on the other hand, our results afford no proof that the minimum was reached. Of course it must be regarded as probable that some waste of nitrogenous matter would be involved in the chemical reconstitution necessary in changing food protein to body protein, while it is not impossible that a certain surplus of protein may be necessary for, or at least favorable to, growth. The tendency of recent investigations, however, is to show that in all branches of feeding the minimum protein requirement has been considerably exaggerated. This has been shown to be true of the maintenance requirement and of the requirement for milk production, while our results suggest that it is also true for growth. At any rate this branch of the subject seems worthy of further investigation.

PART II. DETAILS OF RESPIRATION CALORIMETER EXPERIMENTS AND OF DIGESTION AND METABOLISM TRIALS.

In the following pages are recorded the details of the respiration-calorimeter experiments of 1905, 1906, and 1907, whose general plan has been stated on pages 23–25, and whose results have been discussed in Part I, and likewise the particulars of the digestion and metabolism trials made during the intermediate feeding periods as described in Part I, pages 66–77, in connection with the discussion of the protein and energy content of the rations consumed.

RESPIRATION CALORIMETER EXPERIMENTS OF 1905.

FEEDING STUFFS.

Hay.—The hay used was nearly pure timothy hay grown upon the experiment station farm. It contained a slight admixture of red clover, but was the purest available. It was cut during the last week in June, 1904, was housed in good condition, and when taken from the mow was very bright and showed no effects of one slight rain to which it was exposed during curing. Two tons of this hay were cut to 4 to 5 centimeter lengths on November 26, 1904. On November 29 the cut hay, which in the meantime had lain on the barn floor protected from the weather, was thoroughly mixed, and two general samples drawn for determination of the composition of the dry matter. The hay was stored in the loft of the barn, protected from the weather, and as portions were weighed out for the successive periods samples were taken for analysis. Table 65 shows the composition of the two general samples and of the seven samples taken during the progress of the experiments. The good general agreement of these nine analyses shows that a reasonably uniform material was used throughout the experiment.

TABLE 65.—*Composition of dry matter of timothy hay, 1905.*

Components.	General samples.			Samples taken during experiments.						
	C.	D.	Average.	Period 1, both steers.	Period 1, steer A only.	Period 2, steer A, and Period 3, steer B.	Period 2, steer B.	Period 3, steer A.	Period 4, steer A.	Period 4, steer B.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Ash	4.78	4.96	4.87	4.13	4.30	4.25	4.60	4.07	4.26	4.05
Protein [1]	4.74	5.41	5.08	4.56	5.21	4.96	6.06	5.09	4.26	4.26
Nonprotein [1]	.59	.18	.39	.78	.40	.52	.07	.77	.71	1.11
Crude fiber	37.72	38.57	38.14	38.23	37.61	39.35	38.16	39.94	40.17	39.20
Nitrogen-free extract	50.12	48.91	49.51	50.32	50.41	49.08	49.42	48.39	48.75	49.40
Ether extract	2.05	1.97	2.01	1.98	2.07	1.84	1.69	1.74	1.85	1.98
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Total nitrogen	.884	.904	.894	.896	.919	.904	.985	.977	.831	.918
Protein nitrogen	.759	.865	.812	.730	.834	.793	.970	.814	.681	.682
Carbon	46.795	46.902	46.849	47.394	47.482	47.039	47.282	47.272	46.985	46.967
Hydrogen	6.521	6.083	6.302	6.032	6.012	6.033	7.340	6.331	6.031	5.679
	Calories.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Energy (calories per gram)	4.4399	4.4218	4.4309	4.4909	4.4957	4.4084	4.4826	4.5015	4.4882	4.4828

[1] Computed from nitrogen, using the factors stated in Part III, page 203.

Wheat bran.—Fresh bran purchased directly from the mill was used. About 500 kilograms were thoroughly mixed and two general samples taken for determination of the composition of the dry matter. The remainder was stored, protected from moisture and vermin, and further samples were taken as the bran was weighed out for the several periods in which it was used. The results of all the analyses are contained in the table below and indicate a satisfactory degree of uniformity in the bran, as was the case with the hay.

TABLE 66.—*Composition of dry matter of wheat bran, 1905.*

Components.	General samples.			Samples taken during experiments.			
	E.	F.	Average.	Period 1, both steers.	Period 1, steer A only.	Period 2, steer A.	Period 2, steer B.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Ash	7.38	7.66	7.52	7.33	7.55	7.54	7.45
Protein [1]	14.49	14.51	14.50	15.27	14.31	14.74	13.90
Nonprotein [1]	.66	.32	.49	.50	.88	.85	1.11
Crude fiber	11.48	11.51	11.49	10.79	10.64	11.29	10.44
Nitrogen-free extract	61.84	61.92	61.88	61.30	61.95	61.31	62.15
Ether extract	4.15	4.08	4.12	4.81	4.67	4.27	4.95
	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Total nitrogen	2.683	2.613	2.648	2.784	2.698	2.767	2.674
Protein nitrogen	2.542	2.545	2.544	2.678	2.510	2.586	2.438
Carbon	46.781	46.003	46.392	45.979	45.623	45.740	44.379
Hydrogen	6.628	6.907	6.768	6.141	6.581	6.392	7.150
	Calories.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Energy (calories per gram)	4.5340	4.5295	4.5318	4.5651	4.5238	4.5584	4.4608

[1] Computed from nitrogen, using the factors stated in Part III, page 203.

PERIODS AND RATIONS.

Beginning on December 10, 1904, the feed of the animals was changed to timothy hay and wheat bran and the ration brought gradually to that assigned to the first period. The several periods and rations were as shown in tables 67 and 68, the dates being inclusive in all cases. Throughout this investigation the term "day" signifies the 24 hours ending upon the date named.

It was found necessary, as appears from Table 67, to postpone Period II for steer B until the very close of the experiments. The same number, however, was retained for this period so as to facilitate comparisons between the different periods and animals.

The ration fed during the transition feeding differed only in amount and not in kind of feeding stuffs from that of the periods proper. As a matter of convenience in connection with the calorimeter experiments, the hour of 6 p. m. was taken as the beginning and ending of the day. Approximately one-half of the feed was given at 6 p. m. and the remainder 12 hours later. The weight of the animal was taken daily at 1 p. m., 24 hours after the last watering. The rectal temperature was then taken and the animal was watered and reweighed, the difference between the two weighings representing the amount of water consumed. On the days when the animal was in the calorimeter the live weight was taken immediately before entering and immediately after leaving the apparatus and the animal was watered immediately after the morning feeding at 6 a. m.

TABLE 67.—*Periods, 1905.*

Periods.	Steer A.		Steer B.	
	Preliminary feeding.	Excreta collected.	Preliminary feeding.	Excreta collected.
I	Dec. 16, 1904, to Jan. 4, 1905.	Jan. 5 to 22, 1905	Dec. 16, 1904, to Jan. 18, 1905.	Jan. 19 to 28, 1905.
Transition feeding.	Jan. 23 to 28, 1905		Mar. 26 to Apr. 1, 1905.	
II	Jan. 29 to Feb. 8, 1905.	Feb. 9 to 18, 1905	Apr. 2 to 26, 1905	Apr. 27 to May 6, 1905.
Transition feeding.			Jan. 29 to Feb. 4, 1905.	
III	Feb. 19 to Mar. 1, 1905.	Mar. 2 to 11, 1905	Feb. 5 to 15, 1905	Feb. 16 to 25, 1905.
Transition feeding.	Mar. 12 to 18, 1905		Feb. 26 to 28, 1905	
IV	Mar. 19 to 22, 1905	Mar. 23 to Apr. 1, 1905.	Feb. 29 to Mar. 15, 1905.	Mar. 16 to 25, 1905.

TABLE 68.—*Daily rations, 1905.*

Periods.	Steer A.		Steer B.	
	Timothy hay.	Wheat bran.	Timothy hay.	Wheat bran.
	Kilos.	*Kilos.*	*Kilos.*	*Kilos.*
I	2.25	1.60	2.00	1.20
II	2.25	3.00	2.00	2.00
III	2.25		2.00	
IV	4.00		3.00	

DIGESTIBILITY OF TOTAL RATIONS.

A uniform aliquot sample of the fresh feces was set aside daily and preserved in a cold place with the addition of a small amount of carbon bisulphid. At the close of the period the total nitrogen was determined in the mixed fresh feces and the other ingredients in an air-dried sample. The daily weights of the excreta, together with the live weights of the animals, weight of water consumed, and the composition of the dry matter of the feces and of the feed refused are recorded in Tables IV, V, and VI of the appendix. From the data there recorded the digestibility of the several rations is computed in the following tables.

In Period I the feed was not readily eaten by steer B and salt was used to render it more palatable. In the computations of digestibility the uneaten residues in this period have been corrected for the salt which they contained on the basis of a determination of soluble chlorin. A smaller but similar correction is also made in Period IV with the same animal.

TABLE 69.—*Feed and excreta—Period I, 1905.*

Feed and feces.	Steer A.				Steer B.			
	Number of days.	Fresh weight.	Dry matter.		Number of days.	Fresh weight.	Dry matter.	
Timothy hay:		*Grams.*	*Per cent.*	*Grams.*		*Grams.*	*Per cent.*	*Grams.*
Total	18	40,500.0	87.91	35,602.2	10	20,000.0	88.50	17,699.8
Offered per day		2,250.0		1,977.8		2,000.0		1,770.0
Wheat bran:								
Total	18	28,800.0	85.64	24,664.2	10	12,000.0	86.04	10,324.8
Offered per day		1,600.0		1,370.2		1,200.0		1,032.5
Uneaten residues:								
Jan. 24						623.0	80.15	499.3
Jan. 26						423.0	89.76	379.8
Jan. 25 and 26						45.2	90.05	40.7
Total					10	1,091.2		919.8
Uneaten per day						109.1		92.0
Feces:								
Collected	18	135,460.0	18.75	25,394.7	10	55,265.0	20.17	11,146.9
Spilled Jan. 19		25.0		12.7				
Spilled Jan. 23		9.2		2.2				
Spilled Jan. 26						66.7	44.84	29.9
In duct Jan. 19		48.2		45.8				
In duct Jan. 27						42.0	94.71	39.8
In duct Jan. 28						16.2		4.1
Total		135,542.0		25,455.4		55,389.9		11,220.7
Excreted per day		7,530.0		1,414.2		5,539.0		1,122.1

TABLE 70.—*Digestibility of rations—Period I, 1905.*

Feed and feces.	Dry matter.	Ash.	Organic matter.	Protein.	Non-protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Total nitrogen.	Carbon.	Hydrogen.	Energy.
Steer A.	*Grams.*	*Gms.*	*Grams.*	*Gms.*	*Grams.*	*Gms.*	*Grams.*	*Gms.*	*Gms.*	*Grams.*	*Gms.*	*Calories.*
Timothy hay[1]	1,977.8	83.5	1,894.3	96.5	11.6	749.9	996.5	39.8	18.0	938.2	119.1	8,886.8
Wheat bran	1,370.2	101.9	1,268.3	202.7	9.5	146.9	844.3	64.9	37.5	627.5	87.2	6,226.6
Total	3,348.0	185.4	3,162.6	299.2	21.1	896.8	1,840.8	104.7	55.5	1,565.7	206.3	15,113.4
Feces	1,414.2	109.9	1,304.3	139.0	....	501.5	636.9	26.9	22.2	666.1	77.4	6,525.3
Digested	1,933.8	75.5	1,858.3	160.2	21.1	395.3	1,203.9	77.8	33.3	899.6	128.9	8,588.1
Percentage digestibility	57.76	40.74	58.75	53.54	[100.00]	44.08	65.40	74.30	60.00	57.46	62.48	56.83
Steer B.												
Timothy hay	1,770.0	73.1	1,696.9	80.7	13.8	676.7	890.7	35.0	15.9	838.9	106.8	7,948.9
Wheat bran	1,032.5	75.7	956.8	157.7	5.1	111.4	632.9	49.7	28.7	474.7	63.4	4,713.5
Total	2,802.5	148.8	2,653.7	238.4	18.9	788.1	1,523.6	84.7	44.6	1,313.6	170.2	12,662.4
Uneaten:												
Jan. 24	[2] 49.9	4.9	45.0	6.8	.8	7.7	27.8	1.9	1.3	22.2	3.4	214.8
Jan. 26	38.0	2.8	35.2	4.6	.2	8.1	21.0	1.3	.8	17.4	1.8	170.7
Jan. 25, 26	4.1	.4	3.7	.6	.0	.7	2.2	.2	.1	1.9	.3	18.3
Total	92.0	8.1	83.9	12.0	1.0	16.5	51.0	3.4	2.2	41.5	5.5	403.8
Eaten	2,710.5	140.7	2,569.8	226.4	17.9	771.6	1,472.6	81.3	42.4	1,272.1	164.7	12,258.6
Feces	1,122.1	98.4	1,023.7	108.9	....	394.4	489.9	30.5	17.4	530.3	63.5	5,252.6
Digested	1,588.4	42.3	1,546.1	117.5	17.9	377.2	982.7	50.8	25.0	741.8	101.2	7,006.0
Percentage digestibility	58.60	30.06	60.16	51.90	100.0	48.89	66.73	62.48	58.96	58.31	61.45	57.15

[1] The average composition of the two samples taken for steer A is used in computing the digestibility.
[2] Exclusive of 6.8 grams of salt.

TABLE 71.—*Feed and excreta—Period II, 1905.*

Feed and feces.	Steer A.				Steer B.			
	Number of days.	Fresh weight.	Dry matter.		Number of days.	Fresh weight.	Dry matter.	
		Grams.	*Per cent.*	*Grams.*		*Grams.*	*Per cent.*	*Grams.*
Timothy hay:								
Total	10	22,500.0	88.69	19,955.7	10	20,000.0	88.95	17,790.0
Offered per day	....	2,250.0	....	1,995.6	....	2,000.0	....	1,779.0
Wheat bran:								
Total	10	30,000.0	86.11	25,832.7	10	20,000.0	90.13	18,026.0
Offered per day	....	3,000.0	....	2,583.2	....	2,000.0	....	1,802.6
Feces:								
Collected	10	94,840.0	18.49	17,538.8	10	68,600.0	19.96	13,689.2
Spilled Feb. 17	....	629.4	27.02	170.1	....	....	....	....
Spilled May 5	....	....	....	....	....	54.6	45.24	24.7
In duct Feb. 16	....	370.2	23.37	91.0	....	....	....	....
In duct Feb. 18	....	378.3	25.44	96.3	....	....	....	....
In duct May 4	....	....	....	....	....	179.5	20.62	37.0
In duct May 6	....	....	....	....	....	42.0	25.48	10.7
Total	....	96,217.9	....	17,896.2	....	68,876.1	....	13,761.6
Excreted per day	....	9,621.8	....	1,789.6	....	6,887.6	....	1,376.2

TABLE 72.—*Digestibility of rations—Period II, 1905.*

	Dry matter.	Ash.	Organic matter.	Protein.	Non-protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Total nitrogen.	Carbon.	Hydrogen.	Energy.
Steer A.	*Grams.*	*Gms.*	*Grams.*	*Gms.*	*Gms.*	*Grams.*	*Grams.*	*Gms.*	*Gms.*	*Grams.*	*Gms.*	*Calories.*
Timothy hay...	1,995.6	84.8	1,910.8	99.0	10.4	785.3	979.4	36.7	18.0	938.7	120.4	8,797.4
Wheat bran....	2,583.2	194.8	2,388.4	380.8	21.9	291.6	1,583.8	110.3	71.5	1,181.6	165.1	11,775.3
	4,578.8	279.6	4,299.2	479.8	32.3	1,076.9	2,563.2	147.0	89.5	2,120.3	285.5	20,572.7
Feces..........	1,789.6	144.2	1,645.4	186.7	.....	601.3	816.2	41.2	29.9	844.0	104.4	8,261.0
Digested.	2,789.2	135.4	2,653.8	293.1	32.3	475.6	1,747.0	105.8	59.6	1,276.3	181.1	12,311.7
Percentage digestibility....	60.91	48.43	61.73	61.09	100.0	44.16	68.16	71.97	66.59	60.19	63.43	59.84
Steer B.												
Timothy hay...	1,779.0	81.8	1,697.2	107.8	1.2	678.9	879.2	30.1	17.5	841.1	130.6	7,974.5
Wheat bran....	1,802.6	134.3	1,668.3	250.6	20.0	188.2	1,120.3	89.2	48.2	800.0	128.9	8,041.0
	3,581.6	216.1	3,365.5	358.4	21.2	867.1	1,999.5	119.3	65.7	1,641.1	259.5	16,015.5
Feces..........	1,376.2	130.0	1,246.2	140.1	.....	468.6	602.1	35.4	22.4	636.0	92.9	6,297.9
Digested.	2,205.4	86.1	2,119.3	218.3	21.2	398.5	1,397.4	83.9	43.3	1,005.1	166.6	9,717.6
Percentage digestibility....	61.57	39.84	62.97	60.91	100.0	45.96	69.89	70.33	65.91	61.25	64.20	60.68

TABLE 73.—*Feed and excreta—Period III, 1905.*

Feed and feces.	Steer A.				Steer B.			
	Number of days.	Fresh weight.	Dry matter.		Number of days.	Fresh weight.	Dry matter.	
Timothy hay:		*Grams.*	*Per cent.*	*Grams.*		*Grams.*	*Per cent.*	*Grams.*
Total..................	10	22,500.0	88.93	20,009.9	10	20,000.0	88.69	17,738.4
Offered per day......		2,250.0		2,001.0		2,000.0		1,773.8
Feces:								
Collected.............	10	44,405.0	20.35	9,035.5	10	36,550.0	21.88	7,996.7
Spilled, Feb. 22......						1.4	92.86	1.3
Spilled, Mar. 10......		25.2	63.24	15.9				
In duct, Feb. 23......						10.8	33.33	3.6
In duct, Feb. 25......						21.4	27.11	5.8
In duct, Mar. 9.......		158.5	23.60	37.4				
In duct, Mar. 11......		9.0	37.36	3.3				
Total.............		44,597.7		9,092.1		36,583.6		8,007.4
Excreted per day..		4,459.8		909.2		3,658.4		800.7

TABLE 74.—*Digestibility of rations—Period III, 1905.*

	Dry matter.	Ash.	Organic matter.	Protein.	Non-protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Total nitrogen.	Carbon.	Hydrogen.	Energy.
Steer A.	*Grams.*	*Gms.*	*Grams.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Cals.*
Timothy hay..	2,001.0	81.4	1,919.6	101.9	15.4	799.2	968.3	34.8	19.5	945.9	126.7	9,007.5
Feces..........	909.2	51.6	857.6	78.3	......	363.1	396.9	19.3	12.5	459.7	52.5	4,419.3
Digested.	1,091.8	29.8	1,062.0	23.6	15.4	436.1	571.4	15.5	7.0	486.2	74.2	4,588.2
Percentage digestibility...	54.56	36.61	55.32	23.16	100.00	54.57	59.01	44.54	36.22	51.40	58.56	50.94
Steer B.												
Timothy hay..	1,773.8	75.4	1,698.4	88.0	9.2	698.0	870.6	32.6	16.0	834.4	107.0	7,819.6
Feces..........	800.7	47.0	753.7	79.1	......	308.4	348.7	17.5	12.7	401.1	47.2	3,918.9
Digested.	973.1	28.4	944.7	8.9	9.2	389.6	521.9	15.1	3.3	433.3	59.8	3,900.7
Percentage digestibility...	54.86	37.67	55.62	10.11	100.00	55.82	59.95	46.32	20.63	51.93	55.89	49.88

TABLE 75.—*Feed and excreta—Period IV, 1905.*

Feed and feces.	Steer A.				Steer B.			
	Number of days.	Fresh weight.	Dry matter.		Number of days.	Fresh weight.	Dry matter.	
Timothy hay:		*Grams.*	*Per cent.*	*Grams.*		*Grams.*	*Per cent.*	*Grams.*
Total	10	40,000.0	87.33	34,931.2	10	30,000.0	88.58	26,573.7
Offered per day		4,000.0		3,493.1		3,000.0		2,657.4
Uneaten residues:								
March 24						481.0	93.25	448.6
March 24						13.0	93.07	12.1
March 25						35.9	91.09	32.7
Total						529.9		493.4
Uneaten per day						53.0		[1] 49.3
Feces:								
Collected	10	97,480.0	17.21	16,779.2	10	58,195.0	20.16	11,730.9
Spilled, Mar. 24						12.0	59.16	7.1
Spilled, Mar. 31		5.0	84.00	4.2				
In duct, Mar. 23						5.8	82.76	4.8
In duct, Mar. 25						4.8	56.25	2.7
In duct, Mar. 30		54.0	37.27	20.1				
In duct, Apr. 1		24.0	52.93	12.7				
Total		97,563.0		16,816.2		58,217.6		11,745.5
Excreted per day		9,756.3		1,681.6		5,821.8		1,174.6

[1] Including salt. Without salt it is 47.8.

TABLE 76.—*Digestibility of rations—Period IV, 1905.*

	Dry matter.	Ash.	Organic matter.	Protein.	Non-protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Total nitrogen.	Carbon.	Hydrogen.	Energy.
Steer A.	*Grams.*	*Gms.*	*Grams.*	*Gms.*	*Gms.*	*Grams.*	*Grams.*	*Gms.*	*Gms.*	*Grams.*	*Gms.*	*Calories.*
Timothy hay	3,493.1	148.8	3,344.3	148.8	24.8	1,403.2	1,702.9	64.6	29.0	1,641.2	210.7	15,677.7
Feces	1,681.6	94.7	1,586.9	136.2	......	690.8	724.4	35.5	21.8	835.3	115.4	8,055.9
Digested	1,811.5	54.1	1,757.4	12.6	24.8	712.4	978.5	29.1	7.2	805.9	95.3	7,621.8
Percentage digestibility	51.86	36.36	52.55	8.47	100.00	50.77	57.46	45.05	24.83	49.10	45.23	48.62
Steer B.												
Timothy hay	2,657.4	107.6	2,549.8	113.2	29.5	1,041.7	1,312.8	52.6	24.4	1,248.1	150.9	11,912.6
Uneaten	[1] 47.8	2.0	45.8	3.6	0.1	17.3	23.6	1.2	0.6	23.2	......	219.6
	2,609.6	105.6	2,504.0	109.6	29.4	1,024.4	1,289.2	51.4	23.8	1,224.9	150.9	11,693.0
Feces	1,174.6	76.3	1,098.3	112.5	......	464.6	497.1	24.1	18.0	584.2	67.0	5,676.8
Digested	1,435.0	29.3	1,405.7	−2.9	29.4	559.8	792.1	27.3	5.8	640.7	83.9	6,016.2
Percentage digestibility	54.99	27.75	56.14	......	100.00	54.65	61.44	53.11	24.33	52.31	55.60	51.45

[1] Exclusive of salt.

DIGESTIBILITY OF TIMOTHY HAY AND OF WHEAT BRAN.

From the data contained in the foregoing tables the percentage digestibility of the several ingredients of the wheat bran may also be computed upon the customary assumption that the latter did not affect the digestibility of the hay. In making this computation the average digestibility of the hay in Periods III and IV has been used, the average being computed as shown in the table below, giving weight to each period in proportion to the amount of hay consumed.

TABLE 77.—*Average digestibility of timothy hay, 1905.*

	Dry matter.	Ash.	Organic matter.	Protein.	Non-protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Total nitrogen.	Carbon.	Hydrogen.	Energy.
Steer A.												
	Gms.	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Calories.*
Fed in Period III..........	2,001.0	81.4	1,919.6	101.9	15.4	799.2	968.3	34.8	19.5	945.9	126.7	9,007.5
Fed in Period IV..........	3,493.1	148.8	3,344.3	148.8	24.8	1,403.2	1,702.9	64.6	29.0	1,641.2	210.7	15,677.7
Total...	5,494.1	230.2	5,263.9	250.7	40.2	2,202.4	2,671.2	99.4	48.5	2,587.1	337.4	24,685.2
Digested in period III...	1,091.8	29.8	1,062.0	23.6	15.4	436.1	571.4	15.5	7.0	486.2	74.2	4,588.2
Digested in Period IV...	1,811.5	54.1	1,757.4	12.6	24.8	712.4	978.5	29.1	7.2	805.9	95.3	7,621.8
Total....	2,903.3	83.9	2,819.4	36.2	40.2	1,148.5	1,549.9	44.6	14.2	1,292.1	169.5	12,210.0
Percentage digestibility...	52.84	36.45	53.56	14.44	100.0	52.15	58.02	44.87	29.28	49.94	50.24	49.46
Steer B.												
Fed in Period III..........	1,773.8	75.4	1,698.4	88.0	9.2	698.0	870.6	32.6	16.0	834.4	107.0	7,819.6
Fed in Period IV..........	2,609.6	105.6	2,504.0	109.6	29.4	1,024.4	1,289.2	51.4	23.8	1,224.9	150.9	11,693.0
Total...	4,383.4	181.0	4,202.4	197.6	38.6	1,722.4	2,159.8	84.0	39.8	2,059.3	257.9	19,512.6
Digested in Period III...	973.1	28.4	944.7	8.9	9.2	389.6	521.9	15.1	3.3	433.3	59.8	3,900.7
Digested in Period IV...	1,435.0	29.3	1,405.7	−2.9	29.4	559.8	792.1	27.3	5.8	640.7	83.9	6,016.2
Total...	2,408.1	57.7	2,350.4	6.0	38.6	949.4	1,314.0	42.4	9.1	1,074.0	143.7	9,916.9
Percentage digestibility ..	54.94	31.88	55.93	3.04	100.0	55.12	60.84	50.48	22.86	52.15	55.72	50.82

In the following computation of the digestibility of the wheat bran it has been assumed that the uneaten residue left by steer B in Period I contained hay and bran in the same proportion as the ration weighed out.

TABLE 78.—*Computed digestibility of wheat bran, 1905.*

	Dry matter.	Ash.	Organic matter	Protein.	Non-protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Total nitrogen.	Carbon.	Hydrogen.	Energy.
Steer A.												
Period I:												
Total digested	*Gms.* 1,933.8	*Gms.* 75.5	*Gms.* 1,858.3	*Gms.* 160.2	*Gms.* 21.1	*Gms.* 395.3	*Gms.* 1,203.9	*Gms.* 77.8	*Gms.* 33.3	*Gms.* 899.6	*Gms.* 128.9	*Calories.* 8,588.1
Computed digestible hay	1,045.1	30.4	1,014.6	13.9	11.6	391.1	578.2	17.9	5.3	468.5	59.8	4,395.5
Digested from bran	888.7	45.1	843.7	146.3	9.5	4.2	625.7	59.9	28.0	431.1	69.1	4,192.6
Total in bran	1,370.2	101.9	1,268.3	202.7	9.5	146.9	844.3	64.9	37.5	627.5	87.2	6,226.6
Percentage digestibility	64.86	44.26	66.52	72.18	100.00	2.86	74.11	92.30	74.67	68.70	79.24	67.33
						63.55						
Period II:												
Total digested	2,789.2	135.4	2,653.8	293.1	32.3	475.6	1,747.0	105.8	59.6	1,276.3	181.1	12,311.7
Computed digestible hay	1,054.5	30.9	1,023.4	14.3	10.4	409.5	568.2	16.5	5.3	468.8	60.5	4,351.2
Digested from bran	1,734.7	104.5	1,630.4	278.8	21.9	66.1	1,178.8	89.3	54.3	807.5	120.6	7,960.5
Total in bran	2,583.2	194.8	2,388.4	380.8	21.9	291.6	1,583.8	110.3	71.5	1,181.6	165.1	11,775.3
Percentage digestibility	67.15	53.64	68.26	73.21	100.00	22.67	74.43	80.96	75.94	68.34	73.05	67.60
						66.38						
Steer B.												
Period I:												
Total digested	1,588.4	42.3	1,546.1	117.5	17.9	377.2	982.7	50.8	25.0	741.8	101.2	7,006.0
Computed digestible hay	940.5	22.0	919.1	2.3	13.1	365.2	523.8	17.0	3.5	423.7	57.6	3,911.0
Digested from bran	647.9	20.3	627.0	115.2	4.8	12.0	458.9	33.8	21.5	318.1	43.6	3,095.0
Total in bran	998.6	71.6	926.6	149.8	4.8	109.1	611.7	47.7	27.3	459.7	61.4	4,563.2
Percentage digestibility	64.88	28.35	67.67	76.90	100.00	11.00	75.02	70.86	78.75	69.20	71.01	67.83
						65.33						
Period II:												
Total digested	2,205.4	86.1	2,119.3	218.3	21.2	398.5	1,397.4	83.9	43.3	1,005.1	166.6	9,717.6
Computed digestible hay	977.4	26.1	949.2	3.3	1.2	374.2	534.9	15.2	4.0	438.6	72.8	4,052.6
Digested from bran	1,228.0	60.0	1,170.1	215.0	20.0	24.3	862.5	68.7	39.3	566.5	93.8	5,665.0
Total in bran	1,802.6	134.3	1,618.3	250.6	20.00	188.2	1,120.3	89.2	48.2	800.0	128.9	8,041.0
Percentage digestibility	68.12	44.68	70.14	85.79	100.00	12.91	76.99	77.02	81.54	70.81	72.77	70.45
						67.77						

URINARY EXCRETION.

In a composite sample of the urine made up of aliquot daily samples, dry matter, total solids, nitrogen, carbon, organic hydrogen, and energy were determined. From the results of these determinations and the data for the weights of the urine contained in Table IV of the appendix, the total excretion has been computed as shown in Table 79. In case urine was spilled it was taken up with water, the total nitrogen determined in the mixed sample, including the water used to take it up, and it was assumed that the content of hydrogen, carbon, and energy was proportional to the nitrogen.

TABLE 79.—*Results on urine (inclusive of wash water), 1905.*

	Weight.	Average specific gravity.	Total solids.		Total nitrogen.		Total carbon.		Total hydrogen.		Energy.	
											Per gram.	Total.
Period I.												
Steer A:	*Gms.*		*Per cent.*	*Gms.*	*Per cent.*	*Gms.*	*Per cent.*	*Gms.*	*Per cent.*	*Gms.*	*Calories.*	*Calories.*
Collected........	54,985.0	1.040	7.037	3,869.3	1.113	611.98	1.957	1,076.06	0.293	161.11	0.1997	10,980.5
Spilled, Jan. 20..	353.7	......	.150	.5	.024	.08	.042	.15	.006	.02	.0043	1.5
Spilled, Jan. 21..	745.0	......	1.247	9.3	.197	1.47	.346	2.58	.052	.39	.0353	26.3
Spilled, Jan. 22..	550.4	......	2.216	12.2	.351	1.93	.617	3.40	.092	.51	.0630	34.7
Total........	......	......	......	3,891.3	......	615.46	......	1,082.19	......	162.03	......	11,043.0
Average(18 days)	......	......	......	216.2	......	34.2	......	60.1	......	9.0	......	613.5
Steer B:												
Collected........	20,675.0	1.044	7.957	1,645.1	1.274	263.40	2.159	446.37	.319	65.95	.2248	4,647.7
Spilled, Jan. 26..	292.5	......	6.371	18.6	1.020	2.98	1.729	5.06	.255	.75	.1800	52.7
Total........	......	......	......	1,663.7	......	266.38	......	451.43	......	66.70	......	4,700.4
Average (9 days)	......	......	......	184.9	......	29.6	......	50.2	......	7.4	......	522.3
Period II.												
Steer A:												
Collected........	32,310.0	1.035	7.684	2,482.7	1.209	390.63	1.742	562.84	.267	86.27	.1809	5,844.9
Spilled, Feb. 18..	449.2	......	.733	3.3	.115	.52	.166	.75	.025	.11	.0172	7.7
Spilled, Feb. 18..	110.5	......	8.861	9.8	1.395	1.54	2.010	2.22	.308	.34	.2087	23.1
Total........	......	......	......	2,495.8	......	392.69	......	565.81	......	86.72	......	5,875.7
Average (7 days)	......	......	......	356.5	......	56.1	......	80.8	......	12.4	......	839.4
Steer B:												
Collected........	21,265.0	1.044	9.595	2,040.4	1.246	264.96	2.603	553.53	.451	95.91	.2587	5,501.3
Spilled, May 5...	408.3	......	13.973	57.1	1.814	7.41	3.790	15.47	.657	2.68	.3766	153.8
Spilled, May 5...	2,036.0	......	.913	18.6	.119	2.42	.249	5.07	.043	.88	.0247	50.3
Total........	......	......	......	2,116.1	......	274.79	......	574.07	......	99.47	......	5,715.4
Average (9 days)	......	......	......	235.1	......	30.5	......	63.8	......	11.1	......	635.0
Period III.												
Steer A:												
Collected........	35,995.0	1.022	5.086	1,830.7	.389	140.02	1.146	412.50	.154	55.43	.1087	3,912.7
Spilled, Mar. 10..	256.9	......	3.561	9.1	.272	.70	.801	2.06	.108	.28	.0761	19.6
Total........	......	......	......	1,839.8	......	140.72	......	414.56	......	55.71	......	3,932.3
Average(10 days)	......	......	......	184.0	......	14.1	......	41.5	......	5.6	......	393.2
Steer B:												
Collected........	14,665.0	......	8.861	1,299.5	1.155	169.38	2.570	376.89	.382	56.02	.2460	3,607.6
Average(10 days)	......	......	......	130.0	......	16.9	......	37.7	......	5.6	......	360.8
Period IV.												
Steer A:												
Collected........	23,015.0	1.037	7.905	1,819.3	.601	138.32	2.396	551.44	.277	63.75	.2193	5,047.2
Spilled, Mar. 25..	196.2	......	12.693	24.9	.966	1.90	3.851	7.56	.445	.87	.3525	69.2
Total........	......	......	......	1,844.2	......	140.22	......	559.00	......	64.62	......	5,116.4
Average(10 days)	......	......	......	184.4	......	14.0	......	55.9	......	6.5	......	511.6
Steer B:												
Collected........	15,525.0	1.043	8.829	1,370.7	.793	123.11	2.610	405.20	.394	61.17	.2428	3,769.5
Spilled, Mar. 23..	2,388.1	......	1.306	31.2	.117	2.79	.385	9.19	.058	1.39	.0358	85.5
Total........	......	......	......	1,401.9	......	125.90	......	414.39	......	62.56	......	3,855.0
Average(10 days)	......	......	......	140.2	......	12.6	......	41.4	......	6.3	......	385.5

The foregoing results are summarized for convenience in Table 80.

TABLE 80.—*Average daily excretion in urine, 1905.*

Periods.	Nitrogen.	Carbon.	Energy.	Energy per gram carbon.
Steer A.	*Grams.*	*Grams.*	*Calories.*	*Calories.*
I	34.2	60.1	613.5	10.21
II	56.1	80.8	839.4	10.39
III	14.1	41.5	393.2	9.47
IV	14.0	55.9	511.6	9.15
Steer B.				
I	29.6	50.2	522.3	10.40
II	30.5	63.8	635.0	9.95
III	16.9	37.7	360.8	9.57
IV	12.6	41.4	385.5	9.31

PRODUCTION OF EPIDERMAL TISSUE.

The steer was thoroughly brushed immediately before entering the calorimeter and after leaving it, and the hair, dandruff, etc., in the latter case collected. To this was added the small amount brushed up from the floor of the calorimeter. In these samples determinations of nitrogen, carbon, and energy were made with the following results:

TABLE 81.—*Weight and composition of brushings for the two days in the calorimeter, 1905.*

	Period I.		Period II.		Period III.		Period IV.	
	Steer A.	Steer B.	Steer A.	Steer B.	Steer A.	Steer B.	Steer A.	Steer B.
Weight........grams..	39.2	46.2	54.7	14.9	25.4	22.5	41.6	38.0
Dry matter........per cent..	94.27	92.46	92.65	81.72	94.72	95.29	90.87	91.86
Weight of dry matter........grams..	37.0	42.7	50.7	12.2	24.1	21.4	37.8	34.9
In dry matter:								
Nitrogen—								
Percentage	5.244	4.441	7.681	4.660	5.426	6.046	7.322	6.562
Weight........grams..	1.94	1.89	3.89	.57	1.31	1.29	2.77	2.29
Carbon—								
Percentage	36.391	40.490	42.657	....	39.629	40.600	43.360	39.412
Weight........grams..	13.45	17.28	21.63	....	9.53	8.69	16.39	13.75
Hydrogen—								
Percentage	4.627	5.258	5.538	....	4.682	4.743	5.576	4.548
Weight........grams..	1.71	2.25	2.81	....	1.13	1.02	2.11	1.59
Energy—								
Calories per gram	4.1925	4.3659	4.7535	....	4.2791	4.4601	4.6748	4.3371
Total........calories..	153.0	186.4	241.0	....	103.0	95.4	176.7	151.4

ESTIMATED GROWTH OF HAIR.

The growth of hair was not determined in the experiments of 1905, but the dry matter in the average daily growth in the experiments of 1906 and 1907 was approximately proportional to the relative surface of the animals as computed in proportion to the two-thirds power of the live weight, except in the case of steer B in 1906, in which the observed result was considerably less than the estimated. Taking the results for steer A in 1907 as the basis of computation as a matter of convenience, Table 82 gives a comparison of actual and estimated daily growth in each series of experiments.

TABLE 82.—*Estimated growth of hair.*

Years.	Steer A.			Steer B.		
	Approximate live weight.	Dry matter in daily growth of hair.		Approximate live weight.	Dry matter in daily growth of hair.	
		Actual.	Estimated.		Actual.	Estimated.
	Kilos.	*Grams.*	*Grams.*	*Kilos.*	*Grams.*	*Grams.*
1905	270	....	3.38	200	....	2.76
1906	400	4.76	4.39	300	2.54	3.62
1907	500	5.09	5.09	375	4.29	4.20

Applying to the estimated daily growth in 1905 the average percentages of nitrogen, carbon, and hydrogen and the average heats of combustion found for both animals in both the other years, we obtain the estimate shown in Table 83 for the amounts of the several elements and of energy contained in the daily growth of hair. These, added to the amounts contained in the brushings, give the average daily production of epidermal tissue which is used in the balance tables on subsequent pages.

TABLE 83.—*Average daily production of epidermal tissue, 1905.*

Components.	Steer A.			Steer B.		
	In estimated growth of hair.	In brushings.	Total.	In estimated growth of hair.	In brushings.	Total.
Dry matter.......grams..	3.38	18.70	22.08	2.76	13.90	16.66
Nitrogen.......do....	.50	1.24	1.74	.41	.76	1.17
Carbon.......do....	1.65	7.63	9.28	1.34	6.62	7.96
Hydrogen.......do....	.24	.97	1.21	.19	.81	1.00
Energy.......calories..	17.95	83.70	101.65	14.65	72.20	86.85

DETERMINATION OF RESPIRATORY PRODUCTS.

At about 1 p. m. on the sixth day of the 10 during which the excreta were collected, the animal was placed in the respiration calorimeter and the air current started. During the following 5 hours the necessary adjustments of the calorimeter were made, and beginning at 6 p. m. the respiratory products, as well as the heat evolved, were measured for the succeeding 48 hours, the time being divided into subperiods of 12 hours each. In other words, the respiration experiments covered the seventh and eighth days out of the 10 (or the fourteenth and fifteenth out of the 18 included in Period I, steer A).

In previous publications the data of the respiration determinations have been given in considerable detail. In Part III of this report the technic of the respiration experiments is described and illustrated by the detailed figures of one subperiod. It has not seemed necessary, however, to occupy space with a complete tabulation of these results for each subperiod, since at best they could scarcely serve any other purpose than verification of the arithmetical accuracy of the calculations. These calculations have been checked independently by two computers and are believed to be substantially correct, while the complete records of the experiments will be carefully preserved in the files of the Institute. Table 84 shows the results obtained for the excretion of carbon and hydrogen in the forms of carbon dioxid, water, and hydrocarbon gases for each subperiod, together with the ratio of hydrogen to carbon in the combustible gases excreted.

TABLE 84.—*Carbon and hydrogen in gaseous excreta, 1905.*

Periods.	In CO_2 and H_2O.		In hydrocarbons.		CH_4 computed from C.	H : C in hydrocarbons.
	Carbon.	Hydrogen.	Carbon.	Hydrogen.		
Period I.						
Steer A, Jan. 18 and 19:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	1:
Subperiod 1	461.4	346.4	30.98	10.21	41.4	3.035
Subperiod 2	457.2	332.0	31.29	10.31	41.8	3.035
First day	918.6	678.4	62.27	20.52	83.2	3.035
Subperiod 3	407.2	286.6	30.84	10.16	41.1	3.036
Subperiod 4	419.8	271.4	30.93	10.19	41.3	3.036
Second day	827.0	558.0	61.77	20.35	82.4	3.036
Average	872.8	618.2	62.02	20.44	82.8	3.035
Steer B, Jan. 25 and 26:						
Subperiod 1	327.1	163.2	22.89	8.04	30.6	2.847
Subperiod 2	356.0	189.5	24.03	7.84	32.1	3.065
First day	683.1	352.7	46.92	15.88	62.7	2.955
Subperiod 3	356.6	204.5	24.52	7.66	32.8	3.201
Subperiod 4	372.8	192.0	27.17	8.54	36.3	3.182
Second day	729.4	396.5	51.69	16.20	69.1	3.191
Average	706.3	374.6	49.31	16.04	65.9	3.074
Period II.						
Steer A, Feb. 15 and 16:						
Subperiod 1	484.5	287.4	38.68	12.31	51.7	3.142
Subperiod 2	511.8	296.0	40.12	12.87	53.6	3.117
First day	996.3	583.4	78.80	25.18	105.3	3.129
Subperiod 3	489.6	330.1	39.27	12.80	[1] 52.5	3.068
Subperiod 4	543.4	336.1	40.47	12.92	54.1	3.132
Second day	1,033.0	666.2	79.74	25.72	106.6	3.100
Average	1,014.7	624.8	79.27	25.45	106.0	3.115
Steer B, May 3 and 4:						
Subperiod 1	379.2	154.3	32.52	10.75	43.5	3.025
Subperiod 2	411.8	164.8	34.48	11.56	46.1	2.983
First day	791.0	319.1	67.00	22.31	89.6	3.003
Subperiod 3	389.5	175.7	33.23	10.89	44.4	3.052
Subperiod 4	396.4	181.2	32.07	10.84	42.8	2.959
Second day	785.9	356.9	65.30	21.73	87.2	3.005
Average	788.5	338.0	66.15	22.02	88.4	3.004

[1] Pump stopped 2.23 to 3.06 a. m.

TABLE 84.—*Carbon and hydrogen in gaseous excreta, 1905*—Continued.

Periods.	In CO_2 and H_2O.		In hydrocarbons.		CH_4 computed from C.	H : C in hydrocarbons.
	Carbon.	Hydrogen.	Carbon.	Hydrogen.		
Period III.						
Steer A, Mar. 8 and 9:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	1 :
Subperiod 1	292.8	155.7	15.67	5.08	20.9	3.085
Subperiod 2	[1] 199.0	138.9	18.27	5.75	24.4	3.177
First day	....	294.6	33.94	10.83	45.3	3.134
Subperiod 3	309.9	127.4	18.11	5.69	24.2	3.183
Subperiod 4	307.7	134.1	17.34	5.33	23.2	3.253
Second day	617.6	261.5	35.45	11.02	47.4	3.217
Average	[2] 606.9	278.1	34.70	10.93	[3] 46.4	3.175
Steer B, Feb. 22 and 23:						
Subperiod 1	258.1	93.5	16.02	4.76	21.4	3.365
Subperiod 2	268.9	103.5	18.19	5.78	24.3	3.147
First day	527.0	197.0	34.21	10.54	45.7	3.246
Subperiod 3	257.8	95.5	16.91	5.18	22.6	3.264
Subperiod 4	254.2	93.0	16.99	5.53	22.7	3.072
Second day	512.0	188.5	33.90	10.71	45.3	3.165
Average	519.5	192.8	34.06	10.63	45.5	3.204
Period IV.						
Steer A, Mar. 29 and 30:						
Subperiod 1	395.2	188.6	29.93	10.74	40.0	2.787
Subperiod 2	400.5	183.5	29.51	9.98	39.4	2.957
First day	795.7	372.1	59.44	20.72	79.4	2.869
Subperiod 3	390.7	169.4	29.48	9.62	39.4	3.065
Subperiod 4	398.9	173.2	29.68	9.72	39.7	3.054
Second day	789.6	342.6	59.16	19.34	79.1	3.059
Average	792.7	357.4	59.30	20.03	79.3	2.961
Steer B, Mar. 22 and 23:						
Subperiod 1	310.9	140.8	22.83	7.50	30.5	3.044
Subperiod 2	292.3	129.3	21.79	7.20	29.1	3.026
First day	603.2	270.1	44.62	14.70	59.6	3.035
Subperiod 3	308.7	149.0	23.00	7.19	30.7	3.199
Subperiod 4	284.2	152.2	21.22	7.18	28.4	2.955
Second day	592.9	301.2	44.22	14.37	59.1	3.077
Average	598.1	285.7	44.42	14.54	59.4	3.055

[1] Probably error in determination of CO_2 in ingoing air. [2] Average of 3 subperiods.

The average ratios of hydrogen to carbon in the combustible gases excreted are shown in Table 85, which justifies the assumption that they consisted chiefly or wholly of methane.

TABLE 85.—*Ratios of hydrogen to carbon in combustible gases, 1905.*

Periods.	Steer A.	Steer B.
	1 :	1 :
I	3.035	3.074
II	3.115	3.004
III	3.175	3.204
IV	2.961	3.055

THE BALANCE OF MATTER.

From the data recorded on the foregoing pages, the following tabulation of the average income and outgo of matter has been made up. Following the customary plan, the gain or loss of organic matter has been regarded as consisting wholly of protein and fat, for which the following elementary composition has been assumed:

	Protein.[1]	Fat.[2]
Carbon	52.54	76.5
Hydrogen	7.14	12.0
Oxygen	23.12	11.5
Nitrogen	16.67	....
Sulphur	.52	....
	100.00	100.0

[1] Köhler; Ztschr. Physiol. Chem.; **31**, 479.
[2] Schulze & Reinecke: Landw. Vers. Stat.; **9**, 97.

In order to determine the water balance on the two respiration calorimeter days, the daily portions of the different feeding stuffs previously weighed out were reweighed very shortly before being fed, any difference being considered to represent a gain or loss of water. Special samples of the feces voided in the calorimeter were taken for the determination of dry matter. No special determinations of the urinary solids were made on the calorimeter days, but in computing the water balance, their amount is assumed to have been proportional to that of the total nitrogen. To the income of water as such is added the amount equivalent to the organic hydrogen oxidized, as shown by the balance of that element. It must be borne in mind that the water balance applies only to the two days spent in the calorimeter, while the other balances may be assumed to represent the average of the entire period.

TABLE 86.—*The balance of matter per day and head, 1905.*

Periods and components.	Dry matter.	Water.		Nitrogen.		Carbon.		Organic hydrogen.	
		Income.	Outgo.	Income.	Outgo.	Income.	Outgo.	Income.	Outgo.
Period I.									
Steer A:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Timothy hay	1,977.8	} 437.0		18.0		938.2		119.1	
Wheat bran	1,370.2			37.5		627.5		87.2	
Water		16,478.0							
Feed residues			112.0						
Feces	1,414.2		4,565.0		22.2		666.1		77.4
Urine	216.2		3,013.0		34.2		60.1		9.0
Brushings and hair	22.1				1.7		9.3		1.2
Methane	82.8						62.0		20.7
Carbon dioxid	3,200.5						872.8		
Water vapor			5,564.0						
Organic hydrogen oxidized		1,027.0							114.1
Gain or loss by body—									
Protein	15.6			2.6		8.2		1.1	
Fat	125.3					96.4		15.0	
Water			4,688.0						
Total		17,942.0	17,942.0	58.1	58.1	1,670.3	1,670.3	222.4	222.4
Steer B:									
Timothy hay	1,770.0	} 281.0		15.9		838.9		106.8	
Wheat bran	1,032.5			28.7		474.7		63.4	
Water		14,303.0							
Feed residues	92.0		24.0		2.2		41.5		5.5
Feces	1,122.1		3,981.0		17.4		530.3		63.5
Urine	184.9		1,498.0		29.6		50.2		7.4
Brushings and hair	16.7				1.2		8.0		1.0
Methane	65.9						49.3		16.4
Carbon dioxid	2,590.0						706.3		
Water vapor			3,372.0						
Organic hydrogen oxidized		786.0							87.3
Gain or loss by body—									
Protein	34.8			5.8		18.3		2.5	
Fat	69.8					53.7		8.4	
Water			6,495.0						
Total		15,370.0	15,370.0	50.4	50.4	1,385.6	1,385.6	181.1	181.1
Period II.									
Steer A:									
Timothy hay	1,995.6	} 825.0		18.0		938.7		120.4	
Wheat bran	2,583.2			71.5		1,181.6		165.1	
Water		10,600.0							
Feed residues			50.0						
Feces	1,789.6		7,416.0		29.9		844.0		104.4
Urine	356.5		3,811.0		56.1		80.8		12.4
Brushings and hair	22.1				1.7		9.3		1.2
Methane	106.0						79.3		26.4
Carbon dioxid	3,720.8						1,014.7		
Water vapor			5,623.0						
Organic hydrogen oxidized		1,141.0							126.8
Gain or loss by body—									
Protein	10.8				1.8		5.7		.8
Fat	112.5						86.5		13.5
Water		4,334.0							
Total		16,900.0	16,900.0	89.5	89.5	2,120.3	2,120.3	285.5	285.5
Steer B:									
Timothy hay	1,779.0	} 425.0		17.5		841.1		130.6	
Wheat bran	1,802.6			48.2		800.0		128.9	
Water		7,425.0							
Feed residues									
Feces	1,376.2		5,811.0		22.4		636.0		92.9
Urine	235.1		2,179.0		30.5		63.8		11.1
Brushings and hair	16.7				1.2		8.0		1.0
Methane	88.4						66.2		22.1
Carbon dioxid	2,891.3						788.5		
Water vapor			3,017.0						
Organic hydrogen oxidized		1,087.0							120.8
Gain or loss by body—									
Protein	69.6				11.6		36.6		5.0
Fat	54.6						42.0		6.6
Water		2,070.0							
Total		11,007.0	11,007.0	65.7	65.7	1,641.1	1,641.1	259.5	259.5

TABLE 86.—*The balance of matter per day and head, 1905*—Continued.

Period and component.	Dry matter.	Water.		Nitrogen.		Carbon.		Organic hydrogen.	
		Income.	Outgo.	Income.	Outgo.	Income.	Outgo.	Income.	Outgo.
Period III.									
Steer A:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Timothy hay	2,001.0	187.0		19.5		945.9		126.7	
Water		4,952.0							
Feed residues									
Feces	909.2		3,738.0		12.5		459.7		52.5
Urine	184.0		2,197.0		14.1		41.5		5.6
Brushings and hair	22.1				1.7		9.3		1.2
Methane	46.4						34.7		11.6
Carbon dioxid	[1]2,225.5						[a] 606.9		
Water vapor			2,478.0						
Organic hydrogen oxidized		787.0							87.4
Gain or loss by body—									
Protein	52.8			8.8		27.7		3.8	
Fat	232.0					178.5		27.8	
Water		2,487.0							
Total		8,413.0	8,413.0	28.3	28.3	1,152.1	1,152.1	158.3	158.3
Steer B:									
Timothy hay	1,773.8	83.0		16.0		834.4		107.0	
Water		3,952.0							
Feed residues									
Feces	800.7		3,154.0		12.7		401.1		47.2
Urine	130.0		1,303.0		16.9		37.7		5.6
Brushings and hair	16.7				1.2		8.0		1.0
Methane	45.5						34.1		11.4
Carbon dioxid	1,905.0						519.5		
Water vapor			1,734.0						
Organic hydrogen oxidized		600.0							66.7
Gain or loss by body—									
Protein	88.8			14.8		46.7		6.3	
Fat	155.1					119.3		18.6	
Water		1,556.0							
Total		6,191.0	6,191.0	30.8	30.8	1,000.4	1,000.4	131.9	131.9
Period IV.									
Steer A:									
Timothy hay	3,493.1	322.0		29.0		1,641.2		210.7	
Water		8,135.0							
Feed residues									
Feces	1,681.6		7,074.0		21.8		835.3		115.4
Urine	184.4		2,054.0		14.0		55.9		6.5
Brushings and hair	22.1				1.7		9.3		1.2
Methane	79.3						59.3		19.8
Carbon dioxid	2,906.8						792.7		
Water vapor			3,216.0						
Organic hydrogen oxidized		761.0							84.6
Gain or loss by body—									
Protein	51.0			8.5		26.8		3.6	
Fat	109.9					84.5		13.2	
Water		3,126.0							
Total		12,344.0	12,344.0	37.5	37.5	1,752.5	1,752.5	227.5	227.5
Steer B:									
Timothy hay	2,657.4	229.0		24.4		1,248.1		150.9	
Water		285.0							
Feed residues	47.8		6.0		.6		23.2		
Feces	1,174.6		3,925.0		18.0		584.2		67.0
Urine	140.2		1,405.0		12.6		41.4		6.3
Brushings and hair	16.7				1.2		8.0		1.0
Methane	59.4						44.4		14.8
Carbon dioxid	2,193.1						598.1		
Water vapor			2,571.0						
Organic hydrogen oxidized		624.0							69.3
Gain or loss by body—									
Protein	48.0			8.0		25.2		3.4	
Fat	33.8					26.0		4.1	
Water		6,769.0							
Total		7,907.0	7,907.0	32.4	32.4	1,299.3	1,299.3	158.4	158.4

[1] From only 3 subperiods.

COMPUTED GAINS OR LOSSES OF LIVE WEIGHT IN THE CALORIMETER.

The results of the heat determinations recorded on subsequent pages, as is there pointed out, require a correction for the amount of matter gained or lost by the body of the animal. In the absence of direct determinations of the oxygen consumed, these gains or losses by the body have been computed in Table 86 on the usual assumption that its small content of carbohydrates remained substantially unchanged and that the gains or losses of organic matter may be regarded as consisting of protein or fat. The ash of the urine not having been determined, it is not possible to compute an ash balance, but this omission does not render the results seriously erroneous for the purpose here in view.

Subject to these relatively small uncertainties, the data of Table 86 show the single factors which make up the gain or loss of live weight during the days spent in the calorimeter. To the results as thus computed there must be added a correction for irregularity of excretion, especially of the feces. In computing the balances of nitrogen, carbon, and hydrogen, the average excretion of dry matter as determined in the 10-day digestion period is rightly made the basis of calculation. The actual amount of dry matter excreted during the two days in the respiration calorimeter, however, differs somewhat from this average. While the differences are relatively insignificant, they are entered as corrections in the proper column of Table 87.

TABLE 87.—*Computed daily gains or losses of live weight in the calorimeter, 1905.*

	Period I.		Period II.		Period III.		Period IV.	
	Loss.	Gain.	Loss.	Gain.	Loss.	Gain.	Loss.	Gain.
Steer A.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Protein[1]	16			11	53		51	
Fat	125			113	232		110	
Water		4,688	4,334		2,487		3,126	
Correction for irregularity of excretion		344		108		25		80
Balance	4,891			4,102		2,747		3,207
	5,032	5,032	4,334	4,334	2,772	2,772	3,287	3,287
Steer B.								
Protein	35			70	89		48	
Fat	70			55	155		34	
Water		6,495	2,070		1,556		6,769	
Correction for irregularity of excretion		176	86			30		176
Balance	6,566			2,031		1,770		6,675
	6,671	6,671	2,156	2,156	1,800	1,800	6,851	6,851

[1] Computed from nitrogen, using the factors stated in Part III, page 203.

Our apparatus does not permit of weighing the animal while in the respiration chamber, so that the observed gains or losses of weight cover the four or five preliminary hours in the calorimeter. A comparison of the computed with the observed changes in live weight for this whole time, however, in the manner described in connection with the experiments of 1906 (pp. 145–147), gives the following results, which show a fairly good agreement:

TABLE 88.—*Computed and observed gains in live weight in the calorimeter, 1905.*

Periods.	Computed.	Observed.
	Kilos.	*Kilos.*
Period I:		
Steer A	(1)	− 5.6
Steer B	(1)	+10.4
Period II:		
Steer A	−13.5	−17.5
Steer B	− 5.2	− 9.2
Period III:		
Steer A	− 7.3	− 8.8
Steer B	− 4.6	− 4.0
Period IV:		
Steer A	− 9.4	−10.6
Steer B	−15.1	−15.9

[1] Records incomplete.

HEAT EMISSION.

The results of the determinations of heat, made in the manner described in Part III of this bulletin, pages 205–216, are contained in the following table. That portion of the heat given off by radiation and conduction and brought out of the calorimeter in the water current is recorded for each animal in the column headed "Radiation," while the second column shows the amount carried off as latent heat of water vapor. The small corrections necessary for feed, excreta, etc., put into and taken out of the calorimeter have been made upon the heat given off by radiation.

TABLE 89.—*Heat emission.*

Periods.	Steer A. By radiation.	Steer A. As latent heat of water vapor.	Steer A. Total.	Steer B. By radiation.	Steer B. As latent heat of water vapor.	Steer B. Total.
Period I.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
First day:						
Subperiod 1	2,823.0	1,845.8	4,668.8	2,079.6	869.4	2,949.0
Subperiod 2	2,578.6	1,769.0	4,347.6	2,132.3	1,009.9	3,142.2
Total	5,401.6	3,614.8	9,016.4	4,211.9	1,879.3	6,091.2
Second day:						
Subperiod 3	2,500.7	1,526.7	4,027.4	2,390.7	1,089.7	3,480.4
Subperiod 4	2,534.8	1,446.0	3,980.8	2,385.8	1,022.9	3,408.7
Total	5,035.5	2,972.7	8,008.2	4,776.5	2,112.6	6,889.1
Daily average	5,218.6	3,293.8	8,512.3	4,494.2	1,996.0	6,490.2
Period II.						
First day:						
Subperiod 1	3,120.5	1,531.4	4,651.9	3,339.4	822.0	4,161.4
Subperiod 2	2,822.3	1,576.8	4,399.1	2,485.1	877.9	3,363.0
Total	5,942.8	3,108.2	9,051.0	5,824.5	1,699.9	7,524.4
Second day:						
Subperiod 3	3,038.1	1,758.8	4,796.9	3,717.7	936.0	3,653.7
Subperiod 4	2,837.7	1,790.7	4,628.4	2,595.5	965.5	3,561.0
Total	5,875.8	3,549.5	9,425.3	5,313.2	1,901.5	7,214.7
Daily average	5,909.3	3,328.9	9,238.2	5,568.9	1,800.7	7,369.6
Period III.						
First day:						
Subperiod 1	2,434.4	829.7	3,264.1	2,484.6	498.0	2,982.6
Subperiod 2	2,417.0	740.3	3,157.3	2,166.5	551.4	2,717.9
Total	4,851.4	1,570.0	6,421.4	4,651.1	1,049.4	5,700.5
Second day:						
Subperiod 3	2,308.6	678.8	2,987.4	1,947.7	509.0	2,456.7
Subperiod 4	2,382.0	714.3	3,096.3	1,861.3	495.4	2,356.7
Total	4,690.6	1,393.1	6,083.7	3,809.0	1,004.4	4,813.4
Daily average	4,771.0	1,481.6	6,252.6	4,230.1	1,026.9	5,257.0
Period IV.						
First day:						
Subperiod 1	2,920.9	1,004.9	3,925.8	1,840.4	750.3	2,590.7
Subperiod 2	2,783.3	977.8	3,761.1	2,107.6	689.1	2,796.7
Total	5,704.2	1,982.7	7,686.9	3,948.0	1,439.4	5,387.4
Second day:						
Subperiod 1	2,760.2	902 5	3,662.7	2,149.7	793.9	2,943.6
Subperiod 2	2,578.6	922.7	3,501.3	2,017.0	810.8	2,827.8
Total	5,338.8	1,825.2	7,164.0	4,166.7	1,604.7	5,771.4
Daily average	5,521.5	1,904.0	7,425.5	4,057.4	1,522.1	5,579.4

HEAT PRODUCTION.

The figures of Table 89 show the amounts of heat given off daily by the animals, but these are not necessarily equal to the amounts actually produced in the same time, since heat may, on the one hand, be retained in the body, or, on the other hand, heat produced previous to an experimental period may be eliminated during that period.

