RUMEN STUDIES

by

ROY JAMES WILSON

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Thesis Approved:

Magnar Ronning
Thesis Adviser

O. L. Norton
Faculty Representative

Duane Medvick
Dean of the Graduate School

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

INTRODUCTION

Information available in the literature is limited with respect to the transition from the essentially "simple stomach" of a calf to the "complex stomach" of a cow. A clear understanding of this transition is vital to nutritional studies involving the young calf.

The main objective of this study was an attempt to devise methods whereby ruminal development of the young calf might be measured. Intraruminal temperature measurements, volumetric measurements of the stomach compartments, and ruminal fluid pH measurements were investigated as possible means of answering, at least in part, this objective.

REVIEW OF LITERATURE

The rumen is a large muscular fermentation vat located in the left side of the abdominal cavity of ruminants. This non-glandular compartment containing water and saliva serves as a holding place for slightly masticated food and provides an excellent medium for innumerable microorganisms which digest the coarse food. This microbial digestion enables a ruminant to consume large quantities of food rapidly, then lie down and let the microorganisms help with the digestion. Simple stomached animals, except those possessing a crop and gizzard, must masticate their food thoroughly during consumption. The four compartments of the ruminant stomach are so closely related both in function and anatomical structure that it would be impractical to study the rumen without considering the other compartments.

Since information about the development of the rumen in small calves is limited, it is necessary when discussing this aspect to use some descriptions and experimental results obtained with mature animals. The esophagus opens into the ruminal-reticular vestibule and functions in swallowing, regurgitation and eructation. The rumen is the largest compartment of the adult ruminant stomach, occupying most of the left half of the abdominal cavity. The furrows in the exterior of the rumen correspond to internal pillars which separate it into compartments and contract during motility. The rumen microorganisms are very important in the nutrition of the host since they produce fatty acids, amino acids, and water soluble vitamins which are essential in the

metabolism of the ruminant.

The reticulum is closely associated with the rumen by a large orifice which is bounded on the ventral side by a large muscular ruminal-reticular fold. The reticulum is the smallest of the four stomach compartments in the adult animal and is lined with a mucous membrane raised into honey-comb like ridges. Finely divided feed works forward from the rumen and part of it is forced into the omasum by reticular contractions.

The elipsoidal organ containing about one hundred laminae of varying sizes is called the omasum. It is a grinding organ and serves as a passage way for fine-particled food between the reticulum and the abomasum. The reticular-omasal orifice is about one-third the size of the omasal-abomasal orifice which opens into the gastric or true stomach. Becker and associates (7) give a detailed description of the omasum.

The anterior or fundus region of the abomasum is lined with soft glandular mucous membrane and is characterized by extensive folds while the posterior or pyloric region is narrower and smooth. A detailed anatomical description of the ruminant stomach and its location in the animal is given by Sisson and Grossman (50).

The two most widely accepted factors affecting rumen capacity are the size and diet of the animal (1,3,21,49,50,53). Flatt and associates (21) found that hay-fed calves have a larger ruminal-reticular capacity than milk or starter fed calves, at four to eight weeks of age, when compared on a body weight basis. They observed a definite correlation between the ruminal-reticular volume and the amount of feed consumed during a fourteen-day period prior to taking volumetric measurement. Warner and associates (53) also found that hay-fed calves had larger

ruminal-reticular capacity than milk and starter-fed calves at sixteen weeks of age, on an ingesta-free body weight basis. McCandless and Dye (37) reported that three to four month old calves had a similar relationship between the capacities of the rumen and abomasum as mature animals. Sisson and Grossman (50) stated that in the newborn calf the rumen and reticulum together are about half as large as the abomasum, but by ten to twelve weeks of age this ratio is reversed. The rumen and reticulum are four times as large as the omasum and abomasum at four months of age and at about one and one-half years of age the compartments have reached their relative capacities, which are: rumen 80 per cent, reticulum 5 per cent, omasum 7 to 8 per cent, and abomasum 7 to 8 per cent of the total stomach volume.

The microbial digestion carried on within the rumen has been discussed by Amadon (3), Dinusson (18), and Huffman (28). Huffman (28) supported the theory that a cow receives part of her nutrients third hand since the bacterial population increases rapidly after feeding and is followed by an increase in protozoa. It appears that the bacteria digest the readily available nutrients and are then devoured by the protozoa which are in turn digested by the cow in the abomasum and small intestine.

Conrad _et al._ (15) found with digestion trials that cud inoculation improved cellulose and dry matter digestion significantly (5 per cent level) but not protein digestion. Inoculated calves were eating hay at three weeks of age while uninoculated calves did not eat significant amounts until four to six weeks of age. Lengemann and Allen (34) observed a gradual, progressive increase in rumen function and development with large within-group variations of animals from birth to two

years of age. The acids in the rumen tended to stabilize by the end of the second month, and at six months of age there was little difference in this respect from mature animals. Hale et al. (23) observed that digestion in the rumen during the first six hours after feeding was mainly of proteins and carbohydrates, with slight cellulose digestion. The second six hour period after feeding was characterized by rapid cellulose digestion, paralleled by protein and carbohydrate digestion. Ruminal digestion became negligible by twelve hours after feeding, and digestion coefficients of the ruminal ingesta were not increased by fasting the cow for an additional twelve hours.

Huffman (28,29) found that bacterial synthesis occurs in the rumen with the production of such organic acids as acetic, propionic, butyric, lactic, and traces of pyruvic and formic. He also found that the amino acids normally considered essential are synthesized, and gas production is mainly carbon dioxide and methane. Ammonia is the only form of nitrogen utilized by the rumen bacteria with other forms needing to be converted into ammonia prior to utilization. Vitamins synthesized by the ruminal microorganisms are thiamine, riboflavin, niacin, pantothenic acid, pyridoxine, folic acid, vitamin B12, biotin, and vitamin K. Savage and McCay (48) also reported finding synthesis of amino acids and water soluble vitamins. Conrad and Hibbs (14) found a high thiamine content in ruminal bacteria and a high riboflavin content in protozoa.

Kesler and Knodt (30) found higher concentrations of thiamine, riboflavin, and niacin in the digestive tract contents of calves two to fourteen weeks of age than could be accounted for by the feed. A high concentration of thiamine was found in the rumen and omasum while the highest concentrations of riboflavin and niacin were in the small

intestine. Synthesis of acetic, propionic, butyric acids, riboflavin, and thiamine was revealed upon analysis of calf ruminal contents by Hibbs et al. (25). Chance et al. (11) found that the ten essential amino acids and the B vitamins were being produced in the rumen of fistulated steers. Hale et al. (23) found that the rapid increase of fatty acids in the rumen immediately after feeding was far above the amount of fatty acids available in the feed. This rapid increase in fatty acids together with their rapid absorption from the rumen suggested that fatty acids may make a highly significant contribution to ruminant nutrition either as an intermediate or an end product of digestion. Pounden et al. (45) found that most of the ruminal microorganisms were digested in the abomasum of the host but a few were found to be excreted intact.

Stomach development begins early in the bovine fetus as shown by Becker and associates (6), who observed differentiation of the honeycomb in the reticulum of fetal stomachs at 72 to 100 days in utero. During early development the empty stomach comprised approximately 1.8 per cent of the total fetal weight. This percentage decreased noticeably from six months to full term at which time the empty stomach was only 1.3 per cent of the total fetal weight. In early fetal development the rumen was the largest of the stomach compartments, but a full term the abomasum comprised one half of the total stomach tissue weight while the rumen averaged 32.8 per cent of the total stomach tissue weight.

Marshall and associates (36), studying postpartum ruminal development, found that the weight of tissue, volume of tissue, and weight of fresh contents of the rumen exceeded those of the abomasum in calves from seven to thirty days of age.