Variations in body temperature.—While the body temperature of a healthy animal is approximately constant, it is, nevertheless, subject to minor variations which in the case of man are of a distinctly periodic character. So far as the writers are aware no similar observations are on record for cattle. The rectal temperatures as recorded in the appendix were taken about 1 p. m., except upon the respiration calorimeter days, and show considerable fluctuation, the extreme range being from 0.5° to 1.0° C., while nearly as great variations are observed in some instances from one day to the next. A rise of body temperature is, of course, equivalent to the storage of a corresponding amount of heat, while, conversely, a fall of temperature is equivalent to the emission of heat previously produced. If the extreme range of 1.0° C. occurred between the beginning and end of a calorimeter experiment, the resulting error in these experiments, assuming a specific heat of 0.8 for the whole body, would be equivalent to about 200 calories for steer A and about 160 calories for steer B. Whether such extreme variations actually took place, the data are insufficient to show. A study of the temperature records shows some peculiar irregularities. In many cases, the body temperature is approximately the same for several successive days and then suddenly for one or two days shows a striking difference. The cattle gave no indications of illness and the results raise a question as to the reliability of the rectal temperature as an index of the true body temperature of these animals. In view of these uncertainties and since, moreover, the temperatures taken at 6 p. m. at the end of the calorimeter runs may not be comparable with those taken at a different hour during the remainder of the experiment, we have not attempted to compute any correction, but content ourselves with calling attention to this source of error.

Gain or loss of matter by the body.—Even if the body maintains a uniform temperature, a gain or loss of matter is equivalent to a gain or loss of heat, since the food, drink, and excreta are reduced to the temperature of the calorimeter actually or by calculation. The data recorded in Table 87 show the nature of these gains and losses and enable a correction to be computed. In the computation of this correction, the temperature of the animal has been regarded as represented by the average body temperature for the period. The specific heat of the fat and protein gained is based on Rosenthal's results.[1] He finds a specific heat of approximately 0.3 for dry muscle tissue and of 0.72 for fat tissue. If we assume the latter to contain 15 per cent of water and 85 per cent of fat, neglecting the small amount of fat-free dry matter, Rosenthal's figure is equivalent to a specific heat of 0.66 for fat. The small correction for the irregular excretion of dry matter may be neglected as entirely insignificant for the purpose

[1] Arch. (anat. u.) Physiol.; 1887, p. 215.

of the calculation. Using Period I, steer A, as an illustration, the calculation is as follows:

Period I.—Steer A.

[Average body temperature, 37.6° C. Calorimeter temperature, 17.2° C.]

Protein	−0.016 kilos×0.30×20.4=	− 0.10 calories.
Fat	−0.125 kilos×0.66×20.4=	− 1.68 calories.
Water	+4.688 kilos×1.00×20.4=	+95.64 calories.
	Correction...............	+93.86 calories.

In Table 90 the heat actually produced by the animals has been computed by applying the correction computed as just illustrated to the figures for heat emission contained in Table 89. The results are, of course, still subject to the uncertainty above mentioned regarding the influence of changes in body temperature.

TABLE 90.—*Average heat production, 1905.*

Periods.	Steer A.			Steer B.		
	Heat emission.	Correction for gain by body.	Heat production.	Heat emission.	Correction for gain by body.	Heat production.
	Calories.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
I	8,512.3	+93.9	8,606.2	6,490.2	+130.7	6,620.9
II	9,238.2	−89.4	9,148.8	7,369.6	− 43.1	7,326.5
III	6,252.6	−56.3	6,196.3	5,257.0	− 35.6	5,221.4
IV	7,425.5	−69.1	7,356.4	5,579.4	−145.0	5,434.4

THE BALANCE OF ENERGY.

The following table shows the energy balance for each period of the experiments, assuming the average heat values of 5.7 calories and 9.5 calories per gram, respectively, for the gains of protein and fat shown by the nitrogen and carbon balances of Table 86 and reckoning 13.344 calories per gram of methane. The energy balance has been divided for convenience so as to show also the metabolizable energy of each ration. Before making the latter computation, however, it is necessary to correct the potential energy of the urine for the gain or loss of nitrogen, since in case of a loss of nitrogen, the urine contains energy derived from body tissue, while in the contrary case energy which would have appeared in the urine is retained in the body. The energy of the urine has accordingly been corrected to nitrogen equilibrium by adding or subtracting Rubner's figure of 7.45 calories for each gram of nitrogen gained or lost by the body. This having been done, however, the same correction must be made in the computed energy of the protein gained or lost by the animal in order to be able to compare the metabolizable energy with the gain by the animal. In the table following these corrections have been made.

TABLE 91.—*The balance of energy per day and head, 1905.*

	Steer A.			Steer B.		
	Dry matter.	Energy.		Dry matter.	Energy.	
		Income.	Outgo.		Income.	Outgo.
Period I.	*Grams.*	*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
Timothy hay	1,977.8	8,886.8		1,770.0	7,948.9	
Wheat bran	1,370.2	6,226.6		1,032.5	4,713.5	
Uneaten residues				92.0		403.8
Feces	1,414.2		6,525.3	1,122.1		5,252.6
Urine (corrected for nitrogen)	216.2		594.1	184.9		479.1
Methane	82.8		1,104.9	65.9		879.4
Metabolizable			6,889.1			5,647.5
Total		15,113.4	15,113.4		12,662.4	12,662.4
Metabolizable		6,889.1			5,647.5	
Heat			8,606.2			6,620.9
Brushings	22.1		101.7	16.7		86.9
Loss by body:						
Protein (corrected for nitrogen)	15.6	69.5			155.2	
Fat	125.3	1,190.3			663.1	
Error		559.0			242.0	
Total		8,707.9	8,707.9		6,707.8	6,707.8
Period II.						
Timothy hay	1,995.6	8,797.4		1,779.0	7,974.5	
Wheat bran	2,583.2	11,775.3		1,802.6	8,041.0	
Feces	1,789.6		8,261.0	1,376.2		6,297.9
Urine (corrected for nitrogen)	356.5		852.8	235.1		721.4
Methane	106.0		1,414.5	88.4		1,179.6
Metabolizable			10,044.4			7,816.6
Total		20,572.7	20,572.7		16,015.5	16,015.5
Metabolizable		10,044.4			7,816.6	
Heat			9,148.8			7,326.5
Brushings	22.1		101.7	16.7		86.9
Gain by body:						
Protein (corrected for nitrogen)	10.8		48.2	69.6		310.3
Fat	112.5		1,068.8	54.6		518.7
Error		323.1			425.8	
Total		10,367.5	10,367.5		8,242.4	8,242.4
Period III.						
Timothy hay	2,001.0	9,007.5		1,773.8	7,819.6	
Feces	909.2		4,419.3	800.7		3,918.9
Urine (corrected for nitrogen)	184.0		327.6	130.0		250.6
Methane	46.4		619.2	45.5		607.2
Metabolizable			3,641.4			3,042.9
Total		9,007.5	9,007.5		7,819.6	7,819.6
Metabolizable		3,641.4			3,042.9	
Heat			6,196.3			5,221.4
Brushings	22.1		101.7	16.7		86.9
Loss by body:						
Protein (corrected for nitrogen)	5.3	235.4		88.8	396.0	
Fat	232.0	2,204.0		155.1	1,473.4	
Error		217.2			396.0	
Total		6,298.0	6,298.0		5,308.3	5,308.3
Period IV.						
Timothy hay	3,493.1	15,677.7		2,657.4	11,912.6	
Uneaten residues				47.8		219.6
Feces	1,681.6		8,055.9	1,174.6		5,676.8
Urine (corrected for nitrogen)	184.4		448.3	140.0		325.9
Methane	79.3		1,058.2	59.4		792.6
Metabolizable			6,115.3			4,897.7
Total		15,677.7	15,677.7		11,912.6	11,912.6
Metabolizable		6,115.3			4,897.7	
Heat			7,356.4			5,434.4
Brushings	32.1		101.7	16.7		86.9
Loss by body:						
Protein (corrected for nitrogen)	51.0	227.4		48.0	214.0	
Fat	109.9	1,044.0		33.8	321.1	
Error		71.4			88.5	
		7,458.1	7,458.1		5,521.3	5,521.3

Under the head of "Error" in the foregoing table there is shown the amount by which the gain or loss of energy by the body as determined by a comparison of the income and outgo of energy differs from that contained in the gain or loss of protein and fat as computed from the nitrogen and carbon balance, or, in other words, the extent to which the results differ from those required by the law of the conservation of energy. With the exception of Period IV, these differences are considerable, and while they may be due in part to the somewhat crude nature of the method by which the gain or loss of matter is computed, this can hardly account for the entire error. The relative magnitude of the difference would seem to be most fairly expressed by comparing the observed heat production with that computed from the balance of nitrogen and carbon, as is done in Table 92.

TABLE 92.—*Observed and computed daily heat production, 1905.*

Periods.	Steer A.				Steer B.			
	Observed.	Computed.	Error.	Computed ÷observed.	Observed.	Computed.	Error.	Computed ÷observed.
	Calories.	*Calories.*	*Calories.*	*Per cent.*	*Calories.*	*Calories.*	*Calories.*	*Per cent.*
I........	8,606.2	8,047.2	−559.0	93.5	6,620.9	6,378.9	−242.0	96.4
II........	9,148.8	8,825.7	−323.1	96.5	7,326.5	6,900.7	−425.8	94.2
III.......	6,196.3	5,979.1	−217.2	96.5	5,221.4	4,825.4	−396.0	92.4
IV.......	7,356.4	7,285.0	− 71.4	99.0	5,434.4	5,345.9	− 88.5	98.4

The errors expressed in this way are relatively large and are in the opposite direction to those observed in most of our previous experiments; that is, in these experiments the observed amounts of heat are greater than correspond to the amounts of carbon dioxid and water produced. The experiments are far from being satisfactory in this respect and correspondingly less weight attaches to the results, but, nevertheless, it has seemed worth while to carry out the computation on the same plan adopted for those of the subsequent two years in which a much closer agreement was obtained. It may be added also that the conclusions regarding the availability of the energy of the feeds do not differ widely whether the observed or the computed heat production is made the basis of the comparison.

METABOLIZABLE ENERGY.

By metabolizable energy, or fuel value, is understood the potential energy of the feed minus the potential energy of the excreta, including the gaseous excreta. The chief channel of loss of potential energy is the feces, although a considerable amount is carried off in the urine and the methane.

From Table 91 it is easy to compute in each case the percentage of the total energy which was lost in the several excreta or was metabolizable, and also, in connection with the results of the digestion trials, to compute the metabolizable energy in calories per unit of total or of digestible organic matter.

TIMOTHY HAY.

From the energy balances of Periods III and IV the percentage distribution of the total energy of the hay and also that of the energy contained in the digested organic matter of the latter may be computed as follows:

TABLE 93.—*Percentage distribution of energy of timothy hay, 1905.*

	Total energy.			Energy of digested matter.		
	Period III.	Period IV.	True average.	Period III.	Period IV.	True average.
Steer A.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
In feces	49.06	51.38	50.54	....	....	....
In urine	3.64	2.86	3.14	7.15	5.88	6.35
In methane	6.87	6.75	6.80	13.49	13.88	13.74
Metabolizable	40.43	39.01	39.52	79.36	80.24	79.91
	100.00	100.00	100.00	100.00	100.00	100.00
Steer B.						
In feces	50.12	48.55	49.16	....	....	....
In urine	3.20	2.79	2.95	6.42	5.42	5.81
In methane	7.76	6.78	7.17	15.56	13.17	14.12
Metabolizable	38.92	41.88	40.70	78.02	81.41	80.07
	100.00	100.00	100.00	100.00	100.00	100.00

The metabolizable energy per gram of organic matter, total or digested, was as follows:

TABLE 94.—*Metabolizable energy per gram organic matter of timothy hay, 1905.*

	Organic matter.[1]		Metabolizable energy.		
	Total.	Digested.	Total.[2]	Per gram total organic matter.	Per gram digested organic matter.
Steer A.	*Grams.*	*Grams.*	*Calories.*	*Calories.*	*Calories.*
Period III	1,919.6	1,062.0	3,641.4	1.897	3.429
Period IV	3,344.3	1,757.4	6,115.3	1.828	3.480
Totals and averages	5,263.9	2,819.4	9,756.7	1.853	3.460
Steer B.					
Period III	1,698.4	944.7	3,042.9	1.792	3.221
Period IV	2,504.0	1,405.7	4,897.7	1.956	3.484
Totals and averages	4,202.4	2,350.4	7,940.6	1.889	3.378

[1] From Tables 74 and 76. [2] From Table 91.

WHEAT BRAN.

The results in Table 91 for Periods I and II show the metabolizable energy of the total rations. That of the bran alone may be computed by difference, assuming, much as in the case of a digestion experiment, that the percentages of the energy of the hay which were lost in the various excreta or which were metabolizable were the same as when the hay was fed alone. For this purpose the averages of Table 93 have been used, each animal being treated separately. As before, the results are expressed both in percentages and as calories per gram of total or digestible organic matter.

TABLE 95.—*Percentage distribution of energy of bran, 1905.*

	Organic matter.[1]		Total energy.	Energy of excreta.			Metabolizable energy.
	Total.	Digested.		Feces.	Urine (corrected).	Methane.	
Steer A.							
Period I:	*Grams.*	*Grams.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
In total ration	3,162.6	1,858.3	15,113.4	6,525.3	594.1	1,104.9	6,889.1
In hay	1,894.3	1,014.6	8,886.8	4,491.4	279.0	604.3	3,512.1
In bran	1,268.3	843.7	6,226.6	2.033.9	315.1	500.6	3,377.0
Per cent of total energy			100.0	32.67	5.06	8.04	54.24
Per cent of digested energy					7.51	11.94	80.55
Period II:							
In total ration	4,299.2	2,653.8	20,572.7	8,261.0	852.8	1,414.5	10,044.4
In hay	1,910.8	1,023.4	8,797.4	4,446.3	276.2	598.2	3,476.7
In bran	2,388.4	1,630.4	11,775.3	3,814.7	576.6	816.3	6,567.7
Per cent of total energy			100.0	32.40	4.90	6.93	55.77
Per cent of digested energy					7.25	10.25	82.50
Steer B.							
Period I:							
In total ration	2,569.8	1,546.1	[2]12,258.6	5,252.6	479.1	879.4	5,647.5
In hay	1,643.2	919.1	[2]7,695.4	3,784.6	227.0	551.8	3,132.0
In bran	926.6	627.0	[2]4,563.2	1,468.0	252.1	327.6	2,515.5
Per cent of total energy			100.0	32.17	5.52	7.18	55.13
Per cent of digested energy					8.14	10.58	81.28
Period II:							
In total ration	3,365.5	2,119.3	16,015.5	6,297.9	721.4	1,179.6	7.816 6
In hay	1,697.2	949.2	7,974.5	3,921.9	235.2	571.8	3,245.6
In bran	1,668.3	1,170.1	8,041.0	2,376.0	486.2	607.8	4,571.0
Per cent of total energy			100.0	29.55	6.04	7.56	56.85
Per cent of digested energy					8.57	10.73	80.70

[1] From Tables 70, 72, and 78. [2] Uneaten residues divided proportionally between hay and bran.

TABLE 96.—*Metabolizable energy per gram of organic matter of wheat bran, 1905.*

Periods.	Organic matter.		Metabolizable energy.		
	Total.	Digested.	Total.	Per gram total organic matter.	Per gram digested organic matter.
Steer A.	*Grams.*	*Grams.*	*Calories.*	*Calories.*	*Calories.*
I	1,268.3	843.7	3,377.0	2.663	4.003
II	2,388.4	1,630.4	6,567.7	2.749	4.028
Steer B.					
I	926.6	627.0	2,515.5	2.715	4.012
II	1,668.3	1,170.1	4,571.0	2.740	3.906

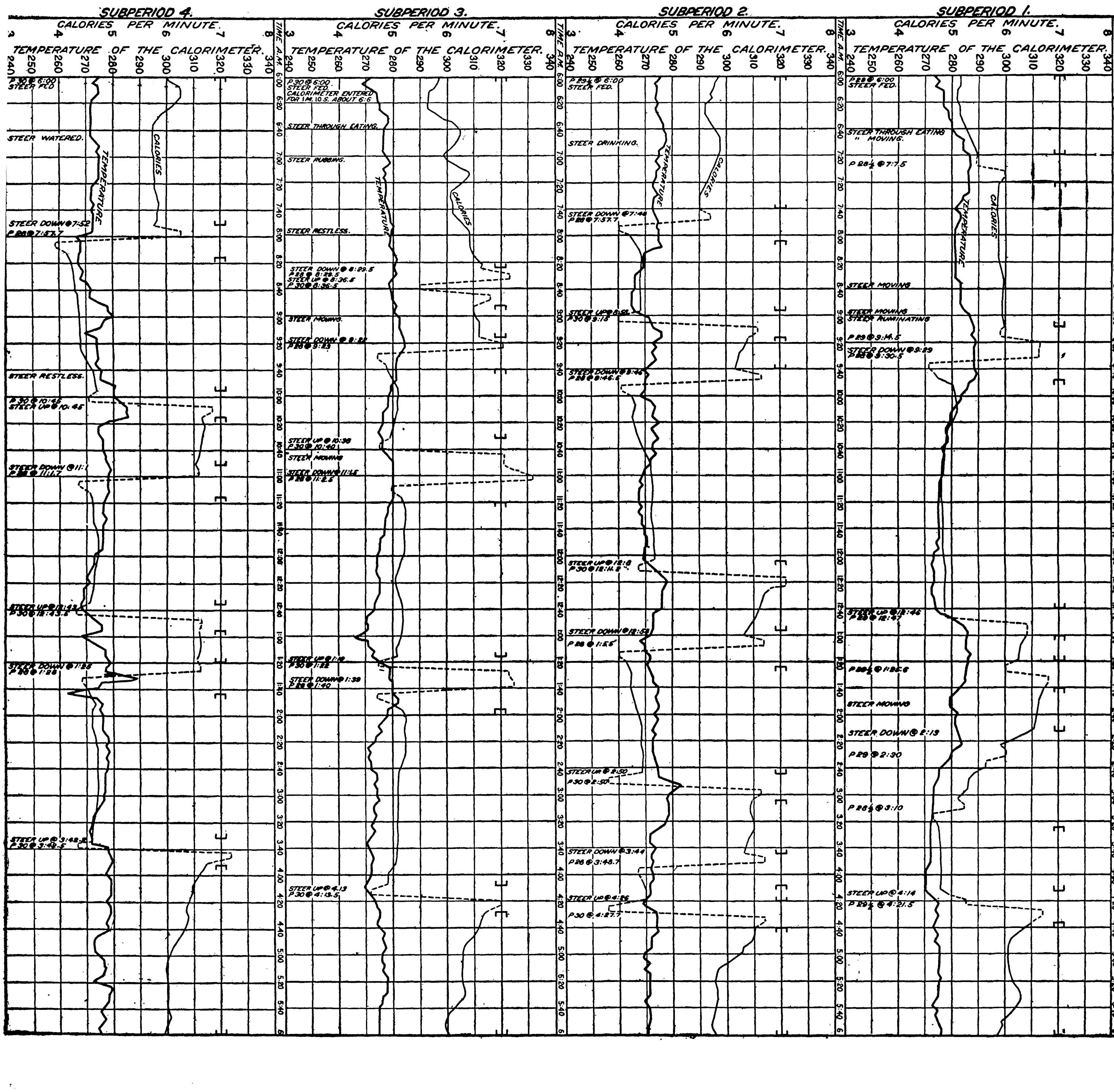
CORRECTION OF HEAT PRODUCTION FOR STANDING AND LYING.

As has been shown by the writers in previous experiments, a very marked effect is exerted upon the heat production of cattle by standing as compared with lying. The differences are so marked that before satisfactory comparisons of different periods can be made it seems necessary to correct the observed results for differences in the proportion of time spent standing and lying.

HEAT EMITTED BY RADIATION AND CONDUCTION.

In previous experiments the basis for such a correction has been obtained by computing the average rate per minute at which heat was brought out of the calorimeter in the water current, either for the entire time spent standing and lying, respectively, or with the omission of such relatively short periods as appeared of little value. In the present experiments a somewhat different plan has been followed. From the records of the rate of flow of water through the heat-absorber system and the observed temperatures of the in-going and outgoing water, the rate per minute at which heat was being brought out was computed at intervals of 4 minutes[1] and the results plotted. Figure 16, representing one of the periods of the experiments of 1907, is a typical example of the results obtained. After a study of these diagrams, those portions of the curves which seemed free from irregularities due to the change from the standing to the lying position, or vice versa, and to the accompanying change in the rate of water flow, and which also seemed fairly free from accidental irregularities, were selected and the average rate per minute at which heat was being given off by radiation and conduction and taken up by the absorber system in the calorimeter computed from these portions of the experiments. In figure 16 the portions selected in that particular subperiod are indicated. In computing the heat during each section of the experiment, the small corrections for capacity and lag, described in Part III, page 208, have been made and consequently the results may be taken to represent, without sensible error, the amounts of heat given off by radiation and conduction to the heat-absorber system during those sections. The table following shows the amounts of heat thus measured.

[1] Each rate was in reality the average for 12 minutes, the successive averages overlapping each other.



SUBPERIOD 4.
SUBPERIOD 3.
SUBPERIOD 2.
SUBPERIOD 1.
CALORIES PER MINUTE.
TEMPERATURE OF THE CALORIMETER.
TIME A.M.
TIME P.M.
TEMPERATURE
CALORIES
STEER FED.
STEER WATERED.
STEER RESTLESS.
STEER THROUGH EATING.
STEER RUBBING.
STEER MOVING
STEER DRINKING.
STEER RUMINATING

TABLE 97.—*Heat emitted by radiation and conduction during periods of standing and lying, 1905.*

Time.	Standing.		Lying.	
	Elapsed time.	Total heat.	Elapsed time.	Total heat.
Period I.				
Steer A:	*Minutes.*	*Calories.*	*Minutes.*	*Calories.*
6.00 p. m. to 9.04 p. m.	184	813.88		
12.00 p. m. to 6.00 a. m.	360	1,299.90		
6.00 a. m. to 12.56 p. m.	416	1,548.68		
1.16 p. m. to 3.24 p. m.			128	326.67
4.40 p. m. to 6.00 p. m.	80	324.78		
6.00 p. m. to 8.40 p. m.	160	617.07		
9.12 p. m. to 10.00 p. m.			48	135.76
10.48 p. m. to 11.28 p. m.			40	121.21
12.40 a. m. to 1.28 a. m.	48	203.33		
5.00 a. m. to 6.00 a. m.	60	235.99		
6.00 a. m. to 7.56 a. m.	116	398.51		
9.48 a. m. to 11.56 a. m.	128	470.78		
12.16 p. m. to 1.40 p. m.			84	181.65
3.04 p. m. to 6.00 p. m.	176	689.35		
Totals	1,728	6,602.27	300	765.29
Correction for feed, water, excreta, etc		+9.06		
		6,611.33		765.29
Heat per minute		3.8260		2.5509
Steer B:				
6.00 p. m. to 9.40 p. m.	220	920.08		
9.44 p. m. to 10.52 p. m.	68			
11.16 p. m. to 12.04 a. m.			48	
12.08 a. m. to 2.44 a. m.			156	1,067.66
2.48 a. m. to 5.56 a. m.			188	
6.00 a. m. to 7.40 a. m.			100	274.76
8.16 a. m. to 9.56 a. m.	100	339.39		
1.20 p. m. to 3.52 p. m.	152	477.44		
6.12 p. m. to 1.12 a. m.	420	1,575.74		
1.48 a. m. to 3.32 a. m.			104	
3.36 a. m. to 4.16 a. m.			40	
4.20 a. m. to 5.28 a. m.			68	603.15
5.32 a. m. to 5.56 a. m.			24	
6.40 a. m. to 9.12 a. m.	152			
9.16 a. m. to 9.36 a. m.	20	1,926.44		
9.40 a. m. to 4.04 p. m.	384			
4.28 p. m. to 5.56 p. m.			88	201.52
Totals	1,516	5,239.09	816	2,147.09
Correction for feed, water, excreta, etc		+21.30		+1.68
		5,260.39		2,148.77
Heat per minute		3.4699		2.6333
Period II.				
Steer A:				
8.00 p. m. to 8.00 a. m.	720	3,093.01		
8.00 a. m. to 11.28 a. m.	208	786.02		
6.00 p. m. to 8.00 p. m.	120	538.93		
8.00 p. m. to 11.48 p. m.	228	1,034.96		
12.12 p. m. to 1.48 p. m.			96	302.28
4.04 p. m. to 5.00 p. m.			56	168.61
4.28 a. m. to 8.00 a. m.	212	912.54		
8.00 a. m. to 10.12 a. m.	132	479.33		
11.08 a. m. to 12.16 p. m.			68	219.38
12.44 p. m. to 3.12 p. m.	148	669.26		
3.32 p. m. to 4.24 p. m.			52	150.40
4.44 p. m. to 6.04 p. m.	80	350.51		
6.36 p. m. to 8.00 p. m.	84	347.96		
Totals	1,932	8,212.52	272	840.67
Correction for feed, water, excreta, etc		+22.28		
		8,234 80		840.67
Heat per minute		4.2623		3.0906
Steer B:				
6.44 p. m. to 8.00 p. m.	76	290.98		
8.24 p. m. to 11.20 p. m.			176	964.25
11.24 p. m. to 1.52 a. m.			148	
2.12 a. m. to 5.56 a. m.	224	953.35		

TABLE 97.—*Heat emitted by radiation and conduction during periods of standing and lying, 1905*—Continued.

Time.	Standing.		Lying.	
	Elapsed time.	Total heat.	Elapsed time.	Total heat.
Period II—Contiuued.				
Steer B—Continued.	*Minutes.*	*Calories.*	*Minutes.*	*Calories.*
8.16 a. m. to 9.56 a. m.			100	329.12
10.32 a. m. to 11.16 a. m.			44	134.43
11.36 a. m. to 12.28 p. m.	52	225.53		
12.44 p. m. to 1.36 p. m.			52	782.43
1.40 p. m. to 4.56 p. m.			196	
5.28 p. m. to 5.56 p. m.	28	131.65		
6.00 p. m. to 8.04 p. m.	124	517.06		
8.48 p. m. to 9.32 p. m.			44	808.93
9.36 p. m. to 1.08 a. m.			212	
1.32 a. m. to 4.24 a. m.	172	759.89		
4.52 a. m. to 5.28 a. m.			36	97.62
5.48 a. m. to 5.56 a. m.	8	30.28		
6.00 a. m. to 9.00 a. m.	180	727.92		
9.28 a. m. to 3.40 p. m.			372	1,179.29
4.04 p. m. to 6.00 p. m.	116	486.57		
Totals	980	4,123.23	1,380	4,294.07
Correction for feed, water, excreta, etc		+23.41		
		4,146.64		4,294.07
Heat per minute		4.2313		3.1116
Period III.				
Steer A:				
10.16 p. m. to 2.36 a. m.	260	945.51		
6.08 a. m. to 8.04 a. m.	116	408.94		
9.20 a. m. to 11.12 a. m.	112	405.71		
12.20 p. m. to 1.28 p. m.			68	164.40
1.40 p. m. to 2.43 p. m.	63	949.11		
2.43 p. m. to 6.00 p. m.	197			
6.00 p. m. to 8.51 p. m.	171	768.30		
8.51 p. m. to 9.28 p. m.	37			
10.04 p. m. to 11.56 p. m.			112	277.70
12.16 a. m. to 12.50 a. m.	34	654.85		
12.50 a. m. to 1.07 a. m.	17			
1.07 a. m. to 3.08 a. m.	121			
3.28 a. m. to 3.31 a. m.			3	302.37
3.31 a. m. to 4.34 a. m.			63	
4.34 a. m. to 5.36 a. m.			62	
6.00 a. m. to 6.42 a. m.	42	936.94		
6.42 a. m. to 8.12 a. m.	90			
8.12 a. m. to 10.32 a. m.	140			
11.52 a. m. to 12.32 p. m.			40	96.91
1.12 p. m. to 6.00 p. m.	288	999.21		
Totals	1,688	6,068.57	348	841.38
Correction for feed, water, excreta, etc		−14.07		
		6,054.50		841.38
Heat per minute		3.5867		2.4177
Steer B:				
8.00 p. m. to 10.52 p. m.	172	1,184.95		
10.56 p. m. to 11.16 p. m.	20			
11.20 p. m. to 11.44 p. m.	24			
11.48 p. m. to 1.40 a. m.	112			
4.24 a. m. to 4.56 a. m.			32	199.72
5.00 a. m. to 5.48 a. m.			48	
6.08 a. m. to 7.08 a. m.	60	1,026.36		
7.12 a. m. to 7.36 a. m.	24			
7.40 a. m. to 8.08 a. m.	28			
8.12 a. m. to 11.40 a. m.	208			
12.16 p. m. to 12.48 p. m.			32	299.38
12.52 p. m. to 12.56 p. m.			4	
1.00 p. m. to 1.44 p. m.			44	
1.48 p. m. to 2.40 p. m.			52	
3.24 p. m. to 5.56 p. m.	152	459.83		
6.00 p. m. to 7.24 p. m.	84	254.40		
7.48 p. m. to 11.40 p. m.			232	533.82
12.00 p. m. to 1.20 a. m.	80	274.83		
1.44 a. m. to 4.44 a. m.			180	438.68
5.00 a. m. to 5.56 a. m.	52	184.37		

TABLE 97.—*Heat emitted by radiation and conduction during periods of standing and lying, 1905*—Continued.

Time.	Standing.		Lying.	
	Elapsed time.	Total heat.	Elapsed time.	Total heat.
Period III—Continued.				
Steer B—Continued.	*Minutes.*	*Calories.*	*Minutes.*	*Calories.*
6.00 a. m. to 7.04 a. m.	64	638.89		
7.08 a. m. to 9.32 a. m.	144			
9.56 a. m. to 10.16 a. m.			20	34.83
10.44 a. m. to 12.00 a. m.	.76	240.50		
12.20 p. m. to 3.12 p. m.			172	495.01
3.16 p. m. to 4.20 p. m.			64	
4.48 p. m. to 6.00 p. m.	72	238.81		
Totals	1,372	4,502.94	888	2,001.44
Correction for feed, water, excreta, etc.		−23.06		
		4,479.88		2,001.44
Heat per minute		3.2652		2.2744
Period IV.				
Steer A:				
6.00 p. m. to 12.28 a. m.	388	1,636.75		
12.48 a. m. to 1.36 a. m.			48	137.63
1.56 a. m. to 6.00 a. m.	244	994.57		
6.00 a. m. to 11.16 a. m.	316	1,220.41		
11.36 a. m. to 12.00 p. m.			24	146.51
12.24 p. m. to 6.00 p. m.	336	1,317.86		
6.00 p. m. to 11.44 p. m.	344	1,415.22		
12.08 a. m. to 2.28 a. m.			140	377.75
2.44 a. m. to 6.00 a. m.	196	834.57		
6.00 a. m. to 8.36 a. m.	156	577.53		
9.00 a. m. to 10.40 a. m.			100	260.96
11.00 a. m. to 12.04 p. m.	64	270.31		
2.04 p. m. to 2.36 p. m.	32	130.99		
3.08 p. m. to 4.08 p. m.	60	239.33		
4.48 p. m. to 6.00 p. m.	72	283.28		
Totals	2,208	8,920.82	312	922.85
Correction for feed, water, excreta, etc.		−20.26		
		8,900.56		922.85
Heat per minute		4.0310		2.9578
Steer B:				
6.00 p. m. to 6.56 p. m.	56	195.27		
11.40 p. m. to 5.40 a. m.			360	963.61
6.04 a. m. to 8.28 a. m.	144	556.33		
9.12 a. m. to 12.52 p. m.			220	556.53
1.40 p. m. to 3.12 p. m.			92	
3.16 p. m. to 4.00 p. m.			44	644.32
4.04 p. m. to 5.56 p. m.			112	
6.00 p. m. to 7.04 p. m.			64	329.07
7.08 p. m. to 8.00 p. m.			52	
9.00 p. m. to 10.04 p. m.	64			
10.08 p. m. to 10.28 p. m.	20	430.23		
10.32 p. m. to 11.08 p. m.	36			
11.36 p. m. to 11.56 p. m.			20	
12.00 p. m. to 12.24 a. m.			24	
12.28 a. m. to 1.36 a. m.			68	910.29
1.40 a. m. to 1.48 a. m.			8	
1.52 a. m. to 2.16 a. m.			24	
2.20 a. m. to 5.36 a. m.			196	
6.04 a. m. to 7.12 a. m.	68	250.77		
7.40 a. m. to 8.24 a. m.			44	
8.28 a. m. to 8.56 a. m.			28	760.78
9.00 a. m. to 12.52 p. m.			232	
1.12 p. m. to 2.16 p. m.	64	571.72		
2.20 p. m. to 4.08 p. m.	108			
4.36 p. m. to 6.00 p. m.			84	180.20
Totals	560	2,004.32	1,672	4,344.80
Correction for feed, water, excreta, etc.		−11.51		+2.16
		1,992.81		4,346.96
Heat per minute		3.5586		2.5999

The average rate per minute at which heat was given off by radiation and conduction in the standing and lying portions of the several periods is summarized in the following table:

TABLE 98.—*Average heat per minute emitted by radiation and conduction, 1905.*

Periods.	Standing.	Lying.
Steer A.	*Calories.*	*Calories.*
I	3.8260	2.5509
II	4.2623	3.0906
III	3.5867	2.4177
IV	4.0310	2.9578
Steer B.		
1	3.4699	2.6333
II	4.2313	3.1116
III	3.2652	2.2744
IV	3.5586	2.5999

HEAT GIVEN OFF AS LATENT HEAT OF WATER VAPOR.

The foregoing table shows the rate at which the animals gave off heat by radiation and conduction when standing and lying, respectively. Unfortunately no such detailed record of the rate at which heat was emitted as latent heat of water vapor is available, since only the total water vapor given off in each subperiod was determined. For the manner in which this was distributed between the standing and lying periods we must therefore depend upon estimates. As was pointed out in a previous paper,[1] the extremes of probable variation would seem to be represented by the assumptions, first, that the heat given off as latent heat of water vapor was proportional to the amount of heat given off by radiation and conduction, or, second, that the total amount given off as latent heat of water vapor was unchanged in the lying as compared with the standing periods. In considering which of these assumptions seems the more probable, it is desirable to anticipate some of the results of the experiments of the two succeeding years.

Table 99 shows the amount of time spent standing and lying in each subperiod of the three series of experiments, the time being expressed both as minutes and as a percentage of the total time, and likewise the percentage of the total heat emitted in each subperiod which was carried off as latent heat of water vapor.

[1] Bureau of Animal Industry Bul. 51, p. 38.

TABLE 99.—*Percentage of heat emitted as latent heat of water vapor.*

Periods.	Experiments of 1905.			Experiments of 1906.			Experiments of 1907.		
	Time standing.		Per cent heat in water vapor.	Time standing.		Per cent heat in water vapor.	Time standing.		Per cent heat in water vapor.
	Minutes.	Per cent.		Minutes.	Per cent.		Minutes.	Per cent.	
Steer A.									
Period I:									
Subperiod 1	720	100.00	39.54	437	60.70	23.05	402	55.84	20.92
Subperiod 2	571	79.31	40.69	526	73.06	21.78	354	49.17	21.52
Subperiod 3	414	57.51	37.88	223	30.97	23.11	346	48.04	22.28
Subperiod 4	569	79.03	36.32	324	45.00	21.30	349	48.48	22.12
Totals and averages	2,274	78.96	38.70	1,510	52.43	22.32	1,451	50.38	21.72
Period II:									
Subperiod 1	720	100.00	32.92	434	60.28	26.74	417	57.92	28.98
Subperiod 2	468	65.01	35.85	440	61.12	25.46	394	54.73	29.58
Subperiod 3	568	78.89	36.66	429	59.58	27.17	617	85.70	29.07
Subperiod 4	519	72.09	38.69	361	50.14	26.65	425	59.03	29.16
Totals and averages	2,275	78.99	36.04	1,664	57.78	26.49	1,853	64.34	29.19
Period III:									
Subperiod 1	580	80.56	25.42	351	48.75	20.49	444	61.67	22.05
Subperiod 2	583	80.98	23.44	537	74.58	18.39	398	55.28	22.04
Subperiod 3	414	57.51	22.72	349	48.48	19.27	264	36.67	21.41
Subperiod 4	597	82.92	23.07	408	56.67	19.16	308	42.78	21.92
Totals and averages	2,174	75.49	23.70	1,645	57.12	19.32	1,414	49.10	21.85
Period IV:									
Subperiod 1	648	90.00	25.60	337	46.81	21.78	334	46.39	24.71
Subperiod 2	679	94.31	26.00	336	46.67	21.57	435	60.42	23.83
Subperiod 3	551	76.53	24.64	409	56.81	23.10	375	52.09	24.32
Subperiod 4	459	63.75	26.35	382	53.06	22.19	266	36.95	25.16
Totals and averages	2,337	81.15	25.64	1,464	50.83	22.19	1,410	48.96	24.50
Steer B.									
Period I:									
Subperiod 1	294	40.84	29.48	376	52.23	25.05	262	36.39	22.66
Subperiod 2	515	71.53	32.14	344	47.78	26.91	455	63.20	22.65
Subperiod 3	437	60.70	31.31	188	26.11	24.76	304	42.22	22.61
Subperiod 4	621	86.25	30.01	454	63.06	24.65	359	49.86	22.43
Totals and averages	1,867	64.83	30.75	1,362	47.29	25.32	1,380	47.92	22.59
Period II:									
Subperiod 1	357	49.58	19.75	305	42.36	24.04	332	46.12	31.21
Subperiod 2	276	38.34	26.10	337	46.81	23.56	317	44.03	31.55
Subperiod 3	375	52.09	25.62	321	44.59	22.66	301	41.81	32.43
Subperiod 4	322	44.72	27.11	340	47.22	23.86	367	50.98	32.06
Totals and averages	1,330	46.18	24.44	1,303	45.24	23.53	1,317	45.73	31.82
Period III:									
Subperiod 1	467	64.87	16.70	362	50.28	21.86	270	37.50	26.19
Subperiod 2	543	75.42	20.29	483	67.09	20.28	388	40.00	26.01
Subperiod 3	257	35.70	20.72	390	54.17	20.38	200	27.78	26.64
Subperiod 4	401	55.70	21.02	399	55.42	19.68	379	52.64	26.01
Totals and averages	1,668	57.92	19.53	1,634	56.74	20.56	1,237	42.95	26.22
Period IV:									
Subperiod 1	156	21.67	28.96	249	34.58	21.39	277	38.48	27.58
Subperiod 2	190	26.39	24.64	217	30.14	19.80	302	41.95	27.31
Subperiod 3	194	26.94	26.97	211	29.31	20.73	253	35.14	30.21
Subperiod 4	267	37.08	28.67	275	38.20	22.52	301	41.81	31.67
Totals and averages	807	28.02	27.28	952	33.05	21.12	1,133	39.34	29.20

If the absolute amount of heat given off as latent heat of water vapor is independent of whether the animal is standing or lying, then in any subperiod in which the percentage time spent standing is greater than the average for the entire period, a larger percentage of the total heat would tend to be given off by radiation and conduction, and a less proportion would appear as latent heat of water vapor. If, on the other hand, the heat given off as latent heat of water vapor is proportional to the heat given off by radiation and conduction, then the ratio between the two would be unaffected by the standing or lying of the animal.

The amount of heat carried off in the water vapor is also influenced, however, by the relative humidity of the ventilating air current and by its temperature, and these effects might mask the effect of the standing and lying in a single experiment. The foregoing table, however, allows of 96 such comparisons, the results of which are as follows:

Out of 46 subperiods in which the percentage of time spent standing was greater than the average for the period, there were 23 cases in which the heat carried off in the water vapor was above the average for the period and 23 in which it was below the average for the period.

Out of 50 subperiods in which the percentage of time spent standing was less than the average for the period, there were 25 cases in which the heat carried off in the water vapor was above the average for the period and 25 in which it was below the average for the period.

In other words, the above figures give no indication of any influence of the standing and lying positions upon the proportions of heat eliminated as latent heat of water vapor and by radiation and conduction, respectively. An entirely similar result may be obtained by similar comparisons of the results of the experiments upon timothy hay reported in Bulletin 51 of this bureau.

Averaging the percentage of total heat brought out in the water vapor in the foregoing 46 and 50 subperiods, respectively, we obtain the following averages:

Percentage of heat as latent heat of water vapor.

	Per cent.
Time spent standing greater than average	25.73
Time spent standing less than average	25.46

The foregoing seems to justify the conclusion that the percentage of the heat which is given off as latent heat of water vapor is independent of the standing or lying of the animal and that at any rate a correction of the observed heat production based upon this assumption will probably not involve any serious error. The method of computing the correction to a uniform number of hours of standing and lying has already been described and illustrated in Part I, page 43.

HEAT PRODUCTION CORRECTED TO 12 HOURS' STANDING.

With the exception of the experiments with steer A in 1905, the time spent standing does not vary widely from 12 hours out of the 24, averaging 710 minutes. It will be convenient, therefore, to correct the heat emission to 12 hours' standing, which will make the correction relatively small in most of the experiments. Applying to the several periods the methods of computation illustrated in Part I, and adding the same correction as in Table 90 for the gain or loss of matter by the body, we have the following results for the heat production corrected to 12 hours' standing:

TABLE 100.—*Heat production corrected to 12 hours' standing, 1905.*

Periods.	Steer A.			Steer B.		
	Corrected total heat emission.	Correction for gain or loss of matter by body.	Corrected total heat production.	Corrected total heat emission.	Correction for gain or loss of matter by body.	Corrected total heat production.
	Calories.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
I	7,644.8	+93.9	7,738.7	6,231.8	+130.7	6,362.5
II	8,474.2	−89.4	8,384.8	7,451.7	− 43.1	7,408.6
III	5,692.1	−56.3	5,635.8	5,116.3	− 35.6	5,080.7
IV	6,778.1	−69.1	6,709.0	5,996.7	−145.0	5,851.7

AVAILABILITY OF METABOLIZABLE ENERGY.

By substituting the foregoing corrected values for the heat production in the energy balances of Table 91, we obtain the corresponding corrected values for the gain or loss of energy by the body of the animal. These can then be compared with the amounts of metabolizable energy supplied in the feed. In the foregoing tables the energy value of the growth of hair and brushings has been given separately. In previous publications this has been treated as part of the gain by the body, but in strictness it should not be thus regarded. The growth of hair and other epidermal tissue goes on substantially independent of the feed supply, except possibly in extreme cases, and is more analogous to an excretum than to a gain of tissue. In the following comparisons "Gain" signifies only the actual increase of protein and fat, exclusive of the growth of hair, etc.

TABLE 101.—*Corrected gains [1] of energy by the animals, 1905.*

Periods.	Steer A.		Steer B.	
	Income.	Outgo.	Income.	Outgo.
Period I.	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Metabolizable	6,889.1		5,647.5	
Brushings and hair		101.7		86.9
Heat (from Table 100)		7,738.7		6,362.5
Gain	951.3		801.9	
Total	7,840.4	7,840.4	6,449.4	6,449.4
Period II.				
Metabolizable	10,044.4		7,816.6	
Brushings and hair		101.7		86.9
Heat (from Table 100)		8,384.8		7,408.6
Gain		1,557.9		321.1
Total	10,044.4	10,044.4	7,816.6	7,816.6
Period III.				
Metabolizable	3,641.4		3,042.9	
Brushings and hair		101.7		86.9
Heat (from Table 100)		5,635.8		5,080.7
Gain	2,096.1		2,124.7	
Total	5,737.5	5,737.5	5,167.6	5,167.6
Period IV.				
Metabolizable	6,115.3		4,897.7	
Brushings and hair		101.7		86.9
Heat (from Table 100)		6,709.0		5,851.7
Gain	695.4		1,040.9	
Total	6,810.7	6,810.7	5,938.6	5.938.6

[1] A gain entered under the heading "Income" is, of course, a negative gain, i. e., a loss.

While the gain or loss of energy by the animal might, of course, be compared with the total energy supplied in the feed, it is in many respects preferable to compare it with the metabolizable energy. In this way the relation is made more independent of accidental variations in the excretion of feces, urine, and methane. Thus, for example, if the excretion of feces in a given period be in error by the equivalent of 100 calories, the metabolizable energy and the gain of energy by the animal are both affected by an equal amount and in the same direction, so that the relation between the two is relatively less affected than is that between the gain and the total energy of the feed. Moreover, the comparison with the metabolizable energy would seem to afford a more rational comparison of the physiological processes of nutrition proper.

The average live weights of the animals for the last six weighings of each period were as follows:

TABLE 102.—*Average live weights in calorimeter experiments, 1905.*

Periods.	Steer A.	Steer B.
	Kilos.	*Kilos.*
I	270.7	198.6
II	279.1	196.9
III	268.8	194.1
IV	277.5	189.6

TIMOTHY HAY.

A comparison of Periods III and IV shows the availability of the metabolizable energy of the hay. Correcting for the differences in live weight by means of the formula in Part I (p. 44), in which $m=$ the percentage availability, we have:

TABLE 103.—*Availability of metabolizable energy of timothy hay, 1905.*

Steer A—Periods IV-III.	Steer B—Periods IV-III.
$n=\left(\frac{268.8}{277.5}\right)^{2/3}=0.9,781$	$n=\left(\frac{194.1}{189.6}\right)^{2/3}=1.016$
$x_3=3,641.4 \quad y_3=-2,096.1$	$x_3=3,042.9 \quad y_3=-2,124.7$
$x_4=6,115.3 \quad y_4=-\ 695.4$	$x_4=4,897.7 \quad y_4=-1,040.9$
$m=\frac{-2,096.1-(0.9781\times-\ 695.4)}{3,641.4-(0.9781\times\ 6,115.3)}=60.51$ per cent.	$m=\frac{-2,124.7-(1.016\times-1,040.9)}{3,042.9-(1.016\times\ 4,897.7)}=55.21$ per cent.

WHEAT BRAN.

In Periods I and II two different amounts of wheat bran were added to the basal ration of Period III. By comparing either Period I or II with Period III, or by comparing Periods I and II with each other, we have the basis on which to compute the availability of the metabolizable energy of the bran. Before this can be done, however, a small correction must be made, in the manner described in Part I (p. 45), for the differences in the amounts of hay consumed. The following table contains these corrections computed on the basis of the results for the average metabolizable energy of the hay per gram of organic matter contained in Table 94 and those for the percentage availability of the latter contained in Table 103. In these computations each animal is considered separately.

TABLE 104.—*Corrections for differences in amount of hay eaten, 1905.*

Periods.	Steer A.			Steer B.		
	Organic matter of hay.	Metabolizable energy of total rations.	Gain by animal.	Organic matter of hay.	Metabolizable energy of total rations.	Gain by animal.
	Grams.	*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
Period III	1,919.6	....	....	1,698.4	....	....
Period I	1,894.3	6,889.1	−951.3	1,643.2	5,647.5	−801.9
Correction	25.3	46.9	28.4	55.2	104.3	+ 57.6
Period I corrected	1,919.6	6,936.0	−922.9	1,698.4	5,751.8	−744.3
Period III	1,919.6	....	....	1,698.4	....	....
Period II	1,910.8	10,044.4	+1,557.9	1,697.2	7,816.6	+321.1
Correction	8.8	16.3	9.9	1.2	2.3	1.3
Period II corrected	1,919.6	10,060.7	+1,567.8	1,698.4	7,818.9	+322.4

Using these corrected figures for Periods I and II, the computations of availability are as follows:

TABLE 105.—*Availability of metabolizable energy of wheat bran, 1905.*

Steer A.—Periods I-III.	Steer B.—Periods I-III.
$n=\left(\frac{268.8}{270.7}\right)^{2/3}=0.9951$	$n=\left(\frac{194.1}{198.6}\right)^{2/3}=0.9847$
$x_3=3,641.4 \quad y_3=-2,096.1$	$x_3=3,042.9 \quad y_3=-2,124.7$
$x_1=6,936.0 \quad y_1=-\ 922.9$	$x_1=5,751.8 \quad y_1=-\ 744.3$
$m=\frac{-2,096.1-(0.9951\times -922.9)}{3,641.4-(0.9951\times 6,936.0)}=36.11$ per cent.	$m=\frac{-2,124.7-(0.9847\times -744.3)}{3,043.9-(0.9847\times 5,751.8)}=53.10$ per cent.
Steer A.—Periods II-III.	**Steer B.—Periods II-III.**
$n=\left(\frac{268.8}{279.1}\right)^{2/3}=0.9752$	$n=\left(\frac{194.1}{196.9}\right)^{2/3}=0.9,904$
$x_3=3,641.4 \quad y_3=-2,096.1$	$x_3=3,042.9 \quad y_3=-2,124.7$
$x_2=10,060.7 \quad y_2=1,567.8$	$x_2=7,818.9 \quad y_2=322.4$
$m=\frac{-2,096.1-(0.9752\times 1,567.8)}{3,641.4-(0.9752\times 10,060.7)}=58.74$ per cent.	$m=\frac{-2,124.7-(0.9904\times 322.4)}{3,042.9-(0.9904\times 7,818.9)}=51.98$ per cent.
Steer A.—Periods II-I.	**Steer B.—Periods II-I.**
$n=\left(\frac{270.7}{279.1}\right)^{2/3}=0.9797$	$n=\left(\frac{198.6}{196.9}\right)^{2/3}=1.006$
$x_1=6,936.0 \quad y_1=-\ 922.9$	$x_1=5,751.8 \quad y_1=-744.3$
$x_2=10,060.7 \quad y_2=1,567.8$	$x_2=7,818.9 \quad y_2=322.4$
$m=\frac{-\ 922.9-(0.9797\times 1,567.8)}{6,936.0-(0.9797\times 10,060.7)}=84.18$ per cent.	$m=\frac{-\ 744.3-(1.006\times 322.4)}{5,751.8-(1.006\times 7,818.9)}=50.55$ per cent.

The results of this series are summarized in Table 106 and represented graphically in figure 7 on page 47, where the abscissas represent the metabolizable energy of the feed and the ordinates the gain or loss by the body of the animal. The diagram includes the corrections for the hay and for the differences in live weight.

TABLE 106.—*Summary of percentage availability of metabolizable energy, 1905.*

	Steer A.	Steer B.
	Per cent.	*Per cent.*
Timothy hay:		
Periods III and IV	60.51	55.21
Wheat bran:		
Periods II and III	58.74	51.98
Periods I and III	36.11	53.10
Periods I and II	84.18	50.55

RESPIRATION CALORIMETER EXPERIMENTS OF 1906.

Beginning on December 4, 1905, the attempt was made to repeat the experiments of 1905 upon wheat bran and timothy hay. The animals, however, showed the same distaste for the exclusive bran ration as in the previous year and in view of the experience of that year it was thought better on the whole to abandon the attempt and to use in the calorimeter experiments the same grain mixture which was employed in the general feeding.

FEEDING STUFFS.

Hay.—The hay used was from the same crop as that employed during the previous year, and, although it had been stored for more than 12 months, was in excellent condition. It was nearly pure timothy containing very little red clover. Somewhat less than 1,000 kilograms was run through the feed cutter on December 12, 1905. Duplicate samples were taken as in the previous year, and the remainder was stored in the same loft previously used. The composition of the two samples taken at this time, as well as of those subsequently taken when the rations were weighed out for the several periods, was as shown in the following table. It will be observed that the two general samples agree very closely in composition. Those taken later show a somewhat higher percentage of nitrogen, with the exception of that in Period III, and also rather more crude fiber, but the differences hardly seem sufficient to seriously disturb the comparison of the periods. That the hay differed considerably in composition from that of the previous year may have been due to variations in quality in different parts of the mow, or possibly to greater losses in handling in the experiments of 1905.

TABLE 107.—*Composition of dry matter of timothy hay, 1906.*

Components.	General samples.			Samples taken during experiments—			
	A.	B.	Average.	Period I.	Period II.	Period III.	Period IV.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Ash	5.87	5.85	5.86	5.71	5.45	5.82	5.87
Protein[1]	6.69	6.74	6.72	7.52	7.28	7.11	7.58
Nonprotein[1]	.84	.81	.83	.56	.75	.50	.66
Crude fiber	33.29	32.76	33.02	34.46	33.29	34.06	34.10
Nitrogen-free extract	50.65	51.38	51.01	49.07	50.68	50.73	49.82
Ether extract	2.66	2.46	2.56	2.68	2.55	1.78	1.97
	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Total nitrogen	1.250	1.252	1.251	1.324	1.325	1.245	1.354
Protein nitrogen	1.071	1.079	1.075	1.204	1.165	1.138	1.213
Carbon				46.52	46.65	47.32	46.72
Hydrogen				7.02	6.39	6.52	6.35
	Calories.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Energy—per gram	4.5669	4.4548	4.5159	4.4831	4.4837	4.5098	4.5090

[1] Computed from nitrogen, using the factors stated in Part III, page 203.

Grain.—The grain consisted of a mixture of one part of bran, three of corn meal, and three of old-process linseed meal by weight. The required daily amount of each grain was weighed out separately and each day's ration mixed before feeding, samples of the individual grains being taken at the same time, the analyses of which are contained in the table following.

TABLE 108.—*Composition of dry matter of grain, 1906.*

Components.	Wheat bran.		Corn meal.		Linseed meal.	
	Period I.	Period II.	Period I.	Period II.	Period I.	Period II.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Ash	[1] 6.90	6.93	1.53	1.50	5.72	5.79
Protein[2]	15.01	13.43	9.17	9.23	26.21	25.09
Nonprotein[2]	2.29	2.95	1.11	.15	6.79	6.21
Crude fiber	9.40	9.80	2.11	2.16	8.76	9.01
Nitrogen-free extract	61.64	62.16	80.83	81.69	43.88	45.82
Ether extract	4.76	4.73	5.25	5.27	8.64	8.08
	100.00	100.00	100.00	100.00	100.00	100.00
Total nitrogen	3.121	2.984	1.765	1.571	6.210	5.884
Protein nitrogen	2.634	2.356	1.529	1.539	4.766	4.562
Carbon	45.02	45.54	45.90	46.25	48.18	48.16
Hydrogen	6.94	6.91	7.04	7.13	6.84	6.88
	Calories.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Energy—per gram	4.5435	4.5136	4.5229	4.5260	4.9088	4.9117

[1] Calculated from composite sample.
[2] Computed from nitrogen, using the factors stated in Part III, page 203.

As the grains were being weighed out, an additional portion of the mixed grain was prepared and an analysis made of this as a check upon the results of the single analyses. Table 109 shows the composition of these composite samples as compared with the composition computed from the weights and composition of individual grains, the results showing a very satisfactory agreement.

TABLE 109.—*Composition of dry matter of mixed grain, 1906.*

Components.	Period I.		Period II.	
	Computed.	Composite sample.	Computed.	Composite sample.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Ash	4.09	4.22	4.11	4.23
Protein[1]	17.31	16.91	16.63	17.09
Nonprotein[1]	3.71	3.65	3.15	3.75
Crude fiber	6.00	6.49	6.19	6.57
Nitrogen-free extract	62.26	62.11	63.52	62.72
Ether extract	6.63	6.62	6.40	5.64
	100.00	100.00	100.00	100.00
Total nitrogen	3.864	3.720	3.621	3.773
Protein nitrogen	3.074	2.944	2.951	2.976
Carbon	46.75	46.51	46.97	47.20
Hydrogen	6.94	6.94	6.99	6.86
	Calories.	*Calories.*	*Calories.*	*Calories.*
Energy per gram	4.6912	4.6925	4.6895	4.7079

[2] Computed from nitrogen, using the factors stated in Part III, page 203.

PERIODS AND RATIONS.

Beginning December 4, 1905, the grain feed of the steers, which up to that time had been the mixture of bran, corn meal, and linseed meal used in the general feeding, was gradually changed to bran alone, which was fed December 17 to 22, inclusive. As already stated, it was not well relished by the animals, the amounts eaten were small, and no gain in weight was made. Accordingly, a return was made to the mixed-grain feed, the experimental periods beginning January 7 for steer A and January 14 for steer B. The dates of the periods and the rations given were as follows, the dates being inclusive, as in previous experiments, and a day signifying the 24 hours ending at 6 p. m. on the date named:

TABLE 110.—*Periods, 1906.*

Periods.	Steer A.		Steer B.	
	Preliminary feeding.	Excreta collected.	Preliminary feeding.	Excreta collected.
I	Jan. 7 to 17	Jan. 18 to 27	Jan. 14 to 24	Jan. 25 to Feb. 2.
Transition feeding[1]	Jan 28 to Feb. 3		Feb. 4 to 10	
II	Feb. 4 to 14	Feb. 15 to 24	Feb. 11 to 22	Feb. 23 to Mar. 3.
III	Feb. 25 to Mar. 7	Mar. 8 to 17	Mar. 4 to 14	Mar. 15 to 24
IV	Mar. 18 to 28	Mar. 29 to Apr. 7	Mar. 25 to Apr. 4	Apr. 5 to 14.

[1] Amount of grain gradually increased.

TABLE 111.—*Daily rations, 1906.*

Periods.	Steer A.				Steer B.			
	Timothy hay.	Wheat bran.	Corn meal.	Linseed meal.	Timothy hay.	Wheat bran.	Corn meal.	Linseed meal.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
I	3,000	300	900	900	2,800	200	600	600
II	3,000	700	2,100	2,100	2,800	357	1,072	1,071
III	3,000				2,800			
IV	5,000				4,300			

DIGESTIBILITY OF THE RATIONS.

The experimental methods were the same as those of the previous year. From the data in Tables VII and VIII of the appendix, the digestibility of the rations is computed in Tables 112 to 119.

TABLE 112.—*Feed and excreta—Period I, 1906.*

	Steer A.				Steer B.			
	Number of days.	Fresh weight.	Dry matter.		Number of days.	Fresh weight.	Dry matter.	
		Grams.	*Per cent.*	*Grams.*		*Grams.*	*Per cent.*	*Grams.*
Timothy hay:								
Total	10	30,000.0	86.95	26,085.0	9	25,200.0	86.95	21,911.4
Uneaten		5.8	96.58	5.6		16.0	84.38	13.5
Eaten		29,994.2		26,079.4		25,184.0		21,897.9
Eaten per day		2,999.4		2,607.9		2,798.2		2,433.1
Wheat bran:								
Total	10	3,000.0	86.59	2,597.7	9	1,800.0	86.59	1,558.6
Eaten per day		300.0		259.8		200.0		173.2
Corn meal:								
Total	10	9,000.0	81.66	7,349.4	9	5,400.0	81.66	4,409.6
Eaten per day		900.0		734.9		600.0		490.0
Linseed meal:								
Total	10	9,000.0	88.59	7,973.1	9	5,400.0	88.59	4,783.9
Eaten per day		900.0		797.3		600.0		531.5
Feces:								
Collected	10	77,372.0	18.88	14,607.8	9	50,305.0	22.50	11,318.6
Spilled, Jan. 24				1.0				
Spilled, Jan. 31						7.2	87.98	6.3
In duct		187.8	22.63	42.5		20.0	63.06	12.6
Total		77,559.8		14,651.3		50,332.2		11,337.5
Excreted per day		7,756.0		1,465.1		5,592.4		1,259.7

TABLE 113.—*Digestibility of rations—Period I, 1906.*

	Dry matter.	Ash.	Organic matter.	Protein.	Non-protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Total nitrogen.	Carbon.	Hydrogen.	Energy.
Steer A.	*Grams.*	*Gms.*	*Grams.*	*Gms.*	*Gms.*	*Grams.*	*Grams.*	*Gms.*	*Gms.*	*Grams.*	*Gms.*	*Calories.*
Timothy hay	2,607.9	148.9	2,459.0	196.1	14.6	898.7	1,279.7	69.9	34.5	1,213.2	183.1	11,691.5
Wheat bran	259.8	[1] 17.9	241.9	39.0	5.9	24.4	160.1	12.4	8.1	117.0	18.0	1,180.4
Corn meal	734.9	11.2	723.7	67.4	8.2	15.5	594.0	38.6	13.0	337.3	51.7	3,323.9
Linseed meal	797.3	45.6	751.7	209.0	54.1	69.8	349.9	68.9	49.5	384.1	54.5	3,913.8
Total	4,399.9	223.6	4,176.3	511.5	82.8	1,008.4	2,383.7	189.8	105.1	2,051.6	307.3	20,109.6
Feces	1,465.1	138.7	1,326.4	195.7		456.4	643.2	31.1	31.3	699.9	93.5	6,855.6
Digested	2,934.8	84.9	2,849.9	315.8	82.8	552.0	1,740.5	158.7	73.8	1,351.7	213.8	13,254.0
Percentage digestibility	66.70	37.97	68.24	61.74	100.00	54.74	73.02	83.61	70.22	65.89	69.56	65.91
Steer B.												
Timothy hay	2,433.1	138.9	2,294.2	183.0	13.6	838.4	1,193.9	65.2	32.2	1,131.9	170.8	10,907.8
Wheat bran	173.2	[1] 12.0	161.2	26.0	4.0	16.3	106.7	8.2	5.4	78.0	12.0	786.9
Corn meal	490.0	7.5	482.5	44.9	5.4	10.3	396.1	25.7	8.6	224.9	34.5	2,216.2
Linseed meal	531.5	30.4	501.1	139.3	36.1	46.6	233.2	45.9	33.0	256.1	36.4	2,609.0
Total	3,627.8	188.8	3,439.0	393.2	59.1	911.6	1,929.9	145.0	79.2	1,690.9	253.7	16,519.9
Feces	1,259.7	114.4	1,145.3	157.1		408.1	553.5	26.6	25.2	606.7	79.9	5,930.0
Digested	2,368.1	74.4	2,293.7	236.1	59.1	503.5	1,376.4	118.4	54.0	1,084.2	173.8	10,589.9
Percentage digestibility	65.28	39.41	66.70	60.05	100.00	55.23	71.32	81.66	68.18	64.12	68.51	64.10

[1] Estimated.