The weight of ruminal tissue and contents from 1 to 16 week old calves was reported by Kesler, Ronning and Knodt (31). The weight of the ruminal tissue increased steadily while the abomasal tissue remained constant from 8 to 32 days of age in one experiment. In another experiment it was shown that the ruminal tissue increased from an average of 0.5 pound at two weeks to 5.1 pounds at sixteen weeks of age, with this tissue more than doubling between the fourth and sixth weeks of age. Marshall and associates (36) reported that ruminal tissue weighed more than abomasal tissue from calves between seven and thirty days of age.

Wise and associates (57) rumenectomized four calves in an attempt to study the physiological role of the rumen as indicated by blood composition. Two of the calves died from operational shock and the two which lived regenerated incomplete rumen-like compartments.

Hibbs and Pounden (26) have demonstrated that ruminal development can be influenced by feeding calves a high ratio of hay to grain. McCandlish (38) found it necessary to change calves from an all milk diet after three months of age in order to promote normal alimentary tract development. Flatt and associates (21) have used fistulated animals to study the expansion of the ruminal-reticular cavity of calves in vivo. A hay-fed group had a greater capacity than milk or milk and starter-fed groups when compared on a body weight basis from eight to fourteen weeks of age.

The establishment of characteristic rumen microorganisms and their association with the digestibility of various rations have been used as criteria for rumen development by Conrad and associates (13, 15). Cud inoculated calves had higher values for the apparent digestibility of protein than uninoculated calves, but they also excreted more

nitrogen in the urine, therefore resulting in no significant difference in nitrogen retention(13).

Larsen and Stoddard (33) observed the effects of feeding a hog ration directly into the omasum of rumen fistulated steers and found that the health became critically endangered by scouring, weakness, unthriftiness, loss of weight, and depressed blood fat levels. Corn particles in the feces appeared the same as when fed, indicating that little or no digestion had taken place. Increasing the feeding schedule from three to eight times per day did not alter the effects of the ration, but it was satisfactory when placed in the rumen and permitted to take its normal course.

Hale and associates (23) used two fistulated cows to study the digestion coefficients of feed based on the analyses of the feces and the rumen contents removed at varying intervals after feeding. The average ruminal digestion coefficients based on the contents removed twelve to fourteen hours after feeding during eight trials were as follows: dry matter 84.4, protein 59.6, nitrogen-free extract 65.2, crude fiber 27.2, cellulose 43.4, other carbohydrates 83.0 and lignin 31.0. Digestion coefficients based on ruminal digestion were quite constant while those based on the feces were quite variable, due in part to the breakdown of lignified plant cells allowing additional digestion of carbohydrates and proteins in the lower portion of digestive tract.

Hibbs and associates (27) found no advantage in feeding a complex, high protein ration to calves which received milk during the first seven weeks of age when high quality hay and grain were fed at a ratio of 2 to 1. When calves were maintained on a hay to grain ratio

of 4 to 1, they excreted more nitrogen which indicated that energy was limiting the effectiveness of the protein. Lofgreen and associates (35) found that calves on a low protein intake would increase nitrogen retention when the non-nitrogenous fraction of the total digestible nutrients was increased.

The esophageal groove, sometimes referred to as the reticular groove, functions as a tube to conduct milk directly into the abomasum of small calves, according to Savage and McCay (48). Alexander (2) found that stimulation of the esophageal groove resulted from the mechanical contact of milk or water in the posterior area of the mouth or pharynx. Alexander (1) also found that superior laryngeal nerve-stimulation produced reflex contractions of the esophageal groove, but, that the entry of water into the posterior part of the mouth was a more certain stimulus. Wise (54) found that drinking tap water stimulated closure of the esophageal groove in calves up to three or four weeks of age, but filling the rumen of a fistulated calf with milk did not stimulate closure of the groove. The act of sucking a clean nipple and the sight of milk at feeding time stimulated closure of the esophageal groove in a month old calf.

Wise and Anderson (55) observed that milk fed to calves from an open pail frequently entered the rumen while milk fed from nipple pails seldom entered the rumen. Water offered by nipple spurted into the rumen in small amounts while almost all of the water given from open pails entered the rumen. Wise and associates (56) found that the vagi are paths over which nerve stimuli may travel to the esophageal groove but are not affected by the position of the head. Schalk and Amadom (49) found that the esophageal groove did not function in regurgitation.

Reticular and ruminal motility are generally considered together since they are so closely related. Alexander (1) reported that the reticular contractions were double in nature. These double contractions occurred about once every minute forcing the digesta into the rumen. The reticulum then relaxed and filled with the digesta from the rumen. The rumen contracted once or twice for each double contraction of the reticulum and was less forceful and slower than the reticular contractions. The dorsal and ventral sacs of the rumen usually contracted alternately. The reticular contractions were rapid while the calves were eating, and slow when they were ruminating. There were continuous, slow, powerful contractions of the omasum, and digesta passed into it continuously, probably with every reticular contraction. When vagi in the neck were exposed and cooled, causing cessation of motility, stimulation of the central end of the vagus did not cause rumination. The subcortical area, in the brain, anterior to the pituitary infundibulum, was found to be concerned with these ruminal-reticular movements, therefore the brain cortex was not necessary for rumination.

Dziuk and Sellers (19) entered the thoracic cavity of calves and connected silver electrodes to the vagal trunks. They used this technique to correlate the spontaneous and stimulated ruminal motility to recordings made by stomach tube pressure changes and a fluoroscope. Roughage-fed calves exhibited strong, regular ruminal contractions, while milk-fed calves did not show spontaneous motility continually.

Dziuk and Sellers (20) applied vagal electrodes to three fistulated cows and studied the spontaneous and stimulated ruminal contractions as exhibited by manometric measurement. Spontaneously the reticulum exhibited two contractions of 8 to 15 millimeters of mercury pressure

for 5 to 7 seconds. A second contraction, involving the anterior pillar as well as more posterior portions, was not recorded by a tip placed near the floor of the anterior dorsal sac. The primary contraction of the anterior ventral rumen sac began about 10 seconds after the second reticular contraction. It exhibited 10 to 20 millimeters of mercury pressure for 10 to 15 seconds. A secondary contraction began 1 to 2 seconds after the increase in pressure of the posterior dorsal sac and exhibited 2 to 6 millimeters of mercury pressure for 7 to 9 seconds when it occurred. The posterior dorsal sac primary contraction, beginning at about the end of the second reticular contraction, caused 6 to 12 millimeters of mercury pressure increase for 8 to 10 seconds. The secondary contraction, when occurring, was 30 to 60 seconds later and exhibited 5 to 7 millimeters of mercury pressure for 5 seconds. Eructations were distinguished from swallowing by only exhibiting 10 to 15 millimeters of mercury pressure for 2 to 4 seconds, while swallowing caused 20 to 40 millimeters of mercury pressure for 1 to 2 seconds. Stimulation of the vagus for 2 to 5 minutes increased motility even when the rumen was subjected to pressure or filled with water and the hind legs elevated. Schalk and Amadon (49) observed essentially the same motility pattern as described above, using fistulated animals and manometric methods.

The contents of the alimentary tract of calves at birth were studied by Parrish and Fountaine (43, 44) who found that the pH of the tract contents decreased in order of the stomach, caecum, small intestine, large intestine, and colon. The pH of the ruminal-reticular contents ranged from 6.3 to 6.7 with an average of 6.3. Marshall and associates (36) studied young calves and observed a range in ruminal

pH from 5.17 to 6.89, and in reticular pH from 5.19 to 7.19. Kesler and associates (31) found an average ruminal pH of 5.5 for calves up to thirty-two days of age. Pounden and Hibbs (46) observed an average pH of 6.7 for forty-three ruminal samples from nine calves of one to ten days of age.

Monroe and Perkins (40, 41) used fistulated cows to study the ruminal pH values by observing samples from six locations in the rumen and at varying hours of the day. Corn and A.I.V. silage ingesta ranged from pH 6.83 to 7.01, while pasture ingesta was slightly more acid. The ruminal contents were more alkaline just prior to the morning feeding than at other times during the day. After the first feeding it dropped, then rose until feeding time at three o'clock in the evening, after which it dropped again. When the cows were on pasture the pH remained relatively constant throughout the day.