TABLE 114.—*Feed and excreta—Period II, 1906.*

	Steer A.				Steer B.			
	Number of days.	Fresh weight.	Dry matter.		Number of days.	Fresh weight.	Dry matter.	
Timothy hay:		*Grams.*	*Per cent.*	*Grams.*		*Grams.*	*Per cent.*	*Grams.*
Total	10	30,000.0	87.76	26,328.0	9	25,200.0	87.76	22,115.5
Uneaten		19.5	96.41	18.8		31.2	96.15	30.0
Eaten		29,980.5		26,309.2		25,168.8		22,085.5
Eaten per day		2,998.1		2,630.9		2,796.5		2,453.9
Wheat bran:								
Total	10	7,000.0	85.20	5,964.0	9	3,213.0	85.20	2,737.5
Eaten per day		700.0		596.4		357.0		304.2
Corn meal:								
Total	10	21,000.0	82.54	17,333.4	9	9,468.0	82.54	7,963.5
Eaten per day		2,100.0		1,733.3		1,072.0		884.8
Linseed meal:								
Total	10	21,000.0	87.76	18,429.6	9	9,639.0	87.77	8,460.2
Eaten per day		2,100.0		1,843.0		1,071.0		940.0
Feces:								
Collected	10	139,310.0	15.43	21,495.5	9	79,250.0	18.18	14,407.7
In duct		1,193.5	17.12	204.3		574.2	20.44	117.4
Spilled, Feb. 15		27.5	33.09	9.1				
Spilled, Feb. 18		6.0	75.00	4.5				
Spilled, Feb. 20		33.5	45.67	15.3				
Spilled, Feb. 23		16.8	84.85	14.3				
Spilled, Mar. 1						10.0	52.00	5.2
Total		140,587.3		21,743.0		79,834.2		14,530.3
Excreted per day		14,058.7		2,174.3		8,870.5		1,614.5

TABLE 115.—*Digestibility of rations—Period II, 1906.*

	Dry matter.	Ash.	Organic matter.	Protein.	Non-protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Total nitrogen.	Carbon.	Hydrogen.	Energy.
Steer A.	*Grams.*	*Gms.*	*Grams.*	*Gms.*	*Gms.*	*Gms.*	*Grams.*	*Gms.*	*Gms.*	*Grams.*	*Gms.*	*Calories.*
Timothy hay	2,630.9	143.4	2,487.5	191.5	19.7	875.8	1,333.3	67.1	34.9	1,227.3	168.1	11,796.2
Wheat bran	596.4	41.3	555.1	80.1	17.6	58.4	370.7	28.2	17.8	271.6	41.2	2,691.9
Corn meal	1,733.3	26.0	1,707.3	160.0	2.6	37.4	1,415.9	91.3	27.2	801.7	123.6	7,844.7
Linseed meal	1,843.2	106.7	1,736.5	462.4	114.5	166.1	844.5	148.9	108.4	887.6	126.8	9,052.3
Total	6,803.8	317.4	6,486.4	894.0	154.4	1,137.7	3,964.4	335.5	188.3	3,188.2	459.7	31,385.1
Feces	2,174.3	184.8	1,989.5	363.5		694.7	883.4	47.8	58.2	1,045.8	145.0	10,196.6
Digested	4,629.5	132.6	4,496.9	530.5	154.4	443.0	3,081.0	287.7	130.1	2,142.4	314.7	21,188.5
Percentage digestibility	68.04	41.78	69.33	59.34	100.00	38.94	77.72	85.75	69.09	67.20	68.46	67.51
Steer B.												
Timothy hay	2,453.9	133.7	2,320.2	178.6	18.4	816.9	1,243.6	62.6	32.5	1,144.7	156.8	11,002.6
Wheat bran	304.2	21.1	283.1	40.8	9.0	29.8	189.1	14.4	9.1	138.5	21.0	1,373.0
Corn meal	884.8	13.3	871.5	81.7	1.3	19.1	722.8	46.6	13.9	409.2	63.1	4,004.6
Linseed meal	940.0	54.4	885.6	235.8	58.4	84.7	430.7	76.0	55.3	452.7	64.7	4,617.0
Total	4,582.9	222.5	4,360.4	536.9	87.1	950.5	2,586.2	199.6	110.8	2,145.1	305.6	20,997.2
Feces	1,614.5	139.0	1,475.5	218.8		563.6	661.0	32.1	35.0	769.6	105.7	7,476.3
Digested	2,968.4	83.5	2,884.9	318.1	87.1	386.9	1,925.2	167.5	75.8	1,375.5	199.9	13,520.9
Percentage digestibility	64.77	37.53	66.16	59.25	100.00	40.70	74.44	83.92	68.41	64.12	65.41	64.39

TABLE 116.—*Feed and excreta—Period III, 1906.*

	Steer A.				Steer B.			
	Number of days.	Fresh weight.	Dry matter.		Number of days.	Fresh weight.	Dry matter.	
Timothy hay:		*Grams.*	*Per cent.*	*Grams.*		*Grams.*	*Per cent.*	*Grams.*
Total	10	30,000.0	88.25	26,475.0	10	28,000.0	88.25	24,710.0
Uneaten				3.4				7.2
Eaten				26,471.6				24,702.8
Eaten per day				2,647.2				2,470.3
Feces:								
Collected	10	54,980.0	21.77	11,969.1	10	46,545.0	23.12	10,761.2
Spilled, Mar. 15		11.3	91.15	10.3				
In duct		39.2	27.30	10.7				3.3
Washed from duct				1.1				4.3
Total		55,030.5		11,991.2		46,545.0		10,768.8
Excreted per day		5,503.1		1,199.1		4,654.5		1,076.9

TABLE 117.—*Digestibility of rations—Period III, 1906.*

	Dry matter.	Ash.	Organic matter.	Protein.	Non-protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Total nitrogen.	Carbon.	Hydrogen.	Energy.
Steer A.	*Grams.*	*Gms.*	*Grams.*	*Gms.*	*Grams.*	*Gms.*	*Grams.*	*Gms.*	*Gms.*	*Grams.*	*Gms.*	*Calories.*
Timothy hay	2,647.2	154.1	2,493.1	188.2	13.2	901.6	1,342.9	47.1	33.0	1,252.7	172.6	11,938.3
Feces	1,199.1	79.1	1,120.0	128.4		415.0	551.8	24.7	20.5	589.2	78.5	5,757.0
Digested	1,448.1	75.0	1,373.1	59.8	13.2	486.6	791.1	22.4	12.5	663.5	94.1	6,181.3
Percentage digestibility	54.70	48.67	55.08	31.77	100.00	53.97	58.91	47.56	37.88	52.97	54.52	51.78
Steer B.												
Timothy hay	2,470.3	143.8	2,326.5	175.6	12.4	841.4	1,253.2	44.0	30.8	1,169.0	161.1	11,140.6
Feces	1,076.9	83.0	993.9	113.7		351.5	503.8	24.9	18.2	533.0	71.1	5,168.3
Digested	1,393.4	60.8	1,332.6	61.9	12.4	489.9	749.4	19.1	12.6	636.0	90.0	5,972.3
Percentage digestibility	56.41	42.28	57.28	35.25	100.00	58.22	59.80	43.41	40.91	54.41	55.87	53.61

TABLE 118.—*Feed and excreta—Period IV, 1906.*

	Steer A.				Steer B.			
	Number of days.	Fresh weight.	Dry matter.		Number of days.	Fresh weight.	Dry matter.	
Timothy hay:		*Grams.*	*Per cent.*	*Grams.*		*Grams.*	*Per cent.*	*Grams.*
Total	10	50,000.0	88.49	44,245.0	10	43,000.0	88.49	38,050.7
Eaten per day		5,000.0		4,424.5		4,300.0		3,805.1
Feces:								
Collected	10	109,865.0	18.86	20,720.5	10	83,585.0	20.44	17,084.8
Spilled, Mar. 13						26.5	50.94	13.5
In duct		170.3	17.92	30.5		93.7	86.31	80.9
Total		110,035.3		20,751.0		83,705.2		17,179.2
Excreted per day		11,003.5		2,075.1		8,370.5		1,717.9

TABLE 119.—*Digestibility of rations—Period IV, 1906.*

	Dry matter.	Ash.	Organic matter.	Protein.	Non-protein.	Crude fiber.	Nitrogen-free tract.	Ether extract.	Total nitrogen.	Carbon.	Hydrogen.	Energy.
Steer A.	*Grams.*	*Gms.*	*Grams.*	*Gms.*	*Gms.*	*Grams.*	*Grams.*	*Gms.*	*Gms.*	*Grams.*	*Gms.*	*Calories.*
Timothy hay..	4,424.5	259.7	4,164.8	335.4	29.2	1,508.8	2,204.3	87.2	59.9	2,067.1	281.0	19,950.2
Feces.........	2,075.1	148.4	1,926.7	216.6	......	723.4	942.3	44.4	34.7	1,013.9	131.4	9,957.4
Digested......	2,349.4	111.3	2,238.1	118.8	29.2	785.4	1,262.0	42.8	25.2	1,053.2	149.6	9,992.8
Percentage digestibility...	53.10	42.86	53.74	35.42	100.00	52.05	57.25	49.08	42.07	50.95	53.24	50.09
Steer B.												
Timothy hay..	3,805.1	223.4	3,581.7	288.4	25.1	1,297.5	1,895.7	75.0	51.5	1,777.7	241.6	17,157.3
Feces.........	1,717.9	128.0	1,589.9	184.3	......	575.5	794.4	35.7	29.5	851.2	115.6	8,235.7
Digested......	2,087.2	95.4	1,991.8	104.1	25.1	722.0	1,101.3	39.3	22.0	926.5	126.0	8,921.6
Percentage digestibility...	54.85	42.70	55.61	36.10	100.00	55.65	58.09	52.40	42.72	52.12	52.15	52.00

DIGESTIBILITY OF TIMOTHY HAY AND OF MIXED GRAIN.

The average digestibility of the timothy hay in Periods III and IV, computed as in the experiments of the previous year, i. e., giving weight to each period in proportion to the amount of hay eaten, is shown in Table 120, while Table 121 contains the computation of the digestibility of the mixed grain.

TABLE 120.—*Average digestibility of timothy hay, 1906.*

	Dry matter.	Ash.	Organic matter.	Protein.	Non-protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Total nitrogen.	Carbon.	Hydrogen.	Energy.
Steer A.	*Grams.*	*Gms.*	*Grams.*	*Gms.*	*Gms.*	*Grams.*	*Grams.*	*Gms.*	*Gms.*	*Grams.*	*Gms.*	*Calories.*
Fed in Period III..........	2,647.2	154.1	2,493.1	188.2	13.2	901.6	1,342.9	47.1	33.0	1,252.7	172.6	11,938.3
Fed in Period IV..........	4,424.5	259.7	4,164.8	335.4	29.2	1,508.8	2,204.3	87.2	59.9	2,067.1	281.0	19,950.2
Total...	7,071.7	413.8	6,657.9	523.6	42.4	2,410.4	3,547.2	134.3	92.9	3,319.8	453.6	31,888.5
Digested in Period III...	1,448.1	75.0	1,373.1	59.8	13.2	486.6	791.1	22.4	12.5	663.5	94.1	6,181.3
Digested in Period IV...	2,349.4	111.3	2,238.1	118.8	29.2	785.4	1,262.0	42.8	25.2	1,053.2	149.6	9,992.8
Total...	3,797.5	186.3	3,611.2	178.6	42.4	1,272.0	2,053.1	65.2	37.7	1,716.7	243.7	16,174.1
Percentage digestibility...	53.70	45.02	54.24	34.11	100.00	52.77	57.88	48.55	40.58	51.71	53.73	50.72
Steer B.												
Fed in Period III..........	2,470.3	143.8	2,326.5	175.6	12.4	841.4	1,253.2	44.0	30.8	1,169.0	161.1	11,140.6
Fed in Period IV..........	3,805.1	223.4	3,581.7	288.4	25.1	1,297.5	1,895.7	75.0	51.5	1,777.7	241.6	17,157.3
Total...	6,275.4	367.2	5,908.2	464.0	37.5	2,138.9	3,148.9	119.0	82.3	2,946.7	402.7	28,297.9
Digested in Period III...	1,393.4	60.8	1,332.6	61.9	12.4	489.9	749.4	19.1	12.6	636.0	90.0	5,972.3
Digested in Period IV...	2,087.2	95.4	1,991.8	104.1	25.1	722.0	1,101.3	39.3	22.0	926.5	126.0	8,921.6
Total...	3,480.6	156.2	3,324.4	166.0	37.5	1,211.9	1,850.7	58.4	34.6	1,562.5	216.0	14,893.9
Percentage digestibility...	55.46	42.54	56.27	35.78	100.00	56.66	58.77	49.08	42.04	53.03	53.64	52.63

TABLE 121.—*Computed digestibility of mixed grain, 1906.*

	Dry matter.	Ash.	Organic matter.	Protein.	Non-protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Total nitrogen.	Carbon.	Hydrogen.	Energy.
Steer A.												
Period I:												
Total digested....	*Grams.* 2,934.8	*Gms.* 84.9	*Grams.* 2,849.9	*Gms.* 315.8	*Gms.* 82.8	*Gms.* 552.0	*Grams.* 1,740.5	*Gms.* 158.7	*Gms.* 73.8	*Grams.* 1,351.7	*Gms.* 213.8	*Calories.* 13,254.0
Computed digestible in hay....	1,400.4	67.0	1,333.8	66.9	14.6	474.2	740.7	33.9	14.0	627.3	98.4	5,929.9
Digested from grain...	1,534.4	17.9	1,516.1	248.9	68.2	77.8	999.8	124.8	59.8	724.4	115.4	7,324.1
Total in grain.....	1,792.0	74.7	1,717.3	315.4	68.2	109.7	1,104.0	119.9	70.6	838.4	124.2	8,418.1
Percentage digestibility....	85.63	23.96	88.28	78.92	100.00	70.92	90.56	104.09	84.70	86.40	92.91	87.00
						88.78						
Period II:												
Total digested....	4,629.5	132.6	4,496.9	530.5	154.4	443.0	3,081.0	287.7	130.1	2,142.4	314.7	21,188.5
Computed digestible in hay....	1,412.8	64.6	1,349.2	65.3	19.7	462.2	771.7	32.6	14.2	634.6	90.3	5,983.0
Digested from grain...	3,216.7	68.0	3,147.7	465.2	134.7	−19.2	2,309.3	255.1	115.9	1,507.8	224.4	15,205.5
Total in grain.....	4,172.9	174.0	3,998.9	702.5	134.7	261.9	2,631.1	268.4	153.4	1,960.9	291.6	19,588.9
Percentage digestibility.....	77.09	39.08	78.71	66.22	100.00	− 7.33	87.77	95.04	75.55	76.89	76.95	77.62
						79.19						
Steer B.												
Period I:												
Total digested....	2,368.1	74.4	2,293.7	236.1	59.1	503.5	1,376.4	118.4	54.0	1,084.2	173.8	10,589.9
Computed digestible in hay....	1,349.4	59.1	1,290.9	65.5	13.6	475.0	701.7	32.0	13.5	600.2	91.6	5,740.8
Digested from grain...	1,018.7	15.3	1,002.8	170.6	45.5	28.5	674.7	86.4	40.5	484.0	82.2	4,849.1
Total in grain.....	1,194.7	49.9	1,144.8	210.2	45.5	73.2	736.0	79.8	47.0	559.0	82.9	5,612.1
Percentage digestibility....	85.27	30.66	87.60	81.16	100.00	38.93	91.67	108.27	86.17	86.58	99.16	86.40
						86.91						
Period II:												
Total digested....	2,968.4	83.5	2,884.9	318.1	87.1	386.9	1,925.2	167.5	75.8	1,375.5	199.9	13,520.9
Computed digestible in hay....	1,360.9	56.9	1,305.6	63.9	18.4	462.9	730.9	30.7	13.7	607.0	84.1	5,790.7
Digested from grain...	1,607.5	26.6	1,579.3	254.2	68.7	−76.0	1,194.3	136.8	62.1	768.5	115.8	7,730.2
Total in grain.....	2,129.0	88.8	2,040.2	358.3	68.7	133.6	1,342.6	137.0	78.3	1,000.4	148.8	9,994.6
Percentage digestibility....	75.50	29.95	77.41	70.95	100.00	−56.88	88.95	99.85	79.31	76.82	77.82	77.34
						75.76						

URINARY EXCRETION.

The urine was collected, sampled, and analyzed in precisely the same way as in the experiment of the previous year, but in addition triplicate determinations of nitrogen were made daily in a sample of the fresh urine. The results of these daily determinations and the daily excretion of nitrogen are recorded in Table VII of the appendix. The result of the nitrogen determination made upon the composite sample for the whole period is likewise recorded in the same table and shows a satisfactory agreement with that computed from the daily analyses. Table 122 contains the results on the urine, which are also summarized in Table 123.

TABLE 122.—*Results on urine (inclusive of wash water), 1906.*

	Weight.	Average specific gravity.	Total solids.		Total nitrogen.		Total carbon.		Total hydrogen.		Energy.	
											Per gram.	Total.
Period I.												
Steer A:	*Grams.*		*P.ct.*	*Gms.*	*P.ct.*	*Gms.*	*P.ct.*	*Grams.*	*P.ct.*	*Gms.*	*Cals.*	*Cals.*
Collected	52,615.0	1.0410	8.310	4,372.3	1.307	687.48	1.903	1,001.26	0.335	176.26	192.7	10,139.4
Spilled, Jan. 21	813.1	......	.032	.3	.005	.04	[1].007	.06	[1].001	.01	[1].7	.6
Spilled, Jan. 27	173.5	......	9.137	15.9	1.437	2.49	[1]2.093	3.63	[1].339	.59	[1]211.8	36.7
Total	......	......	......	4,388.5	......	690.01	......	1,004.95	......	176.86	......	10,176.7
Average (10 days)	......	......	......	438.9	......	69.00	......	100.50	......	17.69	......	1,017.7
Steer B:												
Collected	27,093.0	1.0531	11.690	......	1.828	495.26	3.004	813.87	.445	120.56	292.8	7,932.5
Average (9 days)	......	......	......	351.9	......	55.02	......	90.43	......	13.40	......	881.4
Period II.												
Steer A:												
Collected	50,815.0	1.0408	9.270	......	2.112	1,073.39	2.529	1,285.11	.448	227.65	259.4	13,180.1
Average (8 days)	......	......	......	588.8	......	134.17	......	160.64	......	28.46	......	1,647.5
Steer B:												
Collected	31,035.0	1.0513	11.679	......	2.195	681.26	3.251	1,008.95	.553	171.62	319.9	9,229.1
Average (9 days)	......	......	......	402.7	......	75.70	......	112.11	......	19.07	......	1,103.2
Period III.												
Steer A:												
Collected	49,805.0	1.0315	6.521	......	.669	333.43	1.358	676.35	.194	96.62	116.1	5,781.0
Average (10 days)	......	......	......	324.8	......	33.34	......	67.64	......	9.66	......	578.1
Steer B:												
Collected	25,685.0	1.0380	8.615	......	.962	247.05	1.989	510.87	.307	78.85	187.6	4,819.8
Average (9 days)	......	......	......	245.9	......	27.45	......	56.76	......	8.76	......	535.5
Period IV.												
Steer A:												
Collected	44,840.0	1.0356	7.838	......	.687	308.02	1.897	850.61	.268	120.17	163.4	7,327.0
Average (10 days)	......	......	......	351.5	......	30.80	......	85.06	......	12.02	......	732.7
Steer B:												
Collected	32,385.0	1.0433	10.412	3,371.9	.930	301.12	2.416	782.42	.431	139.58	217.2	7,032.5
Spilled, Apr. 12	157.0	......	8.252	13.0	.737	1.16	[1]1.915	3.01	[1].281	.44	[1]172.1	27.0
Total	......	......	......	3,384.9	......	302.28	......	785.43	......	140.02	......	7,059.5
Average (10 days)	......	......	......	338.5	......	30.23	......	78.54	......	14.00	......	706.0

[1] Assumed to be proportional to nitrogen content.

TABLE 123.—*Average daily excretion in urine, 1906.*

Periods.	Nitrogen.	Carbon.	Energy.	Energy per gram of carbon.
Steer A.	*Grams.*	*Grams.*	*Calories.*	*Calories.*
I	69.00	100.50	1,017.7	10.13
II	134.17	160.64	1,647.5	10.26
III	33.34	67.64	578.1	8.55
IV	30.80	85.06	732.7	8.61
Steer B.				
I	55.02	90.43	881.4	9.75
II	75.70	112.11	1,103.2	9.84
III	27.45	56.76	535.5	9.43
IV	30.23	78.54	706.0	8.99

PRODUCTION OF EPIDERMAL TISSUE.

As in the previous year's experiments, the steer was thoroughly brushed before entering and after leaving the calorimeter and the material thus obtained weighed and analyzed. The results of these determinations are contained in Table 124.

TABLE 124.—*Weight and composition of brushings for the two days in the calorimeter, 1906.*

Components and energy.	Steer A.				Steer B.			
	Period I.	Period II.	Period III.	Period IV.	Period I.	Period II.	Period III.	Period IV.
Weight ... grams	37.8	60.0	24.5	25.8	43.0	47.0	26.2	29.1
Dry matter ... per cent	95.67	94.87	95.70	95.75	97.61	95.30	95.97	94.29
Weight of dry matter ... grams	36.16	56.92	23.45	24.70	41.97	44.79	25.14	27.44
In dry matter:								
Nitrogen—								
Percentage	4.70	4.80	4.98	5.85	4.46	4.59	7.07	5.39
Weight ... grams	1.70	2.73	1.17	1.44	1.87	2.06	1.78	1.48
Carbon—								
Percentage	36.72	40.48	41.56	40.76	37.89	40.96	41.74	37.90
Weight ... grams	13.28	23.04	9.75	10.07	15.90	18.35	10.49	10.40
Hydrogen—								
Percentage	5.14	5.49	5.63	5.79	5.06	5.52	5.94	5.20
Weight ... grams	1.86	3.12	1.32	1.43	2.12	2.47	1.49	1.43
Energy—								
Per gram ... calories	4.244	4.447	4.534	4.564	4.223	4.415	4.603	4.193
Total ... do	153.46	253.12	106.32	112.73	177.24	197.75	115.72	115.06

The steers were clipped just before the beginning of the experiment, viz, steer A on January 5 and steer B January 11, and were again clipped shortly after the close of the experiment, steer A on April 19 and steer B on April 20. The weights and composition of the hair obtained at this second clipping were as follows:

TABLE 125.—*Weight and composition of hair, 1906.*

Components and energy.	Steer A.	Steer B.
Number of days	104	99
Weight .... grams..	554.00	289.00
Dry matter .... per cent..	89.40	87.11
Weight of dry matter .... grams..	495.28	251.75
Dry matter per day .... do....	4.76	2.54
In dry matter:		
Nitrogen—		
Percentage	15.45	15.64
Weight .... grams..	76.52	39.37
Daily average .... do....	.74	.40
Carbon—		
Percentage	49.45	49.26
Weight .... grams..	244.92	124.01
Daily average .... do....	2.36	1.25
Hydrogen—		
Percentage	7.78	7.91
Weight .... grams..	38.54	19.91
Daily average .... do....	.37	.20
Energy—		
Per gram .... calories..	5,380.00	5,391.00
Total .... do....	2,664.61	1,357.18
Daily average .... do....	25.62	13.71

If we may assume that the brushings represent fairly well the average daily loss of hair and epidermis, the sum of the brushings and hair would represent the daily growth of epidermal tissue, exclusive, of course, of that of hoofs and horns. The results as computed are shown in Table 126. They may, perhaps, be regarded as being somewhat too high, since the brushings may exceed the average daily loss, but they may fairly be taken to represent with a sufficient degree of approximation the daily demand of material for this growth.

TABLE 126.—*Average daily production of epidermal tissue, 1906.*

Components and energy.	Steer A.	Steer B.
Dry matter .... grams..	22.42	19.96
Nitrogen .... do....	1.62	1.30
Carbon .... do....	9.38	8.14
Hydrogen .... do....	1.34	1.14
Energy .... calories..	103.83	89.43

DETERMINATION OF RESPIRATORY PRODUCTS.

The methods employed were the same as those of the previous year and the results are tabulated below in the same form. The average ratio of hydrogen to carbon in the hydrocarbon gases excreted was as follows:

TABLE 127.—*Ratio of hydrogen to carbon in combustible gases, 1906.*

Periods.	Steer A.	Steer B.
	1 :	1 :
I	3.171	3.221
II	3.171	3.345
III	3.355	3.510
IV	[1] 3.212	3.191

[1] Second day only.

TABLE 128.—*Carbon and hydrogen in gaseous excreta, 1906.*

	In CO_2 and H_2O.		In hydrocarbons.		CH_4 computed from C.	H:C in hydrocarbons.
	Carbon.	Hydrogen.	Carbon.	Hydrogen.		
Period I.						
Steer A, Jan. 24 and 25:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	1:
Subperiod 1	525.51	212.87	35.64	10.96	47.61	3.252
Subperiod 2	529.95	195.20	37.59	12.06	50.22	3.117
First day	1,055.46	408.07	73.23	23.02	97.83	3.181
Subperiod 3	514.35	198.94	38.21	12.02	51.04	3.179
Subperiod 4	519.59	184.58	41.03	13.05	54.82	3.144
Second day	1,033.94	383.52	79.24	25.07	105.86	3.161
Average	1,044.70	395.80	76.24	24.05	101.85	3.171
Steer B, Jan. 31 and Feb. 1:						
Subperiod 1	488.21	222.56	30.69	9.62	41.00	3.190
Subperiod 2	491.02	217.24	29.92	9.34	39.97	3.203
First day	979.23	439.80	60.61	18.96	80.97	3.197
Subperiod 3	467.92	205.46	26.60	8.15	35.54	3.264
Subperiod 4	494.84	208.36	23.56	7.28	31.48	3.236
Second day	962.76	413.82	50.16	15.43	67.02	3.251
Average	971.00	426.81	53.39	17.20	74.00	3.221
Period II.						
Steer A, Feb. 21 and 22:						
Subperiod 1[1]	735.05	332.42	39.10	12.46	52.24	3.138
Subperiod 2	760.89	308.06	35.86	11.28	47.91	3.179
First day	1,495.94	640.48	74.96	23.74	100.15	3.158
Subperiod 3	754.31	342.13	30.40	9.46	40.61	3.214
Subperiod 4	755.51	318.04	34.28	10.83	45.80	3.165
Second day	1,509.82	660.17	64.68	20.29	86.41	3.188
Average	1,502.88	650.33	69.82	22.02	93.28	3.171
Steer B, Feb. 28 and Mar. 1:						
Subperiod 1	540.42	224.80	23.78	7.05	31.77	3.373
Subperiod 2	537.22	215.91	34.07	10.79	45.52	3.158
First day	1,077.64	440.71	57.85	17.84	77.29	3.243
Subperiod 3	540.35	209.12	24.15	6.49	32.26	3.721
Subperiod 4	543.87	221.98	22.98	7.05	30.70	3.260
Second day	1,084.22	431.10	47.13	13.54	62.96	3.481
Average	1,080.93	435.91	52.49	15.69	70.13	3.345
Period III.						
Steer A, Mar. 14 and 15:						
Subperiod 1	384.19	143.33	16.72	4.83	22.34	3.462
Subperiod 2	385.25	131.90	16.56	4.87	22.12	3.400
First day	769.44	275.23	33.28	9.70	44.46	3.431
Subperiod 3	379.44	138.11	22.30	6.80	29.79	3.279
Subperiod 4	379.74	134.81	21.02	6.30	28.08	3.336
Second day	759.18	272.92	43.32	13.10	57.87	3.307
Average	764.31	274.08	38.30	11.40	51.17	3.355

[1] Uncertain. Power off at intervals.

TABLE 128.—*Carbon and hydrogen in gaseous excreta, 1906*—Continued.

	In CO_2 and H_2O.		In hydrocarbons.		CH_4 computed from C.	H:C in hydrocarbons.
	Carbon.	Hydrogen.	Carbon.	Hydrogen.		
Period III—Continued.						
Steer B, Mar. 21 and 22:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	1:
Subperiod 1	355.06	143.24	14.77	4.17	19.73	3.542
Subperiod 2	352.35	129.85	16.70	5.04	22.31	3.313
First day	707.41	273.09	31.47	9.21	42.04	3.417
Subperiod 3	357.40	135.63	13.27	3.59	17.73	3.696
Subperiod 4	349.08	126.25	14.44	4.06	19.29	3.557
Second day	706.48	261.88	27.71	7.65	37.02	3.622
Average	706.95	267.49	29.59	8.43	39.53	3.510
Period IV.						
Steer A, Apr. 4 and 5:						
Subperiod 1	450.86	166.75	[15.21]	4.51	....	....
Subperiod 2	452.41	165.05	22.30	6.84	29.79	3.260
First day	903.27	331.80	37.51	11.35	....	....
Subperiod 3	464.51	193.30	23.09	7.05	30.85	3.275
Subperiod 4	460.88	172.66	32.48	10.25	43.39	3.169
Second day	925.39	365.96	55.57	17.30	74.24	3.212
Average	914.33	348.88	51.91	14.33	69.35	....
Steer B, Apr. 11 and 12:						
Subperiod 1	408.13	153.17	25.97	7.94	34.70	3.271
Subperiod 2	404.95	130.83	30.05	9.48	40.14	3.170
First day	813.08	284.00	56.02	17.42	74.84	3.216
Subperiod 3	412.90	150.48	30.82	9.71	41.18	3.174
Subperiod 4	409.97	155.39	30.51	9.64	40.76	3.165
Second day	822.87	305.87	61.33	19.35	81.94	3.170
Average	817.98	294.94	58.68	18.39	78.39	3.191

COMPUTED METHANE PRODUCTION.

In the experiments of 1906 the supply of gas to the furnaces in which the combustible gases produced by the animal were oxidized was inadequate, and it is questionable whether the oxidation was complete. The researches of Kellner have shown that the amount of methane produced bears a fairly constant ratio to the total amount of carbohydrates digested. The following table shows the amount of carbon found in the combustible gases in the experiments of each of the three years, expressed both in grams and as a percentage of the amount of carbohydrates digested. The results for 1906 seem to show very clearly that the methane was irregularly and incompletely oxidized, the ratio of methane carbon to carbohydrate being much lower than in the other series or in Kellner's experiments.

TABLE 129.—*Methane carbon.*

	Steer A.			Steer B.		
	Digested carbohydrates.	Carbon in combustible gases.	Per cent.	Digested carbohydrates.	Carbon in combustible gases.	Per cent.
Experiments of 1905:	*Grams.*	*Grams.*		*Grams.*	*Grams.*	
Period I	1,599.2	62.02	3.88	1,359.9	49.31	3.63
Period II	2,222.6	79.27	3.57	1,795.9	66.15	3.68
Period III	1,007.5	34.70	3.44	911.5	34.06	3.74
Period IV	1,690.9	59.30	3.51	1,351.9	44.42	3.29
Experiments of 1906:						
Period I	2,292.5	76.24	3.33	1,679.9	55.39	2.95
Period II	3,524.0	69.82	1.98	2,312.1	52.49	2.27
Period III	1,277.7	38.30	3.00	1,239.3	29.59	2.39
Period IV	2,047.4	51.91	2.54	1,823.3	38.68	3.22
Experiments of 1907:						
Period I	2,772.8	103.69	3.74	2,269.9	90.34	3.98
Period II	4,301.5	150.66	3.50	3,132.7	117.67	3.76
Period III	1,676.4	61.45	3.67	1,562.3	59.27	3.79
Period IV	2,693.3	97.94	3.64	2,521.8	92.08	3.65

The average percentage for the experiments of 1905 and 1907 is 3.65. In view of what seem to be the obviously erroneous results in 1906, we have felt justified in using this factor to compute the methane from the digestible carbohydrates. The results of this computation are contained in the following table and are used on succeeding pages in computing the carbon and energy balances:

TABLE 130.—*Computed methane production, 1906.*

Periods.	Computed carbon in methane.	Equivalent methane.	Equivalent hydrogen.	Equivalent. energy.
Steer A.	*Grams.*	*Grams.*	*Grams.*	*Calories.*
I	83.68	111.80	28.12	1,491.81
II	128.63	171.85	43.22	2,293.16
III	46.63	62.30	15.67	831.30
IV	74.73	99.84	25.11	1,332.26
Steer B.				
I	68.62	91.68	23.06	1,223.33
II	84.39	112.75	28.36	1,504.47
III	45.23	60.43	15.20	806.34
IV	66.55	88.91	22.36	1,186.43

THE BALANCE OF MATTER.

From the data on previous pages, the balances following, including the water balance for the two days in the calorimeter, have been computed in the same manner as for the previous year's experiments.

TABLE 131.—*The balance of matter per day and head, 1906.*

	Dry matter.	Water.		Nitrogen.		Carbon.		Organic hydrogen.	
		Income.	Outgo.	Income.	Outgo.	Income.	Outgo.	Income.	Outgo.
Period I.									
Steer A:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Timothy hay	2,607.9	175		34.5		1,213.2		183.1	
Wheat bran	259.8	} 318		8.1		117.0		18.0	
Corn meal	734.9			13.0		337.3		51.7	
Linseed meal	797.3			49.5		384.1		54.5	
Water		10,180							
Feces	1,465.1		6,198		31.3		699.9		93.5
Urine	438.9		3,848		69.0		100.5		17.7
Brushings and hair	22.4				1.6		9.4		1.3
Methane (computed)	111.8						83.7		28.1
Carbon dioxid	3,830.9						1,044.7		
Water vapor			3,563						
Organic hydrogen oxidized		1,342							149.9
Gain or loss by body—									
Protein	19.2				3.2		10.1		1.4
Fat	135.0						103.3		16.2
Water		1,594							
		13,609	13,609	105.1	105.1	2,051.6	2,051.6	307.3	307.3
Steer B:									
Timothy hay	2,433.1	173		32.2		1,131.9		170.8	
Wheat bran	173.2	} 200		5.4		78.0		12.0	
Corn meal	490.0			8.6		224.9		34.5	
Linseed meal	531.5			33.0		256.1		36.4	
Water		10,003							
Feces	1,259.7		4,381		25.2		606.7		79.9
Urine	351.9		2,064		55.0		90.4		13.4
Brushings and hair	20.0				1.3		8.1		1.1
Methane (computed)	91.7						68.6		23.1
Carbon dioxid	3,560.7						971.0		
Water vapor			3,841						
Organic hydrogen oxidized		1,302							144.5
Gain or loss by body—									
Protein	13.8			2.3		7.3		1.0	
Fat	60.9					46.6		7.3	
Water			1,392						
		11,678	11,678	81.5	81.5	1,744.8	1,744.8	262.0	262.0
Period II.									
Steer A:									
Timothy hay	2,630.9	250		34.9		1,227.3		168.1	
Wheat bran	596.4	} 710		17.8		271.6		41.2	
Corn meal	1,733.3			27.2		801.7		123.6	
Linseed meal	1,843.0			108.4		887.6		126.8	
Water		15,528							
Feces	2,174.3		11,194		58.2		1,045.8		145.0
Urine	588.8		5,661		134.2		160.6		28.5
Brushings and hair	22.4				1.6		9.4		1.3
Methane (computed)	171.9						128.6		43.2
Carbon dioxid	5,511.1						1,502.9		
Water vapor			5,853						
Organic hydrogen oxidized		1,690							187.8
Gain or loss by body—									
Protein	34.2			5.7		18.0		2.4	
Fat	469.2						358.9		56.3
Water		4,530							
		22,708	22,708	194.0	194.0	3,206.2	3,206.2	462.1	462.1
Steer B:									
Timothy hay	2,453.9	233		32.5		1,144.7		156.8	
Wheat bran	304.2	} 376		9.1		138.5		21.0	
Corn meal	884.8			13.9		409.2		63.1	
Linseed meal	940.0			55.3		452.7		64.7	
Water		9,420							
Feces	1,614.5		7,252		35.0		769.6		105.7
Urine	402.7		3,193		75.7		112.1		19.1

TABLE 131.—*The balance of matter per day and head, 1906*—Continued.

	Dry matter.	Water.		Nitrogen.		Carbon.		Organic hydrogen.	
		Income.	Outgo.	Income.	Outgo.	Income.	Outgo.	Income.	Outgo.
Period II—Continued.									
Steer B—Continued.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Brushings and hair	20.0				1.3		8.1		1.1
Methane (computed)	112.8						84.4		28.4
Carbon dioxid	3,963.8						1,080.9		
Water vapor			3,923						
Organic hydrogen oxidized		1,234							137.1
Gain or loss by body—									
Protein	7.2			1.2		3.8		0.5	
Fat	122.6						93.8		14.7
Water		3,105							
		14,368	14,368	112.0	112.0	2,148.9	2,148.9	306.1	306.1
Period III.									
Steer A:									
Timothy hay	2,647.2	206		33.0		1,252.7		172.6	
Water		7,115							
Feces	1,199.1		4,644		20.5		589.2		78.5
Urine	324.8		3,214		33.3		67.6		9.7
Brushings and hair	22.4				1.6		9.4		1.3
Methane (computed)	62.3						46.6		15.7
Carbon dioxid	2,802.7						764.3		
Water vapor			2,467						
Organic hydrogen oxidized		910							101.1
Gain or loss by body—									
Protein	134.4			22.4		70.6		9.6	
Fat	201.1					153.8		24.1	
Water		2,094							
		10,325	10,325	55.4	55.4	1,477.1	1,477.1	206.3	206.3
Steer B:									
Timothy hay	2,470.3	165		30.8		1,169.0		161.1	
Water		9,913							
Feces	1,076.9		3,742		18.2		533.0		71.1
Urine	245.9		2,018		27.5		56.8		8.8
Brushings and hair	20.0				1.3		8.1		1.1
Methane (computed)	60.4						45.2		15.2
Carbon dioxid	2,592.4						707.0		
Water vapor			2,408						
Organic hydrogen oxidized		830							
Gain or loss by body—									
Protein	97.2			16.2		51.1		6.9	
Fat	169.9					130.0		20.4	
Water			2,740						92.2
		10,908	10,908	47.0	47.0	1,350.1	1,350.1	188.4	188.4
Period IV.									
Steer A:									
Timothy hay	4,424.5	325		59.9		2,067.1		281.0	
Water		10,078							
Feces	2,075.1		9,615		34.7		1,013.9		131.4
Urine	351.5		3,587		30.8		85.1		12.0
Brushings and hair	22.4				1.6		9.4		1.3
Methane (computed)	99.8						74.7		25.1
Carbon dioxid	3,352.7						914.3		
Water vapor			3,140						
Organic hydrogen oxidized		1,040							115.5
Gain or loss by body—									
Protein	43.2			7.2		22.7		3.1	
Fat	9.9					7.6		1.2	
Water		4,899							
		16,342	16,342	67.1	67.1	2,097.4	2,097.4	285.3	285.3

TABLE 131.—*The balance of matter per day and head, 1906*—Continued.

	Dry matter.	Water.		Nitrogen.		Carbon.		Organic hydrogen.	
		Income.	Outgo.	Income.	Outgo.	Income.	Outgo.	Income.	Outgo.
Period IV—Continued.									
Steer B:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Timothy hay	3,805.1	275		51.5		1,777.7		241.6	
Water		11,090							
Feces	1,717.9		6,961		29.5		851.2		115.6
Urine	338.5		2,547		30.2		78.5		14.0
Brushings and hair	20.0				1.3		8.1		1.1
Methane (computed)	88.9						66.6		22.4
Carbon dioxid	2,999.6						818.0		
Water vapor			2,655						
Organic hydrogen oxidized		854							94.9
Gain or loss by body—									
Protein	57.0			9.5		29.9		4.1	
Fat	19.3					14.8		2.3	
Water			56						
		12,219	12,219	61.0	61.0	1,822.4	1,822.4	248.0	248.0

COMPUTED GAINS OR LOSSES OF LIVE WEIGHT IN THE CALORIMETER.

Table 132 summarizes the single factors which make up the estimated gain or loss of live weight by the animal while in the calorimeter as computed from the data of Table 131 in the same manner as in the experiments of 1905 (p. 109.)

TABLE 132.—*Computed daily gains or losses of live weight in the calorimeter, 1906.*

	Period I.		Period II.		Period III.		Period IV.	
	Loss.	Gain.	Loss.	Gain.	Loss.	Gain.	Loss.	Gain.
Steer A.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Protein		19	34		134		43	
Fat		135		469	201		10	
Water	1,594		4,530		2,094		4,899	
Correction for irregularity of excretion			29		3		46	
Balance		1,440		4,124		2,432		5,098
Total	1,594	1,594	4,593	4,593	2,432	2,432	5,098	5,098
Steer B.								
Protein	14		7		97		57	
Fat	61			123	170		19	
Water		1,392	3,105			2,740		56
Correction for irregularity of excretion		26	30			10	1	
Balance	1,343			3,019	2,483			21
Total	1,418	1,418	3,142	3,142	2,750	2,750	77	77

COMPARISON OF OBSERVED AND COMPUTED GAIN OR LOSS OF LIVE WEIGHT.

The respiration calorimeter is not provided with means for taking the weight of the animal while in the respiration chamber. Its weight was taken, however, immediately before entering and immediately after leaving the apparatus, the time of weighing being noted, while the weights of the visible excreta for the four or five hours preliminary to the actual experiment were recorded in the last three periods.

While it is not possible to compute a complete balance for these preliminary hours, if we may assume that the excretion of carbon dioxid and water went on at the same rate as in the experiment proper, we have sufficient data for an approximate computation of the loss in weight during the preliminary hours. This can then be combined with the computed loss of weight in the 48 hours of the experiment proper and the result compared with that of the actual weighing. It scarcely need be said that such a comparison can be nothing more than a general check upon the accuracy of the work. An exact agreement could not be looked for, but any gross error in the experiments would probably be revealed. The method for computing the correction may be conveniently illustrated by the results for steer A in Period II. The animal entered the calorimeter at 1.38 p. m., the preliminary period thus amounting to 262 minutes. During this time neither food nor drink was consumed and a loss of weight must have taken place, due to the continued excretion. The amounts of the visible excreta which were recorded need simply to be deducted from the live weight. This is not true of the carbon dioxid and water excreted, since at least a considerable part of their oxygen is derived from the air and we have no experimental data as to the amount of the latter taken up. For the purpose of this approximate computation, however, it seems permissible to neglect the katabolism of the protein and to consider only the nonnitrogenous material oxidized. If this consisted only of carbohydrates—that is, if the respiratory quotient was equal to one—the corresponding loss of weight by the animal would evidently be equal to the water given off plus the carbon of the carbon dioxid excreted. If some of the material oxidized consisted of fat, however, the loss of weight would be less than that indicated above, since some of the oxygen of the water eliminated as well as all that contained in the carbon dioxid would have been derived from the air. On the other hand, if a formation of fat from carbohydrates took place, the contrary would be true, some of the oxygen of the carbon dioxid being derived from the carbohydrates consumed and not from the air. On the basis of the average composition of animal fat, viz,

$$C=76.5$$
$$H=12.0$$
$$O=11.5$$

the following correction may be computed:

Oxidation of 100 grams of fat.

	Grams.
O required for oxidation of H	96.0
O contained in fat	11.5
O derived from atmosphere	84.5

Formation of 100 grams of fat.

	Grams.
$C_6H_{12}O_6$ required to furnish C	191.25
O in 191.25 grams $C_6H_{12}O_6$	102.0
O in 100 grams fat	11.5
O of carbohydrate excreted in CO_2	90.5

On the above basis, we may compute the change in weight by steer A in Period II as follows:

	Grams.
In preliminary period (262 minutes):	
Feces	130
Urine	1,470
Methane $93.3\times\frac{262}{1440}$	17
C of CO_2 $1,502.9\times\frac{262}{1440}$	273
Water vapor $5,853\times\frac{262}{1440}$	1,065
Oxygen equivalent to fat gained $4.692\times90.5\times\frac{262}{1440}$	77
In calorimeter period:	
Net loss, Table 132, computed to 48 hours	8,248
Computed loss of weight	11,270
Actual loss of weight	11,800

A similar computation for the several periods, with the exception of the first, for which the weights of feces and urine excreted during the preliminary period were not recorded, gives the following comparison:

TABLE 133.—*Computed and observed gains in live weight, 1906.*

	Computed.	Observed.
Period II.	*Kilos.*	*Kilos.*
Steer A	−11.3	−11.8
Steer B	− 7.5	− 8.2
Period III.		
Steer A	− 5.6	− 5.3
Steer B	+ 4.5	+ 4.2
Period IV.		
Steer A	−11.8	−11.9
Steer B	− 2.6	− 2.9

The generally good agreement in the foregoing table indicates at least that no gross errors have crept into the work, while it also tends to confirm our confidence in the reasonable accuracy of the computations of the nature of the gain or loss which are contained in Table 132.

HEAT EMISSION AND HEAT PRODUCTION.

The following tables show the results of the determinations of the heat given off by the animals, and likewise the heat production computed by correcting for the gain or loss of matter by the body in the manner described in connection with the experiments of 1905 (pp. 112–113).

TABLE 134.—*Heat emission, 1906.*

	Steer A.			Steer B.		
	By radiation.	As latent heat of water vapor.	Total.	By radiation.	As latent heat of water vapor.	Total.
Period I.						
First day:	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Subperiod 1	3,752.2	1,124.6	4,876.8	3,516.0	1,175.8	4,691.8
Subperiod 2	3,715.5	1,031.2	4,746.7	3,125.0	1,147.7	4,272.7
Total	7,467.7	2,155.8	9,623.5	6,641.0	2,323.5	8,964.5
Second day:						
Subperiod 3	3,497.8	1,051.0	4,548.8	3,305.3	1,085.4	4,390.7
Subperiod 4	3,593.0	975.1	4,568.1	3,359.6	1,101.3	4,460.9
Total	7,090.8	2,026.1	9,116.9	6,664.9	2,186.7	8,851.6
Daily average	7,279.2	2,091.0	9,370.2	6,653.0	2,255.1	8,908.1
Period II.						
First day:						
Subperiod 1	[1] 4,810.2	1,756.2	6,566.4	[2] 3,779.3	1,187.6	4,966.9
Subperiod 2	4,760.3	1,627.5	6,387.8	3,685.0	1,140.6	4,825.6
Total	9,570.5	3,383.7	12,954.2	7,464.3	2,328.2	9,792.5
Second day:						
Subperiod 3	4,843.8	1,807.5	6,651.3	3,776.0	1,104.8	4,880.8
Subperiod 4	4,629.0	1,680.2	6,309.2	3,749.8	1,172.8	4,922.6
Total	9,472.8	3,487.7	12,960.5	7,525.8	2,277.6	9,803.4
Daily average	9,521.7	3,435.7	12,957.4	7,495.1	2,302.9	9,798.0
Period III.						
First day:						
Subperiod 1	2,944.7	757.2	3,701.9	2,705.2	756.8	3,462.0
Subperiod 2	3,090.8	696.9	3,787.7	2,698.4	686.0	3,384.4
Total	6,035.5	1,454.1	7,489.6	5,403.6	1,442.8	6,846.4
Second day:						
Subperiod 3	3,060.8	729.6	3,790.4	2,798.1	2,716.5	3,514.6
Subperiod 4	3,005.1	712.2	3,717.3	2,720.5	667.0	3,387.5
Total	6,065.9	1,441.8	7,507.7	5,518.6	1,383.5	6,902.1
Daily average	6,050.7	1,448.0	7,498.7	5,461.2	1,413.1	6,874.3
Period IV.						
First day:						
Subperiod 1	3,159.7	881.0	4,040.7	2,968.0	809.2	3,777.2
Subperiod 2	3,182.8	872.0	4,054.8	2,809.4	691.2	3,500.6
Total	6,342.5	1,753.0	8,095.5	5,777.4	1,500.4	7,277.8
Second day:						
Subperiod 3	3,391.0	1,021.3	4,412.3	3,035.4	795.0	3,830.4
Subperiod 4	3,197.4	912.1	4,109.5	2,828.9	820.9	3,649.8
Total	6,588.4	1,933.4	8,521.8	5,864.3	1,615.9	7,480.2
Daily average	6,465.5	1,843.2	8,308.7	5,820.8	1,558.2	7,379.0

[1] Computed for first 102 minutes from average heat emission standing and lying, page 156.
[2] First 30 minutes computed.

TABLE 135.—*Average heat production, 1906.*

Period.	Steer A. Heat emission.	Steer A. Correction for gain by body.	Steer A. Heat production.	Steer B. Heat emission.	Steer B. Correction for gain by body.	Steer B. Heat production.
	Calories.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
I	9,370.2	− 31.1	9,339.1	8,908.1	+28.8	8,936.9
II	12,957.4	− 85.7	12,871.7	9,798.0	−61.9	9,736.1
III	7,498.7	− 46.3	7,452.4	6,874.3	+54.1	6,928.4
IV	8,308.7	−100.2	8,208.5	7,379.0	+ 1.0	7,380.0

THE BALANCE OF ENERGY.

The balance of energy in the several periods, computed on the same basis as in the experiments of 1905 (pp. 113–114), is as follows:

TABLE 136.—*The balance of energy per day and head, 1906.*

Periods and components.	Steer A. Dry matter.	Steer A. Energy. Income.	Steer A. Energy. Outgo.	Steer B. Dry matter.	Steer B. Energy. Income.	Steer B. Energy. Outgo.
Period I.	*Grams.*	*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
Timothy hay	2,607.9	11,691.5		2,433.1	10,907.8	
Wheat bran	259.8	1,180.4		173.2	786.9	
Corn meal	734.9	3,323.9		490.0	2,216.2	
Linseed meal	797.3	3,913.8		531.5	2,609.0	
Feces	1,465.1		6,855.6	1,259.7		5,930.0
Urine (corrected for nitrogen)	438.9		1,041.5	351.9		864.3
Methane	111.8		1,491.8	91.7		1,223.3
Metabolizable			10,720.7			8,502.3
Total		20,109.6	20,109.6		16,519.9	16,519.9
Metabolizable		10,720.7			8,502.3	
Heat			9,339.1			8,936.9
Brushings	22.4		103.8	20.0		89.4
Gain or loss by body:						
Protein (corrected for nitrogen)	19.2		85.6	13.8	61.6	
Fat	135.0		1,282.5	60.9	578.6	
Error		90.3				116.2
Total		10,811.0	10,811.0		9,142.5	9,142.5
Period II.						
Timothy hay	2,630.9	11,796.2		2,453.9	11,002.6	
Wheat bran	596.4	2,691.9		304.2	1,373.0	
Corn meal	1,733.3	7,844.7		884.8	4,004.6	
Linseed meal	1,843.0	9,052.3		940.0	4,617.0	
Feces	2,174.3		10,196.6	1,614.5		7,476.3
Urine (corrected for nitrogen)	588.8		1,605.0	402.7		1,094.3
Methane	171.9		2,293.2	112.8		1,504.5
Metabolizable			17,290.3			10,922.1
Total		31,385.1	31,385.1		20,997.2	20,997.2
Metabolizable		17,290.3			10,922.1	
Heat			12,871.7			9,736.1
Brushings	22.4		103.8	20.0		89.4
Gain or loss by body:						
Protein (corrected for nitrogen)	34.2	152.4		7.2	32.1	
Fat	469.2		4,457.4	122.6		1,164.7
Error			9.8		36.0	
Total		17,442.7	17,442.7		10,990.2	10,990.2

TABLE 136.—*The balance of energy per day and head, 1906*—Continued.

Periods and components.	Steer A. Dry matter.	Steer A. Energy. Income.	Steer A. Energy. Outgo.	Steer B. Dry matter.	Steer B. Energy. Income.	Steer B. Energy. Outgo.
Period III.	*Grams.*	*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
Timothy hay	2,647.2	11,938.3		2,470.3	11,140.6	
Feces	1,199.1		5,757.0	1,076.9		5,168.3
Urine (corrected for nitrogen)	324.8		411.2	245.9		414.8
Methane	62.3		831.3	60.4		806.3
Metabolizable			4,938.8			4,751.2
Total		11,938.3	11,938.3		11,140.6	11,140.6
Metabolizable		4,938.8			4,751.2	
Heat			7,452.4			6,928.4
Brushings	22.4		103.8	20.0		89.4
Gain or loss by body:						
Protein (corrected for nitrogen)	134.4	599.2		97.2	433.3	
Fat	20.1	1,910.5		169.9	1,614.1	
Error		107.7			219.2	
Total		7,556.2	7,556.2		7,017.8	7,017.8
Period IV.						
Timothy hay	4,424.5	19,950.2		3,805.1	17,157.3	
Feces	2,075.1		9,957.4	1,717.9		8,235.7
Urine (corrected for nitrogen)	351.5		679.1	337.3		635.2
Methane	99.8		1,332.3	88.9		1,186.4
Metabolizable			7,981.4			7,100.0
Total		19,950.2	19,950.2		17,157.3	17,157.3
Metabolizable		7,981.4			7,100.0	
Heat			8,208.5			7,380.0
Brushings	22.4		103.8	20.0		89.4
Gain or loss by body:						
Protein (corrected for nitrogen)	43.2	192.7		57.0	254.1	
Fat	9.2	94.1		19.3	183.4	
Error		44.1				68.1
Total		8,312.3	8,312.3		7,537.5	7,537.5

It is apparent from the foregoing tabulation that a much better agreement between the observed and computed heat production was obtained in this series of experiments than in those of the previous year, as is clearly shown by the following summary, and also that the differences are in both directions:

TABLE 137.—*Observed and computed daily heat production, 1906.*

Periods.	Steer A. Observed.	Steer A. Computed.	Steer A. Error.	Steer A. Computed ÷ observed.	Steer B. Observed.	Steer B. Computed.	Steer B. Error.	Steer B. Computed ÷ observed.
	Calories.	*Calories.*	*Calories.*	*Per cent.*	*Calories.*	*Calories.*	*Calories.*	*Per cent.*
I	9,339.1	9,248.8	− 90.3	99.0	8,936.9	9,053.1	+116.2	101.3
II	12,871.7	12,881.5	+ 9.8	100.1	9,736.1	9,700.1	− 36.0	99.6
III	7,452.4	7,344.7	−107.7	98.6	6,928.4	6,709.2	−219.2	96.8
IV	8,208.5	8,164.4	− 44.1	99.5	7,380.0	7,448.1	+ 68.1	100.9

METABOLIZABLE ENERGY.

The results for the metabolizable energy of the timothy hay and of the mixed grain in these experiments are tabulated in the following pages in the same form as in the experiments of the previous year (pp. 115–117).

TABLE 138.—*Percentage distribution of energy of timothy hay, 1906.*

	Total energy.			Energy of digested matter.		
	Period III.	Period IV.	True average.	Period III.	Period IV.	True average.
Steer A.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
In feces	48.22	49.91	49.28	....	....	....
In urine	3.44	3.40	3.42	6.64	6.79	6.74
In methane	6.97	6.68	6.78	13.46	13.34	13.38
Metabolizable	41.37	40.01	40.52	79.90	79.87	79.88
	100.00	100.00	100.00	100.00	100.00	100.00
Steer B.						
In feces	46.39	48.00	47.37	....	....	....
In urine	3.72	3.70	3.71	6.94	7.12	7.05
In methane	7.24	6.92	7.04	13.51	13.30	13.38
Metabolizable	42.65	41.38	41.88	79.55	79.58	79.57
	100.00	100.00	100.00	100.00	100.00	100.00

TABLE 139.—*Metabolizable energy per gram of organic matter of timothy hay, 1906.*

Periods.	Organic matter.		Metabolizable energy.		
	Total.	Digested.	Total.	Per gram total organic matter.	Per gram digested organic matter.
Steer A.	*Grams.*	*Grams.*	*Calories.*	*Calories.*	*Calories.*
III	2,493.1	1,373.1	4,938.8	1.981	3.597
IV	4,164.8	2,238.1	7,981.4	1.916	3.566
Totals and averages	6,657.9	3,611.2	12,920.2	1.941	3.578
Steer B.					
III	2,326.5	1,332.6	4,751.2	2.042	3.565
IV	3,581.7	1,991.8	7,100.0	1.982	3.565
Totals and averages	5,908.2	3,324.4	11,851.2	2.006	3.565

TABLE 140.—*Percentage distribution of energy of mixed grain, 1906.*

	Organic matter.		Total energy.	Energy of excreta.			Metabolizable energy.
	Total.	Digested.		Feces.	Urine (corrected).	Methane (computed).	
Steer A.							
Period I:	*Grams.*	*Grams.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
In total ration	4,176.3	2,849.9	20,109.6	6,855.6	1,041.5	1,491.8	10,720.7
In hay	2,459.0	1,333.8	11,691.5	5,761.6	399.8	792.7	4,737.4
In grain	1,717.3	1,516.1	8,418.1	1,094.0	641.7	699.1	5,983.3
Per cent of total energy			100.00	13.00	7.62	8.30	71.08
Per cent of digested energy					8.76	9.54	81.70
Period II:							
In total ration	6,486.4	4,496.9	31,385.1	10,196.6	1,605.0	2,293.2	17,290.3
In hay	2,487.5	1,349.2	11,796.2	5,813.2	403.4	799.8	4,779.8
In grain	3,998.9	3,147.7	19,588.9	4,383.4	1,201.6	1,493.4	12,510.5
Per cent of total energy			100.00	22.38	6.13	7.63	63.86
Per cent of digested energy					7.90	9.83	82.27
Steer B.							
Period I:							
In total ration	3,439.0	2,293.7	16,519.9	5,930.0	864.3	1,223.3	8,502.3
In hay	2,294.2	1,290.9	10,907.8	5,167.0	404.7	767.9	4,568.2
In grain	1,144.8	1,002.8	5,612.1	763.0	459.6	455.4	3,934.1
Per cent of total energy			100.00	13.60	8.19	8.11	70.10
Per cent of digested energy					9.48	9.38	81.14
Period II:							
In total ration	4,360.4	2,884.9	20,997.2	7,476.3	1,094.3	1,504.5	10,922.1
In hay	2,320.2	1,305.6	11,002.6	5,211.9	408.2	774.6	4,607.9
In grain	2,040.2	1,579.3	9,994.6	2,264.4	686.1	729.9	6,314.2
Per cent of total energy			100.00	22.66	6.86	7.30	63.18
Per cent of digested energy					8.89	9.44	81.67

TABLE 141.—*Metabolizable energy per gram organic matter of mixed grain, 1906.*

Periods.	Organic matter.		Metabolizable energy.		
	Total.	Digested.	Total.	Per gram total organic matter.	Per gram digested organic matter.
Steer A.	*Grams.*	*Grams.*	*Calories.*	*Calories.*	*Calories.*
I	1,717.3	1,516.1	5,983.3	3.484	3.946
II	3,998.9	3,147.7	12,510.5	3.128	3.974
	5,716.2			3.306	
Steer B.					
I	1,144.8	1,002.8	3,934.4	3,437	3.923
II	2,040.2	1,579.3	6,314.2	3.095	3.998
	3,185.0			3.266	

CORRECTION OF HEAT PRODUCTION FOR STANDING AND LYING.

HEAT EMITTED BY RADIATION AND CONDUCTION.

The foregoing results for heat production have still to be corrected for differences in the amount of time spent standing and lying, in accordance with the methods discussed on pages 41 and 118. The following tables show for each period the results in the individual sections which were selected for comparison and likewise the average heat emitted per minute by radiation and conduction during the several periods and brought out of the apparatus in the water current.

TABLE 142.—*Heat emitted by radiation and conduction during periods of standing and lying, 1906.*

Periods.	Standing.		Lying.	
	Elapsed time.	Total heat.	Elapsed time.	Total heat.
Period I.				
Steer A:	*Minutes.*	*Calories.*	*Minutes.*	*Calories.*
6.00 p. m. to 8.08 p. m.	128	702.99		
9.16 p. m. to 9.44 p. m.			28	114.73
10.12 p. m. to 11.36 p. m.	84	512.99		
11.56 p. m. to 1.36 a. m.			100	444.92
2.40 a. m. to 3.32 a. m.			52	232.62
4.28 a. m. to 5.56 a. m.	92	539.02		
6.00 a. m. to 9.04 a. m.	184	971.02		
9.24 a. m. to 12.16 p. m.			172	691.96
12.36 p. m. to 5.36 p. m.	324	1,830.76		
6.00 p. m. to 7.20 p. m.	80	442.59		
7.48 p. m. to 10.08 p. m.			140	395.68
11.36 p. m. to 2.32 a. m.			176	809.21
3.44 a. m. to 5.00 a. m.			76	339.67
5.20 a. m. to 5.56 a. m.	40	249.08		
6.00 a. m. to 7.16 a. m.	76	440.23		
7.48 a. m. to 9.56 a. m.			128	510.62
10.20 a. m. to 11.20 a. m.	60	337.82		
12.00 p. m. to 3.04 p. m.			184	867.74
3.32 p. m. to 6.00 p. m.	148	865.33		
Totals	1,216	6,890.91	1,056	4,607.18
Total corrections for capacity, feed, water, excreta, etc.		+79.51		−96.40
		6,970.42		4,510.78
Heat per minute		5.7323		4.2716
Steer B:				
6.40 p. m. to 9.20 p. m.	160	907.02		
10.20 p. m. to 11.48 p. m.			88	348.56
12.08 a. m. to 12.36 a. m.	28	160.41		
12.36 a. m. to 2.32 a. m.	116	680.21		
3.20 a. m. to 4.40 a. m.			80	300.47
5.04 a. m. to 6.00 a. m.	56	312.26		
6.00 a. m. to 7.20 a. m.	80	401.12		
8.00 a. m. to 10.16 a. m.	136	681.08		
10.40 a. m. to 4.32 p. m.			352	1,291.61
4.52 p. m. to 6.00 p. m.	68	373.93		
6.00 p. m. to 7.16 p. m.	76	416.38		
7.44 p. m. to 10.40 p. m.			176	710.12
10.40 p. m. to 4.12 a. m.			332	1,434.06
5.08 a. m. to 6.00 a. m.	52	292.40		
6.00 a. m. to 9.36 a. m.	216	1,128.18		
9.56 a. m. to 11.04 a. m.			68	234.06
11.04 a. m. to 2.48 p. m.	204	1,086.13		
3.20 p. m. to 6.00 p. m.			160	574.53
Totals	1,192	6,439.12	1,256	4,893.41
Total corrections for capacity, feed, water, excreta, etc.		−23.24		−13.85
		6,415.88		4,879.56
Heat per minute		5.3824		3.8850

TABLE 142.—*Heat emitted by radiation and conduction during periods of standing and lying, 1906*—Continued.

Periods.	Standing.		Lying.	
	Elapsed time.	Total heat.	Elapsed time.	Total heat.
Period II.				
Steer A:	*Minutes.*	*Calories.*	*Minutes.*	*Calories.*
8.52 p. m. to 9.28 p. m.			36	220.89
9.48 p. m. to 10.44 p. m.	56	444.81		
11.16 p. m. to 11.28 p. m.	12	96.06		
11.28 p. m. to 12.40 a. m.	72	562.22		
1.00 a. m. to 2.24 a. m.	84	608.58		
2.44 a. m. to 4.56 a. m.			132	667.92
5.20 a. m. to 6.00 a. m.	40	286.74		
6.00 a. m. to 8.16 a. m.	136	929.83		
8.40 a. m. to 9.14 a. m.			34	175.09
9.14 a. m. to 9.44 a. m.			30	162.88
10.00 a. m. to 10.23 a. m.	23	168.54		
10.23 a. m. to 11.08 a. m.	45	338.53		
11.52 a. m. to 12.24 p. m.			32	186.74
12.40 p. m. to 12.575 p. m.	17.5	130.45		
12.575 p. m. to 1.185 p. m.	21	161.15		
1.185 p. m. to 1.36 p. m.	17.5	140.66		
2.08 p. m. to 2.48 p. m.	40	294.51		
3.12 p. m. to 4.48 p. m.			96	494.25
5.08 p. m. to 6.00 p. m.	52	389.24		
6.00 p. m. to 7.44 p. m.	104	767.30		
8.08 p. m. to 9.20 p. m.			72	398.48
9.40 p. m. to 12.24 a. m.	164	1,283.57		
12.44 a. m. to 1.16 a. m.			32	178.43
1.36 a. m. to 1.56 a. m.	20	157.13		
2.16 a. m. to 4.20 a. m.			124	676.29
4.40 a. m. to 6.00 a. m.	80	591.34		
6.00 a. m. to 7.56 a. m.	116	780.21		
8.32 a. m. to 10.08 a. m.			96	504.22
10.28 a. m. to 10.48 a. m.	20	151.85		
11.08 a. m. to 12.56 p. m.			108	588.97
1.16 p. m. to 1.56 p. m.	40	338.55		
2.16 p. m. to 3.52 p. m.			96	504.29
4.12 p. m. to 6.00 p. m.	108	837.81		
Totals	1,268	9,459.08	888	4,758.45
Total corrections for capacity, feed, water, excreta, etc		+110.37		−118.70
		9,569.45		4,639.75
Heat per minute		7.5469		5.2249
Steer B:				
6.52 p. m. to 8.04 p. m.	72	412.48		
8.28 p. m. to 9.56 p. m.			88	358.68
10.16 p. m. to 11.36 p. m.	80	520.34		
12.00 a. m. to 1.36 a. m.			96	427.46
2.00 a. m. to 4.40 a. m.			160	730.79
5.00 a. m. to 6.00 a. m.	60	369.97		
6.00 a. m. to 7.44 a. m.	104	617.37		
8.08 a. m. to 10.52 a. m.			164	700.95
11.12 a. m. to 1.36 p. m.	144	897.29		
2.00 p. m. to 4.48 p. m.			168	705.54
5.04 p. m. to 6.00 p. m.	56	332.86		
6.00 p. m. to 8.00 p. m.	120	703.06		
8.20 p. m. to 9.32 p. m.			72	305.02
9.52 p. m. to 11.12 p. m.	80	524.44		
11.36 p. m. to 12.52 a. m.			76	333.91
1.12 a. m. to 2.00 a. m.	48	321.66		
2.24 a. m. to 5.28 a. m.			184	821.57
6.00 a. m. to 7.28 a. m.	88	532.36		
8.00 a. m. to 10.56 a. m.			176	737.02
11.16 a. m. to 12.32 p. m.	76	490.99		
12.56 p. m. to 3.24 p. m.			148	612.76
3.44 p. m. to 6.00 p. m.	136	785.91		
Totals	1,064	6,508.93	1,332	5,733.70
Total corrections for capacity, water, feed, excreta, etc		+54.17		−44.81
		6,563.10		5,688.89
Heat per minute		6.1683		4.2709

TABLE 142.—*Heat emitted by radiation and conduction during periods of standing and lying, 1906*—Continued.

Periods.	Standing.		Lying.	
	Elapsed time.	Total heat.	Elapsed time.	Total heat.
Period III.				
Steer A:	*Minutes.*	*Calories.*	*Minutes.*	*Calories.*
6.00 p. m. to 9.08 p. m.	188	768.07		
10.20 p. m. to 1.16 a. m.			176	648.79
1.36 a. m. to 3.08 a. m.	92	486.12		
3.32 a. m. to 5.08 a. m.			96	354.56
5.28 a. m. to 6.00 a. m.	32	160.37		
6.00 a. m. to 9.08 a. m.	188	855.44		
9.32 a. m. to 12.08 p. m.			156	517.42
12.28 p. m. to 6.00 p. m.	332	1,534.39		
6.00 p. m. to 8.36 p. m.	156	706.59		
9.00 p. m. to 11.40 p. m.			160	576.37
12.20 a. m. to 12.56 a. m.	36	193.26		
1.20 a. m. to 3.56 a. m.			156	581.78
4.16 a. m. to 6.00 a. m.	104	525.58		
6.00 a. m. to 8.16 a. m.	136	619.10		
8.40 a. m. to 11.16 a. m.			156	521.91
11.36 a. m. to 1.48 p. m.	132	637.78		
2.12 p. m. to 3.56 p. m.			104	350.52
4.16 p. m. to 6.00 p. m.	104	511.67		
Totals	1,500	6,998.37	1,004	3,551.35
Total corrections for capacity, feed, water, excreta, etc		−36.88		−45.62
		6,961.49		3,505.73
Heat per minute		4.6410		3.4918
Steer B:				
6.00 p. m. to 9.24 p. m.	204	830.14		
9.48 p. m. to 11.32 p. m.			104	318.23
11.52 p. m. to 1.40 a. m.	108	509.92		
2.04 a. m. to 5.32 a. m.			208	661.71
6.00 a. m. to 10.16 a. m.	256	1,067.24		
10.40 a. m. to 11.48 a. m.			68	192.69
12.08 p. m. to 2.44 p. m.	156	695.19		
3.12 p. m. to 3.28 p. m.			16	44.41
3.28 p. m. to 5.12 p. m.			104	300.17
5.32 p. m. to 6.00 p. m.	28	113.06		
6.00 p. m. to 9.16 p. m.	196	838.40		
9.40 p. m. to 11.12 p. m.			92	286.32
11.32 p. m. to 12.28 a. m.	56	266.96		
12.52 a. m. to 2.40 a. m.			108	337.26
3.00 a. m. to 4.12 a. m.	72	346.48		
4.36 a. m. to 5.28 a. m.			52	173.46
5.48 a. m. to 6.00 a. m.	12	43.94		
6.00 a. m. to 7.40 a. m.	100	432.93		
8.04 a. m. to 9.52 a. m.			108	312.18
10.12 a. m. to 11.56 a. m.	104	460.65		
12.32 p. m. to 3.16 p. m.			164	505.09
3.36 p. m. to 6.00 p. m.	144	631.19		
Totals	1,436	6,236.10	1,024	3,131.52
Total corrections for capacity, feed, water, excreta, etc		−57.18		+13.19
		6,178.92		3,144.71
Heat per minute		4.3029		3.0710
Period IV.				
Steer A:				
6.00 p. m. to 8.12 p. m.	132	602.25		
8.36 p. m. to 10.24 p. m.			108	399.66
11.12 p. m. to 12.08 a. m.	56	309.72		
12.28 a. m. to 3.08 a. m.			160	619.81
3.28 a. m. to 3.56 a. m.	28	152.94		
6.12 a. m. to 8.04 a. m.	112	566.37		
8.28 a. m. to 10.52 a. m.			144	521.01
11.12 a. m. to 12.04 p. m.	52	281.05		
12.52 p. m. to 1.08 p. m.	16	81.23		
1.28 p. m. to 2.28 p. m.			60	217.58
2.40 p. m. to 3.08 p. m.	28	148.19		
3.52 p. m. to 5.08 p. m.			76	283.73
5.44 p. m. to 6.00 p. m.	16	84.05		
6.20 p. m. to 8.28 p. m.	128	662.69		

TABLE 142.—*Heat emitted by radiation and conduction during periods of standing and lying, 1906*—Continued.

Periods.	Standing.		Lying.	
	Elapsed time.	Total heat.	Elapsed time.	Total heat.
Period IV—Continued.				
Steer A—Continued.	*Minutes.*	*Calories.*	*Minutes.*	*Calories.*
8.48 p. m. to 12.00 a. m.			192	753.22
12.20 a. m to 1.24 a. m.	64	373.80		
2.00 a. m to 3.04 a. m.			64	253.75
3.24 a. m to 4.32 a. m.	68	365.21		
4.52 a. m. to 6.00 a. m.	68	335.99		
6.00 a. m. to 7.12 a. m.	72	331.66		
7.32 a. m. to 8.56 a. m.			84	290.03
9.16 a. m. to 9.48 a. m.	32	166.64		
10.08 a. m. to 10.32 a. m.			24	84.95
10.52 a. m. to 11.44 a. m.	52	272.66		
12.20 p. m. to 2.52 p. m.			152	548.02
4.24 p. m. to 6.00 p. m.	96	488.67		
Totals	1,020	5,223.12	1,064	3,971.76
Total corrections for capacity, feed, water, excreta, etc		+97.81		−52.63
		5,320.93		3,919.13
Heat per minute		5.2166		3.6834
Steer B:				
6.00 p. m. to 7.04 p. m.	64	275.22		
7.24 p. m. to 8.36 p. m.			72	241.86
10.00 p. m. to 12.00 a. m.			120	459.90
12.36 a. m. to 1.00 a. m.	24	128.45		
1.28 a. m. to 4.52 a. m.			204	752.00
5.20 a. m. to 6.00 a. m.	40	213.45		
6.00 a. m. to 7.20 a. m.	80	374.17		
8.00 a. m. to 10.16 a. m.			136	441.72
11.28 a. m to 1.24 p. m.			116	398.73
1.44 p. m. to 2.08 p. m.	24	122.15		
2.48 p. m. to 4.52 p. m.			124	446.59
5.04 p. m. to 5.18 p. m.	14	71.87		
5.18 p. m. to 5.38 p. m.	20	103.19		
5.42 p. m. to 6.00 p. m.	18	90.92		
6.00 p. m. to 6.32 p. m.	32	164.12		
6.32 p. m. to 7.08 p. m.	36	178.35		
7.28 p. m. to 8.07 p. m.			39	157.10
8.07 p. m. to 9.08 p. m.			61	215.94
9.48 p. m. to 1.12 a. m.			204	769.86
1.56 a. m. to 4.20 a. m.			144	555.98
5.44 a. m. to 6.00 a. m.	16	78.09		
6.00 a. m. to 7.48 a. m.	108	497.66		
8.16 a. m. to 8.56 a. m.			40	125.20
9.16 a. m. to 9.40 a. m.	24	116.25		
10.00 a. m. to 2.04 p. m.			244	813.15
2.16 p. m. to 2 38 p. m.	32	158.44		
2.38 p. m. to 3.14 p. m.	36	172.60		
3.36 p. m. to 5.12 p. m.			96	342.37
5.40 p. m. to 6.00 p. m.	20	96.11		
Totals	588	2,841.04	1,600	5,720.40
Total corrections for capacity, feed, water, excreta, etc		+94.19		−95.12
		2,935.23		5,625.28
Heat per minute		4.9919		3.5158

TABLE 143.—*Average heat per minute emitted by radiation and conduction, 1906.*

Periods.	Standing.	Lying.
Steer A.	*Calories.*	*Calories.*
I	5.7323	4.2716
II	7.5469	5.2249
III	4.6410	3.4918
IV	5.2166	3.6834
Steer B.		
I	5.3824	3.8850
II	6.1683	4.2709
III	4.3029	3.0710
IV	4.9919	3.5158

HEAT GIVEN OFF AS LATENT HEAT OF WATER VAPOR.

On the basis of the discussion on pages 122 to 124, it is assumed that the percentage of the total heat emitted which was given off as latent heat of water vapor was independent of the standing or lying of the animal.

HEAT EMISSION AND PRODUCTION COMPUTED TO 12 HOURS STANDING.

With the exception of steer B in Period IV, the time spent standing did not vary greatly from 12 hours, and consequently the correction, computed as in the previous year's experiments (see p. 43), is comparatively small. The following are the final results of the computation:

TABLE 144.—*Heat production corrected to 12 hours standing, 1906.*

Periods.	Steer A.			Steer B.		
	Corrected total heat emission.	Correction for gain or loss of matter by body.	Corrected total heat production.	Corrected total heat emission.	Correction for gain or loss of matter by body.	Corrected total heat production.
	Calories.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
I	9,305.0	− 31.1	9,273.9	8,986.9	+28.8	9,015.7
II	12,599.2	− 85.7	12,513.5	9,971.3	−61.9	9,909.4
III	7,291.7	− 46.3	7,245.4	6,724.2	+54.1	6,778.3
IV	8,285.7	−100.2	8,185.5	7,836.1	+ 1.0	7,837.1

AVAILABILITY OF METABOLIZABLE ENERGY.

By substituting the foregoing corrected values for the heat production in the balances of energy contained in Table 136, we obtain the corresponding corrected values for the gains of energy by the animals, as follows:

TABLE 145.—*Corrected gains of energy by the animals, 1906.*

Periods.	Steer A.		Steer B.	
	Income.	Outgo.	Income.	Outgo.
Period I:	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Metabolizable	10,720.7		8,502.3	
Brushings		103.8		89.4
Heat (from Table 144)		9,273.9		9,015.7
Gain		1,343.0	602.8	
	10,720.7	10,720.7	9,105.1	9,105.1
Period II:				
Metabolizable	17,290.3		10,922.1	
Brushings		103.8		89.4
Heat (from Table 144)		12,513.5		9,909.4
Gain		4,673.0		923.3
	17,290.3	17,290.3	10,922.1	10,922.1
Period III:				
Metabolizable	4,938.8		4,751.2	
Brushings		103.8		89.4
Heat (from Table 144)		7,245.4		6,778.3
Gain	2,410.4		2,116.5	
	7,349.2	7,349.2	6,867.7	6,867.7
Period IV:				
Metabolizable	7,981.4		7,100.0	
Brushings		103.8		89.4
Heat (from Table 144)		8,185.5		7,837.1
Gain	307.9		826.5	
	8,289.3	8,289.3	7,926.5	7,926.5

From the data of the foregoing table, the percentage availability of the metabolizable energy of the hay and of the mixed grain may be computed in the same manner as in the experiments of 1905 (pp. 126–128). The corrections for live weight are based on the averages of the last six weighings of each period, as follows:

TABLE 146.—*Average live weights in calorimeter periods, 1906.*

Periods.	Steer A.	Steer B.
	Kilos.	*Kilos.*
I	404.0	298.0
II	420.7	309.6
III	399.1	296.2
IV	406.6	308.6

TIMOTHY HAY.

The availability of the metabolizable energy of the hay may be computed from the results of Periods III and IV, making the necessary correction for live weight, as follows:

TABLE 147.—*Availability of metabolizable energy of timothy hay, 1906.*

Steer A—Periods IV-III.	Steer B—Periods IV-III.
$n=\left(\frac{399.1}{406.6}\right)^{2/3}=0.9879$	$n=\left(\frac{296.2}{308.6}\right)^{2/3}=0.9729$
$x_3=4{,}938.8 \quad y_3=-2{,}410.4$	$x_3=4{,}751.2 \quad y_3=-2{,}116.5$
$x_4=7{,}981.4 \quad y_4=-\ 307.9$	$x_4=7{,}100.0 \quad y_4=-\ 826.5$
$m=\frac{-2{,}410.4-(0.9879\times-307.9)}{4938.8-(0.9879\times7{,}981.4)}=71.49$ per cent.	$m=\frac{-2{,}116.5-(0.9729\times-826.5)}{4{,}751.2-(0.9729\times7{,}100.0)}=60.86$ per cent.

MIXED GRAIN.

The following tables show the corrections for the variations in the amount of hay consumed in Periods I and II, on the mixed rations, and the availability of the metabolizable energy of the mixed grain, computed in the same manner as in the experiments of 1905.

TABLE 148.—*Correction for differences in amounts of hay eaten, 1906.*

Periods.	Steer A.			Steer B.		
	Organic matter of hay.	Metabolizable energy of total ration.	Gain by animal.	Organic matter of hay.	Metabolizable energy of total ration.	Gain by animal.
	Grams.	*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
Period III	2,493.1	....	....	2,326.5	....	....
Period I	2,459.0	10,720.7	1,343.0	2,294.2	8,502.3	−602.8
Correction	34.1	66.2	47.3	32.3	64.8	39.4
Period I corrected	2,493.1	10,786.9	1,390.3	2,326.5	8,567.1	−563.4
Period III	2,493.1	....	....	2,326.5	....	....
Period II	2,487.5	17,290.3	4,673.0	2,320.2	10,922.1	923.3
Correction	5.6	10.9	7.8	6.3	12.6	7.7
Period II corrected	2,493.1	17,301.2	4,680.8	2,326.5	10,934.7	931.0

TABLE 149.—*Availability of metabolizable energy of mixed grain, 1906.*

Steer A—Periods I-III.

$$n=\left(\frac{399.1}{404.0}\right)^{2/3}=0.9199$$

$$x_3=4,938.8 \qquad y_3=-2,410.4$$

$$x_1=10,786.9 \qquad y_1=1,390.3$$

$$m=\frac{-2,410.4-(0.9199\times 1,390.3)}{4,938.3-(0.9199\times 10,786.9)}=74.02 \text{ per cent.}$$

Steer B—Periods I-III.

$$n=\left(\frac{296.2}{298.0}\right)^{2/3}=0.9961$$

$$x_3=4,751.2 \qquad y_3=-2,116.5$$

$$x_1=8,567.1 \qquad y_1=-563.4$$

$$m=\frac{-2,116.5-(0.9961\times -563.4)}{4,751.2-(0.9961\times 8,567.1)}=41.12 \text{ per cent.}$$

Steer A—Periods II-III.

$$n=\left(\frac{399.1}{420.7}\right)^{2/3}=0.9656$$

$$x_3=4,938.8 \qquad y_3=-2,410.4$$

$$x_2=17,301.2 \qquad y_2=4,680.8$$

$$m=\frac{-2,410.4-(0.9656\times 4,680.8)}{4,938.8-(0.9656\times 17,301.2)}=58.89 \text{ per cent.}$$

Steer B—Periods II-III.

$$n=\left(\frac{296.2}{309.6}\right)^{2/3}=0.9707$$

$$x_3=4,751.2 \qquad y_3=-2,116.5$$

$$x_2=10,934.7 \qquad y_2=931.0$$

$$m=\frac{-2,116.5-(0.9707\times 931.0)}{4,751.2-(0.9707\times 10,934.7)}=51.51 \text{ per cent.}$$

Steer A—Periods II-I.

$$n=\left(\frac{404.0}{420.7}\right)^{2/3}=0.9734$$

$$x_1=10,786.9 \qquad y_1=1,390.3$$

$$x_2=17,301.2 \qquad y_2=4,680.8$$

$$m=\frac{1,390.3-(0.9734\times 4,680.8)}{10,786.9-(0.9734\times 17,301.2)}=52.30 \text{ per cent.}$$

Steer B—Periods II-I.

$$n=\left(\frac{298.0}{309.6}\right)^{2/3}=0.9744$$

$$x_1=8,567.1 \qquad y_1=-563.4$$

$$x_2=10,934.7 \qquad y_2=931.0$$

$$m=\frac{-563.4-(0.9744\times 931.0)}{8,567.1-(0.9744\times 10,934.7)}=70.44 \text{ per cent.}$$

TABLE 150.—*Summary of percentage availability of metabolizable energy, 1906.*

	Steer A.	Steer B.
	Per cent.	*Per cent.*
Timothy hay:		
Periods III and IV	71.49	60.86
Mixed grain:		
Periods I and III	74.02	41.12
Periods II and I	52.30	70.44
Periods II and III	58.89	51.51

The foregoing results are also represented graphically in figure 8 of Part I (p. 48).

RESPIRATION CALORIMETER EXPERIMENTS OF 1907.

These were substantially a repetition of the experiments of the previous year, the amount of feed given being increased to correspond to the increased weight of the animals.

FEEDING STUFFS.

Hay.—The hay was very nearly pure timothy, grown upon the experiment station farm and harvested about the last of June or the first of July in unusually good condition. No clover was noticed when handling the hay. The hay was cut and sampled on December

18 and 19, 1906, duplicate samples being taken for analysis and the remainder stored as in the previous year. Table 151 shows the composition of the two general samples and also of the four taken during the progress of the experiments.

TABLE 151.—*Composition of dry matter of timothy hay, 1907.*

Components and energy.	General samples.			Samples taken during experiment.			
	A.	B.	Average.	Period I.	Period II.	Period III.	Period IV.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Ash	5.110	4.915	5.013	4.973	4.956	4.978	5.115
Protein [1]	7.094	6.700	6.897	6.850	6.419	6.331	6.913
Nonprotein [1]	0.244	0.244	0.244	0.428	0.597	0.691	0.423
Crude fiber	30.675	31.619	31.147	30.930	31.170	31.114	29.980
Nitrogen-free extract	54.472	54.632	54.552	54.610	54.973	54.804	55.409
Ether extract	2.405	1.890	2.147	2.209	1.885	2.082	2.160
	100.000	100.000	100.000	100.000	100.000	100.000	100.000
Total nitrogen	1.187	1.124	1.155	1.187	1.154	1.160	1.196
Protein nitrogen	1.135	1.072	1.104	1.096	1.027	1.013	1.106
Carbon				46.793	46.961	46.930	47.087
Hydrogen				5.775	5.742	5.792	5.806
	Calories.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Energy per gram				4,493.4	4,497.5	4,509.3	4,520.8

[1] Computed from nitrogen, using factors stated in Part III, page 203.

Grain.—The same mixture of bran, corn meal, and old-process linseed meal was used as in the previous year and the sampling was done in the same way. Check analyses of samples of the mixed grain were also included. The results were as follows:

TABLE 152.—*Composition of dry matter of grain, 1907.*

Components and energy.	Wheat bran.		Corn meal.		Linseed meal.	
	Period I.	Period II.	Period I.	Period II.	Period I.	Period II.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Ash	7.156	7.019	1.495	1.477	5.816	5.811
Protein [1]	13.298	13.503	10.090	9.744	27.150	27.819
Nonprotein [1]	3.158	3.050	0.155	0.517	3.972	3.633
Crude fiber	10.400	10.060	2.220	2.061	8.810	8.840
Nitrogen-free extract	61.905	62.474	81.972	82.172	47.614	47.259
Ether extract	4.083	3.894	4.068	4.029	6.638	[2] 6.638
	100.000	100.000	100.000	100.000	100.000	100.000
Total nitrogen	3.005	3.018	1.715	1.734	5.782	5.831
Protein nitrogen	2.333	2.369	1.682	1.624	4.937	5.058
Carbon	45.685	45.867	46.360	46.141	47.816	48.295
Hydrogen	5.954	5.995	6.247	6.153	6.049	5.948
	Calories.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Energy, per gram	4.5789	4.5835	4.5348	4.5276	4.8010	4.8747

[1] Computed from nitrogen, using factors stated in Part III, page 203.
[2] Assumed same as Period I.

TABLE 153.—*Composition of dry matter of mixed grain.*

Components and energy.	Period I.		Period II.	
	Computed.	Composite sample.	Computed.	Composite sample.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Ash	4.156	4.283	4.126	4.129
Protein[1]	17.861	18.215	18.030	18.763
Nonprotein[1]	2.220	1.889	2.214	2.120
Crude fiber	6.213	6.404	6.109	6.342
Nitrogen-free extract	64.378	63.775	64.393	63.461
Ether extract	5.172	5.434	5.128	5.185
	100.000	100.000	100.000	100.000
Total nitrogen	3.642	3.635	3.673	3.783
Protein nitrogen	3.170	3.233	3.202	3.332
Carbon	46.888	46.818	47.025	47.074
Hydrogen	6.120	6.467	6.043	5.827
	Calories.	*Calories.*	*Calories.*	*Calories.*
Energy per gram	4.6552	4.6806	4.6843	4.6959

[1] Computed from nitrogen, using factors stated in Part III, page 203.

PERIODS AND RATIONS.

The periods and rations are tabulated in the same manner as before, the dates being inclusive in all cases.

TABLE 154 —*Periods, 1907.*

Periods.	Steer A.		Steer B.	
	Preliminary feeding.	Excreta collected.	Preliminary feeding.	Excreta collected.
I	Jan. 20 to 30	Jan. 31 to Feb. 9	Jan. 27 to Feb. 6	Feb. 7 to 16.
Transition	Feb. 10 to 16		Feb. 17 to 23	
II	Feb. 17 to 27	Feb. 28 to Mar. 9	Feb. 24 to Mar. 6	Mar. 7 to 16.
III	Mar. 10 to 20	Mar. 21 to 30	Mar. 17 to 27	Mar. 28 to Apr. 6.
IV	Mar. 31 to Apr. 10	Apr. 11 to 20	Apr. 7 to 17	Apr. 18 to 27.

TABLE 155.—*Daily rations, 1907.*

Periods.	Steer A.				Steer B.			
	Timothy hay.	Wheat bran.	Corn meal.	Linseed meal.	Timothy hay.	Wheat bran.	Corn meal.	Linseed meal.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
I	3,400	335	1,000	1,000	3,200	235	700	700
II	3,400	800	2,400	2,400	3,200	450	1,350	1,350
III	3,400				3,200			
IV	5,600				5,300			

DIGESTIBILITY OF THE RATIONS.

The digestibility of the rations is computed from the figures in Tables IX and X of the appendix in the same manner as before with the following results.

TABLE 156.—*Feed and excreta—Period I, 1907.*

	Steer A.				Steer B.			
	Number of days.	Fresh weight.	Dry matter.		Number of days.	Fresh weight.	Dry matter.	
		Grams.	*Per cent.*	*Grams.*		*Grams.*	*Per cent.*	*Grams.*
Timothy hay:								
Total	10	34,000.0	86.33	29,351.5	10	32,000.0	86.33	27,625.0
Uneaten	....	2.5	86.33	2.2	....	19.4	86.33	16.8
Eaten	....	33,997.5	....	29,349.5	....	31,980.8	....	27,608.2
Eaten per day	....	3,399.8	....	2,935.0	....	3,198.1	....	2,760.8
Wheat bran:								
Total	....	3,350.0	84.97	2,846.6	10	2,350.0	84.97	1,996.9
Eaten per day	....	335.0	....	284.7	....	235.0	....	199.7
Corn meal:								
Total	....	10,000.0	83.71	8,370.9	10	7,000.0	83.71	5,859.6
Eaten per day	....	1,000.0	....	837.1	....	700.0	....	586.0
Linseed meal:								
Total	10	10,000.0	87.44	8,743.8	10	7,000.0	87.44	6,120.7
Eaten per day	....	1,000.0	....	874.4	....	700.0	....	612.1
Feces:								
Collected	....	84,590.0	18.12	15,323.5	10	60,950.0	23.14	14,105.1
Spilled Feb. 7	....	5.0	80.68	4.0	....	....	....	....
In duct	....	616.9	21.77	134.3	....	7.4	50.68	3.7
Total	....	85,211.9	....	15,461.8	....	60,957.4	....	14,108.8
Excretion per day	....	8,521.2	....	1,546.2	....	6,095.7	....	1,410.9

TABLE 157.—*Digestibility of rations—Period I, 1907.*

	Dry matter.	Ash.	Organic matter.	Protein.	Non-protein.	Crude fiber.	Nitrogen-free extract	Ether extract.	Total nitrogen.	Carbon.	Hydrogen.	Energy.
Steer A.	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Calories.*
Timothy hay	2,934.9	146.0	2,788.9	201.0	12.6	907.8	1,602.7	64.8	34.8	1,373.3	169.5	13,187.7
Wheat bran	284.7	20.4	264.3	37.9	8.9	29.6	176.2	11.6	8.6	130.1	17.0	1,303.6
Corn meal	837.1	12.5	824.6	84.5	1.3	18.6	686.2	34.1	14.4	388.1	52.3	3,796.1
Linseed meal	874.4	50.9	823.5	237.4	34.7	77.0	416.3	58.0	50.6	418.1	52.9	4,198.0
Total	4,931.1	229.8	4,701.3	560.8	57.5	1,033.0	2,881.4	168.5	108.4	2,309.6	291.7	22,485.4
Feces	1,546.2	149.6	1,396.6	206.9	......	448.9	704.6	36.3	33.1	750.0	87.7	7,359.3
Digested	3,384.9	80.2	3,304.7	353.9	57.5	584.1	2,176.8	132.2	75.3	1,559.6	204.0	15,126.1
Percentage digestibility	68.64	34.90	70.29	63.09	100.00	56.54	75.55	78.46	69.46	67.53	69.93	67.27
Steer B.												
Timothy hay	2,760.8	137.3	2,623.5	189.1	11.8	853.9	1,507.7	61.0	32.8	1,291.9	159.4	12,405.4
Wheat bran	199.7	14.3	185.4	26.6	6.3	20.8	123.6	8.2	6.0	91.2	11.9	914.4
Corn meal	586.0	8.8	577.2	59.1	0.9	13.0	480.4	23.8	10.0	271.7	36.6	2,657.4
Linseed meal	612.1	35.6	576.5	166.2	24.3	53.9	291.4	40.6	35.4	292.7	37.0	2,938.7
Total	4,158.6	196.0	3,962.6	441.0	43.3	941.6	2,403.1	133.6	84.2	1,947.5	244.9	18,915.9
Feces	1,410.9	135.9	1,275.0	152.8	......	419.0	664.1	39.0	24.5	682.3	81.1	6,767.7
Digested	2,747.7	60.1	2,687.6	288.2	43.3	522.6	1,739.0	94.6	59.7	1,265.2	163.8	12,148.2
Percentage digestibility	66.07	30.66	67.82	65.35	100.00	55.50	72.36	70.80	70.90	64.97	66.88	64.22

TABLE 158.—*Feed and excreta—Period II, 1907.*

	Steer A.				Steer B.			
	Number of days.	Fresh weight.	Dry matter.		Number of days.	Fresh weight.	Dry matter.	
		Grams.	*Per cent.*	*Grams.*		*Grams.*	*Per cent.*	*Grams.*
Timothy:								
Total	10	34,000.0	86.75	29,495.0	10	32,000.0	86.75	27,760.0
Uneaten		9.8	86.75	8.5		20.0	86.75	17.4
Eaten		33,990.2		29,486.5		31,980.0		27,742.6
Eaten per day		3,399.0		2,948.7		3,198.0		2,774.3
Wheat bran:								
Total	10	8,000.0	83.78	6,702.5	10	4,500.0	83.78	3,770.2
Eaten per day		800.0		670.3		450.0		377.0
Corn meal:								
Total		24,000.0	83.28	19,987.9	10	13,500.0	83.28	11,243.2
Eaten per day		2,400.0		1,998.8		1,350.0		1,124.3
Linseed meal:								
Total		24,000.0	87.08	20,899.4	10	13,500.0	87.08	11,755.9
Eaten per day		2,400.0		2,089.9		1,350.0		1,175.6
Feces:								
Collected		132,550.0	16.42	21,766.0		74,695.0	20.41	15,242.3
Spilled Mar. 7		142.3	38.79	55.2				
Spilled Mar. 14						69.3	52.22	36.2
In duct		1,241.0	18.13	224.9		569.6	25.78	146.8
Total		133,933.3		22,046.1		75,333.9		15,425.3
Excretion per day		13,393.3		2,204.6		7,533.4		1,542.5

TABLE 159.—*Digestibility of rations—Period II, 1907.*

	Dry matter.	Ash.	Organic matter.	Protein.	Non-protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Total nitrogen.	Carbon.	Hydrogen.	Energy.
Steer A.												
	Gms.	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Gms.*	*Calories.*
Timothy hay	2,948.7	146.1	2,802.6	189.3	17.6	919.1	1,621.0	55.6	34.0	1,384.7	169.3	13,261.8
Wheat bran	670.2	47.0	623.2	90.5	20.4	67.4	418.7	26.1	20.2	307.4	40.2	3,071.9
Corn meal	1,998.8	29.5	1,969.3	208.0	10.3	41.2	1,642.5	80.5	34.7	922.3	123.0	9,049.8
Linseed meal	2,090.0	121.4	1,968.6	581.4	75.9	184.8	987.8	[1]138.7	121.9	1,009.4	124.3	10,188.1
Total	7,707.7	344.0	7,363.7	1,069.2	124.2	1,212.5	4,670.0	300.9	210.8	3,623.8	456.8	35,571.6
Feces	2,204.6	229.0	1,975.6	343.8		656.5	927.1	48.2	55.0	1,049.3	124.4	10,340.7
Digested	5,503.1	115.0	5,388.1	725.4	124.2	556.0	3,742.9	252.7	155.8	2,574.5	332.4	25,230.9
Percentage digestibility	71.40	33.43	73.17	67.84	100.00	45.89	80.15	83.98	73.91	71.04	72.77	70.93
Steer B.												
Timothy hay	2,774.3	137.5	2,636.8	178.1	16.6	864.7	1,525.1	52.3	32.0	1,302.8	159.3	12,477.4
Wheat bran	377.0	26.5	350.5	50.9	11.5	37.9	235.5	14.7	11.4	172.9	22.6	1,728.0
Corn meal	1,124.3	16.6	1,107.7	117.0	5.8	23.2	923.9	45.3	19.5	518.8	69.2	5,090.3
Linseed meal	1,175.6	68.3	1,107.3	327.0	42.7	103.9	555.6	[1]78.0	68.5	567.8	69.9	5,730.7
Total	5,451.2	248.9	5,202.3	673.0	76.6	1,029.7	3,240.1	190.3	131.4	2,562.3	321.0	25,026.4
Feces	1,542.5	154.4	1,388.1	205.1		459.0	685.2	38.8	32.8	737.5	84.5	7,371.1
Digested	3,908.7	94.5	3,814.2	467.9	76.6	570.7	2,554.9	151.5	98.6	1,824.8	236.5	17,655.3
Percentage digestibility	71.70	37.97	73.32	69.53	100.00	55.42	78.85	79.61	75.04	71.22	73.68	70.55

[1] Percentage of ether extract assumed to have been the same as in Period I.

TABLE 160.—*Feed and excreta—Period III, 1907.*

	Steer A.				Steer B.			
	Number of days.	Fresh weight.	Dry matter.		Number of days.	Fresh weight.	Dry matter.	
Timothy hay:		*Grams.*	*Per cent.*	*Grams.*		*Grams.*	*Per cent.*	*Grams.*
Total	10	34,000.0	87.49	29,745.6	10	32,000.0	87.49	27,995.8
Uneaten	....	3.7	87.49	3.2	....	15.1	87.49	13.2
Eaten	....	33,996.3	....	29,742.4	....	31,984.9	....	27,982.6
Eaten per day	....	3,399.6	....	2,974.2	....	3,198.5	....	2,798.3
Feces:								
Collected	....	50,165.0	21.97	11,021.8	....	47,785.0	22.17	10,595.8
Spilled Mar. 28	....	64.0	48.55	31.1	....	....	....	....
Spilled Apr. 4	....	....	....	....	....	4.2	81.60	3.4
In duct	....	176.8	33.14	58.6	....	73.7	33.06	24.4
Washings from duct	....	185.0	5.04	9.3	....	....	....	....
Total	....	50,590.8	....	11,120.8	....	47,862.9	....	10,623.6
Excretion per day	....	5,059.1	....	1,112.1	....	4,786.3	....	1,062.4

TABLE 161.—*Digestibility of rations—Period III, 1907.*

	Dry matter.	Ash.	Organic matter.	Protein.	Non-protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Total nitrogen.	Carbon.	Hydrogen.	Energy.
Steer A.	*Grams.*	*Gms.*	*Grams.*	*Gms.*	*Gms.*	*Gms.*	*Grams.*	*Gms.*	*Gms.*	*Grams.*	*Gms.*	*Calories.*
Timothy hay	2,974.2	148.1	2,826.1	188.3	20.6	925.3	1,630.0	61.9	34.5	1,395.8	172.3	13,411.6
Feces	1,112.1	89.3	1,022.8	111.3	......	341.7	537.2	32.6	17.8	551.9	65.4	5,475.1
Digested	1,862.1	58.8	1,803.3	77.0	20.6	583.6	1,092.8	29.3	16.7	843.9	106.9	7,936.5
Percentage digestibility	62.61	39.70	63.81	40.89	100.00	63.07	67.04	47.33	48.41	60.46	62.04	59.18
Steer B.												
Timothy hay	2,798.3	139.3	2,659.0	177.2	19.3	870.6	1,533.6	58.3	32.5	1,313.2	162.1	12,618.4
Feces	1,062.4	87.1	975.3	101.0	......	312.3	529.6	32.4	16.2	527.9	60.8	5,247.0
Digested	1,735.9	52.2	1,683.7	76.2	19.3	558.3	1,004.0	25.9	16.3	785.3	101.3	7,371.4
Percentage digestibility	62.03	37.47	63.32	43.00	100.00	64.13	65.47	44.43	50.15	59.80	62.49	58.42

TABLE 162.—*Feed and excreta—Period IV, 1907.*

	Steer A.				Steer B.			
	Number of days.	Fresh weight.	Dry matter.		Number of days.	Fresh weight.	Dry matter.	
Timothy hay:		*Grams.*	*Per cent.*	*Grams.*		*Grams.*	*Per cent.*	*Grams.*
Total	10	56,000.0	87.37	48,925.0	10	53,000.0	87.37	46,304.0
Uneaten	....	5.3	87.37	4.6	....	6.3	87.37	5.5
Eaten	....	55,994.7	....	48,920.4	....	58,993.7	....	46,298.5
Eaten per day	....	5,599.5	....	4,892.0	....	5,399.4	....	4,629.9
Feces:								
Collected	....	99,655.0	18.79	18,725.2	....	92,455.0	19.47	18,001.0
Spilled Apr. 18	....	27.6	68.46	18.9	....	....	....	....
In duct	....	402.5	5.09	20.5	....	18.8	90.46	17.0
Total	....	100,088.1	....	18,764.6	....	92,473.8	....	18,018.0
Excretion per day	....	10,008.5	....	1,876.5	....	9,247.4	....	1,801.8

TABLE 163.—*Digestibility of rations—Period IV, 1907.*

	Dry matter.	Ash.	Organic matter.	Protein.	Nonprotein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Total nitrogen.	Carbon.	Hydrogen.	Energy.
Steer A.	*Grams.*	*Gms.*	*Grams.*	*Gms.*	*Gms.*	*Grams.*	*Grams.*	*Gms.*	*Gms.*	*Grams.*	*Gms.*	*Calories.*
Timothy hay..	4,892.0	250.2	4,641.8	338.2	20.7	1,466.6	2,710.6	105.7	58.5	2,303.5	284.0	22,115.8
Feces.........	1,876.9	154.2	1,724.4	184.4	......	548.4	935.5	54.5	29.5	931.8	108.9	9,236.8
Digested...	3,015.1	96.0	2,917.4	153.8	20.7	918.2	1,775.1	51.2	29.0	1,371.7	175.1	12,879.0
Percentage digestibility...	61.64	38.37	62.85	45.48	100.00	62.60	65.49	48.44	49.57	59.55	61.65	58.23
Steer B.												
Timothy hay..	4,629.8	236.8	4,393.0	320.1	19.6	1,388.0	2,565.3	100.0	55.4	2,180.0	268.8	20,930.4
Feces.........	1,801.8	141.8	1,660.0	179.3	......	531.7	899.8	49.3	28.7	889.2	103.0	8,879.1
Digested...	2,828.0	95.0	2,733.0	140.8	19.6	856.3	1,665.5	50.7	26.7	1,290.8	165.8	12,051.3
Percentage digestibility...	61.02	40.12	62.21	43.99	100.00	61.69	64.92	50.70	48.19	59.21	61.68	57.58

DIGESTIBILITY OF TIMOTHY HAY AND OF MIXED GRAIN.

From the data of Tables 156–163, the average digestibility of the timothy hay in Periods III and IV and the percentage digestibility of the mixed grains in Periods I and II are computed in the two following tables in the same manner as in the previous years:

TABLE 164.—*Average digestibility of timothy hay, 1907.*

	Dry matter.	Ash.	Organic matter.	Protein.	Nonprotein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Total nitrogen.	Carbon.	Hydrogen.	Energy.
Steer A.	*Grams.*	*Gms.*	*Grams.*	*Gms.*	*Gms.*	*Grams.*	*Grams.*	*Gms.*	*Gms.*	*Grams.*	*Gms.*	*Calories.*
Fed in Period III..........	2,974.2	148.1	2,826.1	188.3	20.6	925.3	1,630.0	61.9	34.5	1,395.8	172.3	13,411.6
Fed in Period IV..........	4,892.0	250.2	4,641.8	338.2	20.7	1,466.6	2,710.6	105.7	58.5	2,303.5	284.0	22,115.8
Total...	7,866.2	398.3	7,467.9	526.5	41.3	2,391.9	4,340.6	167.6	93.0	3,699.3	456.3	35,527.4
Digested in Period III...	1,862.1	58.8	1,803.3	77.0	20.6	583.6	1,092.8	29.3	16.7	843.9	106.9	7,936.5
Digested in Period IV...	3,015.1	96.0	2,917.4	153.8	20.7	918.2	1,775.1	51.2	29.0	1,371.7	175.1	12,879.0
Total...	4,877.2	154.8	4,720.7	230.8	41.3	1,501.8	2,867.9	80.5	45.7	2,215.6	282.0	20,815.5
Percentage digestibility...	62.00	38.87	63.21	43.84	100.00	62.79	66.07	48.03	49.14	59.89	61.80	58.59
Steer B.												
Fed in Period III..........	2,798.3	139.3	2,659.0	177.2	19.3	870.6	1,533.6	58.3	32.5	1,313.2	162.1	12,618.4
Fed in Period IV..........	4,629.8	236.8	4,393.0	320.1	19.6	1,388.0	2,565.3	100.00	55.4	2,180.0	268.8	20,930.4
Total...	7,428.1	376.1	7,052.0	497.3	38.9	2,258.6	4,098.9	158.3	87.9	3,493.2	430.9	33,548.8
Digested in Period III...	1,735.9	52.2	1,683.7	76.2	19.3	558.3	1,004.0	25.9	16.3	785.3	101.3	7,371.4
Digested in Period IV...	2,828.0	95.0	2,733.0	140.8	19.6	856.3	1,665.5	50.7	26.7	1,290.8	165.8	12,051.3
Total...	4,563.9	147.2	4,416.7	217.0	38.9	1,414.6	2,669.5	76.6	43.0	2,076.1	267.1	19,422.7
Percentage digestibility...	61.44	39.14	62.63	43.64	100.00	62.63	65.13	48.39	48.92	59.43	61.99	57.89

TABLE 165.—*Computed digestibility of mixed grain, 1907.*

	Dry matter.	Ash.	Organic matter.	Protein.	Non-protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Total nitrogen.	Carbon.	Hydrogen.	Energy.
Steer A.												
Period I:												
Total digested....	*Grams.* 3,384.9	*Gms.* 80.2	*Grams.* 3,304.7	*Gms.* 353.9	*Gms.* 57.5	*Grams.* 584.1	*Grams.* 2,176.8	*Gms.* 132.2	*Gms.* 75.3	*Grams.* 1,559.6	*Gms.* 204.0	*Calories.* 15,126.1
Computed digestible in hay ...	1,819.6	56.8	1,762.9	88.1	12.6	570.0	1,058.9	31.1	17.1	822.5	104.8	7,726.7
Digested from grain...	1,565.3	23.4	1,541.8	265.8	44.9	14.1	1,117.9	101.1	58.2	737.1	99.2	7,399.4
Total in grain.....	1,996.2	83.8	1,912.4	359.8	44.9	125.2	1,278.7	103.7	73.6	936.3	122.2	9,297.7
Percentage digestibility	78.41	27.92	80.62	73.87	100.00	11.26	87.42	97.49	79.08	78.72	81.18	79.58
							80.64					
Period II:												
Total digested....	5,503.1	115.0	5,388.1	725.4	124.2	556.0	3,742.9	252.7	155.8	2,574.5	332.4	25,230.9
Computed digestible in hay ...	1,828.2	56.8	1,771.5	83.0	17.6	577.1	1,071.0	26.7	16.7	829.3	104.6	7,770.1
Digested from grain...	3,674.9	58.2	3,616.6	642.4	106.6	—21.1	2,671.9	226.0	139.1	1,745.2	227.8	17,460.8
Total in grain.....	4,759.0	197.9	4,561.1	879.9	106.6	293.2	3,049.0	245.3	176.8	2,239.1	287.5	22,309.8
Percentage digestibility	77.22	29.41	79.29	73.01	100.00	—7.19	87.63	92.13	78.68	77.94	79.23	78.27
							79.30					
Steer B.												
Period I:												
Total digested....	2,747.7	60.1	2,687.6	288.2	43.3	522.6	1,739.0	94.6	59.7	1,265.2	163.8	12,148.2
Computed digestible in hay......	1,696.2	53.7	1,643.1	82.5	11.8	—534.8	982.0	29.5	16.0	767.8	98.8	7,181.5
Digested from grain...	1,051.5	6.4	1,044.5	205.7	31.5	—12.2	757.0	65.1	43.7	497.4	65.0	4,966.7
Total in grain.....	1,397.8	58.7	1,339.1	251.9	31.5	87.7	895.4	72.6	51.4	655.6	85.5	6,510.5
Percentage digestibility....	75.23	10.90	78.02	81.66	100.00	—13.91	84.54	89.67	85.02	75.87	76.02	76.29
							75.76					
Period II:												
Total digested....	3,908.7	94.5	3,814.2	467.9	76.6	570.7	2,554.9	151.5	98.6	1,824.8	236.5	17,655.3
Computed digestible in hay......	1,704.5	53.8	1,651.4	77.7	16.6	541.6	993.3	25.3	15.7	774.3	98.8	7,223.2
Digested from grain...	2,204.2	40.7	2,162.8	390.2	60.0	29.1	1,561.6	126.2	82.9	1,050.5	137.7	10,432.1
Total in grain.....	2,676.9	111.4	2,565.5	494.9	60.0	165.0	1,715.0	138.0	99.4	1,259.5	161.7	12,549.0
Percentage digestibility....	82.34	36.54	84.30	78.84	100.00	17.64	91.06	91.45	83.40	83.41	85.16	83.13
							84.61					

URINARY EXCRETION.

The urine was collected, sampled, and analyzed as in the experiments of 1906, including daily determinations of nitrogen. The urinary excretion is tabulated in detail in Table IX of the appendix, and the results are summarized in the following tables in the same form as in the previous experiments:

TABLE 166.—*Results on urine (inclusive of wash water), 1907.*

	Weight.	Average specific gravity.	Total solids.		Total nitrogen.		Total carbon.		Total hydrogen.		Energy.	
											Per gram.	Total.
Period I.												
Steer A:	*Grams.*		*Per cent.*	*Grams.*	*Per cent.*	*Grams.*	*Per cent.*	*Grams.*	*Per cent.*	*Gms.*	*Calories.*	*Calories.*
Total collected	42,440.0	1.0446	10.384	4,407.0	1.682	713.84	2.786	1,182.38	0.381	161.70	0.2814	11,942.6
Spilled, Feb. 7	975.0	......	5.464	53.3	.885	8.63	[1]1.466	14.29	[1].200	1.95	[1].1481	144.4
Total	43,415.0	......	......	4,460.3	......	722.47	......	1,196.67	......	163.65	......	12,087.0
Daily average (10 days)	4,341.5	......	......	446.0	......	72.25	......	119.67	......	16.37	......	1,208.7
Steer B:												
Total collected	32,020.0	1.0501	12,366	3,959.2	1.820	582.76	3.360	1,075.87	.466	149.21	.3411	10,922.0
Spilled, Feb. 16	1,120.7	......	2.867	32.1	.422	4.73	[1].779	8.73	[1].108	1.21	[1].0791	88.6
Total	33,140.7	......	......	3,991.3	......	587.49	......	1,084.60	......	150.42	......	11,010.6
Daily average (10 days)	3,314.1	......	......	399.1	......	58.75	......	108.46	......	15.04	......	1,101.1
Period II.												
Steer A:												
Total collected	81,030.0	1.0322	9.433	7,643.6	1.847	1,496.62	2.329	1,887.19	.419	339.52	.2415	19,568.7
Spilled, Mar. 5	270.4	......	11.149	30.2	2.183	5.90	[1]2.753	7.44	[1].495	1.34	.2854	77.2
Total	81,300.4	......	......	7,673.80	......	1,502.52	......	1,894.63	......	340.86	......	19,645.9
Daily average (10 days)	8,130.0	......	......	767.4	......	150.25	......	189.46	......	34.09	......	1,964.6
Steer B:												
Total collected	37,785.0	1.0518	13.392	5,060.2	2.291	865.65	3.774	1,426.01	.577	218.02	.3844	14,524.6
Spilled, Mar. 10	269.6	......	12.602	34.0	2.156	5.81	[1]3.552	9.58	.543	1.47	.3617	97.5
Spilled, Mar. 15	102.2	......	7.307	7.5	1.250	1.28	[1]2.059	2.10	.315	.32	.2097	21.4
Spilled, Mar. 16	173.2	......	1.058	1.8	.181	.31	[1].298	.52	[1].046	.08	.0304	5.3
Total	38,330.0	......	......	5,103.5	......	873.05	......	1,438.21	......	219.89	......	14,648.8
Daily average	3,833.0	......	......	510.4	......	87.31	......	143.82	......	21.99	......	1,464.9
Period III.												
Steer A:												
Total collected	60,035.0	1.0292	6.710	4,028.4	.490	293.85	1.176	706.01	.182	109.26	.1109	6,657.9
Daily average (9 days)	6,670.55	......	......	447.6	......	32.65	......	78.45	......	12.14	......	739.8

[1] Assumed to be proportional to nitrogen content.

TABLE 166.—*Results on urine (inclusive of wash water), 1907*—Continued.

	Weight.	Average specific gravity.	Total solids.		Total nitrogen.		Total carbon.		Total hydrogen.		Energy.	
											Per gram.	Total.
Period III—Con.												
Steer B:			*Per cent.*	*Grams.*	*Per cent.*	*Grams.*	*Per cent.*	*Grams.*	*Per cent.*	*Gms.*	*Calories.*	*Calories.*
Total collected	*Grams.* 39,195.0	1.0395	9.265	3,631.4	.725	284.00	1.932	757.25	.285	111.71	.1860	7,290.3
Spilled, Mar. 28	188.8	......	1.866	3.5	.146	.28	[1].389	.73	[1].057	.11	[1].0375	7.1
Spilled, Mar. 28[2]	50.0	......	11.679	5.8	.914	.46	2.436	1.22	[1].359	.18	.2345	11.7
Total	39,433.8	......	......	3,640.7	......	284.74	......	759.20	......	112.00	......	7,309.1
Daily average (10 days)	3,943.4	......	......	364.1	......	28.47	......	75.92	......	11.20	......	730.9
Period IV.												
Steer A:												
Total collected	61,415.0	1.0354	8.240	5,060.6	.466	286.19	1.757	1,079.06	.239	146.78	.1605	9,857.1
Spilled, Apr. 11	226.5	......	1.390	3.2	.079	.18	[1].298	.67	[1].041	.09	[1].0272	6.2
Total	61,641.5	......	......	5,063.8	......	286.37	......	1,079.73	......	146.87	......	9,863.3
Daily average (10 days)	6,164.2	......	......	506.4	......	28.64	......	107.97	......	14.69	......	986.3
Steer B:												
Total collected	55,225.0	1.0410	8.434	4,657.7	.447	246.86	1.707	942.69	.236	130.33	.1601	8,841.5
Daily average (9 days)	6,136.1	......	......	517.5	......	27.43	......	104.74	......	14.48	......	982.4

[1] Assumed to be proportional to nitrogen content. [2] Estimated.

TABLE 167.—*Average daily excretion in urine, 1907.*

Period.	Nitrogen.	Carbon.	Energy.	
			Total.	Per gram carbon.
Steer A.	*Grams.*	*Grams.*	*Calories.*	*Calories.*
I	72.25	119.67	1,208.7	10.10
II	150.25	189.46	1,964.6	10.37
III	32.65	78.45	739.8	9.43
IV	28.64	107.97	986.3	9.13
Steer B.				
I	58.75	108.46	1,101.1	10.15
II	87.31	143.82	1,464.9	10.19
III	28.47	75.92	730.9	9.63
IV	27.43	104.74	982.4	9.38

PRODUCTION OF EPIDERMAL TISSUE.

Steer A was clipped on January 7 before beginning the experiments and at their close on May 7, and steer B on January 8 and May 6. The brushings of the animals were collected as in the previous year. The results of these determinations are contained in the following tables:

TABLE 168.—*Weights and composition of brushings for the two days in the calorimeter, 1907.*

Components and energy.	Steer A.				Steer B.			
	Period I.	Period II.	Period III.	Period IV.	Period I.	Period II.	Period III.	Period IV.
Weight.......grams..	35.1	62.7	39.6	42.3	45.9	52.7	39.7	Lost.
Dry matter.per cent..	95.647	93.991	90.962	94.382	85.875	96.128	94.765	....
Weight of dry matter.........grams..	33.57	58.93	36.02	39.92	39.42	50.66	37.62	....
In dry matter:								
Nitrogen—								
Percentage.......	5.408	5.308	5.446	6.643	4.059	5.197	6.347	....
Weight..grams..	1.82	3.13	1.96	2.65	1.60	2.63	2.39	....
Carbon—								
Percentage.......	39.083	40.412	41.584	41.984	37.156	40.355	41.120	....
Weight..grams..	13.12	23.81	14.98	16.76	14.65	20.44	15.47	....
Hydrogen—								
Percentage.......	4.833	5.244	5.340	5.457	4.677	5.213	5.335	....
Weight..grams..	1.62	3.09	1.92	2.18	1.84	2.64	2.01	....
Energy—								
Per gram, calories..	4.4298	4.5842	4.5951	4.7393	4.2212	4.5496	4.6251	....
Total......do....	148.7	270.2	165.5	189.2	166.4	230.5	174.0	....

TABLE 169.—*Weights and composition of hair, 1907.*

Components and energy.	Steer A.	Steer B.
Number of days	120	118
Weight.....grams..	770	607
Dry matter.....per cent..	79.333	83.437
Dry matter.....grams..	610.86	506.46
Daily average.....do....	5.09	4.29
In dry matter:		
Nitrogen—		
Percentage	13.727	14.624
Weight.....grams..	83.85	74.06
Daily average.....do....	.70	.63
Carbon—		
Percentage	47.796	48.157
Weight.....grams..	291.97	243.90
Daily average.....do....	2.43	2.07
Hydrogen—		
Percentage	5.980	6.280
Weight.....grams..	36.53	31.81
Daily average.....do....	.304	.270
Energy—		
Per gram.....calories..	5.1673	5.2993
Total.....do....	3,156.5	2,683.9
Daily average.....do....	26.3	22.7

TABLE 170.—*Average daily production of epidermal tissue, 1907.*

Components and energy.	Steer A.	Steer B.
Dry matter.....grams..	26.15	25.58
Nitrogen.....do....	1.90	1.74
Carbon.....do....	11.02	10.50
Hydrogen.....do....	1.40	1.35
Energy.....calories..	123.0	117.9

DETERMINATION OF RESPIRATORY PRODUCTS.