Chance and associates (12) using fistulated steers observed a steady drop in pH from a range of 6.8 to 7.0, to a range of 5.5 to 6.5 during the first eight to ten hours after feeding. The pH of the ruminal contents of one steer dropped considerably more than that of the other. Using fistulated cows Smith (51) found a mean ruminal pH of 6.27 for those fed on alfalfa hay alone, and a mean ruminal pH of 6.00 for cows on alfalfa hay and beet pulp, based on five days with three reading per day. Two hour interval readings for a twenty-four hour period gave a mean pH of 6.30 for alfalfa hay ingesta and a mean pH of 6.07 for alfalfa and beet pulp ingesta. The pH of the ingesta fluctuated throughout the day but in general was more alkaline shortly before and after feeding. Smith (51) also found a range in the mean pH from 6.27 to 6.00 in samples from the front and from the rear of

the rumen, respectively. Lower pH was observed *in vivo* than *in vitro*.

Cason *et al.* (10) observed a significant positive correlation between the ash content and the pH of ingesta. This relationship appeared to be due to the buffering capacity of the ash, which with the buffering action of the saliva, tended to keep the pH of the ruminal contents within narrow limits. Huffman (38) promoted the theory that saliva played an important role in ruminal pH regulation. Alexander (2) reported that the pH of saliva ranged from 8.5-8.8. Olson (42) measured 473 ruminal samples from dead animals and established a mean ruminal pH of 6.859, with time of the year or feeding conditions having no apparent effects.

Temperature is another tool which has been used for many years as an indication of the animal's well being. Regan and Richardson (47) used a psychrometric room to observe the reactions of a cow when subjected to various temperatures from 40° to 104° F. with air flow and humidity being maintained at constant rates during the trials. There was a uniform increase in respiration rate, from 12 per minute at 40° F. to 100 per minute at 100° F. The pulse rate decreased and a pyrexial point was reached at 80° to 85° F., at which point the animal could no longer maintain heat balance and exhibited a decrease in milk flow and feed consumption. Brody (8) used the term, "critical temperature" for the temperature point at which a cow would show a decline in milk production and feed consumption, and a rise in rectal temperature. It was found to be between 70° and 85° F., varying with body size and milk yield, with large or high producing cows having low "critical temperatures."

The normal temperature of cattle is around 101.0° F. but there is considerable individual daily variation. Gaalaas (22) studied body

temperature with 3,298 readings taken over a 16 month period, and observed a range from 101.0° F. to 103.2° F. at air temperatures of 50° F. and 95° F. respectively. Hewitt (24) reported larger variations in the body temperature of cattle than those generally quoted observing extreme cases with a range of 4.4° F. between high and low values. McDowell and Hilder (39) found that lactating and dry cows had the same body temperatures in a 65° F. atmosphere, but that lactating cows' body temperature were slightly higher than that of dry cows in a 90° to 100° F. air temperature. The greatest rise in body temperature was demonstrated by both those dry and lactating cows which consumed the greater amounts of feed.

Kriss (32) found that the location of the recording instrument was important when measuring body temperature. Rectal temperatures averaged 0.3° F. above the vaginal temperature measured at a depth of seven inches, and rectal temperatures were also higher at a depth of 6 to 7 inches than at 4 to 5 inches. There was no material difference in temperature measured at depths of 6 and 7 inches, while there was a difference between 4 and 6 inches. The position of the animal had very little effect on the temperature, and there was no difference in temperature before and after defecation. Feed consumption resulted in a rise in body temperature of cows on a maintenance ration for about thirty minutes after feeding. There were considerable individual variations in body temperatures from day to day, even with animals on constant feed and water intakes.

Ruminal temperature gradients were measured by Dale and associates (16) on fasting and normally fed cows. They used a series of thermocouples and a Brown recording potentiometer to make the readings. Three thermocouples were arranged in an 18-inch stainless steel inseminating rod in such a way that one recorded at the tip, one six inches from the

tip, and one twelve inches from the tip with the inseminating rod being placed into the rumen through a stab fistula. Another thermocouple was inserted in the rectum to a depth of six inches. Under conditions of both feeding and fasting the rumen showed a temperature gradient from top to bottom which may have been associated with either differences in heat production or heat loss at various levels in the rumen. Ingestion of four pounds of chopped alfalfa hay by a fasting cow disrupted the top to bottom gradient by causing a fairly steep rise at the level of the middle thermocouple, presumably located close to, or a little above, the center of the rumen. There was a slight rise in rectal temperature within fifteen minutes after feeding the chopped alfalfa hay. Fourteen pounds of 62° F. water affected mostly the highest level and warmest part of the ingesta when pumped into the rumen through a stomach tube, passed orally to approximately the depth of the thermocouple probe. The return to normal temperature showed two phases: first, there was a rapid rise in temperature apparently due to mixing, followed by a second period of gradual return to normal apparently due to warming of the chilled ingesta. The rumen temperature of a cow fasted for twenty-four hours was 1.5° F. above the rectal temperature, but when feed was available constantly the rumen temperature was 4° F. above the rectal temperature. The rectal temperature of a fasted cow was slightly lower than that of the same animal when fed normally.

Beakley and Findlay (5) used thermocouples at eight body locations to measure the effect of environmental temperature on skin temperature. They recorded individual temperatures at five-minute intervals during six-hour periods daily for forty-five days. There were no significant differences in skin temperatures due to location, but they rose as a

result of increases in environmental temperature, humidity and time of exposure with variations in skin temperatures being greater at low temperatures. When calves were subjected to a different environmental temperature, the skin adjusted accordingly in ten minutes. Beakley and Findlay (4) using two thermocouples and a thermistor in a polythene tube, observed that rectal temperatures of calves were elevated by increases in environmental temperature and humidity. A rise in rectal temperature occurred after about four hours in the room regardless of the environmental temperature.

Brody, Stewart, and Dale (9) used the same technique as described by Dale (16) with the addition of a thermocouple inserted in a polyethylene catheter for recording the blood temperature. The rumen and rectal measurements were made as described previously. The temperature of the blood, as measured with thermocouple inserted into the right jugular vein, was 99.1° F. at 6 to 18 inches deep and 100.3° F. at 24 to 36 inches deep. Injection of antipyretics first lowered the rectal temperature after which there was an increase in rumen temperature.

Dillon and Nichols (17) used thermocouples to measure the ruminal - reticular temperature changes following the drinking of water. The temperature changed first in the cardia, then the reticulum, and finally in the ventral sac of the rumen, with return to pre-drinking temperature occurring in the same order. The amount and temperature of the water affected the magnitude of the temperature changes.

EXPERIMENTAL

Purebred dairy calves were obtained from the Oklahoma Agricultural and Mechanical College dairy herd for experiments terminating with the sacrifice of the animal. Consequently, there was a predominance of male animals, with four of the dairy breeds represented but with no concentration of animals in any one breed.

The calves were removed from their dams at 48 hours of age and tied in individual partitioned stalls bedded with wood shavings. The stalls were equipped with a feed box, hay rack, and a water bucket and were located in a heated and ventilated barn.

The calves were fed a maximum of 450 pounds of Holstein herd milk at the rate of 10% of bodyweight daily. A 16% protein starter was offered free choice until a maximum of four pounds per day was consumed and good quality prairie hay was fed ad libitum. An ample supply of water was available at all times. Exercise was permitted in an open lot two hours daily during fair weather. All deviations from this procedure are discussed as consequential conditions are encountered.

EXPERIMENT I

EXPERIMENTAL PROCEDURE

This experiment was designed to observe and record the normal temperature patterns of the developing rumen of normal calves and to establish new techniques for rumen studies. The primary objective was accomplished in part by the use of a Leeds and Northrup multiple range potentiometer indicator with visual reading accuracy of $\pm 0.25^{\circ}$ F. or $\pm 0.10^{\circ}$ C. Three thermocouples (18 feet long) were connected to a multiple lead switch making it possible to measure the ruminal, rectal and epidermal temperatures concomitantly. The thermocouples were iron-constantan wire, of standard gauge 24, with heat-resistant rubber insulation.