The respiratory products were determined upon two consecutive days of each period as in the previous year with the results shown in Table 172. In the combustible gases given off by the animals the ratio of hydrogen to carbon was as follows:

TABLE 171.—*Ratio of hydrogen to carbon in combustible gases, 1907.*

Periods.	Steer A, 1:	Steer B, 1:
I	3.114	3.110
II	3.059	3.076
III	3.168	3.158
IV	3.121	3.106

TABLE 172.—*Carbon and hydrogen in gaseous excreta, 1907.*

Periods.	In CO_2 and H_2O.		In hydrocarbons.		CH_4 computed from C.	H : C in hydrocarbon.
	Carbon.	Hydrogen.	Carbon.	Hydrogen.		
Period I.						
Steer A, Feb. 6 and 7:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	1 :
Subperiod 1	592.65	200.21	52.27	16.62	69.83	3.145
Subperiod 2	592.06	200.61	50.82	16.42	67.90	3.095
First day	1,184.71	400.82	103.09	33.04	137.73	3.120
Subperiod 3	594.71	223.66	52.64	16.89	70.33	3.117
Subperiod 4	595.10	211.99	51.64	16.66	68.99	3.100
Second day	1,189.81	435.65	104.28	33.55	139.32	3.108
Average	1,187.26	418.24	103.69	33.30	138.53	3.114
Steer B, Feb. 13 and 14:						
Subperiod 1	530.04	204.44	45.44	14.31	60.71	3.175
Subperiod 2	543.22	207.09	45.26	14.83	60.47	3.052
First day	1,073.26	411.53	90.70	29.14	121.18	3.113
Subperiod 3	529.31	205.42	43.96	14.19	58.74	3.098
Subperiod 4	537.34	203.22	46.02	14.76	61.48	3.118
Second day	1,066.65	408.64	89.98	28.95	120.22	3.108
Average	1,069.96	410.09	90.34	29.05	120.70	3.110
Period II.						
Steer A, Mar. 6 and 7:						
Subperiod 1	840.05	388.91	77.07	25.01	102.96	3.082
Subperiod 2	868.33	403.48	77.62	25.51	103.70	3.043
First day	1,708.38	792.39	154.69	50.52	206.66	3.062
Subperiod 3	862.26	414.33	74.11	24.26	99.01	3.055
Subperiod 4	847.76	373.35	72.51	23.72	96.88	3.057
Second day	1,710.02	787.68	146.62	47.98	195.89	3.056
Average	1,709.20	790.04	150.66	49.25	201.28	3.059
Steer B, Mar. 13 and 14:						
Subperiod 1	657.47	345.12	58.58	19.00	78.26	3.083
Subperiod 2	669.19	333.21	59.08	19.20	78.94	3.077
First day	1,326.66	678.33	117.66	38.20	157.20	3.080
Subperiod 3	660.77	359.64	59.02	19.29	78.86	3.060
Subperiod 4	684.48	349.57	58.66	19.01	78.37	3.086
Second day	1,345.25	709.21	117.68	38.30	157.23	3.073
Average	1,335.96	693.77	117.67	38.25	157.22	3.076

TABLE 172.—*Carbon and hydrogen in gaseous excreta, 1907*—Continued.

Period.	In CO_2 and H_2O.		In hydrocarbons.		CH_4 computed from C.	H : C in hydrocarbon.
	Carbon.	Hydrogen.	Carbon.	Hydrogen.		
Period III.						
Steer A, Mar. 27 and 28:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	1 :
Subperiod 1	425.79	169.27	30.35	9.61	40.55	3.158
Subperiod 2	425.52	157.15	30.52	9.80	40.78	3.114
First day	851.31	326.42	60.87	19.41	81.33	3.136
Subperiod 3	417.80	159.66	31.62	9.89	42.25	3.197
Subperiod 4	418.90	159.19	30.40	9.50	40.62	3.200
Second day	836.70	318.85	62.02	19.39	82.87	3.199
Average	844.01	322.64	61.45	19.40	82.10	3.168
Steer B, Apr. 3 and 4:						
Subperiod 1	422.62	198.60	29.43	9.21	39.32	3.195
Subperiod 2	420.29	191.17	29.78	9.64	39.79	3.089
First day	842.91	389.77	59.21	18.85	79.11	3.141
Subperiod 3	414.63	199.37	29.64	9.22	39.60	3.215
Subperiod 4	417.03	190.53	29.68	9.46	39.66	3.137
Second day	831.66	389.90	59.32	18.68	79.26	3.176
Average	837.29	389.84	59.27	18.77	79.19	3.158
Period IV.						
Steer A, Apr. 17 and 18:						
Subperiod 1	547.94	222.84	49.22	15.51	65.76	3.173
Subperiod 2	554.95	215.46	48.84	15.76	65.26	3.099
First day	1,102.89	438.30	98.06	31.27	131.02	3.136
Subperiod 3	556.31	229.72	49.31	15.81	65.88	3.119
Subperiod 4	552.24	221.33	48.51	15.68	64.81	3.094
Second day	1,108.55	451.05	97.82	31.49	130.69	3.106
Average	1,105.72	444.68	97.94	31.38	130.86	3.121
Steer B, Apr. 24 and 25:						
Subperiod 1	533.21	251.08	46.32	14.84	61.89	3.121
Subperiod 2	541.51	237.25	46.21	15.10	61.74	3.060
First day	1,074.72	488.33	92.53	29.94	123.63	3.091
Subperiod 3	531.81	271.22	45.00	14.42	60.12	3.121
Subperiod 4	538.96	280.41	46.63	14.94	62.30	3.121
Second day	1,070.77	551.63	91.63	29.36	122.42	3.121
Average	1,072.75	519.98	92.08	29.65	123.03	3.106

THE BALANCE OF MATTER.

From the data contained in the foregoing pages the following balances have been computed in the same manner as in the previous experiments.

TABLE 173.—*The balance of matter per day and head, 1907.*

Periods and components.	Dry matter.	Water.		Nitrogen.		Carbon.		Organic hydrogen.	
		Income.	Outgo.	Income.	Outgo.	Income.	Outgo.	Income.	Outgo.
Period I.									
Steer A:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Timothy hay	2,934.9	183		34.8		1,373.3		169.5	
Wheat bran	284.7			8.6		130.1		17.0	
Corn meal	837.1	327		14.4		388.1		52.3	
Linseed meal	874.4			50.6		418.1		52.9	
Water		12,535							
Feed residues			130						
Feces	1,546.2		7,306		33.1		750.0		87.7
Urine	446.0		[1]3,162		72.3		119.7		16.4
Brushings and hair	26.2		3,764		1.9		11.0		1.4
Methane	138.5						103.7		[2]34.6
Carbon dioxid	4,353.7						1,187.3		
Water vapor			3,764						
Gain or loss by body—									
Protein	6.6				1.1		3.5		.5
Fat	175.7						134.4		21.1
Water		147							
Organic hydrogen oxidized		1,170							130.0
		14,362	14,362	108.4	108.4	2,309.6	2,309.6	291.7	291.7
Steer B:									
Timothy hay	2,760.8	146		32.8		1,291.9		159.4	
Wheat bran	199.7			6.0		91.2		11.9	
Corn meal	586.0	226		10.0		271.7		36.6	
Linseed meal	612.1			35.4		292.7		37.0	
Water		7,175							
Feed residues			10						
Feces	1,410.9		4,973		24.5		682.3		81.1
Urine	399.1		[1]2,354		58.8		108.5		15.0
Brushings and hair	25.6				1.7		10.5		1.4
Methane	120.7						90.3		30.2
Carbon dioxid	3,923.6						1,070.0		
Water vapor			3,691						
Gain or loss by body—									
Protein	4.8			.8		2.5		.3	
Fat	15.2					11.6		1.8	
Water		2,407							
Organic hydrogen oxidized		1,074							119.3
		11,028	11,028	85.0	85.0	1,961.6	1,961.6	247.0	247.0
Period II.									
Steer A:									
Timothy hay	2,948.7	223		34.0		1,384.7		169.3	
Wheat bran	670.2			20.2		307.4		40.2	
Corn meal	1,998.8	862		34.7		922.3		123.0	
Linseed meal	2,090.0			121.9		1,009.4		124.3	
Water		17,445							
Feed residues			40						
Feces	2,204.6		11,306		55.0		1,049.3		124.4
Urine	767.4		7,158		150.3		189.5		34.1
Brushings and hair	26.2				1.9		11.0		1.4
Methane	201.3						150.7		50.2
Carbon dioxid	6,267.7						1,709.2		
Water vapor			7,110						
Gain or loss by body—									
Protein	21.6				3.6		11.3		1.5
Fat	657.3						502.8		78.9
Water		5,587							
Organic hydrogen oxidized		1,497							166.3
		25,614	25,614	210.8	210.8	3,623.8	3,623.8	456.8	456.8

[1] In absence of daily determination of nitrogen the urine solids computed in proportion to specific gravity.
[2] Computed.

TABLE 173.—*The balance of matter per day and head, 1907*—Continued.

Periods and components.	Dry matter.	Water.		Nitrogen.		Carbon.		Organic hydrogen.	
		Income.	Outgo.	Income.	Outgo.	Income.	Outgo.	Income.	Outgo.
Period II—Contd.									
Steer B:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Timothy hay	2,774.3	232		32.0		1,302.8		159.3	
Wheat bran	377.0			11.4		172.9		22.6	
Corn meal	1,124.3	483		19.5		518.8		69.2	
Linseed meal	1,175.6			68.5		567.8		69.9	
Water		12,845							
Feces	1,542.5		5,598		32.8		737.5		84.5
Urine	510.4		2,976		87.3		143.8		22.0
Brushings and hair	25.6				1.7		10.5		1.4
Methane	157.2						117.7		39.2
Carbon dioxid	4,899.0						1,336.0		
Water vapor			6,244						
Gain or loss by body—									
Protein	57.6				9.6		30.3		4.1
Fat	243.8						186.5		29.3
Water			6						
Organic hydrogen oxidized		1,264							140.5
		14,824	14,824	131.4	131.4	2,562.3	2,562.3	321.0	321.0
Period III.									
Steer A:									
Timothy hay	2,874.2	223		34.5		1,395.8		172.3	
Water		8,000							
Feed residues			23						
Feces	1,112.1		3,717		17.8		551.9		65.4
Urine	447.6		3,231		32.7		78.5		12.1
Brushings and hair	26.2				1.9		11.0		1.4
Methane	82.1						61.5		20.5
Carbon dioxid	3,095.0						844.0		
Water vapor			2,904						
Gain or loss by body—									
Protein	107.4			17.9		56.4		7.7	
Fat	123.8					94.7		14.8	
Water		793							
Organic hydrogen oxidized		859							95.4
		9,875	9,875	52.4	52.4	1,546.9	1,546.9	194.8	194.8
Steer B:									
Timothy hay	2,798.3	210		32.5		1,313.2		162.1	
Water		10,420							
Feces	1,062.4		3,452		16.2		527.9		60.8
Urine	364.1		1,731		28.5		75.9		11.2
Brushings and hair	25.6				1.7		10.5		1.4
Methane	79.2						59.3		19.8
Carbon dioxid	3,070.4						837.3		
Water vapor			3,509						
Gain or loss by body—									
Protein	83.4			13.9		43.8		6.0	
Fat	201.2					153.9		24.1	
Water			2,829						
Organic hydrogen oxidized		891							99.0
		11,521	11,521	46.4	46.4	1,510.9	1,510.9	192.2	192.2
Period IV.									
Steer A:									
Timothy hay	4,692.0	375							
Water		10,585		58.5		2,303.5		284.0	
Feed residues			83						
Feces	1,876.9		8,255		29.5		931.8		108.9
Urine	506.4		4,365		28.6		108.0		14.7
Brushings and hair	26.2				1.9		11.0		1.4
Methane	130.9						97.9		32.7

TABLE 173.—*The balance of matter per day and head, 1907*—Continued.

Periods and components.	Dry matter.	Water.		Nitrogen.		Carbon.		Organic hydrogen.	
		Income.	Outgo.	Income.	Outgo.	Income.	Outgo.	Income.	Outgo.
Period IV—Contd.									
Steer A—Continued.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Carbon dioxid	4,054.7						1,105.7		
Water vapor			4,002						
Gain or loss by body—									
Protein	9.0			1.5		4.7		.6	
Fat	70.3						53.8		8.4
Water		4,678							
Organic hydrogen oxidized		1,067							118.5
		16,705	16,705	60.0	60.0	2,308.2	2,308.2	284.6	284.6
Steer B:									
Timothy hay	4,629.8	337		55.4		2,180.0		268.8	
Water		13,725							
Feces	1,801.8		7,274		28.7		889.2		103.0
Urine	517.5		[1] 1,939		27.4		104.7		14.5
Brushings and hair	25.6				1.7		10.5		1.4
Methane	123.0						92.1		30.7
Carbon dioxid	3,933.8						1,072.8		
Water vapor			4,680						
Gain or loss by body—									
Protein	14.4			2.4		7.6		1.0	
Fat	23.9						18.3		2.9
Water			1,225						
Organic hydrogen oxidized		1,056							117.3
		15,118	15,118	57.8	57.8	2,187.6	2,187.6	269.8	269.8

[1] Only 1 day; was spilled on second day.

COMPUTED GAINS OR LOSSES OF LIVE WEIGHT.

The following tables show the computed changes of live weight in the calorimeter and the comparison of the computed and observed gain by the animals, computed in the same manner as in the experiments of 1905 and 1906:

TABLE 174.—*Computed daily gains or losses of live weight in the calorimeter, 1907.*

Components.	Period I.		Period II.		Period III.		Period IV.	
	Loss.	Gain.	Loss.	Gain.	Loss.	Gain.	Loss.	Gain.
Steer A:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Protein		7		22	107		9	
Fat		176		657	124			70
Water	147		5,587		793		4,678	
Correction for irregularity of excretion	27		54			43	62	
Balance	9			4,962		981		4,679
	183	183	5,641	5,641	1,024	1,024	4,749	4,749
Steer B:								
Protein	5			58	83		14	
Fat	15			244	201			24
Water	2,407			6		2,829		1,225
Correction for irregularity of excretion		160		99		38	12	
Balance		2,267	407		2,583		1,223	
	2,427	2,427	407	407	2,867	2,867	1,249	1,249

TABLE 175.—*Computed and observed gain in live weight, 1907.*

Period.	Computed.	Observed.
	Kilos.	*Kilos.*
Period I:		
Steer A	(1)	(1)
Steer B	− 6.1	− 5.4
Period II:		
Steer A	−13.4	−14.0
Steer B	− 1.5	− 1.2
Period III:		
Steer A	− 4.6	− 4.2
Steer B	3.6	4.2
Period IV:		
Steer A	−11.6	−13.6
Steer B	0.9	0.6

[1] Weights not recorded.

HEAT EMISSION AND HEAT PRODUCTION.

The following tables show the results of the determinations of the heat given off by the animals and likewise the heat production, computed by correcting for the gain or loss of matter by the body in the manner described in connection with the experiments of 1905:

TABLE 176.—*Heat emission, 1907.*

Periods.	Steer A.			Steer B.		
	By radiation.	As latent heat of water vapor.	Total.	By radiation.	As latent heat of water vapor.	Total.
Period I.						
First day—	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Subperiod 1	3,998.1	1,057.7	5,055.8	3,678.4	1,080.1	4,758.5
Subperiod 2	3,853.7	1,059.8	4,913.5	3,729.3	1,094.0	4,823.3
Total	7,851.8	2,117.5	9,969.3	7,407.7	2,174.1	9,581.8
Second day—						
Subperiod 3	4,130.2	1,181.6	5,311.8	3,717.6	1,085.3	4,802.9
Subperiod 4	3,947.1	1,119.9	5,067.0	3,710.9	1,073.6	4,784.5
Total	8,077.3	2,301.5	10,378.8	7,428.5	2,158.9	9,587.4
Daily average	7,964.6	2,209.5	10,174.1	7,418.1	2,166.5	9,584.6
Period II.						
First day—						
Subperiod 1	5,021.3	2,054.6	7,075.9	4,013.4	1,823.2	5,836.6
Subperiod 2	5,081.9	2,131.6	7,213.5	3,815.3	1,760.4	5,575.7
Total	10,103.2	4,186.2	14,289.4	7,828.7	3,583.6	11,412.3
Second day—						
Subperiod 3	5,351.9	2,188.9	7,540.8	3,957.5	1,899.9	5,857.4
Subperiod 4	4,691.4	1,972.4	6,663.8	3,918.4	1,846.8	5,765.2
Total	10,043.3	4,161.3	14,204.6	7,875.9	3,746.7	11,622.6
Daily average	10,073.3	4,173.8	14,247.0	7,852.3	3,665.2	11,517.5
Period III.						
First day—						
Subperiod 1	3,145.0	894.3	4,039.3	2,940.2	1,049.2	3,989.4
Subperiod 2	2,944.0	830.2	3,774.2	2,857.5	1,010.0	3,867.5
Total	6,089.0	1,724.5	7,813.5	5,797.7	2,059.2	7,856.9

TABLE 176.—*Heat emission, 1907*—Continued.

Periods.	Steer A.			Steer B.		
	By radiation.	As latent heat of water vapor.	Total.	By radiation.	As latent heat of water vapor.	Total.
Period III—Continued.						
Second day—	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Subperiod 3	3,086.5	843.5	3,930.0	2,899.0	1,053.3	3,952.3
Subperiod 4	2,997.6	841.0	3,838.6	2,866.3	1,006.5	3,872.8
Total	6,084.1	1,684.5	7,768.6	5,765.3	2,059.8	7,825.1
Daily average	6,086.6	1,704.5	7,791.1	5,781.5	2,059.5	7,841.0
Period IV.						
First day—						
Subperiod 1	3,573.2	1,177.3	4,750.5	3,461.4	1,326.5	4,787.9
Subperiod 2	3,638.3	1,138.3	4,776.6	3,337.7	1,253.3	4,591.0
Total	7,211.5	2,315.6	9,527.1	6,799.1	2,579.8	9,378.9
Second day—						
Subperiod 3	3,774.3	1,213.6	4,987.9	3,320.9	1,432.9	4,753.8
Subperiod 4	3,490.9	1,169.3	4,660.2	3,190.9	1,481.4	4,672.3
Total	7,265.2	2,382.9	9,648.1	6,511.8	2,914.3	9,426.1
Daily average	7,238.3	2,349.3	9,587.6	6,655.4	2,747.1	9,402.5

TABLE 177.—*Average heat production, 1907.*

Periods.	Steer A.			Steer B.		
	Heat emission.	Correction for gain by body.	Heat production.	Heat emission.	Correction for gain by body.	Heat production.
	Calories.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
I	10,174.1	− 0.6	10,173.5	9,584.6	−48.6	9,536.0
II	14,247.0	−107.5	14,139.5	11,517.5	3.8	11,521.3
III	7,791.1	− 18.2	7,772.9	7,841.0	54.0	7,895.0
IV	9,587.6	− 95.0	9,492.6	9,402.5	25.5	9,428.0

THE BALANCE OF ENERGY.

The energy balances, computed on the same basis as in the experiments of the previous two years, are as follows:

TABLE 178.—*The balance of energy per day and head, 1907.*

Periods and components.	Steer A.			Steer B.		
	Dry matter.	Energy.		Dry matter.	Energy.	
		Income.	Outgo.		Income.	Outgo.
Period I.	*Grams.*	*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
Timothy hay	2,934.9	13,187.7	....	2,760.8	12,405.4	....
Wheat bran	284.7	1,303.6	....	199.7	914.4	....
Corn meal	837.1	3,796.1	....	586.0	2,657.4	....
Linseed meal	874.4	4,198.0	....	612.1	2,938.7	....
Feces	1,546.2	....	7,359.3	1,410.9	....	6,767.7
Urine (corrected for nitrogen)	446.0	....	1,216.9	399.1	....	1,095.1
Methane	138.5	....	1,848.2	120.7	....	1,610.6
Metabolizable	....	....	12,061.0	....	....	9,442.5
Total	....	22,485.4	22,485.4	....	18,915.9	18,915.9

TABLE 178.—*The balance of energy per day and head, 1907*—Continued.

Periods and components.	Steer A.			Steer B.		
	Dry matter.	Energy.		Dry matter.	Energy.	
		Income.	Outgo.		Income.	Outgo.
Period I—Continued.	*Grams.*	*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
Metabolizable		12,061.0			9,442.5	
Heat			10,173.5			9,536.0
Brushings	26.2		123.0	25.6		117.9
Gain or loss by body:						
Protein (corrected for nitrogen)	6.6		29.4	4.8	21.4	
Fat	175.7		1,669.1	15.2	144.4	
Error			66.0		45.6	
Total		12,061.0	12,061.0		9,653.9	9,653.9
Period II.						
Timothy hay	2,948.7	13,261.8		2,774.3	12,477.4	
Wheat bran	670.2	3,071.9		377.0	1,728.0	
Corn meal	1,998.8	9,049.8		1,124.3	5,090.3	
Linseed meal	2,090.0	10,188.1		1,175.6	5,730.7	
Feces	2,204.6		10,340.7	1,542.5		7,371.1
Urine (corrected for nitrogen)	764.4		1,991.4	510.4		1,536.4
Methane			2,686.2	157.2		2,097.8
Metabolizable			20,553.3			14,021.1
Total		35,571.6	35,571.6		25,026.4	25,026.4
Metabolizable		20,553.3			14,021.1	
Heat			14,139.5			11,521.3
Brushings	26.2		123.0	25.6		117.9
Gain or loss by body:						
Protein (corrected for nitrogen)	21.6		96.3	57.6		256.8
Fat	657.3		6,244.2	243.8		2,316.2
Error		49.7			191.1	
Total		20,603.0	20,603.0		14,212.2	14,212.2
Period III.						
Timothy hay	2,974.2	13,411.6		2,798.3	12,618.4	
Feces	1,112.1		5,475.1	1,062.4		5,247.0
Urine (corrected for nitrogen)	447.6		606.4	364.1		627.3
Methane	82.1		1,095.6	79.2		1,056.8
Metabolizable			6,234.5			5,687.3
Total		13,411.6	13,411.6		12,618.4	12,618.4
Metabolizable		6,234.5				
Heat			7,772.9		5,687.3	7,895.0
Brushings	26.2		123.0	25.6		117.9
Loss by body:						
Protein (corrected for nitrogen)	107.4	478.8		83.4	371.7	
Fat	123.8	1,176.0		201.2	1,911.4	
Error		6.6			42.5	
Total		7,895.9	7,895.9		8,012.9	8,012.9
Period IV.						
Timothy hay	4,892.0	22,115.8		4,629.8	20,930.4	
Feces	1,876.9		9,236.8	1,801.8		8,879.1
Urine (corrected for nitrogen)	506.4		975.1	517.6		964.5
Methane	130.9		1,746.7	123.0		1,641.3
Metabolizable			10,157.2			9,445.5
Total		22,115.8	22,115.8		20,930.4	20,930.4
Metabolizable		10,157.2			9,445.5	
Heat			9,492.6			9,428.0
Brushings	26.2		123.0	25.6		117.9
Gain or loss by body:						
Protein (corrected for nitrogen)	9.0	40.1		14.4	64.1	
Fat	70.3		667.8	23.9		227.1
Error		86.1			263.4	
Total		10,283.4	10,283.4		9,773.0	9,773.0

In general, there is an excellent agreement between the observed heat production and that computed from the carbon and nitrogen balance in the customary way, the principal exception being with Steer B in Period IV.

TABLE 179.—*Observed and computed heat production, 1907.*

Periods.	Steer A.				Steer B.			
	Observed.	Computed.	Error.	Computed ÷observed.	Observed.	Computed.	Error.	Computed ÷observed.
	Calories.	*Calories.*	*Calories.*	*Per cent.*	*Calories.*	*Calories.*	*Calories.*	*Per cent.*
I	10,173.5	10,239.5	+66.0	100.6	9,536.0	9,490.4	− 45.6	99.5
II	14,139.5	14,089.8	−49.7	99.6	11,521.3	11,330.2	−191.1	98.3
III	7,772.9	7,766.3	− 6.6	99.9	7,895.0	7,852.5	− 42.5	99.5
IV	9,492.6	9,406.5	−86.1	99.1	9,428.0	9,164.6	−263.4	97.2

METABOLIZABLE ENERGY.

The results for the metabolizable energy of the timothy hay and of the mixed grain are contained in the following tables, being stated in the same form as in the experiments of the two previous years.

TABLE 180.—*Percentage distribution of energy of timothy hay, 1907.*

	Total energy.			Energy of digested matter.		
	Period III.	Period IV.	True average.	Period III.	Period IV.	True average.
Steer A.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
In feces	40.82	41.77	41.41	....	....	....
In urine	4.52	4.40	4.45	7.64	7.56	7.60
In methane	8.17	7.90	8.00	13.81	13.57	13.65
Metabolizable	46.49	45.93	46.14	78.55	78.87	78.75
	100.00	100.00	100.00	100.00	100.00	100.00
Steer B.						
In feces	41.58	42.42	42.11	....	....	....
In urine	4.97	4.61	4.74	8.51	8.01	8.19
In methane	8.38	7.84	8.04	14.34	13.61	13.89
Metabolizable	45.07	45.13	45.11	77.15	78.38	77.92
	100.00	100.00	100.00	100.00	100.00	100.00

TABLE 181.—*Metabolizable energy per gram of organic matter of timothy hay, 1907.*

Period.	Organic matter.		Metabolizable energy.		
	Total.	Digested.	Total.	Per gram total organic matter.	Per gram digested organic matter.
Steer A.	*Grams.*	*Grams.*	*Calories.*	*Calories.*	*Calories.*
III	2,826.1	1,803.3	6,234.5	2.206	3.457
IV	4,641.8	2,917.4	10,157.2	2.188	3.482
Totals and averages	7,467.9	4,720.7	16,391.7	2.195	3.472
Steer B.					
III	2,659.0	1,683.7	5,687.3	2.139	3.378
IV	4,393.0	2,733.0	9,445.5	2.150	3.456
Totals and averages	7,052.0	4,416.7	15,132.8	1.146	3.426

TABLE 182.—*Percentage distribution of energy of mixed grains, 1907.*

	Organic matter.		Total energy.	Energy of excreta.			Metabolizable energy.
	Total.	Digestible.		Feces.	Urine (corrected).	Methane.	
Steer A.							
Period I:	*Grams.*	*Grams.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
In total ration	4,701.3	3,304.7	22,485.4	7,359.3	1,216.9	1,848.2	12,061.0
In hay	2,788.9	1,762.9	13,187.7	5,461.0	586.9	1,055.0	6,084.8
In grain	1,912.4	1,541.8	9,297.7	1,898.3	630.0	793.2	5,976.2
Per cent of total energy			100.00	20.42	6.78	8.52	64.28
Per cent of digested energy					8.52	10.70	80.78
Period II:							
In total ration	7,363.7	5,388.1	35,571.6	10,340.7	1,991.4	2,686.2	20,553.3
In hay	2,802.6	1,771.5	13,261.8	5,491.7	590.2	1,060.9	6,119.0
In grain	4,561.1	3,616.6	22,309.8	4,849.0	1,401.2	1,625.3	14,434.3
Per cent of total energy			100.00	21.73	6.28	7.29	64.70
Per cent of digested energy					8.02	9.31	82.67
Steer B.							
Period I:							
In total ration	3,962.6	2,687.6	18,915.9	6,767.7	1,095.1	1,610.6	9,442.5
In hay	2,623.5	1,643.1	12,405.4	5,223.9	588.0	997.4	5,596.1
In grain	1,339.1	1,044.5	6,510.5	1,543.8	507.1	613.2	3,846.4
Per cent of total energy			100.00	23.71	7.79	9.42	59.08
Per cent of digested energy					10.21	12.35	77.44
Period II:							
In total ration	5,202.3	3,814.2	25,026.4	7,371.1	1,536.4	2,097.8	14,021.1
In hay	2,636.8	1,651.4	12,477.4	5,254.2	591.4	1,003.2	5,628.6
In grain	2,565.5	2,162.8	12,549.0	2,116.9	945.0	1,094.6	8,392.5
Per cent of total energy			100.00	16.87	7.53	8.72	66.88
Per cent of digested energy					9.06	10.48	80.46

TABLE 183.—*Metabolizable energy per gram organic matter of mixed grain, 1907.*

Periods.	Organic matter.		Metabolizable energy.		
	Total.	Digested.	Total.	Per gram total organic matter.	Per gram digested organic matter.
Steer A.	*Grams.*	*Grams.*	*Calories.*	*Calories.*	*Calories.*
I	1,912.4	1,541.8	5,976.2	3.125	3.876
II	4,561.1	3,616.6	14,434.3	3.165	3.991
Average				3.145	
Steer B.					
I	1,339.1	1,044.5	3,846.4	2.872	3.683
II	2,565.5	2,162.8	8,392.5	3.271	3.880
Average				3.072	

CORRECTION OF HEAT PRODUCTION FOR STANDING AND LYING.

The following tables afford the data necessary for correcting the observed heat production for variations in the proportion of time spent standing and lying:

TABLE 184.—*Heat emitted by radiation and conduction during periods of standing and lying, 1907.*

Periods.	Standing.		Lying.	
	Elapsed time.	Total heat.	Elapsed time.	Total heat.
Period I.				
Steer A:	*Minutes.*	*Calories.*	*Minutes.*	*Calories.*
6.00 p. m. to 7.00 p. m.	60	314.14		
7.20 p. m. to 9.08 p. m.	108	637.21		
9.48 p. m. to 12.40 a. m.			172	841.88
1.00 a. m. to 1.20 a. m.	20	125.72		
1.40 a. m. to 2.12 a. m.	32	212.22		
3.24 a. m. to 4.12 a. m.			48	230.09
4.36 a. m. to 6.00 a. m.	84	517.60		
6.00 a. m. to 7.40 a. m.	100	573.14		
8.04 a. m. to 8.56 a. m.			52	229.91
9.16 a. m. to 9.40 a. m.	24	151.41		
10.00 a. m. to 12.04 p. m.			124	564.44
12.24 p. m. to 12.56 p. m.	32	211.85		
1.24 p. m. to 2.44 p. m.			80	350.30
3.04 p. m. to 3.44 p. m.	40	259.28		
4.08 p. m. to 4.20 p. m.			12	54.49
4.40 p. m. to 6.00 p. m.	80	483.20		
6.00 p. m. to 8.24 p. m.	144	887.25		
8.52 p. m. to 9.16 p. m.	24	156.98		
9.40 p. m. to 10.32 p. m.			52	261.76
11.20 p. m. to 1.16 a. m.			116	600.74
1.56 a. m. to 4.08 a. m.			132	676.36
4.28 a. m. to 6.00 a. m.	92	582.27		
6.00 a. m. to 7.52 a. m.	112	661.39		
8.16 a. m. to 9.56 a. m.			100	441.28
10.16 a. m. to 10.52 a. m.	36	239.38		
11.16 a. m. to 12.36 p. m.			80	372.09
12.56 p. m. to 1.20 p. m.	24	159.08		
1.44 p. m. to 3.32 p. m.			108	503.16
3.52 p. m. to 6.00 p. m.	128	795.35		
Totals	1,140	6,967.47	1,076	5,126.50
Corrections for capacity, feed, water, excreta, etc.		+63.97		−72.33
		7,031.44		5,054.17
Heat per minute		6.1679		4.6972
Steer B:				
6.20 p. m. to 7.20 p. m.	60	333.30		
7.56 p. m. to 12.08 a. m.			252	1,139.94
12.44 a. m. to 2.04 a. m.	80	525.91		
2.28 a. m. to 4.40 a. m.			132	589.50
5.08 a. m. to 6.00 a. m.	52	317.07		
6.00 a. m. to 7.56 a. m.	116	664.87		
8.20 a. m. to 10.24 a. m.			124	467.31
10.44 a. m. to 11.105 a. m.	26.5	171.75		
11.15 a. m. to 12.28 p. m.	77.5	496.54		
12.52 p. m. to 2.20 p. m.			88	346.51
2.40 p. m. to 6.00 p. m.	200	1,131.33		
6.00 p. m. to 8.08 p. m.	128	757.06		
8.32 p. m. to 10.12 p. m.			100	441.98
10.32 p. m. to 12.24 a. m.	112	715.39		
12.48 a. m. to 5.24 a. m.			276	1,221.74
5.44 a. m. to 6.00 a. m.	16	99.93		
6.00 a. m. to 9.04 a. m.	184	1,069.85		
9.28 a. m. to 12.56 p. m.			208	869.01
1.20 p. m. to 3.08 p. m.			108	481.86
3.28 p. m. to 3.58 p. m.	30	178.22		
3.58 p. m. to 4.385 p. m.	40.5	248.98		
4.38 p. m. to 6.00 p. m.	81.5	486.07		
Totals	1,204	7,196.27	1,288	5,557.85
Corrections for capacity, feed, water, excreta, etc.		+8.77		−41.42
		7,205.04		5,516.43
Heat per minute		5.9843		4.2829

TABLE 184.—*Heat emitted by radiation and conduction during periods of standing and lying, 1907*—Continued.

Periods.	Standing.		Lying.	
	Elapsed time.	Total heat.	Elapsed time.	Total heat.
Period II.				
Steer A:	*Minutes.*	*Calories.*	*Minutes.*	*Calories.*
6.00 p. m. to 7.16 p. m.	76	536.73		
7.40 p. m. to 8.04 p. m.			24	135.95
9.24 p. m. to 11.00 p. m.	96	853.67		
12.12 a. m. to 1.24 a. m.	72	598.91		
1.48 a. m. to 4.40 a. m.			172	916.21
5.12 a. m. to 6.00 a. m.	48	374.87		
6.00 a. m. to 6.225 a. m.	22.5	175.31		
6.22 a. m. to 7.20 a. m.	57.5	433.01		
7.40 a. m. to 8.03 a. m.			23	128.35
8.03 a. m. to 8.32 a. m.			29	149.60
9.28 a. m. to 10.08 a. m.			40	211.64
11.40 a. m. to 12.28 p. m.			48	300.34
12.48 p. m. to 1.12 p. m.	24	209.71		
1.28 p. m. to 2.28 p. m.			60	340.32
2.48 p. m. to 3.16 p. m.	28	238.24		
3.44 p. m. to 6.00 p. m.	136	1,014.72		
6.00 p. m. to 10.48 p. m.	288	2,273.52		
11.08 p. m. to 11.24 p. m.			16	91.08
11.48 p. m. to 12.28 a. m.	40	328.69		
12.44 a. m. to 1.44 a. m.	60	470.31		
4.40 a. m. to 6.00 a. m.	80	526.81		
6.00 a. m. to 7.285 a. m.	88.5	606.22		
7.285 a. m. to 8.08 a. m.	39.5	263.62		
8.40 a. m. to 9.30 a. m.			50	264.66
9.30 a. m. to 10.12 a. m.			42	202.09
10.32 a. m. to 11.08 a. m.	36	291.42		
11.32 a. m. to 12.16 p. m.			44	226.28
12.40 p. m. to 3.12 p. m.	152	1,191.70		
3.32 p. m. to 5.00 p. m.			88	404.92
5.20 p. m. to 6.00 p. m.	40	301.63		
Totals	1,384	10,689.09	636	3,371.44
Corrections for capacity, feed, water, excreta, etc.		+104.54		−31.93
		10,793.63		3,339.51
Heat per minute		7.7989		5.2508
Steer B:				
6.00 p. m. to 7.24 p. m.	84	569.87		
8.16 p. m. to 8.40 p. m.	24	168.39		
9.00 p. m. to 9.217 p. m.			21.7	99.83
9.217 p. m. to 9.56 p. m.			34.3	140.09
10.16 p. m. to 11.00 p. m.	44	305.23		
11.24 p. m. to 12.12 a. m.			48	201.80
12.32 a. m. to 12.56 a. m.	24	177.55		
1.40 a. m. to 2.36 a. m.			56	255.47
2.56 a. m. to 3.12 a. m.	16	115.34		
3.36 a. m. to 4.44 a. m.			68	307.07
5.04 a. m. to 6.00 a. m.	56	443.03		
6.00 a. m. to 7.32 a. m.	92	552.49		
7.56 a. m. to 9.16 a. m.			80	323.00
9.36 a. m. to 10.52 a. m.	76	541.00		
11.44 a. m. to 12.44 p. m.			60	243.13
1.04 p. m. to 1.20 p. m.	16	115.71		
1.44 p. m. to 3.04 p. m.			80	349.65
3.56 p. m. to 5.08 p. m.			72	277.72
5.28 p. m. to 6.00 p. m.	32	222.73		
6.00 p. m. to 7.20 p. m.	80	529.05		
7.44 p. m. to 8.36 p. m.			52	220.61
8.56 p. m. to 9.04 p. m.			8	41.77
9.24 p. m. to 9.40 p. m.			16	88.05
10.00 p. m. to 11.44 p. m.	104	718.15		
12.32 a. m. to 1.04 a. m.			32	127.65
1.28 a. m. to 4.20 a. m.			172	790.97
4.40 a. m. to 6.00 a. m.	80	530.58		
6.00 a. m. to 6.34 a. m.	34	216.99		
6.34 a. m. to 8.08 a. m.	94	548.19		
8.32 a. m. to 11.56 a. m.			204	888.34
12.16 p. m. to 1.52 p. m.	96	679.84		
2.16 p. m. to 4.00 p. m.			104	459.45
4.20 p. m. to 6.00 p. m.	100	625.25		
Totals	1,052	7,059.39	1,108	4,814.60
Corrections for capacity, water, feed, excreta, etc.		−103.57		+66.30
		6,955.82		4,880.90
Heat per minute		6.6120		4.4051

TABLE 184.—*Heat emitted by radiation and conduction during periods of standing and lying, 1907*—Continued.

Periods.	Standing.		Lying.	
	Elapsed time.	Total heat.	Elapsed time.	Total heat.
Period III.				
Steer A:	*Minutes.*	*Calories.*	*Minutes.*	*Calories.*
6.00 p. m. to 7.02 p. m.	62	256.20		
7.02 p. m. to 7.505 p. m.	48.5	212.71		
7.505 p. m. to 8.02 p. m.	12.2	53.75		
8.02 p. m. to 8.075 p. m.	4.8	22.37		
8.075 p. m. to 8.505 p. m.	43.0	206.33		
8.505 p. m. to 11.24 p. m.	153.5	792.00		
11.48 p. m. to 12.14 a. m.			26	93.07
12.14 a. m. to 3.56 a. m.			222	821.08
4.16 a. m. to 6.00 a. m.	104	531.62		
6.00 a. m. to 8.32 a. m.	152	706.34		
8.56 a. m. to 12.12 p. m.			196	648.45
1.24 p. m. to 3.60 p. m.			96	366.00
3.20 p. m. to 6.00 p. m.	160	770.27		
6.00 p. m. to 7.36 p. m.	96	459.20		
8.00 p. m. to 11.00 p. m.			180	650.60
11.20 p. m. to 11.40 p. m.	20	109.79		
12.04 a. m. to 1.04 a. m.			60	241.57
1.24 a. m. to 1.48 a. m.	24	137.05		
2.12 a. m. to 4.44 a. m.			152	569.40
5.04 a. m. to 6.00 a. m.	56	292.54		
6.00 a. m. to 7.36 a. m.	96	454.25		
8.40 a. m. to 10.12 a. m.			92	308.70
10.32 a. m. to 11.04 a. m.	32	162.56		
11.28 a. m. to 1.08 p. m.			100	368.39
1.28 p. m. to 1.56 p. m.	28	139.00		
2.20 p. m. to 4.04 p. m.			104	374.88
4.24 p. m. to 5.07 p. m.	43	215.00		
5.07 p. m. to 6.00 p. m.	53	269.77		
Totals	1,188	5,790.75	1,228	4,442.14
Corrections for capacity, water, feed, excreta, etc.		−47.9		−33.64
		5,742.85		4,408.50
Heat per minute		4.8340		3.5900
Steer B:				
6.00 p. m. to 8.08 p. m.	128	602.47		
8.32 p. m. to 10.12 p. m.			100	331.24
10.32 p. m. to 11.24 p. m.	52	279.14		
11.52 p. m. to 3.12 a. m.			200	729.79
3.32 a. m. to 4.16 a. m.	44	227.16		
4.40 a. m. to 5.40 a. m.			60	209.76
6.00 a. m. to 8.44 a. m.	164	742.63		
9.08 a. m. to 11.56 a. m.			168	506.33
1.24 p. m. to 4.04 p. m.			160	571.79
4.24 p. m. to 6.00 p. m.	96	474.01		
6.00 p. m. to 7.12 p. m.	72	327.70		
7.36 p. m. to 10.32 p. m.			176	634.84
11.28 p. m. to 1.40 a. m.			132	491.45
2.16 a. m. to 4.00 a. m.			104	404.38
4.12 a. m. to 4.30 a. m.	18	89.43		
5.20 a. m. to 5.265 a. m.	6.5	35.44		
5.265 a. m. to 6.00 a. m.	33.5	176.50		
6.00 a. m. to 7.40 a. m.	100	476.87		
8.04 a. m. to 10.12 a. m.			128	426.33
10.32 a. m. to 10.52 a. m.	20	100.96		
11.16 a. m. to 1.08 p. m.			112	384.03
1.28 p. m. to 1.48 p. m.	20	100.05		
2.12 p. m. to 3.40 p. m.			88	299.31
4.00 p. m. to 4.245 p. m.	24.5	124.27		
4.245 p. m. to 4.40 p. m.	15.5	77.87		
5.04 p. m. to 5.20 p. m.			16	52.14
5.40 p. m. to 6.00 p. m.	20	98.31		
Totals	814	3,932.80	1,444	5,041.39
Corrections for capacity, water, feed, excreta, etc.		−93.03		−53.94
		3,839.77		4,987.45
Heat per minute		4.7172		3.4539

TABLE 184.—*Heat emitted by radiation and conduction during periods of standing and lying, 1907*—Continued.

Periods.	Standing.		Lying.	
	Elapsed. time.	Total heat.	Elapsed time.	Total heat.
Period IV.				
Steer A:	*Minutes.*	*Calories.*	*Minutes.*	*Calories.*
6.00 p. m. to 7.36 p. m.	96	526.62		
8.28 p. m. to 10.28 p. m.	120	711.38		
10.52 p. m. to 2.08 a. m.			196	818.42
2.48 a. m. to 4.36 a. m.			108	475.47
4.56 a. m. to 6.00 a. m.	64	377.00		
6.00 a. m. to 7.44 a. m.	104	582.10		
8.08 a. m. to 8.28 a. m.			20	80.83
8.48 a. m. to 9.16 a. m.	28	160.18		
9.40 a. m. to 10.24 a. m.			44	175.66
10.44 a. m. to 12.32 p. m.	108	631.48		
12.56 p. m. to 3.20 p. m.			144	571.97
3.40 p. m. to 6.00 p. m.	140	785.35		
6.00 p. m. to 7.48 p. m.	108	607.77		
8.12 p. m. to 8.52 p. m.			40	185.18
9.12 p. m. to 9.52 p. m.	40	254.71		
10.16 p. m. to 11.40 p. m.			84	392.41
12.00 a. m. to 1.04 a. m.	64	407.00		
1.28 a. m. to 3.56 a. m.			148	632.39
4.16 a. m. to 4.575 a. m.	41.5	253.22		
4.575 a. m. to 6.00 a. m.	62.5	361.57		
6.00 a. m. to 7.12 a. m.	72	403.18		
7.36 a. m. to 8.28 a. m.			52	211.28
9.16 a. m. to 9.36 a. m.			20	91.52
9.56 a. m. to 10.12 a. m.	16	99.89		
10.40 a. m. to 1.48 p. m.			188	802.50
2.36 p. m. to 4.04 p. m.			88	386.57
4.24 p. m. to 6.00 p. m.	96	563.71		
Totals	1,160	6 725.10	1,132	4,824.20
Corrections for capacity, water, feed, excreta, etc		−5.94		−45.09
		6,719.16		4,779.11
Heat per minute		5.7924		4.2218
Steer B:				
6.00 p. m. to 6.48 p. m.	48	266.10		
7.12 p. m. to 8.00 p. m.			48	188.52
8.20 p. m. to 8.52 p. m.	32	191.30		
9.16 p. m. to 10.44 p. m.			88	376.85
11.04 p. m. to 11.36 p. m.	32	199.52		
12.04 a. m. to 12.44 a. m.			40	160.31
1.04 a. m. to 1.28 a. m.	24	148.10		
2.00 a. m. to 4.28 a. m.			148	600.22
4.48 a. m. to 6.00 a. m.	72	417.37		
6.00 a. m. to 7.28 a. m.	88	471.32		
7.28 a. m. to 8.56 a. m.			64	226.09
9.16 a. m. to 10.16 a. m.	60	334.36		
10.44 a. m. to 11.28 a. m.			44	159.96
11.48 a. m. to 12.36 p. m.	48	281.00		
1.00 p. m. to 3.04 p. m.			124	490.71
3.34 p. m. to 4.12 p. m.	48	285.75		
4.36 p. m. to 5.36 p. m.			60	233.27
6.00 p. m. to 7.16 p. m.	76	417.20		
7.40 p. m. to 8.36 p. m.			56	223.26
8.56 p. m. to 9.28 p. m.	32	196.24		
9.52 p. m. to 11.12 p. m.			80	323.61
11.32 p. m. to 12.24 a. m.	52	308.21		
12.48 a. m. to 4.20 a. m.			212	838.73
6.00 a. m. to 7.08 a. m.	68	364.17		
7.32 a. m. to 10.04 a. m.			152	540.32
10.24 a. m. to 11.24 a. m.	60	330.47		
11.48 a. m. to 12.12 p. m.			24	101.75
12.32 p. m. to 12.56 p. m.	24	135.79		
1.20 p. m. to 2.16 p. m.			56	216.19
2.40 p. m. to 4.04 p. m.			84	313.92
4.24 p. m. to 6.00 p. m.	96	486.89		
Totals	860	4,833.79	1,280	4,993.72
Corrections for capacity, water, feed, excreta, etc		−7.08		−86.64
		4,826.71		4,907.08
Heat per minute		5.6125		3.8337

TABLE 185.—*Average heat per minute emitted by radiation and conduction, 1907.*

Periods.	Standing.	Lying.
Steer A.	*Calories.*	*Calories.*
I	6.1679	4.6972
II	7.7989	5.2508
III	4.8340	3.5900
IV	5.7924	4.2218
Steer B.		
I	5.9843	4.2829
II	6.6120	4.4051
III	4.7172	3.4539
IV	5.6125	3.8337

The following table shows the total heat emission and production corrected to 12 hours standing, as in the previous experiments.

TABLE 186.—*Heat production corrected to 12 hours standing, 1907.*

Periods.	Steer A.			Steer B.		
	Total heat emission.	Correction for gain of matter by body.	Total heat production.	Total heat emission.	Correction for gain of matter by body.	Total heat production.
	Calories.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
I	10,164.3	− 0.6	10,163.7	9,648.8	−48.6	9,600.2
II	13,482.7	−107.5	13,375.2	11,716.0	+ 3.8	11,719.8
III	7,809.1	− 18.2	7,790.9	8,009.9	+54.0	8,063.9
IV	9,618.4	− 95.0	9,523.4	9,786.0	+25.5	9,811.5

AVAILABILITY OF METABOLIZABLE ENERGY.

The following tables show the gain of energy by the animals, as computed from the corrected heat production of Table 186, and the average live weights of the animals for the last six days of each period.

TABLE 187.—*Corrected gains of energy by the animals, 1907.*

	Steer A.		Steer B.	
	Income.	Outgo.	Income.	Outgo.
Period I:	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Metabolizable	12,061.0		9,442.5	
Brushings		123.0		117.9
Heat (from Table 186)		10,163.7		9,600.2
Gain		1,774.3	275.6	
	12,061.0	12,061.0	9,718.1	9,718.1
Period II:				
Metabolizable	20,553.3		14,021.1	
Brushings		123.0		117.9
Heat (from Table 186)		13,375.2		11,719.8
Gain		7,055.1		2,183.4
	20,553.3	20,553.3	14,021.1	14,021.1
Period III:				
Metabolizable	6,234.5		5,687.3	
Brushings		123.0		117.9
Heat (from Table 186)		7,790.9		8,063.9
Gain	1,679.4		2,494.5	
	7,913.9	7,913.9	8,181.8	8,181.8
Period IV:				
Metabolizable	10,157.2		9,445.5	
Brushings		123.0		117.9
Heat (from Table 186)		9,523.4		9,811.5
Gain		510.8	483.9	
	10,157.2	10,157.2	9,929.4	9,929.4

TABLE 188.—*Average live weights for last six days of each period, 1907.*

Periods.	Steer A.	Steer B.
	Kilos.	*Kilos.*
I	498.6	372.6
II	518.7	386.4
III	507.3	373.7
IV	514.2	384.9

TIMOTHY HAY.

A comparison of Periods III and IV in the same manner as in previous experiments gives the following results for the availability of the metabolizable energy of the timothy hay:

TABLE 189.—*Availability of metabolizable energy of timothy hay, 1907.*

Steer A—Periods IV-III.	Steer B—Periods IV-III.
$n=\left(\frac{507.3}{514.2}\right)^{2/3}=0.9910.$	$n=\left(\frac{373.7}{384.9}\right)^{2/3}=0.9806$
$x_3=6,234.5 \quad y_3=-1,679.4$	$x_3=5,687.3 \quad y_3=-2,494.5$
$x_4=10,157.2 \quad y_4=510.8$	$x_4=9,445.5 \quad y_4=-483.9$
$m=\frac{-1,679.4-(0.991\times 510.8)}{6,234.5-(0.991\times 10,157.2)}=57.05$ per cent.	$m=\frac{-2,494.5-(0.9806\times -483.9)}{5,687.3-(0.9806\times 9,445.5)}=56.50$ per cent.

MIXED GRAIN.

Correcting the results of Periods I and II for the differences in the amounts of hay consumed as compared with the basal ration of Period III, the availability of the metabolizable energy of the mixed grain may be computed as follows:

TABLE 190.—*Correction for differences in amounts of hay eaten, 1907.*

Periods.	Steer A.			Steer B.		
	Organic matter of hay.	Metabolizable energy of total ration.	Gain by animal.	Organic matter of hay.	Metabolizable energy of total ration.	Gain by animal.
	Grams.	*Calories.*	*Calories.*	*Grams.*	*Calories.*	*Calories.*
Period III	2,826.1			2,659.0		
Period I	2,788.9	12,061.0	1,774.3	2,623.5	9,442.5	−275.6
Correction	37.2	81.7	46.6	35.5	76.2	43.1
Period I, corrected	2,826.1	12,142.7	1,820.9	2,659.0	9,518.7	−232.5
Period III	2,826.1			2,659.0		
Period II	2,802.6	20,553.3	7,055.1	2,636.8	14,021.1	2,183.4
Correction	23.5	51.6	29.4	22.2	47.6	26.9
Period II, corrected	2,826.1	20,604.9	7,084.5	2,659.0	14,068.7	2,210.3

TABLE 191.—*Availability of metabolizable energy of mixed grain.*

Steer A—Periods I-III.	Steer B—Periods I-III.
$n=\left(\frac{507.3}{498.6}\right)^{2/3}=1.012$	$n=\left(\frac{373.7}{372.6}\right)^{2/3}=1.002$
$x_3=6,234.5$ $y_3=-1,679.4$	$x_3=5,687.3$ $y_3=-2,494.5$
$x_1=12,142.7$ $y_1=1,820.9$	$x_1=9,518.7$ $y_1=-232.5$
$m=\frac{-1,679.4-(1.012\times 1,820.9)}{6,234.5-(1.012\times 12,142.7)}=58.18$ per cent.	$m=\frac{-6,494.5-(1.002\times -232.5)}{5,687.3-(1.002\times 9,518.7)}=58.73$ per cent.

Steer A—Periods II-III.	Steer B—Periods II-III.
$n=\left(\frac{507.3}{518.7}\right)^{2/3}=0.9854$	$n=\left(\frac{373.7}{386.4}\right)^{2/3}=0.9777$
$x_3=6,234.5$ $y_3=-1,679.4$	$x_3=5,687.3$ $y_3=-2,494.5$
$x_2=20,604.9$ $y_2=7,084.5$	$x_2=14,068.7$ $y_2=2,210.3$
$m=\frac{-1,679.4-(0.9854\times 7,084.5)}{6,234.5-(0.9854\times 20,604.9)}=61.55$ per cent.	$m=\frac{-2,494.5-(0.9777\times 2,210.3)}{5,687.3-(0.9777\times 14,068.7)}=57.71$ per cent.

Steer A—Periods II-I.	Steer B—Periods II-I.
$n=\left(\frac{498.6}{518.7}\right)^{2/3}=0.9738$	$n=\left(\frac{372.6}{386.4}\right)^{2/3}=0.9757$
$x_1=12,142.7$ $y_1=1,820.9$	$x_1=9,518.7$ $y_1=-232.5$
$x_2=20,604.9$ $y_2=7,084.5$	$x_2=14,068.7$ $y_2=2,210.3$
$m=\frac{1,820.9-(0.9738\times 7,084.5)}{12,142.7-(0.9738\times 20,604.9)}=64.10$ per cent.	$m=\frac{-232.5-(0.9757\times 2,210.3)}{9,518.7-(0.9757\times 14,068.7)}=56.74$ per cent.

The results are summarized in the following table and represented graphically in figure 9:

TABLE 192.—*Summary of percentage availability of metabolizable energy.*

Feed.	Steer A.	Steer B.
Timothy hay	57.05	56.50
Mixed grain:		
Periods I-III	58.18	58.73
Periods II-I	64.10	56.74
Periods II-III	61.55	57.71

RECALCULATION OF RESPIRATION CALORIMETER EXPERIMENTS OF 1903.

As noted in Part I of the present bulletin, the results regarding availability reported in Bulletin 74 of this Bureau were computed without the correction to a uniform time of standing and lying which has been applied to the later experiments. The difference in this respect is sufficient to materially alter the teaching of the experiments, hence a recalculation of the results as published in Bulletin 74 has been made, which is tabulated below.

As a basis for the computation, the heat emission per day, as formerly reported, is retabulated so as to show the percentage of heat given off as latent heat of water vapor.

TABLE 193.—*Heat emission per day, 1903.*

Periods.	Radiation and conduction.	In water vapor.	Total.	Per cent in water vapor.
	Calories.	*Calories.*	*Calories.*	*Per cent.*
I	8,933.43	2,721.95	11,655.38	23.35
II	7,477.55	2,608.97	10,086.52	25.87
III	7,723.05	2,807.33	10,530.38	26.66
IV	10,436.31	4,180.87	14,617.18	28.60

The average time spent standing during the four periods was 925.75 minutes per day. In order to make the corrections as small as possible, the results have been computed to a uniform basis of 925 minutes standing. The correction computed in the same manner as in the foregoing experiments, the corrected amount of heat given off by radiation and conduction, and the corrected heat emission are shown in the following tables:

TABLE 194.—*Heat emission per day corrected to 925 minutes standing, 1903.*

Periods.	Correction.	Corrected radiation and conduction.	Corrected total.
	Calories.	*Calories.*	*Calories.*
I	+ 105.96	9,039.39	11,793.1
II	+ 34.12	7,511.67	10,133.1
III	+ 270.54	7,993.59	10,899.4
IV	+ 551.03	9,885.28	13,844.9

TABLE 195.—*Heat production corrected to 925 minutes standing, 1903.*

Periods.	Corrected emission.	Correction for water balance.	Corrected heat production.
	Calories.	*Calories.*	*Calories.*
I	11,793.1	− 126.3	11,666.8
II	10,133.1	+ 36.6	10,169.7
III	10,899.4	+ 9.8	10,909.2
IV	13,844.9	+ 34.7	13,879.6

TABLE 196.—*Corrected gains of energy by animals, 1903.*

	Income.	Outgo.
Period I:	*Calories.*	*Calories.*
Metabolizable	8,449	....
Brushings	....	81
Heat	....	11,667
Gain	3,299	....
	11,748	11,748
Period II:		
Metabolizable	6,154	....
Brushings	....	81
Heat	....	10,170
Gain	4,097	....
	10,251	10,251
Period III:		
Metabolizable	8,238	....
Brushings	....	81
Heat	....	10,899
Gain	2,742	....
	10,980	10,980
Period IV:		
Metabolizable	17,973	....
Brushings	....	81
Heat	....	13,845
Gain	....	4,047
	17,973	17,973

TABLE 197.—*Average live weights, 1903.*

	Kilos.
Period I	550.2
Period II	525.1
Period III	519.2
Period IV	525.9

TABLE 198.—*Availability of metabolizable energy of clover hay, Periods I–II.*

$$n=\left(\frac{525.1}{550.2}\right)^{2/3}=0.9694$$

$$x_2=6{,}154 \qquad y_2=-4{,}097$$
$$x_1=8{,}449 \qquad y_1=-3{,}299$$

$$m=\frac{-4{,}097-(0.9694\times-3{,}299)}{6{,}154-(0.9694\times 8{,}454)}=44.04 \text{ per cent.}$$

TABLE 199.—*Correction for differences in amount of hay eaten.*

Periods.	Organic matter of hay.	Metabolizable energy of total ration.	Gain by animal.
	Grams.	*Calories.*	*Calories.*
Period II	2,940.8	....	....
Period III	2,952.8	8,238	−2,742
Correction	−12.0	−25	−11
Period III, corrected	2,940.8	8,213	−2,753
Period II	2,940.8	....	....
Period IV	2,974.8	17,973	4,047
Correction	−34.0	−71	−31
Period IV, corrected	2,940.8	17,902	4,016

TABLE 200.—*Availability of metabolizable energy of corn meal.*

PERIODS III-II.

$$n=\left(\frac{525.1}{519.2}\right)^{2/3}=1.008$$

$$x_2=6{,}154 \qquad y_2=-4{,}097$$
$$x_3=8{,}213 \qquad y_3=-2{,}753$$

$$m=\frac{-4{,}097-(1.008\times-2{,}753)}{6{,}154-(1.008\times8{,}213)}=62.22 \text{ per cen}$$

PERIODS IV-II.

$$n=\left(\frac{525.1}{525.9}\right)^{2/3}=0.9991$$

$$x_2=6{,}154 \qquad y_2=-4{,}097$$
$$x_4=17{,}902 \qquad y_4=4{,}016$$

$$m=\frac{-4{,}097-(0.9991\times4{,}016)}{6{,}154-(0.9991\times17{,}902)}=69.12 \text{ per cent.}$$

PERIODS IV-III.

$$n=\left(\frac{519.2}{525.9}\right)^{2/3}=0.9915$$

$$x_3=8{,}213 \qquad y_3=-2{,}753$$
$$x_4=17{,}902 \qquad y_4=4{,}016$$

$$m=\frac{-2{,}753-(0.9915\times4{,}016)}{8{,}213-(0.9915\times17{,}902)}=70.83 \text{ per cent.}$$

DIGESTION AND METABOLISM TRIALS DURING THE INTERMEDIATE FEEDING PERIODS.

As stated in Part I, pages 13 and 66–69, four digestion and metabolism experiments were made in the course of what have been designated as the intermediate feeding periods. Full data regarding the composition of the feeding stuffs used in these experiments are contained in Table 26 of Part I (p. 63). The details of the experiments follow, including some repetition of data already presented in Part I.

DIGESTIBILITY OF THE RATIONS.

TRIAL OF DECEMBER 1–10, 1904.

The rations offered daily were identical with those consumed for the preceding month, but a considerable portion of the hay was rejected by the animals.

TABLE 201.—*Daily rations during digestion trial, December 1–10, 1904.*

Feed.	Steer A.	Steer B.
	Grams.	*Grams.*
Mixed hay	3,629	3,629
Wheat bran	254	180
Corn meal	761	540
Old-process linseed meal	761	540

During October and November long hay was fed. On November 26, 1904, a portion of the same hay was cut for the digestion trials and duplicate samples were taken in which the composition of the dry matter was determined. The average of these two analyses is regarded as representing the composition of the dry matter of the hay used in the digestion experiment and also of that previously fed.

On November 28, when the feeds were weighed out for the digestion experiment, a second sample was taken in which only the loss in air drying and the nitrogen were determined. The percentage of moisture in the dry-air matter has been computed on the assumption that the nitrogen content of the dry matter was the same as the average of the two previous samples.

In the samples of grain taken during this period, the determination of the moisture in the air-dry material was overlooked. The percentage given in Table 26 of Part I is estimated from that found in similar samples in these and previous experiments. The close agreement of the percentages of total nitrogen in the dry matter as computed on this basis indicates its substantial correctness. It may be noted also that this error does not affect the determination of the total amount of nitrogen consumed and therefore does not affect the nitrogen balance subsequently computed. On this basis, the composition of the feeding stuffs used was as follows:

TABLE 202.—*Composition of feeding stuffs in digestion trial, December 1–10, 1904.*

Component.	Mixed hay.	Wheat bran.	Corn meal.	Old-process linseed meal.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Water	17.58	16.64	13.61	11.51
Dry matter	82.42	83.36	86.39	88.49
	100.00	100.00	100.00	100.00
In dry matter:				
Ash	8.01	1.52	8.81	5.78
Protein Nonprotein	13.04	9.65	14.94	30.46
Crude fiber	28.27	1.84	10.55	9.39
Nitrogen-free extract Ether extract	50.68	86.99	65.70	54.37
Estimated nonprotein (average)	1.46	.39	2.20	4.39

The live weights of the animals, the weights of water consumed and excreta collected, and the composition of the dry matter of the feces are contained in Tables XI and XII of the appendix. From these data the results as regards the digestibility of the ration are computed in the following table. While the energy of the feeds and feces was not determined, the results in the other three trials are so uniform that it appears safe to apply their average to the computation of this experiment. These averages are:

Average energy per gram dry matter.

	Calories.
Mixed hay	4.5159
Wheat bran	4.5432
Corn meal [1]	4.4425
Linseed meal	4.8908
Feces	4.7201

TABLE 203.—*Feed and excreta, December 1–10, 1904.*

	Steer A.				Steer B.			
	Number of days.	Fresh weight.	Dry matter.		Number of days.	Fresh weight.	Dry matter.	
		Grams.	*Per cent.*	*Grams.*		*Grams.*	*Per cent.*	*Grams.*
Mixed hay:								
Total	10	36,290.0	82.42	29,910.2	10	36,290.0	82.42	29,910.2
Uneaten		12,367.0	83.83	10,367.3		5,086.0	84.23	4,283.9
Eaten		24,923.0		19,542.9		31,204.0		25,626.3
Eaten per day		2,492.3		1,954.3		3120.4		2,562.6
Wheat bran:								
Total	10	2,540.0	86.39	2,194.3	10	1,800.0	86.39	1,555.0
Eaten per day		254.0		219.4		180.0		155.5
Corn meal:								
Total	10	7,610.0	83.36	6,343.7	10	5,400.0	83.36	4,501.4
Eaten per day		761.0		634.4		540.0		450.1
Old-process linseed meal:								
Total	10	7,610.0	88.49	6,734.1	10	5,400.0	88.49	4,778.5
Eaten per day		761.0		673.4		540.0		477.9
Feces:								
Collected	10	83,720.0	18.08	15,139.1	10	79,650.0	19.51	15,539.7
In duct		980.0	18.08	177.2		535.0	19.51	104.4
Total				15,316.3		80,185.0		15,644.1
Excreted per day				1,531.6		8,018.5		1,564.4

TABLE 204.—*Digestibility of rations, December 1–10, 1904.*

	Dry matter.	Ash.	Organic matter.	Crude protein.	Non-protein.	Crude fiber.	Nitrogen-free and ether extracts.	Total nitrogen.	Computed energy.
Steer A.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*G ams.*	*Grams.*	*Grams.*	*Calories.*
Mixed hay	2,991.0	239.6	2,751.4	390.0	43.7	845.6	1,515.8	62.5	13,507.1
Wheat bran	219.4	19.3	200.1	32.8	4.8	23.1	144.2	5.8	996.8
Corn meal	634.4	9.6	624.8	61.2	2.5	11.7	551.9	10.2	2,818.3
Linseed meal	673.4	38.9	634.5	205.1	29.6	63.2	366.2	37.3	3,293.5
Total	4,518.2	307.4	4,210.8	689.1	80.6	943.6	2,578.1	115.8	20,615.7
Refused	1,036.7	123.6	913.1	197.6	15.1	145.6	569.9	31.6	4,681.6
Eaten	3,481.5	183.8	3,297.7	491.5	65.5	798.0	2,008.2	84.2	15,934.1
Feces	1,531.6	151.0	1,380.6	274.8		443.2	662.6	44.0	7,229.3
Digested	1,949.9	32.8	1,917.1	216.7	65.5	354.8	1,345.6	40.2	8,704.8
Percentage digestibility	56.01	17.85	58.13	44.09	100.00	44.46	67.00	47.74	54.63
Steer B.									
Mixed hay	2,991.0	239.6	2,751.4	390.0	43.7	845.6	1,515.8	62.5	13,507.1
Wheat bran	155.5	13.7	141.8	23.2	3.4	16.4	102.2	4.1	706.5
Corn meal	450.1	6.8	443.3	43.4	1.8	8.3	391.5	7.2	1,999.6
Linseed meal	477.9	27.6	450.3	145.6	21.0	44.9	259.8	26.5	2,337.3
Total	4,074.5	287.7	3,786.8	602.2	69.9	915.2	2,269.3	100.3	18,550.5
Refused	428.4	44.8	383.6	85.4	6.3	43.4	254.7	13.7	1,934.6
Eaten	3,646.1	242.9	3,403.2	516.8	63.6	871.8	2,014.6	86.6	16,615.9
Feces	1,564.4	155.0	1,409.4	256.2		477.0	676.2	41.0	7,384.1
Digested	2,081.7	87.9	1,993.8	260.6	63.6	394.8	1,338.4	45.6	9,231.8
Percentage digestibility	57.09	36.19	58.59	50.43	100.00	45.29	66.44	52.66	55.56

[1] Average of second and third trials only.

The percentage digestibility of the total ration appears low as compared with the results obtained in subsequent periods in which approximately the same proportion of hay and grain was consumed. As will appear subsequently, the nitrogen balance indicates some serious error in the work and the results of this trial should therefore be accepted with considerable reserve.

TRIAL OF JULY 6–15, 1905.

The feeding stuffs for this experiment were weighed out on June 28 and samples taken at the same time, the composition of which is shown in the following table:

TABLE 205.—*Composition of feeding stuffs in digestion trial, July 6–15, 1905.*

Component and energy.	Mixed hay.	Wheat bran.	Corn meal.	Old-process linseed meal.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Water	15.75	11.30	12.97	9.15
Dry matter	84.25	88.70	87.03	90.85
	100.00	100.00	100.00	100.00
In dry matter:				
Ash	6.69	7.02	1.48	5.67
Protein [1]	12.25	12.54	8.22	27.21
Nonprotein [1]	1.22	2.12	.61	2.93
Crude fiber	30.39	10.13	2.40	9.46
Nitrogen-free extract	46.09	63.02	83.69	47.07
Ether extract	3.36	5.17	3.60	7.66
	100.00	100.00	100.00	100.00
	Calories.	*Calories.*	*Calories.*	*Calories.*
Energy per gram dry matter	4.5940	4.5841	4.4773	4.9244

[1] Computed from nitrogen, using the factors stated in Part III, page 203.

While the preliminary period covered only 5 days, viz, July 1–5, the daily grain ration for 34 days previous had differed only 20 grams in the case of steer A and only 5 grams in the case of steer B from the amounts weighed out for the digestion period. For the same 34 days, the average hay consumed was, by steer A, 3,120 grams, and by steer B 2,990 grams. The rations during the digestion trial were:

TABLE 206.—*Daily rations during digestion trial, July 6–15, 1905.*

Feed.	Steer A.	Steer B.
	Grams.	*Grams.*
Mixed hay	2,800	2,800
Wheat bran	360	285
Corn meal	1,080	855
Old-process linseed meal	1,080	855

From the foregoing data and from the records of the appendix, the following results as regards digestibility are computed:

TABLE 207.—*Feed and excreta, July 6-15, 1905.*

	Steer A.				Steer B.			
	Number of days.	Fresh weight.	Dry matter.		Number of days.	Fresh weight.	Dry matter.	
		Grams.	*Per cent.*	*Grams.*		*Grams.*	*Per cent.*	*Grams.*
Mixed hay:								
Total	10	28,000.0	84.17	23,567.6	10	28,000.0	84.17	23,567.6
Eaten per day		2,800.0		2,356.8		2,800.0		2,356.8
Wheat bran:								
Total	10	3,600.0	88.70	3,193.2	10	2,850.0	88.70	2,527.95
Eaten per day		360.0		319.3		285.0		252.8
Corn meal:								
Total	10	10,800.0	87.03	9,399.2	10	8,550.0	87.03	7,441.06
Eaten per day		1,080.0		939.9		855.0		744.1
Linseed meal:								
Total	10	10,800.0	90.85	9,811.8	10	8,550.0	90.85	7,767.7
Eaten per day		1,080.0		981.2		855.0		776.8
Feces:								
Collected	9	72,995.0	19.41	14,168.3	10	73,100.0	16.16	12,141.9
Spilled, July 7				30.0				
In duct	10			80.0				68.0
Total				14,278.3				12,209.9
Excreted per day				1,585.6				1,221.0

TABLE 208.—*Digestibility of rations, July 6-15, 1905.*

	Dry matter.	Ash.	Organic matter.	Protein.	Non-protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Total nitrogen.	Energy.
Steer A.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Hay	2,356.8	157.7	2,199.1	288.7	28.8	716.2	1,086.2	79.2	52.3	10,827.1
Bran	319.3	22.4	296.9	40.0	6.8	32.3	201.3	16.5	8.5	1,463.7
Corn meal	939.9	13.9	926.0	77.3	5.7	22.6	786.6	33.8	14.0	4,208.2
Linseed meal	981.2	55.6	925.6	267.0	28.7	92.8	461.9	75.2	53.5	4,831.8
Total	4,597.2	249.6	4,347.6	673.0	70.0	863.9	2,536.0	204.7	128.3	21,330.8
Feces	1,585.3	153.1	1,432.2	270.0		536.5	578.6	47.1	43.2	7,574.2
Digested	3,011.9	96.5	2,915.4	403.0	70.0	327.4	1,957.4	157.6	85.1	13,756.6
Percentage digestibility	65.52	38.66	67.06	59.88	100.00	37.90	77.18	76.99	66.33	64.49
Steer B.										
Hay	2,356.8	157.7	2,199.1	288.7	28.8	716.2	1,086.2	79.2	52.3	10,827.1
Bran	252.8	17.7	235.1	31.7	5.4	25.6	159.3	13.1	6.7	1,158.9
Corn meal	744.1	11.0	733.1	61.2	4.5	17.9	622.7	26.8	11.1	3,331.6
Linseed meal	776.8	44.0	732.8	211.4	22.8	73.5	365.6	59.5	42.3	3,825.3
Total	4,130.5	230.4	3,900.1	593.0	61.5	833.2	2,233.8	178.6	112.4	19,142.9
Feces	1,221.0	117.9	1,103.1	244.0		384.7	437.6	36.8	39.0	5,852.1
Digested	2,909.5	112.5	2,797.0	349.0	61.5	448.5	1,796.2	141.8	73.4	13,290.8
Percentage digestibility	70.44	48.83	71.72	58.85	100.00	53.83	80.41	79.40	65.30	69.43

TRIAL OF NOVEMBER 13–22, 1905.

The grain for tnis trial was weighed out and sampled November 4 and the hay on November 6. The feeding began November 8, and the collection of excreta on November 13. The rations consumed were as follows:

TABLE 209.—*Daily rations during digestion trial, November 13–22, 1905.*

Feed.	Steer A.	Steer B.
	Grams.	*Grams.*
Mixed hay	3,440	3,600
Wheat bran	360	285
Corn meal	1,080	855
New-process linseed meal	1,080	855

Practically the same amount of the same grain mixture (2,500 grams) had been fed daily since the previous digestion experiment in July. After the use of green crops during the summer had been discontinued the animals received hay beginning October 6, the average amounts consumed daily up to November 8 being, steer A, 3,300 grams; steer B, 3,130 grams.

The composition of the feeding stuffs is shown in the following table:

TABLE 210.—*Composition of feeding stuffs in digestion trial, November 13–22, 1905.*

Component and energy.	Mixed hay.	Wheat bran.	Corn meal.	New-process linseed meal.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Water	12.37	12.34	12.97	9.48
Dry matter	87.63	87.66	87.03	90.52
	100.00	100.00	100.00	100.00
In dry matter:				
Ash	5.98	7.08	1.39	4.91
Protein [1]	8.26	13.38	8.99	29.87
Nonprotein [1]	2.14	2.32	0.30	3.58
Crude fiber	31.70	9.70	2.27	8.00
Nitrogen-free extract	48.83	63.58	84.14	52.15
Ether extract	3.09	3.94	2.91	1.49
	100.00	100.00	100.00	100.00
	Calories.	*Calories.*	*Calories.*	*Calories.*
Energy per gram dry matter	4.5005	4.5058	4.4077	4.7838

[1] Computed from nitrogen, using the factors stated in Part III, page 203.

TABLE 211.—*Feed and excreta, November 13–22, 1905.*

	Steer A.				Steer B.			
	Number of days.	Fresh weight.	Dry matter.		Number of days.	Fresh weight.	Dry matter.	
		Grams.	*Per cent.*	*Grams.*		*Grams.*	*Per cent.*	*Grams.*
Timothy hay:								
Total	10	34,400.0	87.63	30,144.4	10	36,000.0	87.63	31,546.4
Eaten per day		3,440.0		3,014.4		3,600.0		3,154.6
Wheat bran:								
Total	10	3,600.0	87.66	3,155.8	10	2,850.0	87.66	2,498.3
Eaten per day		360.0		315.6		285.0		249.8
Corn meal:								
Total	10	10,800.0	87.03	9,399.7	10	8,550.0	87.03	7,441.4
Eaten per day		1,080.0		940.0		855.0		744.1
Linseed meal:								
Total	10	10,800.0	90.52	9,776.4	10	8,550.0	90.52	7,739.6
Eaten per day		1,080.0		977.6		855.0		774.0
Feces:								
Collected	10	103,170.0	16.93	17,470.8	9	75,580.0	19.84	14,997.3
In duct				134.8	10			55.5
Total				17,605.6				15,052.8
Excreted per day		10,317.0		1,760.6				1,672.0

TABLE 212.—*Digestibility of rations, November 13–22, 1905.*

	Dry matter.	Ash.	Organic matter.	Protein.	Non-protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Total nitrogen.	Energy.
Steer A.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Timothy hay	3,014.4	180.4	2,834.0	249.1	64.4	955.4	1,472.1	93.0	47.2	13,566.3
Wheat bran	315.6	22.4	293.2	42.2	7.3	30.6	200.7	12.4	9.0	1,422.0
Corn meal	940.0	13.1	926.9	84.5	2.8	21.3	791.0	27.3	14.7	4,143.2
Linseed meal	977.6	48.0	929.6	292.0	35.0	78.2	509.8	14.6	60.5	4,676.6
Total	5,247.6	263.9	4,983.7	667.8	109.5	1,085.5	2,973.6	147.3	131.4	23,808.1
Feces	1,760.6	178.0	1,582.6	261.2		465.1	816.5	39.8	41.8	8,198.2
Digested	3,487.0	85.9	3,401.1	406.6	109.5	620.4	2,157.1	107.5	89.6	15,609.9
Percentage digestibility	66.45	32.55	68.24	60.89	100.00	57.16	72.54	72.98	68.19	65.56
Steer B.										
Timothy hay	3,154.6	188.7	2,965.9	260.7	67.4	999.9	1,540.5	97.4	49.3	14,197.3
Wheat bran	249.8	17.7	232.1	33.4	5.8	24.2	158.8	9.8	7.1	1,125.5
Corn meal	744.1	10.4	733.7	66.9	2.2	16.9	626.1	21.6	11.6	3,279.8
Linseed meal	774.0	38.0	736.0	231.2	27.7	61.9	403.7	11.6	47.9	3,702.7
Total	4,922.5	254.8	4,667.7	592.2	103.1	1,102.9	2,729.1	140.4	115.9	22,305.3
Feces	1,672.0	170.6	1,501.4	229.1		487.2	746.4	38.7	36.7	7,739.6
Digested	3,250.5	84.2	3,166.3	363.1	103.1	615.7	1,982.7	101.7	79.2	14,565.7
Percentage digestibility	66.03	33.05	67.83	61.31	100.00	55.83	72.65	72.44	68.33	65.30

TRIAL OF JUNE 27–JULY 6, 1906.

The grain for the digestion trial was weighed out on June 16 and the hay on June 18, the composition of the samples taken at that time being as shown in the table below. The amounts consumed daily were:

TABLE 213.—*Daily rations during digestion trial, June 27–July 6, 1906.*

Feed.	Steer A.	Steer B.
	Grams.	*Grams.*
Mixed hay	5,120	4,080
Wheat bran	635	460
Corn-and-cob meal	1,905	1,380
Old-process linseed meal	635	460

The feeding of this exact ration was begun on June 20. The daily grain ration, however, had been the same in amount since June 1 and during the same time the daily hay consumed was by steer A 4,980 grams, and by steer B 4,000 grams.

TABLE 214.—*Composition of feeding stuffs in digestion trial, June 27–July 6, 1906.*

Component and energy.	Mixed hay.	Wheat bran.	Corn-and-cob meal.	Old-process linseed meal.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Water	13.29	13.44	13.87	11.95
Dry matter	86.71	86.56	86.13	88.05
	100.00	100.00	100.00	100.00
In dry matter:				
Ash	7.12	7.56	1.76	5.62
Protein [1]	11.14	14.56	8.54	26.05
Nonprotein [1]	1.20	2.15	.26	6.66
Crude fiber	30.04	9.65	8.41	9.09
Nitrogen-free extract	47.91	61.07	77.14	44.56
Ether extract	2.59	5.01	3.89	8.02
	100.00	100.00	100.00	100.00
	Calories.	*Calories.*	*Calories.*	*Calories.*
Energy per gram dry matter	4.4531	4.5397	4.5233	4.9642

[1] Computed from nitrogen, using the factors stated in Part III, page 203.

TABLE 215.—*Feed and excreta, June 27–July 6, 1906.*

	Steer A.				Steer B.			
	Number of days.	Fresh weight.	Dry matter.		Number of days.	Fresh weight.	Dry matter.	
		Grams.	*Per cent.*	*Grams.*		*Grams.*	*Per cent.*	*Grams.*
Mixed hay:								
Total	10	51,200.0	86.71	44,394.0	10	40,800.0	86.71	35,376.5
Eaten per day		5,120.0		4,439.4		4,080.0		3,537.7
Wheat bran:								
Total	10	6,350.0	86.56	5,496.4	10	4,600.0	86.56	3,981.6
Eaten per day		635.0		549.6		460.0		398.2
Corn meal:								
Total	10	19,050.0	86.13	16,406.8	10	13,800.0	86.13	11,885.3
Eaten per day		1,905.0		1,640.7		1,380.0		1,188.5
Linseed meal:								
Total	10	6,350.0	88.05	5,591.4	10	4,600.0	88.05	4,050.5
Eaten per day		635.0		559.1		460.0		405.0
Feces:								
Collected	10	167,505.0	14.42	24,160.9	10	94,045.0	19.65	18,478.9
In duct		1,913.0	14.42	275.8		934.0	18.31	171.0
Total		169,418.0		24,436.7		94,979.0	37.96	18,649.9
Excreted per day		16,941.8		2,443.7		9,497.9		1,864.9

TABLE 216.—*Digestibility of rations, June 27–July 6, 1906.*

	Dry matter.	Ash.	Organic matter.	Protein.	Non-protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Total nitrogen.	Energy.
Steer A.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Calories.*
Mixed hay	4,439.4	316.1	4,123.3	494.5	53.3	1,333.6	2,126.9	115.0	90.5	19,769.1
Wheat bran	549.6	41.5	508.1	80.0	11.8	53.0	335.8	27.5	16.6	2,495.0
Corn chop	1,640.7	28.9	1,611.8	140.1	4.3	138.0	1,265.6	63.8	24.2	7,421.4
Linseed meal	559.1	31.4	527.7	145.6	37.2	50.8	249.3	44.8	34.4	2,775.5
Total	7,188.8	417.9	6,770.9	860.2	106.6	1,575.4	3,977.6	251.1	165.7	32,461.0
Feces	2,443.7	226.5	2,217.2	409.8	....	763.4	987.6	56.4	65.6	11,436.3
Digested	4,745.1	191.4	4,553.7	450.4	106.6	812.0	2,990.0	194.7	100.1	21,024.7
Percentage digestibility	66.01	45.80	67.25	52.36	100.00	51.54	75.17	77.54	60.41	64.77
Steer B.										
Mixed hay	3,537.6	251.9	3,285.7	394.1	42.5	1,062.7	1,694.8	91.6	72.1	15,753.3
Wheat bran	398.2	30.1	368.1	58.0	8.6	38.4	243.2	19.9	12.0	1,807.7
Corn-and-cob meal	1,188.5	20.9	1,167.6	101.5	3.1	100.0	916.8	46.2	17.6	5,375.9
Linseed meal	405.0	22.8	382.2	105.5	27.0	36.8	180.4	32.5	24.9	2,010.5
Total	5,529.3	325.7	5,203.6	659.1	81.2	1,237.9	3,035.2	190.2	126.6	24,947.4
Feces	1,864.9	179.6	1,685.3	278.2	....	578.1	780.4	48.6	44.5	8,884.2
Digested	3,664.4	146.1	3,518.3	380.9	81.2	659.8	2,254.8	141.6	82.1	16,063.2
Percentage digestibility	66.27	44.86	67.61	57.79	100.00	53.30	74.29	74.45	64.85	64.39

NITROGEN BALANCES.

During the several digestion trials described above, the urine of the animals was also collected quantitatively and its percentage of nitrogen, and in two cases its content of potential energy, determined. Table XI of the appendix records the daily excretion in each period and the corresponding amounts of nitrogen. In the first three trials the amount of nitrogen excreted was determined by an analysis of a composite sample made by taking one-fiftieth of the amount excreted each day. In the fourth trial, a nitrogen determination was made in each daily sample, a check determination being also made upon a composite sample taken as above described. The close agreement of the results obtained by the two methods attests the accuracy of the work and indicates that the results obtained in the three previous trials are in all probability substantially accurate.

It is evident, however, that there is some undiscovered source of error in the first of these trials. The animals were transferred from the barn to the calorimeter building very shortly before the beginning of the digestion period, and during the entire period were apparently somewhat disturbed by their new surroundings and failed to eat a normal amount. This was especially the case with steer A, as shown by the large uneaten residues, consisting in part of grain as well as of hay. Even after making all allowance for this disturbing element, however, the percentage digestibility in both cases, as already noted, seems abnormally low, while the nitrogen balance shows such a large loss of nitrogen from the body as to raise a suspicion of some undiscovered error in weighing or analysis. While no such error is apparent upon the face of the records, it is evident nevertheless that the results of this experiment must be looked upon with considerable suspicion.

In the digestion trial of June 27 to July 6, 1906, the records show that the daily excretion of urinary nitrogen increased toward the end of the trial with both animals, suggesting the influence of some external cause, although none was apparent. It is possible, therefore, that the computed gains of protein in this trial are too small.

The data for nitrogen do not include determinations of that contained in the growth of epidermal tissue, while in the respiration calorimeter experiments the latter was determined and entered separately in the nitrogen balance. Obviously this is the proper method, since the growth of these tissues goes on more or less independently of the state of nutrition of the animal, and the immediate effect of the feed is more accurately measured by the gain or loss of the other nitrogenous tissues.

The average amount of nitrogen in the daily growth of epidermal tissue in the three series of respiration calorimeter experiments as determined and also as computed to the uniform live weight of 500 kilograms in proportion to the relative surfaces of the animal, that is, to the two-thirds power of the live weight, was as follows:

TABLE 217.—*Nitrogen in average daily growth of epidermal tissue in respiration calorimeter experiments.*

	Steer A.			Steer B.		
	Average live weight.[1]	Nitrogen.		Average live weight.[1]	Nitrogen.	
		Per head.	Per 500 kilos live weight.		Per head.	Per 500 kilos live weight.
	Kilos.	*Grams.*	*Grams.*	*Kilos.*	*Grams.*	*Grams.*
1905	274.0	1.74	2.60	194.8	1.17	2.19
1906	407.6	1.62	1.86	303.1	1.30	1.82
1907	509.7	1.90	1.88	379.4	1.74	2.09
Average			2.11			2.03

[1] Mean of the averages computed for each of the respiration calorimeter experiments separately.

Applying the average figure of 2.07 grams per 500 kilograms live weight for the nitrogen in the epidermal tissue to the live weights of the animals in the metabolism trials, we may compute the average nitrogen in their daily growth of epidermal tissue as follows:

TABLE 218.—*Computed nitrogen in daily growth of epidermal tissue in digestion trials.*

Periods.	Steer A.		Steer B.	
	Average live weight.	Nitrogen per head.	Average live weight.	Nitrogen per head.
	Kilos.	*Grams.*	*Kilos.*	*Grams.*
Dec. 1 to 10, 1904	278.3	1.40	215.5	1.18
July 6 to 15, 1905	312.3	1.51	232.4	1.24
Nov. 13 to 22, 1905	379.3	1.72	288.0	1.43
June 27 to July 6, 1906	451.4	1.93	340.9	1.60

Including the foregoing estimates, the nitrogen balances in these trials are as follows:

TABLE 219.—*Nitrogen balance per day and head in digestion trials.*

	Dec. 1-10, 1904.		July 6-15, 1905.		Nov. 13-22, 1905.		June 27-July 6, 1906.	
	Nitrogen of feed.	Nitrogen of excreta.	Nitrogen of feed.	Nitrogen of excreta.	Nitrogen of feed.	Nitrogen of excreta.	Nitrogen of feed.	Nitrogen of excreta.
Steer A.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Mixed hay	62.5		52.3		47.2		90.5	
Wheat bran	5.8		8.5		9.0		16.6	
Corn meal	10.2		14.0		14.7		24.2	
Linseed meal	37.3		53.5		60.5		34.4	
Uneaten feed		31.6						
Feces		44.0		43.2		41.8		65.6
Urine		78.5		79.1		85.0		[1]99.7
Hair and brushings (estimated)		1.4		1.5		1.7		1.9
Balance	39.7			4.4		2.9	1.5	
	155.5	155.5	128.2	128.2	131.4	131.4	167.2	167.2
Steer B.								
Mixed hay	62.5		52.3		49.3		72.1	
Wheat bran	4.1		6.7		7.1		12.0	
Corn meal	7.2		11.1		11.6		17.6	
Linseed meal	26.5		42.3		47.9		24.9	
Uneaten feed		13.7						
Feces		41.0		39.0		36.7		44.5
Urine		69.8		65.9		72.4		[1]77.9
Hair and brushings (estimated)		1.2		1.2		1.4		1.6
Balance	25.4			6.3		5.4		2.6
	125.7	125.7	112.4	112.4	115.9	115.9	126.6	126.6

[1] The records of both steers, but especially of steer A, show increase of urinary nitrogen in later days of period.

PART III. EXPERIMENTAL METHODS.

For the convenience of the reader, and to avoid needless repetitions in the body of the article, the following summary of the experimental methods used in these investigations is presented:

RECORDS OF ANIMALS.

The quantitative collection of the excreta in the respiration calorimeter experiments and also in the digestion and metabolism trials was conducted in the special stalls contained in the respiration calorimeter building. In the respiration calorimeter experiments each period covered three weeks, of which the first 11 days were regarded as the preliminary feeding. During the larger part of the latter the animals were kept in the barn of the experiment station, partly in a box stall and in part in an open yard where no feed was accessible, the object being to allow more freedom of motion and to maintain their health. In some cases, as shown in the account of the experiments, a transition feeding was introduced between two periods, which lengthened the time spent at the barn by a week. The digestion trials included in the intermediate feeding periods were made as nearly as possible upon the average ration of the preceding month, and consequently only a short preliminary feeding was observed.

Live weight.—Except on the days of the respiration calorimeter experiments, the weights of the animals were taken at 1 p. m., 24 hours after the last watering, on scales sensitive to about 0.1 kilogram.

Water consumed.—Water at a temperature of 15°–16° C. was offered once daily, immediately after weighing, the amount not being limited. Immediately after drinking, the animals were reweighed, the difference between the two weighings being regarded as representing the water consumed.

Rectal temperature.—The rectal temperature was taken immediately before watering and also immediately before entering and after leaving the calorimeter.

Measurements.—The measurements recorded in Table I of the appendix were taken by means of a tape line and calipers. They were not of the highest degree of accuracy, but it is thought that they were sufficiently exact for the purpose, which was to give a general picture of the rate of increase in the size of the two animals.

FEEDING STUFFS.

GRAIN.

The total supply of each grain required for a period was thoroughly mixed and the entire quantity spread out in a thin layer on a tight floor. It was then divided in quarters and the two opposite quarters of the mass removed, care being taken to secure all of the material. The portion thus taken was thoroughly mixed and resampled in the same way, the operation being repeated as many times as necessary to secure a manageable sample. Usually not less than 1 to 2 kilograms were taken as a final sample. This sample served for the determination of the composition of the dry matter of the grain.

HAY.

With the exception of the first two months (October and November, 1904), cut hay was used on account of the greater convenience of handling and greater accuracy of weighing out and sampling. For this purpose a suitable quantity was cut up at one time, thoroughly mixed, and stored. In most instances, and always in the respiration calorimeter experiments, samples were taken at the time when the hay was cut up. In some other cases samples were taken only as the hay was being fed out for the digestion trials.

Special care was taken to secure a uniform quality of hay in the several respiration calorimeter experiments of the same year. To this end, a stock more than sufficient for all the anticipated experiments was prepared at the outset. The method employed, which was substantially that followed also in the preparation of the stock used for the digestion and metabolism trials, was as follows:

The entire amount (1,000 to 2,000 kilograms) was cut in lengths of 4 to 5 centimeters. The mass of cut hay was thoroughly mixed with scoop shovels upon a tight floor and then spread out evenly in a mass 0.5 to 1 meter deep. A narrow ditch was then cut diagonally through the mass, the hay thus removed being set aside. A second ditch was then cut through at right angles to the first, and the material thus obtained also set aside. In all cases care was taken to secure the material down to the floor, including the finer particles. Each of the two large samples thus secured was thoroughly mixed, spread out on a tight floor, and subsampled by the method of quartering as already described for the grain, the process being repeated as often as necessary to secure a manageable sample. The sample was chopped rather fine in a meat chopper and resampled, 2 to 3 kilograms being finally taken to the laboratory for determination of the composition of the dry matter.

WEIGHING OUT AND SAMPLING RATIONS.

The daily rations for each respiration calorimeter period or digestion trial were weighed out in advance for the whole time, the hay in cloth bags and the grain in closed receptacles, lard pails being usually employed. In this way it was insured that the animals should receive a uniform amount of dry matter each day. In weighing out the hay, the material was taken from the side of the pile, care being taken to secure all of it down to the floor. As each bag or other receptacle was filled a small portion was laid aside. As soon as the weighing out was finished the samples thus obtained were mixed and subsampled if necessary, the work being done as expeditiously as possible to prevent gain or loss of moisture and the final samples being taken to the laboratory in closed vessels. The results of each period were based upon the composition of the samples taken for that period, the results on the two general samples serving as a check.

The stalls are so arranged as to prevent scattering of feed by the animals. When small uneaten residues were left they were dried and fed back on the succeeding day. Larger residues, of which there were relatively few, were, of course, weighed, sampled, and analyzed.

VISIBLE EXCRETA.

FECES.

The feces were collected by means of the rubber duct mentioned in previous publications and originally described in Bulletin 42 of the Pennsylvania Experiment Station. The total excretion was weighed at the end of each 24 hours. Feces adhering to the duct were scraped or washed off at the close of the period and their dry matter determined, it being assumed that the composition of the latter was the same as that of the feces collected. Any material spilled was scraped up, but few such instances occurred.

A uniform aliquot sample of the fresh feces was set aside daily in a closed zinc can, a little carbon bisulphid being added as a preservative. At the close of the experiment the sample thus obtained was thoroughly mixed and constituted the sample for analysis. No daily analyses of the feces were made in these experiments.

URINE.

The urine was collected by means of an ordinary urine funnel. The latter was rinsed out with water at the end of each 24 hours and the weight of the combined urine and wash water taken. No preservative was used in the receptacle, no indication of a necessity for it appearing.

A uniform aliquot sample of the urine was taken daily after thorough shaking, and these aliquots were mixed to form a composite sample which was preserved by the use of chloroform. With the exception of the respiration calorimeter experiments of 1905 and of the first 3 digestion and metabolism trials, a daily sample of the urine was also taken for determination of total nitrogen. Any urine spilled was taken up as completely as possible by means of sponges and distilled water, and a nitrogen determination made on the recovered material as a basis for a correction.

ANALYTICAL METHODS.

FEEDS AND FECES.

Partial drying.—The necessary preliminary drying was conducted by spreading the material out on trays and exposing it in a drying closet to a current of air which passed over a steam coil, the temperature of the closet being about 60° C. When thoroughly dry, the material was exposed to the air of the grinding room, properly protected, for two or three days. It was then weighed, an especially dry or damp day being avoided, and the material ground as rapidly as possible and preserved in sealed glass-stoppered bottles.

Dry matter.—In the experiments of 1905 the dry matter was determined by exposure to the temperature of boiling water, this being the method recommended by the Association of Official Agricultural Chemists.[1] Subsequent to that time, the dry matter was determined by drying at ordinary temperature in a high vacuum substantially by the method described by Benedict and Manning.[2]

Ash.—The figures reported for the ash refer to crude ash as determined by incineration at a low red heat.

Crude fiber.—The crude fiber was determined by the Weende method, following strictly the directions approved by the Association of Official Agricultural Chemists.[1]

Ether extract.—The ether extract was obtained by extracting the dry feed with anhydrous sulphuric ether, the extract being dried and weighed.

Nitrogen.—The total nitrogen was determined by the Kjeldahl method, using mercury as a catalyser. The total nitrogen in the sample of fresh feces was determined by König's method. Protein nitrogen was determined by precipitation with copper hydrate, substantially according to Stutzer, as recommended by the Association of Official Agricultural Chemists.[1]

Protein was computed from the protein nitrogen by multiplying by the following factors: For wheat bran, 5.7; corn meal, 6; linseed meal, 5.5; hay, 6.25; feces, 6.25. For the nonprotein, in the absence of any better data, the factor for asparagin, 4.7, was applied to the nonprotein nitrogen.

Carbon and hydrogen.—Carbon and hydrogen were determined by combustion with copper oxid with the addition of a little lead chromate in a current of pure air, finishing with oxygen. The water was absorbed in a Winkler spiral containing sulphuric acid, followed by a U tube containing pumice stone drenched with sulphuric acid and the carbon dioxid in a U tube containing soda lime followed by one containing pumice stone and sulphuric acid.

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[1] U. S. Dept. Agr., Bureau of Chemistry, Bulletin 107.

[2] Amer. Jour. Physiol., **13**, 309; **18**, 213.

Energy.—The energy content was determined by means of the Berthelot-Hempel bomb as modified by Atwater. The details of the methods employed have been fully described in previous bulletins.[1]

URINE.

Nitrogen.—Nitrogen was determined in the fresh urine by the Kjeldahl method as described for feeding stuffs.

Drying.—It was of course necessary to dry the urine for the determination of carbon, hydrogen, and energy. In this drying some losses are unavoidable. For the determinations of carbon and hydrogen the urine was dried in a platinum boat at 60° C. in a current of air, this air current being purified by passing over sulphuric acid and soda lime. After passing over the substance the air current passed through standard acid, then through a sulphuric-acid drying bottle, followed by a U tube containing pumice stone and sulphuric acid, and finally through a soda-lime tube followed by a sulphuric-acid tube. The carbon of the carbon dioxid and the hydrogen of the ammonia given off, as thus determined, were added to the results obtained by the combustion of the dried residue.

Carbon and hydrogen were determined as in the feeds and feces.

Energy.—For the determination of energy six or seven samples of the urine, of about 10 grams each, were dried at ordinary temperature in a high vacuum in the platinum capsules used in the bomb calorimeter. Three of these samples served for the determination of energy and two as a check upon the amount of nitrogen lost during evaporation, the remaining samples constituting a reserve in case of accident. The residual solids in our experience have burned perfectly in the bomb calorimeter without the use of the celluloid block or any kindling material. To the energy thus determined was added the energy of the amount of urea corresponding to the nitrogen lost by the parallel samples.

DETERMINATION OF RESPIRATORY PRODUCTS AND HEAT.

These determinations were made by means of the respiration calorimeter, which is a modification of the original form of the Atwater-Rosa apparatus.[2] It consists of a respiration apparatus, of the Pettenkofer type, which also serves as an animal calorimeter. The general construction of the apparatus has been described in previous publications. At the beginning of 1906 the large copper freezing cans previously used for condensing the larger share of the water vapor coming from the respiration chamber were removed and the outcoming air allowed to pass directly from the chamber to the meter pump, the results of the earlier experiments showing that with the

[1] Fries: U. S. Dept. of Agr., Bureau of Animal Industry, Bulletins 94 and 124.
[2] U. S. Dept. of Agr., Office of Experiment Stations, Bulletins 63 and 136.

very dry air supply used there was no danger of a condensation of moisture in the connections or the meter pump. The air samples taken automatically by the meter pump were allowed to bubble through concentrated sulphuric acid contained in a large gas washing bottle, passing from thence to the usual absorbing train. This arrangement proved to be fully as effective as the freezing cans, and at the same time simpler and more accurate. In addition to the samples taken by the meter pump, large aspirators of 800 liters capacity were also provided, by means of which an additional sample of the outgoing air was taken, especially as a control upon the moisture determinations.

RESPIRATORY PRODUCTS.

No material changes were made in the methods of determining the respiratory products which were described in a previous publication.[1] In the experiments of 1907, in which, as already stated, the outgoing air was sampled both by means of the meter pump and by an aspirator, the average of the closely concordant results for carbon dioxid and water obtained by the two methods has been used. The methane in every case is computed from the carbon found in the combustible gases. The general methods of respiration experiments seem too familiar to require detailed description.

HEAT.

The methods for determining the heat production of the animals were also largely the same as those described in the publication just cited, but some minor modifications were introduced and it seems appropriate to illustrate the methods by the record of one subperiod. For this purpose the first subperiod of Period I of the Experiments of 1907 upon steer A has been selected.

The heat given off by the animal leaves the calorimeter in part as the latent heat of evaporation of the water vapor produced. This portion is calculated from the amount of water vapor given off, using Smith's[2] factor of 0.587 calories per gram at 18° C. The remainder of the heat is taken up by the current of water passing through the pipes of the absorber system, the temperature of the ingoing and outcoming water being recorded every 4 minutes. The absorber pipes are partly protected by a shield, which can be raised or lowered by the operator so as to remove the heat from the chamber more or less rapidly, as may be necessary to maintain as nearly as possible a constant temperature. The walls of the respiration chamber are maintained adiabatic by heating or cooling the surrounding air spaces and the temperature of the ingoing air is maintained equal to that of the outcoming.

Table 220 is a transcript of one hour's record of the subperiod.

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[1] Bureau of Animal Industry, Bul. 51.

[2] Physical Review, **25**, 170.

TABLE 220.—*Record of heat measurements.*

[Date Feb. 5, 1907. Experiment 207. Period I; subperiod 1. Animal A.]

1	2		3	4	5	6	7		8	9
Time 9 p. m.	Water thermometers.		Inside temperature by bridge.	Inner wall.	Middle wall.	Air current.	Water meters.		Lamps on air.	Sundries.
	Observed.	Difference.					No. 1.	No. 2.		
	° *C.*	° *C.*	*m. m.*	− +	− +	− +				
00	11.38 5.62	5.76	287 287	.5	1	1.5	....	....	....	Steer moving head. A=18. B=17.6.
02	....	....	....	....	....	....	....	....	....	Steer chewing cud.
04	11.38 5.62	5.76	287 287	.5	1	1	....	....	....	Shield on balance.
06	....	....	....	....	....	....	....	....	11½	
08	11.44 5.62	5.82	290 288	.5	1	1	....	....	....	
10	....	....	....	....	....	....	....	....	....	
12	11.44 5.61	5.83	290 288	1.5	4	.5	91 L	....	....	9°, 14′, 30″ Pointer 29.
14	....	....	....	....	....	....	....	....	....	
16	11.13 5.52	5.61	287 287	1.5	4	0	....	....	....	
18	....	....	....	....	....	....	....	....	....	
20	10.84 5.47	5.37	289 289	.5	4	.5	9, 21, 50	....	....	
22	....	....	....	....	....	....	....	....	....	
24	10.74 5.47	5.27	285 288	0.5	4	1.5	....	....	....	
26	....	....	....	....	....	....	....	....	....	
28	10.72 5.48	5.24	281 288	.2	4	1	....	....	....	Steer down on left side.
30	....	....	....	....	....	....	....	11 L	....	Pointer 28, 9°, 30′, 30″.
32	10.94 5.56	5.38	288 288	.3	4	3	....	....	....	Shield up 15.
34	....	....	....	....	....	....	....	....	11	
36	11.43 5.76	5.67	290 288	3.5	4.5	3.5	....	....	....	A=18.1. B=17.6.
38	....	....	....	....	....	....	....	....	....	Shield down 10.
40	11.55 5.82	5.73	290 288	3	4.5	3	....	....	....	
42	....	....	....	....	....	....	....	....	....	
44	11.62 5.84	5.78	290 289	2.5	4.5	2.5	....	....	....	Shield down 6.
46	....	....	....	....	....	....	....	....	....	
48	11.97 5.85	6.12	289 288	3.5	3.5	2.5	....	....	....	
50	....	....	....	....	....	....	....	....	....	
52	12.15 5.86	6.29	288 286	4.5	2.5	2	....	....	....	
54	....	....	....	....	....	....	....	....	....	
56	12.18 5.86	6.32	283 285	2	3.5	2	....	....	....	
58	....	....	....	....	....	....	....	....	....	

In the foregoing table the double column 2 shows the readings of the water thermometers and the difference between the temperatures of the ingoing and outcoming water. Column 3 shows the temperature of the interior of the calorimeter as measured by copper resistance thermometers and a Wheatstone slide wire bridge, the readings being recorded in millimeters of the bridge scale, one millimeter equalling about 0.01° C. The upper number represents the temperature of the air and the lower the temperature of the walls. Column 4 shows the positive or negative deflections of the galvanometer, indicating the relative temperature of the inner copper and outer zinc sheets composing the walls of the respiration chamber proper. The figures express millimeters on the scale of the reflecting galvanometer, one millimeter being equivalent to about 0.01° C. The positive and negative deviations are made to compensate each other in the course of an experiment. Columns 5 and 6 show the corresponding results for the middle wall of the calorimeter and for the ventilating air current. Column 7 shows the time at which each of the two water meters filled and also the number of liters contained in it at the time the rate of flow of the water was changed, this rate being indicated in column 9 by the position of the pointer attached to the water valve. The letters A and B in column 9 refer to the readings of two mercurial thermometers suspended in the respiration chamber.

Corrections.—For each period of uniform water flow, the product of the amount of water passing through the heat absorbers into the average temperature difference equals the amount of heat brought out in the water current. Two corrections, however, are necessary.

First, the pipe composing our absorber system being of small diameter, there is a not inconsiderable pressure upon the bulbs of the thermometers, and this pressure varies with the rate of flow of the water. Since this pressure is greater upon the ingoing than upon the outcoming thermometer, the effect is to render the observed difference in temperature too small. A correction for this effect was worked out experimentally for the range of pressure used and is applied in the table.

Second, the friction of the water in the absorbers is itself the source of a small amount of heat, which has been computed from the difference in pressure at entrance and exit and the weight of the water passing through the absorbers.

For the specific heat of water between the temperatures observed, we have used the average of Dieterici and Barnes' figures,[1] which give the final result in mean calories, a mean calorie being defined as one-hundredth of the amount of heat required to raise the temperature of one kilogram of water from 0° to 100° C.

The first part of Table 221, on page 210, shows the results as thus computed for the whole of subperiod 1. To the heat thus measured must be added the latent heat of evaporation of the water vaporized as already explained. Furthermore, certain other small corrections are required, as follows:

First, corrections have to be made for the heat introduced into the apparatus or withdrawn from it in case the feed, drink, excreta, and vessels containing them were introduced or removed at a temperature different from that of the calorimeter. The net amount of these corrections is ordinarily small, but the single factors are sometimes not inconsiderable. This is especially the case with the feces, where considerable difficulty is sometimes experienced in determining satisfactorily the true average temperature of the mass.

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[1] Ann. Phys., **16**, 616.

Second, the temperature of the walls of the chamber is subject to slight fluctuations. This temperature is expressed, as already noted, in millimeters of the scale of the slide wire bridge. It has been experimentally determined that 1 millimeter difference in temperature on this scale is equivalent to a capacity correction of 2 calories. The temperature of the contained air also varies slightly, but the error thus introduced is so small as to be negligible.

Third, a correction for so-called lag is also necessary. The water temperatures which are compared are read simultaneously at the inlet and outlet of the absorber system. A certain time is required, however, for the water to pass from one of these points to the other, and, if the temperature of the ingoing water is changing, the ingoing thermometer is affected before the outgoing one. Assuming the rate of emission of heat in the calorimeter and the rate of flow of the water through the absorbers to remain constant, let the lines AA and BB in figure 17 represent the temperatures of the ingoing and outcoming water, respectively, and let the distances between the vertical

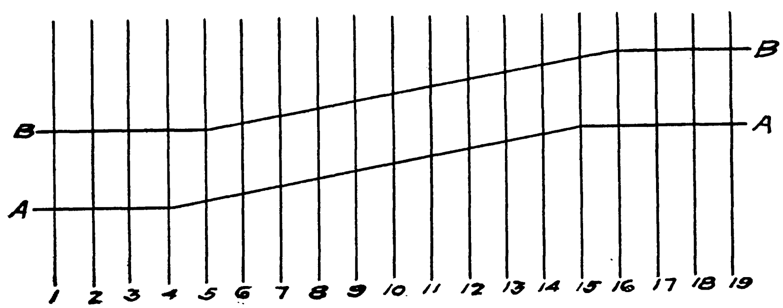

FIG. 17.—Temperature of ingoing and outcoming water in calorimeter.

lines represent the time required for the water to pass from the inlet to the outlet of the absorber system. At the instant *4* the temperature of the ingoing water begins to rise at a uniform rate and continues to do so until the instant *15*, when it again becomes constant. The temperature of the outgoing water will not be affected, however, until the warmer water has passed through the absorbers and will therefore lag behind that of the ingoing water. Its rise of temperature, disregarding possible convection currents in the flowing water and heat conduction by the metal of the absorbers, will begin at the instant *5* and continue until *16* and from the 5th to the 15th instant, inclusive, the apparent temperature difference will be too small by the amount by which the temperature of the ingoing water rises in one interval. If the two thermometers are read simultaneously at the end of each interval, the correction for lag will obviously equal the amount of water contained in the absorber system (in our apparatus 3 kilograms) multiplied by the rise in temperature of the ingoing water during one interval. With a falling temperature of the ingoing water the effect would be reversed, the apparent temperature difference being too great. Plainly, then, we may use the net rise or fall of temperature of the ingoing water during the whole of an experiment or period as the basis of the correction without regard to intermediate fluctuations. The error due to lag is superadded to any effects of changes in the temperature of the outgoing water due to other causes, such as variations in the rate of heat emission in the calorimeter or in the rate of flow of water through the absorbers. In practice, the temperatures are seldom read at intervals corresponding exactly to the rate of flow of the water, and in this way complications are introduced into the exact calculation of the lag correction, but in view of the small total amount of heat involved the correction computed in the manner indicated has been regarded as a sufficiently close approximation.

Fourth, the temperature of the absorber system may differ at the beginning and end of a subperiod, thus requiring a capacity correction. Our absorber system, including the contained water, is equivalent in heat capacity to 6 kilograms of water. If we suppose the temperature of the ingoing water to remain constant the mean temperature of the system may be assumed to be equal to the average of the temperature of the entering and outgoing water, and this difference multiplied by the water equivalent of the system gives the correction to be applied.

If, however, the temperature of the ingoing water varies, the case is different. For example, in the case considered in the previous paragraph, the temperature of the absorber system rises, but this is caused by a storing up in it of heat supplied by the water current and not by heat generated in the calorimeter, and therefore there is no capacity correction. Similarly, in the reverse case, while the temperature of the absorber system falls this is virtually due to the abstraction from it of heat previously imparted to it by the water current, and again there is no capacity correction. Only when the temperature at the inlet and exit vary by different amounts is there a capacity correction equal to the water equivalent of the absorber system multiplied by one-half the difference between the average temperature differences at the beginning and end of the period under consideration. For example:

	At beginning of period.	At end of period.
Temperature at outlet	10°	13°
Temperature at inlet	4°	5°
	6°	8°

$$\text{Correction } \frac{8^\circ - 6^\circ}{2} \times 6 \text{ kilos} = 6 \text{ calories.}$$

All the foregoing corrections are included in the second part of Table 221.

TABLE 221.—*Heat emission.*

[Date, February 5 and 6, 1907. Experiment, 207. Period, I; subperiod, 1. Animal, A.]

Period.	Minutes.	Relative rate of flow—pointer at—	Average temperature of water current.					Total water.	Average specific heat of water.	Mean calories.	Heat produced in absorbers.		Total heat—mean calories.
			Ingoing.	Outcoming.	Difference.	Correction for pressure.	Corrected difference.				Difference of pressure.	Equivalent heat.	
			° C.	*° C.*	*° C.*	*° C.*+	*° C.*	*Liters.*			*Cm.*	*Cal.*	
6.00 p. m. to 7.07 p. m.	67	28	5.8539	11.7600	5.9061	0.0006	5.9067	60	1.0036	355.68	0.30	0.01	355.67
7.07 p. m. to 9.14 p. m.	127	28½	5.6644	11.3785	5.7141	.0007	5.7148	131	1.0037	751.41	.35	.01	751.40
9.14 p. m. to 9.30 p. m.	16	29	5.4975	10.8125	5.3150	.0008	5.3158	20	1.0039	106.73	.40	.00	106.73
9.30 p. m. to 12.47 a. m.	197	28	5.7988	11.8872	6.0884	.0006	6.0890	157	1.0036	959.41	.30	.01	959.40
12.47 a. m. to 1.25 a. m.	38	29	5.4770	11.1360	5.6590	.0008	5.6598	42½	1.0038	241.46	.40	.01	241.45
1.25 a. m. to 2.15 a. m.	50	29½	5.3108	10.0883	4.7775	.0009	4.7784	69½	1.0042	333.49	.45	.01	333.48
2.15 a. m. to 2.30 a. m.	15	29½	5.2967	9.5367	4.2400	.0009	4.2409	20	1.0040	85.16	.45	.00	85.16
2.30 a. m. to 3.10 a. m.	40	29	5.3680	9.7450	4.3770	.0008	4.3778	49	1.0042	215.41	.40	.01	215.40
3.10 a. m. to 4.21 a. m.	71	28½	5.4706	10.3311	4.8605	.0007	4.8612	71	1.0040	346.53	.35	.01	346.52
4.21 a. m. to 6.00 a. m.	99	29½	5.1792	9.7009	4.5217	.0009	4.5226	133	1.0043	604.09	.45	.02	604.07
Total heat from absorbers													3,999.28
Latent heat of water vapor at 18° C., 1,801.91 grams×0.587=													1,057.72
Sum													5,057.00

Corrections.							
	Temperature, °C.	Weight.	Specific heat.[1]	Temperature difference.	+Calories.	−Calories.	
Temperature of chamber	17.9						
Feed introduced:							
Dry matter—							
Hay	18.3	1.468 kilos	×0.4000	×+0.4 °C.		0.23	
Grain	17.2	1.001 kilos	×0.4000	×−0.7 °C.=	0.28		
Water—							
Hay	18.3	.090 kilo	×1.0000	×0.4 °C.		.04	
Grain	17.2	.165 kilo	×1.0000	×−0.7 °C.=	.12		
Feed box introduced	18.3	12.955 kilos	×0.1138	×+0.4 °C.=		.59	
Urine box introduced	18.0	3.045 kilos	×0.0930	×+0.1 °C.=		.03	
Feces box introduced	18.0	8.715 kilos	×0.1138	×+0.1 °C.=		.10	
Changes in temperature of absorber system		6 kilos	×1.0000	×−0.745 °C.=		4.47	
Changes in temperature of wall		2 calories		×+3 mm.=	6.00		
Changes in temperature of ingoing water (lag)		3 kilos		×−0.72 °C.=		2.16	
Total					6.40	7.62	
Algebraic sum							−1.22
Total heat emission corrected							5,055.78

[1] This column contains the specific heats that are used in making corrections for substances introduced into or removed from the calorimeter.

Rate of heat emission.—The rate of heat emission per minute, which is represented graphically in figure 16 (see p. 118), is computed as follows:

First, the average rate of flow of water through the heat absorbers between the times when the rate is purposely changed by the operator is computed in the manner illustrated in Table 222. The results for the short periods serve as a check upon the uniformity of the rate of flow.

TABLE 222.—*Record of water flow from heat absorbers.*

[Date, Feb. 5, 1907. Experiment 207. Period I, subperiod 1. Animal A.]

Sundries.	Water-flow record.				Average flow in liters per minute.					
	Valve pointer.	Time.	Meter.		Short periods.			Longer periods.		
		Hr. min. P. M.	*No.*	*Liters.*	*Min.*	*Liters.*	*Flow.*	*Min.*	*Liters.*	*Flow.*
	28½	4 55¾	II	71½	......	......	......	......	......	......
		5 26¾	II	100	31	28½	0.9194	......	......	......
Began	......	6 00	I	29½	33¼	29½	.8872	64¼	58	0.9027
Steer up	28	7 7½	II	60	67½	60	.8889	67½	60	.8889
	28½	7 45½	II	100	38	40	1.0526	......	......	......
		9 14½	I	91	89	91	1.0225	127	131	1.0315
No. 1 failed to ring off	29	9 21¾	I	100	7¼	9	1.2414	......	......	......
Steer down 9° 29′	......	9 30½	II	11	8¾	11	1.2571	16	20	1.2500
	28	11 21½	II	100	111	89	.8018	......	......	......
Steer up 12° 46′ a. m.	......	A. M. 12 47	I	68	85½	68	.7953	196½	157	.7990
No. 1 failed to ring off when full	29	[1] 1 15.68	I	100	28.68	32	[1] 1.1159	......	......	......
		1 21½	II	6½	5.82	6½	[1] 1.1159	......	......	......
		1 25½	II	10½	4	4	1.0000	38.50	42.5	[1] 1.1039
Steer down 2° 15′	29½	2 15	II	80	49½	69½	1.4040	......	......	......
		2 30	II	100	15	20	1.3333	64½	89½	1.3876
	29	3 10	I	49	40	49	1.2250	40	49	1.2250
No. 1 failed to ring off	28½	4 [2] 1.36	I	100	51.36	51	[2] .9930	......	......	......
		4 21½	II	20	20.14	20	[2] .9930	71.50	71	.9930
	29½	5 20	II	100	58½	80	1.3675	......	......	......
End	......	6 00	I	53	38½	53	1.3766	97	133	1.3711
Clock set ahead 1½ minutes (subtract 1½ minutes)	......	......	......	......	1½	......	......	1½	......	......
					720.0	......	......	720	......	......
					718.5	753	......	718.5	753	......

[1] Time and flow calculated from 12.47 to 1.21½.
[2] Time and flow calculated from 3.10 to 4.21½.

Second, the average temperature differences for overlapping periods of 12 minutes each are computed and entered, as shown in Table 223, opposite the time corresponding to the middle of the 12-minute period. The following example, taken from another experiment, serves to illustrate the method of computing these temperature differences.

Time.	Recorded temperature differences.	Average temperature differences.
	°	
9.20	3.71	
9.24	3.75	3.75
9.28	3.80	3.79
9.32	3.83	3.82
9.36	3.83	

At transition points between two rates of flow, the last two recorded temperature differences under the old rate of flow are averaged and this average entered opposite the time corresponding to the last temperature difference. The temperature differences recorded under the new rate of flow are treated similarly, as in the following example.

Time.	Recorded temperature differences.	Average temperature differences.
1.36	4.11	
1.40	4.11	4.12
1.44	4.14	4.13
Flow changed.		
1.48	1.95	
1.52	1.74	1.85
1.50	1.76	1.82

The products of these average temperature differences into the average rate of water flow per minute as computed in Table 222 are regarded as expressing the average rate of heat emission at that time. Of course this includes only the heat imparted to the water in the absorbers by radiation, conduction, and convection from the animal and does not cover the heat given off as latent heat of water vapor.

TABLE 223.—*Average heat radiation per minute.*

[Date, Feb. 5, 1907. Experiment 207. Period I, subperiod 1. Animal A.]

Time.	6 p. m. to 9 p. m.			9 p. m. to 12 a. m.			12 a. m. to 3 a. m.			3 a. m. to 6 a. m.		
	Average temperature difference.	Flow (liters per minute).	Heat (calories per minute).	Average temperature difference.	Flow (liters per minute).	Heat (calories per minute).	Average temperature difference.	Flow (liters per minute).	Heat (calories per minute).	Average temperature difference.	Flow (liters per minute).	Heat (calories per minute).
	°C.			°C.			°C.			°C.		
00....	5.79	0.8889	5.1467	5.76	....	5.9414	6.07	....	4.8499	......	....	....
04....	5.81	....	5.1645	5.78	....	5.9621	6.07	....	4.8499	4.17	....	5.1083
08....	5.78	....	5.1378	5.80	....	5.9827	6.08	....	4.8579	4.28	....	5.2430
12....	5.73	....	5.0934	5.72	....	5.9002	6.09	....	4.8659	4.28	....	5.2430
16....	5.72	....	5.0845	5.72	....	5.9002	6.10	....	4.8739	4.70	0.9930	4.6671
20....	5.75	....	5.1112	5.32	1.2500	6.6500	6.09	....	4.8659	4.70	....	4.6671
24....	5.78	....	5.1378	5.32	....	6.6500	6.07	....	4.8499	4.78	....	4.7465
28....	5.80	....	5.1556	5.31	....	6.6375	6.06	....	4.8419	4.79	....	4.7565
32....	5.82	....	5.1734	5.31	....	6.6375	6.07	....	4.8499	4.81	....	4.7763
36....	5.87	....	5.2178	5.70	.7990	4.5543	6.08	....	4.8579	4.81	....	4.7763
40....	5.92	....	5.2623	5.70	....	4.5543	6.08	....	4.8579	4.81	....	4.7763
44....	5.97	....	5.3067	5.84	....	4.6662	6.09	....	4.8659	4.81	....	4.7763
48....	6.01	....	5.3423	6.06	....	4.8419	6.09	....	4.8659	4.81	....	4.7763
52....	6.06	....	5.3867	6.24	....	4.9858	5.81	1.1040	6.4142	4.82	....	4.7863
56....	6.10	....	5.4223	6.32	....	5.0497	5.81	....	6.4142	4.83	....	4.7962
00....	6.14	....	5.4578	6.33	....	5.0577	5.79	....	6.3922	4.84	....	4.8061
04....	6.13	....	5.4490	6.34	....	5.0657	5.73	....	6.3259	4.84	....	4.8061
08....	6.13	....	5.4490	6.35	....	5.0737	5.68	....	6.2707	4.82	....	4.7863
12....	5.81	1.0315	5.9930	6.36	....	5.0816	5.67	....	6.2597	4.82	....	4.7863
16....	5.81	....	5.9930	6.33	....	5.0577	5.66	....	6.2486	5.01	....	4.9749
20....	5.71	....	5.8899	6.25	....	4.9938	5.65	....	6.2376	5.33	....	5.2927
24....	5.68	....	5.8589	6.17	....	4.9298	5.45	....	6.0168	5.33	....	5.2927
28....	5.66	....	5.8383	6.12	....	4.8899	5.45	....	6.0168	4.90	1.3711	6.7184
32....	5.65	....	5.8280	6.12	....	4.8899	4.90	1.3876	6.7992	4.90	....	6.7184
36....	5.64	....	5.8177	6.12	....	4.8899	4.90	....	6.7992	4.77	....	6.5401
40....	5.65	....	5.8280	6.10	....	4.8739	4.84	....	6.7160	4.68	....	6.4167
44....	5.64	....	5.8280	6.07	....	4.8499	4.82	....	6.6882	4.57	....	6.2659
48....	5.67	....	5.8486	6.04	....	4.8260	4.78	....	6.6327	4.47	....	6.1288
52....	5.68	....	5.8589	6.02	....	4.8100	4.77	....	6.6189	4.43	....	6.0740
56....	5.68	....	5.8589	6.02	....	4.8100	4.76	....	6.6050	4.42	....	6.0603
00....	5.66	....	5.8383	6.02	....	4.8100	4.75	....	6.5911	4.41	....	6.0466
04....	5.66	....	5.8383	6.02	....	4.8100	4.73	....	6.5633	4.41	....	6.0466
08....	5.66	....	5.8383	6.01	....	4.8020	4.72	....	6.5495	4.42	....	6.0603
12....	5.67	....	5.8486	6.02	....	4.8100	4.70	....	6.5217	4.43	....	6.0740
16....	5.68	....	5.8589	6.03	....	4.8180	4.55	....	6.3136	4.45	....	6.1014
20....	5.69	....	5.8692	6.05	....	4.8340	4.38	....	6.0777	4.46	....	6.1151
24....	5.71	....	5.8899	6.05	....	4.8340	4.24	....	5.8834	4.52	....	6.1974
28....	5.74	....	5.9208	6.06	....	4.8419	4.35	....	6.0361	4.57	....	6.2659
32....	5.78	....	5.9621	6.06	....	4.8419	4.35	....	6.0361	4.59	....	6.2933
36....	5.79	....	5.9724	6.06	....	4.8419	4.59	1.2250	5.6228	4.59	....	6.2933
40....	5.78	....	5.9621	6.05	....	4.8340	4.59	....	5.6228	4.54	....	6.2248
44....	5.76	....	5.9414	6.05	....	4.8340	4.42	....	5.4145	4.47	....	6.1288
48....	5.76	....	5.9414	6.04	....	4.8260	4.36	....	5.3410	4.38	....	6.0054
52....	5.76	....	5.9414	6.05	....	4.8340	4.33	....	5.3043	4.32	....	5.9232
56....	5.76	....	5.9414	......	....	4.8340	4.33	....	5.3043	4.33	....	5.9369
00....	....	....	....	......	....	....	......	....	....	4.41	....	6.0466

From selected portions of the curve, as indicated on figure 16, the average heat emission per minute standing and lying is computed in the manner shown in Tables 224 and 225. The capacity corrections for walls and absorber system and the lag correction are computed for each section separately.