The rectal thermocouple was made rigid by applying a six inch plastic splint to the recording end. The ruminal thermocouple was placed in an eighty-two inch length of small diameter, heavy-walled vacuum hose for protection and rigidity, thus, enabling penetration of the esophagus. The end of the epidermal thermocouple insulation was wrapped with plastic tape to lend rigidity and prevent fraying of the insulation.

The calf to be measured was placed in a stanchion, in such a way that the operator was allowed to move freely around the animal. About fifteen minutes were allowed for the instrument to adjust to room temperature, after which the galvanometer scale was set at zero and the readings were taken.

The rectal thermocouple was inserted into the rectum to a depth of six inches and remained in place unrestrained, unless defecation occurred in which case the thermocouple was replaced after defecation.

A leather halter fitted with a seven-inch wooden bit was placed on the calf and the ruminal thermocouple was inserted through a hole in the bit and forced gently through the esophagus to a point beyond that necessary for the emission of characteristic rumen gas (Fig. 1). The depth to which the ruminal thermocouple was inserted varied with the size of the calf and was estimated to be twelve to twenty-four inches beyond the cardiac region of the esophagus. The distance of insertion of the hose beyond the point of requiring increased pressure to penetrate the cardiac sphincter was used as a basis for estimating the depth to which the thermocouple was inserted.

The epidermal thermocouple was held in contact with the skin, at the junction of the neck and shoulder at a point about mid-way between the withers and the point of the shoulder. The thermocouples remained in place for at least five minutes before temperature readings were taken.

Since this was a pilot experiment a number of readings were taken at varying intervals after feeding in order to establish a logical interval for making temperature observations, and this appeared to be at one and two hours after feeding. Six of the calves were measured before feeding and at each of the after feeding intervals the same day, for a total of eighty-three readings per interval. During the time of intensive measuring, the initial readings were taken before the morning feeding. Following a thirty minute eating period the one and two-hour after feeding measurements were taken. The calves

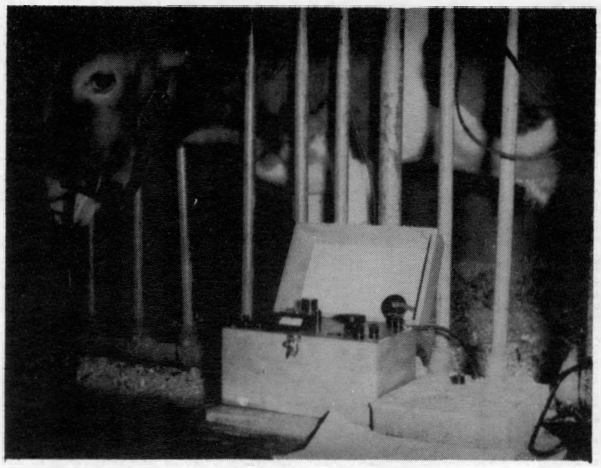


Fig. 1 Calf with thermocouples in place for temperature measurement.

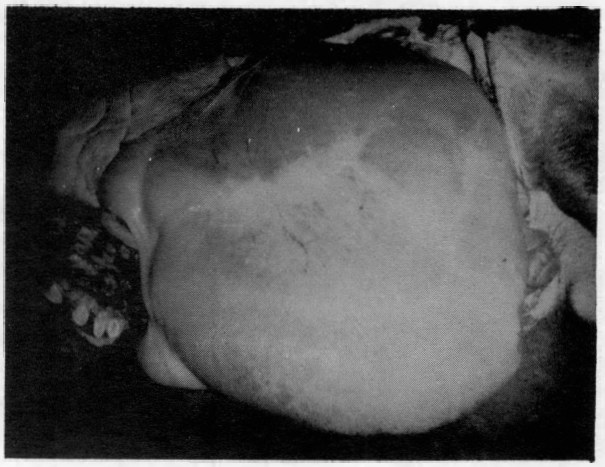


Fig. 2 Stomach exposed, ready for esophageal and intestinal ligation.

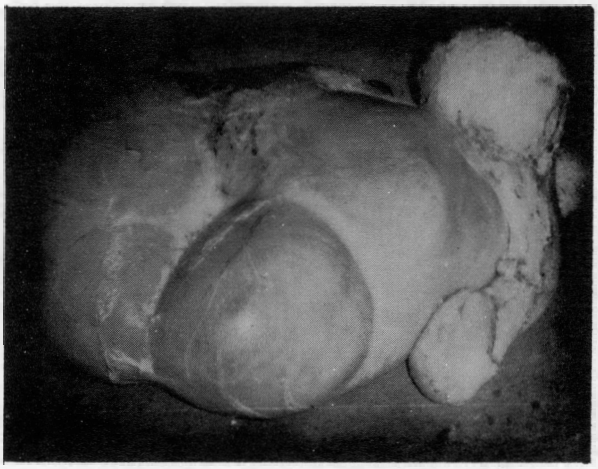


Fig. 3 Stomach after ligation, severing and removal of extra tissue.

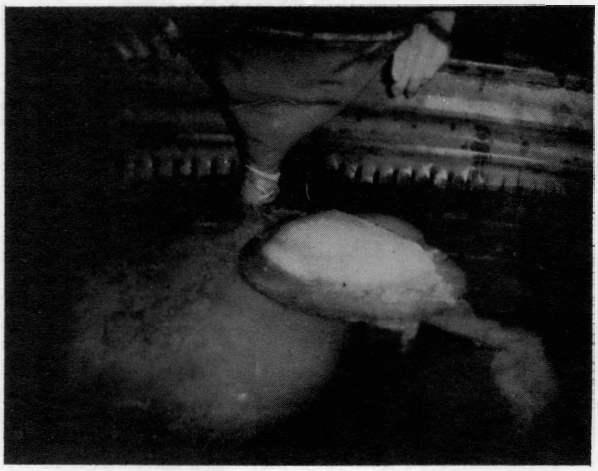


Fig. 4 Ruminal-reticular tissue filled with water for measurement.

Fig. 5 Inflated fistula plug (left) and insert (right) before assembly.

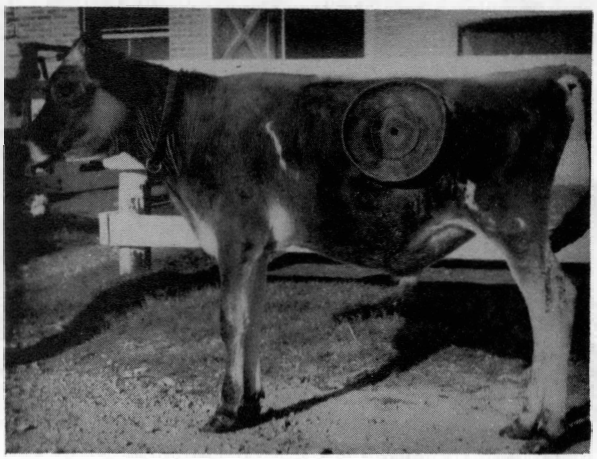


Fig. 6 Fistula plug and insert as assembled in the fistulated calf.

were not watered until after all of the measurements had been taken.

RESULTS AND DISCUSSION

The temperature data obtained with twenty calves are summarized in Table 1, and the original data are presented in Appendix Tables II through XI. Linear regression by the least squares method was used to establish the lines plotted in Figures 7 through 11 (52). The equations for the lines in Figure 7 are as follows: before feeding ($y = 102.39 - .05x$), after feeding (1 hour) ($y = 104.10 - .15x$), and after feeding (2 hours) ($y = 103.37 - .08x$). The lines in Figures 8 through 10 are individual duplications from Figure 7 with the plotted means for each age group. While all of the after feeding measurements from zero to one and one-half hours inclusive were combined into the after feeding (1 hour) group and all other after feeding measurements were combined into the after feeding (2 hour) group for the analysis, two-thirds of the measurements were taken at the prescribed intervals. The line for temperature in relation to time of feeding ($y = 102.33 + .36x$), with the means of the combined readings plotted about it, is presented in Figure 11.

The rectal temperature apparently follows the same general trend exhibited by the ruminal temperature, but with more moderate fluctuations due to feeding. The epidermal temperatures showed a very wide range but were in general about 5° F. below the rectal temperature.

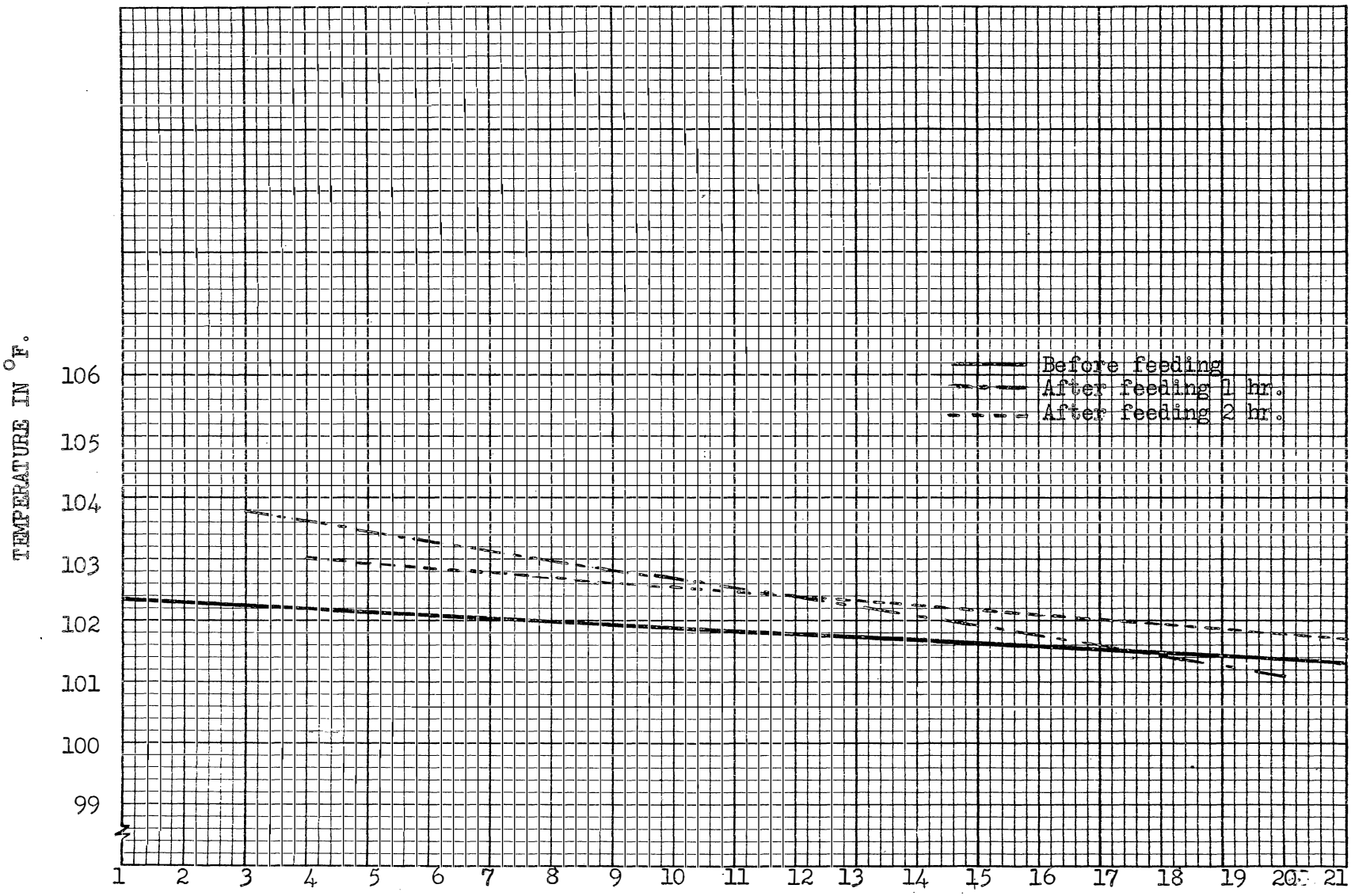
The gradual drop in ruminal temperature with age as indicated in Figure 1 cannot be explained. It can only be assumed that the more rapid decrease in temperature at the one hour after feeding interval

TABLE 1

SUMMARY OF THE TEMPERATURE DATA BY AGE AND TIME OF MEASUREMENT

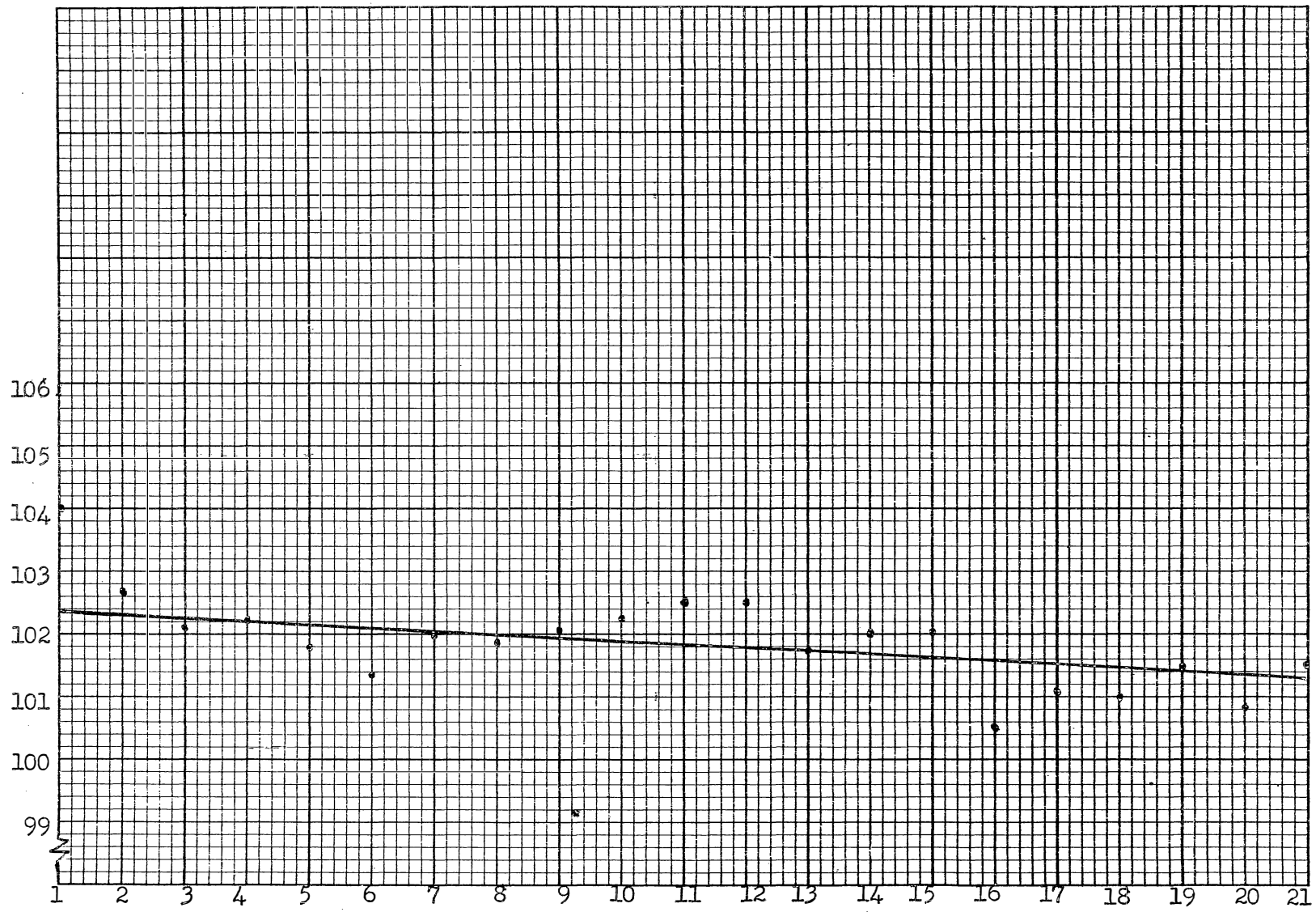
Age Mo.	Before Feeding			After feeding 1 hr.			After feeding 2 hrs.		
	Sum	N	Mean	Sum	N	Mean	Sum	N	Mean
1	208.0	2	104.00		0			0	
2	308.0	3	102.66		0			0	
3	613.0	6	102.17	103.5	1	103.50		0	
4	715.5	7	102.21	412.5	4	103.13	413.5	4	103.38
5	509.0	5	101.80	616.0	6	102.67	512.5	5	102.50
6	1318.0	13	101.38	923.0	9	102.56	1026.0	10	102.60
7	1122.0	11	102.00	1028.0	10	102.80	1028.5	10	102.85
8	3769.5	37	101.88	3097.0	30	103.23	3597.0	35	102.77
9	1939.0	19	102.05	1550.0	15	103.33	1547.0	15	103.13
10	1329.0	13	102.23	1540.0	15	102.67	1435.5	14	102.54
11	205.0	2	102.50		0			0	
12	1127.5	11	102.50		0		102.5	1	102.50
13	2135.5	21	101.69	511.5	5	102.30	304.0	3	101.33
14	918.5	9	102.06	204.5	2	102.25	407.5	4	101.88
15	1020.5	10	102.05	404.5	4	101.13	1123.5	11	102.14
16	201.0	2	100.50	408.5	4	102.13	204.0	2	102.00
17	303.5	3	101.05	198.5	2	99.25[1]	306.5	3	102.17
18	808.0	8	101.00	304.0	3	101.33	204.0	2	102.00
19	406.0	4	101.50	607.5	6	101.25	101.0	1	101.00
20	403.5	4	100.88	606.0	6	101.00	405.0	4	101.25
21	101.5	1	101.50		0		103.0	1	103.00