TABLE 224.—*Heat emission—Standing.*

[Date Feb. 5 and 6, 1907. Experiment 207. Period I A. Animal A.]

Periods.	Minutes.	Pointer.	Rate of flow per minute.	Average temperature of water current.					Total water.	Average specific heat of water.	Mean calories.	Capacity corrections.			Heat produced in absorbers.		Total heat—mean calories.
				Ingoing.	Outcoming.	Difference.	Plus correction for pressure on thermometers.	Corrected difference.				Lag.	Absorber system.	Walls.	Difference in pressure.	Equivalent heat.	
			Liters.	*° C.*	*° C.*	*° C.*	*° C.*	*° C.*	*Liters.*			*Cal.*	*Cal.*	*Cal.*	*Cm.*	*Cal.*	
6.00 p. m. to 7.00 p. m.	60	28	0.8889	5.8556	11.7338	5.8782	0.0006	5.8788	53.33	1.00201	314.15	+0.03	+1.05	+28	0.30	0.01	343.22
7.20 p. m. to 9.08 p. m.	108	28.5	1.0315	5.6668	11.3739	5.7071	.0007	5.7078	111.40	1.00216	637.22	− .27	+ .39	+ 4	.35	.01	641.33
1.00 a. m. to 1.20 a. m.	20	29	1.1039	5.4800	11.1600	5.6800	.0008	5.6808	22.08	1.00226	125.72	− .03	− .33	0	.40	.00	125.36
1.40 a. m. to 2.12 a. m.	32	29.5	1.3876	5.3089	10.0756	4.7667	.0009	4.7676	44.40	1.00256	212.22	− .03	− .33	− 2	.45	.00	209.86
4.36 a. m. to 6.00 a. m.	84	29.5	1.3711	5.1719	9.6532	4.4813	.0009	4.4822	115.17	1.00272	517.62	− .27	−1.41	+ 4	.45	.02	519.92
6.00 a. m. to 7.40 a. m.	100	29.5	1.2975	5.0938	9.4981	4.4043	.0009	4.4052	129.75	1.00278	573.16	− .21	− .45	− 6	.45	.02	566.48
9.16 a. m. to 9.40 a. m.	24	30	1.4589	4.9100	9.2214	4.3114	.0010	4.3124	35.01	1.00292	151.42	− .06	− .42	−12	.50	.01	138.93
12.24 p. m. to 12.56 p. m.	32	30	1.4147	4.8311	9.4967	4.6656	.0010	4.6666	45.27	1.00286	211.86	− .21	− .78	− 8	.50	.01	202.86
3.04 p. m. to 3.44 p. m.	40	30	1.4979	4.8900	9.2036	4.3136	.0010	4.3146	59.92	1.00292	259.29	− .06	− .33	−10	.50	.01	248.89
4.40 p. m. to 6.00 p. m.	80	30	1.5556	4.8652	8.7352	3.8700	.0010	3.8710	124.45	1.00306	483.22	− .06	−1.41	− 8	.50	.02	473.73
6.00 p. m. to 8.24 p. m.	144	30	1.5585	4.9184	8.8592	3.9408	.0010	3.9418	224.42	1.00302	887.29	+ .12	+1.86	+18	.50	.04	907.23
8.52 p. m. to 9.16 p. m.	24	30	1.5484	4.9371	9.1486	4.2115	.0010	4.2125	37.16	1.00291	156.99	+ .06	+ .24	+ 6	.50	.01	163.28
4.28 a. m. to 6.00 a. m.	92	30	1.5142	4.9729	9.1396	4.1667	.0010	4.1677	139.31	1.00291	582.29	− .24	−1.44	0	.50	.02	580.59
6.00 a. m. to 7.52 a. m.	112	30	1.4777	4.9241	8.9076	3.9835	.0010	3.9845	165.50	1.00300	661.42	− .06	− .06	− 4	.50	.03	657.27
10.16 a. m. to 10.52 a. m.	36	30	1.3843	4.9690	9.7590	4.7900	.0010	4.7910	49.83	1.00276	239.39	− .03	− .15	−16	.50	.01	223.20
12.56 p. m. to 1.20 p. m.	24	30	1.4663	5.4729	9.9814	4.5085	.0010	4.5095	35.19	1.00254	159.09	+ .15	− .09	+ 6	.50	.01	165.14
3.52 p. m. to 6.00 p. m.	128	30	1.5200	5.8655	9.9427	4.0772	.0010	4.0782	194.56	1.00242	795.38	+ .06	−1.38	− 6	.50	.03	788.03
	1,140																6,955.32
Corrections for feed, feed boxes, dung, and urine introduced and removed																	+76.12
																	7,031.44
Average heat emission (calories per minute)																	6.1679

TABLE 225.—*Heat emission—Lying.*

[Date Feb. 5 and 6, 1907. Experiment 207. Period I A. Animal A.]

Periods.	Minutes.	Pointer.	Rate of flow per minute.	Average temperature of water current.					Total water.	Average specific heat of water.	Mean calories.	Capacity corrections.			Heat produced in absorbers.		Total heat—mean calories.
				Ingoing.	Outcoming.	Difference.	Plus correction for pressure on thermometers.	Corrected difference.				Lag.	Absorber system.	Walls.	Difference in pressure.	Equivalent heat.	
			Liters.	°*C.*	°*C.*	°*C.*	°*C.*	°*C.*	*Liters.*			*Cal.*	*Cal.*	*Cal.*	*Cm.*	*Cal.*	
9.48 p. m. to 12.40 a. m....	172	28	0.7990	5.8005	11.9136	6.1131	0.0006	6.1137	137.43	1.00200	841.89	−0.21	−0.12	−28	0.30	0.01	813.55
3.24 a. m. to 4.12 a. m....	48	28.5	.9930	5.4808	10.2962	4.8154	.0007	4.8161	47.66	1.00245	230.10	− .09	+ .09	− 4	.35	.01	226.09
8.04 a. m. to 8.56 a. m....	52	28	.7362	5.5929	11.5857	5.9928	.0006	5.9934	38.28	1.00212	229.91	− .42	+ .66	−18	.30	.00	212.15
10.00 a. m. to 12.04 p. m....	124	28	.6891	5.3384	11.9294	6.5910	.0006	6.5916	85.45	1.00213	564.45	− .12	+1.83	+ 4	.30	.01	570.15
1.24 p. m. to 2.44 p. m....	80	28	.7033	5.3662	11.5786	6.2124	.0006	6.2130	56.26	1.00220	350.31	+ .30	+ .99	+ 8	.30	.01	359.59
4.08 p. m. to 4.20 p. m....	12	28	.8333	5.2525	10.6875	5.4350	.0006	5.4356	10.00	1.00243	54.49	+ .06	+ .06	− 4	.30	.00	50.61
9.40 p. m. to 10.32 p. m....	52	28	.7987	5.3843	11.6729	6.2886	.0006	6.2892	41.53	1.00218	261.76	0	+ .30	−10	.30	.00	252.06
11.20 p. m. to 1.16 a. m....	116	28	.8459	5.3530	11.4613	6.1083	.0006	6.1089	98.12	1.00224	600.75	+ .03	− .54	−14	.30	.01	586.23
1.56 a. m. to 4.08 a. m....	132	28	.8664	5.3626	11.2629	5.9003	.0006	5.9009	114.36	1.00228	676.37	− .09	− .78	−16	.30	.01	659.49
8.16 a. m. to 9.56 a. m....	100	28	.7002	5.3750	11.6631	6.2881	.0006	6.2887	70.02	1.00218	441.29	+ .15	+2.10	+26	.30	.01	469.53
11.16 a. m. to 12.36 p. m....	80	28	.7150	5.5286	12.0200	6.4914	.0006	6.4920	57.20	1.00205	372.10	+1.23	− .21	−18	.30	.01	355.11
1.44 p. m. to 3.32 p. m....	108	28	.7249	6.1961	12.6114	6.4153	.0006	6.4159	78.29	1.00173	503.17	− .30	+ .75	− 4	.30	.01	499.61
	1,076																5,054.17
Average heat emission (calories per minute)........	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4.6972

CHECK TESTS WITH THE RESPIRATION CALORIMETER.

The accuracy of a complicated apparatus like the respiration calorimeter can, of course, be satisfactorily determined only by actual test. Our check tests have been made by burning known amounts of ethyl alcohol in the respiration chamber and measuring the amounts of carbon dioxid, water, and heat evolved precisely as in an animal experiment.

So-called absolute alcohol, purchased from Eimer and Amend, was diluted to a strength of about 90 per cent with distilled water and the amount of anhydrous alcohol contained in the mixture computed from the specific gravity as determined by a 50 c. c. Squibb's pyknometer at 15.6° C. The alcohol was burned in an argand lamp, into which it was fed from outside the chamber by a device which maintained a constant level in the lamp. This lamp was burned for at least two preliminary hours, during which regular ventilation of the chamber was maintained and the heat removed by the water current as fast as produced. Only when everything was in equilibrium was the actual experiment begun.

Except in the tests of January 12 and May 8, 1906, in which Atwater and Benedict's average of 7.067 calories per gram was used, the heat of combustion of the alcohol used was determined by means of the bomb calorimeter, and ranged from 7.131 to 7.184 calories per gram of anhydrous alcohol. These figures are materially higher than the average used by Atwater and Benedict.

Up to the end of the year 1908–9 there had been made in all 18 alcohol check experiments, excluding those made on January 7, 1907, and April 29, 1908, which seemed clearly erroneous.[1]

Table 226 contains the results of these 18 check tests, divided into two groups, the first including those made with the original form of apparatus and the second those made with the apparatus as described on page 204, viz, without the freezing cans for the removal of the moisture from the outgoing air, the carbon dioxid and water in the outgoing air being determined both in a sample taken by the meter pump and also in a sample taken by an aspirator.

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[1] In the first of these two tests, less than 90 per cent of the water produced was recovered, but notwithstanding this the heat found was much too high. In the second of the two tests the results for carbon dioxid and water were both much too low. Since in general the results for carbon dioxid are very accurate and those for water tend to be too high, we have felt justified in rejecting these two check tests.

TABLE 226.—*Results of alcohol check tests.*

Date.	Number of hours.	Weight of alcohol.		Water.					Carbon dioxid.					Heat.						
					Results by meter pump.		Results by aspirator.			Results by meter pump.		Results by aspirator.			Results by meter pump.		Results by aspirator.		Results corrected for excess of water.	
		Hydrated.	Anhydrous.	Computed.	Observed.	Percentage observed.	Observed.	Percentage observed.	Computed.	Observed.	Percentage observed.	Observed.	Percentage observed.	Computed.	Observed.	Percentage observed.	Observed.	Percentage observed.	Observed.	Percentage observed.
Using copper freezing cans.		*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Per cent.*	*Grams.*	*Per cent.*	*Grams.*	*Grams.*	*Per cent.*	*Grams.*	*Per cent.*	*Calories*	*Calories.*	*Per cent.*	*Calories.*	*Per cent.*	*Calories.*	*Per cent.*
Jan. 16, 1902.	6	564.85	511.41	653.68	689.61	105.5	......	......	977.30	963.15	98.5	......	......	3,647.78	3,743.82	102.6	......	......	3,722.55	102.05
Jan. 29, 1902.	6	592.86	536.77	686.10	767.50	111.9	......	......	1,025.77	1,017.86	99.2	......	......	3,828.67	3,862.08	100.9	......	......	3,813.89	99.61
Apr. 29, 1902.	11	972.68	876.74	1,125.04	1,296.43	115.2	......	......	1,675.30	1,665.14	99.4	......	......	6,298.50	6,346.62	100.7	......	......	6,245.16	99.17
Jan. 20, 1903.	6	527.67	475.62	610.28	629.42	103.1	......	......	908.91	891.58	98.1	......	......	3,417.09	[1]3,427.16	100.3	......	......	3,415.83	99.96
Mar. 26, 1903.	6	526.53	474.60	608.98	687.97	112.9	......	......	906.96	891.24	98.3	......	......	3,409.76	[2]3,407.01	99.9	......	......	3,360.25	98.55
Apr. 28, 1903.	6	503.16	453.53	581.94	676.90	116.3	......	......	866.69	855.73	98.7	......	......	3,258.38	[3]3,190.31	97.9	......	......	3,134.09	96.19
Jan. 5, 1904.	6	487.12	436.89	563.01	633.97	112.6	......	......	834.90	830.58	99.5	......	......	3,125.29	3,142.76	100.6	......	......	3,100.75	99.21
Mar. 25, 1904.	7	541.68	485.82	626.07	675.83	107.9	......	......	928.40	907.51	97.7	......	......	3,475.31	3,549.00	102.1	......	......	3,519.52	101.27
Dec. 13, 1904.	6	506.92	455.90	586.11	635.23	108.4	......	......	871.22	839.19	96.3	......	......	3,251.05	3,308.19	101.8	......	......	3,279.11	100.9
Feb. 10-11, 1905	12	1,238.58	1,111.78	1,431.70	1,515.88	105.9	......	......	2,124.61	2,148.15	101.1	......	......	7,928.28	8,031.60	101.3	......	......	7,981.77	100.7
May 9, 1905.	10	939.94	843.73	1,086.50	1,211.84	111.5	......	......	1,612.37	1,597.93	99.1	......	......	6,016.70	6,090.58	101.2	......	......	6,016.78	100.0
Jan. 12, 1906[4]	8	750.76	671.07	867.32	890.72	102.7	......	......	1,282.41	1,278.49	99.7	......	......	4,785.45	4,826.07	100.9	......	......	4,812.22	100.56
Totals	......	8,152.75	7,333.86	9,426.73	10,311.30	......	......	......	14,014.84	13,886.55	......	......	......	52,442.26	52,925.20	......	......	......	52,401.92	......
Averages	......	677.73	611.16	785.56	859.28	109.38	......	......	1,167.90	1,157.21	99.08	......	......	4,370.19	4,410.43	100.92	......	......	4,366.83	99.92
Without copper freezing cans.																				
May 8, 1906.	7.5	702.81	628.21	812.68	846.62	104.18	821.85	101.13	1,200.50	1,187.79	98.94	1,197.72	99.76	4,479.78	4,523.89	100.98	4,509.23	100.65	4,503.80	100.53
Jan. 15, 1907.	7	621.73	555.73	720.17	792.18	110.00	743.47	103.24	1,062.01	1,050.79	98.94	1,059.59	99.77	3,962.98	4,025.53	101.58	3,996.67	100.87	3,982.90	100.51
May 3, 1907.	8	706.23	627.68	815.26	922.88	113.20	833.63	102.25	1,199.50	1,198.82	99.94	1,201.46	100.16	4,476.05	4,559.31	101.87	4,506.48	100.68	4,495.60	100.43
Nov. 12, 1907.	9	809.95	716.98	931.23	960.04	103.1	886.50	95.2	1,370.14	1,363.68	99.53	1,368.91	99.92	5,112.81	5,137.65	100.5	5,094.48	99.6	5,120.74	100.10
Nov. 17, 1908.	8	676.40	601.17	780.82	866.18	110.9	829.00	106.2	1,148.89	1,138.04	99.0	1,146.18	99.8	4,286.98	4,310.68	100.6	4,288.85	100.05	4,260.57	99.40
Apr. 15, 1909.	8	666.89	593.76	770.02	807.19	104.8	725.38	94.2	1,134.73	1,121.89	98.9	1,131.32	99.7	4,234.13	4,241.08	100.1	4,193.06	99.00	4,219.26	99.70
Totals	......	4,184.01	3,723.53	4,830.18	5,195.09	......	4,839.83	......	7,115.77	7,061.01	......	7,105.18	......	26,552.73	26,798.14	......	26,588.77	......	26,582.87	......
Averages	......	697.34	620.59	805.03	865.85	107.55	806.64	100.20	1,185.96	1,176.83	99.23	1,184.20	99.85	4,425.46	4,466.36	100.92	4,431.46	100.14	4,430.48	100.11
Both series.																				
Totals	......	12,336.76	11,057.39	14,256.91	15,506.39	......	4,839.83	......	21,130.61	20,947.56	......	7,105.18	......	78,994.99	79,723.36	......	26,588.77	......	78,984.79	......
Averages	......	685.38	614.30	792.05	861.47	108.76	806.64	100.2	1,173.92	1,163.75	99.13	1,184.20	99.85	4,388.61	4,429.07	100.92	4,431.46	100.14	4,388.04	99.99

[1] Capacity correction of −6 calories applied. [2] Capacity correction of +27 calories applied. [3] Capacity correction of +44 calories applied. [4] Freezing cans not used.

TABLE 227.—*Summary of results of alcohol check tests.*

	Results with samples taken by meter pump.	Results on samples taken by aspirator.
Using copper freezing cans:		
Carbon dioxid—		
Average percentage recovered	99.1	....
Range of single results	±2.4	....
Water—		
Average percentage recovered	109.4	....
Range of single results	±6.8	....
Heat—		
Average percentage recovered	100.9	....
Range of single results	±2.4	....
Without copper freezing cans:		
Carbon dioxid—		
Average percentage recovered	99.2	99.9
Range of single results	± .5	± .2
Water—		
Average percentage recovered	107.6	100.2
Range of single results	±5.1	±6.0
Heat—		
Average percentage recovered	100.9	100.1
Range of single results	± .9	± .9

The last two columns of Table 226 show the heat production corrected for the apparent error in the water determination. These results are obtained by adding to the heat as measured directly in the water current the latent heat of evaporation corresponding to the computed amount of water formed from the alcohol burned. On the average these results for heat agree very closely with the theoretical, the percentages recovered and the corresponding range of single results being:

	Percentage recovered.	Range of single results.
With freezing cans	99.92	[1] ±2.93
Without freezing cans	100.11	±0.57
Average of all	99.99	[1] ±2.93

[1] The omission of 1 result reduces this to 1.75.

Apparently the most serious error in the heat determinations lies in the measurement of the water vapor given off, and the more accurate determination of the latter by means of the aspirator samples reduces the average error to a very small amount, although it does not seem to materially reduce the range of the single results. The removal of the copper freezing cans appears not to have affected the average accuracy of the determinations. That the range of the single results is reduced may be due in part to increased experience in the use of the apparatus.

The experiments on animals in 1905 which are reported in this paper, as well as those described in previous publications, were made with the old form of apparatus, which, in the alcohol check tests, gave uniformly too high results for water. The effect of this, as already noted, is to make the results for heat also too high, but the error in animal experiments is relatively smaller—first, because it affects only the amount estimated for the latent heat of water vapor, which constituted only about one-fourth of the total heat measured, and, second, because the error appears to affect chiefly the first few hours of an experiment, and is therefore far less serious in an animal experiment extending over 48 hours than in an alcohol check test lasting for but 6 to 12 hours.

The excess of water vapor found in the samples taken by the meter pump seems to be due to a drying out of the sampling pans and especially of their rubber covers during the earlier hours of the experiment. The meter pump takes a sample of one two-hundredth of the total outgoing air. A comparatively small amount of residual moisture in the pans at the beginning of an experiment multiplied by the factor 200 will evidently cause a considerable error in the relatively short alcohol check experiments, while the effect on a long experiment would be inconsiderable.

That such is actually the case is shown by the results of those experiments upon animals in which results with the meter pump and the aspirator samples can be compared. Such of these results as are now available are contained in Table 228, the experiments being designated by their numbers simply.

TABLE 228.—*Comparison of results with meter pump and aspirator in experiments on animals.*

Animal.	Period.	Sub-period.	Water.			CO_2.		
			By meter pump.	By aspirator.	Excess by meter pump.	By meter pump.	By aspirator.	Excess by meter pump.
	Experiment No. 207.							
A.	Period I	1	1,816.2	1,792.1	+ 24.1	2,178.7	2,173.0	+ 5.7
		2	1,797.1	1,804.1	− 7.0	2,171.7	2,167.1	+ 4.6
		3	2,021.2	2,008.9	+ 12.3	2,188.6	2,174.6	+ 14.0
		4	1,905.9	1,908.7	− 2.8	2,177.8	2,186.5	− 8.7
B.	Period I	1	1,830.9	1,843.8	− 12.9	1,935.0	1,948.3	− 13.3
		2	1,867.0	1,858.4	+ 8.6	1,984.2	1,993.1	− 8.9
		3	1,817.8	1,861.9	− 44.1	1,913.7	1,968.6	− 54.9
		4	1,838.0	1,838.8	− .8	1,970.5	1,972.9	− 2.4
A.	Period II	1	3,469.7	3,534.2	− 64.5	3,114.6	3,138.6	− 24.0
		2	3,627.9	3,631.4	− 3.5	3,193.8	3,169.3	+ 24.5
		3	3,719.8	3,737.4	− 17.6	3,150.9	3,180.0	− 29.1
		4	3,351.4	3,359.3	− 7.9	3,089.6	3,106.0	− 16.4
B.	Period II	1	3,074.6	3,117.8	− 43.2	2,396.3	2,420.7	− 24.4
		2	2,982.8	2,998.8	− 16.0	2,444.9	2,457.3	− 12.4
		3	3,244.7	3,240.1	+ 4.6	2,427.6	2,423.4	+ 4.2
		4	3,139.2	3,154.4	− 15.2	2,510.8	2,511.1	− .3
A.	Period III	1	1,559.2	1,486.9	+ 72.3	1,558.2	1,571.4	− 13.2
		2	1,412.3	1,407.9	+ 4.4	1,548.7	1,565.7	− 17.0
		3	1,433.2	1,437.0	− 3.8	1,534.4	1,535.2	− .8
		4	1,434.7	1,428.7	+ 6.0	1,533.0	1,537.0	− 4.0
B.	Period III	1	1,828.6	1,764.6	+ 64.0	1,543.0	1,551.2	− 8.2
		2	1,721.2	1,723.7	− 2.5	1,532.1	1,552.7	− 20.6
		3	1,799.7	1,788.4	+ 11.3	1,519.3	1,521.5	− 2.2
		4	1,715.7	1,708.8	+ 6.9	1,526.9	1,532.4	− 5.5

TABLE 228.—*Comparison of results with meter pump and aspirator in experiments on animals*—Continued.

Animal.	Period.	Subperiod.	Water.			CO_2.		
			By meter pump.	By aspirator.	Excess by meter pump.	By meter pump.	By aspirator.	Excess by meter pump.
	Experiment No. 207—Con.							
A.	Period IV	1	2,049.5	1,988.6	+ 60.9	2,004.2	2,018.8	− 14.6
		2	1,951.5	1,940.4	+ 11.1	2,033.4	2,039.7	− 6.3
		3	2,062.8	2,059.2	+ 3.6	2,032.9	2,038.7	− 5.8
		4	1,992.4	1,994.4	− 2.0	2,023.7	2,031.6	− 7.9
B.	Period IV	1	2,300.2	2,257.8	+ 42.4	1,952.8	1,964.9	− 12.1
		2	2,146.6	2,136.1	+ 10.5	1,990.6	1,985.8	+ 4.8
		3	2,412.3	2,429.4	− 17.1	1,939.2	1,949.8	− 10.6
		4	2,519.1	2,532.2	− 13.1	1,973.3	1,986.5	− 13.2
	Experiment No. 208.							
E.	Period I	1	1,565.8	1,509.6	+ 56.2	1,460.2	1,458.4	+ 1.8
		2	1,376.1	1,384.4	− 8.3	1,472.2	1,485.8	− 13.6
		3	1,413.2	1,391.5	+ 11.7	1,439.3	1,441.7	− 2.4
		4	1,304.6	1,317.7	− 13.1	1,476.0	1,477.3	− 1.3
E.	Period II	1	1,058.3	983.7	+ 74.6	1,048.8	1,063.4	− 14.6
		2	968.7	964.4	+ 4.3	1,063.5	1,059.3	+ 4.2
		3	953.8	946.5	+ 7.3	1,035.0	1,031.1	+ 3.9
		4	963.1	973.7	− 10.6	1,102.9	1,112.9	− 10.0
E.	Period III	1	901.2	863.4	+ 37.8	874.3	889.3	− 15.0
		2	838.8	831.4	+ 7.4	894.0	901.0	− 7.0
		3	890.2	889.5	+ .7	895.4	897.5	− 2.1
		4	838.2	842.7	− 4.5	888.3	895.9	− 7.6
E.	Period IV	1	1,812.8	1,769.7	+ 43.1	1,578.7	1,593.5	− 14.8
		2	1,615.7	1,630.9	− 15.2.	1,563.4	1,544.8	+ 18.6
		3	1,709.3	1,700.7	+ 8.6	1,486.8	1,492.5	− 5.7
		4	1,487.8	1,499.4	− 11.6	1,508.6	1,528.0	− 19.4
E.	Period V	1	1,209.8	1,134.1	+ 75.7	1,090.8	1,103.6	− 12.8
		2	1,066.8	1,051.7	+ 15.1	1,091.1	1,099.2	− 8.1
		3	1,095.3	1,093.4	+ 1.9	1,084.7	1,091.1	− 6.4
		4	1,036.3	1,044.5	− 2.8	1,095.5	1,103.9	− 8.4
E.	Period VI	1	960.2	906.6	+ 53.6	847.9	859.6	− 11.7
		2	835.4	815.5	+ 19.9	823.1	826.9	− 3.8
		3	857.2	832.0	+ 25.2	829.2	819.8	+ 9.4
		4	774.6	774.3	+ .3	819.8	825.1	− 5.3
D.	Period I	1	1,405.7	1,283.0	+122.7	978.6	991.8	− 13.2
		2	1,402.0	1,383.8	+ 18.2	955.2	955.9	− .7
		3	1,226.1	1,221.1	+ 5.0	948.0	957.7	− 9.7
		4	1,400.1	1,419.4	− 19.3	983.9	991.3	− 7.4
D.	Period II	1	984.2	925.8	+ 58.4	732.4	737.5	− 5.1
		2	897.8	888.5	+ 9.3	746.5	752.3	− 5.8
		3	858.1	851.3	+ 6.8	723.1	726.7	− 3.6
		4	797.9	801.3	− 3.4	716.9	723.2	− 6.3
C.	Period II	1	1,401.4	1,322.6	+ 78.8	1,287.9	1,298.6	− 10.7
		2	1,247.3	1,236.7	+ 10.6	1,286.1	1,288.4	− 2.3
		3	1,354.1	1,346.2	+ 7.9	1,341.3	1,338.5	+ 2.8
		4	1,526.9	1,559.6	− 32.7	1,442.7	1,451.7	− 9.0

The error due to the evaporation of water from the pans would naturally affect principally or entirely the first subperiod of 12 hours and this is precisely what seems to have occurred. In experiment No. 208 there is an excess of water in the first subperiod as determined by the meter pump in every case, and in experiment No. 207, there is a similar excess in five cases out of eight, while there is no such difference in the results for carbon dioxid. The average excess of water found by the meter pump over that found by the aspirator in the first subperiod, omitting negative results, is 61.8 grams, or including all the negative results, 43.8 grams. In the remaining subperiods the excess of water found by the meter pump over that found by the aspirator is positive in 27 cases and negative in 24 cases, the average algebraic differences being:

	Grams.
In experiment 207	−3. 1
In experiment 208	+1. 4
Average of all	− . 7

In the later alcohol check tests previously tabulated, which are all short, corresponding in this respect to the first subperiods of the animal experiments, the average difference between the water vapor as determined by the meter pump and that determined by the aspirator was 59.2 grams, an amount agreeing well with the average excess found in the first subperiods of the animal experiments.

In the light of the foregoing results and discussion, we feel justified in concluding that the results of a single experiment with the respiration calorimeter may be regarded as accurate to within approximately the following percentages of the total amounts determined:

	Per cent.
Carbon dioxid	0. 5
Water (in aspirator samples)	6. 0
Heat	1. 0

APPENDIX.

MEASUREMENTS, WEIGHTS, AND FEEDING RECORD OF ANIMALS.

TABLE I.—*Measurements of animals.*

Date.	Chest girth.	Length from poll to root of tail.	Thickness at shoulder.	Thickness at paunch.	Thickness at hips.	Depth of chest.	Height of shoulder.
Steer A.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Nov. 1, 1904	60.0	67.0	15.0	21.0	16.0	21.5	44.75
Dec. 6, 1904	61.0	67.0	16.75	22.0	18.5	22.0	45.00
June 5, 1905	62.5	69.0	16.0	19.75	16.0	21.0	44.5
Feb. 1, 1905	61.0	67.0	15.75	20.25	16.25	22.0	45.0
Mar. 1, 1905	62.5	66.0	16.25	20.25	16.0	21.5	44.0
Apr. 3, 1905	61.25	66.0	15.25	20.0	15.25	22.0	45.25
May 1, 1905	62.0	[1] 66.75	16.0	20.5	16.25	23.0	46.25
June 1, 1905	64.0	67.0	17.0	22.5	17.75	23.5	46.5
July 3, 1905	63.5	70.0	16.75	22.0	16.5	23.25	47.5
July 31, 1905	64.5	69.5	16.0	22.75	16.75	24.0	46.0
Oct. 4, 1905	66.0	72.0	18.0	23.25	16.5	24.25	47.5
Oct. 31, 1905	66.0	72.5	17.25	23.5	16.5	24.5	47.0
Dec. 2, 1905	68.5	72.5	17.5	26.0	17.0	24.75	48.25
Feb. 5, 1906	71.75	72.5	18.75	25.0	18.0	25.5	49.25
Mar. 5, 1906	71.5	72.0	18.75	22.0	17.75	25.25	49.0
Apr. 6, 1906	71.5	72.0	18.75	22.5	18.5	25.0	49.0
May 5, 1906	72.0	72.0	18.75	25.75	18.0	25.75	49.5
June 5, 1906	73.0	72.0	18.75	28.50	[1] 19.0	26.0	49.5
July 7, 1906	75.0	72.0	18.5	25.5	[1] 21.0	26.5	50.0
Aug. 6, 1906	74.5	73.0	17.5	22.5	17.5	25.5	50.0
Sept. 8, 1906	73.0	73.5	17.5	22.5	[1] 17.0	25.0	50.5
Oct. 6, 1906	74.0	73.5	17.5	24.0	18.0	26.5	50.75
Nov. 5, 1906	75.0	73.0	18.0	25.5	18.0	26.5	50.75
Dec. 6, 1906	74.25	73.0	18.5	27.0	18.25	26.75	50.5
Jan. 5, 1907	74.25	72.5	18.75	26.5	18.75	27.25	51.0
Feb. 4, 1907	75.0	74.0	19.0	26.0	18.5	27.25	51.0
Mar. 15, 1907	76.5	74.25	19.25	27.0	18.5	27.5	51.0
Apr. 5, 1907	77.0	74.5	19.0	31.0	18.75	27.5	51.5
May 9, 1907	76.5	74.5	19.5	28.5	18.75	27.75	51.5
Steer B.							
Nov. 1, 1904	58.0	61.0	11.5	17.0	13.25	21.25	44.75
Dec. 6, 1904	58.0	63.0	13.5	19.25	14.5	21.5	45.75
Jan. 5, 1905	56.0	64.0	12.5	17.75	13.5	21.25	46.0
Feb. 1, 1905	57.0	65.0	12.5	17.5	13.5	22.5	44.5
Mar. 1, 1905	56.0	63.0	12.25	17.5	13.0	21.5	45.5
Apr. 3, 1905	56.5	64.0	12.0	16.75	13.0	22.25	46.5
May 1, 1905	58.0	63.5	12.75	16.25	13.5	21.5	46.0
June 1, 1905	58.5	62.5	11.75	18.5	14.0	23.0	47.5
July 3, 1905	59.0	63.5	14.0	19.0	14.5	22.0	48.25
July 31, 1905	60.0	65.0	14.0	18.5	14.5	23.75	48.75
Oct. 4, 1905	60.5	67.0	14.75	19.25	15.0	24.25	49.25
Oct. 31, 1905	61.0	67.0	14.75	20.75	15.25	24.5	49.5
Dec. 2, 1905	63.75	67.0	14.75	23.0	15.5	24.75	50.0
Feb. 5, 1906	67.0	69.5	15.0	19.25	15.75	25.5	51.75
Mar. 5, 1906	68.0	69.0	15.25	19.0	15.5	25.75	52.25
Apr. 6, 1906	68.0	69.25	16.0	20.5	15.5	25.75	52.0
May 5, 1906	68.0	70.0	15.5	20.0	16.25	25.5	52.0
June 5, 1906	70.0	70.0	15.25	21.0	16.5	26.0	53.0
July 7, 1906	70.5	70.0	15.75	20.5	16.5	26.75	53.0
Aug. 6, 1906	70.5	70.0	[1] 14.75	18.5	16.5	[1] 25.5	53.0
Sept. 8, 1906	71.0	71.0	15.0	19.0	16.0	26.0	[1] 52.5
Oct. 6, 1906	72.0	72.0	16.0	21.0	16.5	27.0	52.75
Nov. 5, 1906	71.0	73.0	16.0	21.5	16.75	27.25	54.0
Dec. 6, 1906	71.0	73.0	16.25	20.75	17.0	27.5	54.0
Jan. 5, 1907	72.0	72.75	16.25	22.5	17.5	28.0	54.0
Feb. 4, 1907	71.0	73.0	16.25	19.0	17.5	28.25	54.0
Mar. 15, 1907	72.5	73.25	16.5	22.0	17.5	28.75	54.0
Apr. 5, 1907	71.0	74.0	16.5	19.5	17.5	28.5	54.25
May 9, 1907	71.5	73.5	16.25	21.5	17.5	28.5	54.5

[1] Probably some error.

TABLE II.—*Live weights.*

Date.	Steer A.	Steer B.
1904.	*Kilos.*	*Kilos.*
Sept. 29	243.2	170.4
Sept. 30	244.1	169.1
Oct. 1	250.9	171.8
Oct. 2	248.6	173.2
Oct. 3	245.9	170.7
Oct. 7	253.2	175.5
Oct. 14	249.3	177.3
Oct. 21	253.9	180.5
Oct. 28	254.1	180.7
Oct. 29	254.1	180.2
Nov. 4	259.1	192.0
Nov. 11	268.6	194.0
Nov. 18	276.4	200.2
Nov. 28	273.6	191.8
Nov. 29	275.0	208.6
Nov. 30	260.0	208.2
Dec. 1	270.4	207.2
Dec. 2	273.6	207.5
Dec. 3	270.9	211.8
Dec. 4	278.1	217.2
Dec. 5	282.4	220.4
Dec. 6	279.5	218.1
Dec. 7	280.8	218.8
Dec. 8	284.5	217.2
Dec. 9	279.0	216.3
Dec. 10	283.6	220.4
Dec. 12	280.0	212.0
Dec. 13	280.0	211.3
Dec. 14	281.2	208.0
Dec. 17	284.8	207.2
Dec. 18	280.0	201.0
Dec. 19	280.0	207.2
Dec. 29	278.5	204.2
Dec. 30	277.8	206.8
Dec. 31	280.8	206.0
1905.		
Jan. 2	279.3	....
Jan. 3	274.3	....
Jan. 4	276.0	....
Jan. 5	271.4	....
Jan. 6	270.3	....
Jan. 7	270.5	....
Jan. 8	266.9	....
Jan. 9	266.0	204.3
Jan. 10	270.8	199.0
Jan. 11	270.1	....
Jan. 12	270.5	....
Jan. 13	270.7	....
Jan. 14	269.1	....
Jan. 15	268.4	....
Jan. 16	267.1	....
Jan. 17	[1] 270.1 [2] 273.6	205.9
Jan. 18	....	196.5
Jan. 19	268.0	200.0
Jan. 20	262.4	202.0
Jan. 21	271.4	199.5
Jan. 22	278.4	199.3
Jan. 23	266.1	196.2
Jan. 24	....	[3] 197.3 [4] 197.2 [2] 195.6
Jan. 26	....	206.0
Jan. 27	....	201.0
Jan. 28	....	191.7
Feb. 7	285.4	....
Feb. 8	280.1	....
Feb. 9	279.3	....
Feb. 10	279.0	....
Feb. 11	279.2	....
Feb. 12	282.0	....
Feb. 13	279.6	....
Feb. 14	[3] 286.3 [2] 292.2	....
Feb. 15	....	191.4
Feb. 16	274.7	193.4
Feb. 17	270.2	192.6
Feb. 18	281.5	192.3
Feb. 19	....	194.4
Feb. 20	....	196.0

Date.	Steer A.	Steer B.
1905.	*Kilos.*	*Kilos.*
Feb. 21	....	[3] 197.5 [2] 197.0
Feb. 23	....	193.0
Feb. 24	....	190.6
Feb. 25	....	193.0
Feb. 28	278.0	....
Mar. 1	279.5	....
Mar. 2	281.3	....
Mar. 3	276.6	....
Mar. 4	273.4	....
Mar. 5	273.6	....
Mar. 6	270.4	....
Mar. 7	272.1	....
Mar. 9	267.8	....
Mar. 10	264.2	....
Mar. 11	264.4	....
Mar. 15	....	198.4 [5] 197.4
Mar. 16	....	193.4
Mar. 17	....	193.5
Mar. 18	....	197.0
Mar. 19	....	193.5
Mar. 20	....	194.2
Mar. 21	276.5	198.6 [5] 198.1
Mar. 22	277.0	....
Mar. 23	275.2	182.2
Mar. 24	278.2	179.4
Mar. 25	275.3	189.9
Mar. 26	273.3	....
Mar. 27	280.0	....
Mar. 28	[3] 280.7 [5] 291.3	....
Mar. 30	280.7	....
Mar. 31	276.0	....
Apr. 1	274.2	....
Apr. 26	....	201.0
Apr. 27	269.0	196.3
Apr. 28	284.0	194.6
Apr. 29	281.3	195.6
Apr. 30	....	197.6
May 1	....	198.7
May 2	....	[3] 200.0 [5] 205.4
May 4	....	196.2
May 5	....	194.5
May 6	283.0	194.3
May 29	314.0	217.0
May 30	312.4	220.9
May 31	310.5	217.5
June 28	313.0	227.0
June 29	315.4	228.4
June 30	317.0 317.6	229.0 230.0
July 1	315.0	230.7
July 2	311.0	228.0
July 3	310.0	229.0
July 4	309.5	227.5
July 5	310.5	231.0
July 6	309.0	229.0
July 7	309.0	231.5
July 8	310.0	231.0
July 9	312.0	231.5
July 10	311.0	233.0
July 11	313.0	234.0
July 12	314.5	231.5
July 13	314.0	233.0
July 14	315.0	235.5
July 15	315.0	234.0
July 27	328.5	244.5
July 28	334.0	241.5
July 29	337.4	246.0
Aug. 12	335.0	249.0
Aug. 19	341.6	256.0
Aug. 29	346.0	261.0
Aug. 30	345.5	257.0
Aug. 31	342.0	258.0
Sept. 9	350.4	262.0
Sept. 16	361.0	266.2
Sept. 27	361.3	263.0
Sept. 28	360.2	265.0

[1] 7 a. m. [2] 1.30 p. m. [3] 8 a. m. [4] 10 a. m. [5] 1 p. m.

TABLE II.—*Live weights*—Continued.

Date.	Steer A.	Steer B.
1905.	*Kilos.*	*Kilos.*
Sept. 29	358.4	262.4
Oct. 7	360.4	256.6
Oct. 14	360.6	263.4
Oct. 21	354.0	275.0
Oct. 28	360.6	275.4
Oct. 30	363.0	285.0
Oct. 31	372.4	290.0
Nov. 1	370.0	287.5
Nov. 4	365.0	286.0
Nov. 7	369.4	286.9
Nov. 8	368.4	275.5
Nov. 9	369.2	290.8
Nov. 10	368.4	283.8
Nov. 11	370.4	283.3
Nov. 12	370.9	281.3
Nov. 13	371.9	283.8
Nov. 14	379.9	285.3
Nov. 15	377.4	287.3
Nov. 16	377.4	288.3
Nov. 17	381.9	287.3
Nov. 18	378.9	287.3
Nov. 19	380.4	289.8
Nov. 20	380.9	290.8
Nov. 21	381.4	290.3
Nov. 22	382.4	289.8
Nov. 25	376.3	286.6
Nov 27	385.0	295.0
Nov. 28	387.5	296.4
Nov. 29	389.5	299.0
Dec. 9	395.2	307.7
Dec. 29	404.0	305.9
1906.		
Jan. 7	396.5	....
Jan. 8	398.3	....
Jan. 9	398.5	....
Jan. 10	393.0	....
Jan. 11	399.9	....
Jan. 12	396.3	....
Jan. 13	398.7	312.1
Jan. 14	389.9	310.8
Jan. 15	399.1	299.5
Jan. 16	397.3	290.5
Jan. 17	396.8	310.9
Jan. 18	395.5	307.6
Jan 19	391.2	306.5
Jan. 20	400.0	305.0
Jan. 21	397.5	305.0
Jan. 22	401.0	305.0
Jan. 23	411.5	304.4
Jan. 24	....	295.0
Jan. 25	407.7	298.2
Jan. 26	399.6	301.4
Jan. 27	406.4	298.4
Jan. 28	....	290.0
Jan. 29	....	300.9
Jan. 30	....	296.2
Jan. 31	....	{ 301.0 [1] 297.6
Feb. 2	....	301.6
Feb. 9	420.9	....
Feb. 10	415.0	....
Feb. 11	417.4	....
Feb. 12	419.2	....
Feb. 13	420.8	....
Feb. 14	418.0	....
Feb. 15	422.0	....
Feb. 16	417.2	316.0
Feb. 17	421.8	318.6
Feb. 18	417.0	314.0
Feb. 19	422.0	316.4
Feb. 20	425.7	307.8
Feb. 21	....	309.3
Feb. 22	424.6	316.1
Feb. 23	410.0	312.2
Feb. 24	424.6	310.4
Feb. 25	....	310.9
Feb. 26	....	309.5
Feb. 27	....	[2] 311.4

Date.	Steer A.	Steer B.
1906.	*Kilos.*	*Kilos.*
Mar. 1	....	311.5
Mar. 2	419.9	303.6
Mar. 3	410.0	310.7
Mar. 4	421.0	....
Mar. 5	410.2	....
Mar. 6	395.6	....
Mar. 7	410.2	....
Mar. 8	398.6	....
Mar. 9	408.6	304.4
Mar. 10	398.2	295.6
Mar. 11	397.2	300.0
Mar. 12	398.3	301.5
Mar. 13	[2] 400.3	299.2
Mar. 14	....	292.3
Mar. 15	[3] 404.1	298.2
Mar. 16	397.0	296.3
Mar. 17	397.9	298.2
Mar. 18	....	293.7
Mar. 19	....	291.4
Mar. 20	....	[2] 301.4
Mar. 22	....	303.1
Mar. 23	398.8	296.6
Mar. 24	404.4	295.4
Mar. 25	404.9	....
Mar. 26	406.9	....
Mar. 27	406.3	....
Mar. 28	404.2	....
Mar. 29	406.4	....
Mar. 30	406.0	297.0
Mar. 31	407.7	299.2
Apr. 1	408.4	302.0
Apr. 2	409.4	299.6
Apr. 3	[2] 412.6	305.5
Apr. 4	....	305.3
Apr. 5	[3] 410.0	307.5
Apr. 6	398.0	306.4
Apr. 7	401.7	307.2
Apr. 9	....	308.0
Apr. 10	....	[2] 312.6
Apr. 12	....	[4] 313.9
Apr. 13	....	305.0
Apr. 14	406.8	304.8
Apr. 21	406.8	311.8
Apr. 28	419.4	317.2
Apr. 29	422.4	317.8
Apr. 30	418.8	315.6
May 5	434.6	317.4
May 12	443.2	317.4
May 19	444.6	328.8
May 26	442.6	322.4
May 28	452.0	325.2
May 29	453.6	335.0
May 30	454.4	327.4
June 2	450.0	328.4
June 9	450.8	330.0
June 16	468.6	340.2
June 19	456.0	338.4
June 20	453.0	331.0
June 21	453.8	340.2
June 22	453.0	335.0
June 23	458.0	335.2
June 24	455.6	340.0
June 25	459.6	334.0
June 26	450.4	336.0
June 27	451.0	338.4
June 28	454.6	336.2
June 29	451.4	339.2
June 30	429.0	337.4
July 1	447.4	342.2
July 2	450.4	344.8
July 3	457.8	343.2
July 4	457.2	343.0
July 5	458.6	342.6
July 6	456.3	342.0
July 14	450.6	334.0
July 21	448.0	328.0
July 28	456.6	335.4
Aug. 4	456.2	329.6
Aug. 11	447.4	330.0

[1] 1 p. m. [2] 8.30 a. m. [3] 6.16 p. m. [4] 6.30 p. m.

TABLE II.—*Live weights*—Continued.

Date.	Steer A.	Steer B.
1906.	*Kilos.*	*Kilos.*
Aug. 18	443.4	333.2
Aug. 25	447.2	332.0
Sept. 1	448.2	337.6
Sept. 8	439.4	337.8
Sept. 15	442.2	334.6
Sept. 22	442.4	337.2
Sept 29	450.2	348.0
Oct. 1	441.6	340.2
Oct. 2	451.2	347.0
Oct. 3	451.2	347.6
Oct. 6	454.0	350.8
Oct. 13	459.8	357.0
Oct. 20	459.2	349.4
Oct. 27	466.8	363.2
Nov. 3	469.8	370.4
Nov. 5	478.0	370.0
Nov. 6	475.4	371.6
Nov. 7	474.4	372.8
Nov. 10	468.3	376.3
Nov. 17	483.0	376.0
Nov. 24	484.6	380.6
Dec. 1	484.6	383.2
Dec. 3	493.6	373.2
Dec. 4	494.6	382.6
Dec. 5	497.2	381.8
Dec. 8	498.2	385.2
Dec. 15	501.6	396.4
Dec. 22	506.0	392.4
Dec. 30	497.0	383.0
Dec. 31	511.0	393.0
1907.		
Jan. 1	504.6	392.6
Jan. 3	489.8	388.2
Jan. 12	480.8	367.0
Jan. 19	492.4	363.8
Jan. 23	497.6	....
Jan. 24	483.2	....
Jan. 25	487.6	....
Jan. 26	493.0	374.8
Jan. 27	483.2	....
Jan. 28	497.0	....
Jan. 29	497.6	....
Jan. 30	493.6	....
Jan. 31	497.8	367.0
Feb. 1	500.0	366.8
Feb. 2	500.0	369.2
Feb. 3	500.4	373.0
Feb. 4	500.0	363.0
Feb. 5	[1] 504.6	371.2
Feb. 6	....	371.6
Feb. 7	498.3	[2] 370.4
Feb. 8	489.0	372.0
Feb. 9	499.0	363.0
Feb. 10	....	371.2
Feb. 11	....	371.0
Feb. 12	....	[3] 368.8 [4] 379.0
Feb. 14	....	[5] 373.6
Feb. 15	....	365.2
Feb. 16	....	365.8
Feb. 21	516.8	....
Feb. 22	518.0	....
Feb. 23	517.8	....
Feb. 24	519.6	....
Feb. 25	519.4	....
Feb. 26	517.4	....
Feb. 27	516.4	....

Date.	Steer A.	Steer B.
1907.	*Kilos.*	*Kilos.*
Feb. 28	519.4	381.4
Mar. 1	516.4	381.2
Mar. 2	519.6	381.0
Mar. 3	516.6	382.4
Mar. 4	521.4	379.0
Mar. 5	[6] 528.0 [7] 536.0	384.2
Mar. 6	....	384.6
Mar. 7	[5] 522.0	380.0
Mar. 8	507.0	380.6
Mar. 9	517.0	383.2
Mar. 10	518.0	386.0
Mar. 11	509.0	386.2
Mar. 12	510.4	[8] 391.2 [9] 392.0
Mar. 13	510.4	....
Mar. 15	522.0	380.6
Mar. 16	522.0	388.0
Mar. 17	513.0	389.6
Mar. 18	516.0	380.2
Mar. 19	519.4	380.0
Mar. 20	515.4	386.8
Mar. 21	509.0	385.0
Mar. 22	510.4	375.2
Mar. 23	510.2	382.0
Mar. 24	509.4	368.0
Mar. 25	509.0	372.0
Mar. 26	[10] 501.8 [11] 515.2	363.4
Mar. 27	....	374.8
Mar. 28	[5] 511.0	378.6
Mar. 29	503.6	372.0
Mar. 30	509.0	377.0
Mar. 31	493.0	374.0
Apr. 1	500.8	372.4
Apr. 2	499.0	[10] 376.4 [7] 372.6
Apr. 3	497.0	....
Apr. 4	503.2	[5] 376.8
Apr. 5	505.0	368.0
Apr. 6	508.0	374.4
Apr. 7	506.6	371.4
Apr. 8	511.6	370.0
Apr. 9	512.0	373.2
Apr. 10	512.2	373.0
Apr. 11	513.4	386.0
Apr. 12	511.0	378.4
Apr. 13	510.4	382.0
Apr. 14	514.0	379.6
Apr. 15	515.8	384.6
Apr. 16	[10] 518.0 [9] 532.0	386.4
Apr. 17	....	387.6
Apr. 18	[5] 518.4	387.6
Apr. 19	506.2	381.8
Apr. 20	513.0	384.6
Apr. 21	....	383.8
Apr. 22	....	383.2
Apr. 23	....	[10] 390.0 389.0
Apr. 25	....	[5] 389.6
Apr. 26	511.0	379.4
Apr. 27	514.6	383.4
Apr. 28	517.0	....
Apr. 29	520.4	....
Apr. 30	[12] 533.4 [13] 540.4	....
May 1	[5] 529.6	....

[1] 8.15 a. m.
[2] 6.15 p. m.
[3] 8 a. m.
[4] 1.15 p. m
[5] 6 p. m.
[6] 7.35 a. m.
[7] 1.20 p .m.
[8] 7.20 a. m.
[9] 1 p. m.
[10] 7.30 a. m.
[11] 1.10 p. m.
[12] 8.30 a. m.
[13] 3.10 p. m.

The following are the average monthly live weights which are shown graphically in figure 5:

TABLE IIa.—*Average live weights.*

Steer A.	Weight.	Steer B.	Weight.
1904.	*Kilos.*	1904.	*Kilos.*
Sept. 29–Oct. 3	246.5	Sept. 29–Oct. 3	171.0
Nov. 4	259.1	Nov. 4	192.0
Nov. 29–Dec. 3	270.0	Nov. 29–Dec. 3	208.7
1905.		Dec. 29–31	205.7
Dec. 30–Jan. 3	278.1	1905.	
Feb. 7–11	280.6	Jan. 26–28	199.6
Mar. 1–5	276.9	Feb. 23–25	192.2
Mar. 30–Apr. 1	277.0	Mar. 23–25	183.8
Apr. 27–29	278.1	Apr. 28–May 2	198.4
May 29–31	312.3	May 29–31	218.5
June 29–July 3	313.7	June 29–July 3	229.0
July 27–July 29	333.3	July 27–29	244.0
Aug. 29–31	344.5	Aug. 29–31	258.7
Sept. 27–29	360.0	Sept. 27–29	263.5
Oct. 30–Nov. 1	368.5	Oct. 30–Nov. 1	287.5
Nov. 27–29	387.3	Nov. 27–29	296.8
Dec. 29	404.0	Dec. 29	305.9
1906.		1906.	
Jan. 25–27	404.6	Jan. 29–Feb. 2	299.9
Mar. 2–5	411.3	Feb. 27–Mar. 3	309.3
Mar. 30–Apr. 3	408.7	Mar. 30–Apr. 3	300.7
Apr. 28–30	420.2	Apr. 28–30	316.9
May 28–30	453.3	May 28–30	329.2
June 29–July 3	451.8	June 29–July 3	341.4
Aug. 4	456.2	Aug. 4	329.6
Sept. 1	448.2	Sept. 1	337.6
Oct. 1–3	448.0	Oct. 1–3	344.9
Nov. 3	469.0	Nov. 3	370.4
Dec. 1–5	492.5	Dec. 1–5	380.2
1907.		1907.	
Dec. 30–Jan. 3	500.6	Dec. 30–Jan. 3	389.2
Jan. 31–Feb. 3	498.4	Jan. 31–Feb. 3	369.0
Feb. 27–Mar. 3	517.7	Feb. 28–Mar. 4	381.0
Mar. 30–Apr. 3	499.8	Mar. 29–Apr. 2	374.4
Apr. 27–May 1	523.0	Apr. 25–27	384.1
Oct. 28	592.8	Oct. 28	427.8
1908.		1908.	
Jan. 4	631.4	Jan. 4	482.2

TABLE III.—*Feeding record.*

Date.	Length of feeding.	Kind of feed.	Hay.		Grain.		Air-dry matter.	Nitrogen.
			Steer A.	Steer B.	Steer A.	Steer B.		
1904.	*Days.*		*Kilos.*	*Kilos.*	*Kilos.*	*Kilos.*	*Per cent.*	*Per cent.*
Oct. 1–31	31	Mixed hay	106.82	106.82			[1] 91.80	1.873
Do	31	Wheat bran			7.57	5.28	92.10	2.475
Do	31	Corn meal			22.71	15.84	92.80	1.450
Do	31	Linseed meal			22.71	15.84	94.40	5.235
Nov. 1–30	30	Mixed hay	109.09	109.09			[1] 91.80	[1] 1.873
Do	30	Wheat bran			7.62	5.41	92.10	2.475
Do	30	Corn meal			22.86	16.23	92.80	1.450
Do	30	Linseed meal			22.86	16.23	94.40	5.235
Dec. 1–10	10	Mixed hay	36.29	36.29			91.80	1.873
Do	10	Wheat bran			2.535	1.265	91.50	2.460
Do	10	Corn meal			7.605	3.795	92.50	1.413
Do	10	Linseed meal			7.605	3.795	93.50	5.380
Dec. 11–24	14	Timothy hay [2]	29.19	25.75			[1] 92.36	[1] .859
Do	14	Wheat bran [2]			21.050	15.450	[1] 91.10	[1] 2.530
Dec. 25–31	7	Timothy hay	15.75	14.00			92.36	.859
Do	7	Wheat bran			11.200	8.400	91.10	2.530

[1] Assumed.

[2] Amount gradually increased.

TABLE III.—*Feeding record*—Continued.

Date.	Length of feeding.	Kind of feed.	Hay.		Grain.		Air-dry matter.	Nitrogen.
			Steer A.	Steer B.	Steer A.	Steer B.		
1905.	*Days.*		*Kilos.*	*Kilos.*	*Kilos.*	*Kilos.*	*Per cent.*	*Per cent.*
Jan. 1-14	14	Timothy hay	31.50				92.36	.859
Do	14	Wheat bran			22.40		91.10	2.530
Jan. 15-21	7	Timothy hay	15.75				91.21	.880
Do	7	Wheat bran			11.20		90.10	2.553
Jan. 1-7	7	Timothy hay		14.00			[1] 92.36	[1] .859
Do	7	Wheat bran				8.40	[1] 91.10	2.530
Jan. 8-28	21	Timothy hay		42.00			92.36	.859
Do	21	Wheat bran				25.20	91.10	2.530
Jan. 22-28	7	Timothy hay	15.75				[1] 93.25	[1] .860
Do	7	Wheat bran			[2] 18.10		[1] 91.09	[1] 2.616
Jan. 29-Feb. 18	21	Timothy hay	47.25				93.23	.860
Do	21	Wheat bran			63.00		91.09	2.616
Feb. 19-Mar. 11	21	Timothy hay	47.25				94.00	.925
Mar. 12-Apr. 1	21	do	90.50				91.60	.793
Jan. 29-Feb. 4	7	do		14.00			[1] 94.00	[1] .925
Do	7	Wheat bran				[3] 11.50	[1] 91.09	[1] 2.616
Feb. 5-25	21	Timothy hay		42.00			93.23	.860
Feb. 26-28	3	do		6.00			93.23	.860
Do	3	Wheat bran				6.00	[1] 91.09	[1] 2.616
Mar. 1-25	25	Timothy hay		75.00			92.70	.878
Mar. 26-Apr. 7	13	do		26.00			[1] 92.70	[1] .878
Do	13	Wheat bran				3.215	[1] 91.10	2.630
Do	13	Corn meal				9.645	[1] 92.50	[1] 1.413
Do	13	Linseed meal				9.645	[1] 93.50	[1] 5.380
Apr. 8-13	6	Timothy hay		12.00			[1] 100.70	[1] .870
Do	6	Wheat bran				15.00	[1] 98.00	[1] 2.460
Apr. 14-May 6	23	Timothy hay		26.00			100.70	.870
Do	23	Wheat bran				26.00	98.00	2.460
Apr. 2-May 2	32	Timothy hay	72.00				[1] 91.60	[1] .793
Do	32	Wheat bran			10.285		94.00	2.485
Do	32	Corn meal			30.855		88.50	1.391
Do	32	Linseed meal			30.855		97.70	5.439
May 3-26	24	Mixed hay	110.75				[1] 98.04	1.803
Do	24	Wheat bran			8.555		94.00	2.485
Do	24	Corn meal			25.665		88.50	1.391
Do	24	Linseed meal			25.665		97.70	5.439
May 7-26	20	Mixed hay		90.00			[1] 98.04	[1] 1.803
Do	20	Wheat bran				5.555	94.00	2.485
Do	20	Corn meal				16.665	88.50	1.391
Do	20	Linseed meal				16.665	97.70	5.439
May 27-June 30	35	Mixed hay	106.05	102.69			[1] 98.04	[1] 1.803
Do	35	Wheat bran			12.50	10.00	94.00	2.485
Do	35	Corn meal			37.50	30.00	88.50	1.391
Do	35	Linseed meal			37.50	30.00	97.70	5.439
July 1-15	15	Mixed hay	42.00	42.00			92.50	2.020
Do	15	Wheat bran			5.40	4.275	98.00	2.400
Do	15	Corn meal			16.20	12.825	96.80	1.340
Do	15	Linseed meal			16.20	12.825	102.00	4.950
July 16-18	3	Mixed hay	5.20	4.40			[1] 92.50	[1] 2.020
July 16-28	13	Alfalfa	219.35	218.00			25.74	2.700
July 29-Aug. 8	11	Soja beans	132.00	132.00			20.75	2.110
Aug. 9-14	6	Cowpeas	72.00	72.00			14.26	2.750
Aug. 15-31	17	Kafir corn and cowpeas.	204.00	204.00			16.57	1.370
Sept. 1-5	5	Alfalfa	60.00	60.00			25.60	3.110
Sept. 6-20	15	Cowpeas	180.00	180.00			15.70	2.880
Sept. 21-Oct. 3	13	Green corn	156.00	156.00			12.00	1.830
Oct. 4-5	2	Clover and grass	24.00	24.00			62.50	2.340
Oct. 6-30	25	Timothy hay	79.83	70.88			99.23	1.210
July 16-Aug. 2	18	Wheat bran			6.43	5.14	94.00	2.485
Do	18	Corn meal			19.29	15.42	88.50	1.391
Do	18	Linseed meal			19.29	15.42	97.70	5.439
Aug. 3-Oct. 13	72	Wheat bran			25.715	20.57	97.26	2.515
Do	72	Corn meal			77.145	61.71	96.33	1.475
Do	72	Linseed meal			77.145	61.71	98.00	5.490
Oct. 14-Nov. 6	24	Wheat bran			8.57	6.855	97.22	2.567
Do	24	Corn meal			25.710	20.565	92.00	1.440
Do	24	Linseed meal			25.710	20.565	95.00	6.000
Oct. 31-Nov. 6	7	Timothy with some clover.	35.00	32.40			90.70	1.620
Nov. 7-21	15	do	51.60	54.00			91.97	1.490
Do	15	Wheat bran			5.40	4.275	91.84	2.710
Do	15	Corn meal			16.20	12.825	91.25	1.490

[1] Assumed. [2] Amount gradually increased. [3] Started to increase, but stopped.