[1]Drank water just prior to one of the readings.



REGRESSION OF RUMINAL TEMPERATURE ON AGE

Fig. 7



REGRESSION OF RUMINAL TEMPERATURE ON AGE BEFORE FEEDING
WITH MEANS FOR EACH MONTH

Fig. 8

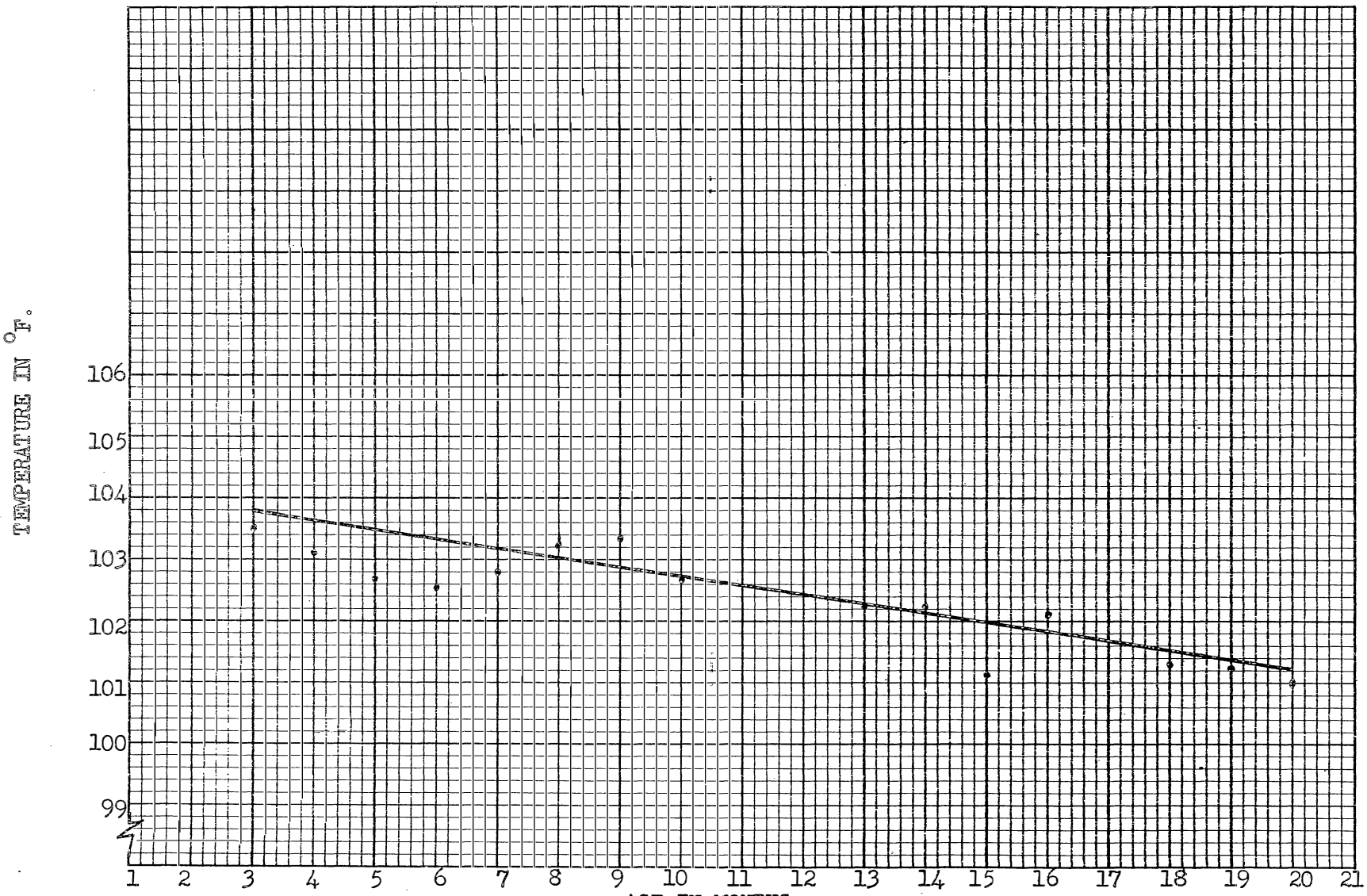
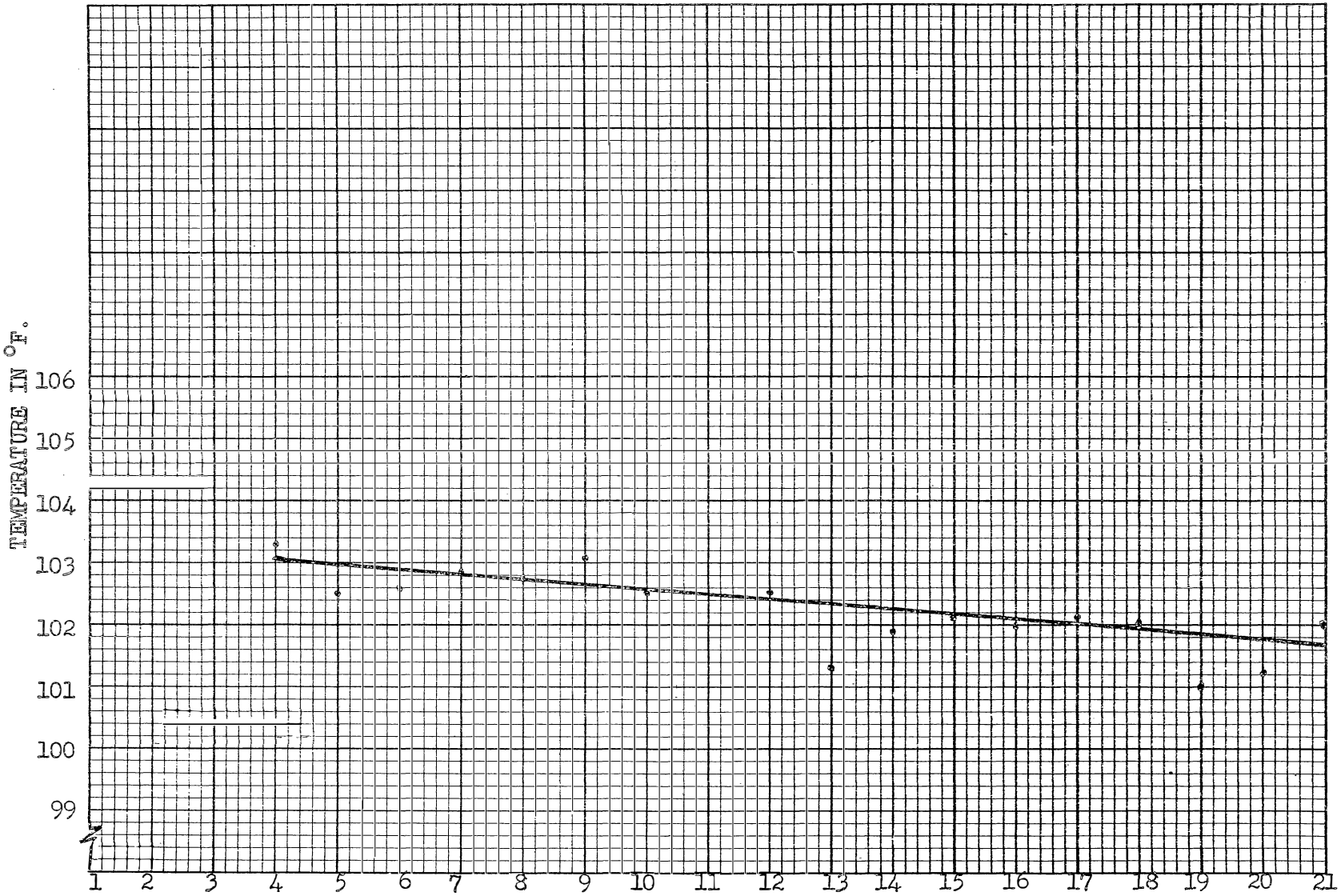
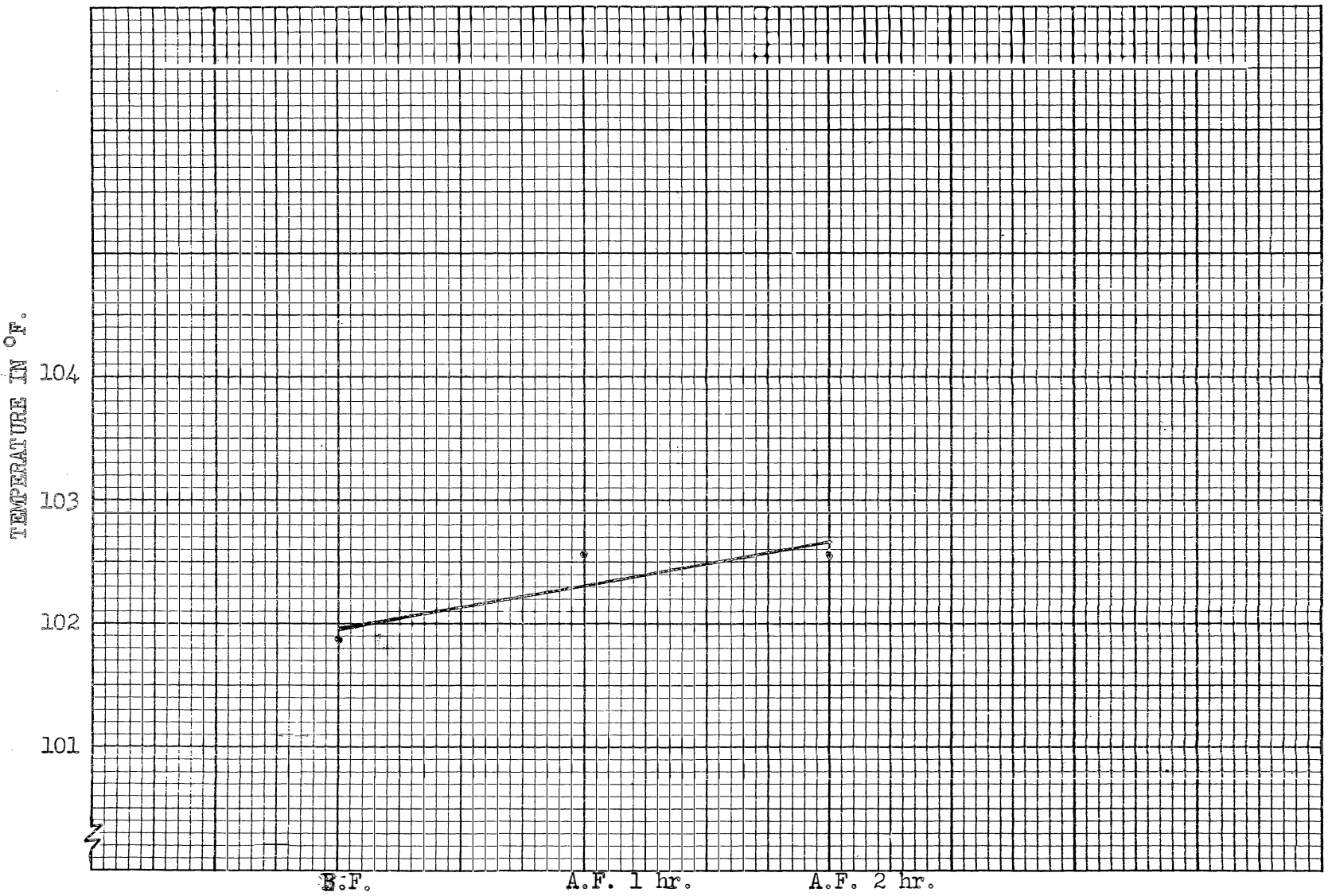


Fig. 9 REGRESSION OF RUMINAL TEMPERATURE ON AGE AFTER FEEDING ONE HOUR WITH MEANS FOR EACH MONTH



REGRESSION OF RUMINAL TEMPERATURE OF AGE AFTER FEEDING
TWO HOURS WITH MEANS FOR EACH MONTH

Fig. 10



REGRESSION OF RUMINAL TEMPERATURE ON FEEDING TIME INTERVAL WITH MEANS PLOTTED

Fig. 11

might be due in part to the cooling effect of the feed consumed. It also might be due in part to the effect of the stratified rumen ingesta keeping the thermocouple junction in the freshly swallowed feed. The cycling effect shown by the means in Figures 8 through 10 could not be explained on the basis of the number of readings or seasonal variations in climatic temperature. The after feeding (1 hour) mean for the seventeenth month was omitted from Figure 9 for it was exceptionally low (99.25°F.) because one of the calves inadvertently drank water just prior to the measurement.

The gradual increase in ruminal temperature on the basis of measurements taken at two intervals after feeding as shown in Figure 11 might be due to increased microbial activity.

Analysis of the limited data acquired in this experiment indicates that extensive measurements should be made at varying intervals after feeding and with more calves in the younger age group.

EXPERIMENT II

EXPERIMENTAL PROCEDURE

This experiment was designed to obtain information necessary in establishing relationships between ruminal capacity and age and body weight. Animals were sacrificed at various ages from four to 617 days. A standard method of water displacement was used to measure the ruminal-reticular capacity.

Immediately after each animal was killed, the stomach was exposed and ligated at the esophagus and small intestine before removal (Fig. 2). The stomach was rolled out and the extraneous tissue removed by blunt surgery (Fig. 3). The omasum was ligated from the reticulum and abomasum to prevent passage of contents.