TABLE III.—*Feeding record*—Continued.

Date.	Length of feeding.	Kind of feed.	Hay.		Grain.		Air-dry matter.	Nitrogen.
			Steer A.	Steer B.	Steer A.	Steer B.		
1905–6.	*Days.*		*Kilos.*	*Kilos.*	*Kilos.*	*Kilos.*	*Per cent.*	*Per cent.*
Nov. 7–21	15	Linseed meal			16.20	12.825	94.52	5.930
Nov. 22–Jan. 6	46	Timothy with some clover.	183.00				90.70	1.620
Nov. 22–Jan. 13	53	do		210.00			90.70	1.620
Nov. 22–Dec. 3	12	Wheat bran			4.035	2.925	97.22	2.567
Do	12	Corn meal			12.105	8.775	92.00	1.440
Do	12	Linseed meal			12.105	8.775	95.00	6.000
Dec. 4–16	13	Wheat bran			[1]1.355	1.535	92.00	2.985
Do	13	Corn meal			[1]4.065	4.605	88.83	1.495
Do	13	Linseed meal			[1]4.065	4.605	94.00	5.885
Dec. 4–21	18	Wheat bran[3]			[2]28.000	22.000	92.00	2.985
Dec. 22–Jan. 6	16	do			3.285		92.00	2.985
Do	16	Corn meal			18.885		88.83	1.495
Do	16	Linseed meal			18.885		94.00	5.885
Dec. 22–Jan. 13	23	Wheat bran				6.900	92.00	2.985
Do	23	Corn meal				20.700	88.83	1.495
Do	23	Linseed meal				20.700	94.00	5.885
1906.								
Jan. 7–27	21	Timothy hay	63.00				92.08	1.250
Do	21	Wheat bran			6.300		91.50	2.953
Do	21	Corn meal			18.900		87.50	1.647
Do	21	Linseed meal			18.900		93.20	5.903
Jan. 14–Feb. 3	21	Timothy hay		58.80			92.08	1.250
Do	21	Wheat bran				4.200	91.50	2.953
Do	21	Corn meal				12.600	87.50	1.647
Do	21	Linseed meal				12.600	93.20	5.903
Jan. 28–Feb. 3	7	Timothy hay	21.00				92.50	1.257
Do	7	Wheat bran			[2]4.023		92.00	2.985
Do	7	Corn meal			[2]12.175		88.83	1.495
Do	7	Linseed meal			[2]12.175		94.00	5.885
Feb. 4–24	21	Timothy hay	63.00				92.50	1.257
Do	21	Wheat bran			14.700		90.40	2.813
Do	21	Corn meal			44.100		88.20	1.470
Do	21	Linseed meal			44.100		93.10	5.547
Feb. 4–10	7	Timothy hay		19.60			92.50	1.257
Do	7	Wheat bran				[2]3.055	91.50	2.953
Do	7	Corn meal				[2]9.165	87.50	1.647
Do	7	Linseed meal				[2]9.165	93.20	5.903
Feb. 11–18	8	Timothy hay		22.40			92.50	1.257
Do	8	Wheat bran				4.000	90.40	2.813
Do	8	Corn meal				12.000	88.20	1.470
Do	8	Linseed meal				12.000	93.10	5.547
Feb. 19–21	3	Off feed						
Feb. 22–Mar. 3	10	Timothy hay		28.00			92.50	1.257
Do	10	Wheat bran				3.570	90.40	2.813
Do	10	Corn meal				10.720	88.20	1.470
Do	10	Linseed meal				10.710	93.10	5.547
Feb. 25–Mar. 17	21	Timothy hay	63.00				94.99	1.157
Mar. 4–24	21	do		58.80			94.99	1.157
Mar. 18–Apr. 7	21	do	105.00				94.54	1.267
Mar. 25–Apr. 14	21	do		90.30			94.54	1.267
Apr. 8–12	5	Wheat bran			2.000		92.00	2.985
Do	5	Corn meal			6.000		88.83	1.495
Do	5	Linseed meal			6.000		94.00	5.885
Apr. 8–May 18	41	Mixed hay	212.40				90.70	1.620
Apr. 13–May 1	19	Wheat bran			10.640		93.30	2.806
Do	19	Corn-and-cob meal			31.920		93.50	1.375
Do	19	Linseed meal			10.640		97.20	5.391
Apr. 15–May 18	34	Mixed hay		174.70			90.70	1.620
Apr. 15–May 1	17	Wheat bran				7.140	93.30	2.806
Do	17	Corn-and-cob meal				21.420	93.50	1.375
Do	17	Linseed meal				7.140	97.20	5.391
May 2–June 1	31	Wheat bran			18.228	13.276	93.30	2.806
Do	31	Corn-and-cob meal			54.684	39.828	93.50	1.375
Do	31	Linseed meal			18.228	13.276	97.20	5.391
May 19–June 19	32	Mixed hay	179.20	144.60			98.14	1.803
June 2–12	11½	Wheat bran			7.301	5.117	93.30	2.806
Do	11½	Corn-and-cob meal			21.903	15.351	93.50	1.375
Do	11½	Linseed meal			7.301	5.117	97.20	5.391
June 13–19	6½	Wheat bran			4.125	2.995	92.60	2.743
Do	6½	Corn-and-cob meal			12.375	8.985	91.50	1.398
Do	6½	Linseed meal			4.125	2.995	96.30	5.278
June 20–July 6	17	Mixed hay	87.04	69.36			98.04	1.803
Do	17	Wheat bran			10.794	7.819	96.00	2.716
Do	17	Corn-and-cob meal			32.382	23.457	95.30	1.336
Do	17	Linseed meal			10.794	7.819	96.30	5.626

[1] Amount gradually decreased. [2] Amount gradually increased. [3] Fed in addition to mixture.

TABLE III.—*Feeding record*—Continued.

Date.	Length of feeding.	Kind of feed.	Hay.		Grain.		Air-dry matter.	Nitrogen.
			Steer A.	Steer B.	Steer A.	Steer B.		
1905-6.	*Days.*		*Kilos.*	*Kilos.*	*Kilos.*	*Kilos.*	*Per cent.*	*Per cent.*
July 6-9	3	Timothy and clover.	18.00	15.00			48.80	1.395
July 10-17	8	Oats and peas	54.00	54.00			18.19	2.575
July 18-21	4	Alfalfa	28.00	28.00			27.37	2.660
July 22-Aug. 4	14	Ensilage (mixed hay).	98.00	103.50			30.20	[1] 1.995
Aug. 5-22	18	Corn	137.00	154.00			16.79	1.905
Aug. 23-29	7	Alfalfa	49.00	56.00			20.71	2.745
Aug. 30-Sept. 3	5	Cowpeas	35.00	40.00			17.16	2.590
Sept. 4-8	5	Alfalfa	35.00	40.00			28.36	2.550
Sept. 9-22	14	Kafir corn and cowpeas.	122.00	136.00			13.34	1.837
Sept. 23-Oct. 1	9	Corn	92.00	101.00			[1] 16.79	[1] 1.905
Oct. 2-5	5	Grass	44.00	48.00			[1] 62.50	2.340
Oct. 6-10	5	Alfalfa	55.00	60.00			20.52	2.670
Oct. 11-13	3	Corn	33.00	36.00			[1] 12.00	1.830
Oct. 14-26	12½	Ensilage [2]	137.00	150.00			25.90	[1] 1.220
Oct. 26-Nov. 30	35½	do. [2]	216.00	216.00			25.90	[1] 1.220
1906.								
July 7-14	8	Wheat bran			3.997	3.199	92.60	2.743
Do	8	Corn-and-cob meal			11.991	9.597	91.50	1.398
Do	8	Linseed meal			3.997	3.199	96.30	5.278
July 15-31	17	Wheat bran			8.001	7.490	92.60	2.743
Do	17	Corn-and-cob meal			24.003	22.470	91.50	1.398
Do	17	Linseed meal			8.001	7.490	96.30	5.278
Aug. 1-Oct. 4	65	Wheat bran [3]			54.165	50.700	98.00	2.634
Do	65	Corn-and-cob meal			108.330	101.400	81.00	1.071
Oct. 27-Dec. 1	36	Mixed hay	99.60	79.20			98.04	1.803
Oct. 5-Dec. 1	58	Wheat bran			48.330	46.400	98.00	2.604
Do	58	Corn-and-cob meal			96.660	92.800	81.00	1.258
Dec. 2-15	14	Wheat bran			4.665	4.665	98.00	2.604
Do	14	Corn-and-cob meal			9.330	9.330	81.00	1.258
Do	14	Mixed hay	97.00	81.40			98.04	1.803
Dec. 16-31	16	do	102.20	99.60			98.04	1.803
1907.								
Jan. 1-9	9	do	30.60				98.04	1.803
Jan. 1-17	17	do		76.00			98.04	1.803
Jan. 10-19	9½	Timothy hay	32.30				[1] 90.70	1.130
Jan. 18-26	9	do		28.80			[1] 90.70	1.130
Jan. 1-19	18½	Wheat bran [4]			5.020		89.70	2.847
Do	18½	Corn meal			15.060		89.90	1.598
Do	18½	Linseed meal			15.060		91.30	5.537
Jan. 7-26	20	Wheat bran				4.095	89.70	2.847
Do	20	Corn meal				12.285	89.90	1.598
Do	20	Linseed meal				12.285	91.30	5.537
Jan. 20-Feb. 9	21	Timothy hay	71.40				90.70	1.150
Do	21	Wheat bran			7.035		89.70	2.847
Do	21	Corn meal			21.000		89.90	1.598
Do	21	Linseed meal			21.000		91.30	5.537
Jan. 27-Feb. 16	21	Timothy hay		67.20			90.70	1.130
Do	21	Wheat bran				4.935	89.70	2.847
Do	21	Corn meal				14.700	89.90	1.598
Do	21	Linseed meal				14.700	91.30	5.537
Feb. 10-16	7	Timothy hay	23.00				[1] 91.00	[1] 1.100
Do	7	Wheat bran			[3] 4.365		[1] 88.20	2.867
Do	7	Corn meal			13.095		[1] 88.70	[1] 1.628
Do	7	Linseed meal			13.095		[1] 91.80	[1] 5.531
Feb. 17-23	7	Timothy hay		22.40			[1] 91.00	[1] 1.100
Do	7	Wheat bran				[3] 2.575	[1] 88.20	2.867
Do	7	Corn meal				7.725	[1] 88.70	[1] 1.628
Do	7	Linseed meal				7.725	[1] 91.80	[1] 5.531
Feb. 17-Mar. 9	21	Timothy hay	71.40				91.00	1.100
Do	21	Wheat bran			16.800		88.20	2.867
Do	21	Corn meal			50.400		88.70	1.628
Do	21	Linseed meal			50.400		91.80	5.531
Feb. 24-Mar. 16	21	Timothy hay		67.20			91.00	1.100
Do	21	Wheat bran				9.450	88.20	2.867
Do	21	Corn meal				28.350	88.70	1.628
Do	21	Linseed meal				28.350	91.80	5.531
Mar. 10-30	21	Timothy hay	71.40				92.40	1.099
Mar. 17-Apr. 6	21	do		67.20			92.40	1.099
Mar. 31-Apr. 20	21	do	117.60				91.80	1.138
Apr. 7-27	21	do		111.30			91.80	1.138

[1] Assumed.
[2] Ensilage fed one meal, hay the other.
[3] Change of mixture: One-third bran; two-thirds corn-and-cob meal.
[4] Special mixture.

RESPIRATION CALORIMETER EXPERIMENTS OF 1905.

TABLE IV.—*Live weights, water consumed, weights of excreta, and rectal temperatures.*

Date.	Live weight.	Water consumed.	Weight of feces.	Weight of urine.	Rectal temperature.
Period I.					
Steer A:	*Kilos.*	*Kilos.*	*Grams.*	*Grams.*	° *C.*
Jan. 5	271.4	10.2	8,760	2,750	37.9
6	270.3	12.1	6,550	2,655	37.1
7	270.5	12.2	7,380	2,940	36.7
8	266.9	15.4	8,600	3,310	37.2
9	266.0	18.0	8,480	2,490	38.8
10	270.8	14.0	8,540	3,470	39.1
11	270.1	13.9	7,615	3,185	36.8
12	270.5	11.8	7,380	3,335	37.2
13	270.7	12.8	7,785	3,065	37.4
14	269.1	11.9	8,080	3,530	37.0
15	268.4	11.3	7,240	3,550	37.9
16	267.1	11.9	8,005	3,425	37.2
17	[1] 270.1	12.0	6,745	2,645	37.0
17	[2] 273.6				36.7
18			6,830	3,585	
19	[3] 268.0		4,540	2,725	
20	[4] 262.4	22.5	8,135	2,640	38.0
21	[4] 271.4	13.6	6,635	2,930	38.8
22	[5] 278.4		8,160	2,755	
Total			135,460	54,985	
Spilled in calorimeter and stall—					
Jan. 19			25.0	353.7	
21				745.0	
22				550.4	
23			9.2		
From duct—					
Jan. 19			48.2		
Steer B:					
Jan. 19	200.0	10.1	6,220	2,515	37.2
20	202.0	8.7	6,275	2,390	38.2
21	199.5	10.5	5,645		38.0
22	199.3	6.9	5,930	2,260	38.5
23	196.2	7.1	4,730	4,070	37.4
24	[4] 197.3		4,995	2,765	36.1
25			4,265	1,125	
26	[8] 206.0		5,650	1,820	
27	[4] 201.0		6,400	1,905	36.7
28	[6] 191.7	2.9	5,155	1,825	37.5
Total			55,265	20,675	
Spilled in calorimeter—					
Jan. 26			66.7	292.5	
From ducts—					
Jan. 27			42.0		
28			16.2		
Period II.					
Steer A:					
Feb. 7	285.4	8.3			
8	280.1	13.3			36.2
9	279.3	16.1	10,530	4,290	38.1
10	279.0	17.4	9,555	4,605	38.9
11	279.2	20.8	9,560	6,725	38.1
12	282.0	15.1	9,725		38.4
13	279.6	18.4	9,880		38.0
14	[4] 286.3	11.0	11,025	4,985	38.7
14	292.2				37.5
15			8,730	3,995	
16	[7] 274.7		9,040	3,920	38.0
17	[8] 270.2	27.0	7,475		39.2
18	281.5	18.5	9,320	3,790	39.0
Total			94,840	32,310	
Spilled in calorimeter and stall—					
Feb. 17			629.4		
18				449.2	
18				110.0	
From duct—					
Feb. 16			370.2		
18			378.3		

[1] At 7 a. m.
[2] At 1.30 p. m.
[3] At 6 p. m.
[4] At 8 a. m.
[5] At 12 m.
[6] At 1 p. m.
[7] At 8.30 p. m.
[8] At 11 a. m.

TABLE IV.—*Live weights, water consumed, weights of excreta, and rectal temperatures*—Continued.

Date.	Live weight.	Water consumed.	Weight of feces.	Weight of urine.	Rectal temperature.
Period II—Continued.					
Steer B:	*Kilos.*	*Kilos.*	*Grams.*	*Grams.*	°*C.*
Apr. 27	196.3	7.3	5,960	2,740	38.3
28	194.6	11.1	6,470	2,580	38.5
29	195.6	11.7	8,440	2,300	39.0
30	197.6	10.4	7,250	....	38.6
May 1	198.7	6.3	6,730	2,130	38.1
2	[1] 205.4	8.2	6,380	2,075	38.8
2	....	....	....	....	38.7
3	....	....	4,660	2,505	....
4	[2] 196.2	....	9,950	1,655	38.5
5	[1] 194.5	11.6	5,540	2,700	39.0
6	194.3	17.7	7,220	2,580	38.7
Total	....	....	68,600	21,265	....
Spilled in calorimeter and stall—					
May 5	....	....	54.6	408.3	....
5	....	....	....	2,036.0	....
From duct—					
May 4	....	....	179.5	....	....
6	....	....	42.0	....	....
Period III.					
Steer A:					
Mar. 2	281.3	9.0	4,150	3,095	38.7
3	276.6	4.7	4,910	5,145	38.7
4	273.4	10.0	4,505	3,750	38.2
5	273.6	5.6	4,375	5,070	38.1
6	270.4	8.4	3,895	3,330	37.7
7	[1] 272.1	8.1	4,110	3,160	38.4
7	[2] 276.6	....	....	....	38.3
8	....	....	4,235	2,615	....
9	[2] 267.6	....	5,190	1,730	39.1
10	[1] 264.2	12.0	3,800	3,140	39.0
11	264.4	12.5	5,235	4,960	37.6
Total	....	....	44,405	35,995	....
Spilled in calorimeter and stall—					
Mar. 10	....	....	25.2	256.9	....
From duct—					
Mar. 9	....	....	158.5	....	....
11	....	....	9.0	....	....
Steer B:					
Feb. 16	193.4	5.6	3,290	1,585	37.8
17	192.6	4.6	3,160	1,565	38.3
18	192.3	5.7	2,610	1,470	37.5
19	194.4	7.2	3,200	1,100	38.5
20	196.0	6.0	4,410	1,580	38.6
21	[1] 197.5	1.8	4,040	1,655	38.6
21	[2] 197.0	....	....	....	38.7
22	....	....	3,035	1,395	....
23	[2] 193.0	....	4,910	1,375	38.9
24	[1] 190.6	10.0	3,205	1,285	38.6
25	193.0	3.0	4,690	1,655	38.2
Total	....	....	36,550	14,665	....
Spilled in calorimeter and stall—					
Feb. 24	....	....	1.4	....	....
From duct—					
Feb. 23	....	....	10.8	....	....
25	....	....	21.4	....	....
Period IV.					
Steer A:					
Mar. 23	275.2	14.8	8,535	2,165	38.7
24	278.2	10.5	9,505	1,950	38.8
25	275.3	11.2	9,845	2,645	38.6
26	273.3	19.5	10,125	2,440	38.8
27	280.0	12.1	11,385	1,995	38.1
28	[1] 280.7	14.1	10,460	2,365	38.6
28	291.3	....	....	....	38.2
29	....	....	9,390	2,190	....
30	[2] 280.7	....	8,110	2,125	38.7
31	[1] 276.0	15.7	10,435	2,600	39.3
Apr. 1	274.2	16.0	9,690	2,540	38.8
Total	....	....	97,480	23,015	....

[1] At 8 a. m. [2] At 6 p. m.

TABLE IV.—*Live weights, water consumed, weights of excreta, and rectal temperatures*—Continued.

Date.	Live weight.	Water consumed.	Weight of feces.	Weight of urine.	Rectal temperature.
Period IV—Continued.					
Steer A—Continued.					
Spilled in calorimeter and stall—	*Kilos.*	*Kilos.*	*Grams.*	*Grams.*	*° C.*
Mar. 25				196.2	
31			5.0		
From duct—					
Mar. 30			54.0		
Apr. 1			24.0		
Steer B:					
Mar. 16	193.4	8.2	4,910	1,505	38.6
17	193.5	13.5	5,080	1,870	38.5
18	197.0	5.7	7,830	1,840	38.8
19	193.5	9.3	6,835	1,575	38.5
20	194.2	10.0	5,990	1,310	38.2
21	[1] 198.6	1.8	7,095	1,730	38.5
21	198.1				38.5
22			4,910	1,350	
23	[2] 182.2		4,985	1,260	38.6
24	[1] 179.4	20.4	3,830	1,695	38.6
25	189.9	11.8	6,730	1,390	38.4
Total			58,195	15,525	
Spilled in calorimeter and stall—					
Mar. 23				2,388	
24			12.0		
From duct—					
Mar. 23			5.8		
25			4.8		

[1] At 8 a. m. [2] At 6 p. m.

TABLE V.—*Composition of dry matter of feces.*

Component.	Period I.		Period II.		Period III.		Period IV.	
	Steer A.	Steer B.	Steer A.	Steer B.	Steer A.	Steer B.	Steer A.	Steer B.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Ash	7.77	8.77	8.06	9.45	5.67	5.87	5.63	6.50
Protein[1] / Nonprotein[1]	9.83	9.70	10.43	10.18	8.61	9.88	8.10	9.58
Crude fiber	35.47	35.15	33.60	34.05	39.94	38.52	41.08	39.55
Nitrogen-free extract	45.03	43.66	45.61	43.75	43.66	43.55	43.08	42.32
Ether extract	1.90	2.72	2.30	2.57	2.12	2.18	2.11	2.05
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Total nitrogen	1.573	1.552	1.668	1.629	1.376	1.581	1.296	1.533
Protein nitrogen	1.200							1.093
Carbon	47.098	47.256	47.160	46.217	50.558	50.097	49.670	49.733
Hydrogen	5.473	5.662	5.832	6.747	5.777	5.890	6.862	5.702
	Calories.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Energy....per gram	4.6141	4.6810	4.6161	4.5763	4.8606	4.8943	4.7906	4.8330

[1] Computed from nitrogen, using factors stated in Part III, page 203.

TABLE VI.—*Composition of dry matter of uneaten residues.*

Component.	Period I—Steer B. Jan. 24.	Jan. 26.	Jan. 25 and 26.	Period IV—Steer B.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Ash	8.60	7.25	8.57	4.06
NaCl	11.86			3.30
Protein[1]	11.98	12.12	14.45	7.19
Nonprotein[1]	1.44	.65	.82	.21
Crude fiber	13.55	21.22	17.34	35.02
Nitrogen-free extract	49.10	55.17	54.66	47.91
Ether extract	3.47	3.59	4.16	2.31
	100.00	100.00	100.00	100.00
Total nitrogen	2.222	2.078	2.487	1.196
Protein nitrogen	1.916	1.939	2.312	1.150
Carbon	39.194	45.705	45.622	[2] 46.967
Hydrogen	6.058	4.842	6.818	
	Calories.	*Calories.*	*Calories.*	*Calories.*
Energy per gram	3.7871	4.4910	4.4645	4.4549

[1] Computed from nitrogen, using factors stated in Part III, page 203.
[2] Assumed same as hay offered.

RESPIRATION CALORIMETER EXPERIMENTS OF 1906.

TABLE VII.—*Live weights, water consumed, weights and composition of excreta, and rectal temperatures.*

	Live weight.	Water consumed.	Weight of feces.	Urine. Weight.	Specific gravity.	Nitrogen. Per cent.	Nitrogen. Weight.	Rectal temperature.
Period I.								
Steer A:	*Kilos.*	*Kilos.*	*Grams.*	*Grams.*			*Grams.*	*° C.*
Jan. 7	396.5	16.4						
8	398.3	13.2						
9	398.5	6.8						
10	393.0	19.4						
11	399.9	9.0						
12	396.3	15.6						
13	398.7	4.8						
14	389.9	21.0						
15	399.1	12.4						
16	397.3	12.5						
17	396.8	13.3						
18	395.5	14.7	7,715	6,065	1.038	1.093	66.29	38.50
19	397.2	15.0	7,700	5,710	1.038	1.252	71.49	38.67
20	400.0	15.0	7,655	4,425	1.040	1.492	66.02	38.67
21	397.5	16.0	7,730	6,285	1.041	1.006	63.23	38.72
22	401.0	17.8	6,630	4,800	1.041	1.344	64.51	38.78
23	411.5	10.0	7,965	5,710	1.040	1.259	71.89	38.67
24		8.0	8,115	5,500	1.039	1.263	69.49	
25	407.7	12.4	7,210	3,070	1.043	2.209	67.82	38.67
26	399.6	22.8	8,455	3,955	1.050	1.906	75.38	38.44
27	406.4	11.1	8,197	7,095	1.040	1.006	71.38	38.22
Total			77,372	52,615			687.48	
Daily average			7,737	5,262		1.307	68.75	38.61
Composite sample						1.353	71.19	
Spilled, Jan. 21				813.1		.005	.04	
25			[1] 1.0					
27				173.5		1.437	2.49	
In duct			187.8					
Steer B:								
Jan. 14	310.8	.6						
15	299.5	.0						
16	290.5	29.3						
17	310.9	9.2						
18	307.6	7.6						
19	306.5	9.0						

[1] Dry matter.

TABLE VII.—*Live weights, water consumed, weights and composition of excreta, and rectal temperatures*—Continued.

	Live weight.	Water consumed.	Weight of feces.	Urine.				Rectal temperature.
				Weight.	Specific gravity.	Nitrogen.		
						Per cent.	Weight.	
Period I—Continued.								
Steer B—Continued.	*Kilos.*	*Kilos.*	*Grams.*	*Grams.*			*Grams.*	° *C.*
Jan. 20	305.0	10.4						
21	305.0	10.8						
22	305.0	10.4						
23	304.4	0						
24	295.0	11.5						
25	298.2	12.4	5,540	2,670	1.050	2.001	53.43	38.44
26	301.4	8.0	5,935	3,680	1.052	1.600	58.88	38.56
27	298.4	.0	5,165	4,115	1.045	1.330	54.73	38.33
28	290.0	21.8	4,775	3,335	1.048	1.553	51.79	38.44
29	300.9	.0	6,245	2,413	1.057	2.163	52.19	38.44
30	296.2	15.0	6,095	2,945	1.060	2.100	61.85	38.67
31	301.0	.0	5,325	3,100	1.051	1.665	51.62	38.78
Feb. 1		9.4	4,160	2,675	1.060	2.194	58.69	
2	301.6	10.6	7,065	2,160	1.055	2.409	52.03	38.89
Total			50,305	27,093			495.21	
Daily average			5,589	3,010		1.828	55.02	38.56
Composite sample						1.802	54.25	
Spilled, Feb. 2			7.2					
In duct			20.0					
Period II.								
Steer A:								
Feb. 9	420.9	17.4						
10	415.0	18.5						38.78
11	417.4	16.6						38.89
12	419.2	19.0						38.78
13	420.8	18.2						39.00
14	418.0	23.8						38.89
15	422.0	17.0	15,515	6,270	1.040	2.104	131.92	38.44
16	417.2	19.8	13,845	5,810	1.043	2.256	131.07	38.89
17	421.8	22.4	14,205	[6,005]	[1.041]	[2.172]	[130.43]	[1] 38.56
18	417.0	27.0	14,155	[5,450]	[1.042]	[2.128]	[115.98]	[1] 38.78
19	422.0	18.0	14,850	6,405	1.042	2.119	135.72	38.56
20	425.7	16.9	12,045	6,625	1.038	1.946	128.92	38.56
21		12.7	13,565	6,025	1.040	2.240	134.96	
22	424.6	18.3	13,195	6,510	1.041	2.178	141.79	38.89
23	410.0	35.2	14,695	6,995	1.042	1.999	139.83	38.67
24	424.6	21.2	13,240	6,175	1.040	2.092	129.18	38.78
Total			139,310	50,815			1,073.39	
Daily average			13,931	6,352		2.112	134.17	38.72
Composite sample						2.097	133.20	
Spilled, Feb. 15			27.5					
18			6.0					
20			33.5					
23			16.8					
In duct			1,193.5					
Steer B:								
Feb. 16	316.0	8.2						
17	318.6	11.6						38.33
18	314.0	16.2						39.44
19	316.4	.0						39.72
20	307.8	.0						39.67
21	309.3	15.6						39.33
22	316.1	8.8						39.17
23	312.2	11.9	9,930	3,315	1.052	2.352	77.97	39.17
24	310.4	11.3	9,520	3,735	1.052	2.079	77.65	38.78
25	310.9	11.0	9,610	3,650	1.053	2.146	78.33	38.72
26	309.5	9.4	10,275	3,510	1.050	2.199	77.18	38.56
27	311.4	10.7	6,695	3,040	1.052	2.064	62.75	38.50
28		9.7	9,195	3,920	1.048	2.072	81.22	
Mar. 1	311.5	9.1	8,575	3,295	1.049	2.269	74.76	38.89
2	303.6	13.4	7,765	3,210	1.055	2.306	74.02	38.22
3	310.7	14.5	7,685	3,360	1.051	2.303	77.38	38.67
Total			79,250	31,035			681.26	
Daily average			8,806	3,448		2.165	75.70	38.94
Composite sample						2.165	74.65	
Spilled, Mar. 1			10.0					
In duct			574.2					

[1] Small loss of urine on these two days. Results not included in averages.

TABLE VII.—*Live weights, water consumed, weights and composition of excreta, and rectal temperatures*—Continued.

	Live weight.	Water consumed.	Weight of feces.	Urine.				Rectal temperature.
				Weight.	Specific gravity.	Nitrogen.		
						Per cent.	Weight.	
Period III.								
Steer A:	*Kilos.*	*Kilos.*	*Grams.*	*Grams.*			*Grams.*	*° C.*
Mar. 2	419.9	.0						
3	410.0	24.2						37.89
4	421.0	.0						38.44
5	410.2	.0						38.33
6	395.6	25.4						38.33
7	410.2	.0						38.39
8	398.6	27.3	5,530	5,600	1.031	0.589	32.98	38.50
9	408.6	.0	5,695	5,200	1.030	.676	35.15	38.89
10	398.8	9.4	4,535	5,355	1.031	.640	34.27	38.06
11	397.2	18.0	5,840	6,125	1.029	.572	35.04	38.22
12	396.2	10.0	4,705	5,850	1.030	.539	31.53	37.83
13	400.3	13.2	5,870	5,955	1.029	.541	32.22	38.00
14		8.9	5,820	4,365	1.030	.736	32.13	
15	404.1	5.3	5,920	2,665	1.034	1.117	29.77	38.67
16	397.0	12.5	5,570	2,975	1.040	1.156	34.39	38.06
17	397.9	14.4	5,495	5,715	1.031	.629	35.95	37.89
Total			54,980	49,805			333.43	
Daily average			5,498	4,981		.669	33.34	38.28
Composite sample						.635	31.63	
Spilled, Mar. 15			11.3					
In duct			39.2					
In duct			[1] 1.0					
Steer B:								
Mar. 9	304.4	.0						
10	295.6	12.9						38.33
11	300.0	11.0						37.89
12	301.5	8.2						38.22
13	299.2	2.9						37.89
14	292.3	14.2						38.11
15	298.2	6.5	4,165	2,955	1.035	.940	27.78	37.78
16	296.3	11.1	4,065					38.44
17	298.2	4.3	5,095	3,585	1.034	.765	27.43	37.83
18	293.7	5.4	4,635	3,285	1.035	.835	27.43	37.89
19	291.4	14.7	4,640	2,895	1.040	.924	26.75	38.33
20	301.4	5.3	4,200	2,265	1.046	1.172	26.55	37.78
21		13.6	4,275	2,410	1.041	1.122	27.04	
22	303.1	6.2	5,530	2,130	1.039	1.367	29.12	38.67
23	296.6	7.4	5,020	2,585	1.040	1.073	27.74	38.50
24	295.4	9.5	4,920	3,575	1.035	.761	27.21	37.56
Total			46,545	25,685			247.05	
Daily average			4,655	2,854		.962	27.45	38.11
Composite sample						.930	26.54	
In duct			[1] 7.6					
Period IV.								
Steer A:								
Mar. 23	398.8	20.7						
24	404.4	15.7						38.11
25	404.9	14.6						38.17
26	406.9	13.6						38.61
27	406.3	14.2						38.89
28	404.2	16.8						38.00
29	406.4	13.9	10,560	4,180	1.040	.752	31.43	38.00
30	406.0	15.1	10,320	4,000	1.035	.772	30.88	38.11
31	407.7	15.6	10,815	4,430	1.040	.721	31.94	37.78
Apr. 1	408.0	16.6	9,810	5,255	1.031	.572	30.06	38.06
2	409.4	13.1	11,305	5,065	1.035	.596	30.19	38.22
3	412.6	13.4	9,060	5,530	1.032	.530	29.31	37.67
4		11.2	11,985	4,400	1.034	.676	29.74	
5	410.0	9.0	11,515	3,450	1.040	.854	29.46	38.78
6	398.0	19.8	11,900	3,900	1.036	.862	33.62	38.44
7	401.7	21.7	12,595	4,630	1.033	.678	31.39	38.78
Total			109,865	44,840			308.02	
Daily average			10,987	4,484		.687	30.80	38.28
Composite sample						.690	30.94	
In duct			170.3					

[1] Dry matter.

TABLE VII.—*Live weights, water consumed, weights and composition of excreta, and rectal temperatures*—Continued.

	Live weight.	Water consumed.	Weight of feces.	Urine.				Rectal temperature.
				Weight.	Specific gravity.	Nitrogen.		
						Per cent.	Weight.	
Period IV—Continued.								
Steer B:	*Kilos.*	*Kilos.*	*Grams.*	*Grams.*			*Grams.*	*° C.*
Mar. 30	297.0	11.5						
31	299.2	12.0						37.56
Apr. 1	302.0	7.0						37.78
2	299.6	14.4						38.67
3	305.5	10.1						37.78
4	305.3	13.7						38.89
5	307.5	9.5	7,610	3,380	1.043	0.922	31.16	38.06
6	306.4	8.0	8,565	3,075	1.045	1.032	31.73	37.83
7	303.4	13.8	7,630	3,275	1.041	.920	30.13	37.89
8	307.2	11.4	8,320	3,240	1.046	.933	30.23	37.78
9	308.0	12.7	8,280	3,955	1.040	.800	31.64	38.11
10	312.6	7.0	8,710	3,215	1.041	.899	28.90	37.89
11		12.4	8,305	2,945	1.045	1.022	30.10	
12	313.9	9.8	8,880	2,800	1.042	1.004	28.11	38.56
13	305.0	11.8	8,835	3,235	1.044	.910	29.44	38.78
14	304.8	12.7	8,250	3,265	1.046	.909	29.68	38.67
Total			83,585	32,385			301.12	
Daily average			8,359	3,239		.930	30.11	38.17
Composite sample						.922	29.86	
Spilled, Mar. 12				157		.737		
13			26.5					
In duct			93.7					

TABLE VIII.—*Composition of dry matter of feces.*

Component and energy.	Period I.		Period II.		Period III.		Period IV.	
	Steer A.	Steer B.	Steer A.	Steer B.	Steer A.	Steer B.	Steer A.	Steer B.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Ash	9.47	9.08	8.50	8.61	6.60	7.71	7.15	7.45
Protein[1] / Nonprotein[1]	13.36	12.47	16.73	13.55	10.71	10.56	10.44	10.73
Crude fiber	31.15	32.40	31.95	34.91	34.61	32.64	34.86	33.50
Nitrogen-free extract	43.90	43.94	40.62	40.94	46.02	46.78	45.41	46.24
Ether extract	2.12	2.11	2.20	1.99	2.06	2.31	2.14	2.08
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Total nitrogen	2.137	1.995	2.676	2.168	1.713	1.690	1.670	1.717
Carbon	47.77	48.16	48.10	47.67	49.14	49.49	48.86	49.55
Hydrogen	6.38	6.34	6.67	6.55	6.55	6.60	6.33	6.73
	Calories.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Energy...per gram	4.6793	4.7075	4.6896	4.6307	4.8011	4.7992	4.7985	4.7940

[1] Computed from nitrogen, using the factors stated in Part III, page 203.

RESPIRATION CALORIMETER EXPERIMENTS OF 1907.

TABLE IX.—*Live weights, water consumed, weights and composition of excreta, and rectal temperatures.*

Period.	Live weight.	Water consumed.	Weight of feces.	Urine.				Rectal temperature.
				Weight.	Specific gravity.	Per cent nitrogen.	Weight of nitrogen.	
Period I.								
Steer A:	*Kilos.*	*Kilos.*	*Grams.*	*Grams.*			*Grams.*	° *C.*
Jan. 23	497.6	1.0						
24	483.2	17.4						38.89
25	487.6	16.2						38.45
26	493.0	0.0						38.00
27	483.2	24.2						37.89
28	497.0	13.2						38.22
29	497.6	8.4						38.34
30	493.8	16.8						38.00
31	497.8	13.6	7,385	3,525	1.047			38.00
Feb. 1	500.0	14.6	9,955	3,750	1.045			38.00
2	500.0	14.6	8,090	4,920	1.040			38.56
3	500.4	12.2	7,785	4,535	1.042			38.22
4	500.0	15.0	8,410	4,290	1.041			38.11
5	504.6	0.0	7,275	6,110	1.038			38.00
6		15.2	8,955	3,565	1.049			
7	498.3	9.8	8,960	3,495	1.045			[2] 38.78
8	489.0	24.2	8,600	3,110	1.050			37.89
9	499.0	20.6	9,175	5,140	1.039			38.00
Total			84,590	42,440				
Daily average			8,459	4,244		1.682		38.21
Spilled Feb. 7			5.0	975		.885		
In duct			616.9					
Steer B:								
Jan. 31	367.0	9.4						37.67
Feb. 1	366.8	12.0						37.78
2	369.2	13.2						37.89
3	373.0	.0						38.67
4	363.0	17.0						37.83
5	371.2	9.4						37.50
6	371.6	8.8						37.89
7	370.4	11.6	6,745	3,565	1.050			37.89
8	372.0	.0	5,485	2,990	1.051			37.67
9	363.0	18.4	6,475	3,400	1.052			38.45
10	371.2	10.0	5,475	3,435	1.050			38.00
11	371.0	3.6	6,425	4,030	1.045			38.22
12	[1] 368.8	13.4	5,380	3,095	1.050			37.56
13		6.8	6,850	2,630	1.054			
14	[2] 373.6	7.5	5,730	2,745	1.053			[2] 39.00
15	365.2	10.4	6,480	3,005	1.052			37.78
16	365.8	12.2	5,905	3,125	1.044			37.89
Total			60,950	32,020				
Daily average			6,095	3,202		1.820		37.98
Spilled, Feb. 16				1,120.7		.422		
In duct			7.4					
Period II.								
Steer A:								
Feb. 21	516.6	21.0						38.34
22	518.0	21.6						38.67
23	517.8	21.8						38.67
24	519.6	23.0						38.78
25	519.4	21.8						38.45
26	517.4	22.8						38.78
27	516.4	21.2						38.56
28	519.4	20.8	12,625	7,395	1.032	1.924	142.28	38.34
Mar. 1	516.4	27.6	14,570	7,725	1.031	1.841	142.22	38.89
2	519.6	22.4	14,010	8,770	1.030	1.705	149.53	38.78
3	516.6	30.4	12,310	10,285	1.030	1.437	147.80	38.78
4	521.4	21.2	14,960	9,285	1.031	1.669	154.97	38.78
5	528.0	17.0	10,815	7,460	1.033	1.767	131.82	38.45
6		13.5	15,155	8,645	1.030	1.847	159.67	
7	522.0	21.4	11,905	7,260	1.034	2.089	151.66	[2] 39.23
8	507.0	31.2	12,655	7,390	1.032	2,126	157.11	38.67
9	517.0	37.0	13,545	6,815	1.039	2.341	159.54	39.12
Total			132,550	81,030			1,496.60	

[1] At 8 a.m. [2] At 6 p.m.

TABLE IX.—*Live weights, water consumed, weights and composition of excreta, and rectal temperature*—Continued.

Period.	Live weight.	Water consumed.	Weight of feces.	Urine.				Rectal temperature.
				Weight.	Specific gravity.	Per cent nitrogen.	Weight of nitrogen.	
Period II—Continued.								
Steer A—Continued.	*Kilos.*	*Kilos.*	*Grams.*	*Grams.*			*Grams.*	*° C.*
Daily average			13,255	8,103		1.847	149.66	38.71
Composite sample						1.836	148.76	
Spilled, Mar. 5				270.4		2.183		
Spilled, Mar. 7			142.3					
In duct			1,241.0					
Steer B:								
Feb. 28	381.4	12.6						38.00
Mar. 1	381.2	15.0						38.56
2	381.0	15.4						38.78
3	382.4	8.6						38.56
4	379.0	17.4						38.45
5	384.2	12.0						38.78
6	384.6	13.8						38.67
7	380.0	14.8	7,410	3,805	1.051	2.360	89.80	38.67
8	380.6	12.8	8,205	3,360	1.052	2.369	79.60	38.56
9	383.2	17.2	5,925	4,165	1.050	2.274	94.71	38.89
10	386.0	13.8	8,245	3,105	1.052	2.434	75.58	38.34
11	386.2	12.6	8,245	3,395	1.052	2.453	83.28	38.34
12	[1] 391.2	7.0	6,920	4,295	1.050	2.177	93.50	38.34
13		13.1	6,875	3,535	1.055	2.420	85.55	
14		12.6	7,195	3,450	1.055	2.643	91.18	[2] 38.89
15	380.6	22.4	7,230	3,270	1.056	2.571	84.07	38.78
16	388.0	18.4	8,445	5,405	1.045	1.632	88.21	37.89
Total			74,695	37,785			865.48	
Daily average			7,469.5	3,778.5		2.291	86.55	38.53
Composite sample						2.216	83.74	
Spilled, Mar. 10				269.6		2.156		
Spilled, Mar. 14			69.3					
Spilled, Mar. 15				102.2		1.250		
Spilled, Mar. 16				173.2		.181		
In duct			569.6					
Period III.								
Steer A:								
Mar. 10	518.0	2.4						
11	509.0	10.0						
12	510.4	14.6						
13	515.2	9.0						
14	510.4	20.4						
15	522.0	18.0						
16	522.0	2.2						38.45
17	513.0	14.4						38.78
18	516.0	16.0						37.89
19	519.4	9.2						38.00
20	515.4	6.0						37.56
21	509.0	15.2	5,280	6,100	1.033	.531	32.39	37.78
22	510.4	14.8	5,635	7,135	1.030	.496	35.39	38.11
23	510.2	15.8	5,345	7,620	1.030	.435	33.15	38.45
24	509.4	12.8	5,135	9,350	1.024	.358	33.47	37.89
25	509.0	0.0	4,435	8,080	1.025	.388	31.35	37.89
26	[3] 501.8	17.0	4,085					37.22
27		10.7	5,475	4,480	1.030	.592	26.52	
28	[2] 511.0	5.3	4,170	2,805	1.035	1.199	33.63	[2] 38.34
29	503.6	22.0	5,600	4,465	1.033	.776	34.65	38.22
30	509.0	0.0	5,005	10,000	1.023	.333	33.30	38.11
Total			50,165	60.035			293.85	
Daily average			5,016.5	6,670.6		.490	32.65	38.05
Composite sample						.479	31.96	
Spilled, Mar. 28			64.0					
In duct			176.8					
Washings from duct			185.0					

[1] At 7.20 a. m. [2] At 6 p. m. [3] At 7.30 a. m.

TABLE IX.—*Live weights, water consumed, weights and composition of excreta, and rectal temperatures*—Continued.

Period.	Live weight.	Water consumed.	Weight of feces.	Urine. Weight.	Urine. Specific gravity.	Urine. Per cent nitrogen.	Urine. Weight of nitrogen.	Rectal temperature.
Period III—Continued.								
Steer B:	*Kilos.*	*Kilos.*	*Grams.*	*Grams.*			*Grams.*	*° C.*
Mar. 17	389.6	0.8						
18	380.2	4.8						
19	382.0	2.2						
20	386.8	2.0						
21	385.0	0.0						
22	375.2	20.2						37.22
23	382.0	0.0						37.78
24	368.0	14.0						38.56
25	372.0	0.0						37.78
26	363.4	18.6						38.11
27	374.8	13.2						38.00
28	378.6	7.8	4,820	3,585	1.040	.914	32.77	38.34
29	372.0	16.2	4,850	4,880	1.034	.665	32.45	38.22
30	377.0	7.0	4,625	4,305	1.033	.694	29.88	37.67
31	374.0	8.4	4,815	4,790	1.033	.578	27.69	37.56
Apr. 1	372.4	10.0	4,580	4,855	1.033	.563	27.33	38.34
2	[1] 376.4	0.0	5,435	3,720	1.040	.617	22.95	38.34
3		13.1	4,530	2,240	1.050	1.044	23.39	
4	[2] 376.8	7.8	4,500	1,875	1.052	1.479	27.73	[2] 38.56
5	368.0	16.0	5,135	2,700	1.048	1.091	29.46	38.11
6	374.4	14.8	4,495	6,245	1.032	.486	30.35	37.67
Total			47,785	39,195			284.00	
Daily average			4,778.5	3,919.5		.725	28.40	38.02
Composite sample						.717	28.10	
Spilled, Mar. 28				188.8		.146		
Spilled, Mar. 28				[3] 50.0				
Spilled, Apr. 4			4.2					
In duct			73.7					
Period IV.								
Steer A:								
Mar. 31	493.0	20.0						
Apr. 1	500.8	10.6						
2	499.0	11.8						
3	497.0	15.3						
4	[4] 503.2	18.8						37.22
5	505.0	19.2						38.22
6	508.0	14.2						38.00
7	506.6	23.8						38.34
8	511.6	16.0						38.34
9	512.0	15.0						38.00
10	512.2	16.6						38.34
11	513.4	16.0	9,185	6,540	1.034	.448	29.30	38.11
12	511.0	18.2	9,865	7,710	1.030	.377	29.07	38.45
13	510.4	19.0	10,690	7,945	1.031	.376	29.87	38.56
14	514.0	18.4	8,830	6,230	1.032	.455	28.35	38.34
15	515.8	14.2	10,095	5,475	1.035	.545	29.84	38.34
16	[1] 518.0	19.4	10,140	5,785	1.036	.466	26.96	38.34
17		11.8	9,565	5,955	1.033	.449	26.74	
18	[2] 518.4	9.4	10,890	3,720	1.043	.717	26.67	[2] 38.67
19	506.2	25.6	10,370	4,465	1.045	.632	28.22	38.56
20	513.0	12.4	10,025	7,590	1.035	.412	31.27	38.00
Total			99,655	61,415			286.29	
Daily average			9,966	6,142		.466	28.63	38.24
Composite sample						.457	28.07	
Spilled, Apr. 11				226.5		.079		
Spilled, Apr. 18			27.6					
In duct			402.5					

[1] At 7.30 a. m. [2] At 6 p. m. [3] Estimated. [4] At 11 a. m.

TABLE IX.—*Live weights, water consumed, weights and composition of excreta, and rectal temperatures*—Continued.

Period.	Live weight.	Water consumed.	Weight of feces.	Urine.				Rectal temperature.
				Weight.	Specific gravity.	Per cent nitrogen.	Weight of nitrogen.	
Period IV—Continued.								
Steer B:	*Kilos.*	*Kilos.*	*Grams.*	*Grams.*			*Grams.*	° *C.*
Apr. 7	371.4	9.0						
8	370.0	12.0						
9	373.2	7.4						
10	373.0	20.4						
11	386.0	4.2						37.33
12	378.4	14.2						38.56
13	382.0	9.6						38.45
14	379.6	20.4						39.00
15	384.6	16.6						38.00
16	386.4	16.4						38.45
17	387.6	16.4						38.78
18	387.6	14.4	8,325	5,600	1.038	.511	28.62	38.78
19	381.8	21.8	10,940	10,290	1.030	.307	31.59	38.56
20	384.6	16.4	9,160	6,585	1.037	.382	25.15	38.56
21	383.8	21.6	9,500	9,560	1.031	.297	28.39	38.67
22	383.2	14.8	10,025	9,550	1.032	.247	23.59	38.34
23	[1] 390.0	4.4	7,835	3,260	1.050	.756	24.65	38.45
24		15.7	9,585	2,375	1.055	.972	23.09	
25	[2] 389.6	11.8	8,755					[2] 38.34
26	379.4	17.6	7,940	3,510	1.053	.834	29.27	38.67
27	383.4	17.6	10,390	4,495	1.043	.720	32.36	38.34
Total			92,455	55,225			246.71	
Daily average			9,245.5	6,136.1		.447	27.41	38.46
Composite sample						.456	27.98	
In duct			18.8					

[1] At 7.30 a. m. [2] At 6 p. m.

TABLE X.—*Composition of dry matter of feces.*

Components and energy.	Period I.		Period II.		Period III.		Period IV.	
	Steer A.	Steer B.	Steer A.	Steer B.	Steer A.	Steer B.	Steer A.	Steer B.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Ash	9.67	9.63	10.39	10.01	8.03	8.20	8.21	7.87
Protein [1]	13.38	10.83	15.59	13.29	10.01	9.51	9.81	9.95
Crude fiber [1]	29.03	29.70	29.78	29.76	30.73	29.40	29.19	29.51
Nitrogen-free extract	45.57	47.07	42.05	44.42	48.30	49.84	49.88	49.93
Ether extract	2.35	2.77	2.19	2.52	2.93	3.05	2.91	2.74
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Total nitrogen	2.141	1.733	2.495	2.127	1.601	1.521	1.570	1.592
Carbon	48.508	48.361	47.598	47.811	49.629	49.685	49.597	49.351
Hydrogen	5.674	5.748	5.644	5.478	5.883	5.722	5.799	5.714
	Calories.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Energy....per gram	4.7596	4.7967	4.6905	4.7787	4.9232	4.9388	4.9166	4.9279

[1] Computed from nitrogen, using the factors stated in Part III, page 203.

DIGESTION AND METABOLISM TRIALS DURING INTERMEDIATE PERIODS.

TABLE XI.—*Live weights, water consumed, and weights and composition of excreta.*

Date.	Live weight.	Water consumed.	Fresh weight of feces.	Urine.			
				Weight.	Specific gravity.	Nitrogen.	
						Per cent.	Weight.
Nov. 28 to Dec. 10, 1904.							
Steer A:	*Kilos.*	*Kilos.*	*Grams.*	*Grams.*			*Grams.*
Nov. 28	273.6	....	....	....	....	....	....
29	275.0	....	....	....	....	....	....
30	260.0	....	....	....	....	....	....
Dec. 1	270.4	20.2	6,385	3,310	....	....	....
2	273.6	14.1	6,560	3,690	....	....	....
3	270.9	22.3	7,475	....	....	....	....
4	278.1	18.9	10,790	6,275	....	....	....
5	282.4	14.4	8,990	5,810	....	....	....
6	279.5	16.4	8,505	5,425	....	....	....
7	280.8	19.1	8,830	5,825	....	....	....
8	284.5	12.7	8,115	4,830	....	....	....
9	279.0	20.5	8,030	6,500	....	....	....
10	283.6	20.5	10,040	7,410	....	....	....
Total	....	....	83,720	49,075	....		....
Daily average	....	....	8,372	5,453	....	1.440	78.52
In duct	....	....	980	....	....	....	....
Steer B:							
Nov. 28	191.8	....	....	....	....	....	....
29	208.6	....	....	....	....	....	....
30	208.2	....	....	....	....	....	....
Dec. 1	207.2	15.0	7,165	3,740	....	....	....
2	207.5	20.0	6,640	3,840	....	....	....
3	211.8	17.9	8,090	4,120	....	....	....
4	217.2	18.6	8,630	6,540	....	....	....
5	220.4	13.2	8,225	5,300	....	....	....
6	218.1	15.9	9,640	5,930	....	....	....
7	218.8	15.5	8,250	5,850	....	....	....
8	217.2	13.2	7,925	6,050	....	....	....
9	216.3	16.2	6,975	5,460	....	....	....
10	220.4	11.4	8,110	5,220	....	....	....
Total	....	....	79,650	52,050	....		....
Daily average	....	....	7,965	5,205	....	1.340	69.75
In duct	....	....	535	....	....	....	....
June 30 to July 15, 1905.							
Steer A:							
June 30	317.6	15.4	....	....	....	....	....
July 1	315.0	15.0	7,850	[1] 5,120	No samples taken.		
2	311.0	17.5	8,920	[1] 5,470			
3	310.0	18.5	9,585	6,410			
4	309.5	21.0	9,180	6,380			
5	310.5	18.0	8,675	[1] 7,350			
6	309.0	21.5	8,205	[7,420]	Some urine lost. No samples of urine taken.		
7	309.0	19.5	8,170	9,670	....	....	....
8	310.0	23.0	6,665	7,740	....	....	....
9	312.0	21.5	8,130	10,130	....	....	....
10	311.0	22.5	8,730	10,300	....	....	....
11	313.0	22.0	....	[9,030]	Some urine lost. No samples of feces or urine taken.		
12	314.5	17.0	7,960	8,660	....	....	....
13	314.0	18.5	7,900	6,525	....	....	....
14	315.0	18.0	7,825	7,580	....	....	....
15	315.0	20.0	9,410	6,230	....	....	....
Total	....	....	72,995	66,835	....		....
Daily average	....	....	8,111	8,604	....	.947	79.12
In duct, July 7	....	....	[2] 30	....	....	....	....
In duct, July 15	....	....	[2] 80	....	....	....	....

[1] Some loss.

[2] Dry matter.

Table XI.—*Live weights, water consumed, and weights and composition of excreta*—Continued.

Date.	Live weight.	Water consumed.	Fresh weight of feces.	Urine.			
				Weight.	Specific gravity.	Nitrogen.	
						Per cent.	Weight.
June 30 to July 15, 1905—Con.							
Steer B:	*Kilos.*	*Kilos.*	*Grams.*	*Grams.*			*Grams.*
June 30	230.0	12.4					
July 1	230.7	11.7	6,630	3,110	No samples taken.		
2	228.0	13.4		3,410			
3	229.0	12.0	8,105	3,130			
4	227.5	18.0	7,915	3,120			
5	231.0	11.0	7,615	4,385			
6	229.0	16.0	7,855	3,170			
7	231.5	12.5	6,290	3,775			
8	231.0	14.0	7,490	3,700			
9	231.5	13.5	7,285	3,445			
10	233.0	17.0	7,015	3,545	No sample of urine taken.		
11	234.0	12.5	8,150	4,415			
12	231.5	13.5	7,930	4,030			
13	233.0	16.5	5,915	3,185			
14	235.5	11.0	7,610	4,365			
15	234.0	12.5	7,560	3,580			
Total			73,100	37,210		1.761	655.26
Daily average			7,310	3,721			
In duct			68[1]				
Urine spilled, July 9				2,311		.161	3.72
Daily average							65.90
Nov. 7 to 22, 1905.							
Steer A:							
Nov. 7	369.4	19.2					
8	368.4	20.0	11,985	3,780			
9	369.2	17.7	13,640	3,465			
10	368.4	20.0	13,125	3,850	No samples taken.		
11	370.4	21.0	12,595	3,850			
12	370.9	16.0	11,535	3,870			
13	371.9	21.5	10,245	4,105	1.045		
14	379.9	11.7	10,945	4,005	1.040		
15	377.4	18.0	10,410	3,720	1.043		
16	377.4	19.0	11,340	[3,940]		Urine not sampled nor included in computation on account of small loss.	
17	381.9	15.5	9,240	4,275	1.041	No sample of feces.	
18	378.9	16.5	10,965	4,810	1.040		
19	380.4	17.0	9,455	4,350	1.040		
20	380.9	16.5	10,425	4,720	1.048		
21	381.4	16.5	10,910	4,925	1.041		
22	382.4	17.2	9,235	5,010	1.040		
Total			103,170	39,920			
Daily average			10,317	4,436		1.916	84.98
From duct			135[1]				
Steer B:							
Nov. 7	286.9				No samples taken.		
8	275.5	29.8	6,740	3,610			
9	290.8	7.0	8,605	3,290			
10	283.8	13.5	11,140	3,080			
11	283.3	13.0	9,920	3,905			
12	281.8	15.0	8,070	3,820			
13	283.8	12.5	7,920	3,655	1.050		
14	285.3	14.0	8,095	3,035	1.052		
15	287.3	14.5	8,470	3,315	1.050		
16	288.3	13.0	9,405	3,730	1.045	Feces not sampled.	
17	287.3	13.5	6,940	4,040	1.044		
18	287.3	16.0	8,380	3,950	1.044		
19	289.8	14.5	7,660	4,215	1.040		
20	290.8	13.0	8,640	3,955	1.046		
21	290.3	13.4	8,225	4,525	1.042		
22	289.8	15.2	8,785	3,965	1.048		
Total			75,580	38,385			
Daily average			8,398	3,839		1.886	72.39
From duct			55.5[1]				

[1] Dry matter.

TABLE XI.—*Live weights, water consumed, and weights and composition of excreta*—Continued.

Date.	Live weight.	Water consumed.	Fresh weight of feces.	Urine.			
				Weight.	Specific gravity.	Nitrogen.	
						Per cent.	Weight.
June 19 to July 6, 1906.							
Steer A:	*Kilos.*	*Kilos.*	*Grams.*	*Grams.*			*Grams.*
June 19	456.0	25.2					
20	453.0	25.4					
21	453.8	27.6					
22	453.0	25.4					
23	458.0	21.0					
24	455.6	25.4					
25	459.6	15.6					
26	450.4	23.6					
27	451.0	28.4	14,586	[1] 5,475	1.045	1.696	92.86
28	454.6	24.8	15,695	5,400	1.045	1.647	88.94
29	451.4	0.0	18,430				
30	429.0	40.0	10,205	5,860	1.048	1.482	86.85
July 1	447.4	32.2	11,510	5,320	1.045	1.872	99.59
2	450.4	36.6	17,355	5,015	1.048	2.043	102.46
3	457.8	32.4	18,270	4,900	1.042	2.243	109.91
4	457.2	31.0	20,565	5,710	1.040	1.926	109.97
5	458.6	31.8	18,770	5,385	1.042	1.923	103.55
6	456.3	33.7	22,120	5,930	1.042	1.745	103.48
Total			167,505	48,795			897.61
Daily average			16,751	5,422		1.840	99.73
Composite sample						1.818	98.57
From duct			1,913				
Steer B:							
June 19	338.4	12.4					
20	331.0	24.0					
21	340.2	14.2					
22	335.0	16.0					
23	335.2	16.8					
24	340.0	8.4					
25	334.0	18.6					
26	336.0	21.6					
27	338.4	16.4	9,735	4,545	1.049	1.674	76.08
28	336.2	21.8	9,645	4,355	1.051	1.642	71.51
29	339.2	18.8	9,220	4,440	1.050	1.720	76.37
30	337.4	23.6	9,125	4,430	1.050	1.703	75.44
July 1	342.2	22.4	9,065	4,485	1.050	1.805	80.95
2	344.8	18.8	9,990	4,360	1.050	1.850	80.66
3	343.2	17.0	9,830	4,635	1.043	1.768	81.95
4	343.0	19.0	9,430	4,635	1.048	1.738	80.56
5	342.6	19.0	8,800	4,810	1.050	1.604	77.15
6	342.0	18.4	9,205				
Total			94,045	40,695			700.66
Daily average			9,405	4,522		1.722	77.85
Composite sample						1.708	77.24
From duct			934				

[1] Includes estimated loss of 200 grams.

TABLE XII.—*Composition of dry matter of feces.*

Component and energy.	Dec. 1 to 10, 1904.		June 30 to July 15, 1905.		Nov. 7 to 22, 1905.		June 19 to July 6, 1906.	
	Steer A.	Steer B.	Steer A.	Steer B.	Steer A.	Steer B.	Steer A.	Steer B.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Ash	9.86	9.91	9.66	9.66	10.11	10.20	9.27	9.63
Protein, Nonprotein	17.94	16.38	17.03	19.98	14.84	13.70	16.77	14.92
Crude fiber	28.94	30.49	33.84	31.51	26.42	29.14	31.24	31.00
Nitrogen-free extract	39.27	39.67	36.50	35.84	46.37	44.65	40.41	41.84
Ether extract	3.99	3.55	2.97	3.05	2.26	2.31	2.31	2.61
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Total nitrogen	2.87	2.62	2.725	3.197	2.374	2.192	2.683	2.387
Protein nitrogen			2.450	2.340	1.859	1.776	2.220	2.125
	Calories.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Calories.*
Energy....per gram	[1] [4.7201]	[1] [4.7201]	4.7778	4.7929	4.6565	4.6495	4.6799	4.7639

[1] Average of the other 3 periods.

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