The contents were removed by flushing the ruminal-reticular and abomasal cavities with water. The empty tissue was submerged in a water bath, the water level marked, and each separate compartment filled with water until the interal and external water surfaces were level, indicating equalization of pressure (Fig. 4). Volume capacities were determined by measuring the amount of water displaced from the bath during the filling of the respective submerged stomach compartments. Volumeteric measurement of the omasal cavity was accomplished in a similar manner except that the total volume displacement was made with this section containing the contents since it was impossible to flush out this material without dissecting the entire structure.

RESULTS AND DISCUSSION

Capacity data for the stomach compartments of 15 calves are presented in Table 2. In order to make observations relative to the development or increase of capacity in relation to age and bodyweight, the data are discussed in terms of volume in liters as well as per cent of the total volume for each compartment.

With respect to age, it seemed that the ruminal-reticular volume increased slowly from the age of 4 days to 103 days after which development became quite rapid, although it was apparently variable between individuals.

While individual measurements of abomasal capacity showed considerable variation, there appeared to be a trend of slow and gradual increase in volume throughout the age range observed. Inconsistencies relative to omasal measurements would obviously be expected to be more pronounced since flushing of the compartment and refilling with water was not permitted. If the more extreme variations could be overlooked, it would appear that omasal volume was increased slowly and gradually during the observed age range.

It appeared that the ruminal-reticular cavity rather consistently contributed about 80 to 90 per cent of the total stomach volume except at the very young age. Only three values deviated from this range and in two of those instances the variation was not large. A relatively consistent relationship between ruminal-reticular capacity and total capacity was strikingly apparent in the case of the last three calves

TABLE 2

THE RELATIVE CAPACITY OF THE STOMACH COMPARTMENTS

Calf No.	Age Da.	Body Wt.Lb.	Capacity in Liters				% of Total Capacity		
			Total	Ruminal Reticular	Omasal	Abomasal	Ruminal Reticular	Omasal	Abomasal
3	4	71	1.475	.49	.005	.98	33.2	.3	66.5
5	31	79	2.45	2.0	.05	.4	81.6	2.1	16.3
16	103	171	8.3	5.7	1.1	1.5	68.7	13.3	18.0
14	130	262	22.6	19.1	2.0	1.5	84.5	8.9	6.6
95	160	277	43.2	38.0	2.7	2.5	88.0	6.2	5.8
20	190	192	17.0	14.3	1.2	1.5	84.1	7.1	8.8
63	247	351	27.8	21.7	4.0	2.1	78.1	14.3	7.6
64	285	500	44.1	38.9	3.4	1.8	88.2	7.7	4.1
8	304	417	31.3	24.1	5.6	1.6	77.0	17.9	5.1
29	316	444	45.9	39.8	4.1	2.0	86.7	8.9	4.4
21	428	565	83.2	74.7	5.0	3.5	89.8	6.0	4.2
71	438	714	89.4	73.8	8.7	6.9	82.6	9.7	7.7
27	520	---	38.7	33.1	3.6	2.0	85.5	9.3	5.2
205	572	---	92.4	78.8	8.7	4.9	85.3	9.4	5.3
28	617	---	54.8	45.6	5.3	3.9	83.2	9.7	7.1

in Table 2. The relatively uniform relationship after 103 days between the three stomach divisions studied indicates that the rate of development during this stage was comparable in all sections.

Ruminal-reticular development with respect to capacity seemed to bear a closer relationship to bodyweight than to age. This would be expected, particularily in view of breed differences in size at given ages. Most probably a real relationship does not exist between either age or bodyweight alone, particularily in the case of very young calves. This was indicated in this study in that the ratio between ruminal-reticular volume and bodyweight was 1:145 in the 4-day old calf but had dropped to 1:40 in the 31-day old calf. The bodyweights of these two individuals, however, were not greatly different. This study does not involve sufficient numbers of calves of any one breed to justify any attempt to study the interaction between age and bodyweight in relation to the development of ruminal-reticular capacity. Furthermore, unfortunate circumstances prevented obtaining the bodyweights of the three oldest animals which further limited the usefulness of these data in studying age-bodyweight relationships.

Between approximately 200 and 400 lb. bodyweights, the ratio of ruminal-reticular volume to bodyweight ranged from 1:13 to 1:17 after which the ratio seemed to become narrower with a range of 1:11 to 1:13. This trend together with the ratios observed with younger calves shows a rapid increase in ruminal-reticular volume at an early age after which the capacity increase of the ruminal-reticular cavity is more nearly in the same order as body growth. Since the ratio seems to become narrower at heavier bodyweights, there is some indication that ruminal-reticular volume development was proceeding

at a faster rate than growth. Material benefit would have been contributed to these comparisons had bodyweights been available for the older animals which were beyond the stage of rapid growth. Further work in this direction should be encouraged.

The technique used in making volumetric measurements of the stomach capacities apparently needs further refinement. As used in this study it seemed to have value in making comparative observations with respect to stomach capacity, but should not be expected to represent a true value of capacity.

EXPERIMENT III

EXPERIMENTAL PROCEDURE

This experiment was designed to observe the ruminal fluid pH pattern of a fistulated calf on two different relations, consisting of concentrates only for 21 days and hay only for 21 days. Changes in the pH of non-buffered samples stored in glass at room temperature were also observed.

A fistula plug was made from four circular pieces of rubber vulcanized in such a way that internal pressure, controlled by air pumped through a valve stem, would cause a more rapid expansion in diameter than depth. This circular pressure gripped the fistula insert which was made by plaiting layers of rubber and vulcanizing them to form two thick rigid circular discs with a hole in the center for the plug (Fig. 5). The rubber forming the edge of the center hole was continuous with both discs forming a liquid and air-tight fit when the plug was in place and inflated. The outer edge of each disc was reinforced with a strong coiled spring, vulcanized inside the rubber. This spring had sufficient flexibility to permit folding of the insert for ease in putting one flange of the insert into the fistula, the other remaining on the outside. The inflated plug could be easily removed or replaced after deflation. The fistula plug in place is shown in Figure 6.

An electric Beckman H-2 pH meter equipped with micro electrodes was used for pH measurements. Samples were taken approximately two

hours after the morning feeding and were collected in glass test tubes by deflating the fistula plug and collecting about ten milliliters of the fluid which flowed freely from the fistula. This procedure was used consistently since the effect of each ration was the primary objective and not the sampling location.

The sample tube was corked and taken immediately to the laboratory and pH measurements made as rapidly as possible, at least within ten minutes after sampling. The remainder of the sample was stored in a stoppered test tube at room temperature for four days following collection in order to observe the reaction of unbuffered ruminal fluid during storage at room temperature.

At the initiation of this experiment the fistulated calf was being fed a normal ration consisting of four pounds of a 16% protein concentrate and good quality prairie hay ad libitum. Ruminal fluid samples were collected daily and treated as described previously for three days before the calf was changed to the first experimental ration and for four days while the calf was being changed gradually to the all concentrate ration. The observations during this seven-day period were considered on the basis of a "normal" ration.

The calf was scheduled to receive the all concentrate ration for twenty-one days, but after sampling on the eighteenth day the fistula plug and insert were accidentally dislodged and the rumen evacuated. This complete evacuation made it impossible to obtain a ruminal sample on the nineteenth day so a reticular sample was collected which had a pH of 7.2. The calf would not eat grain and ruminal motility practically ceased. Since the all concentrate trial was only three days from completion and the ruminal contents were abnormal it was decided

to initiate the all hay ration. Coarsely chopped stemmy alfalfa hay and three gallons of warm water were placed in the rumen through the fistula insert on the twentieth day. The plug was replaced and the calf was eating hay readily by the next morning. Samples were collected for pH measurement and microscopic examination throughout this recovery period. Hay alone was fed during this period and on the seventh day after the accident, appetite, pH measurements, and microscopic examinations indicated that ruminal function had returned to normal. Although pH measurements were made during this recovery period their values were not included in this study.

The all hay ration, consisting of good quality prairie hay and sufficient alfalfa hay to maintain the protein requirement, was continued for 21 days with rumen samples being collected and measured according to the same procedure used on the "all concentrate" samples.

RESULTS AND DISCUSSION

The ruminal fluid pH data obtained by sampling from a fistulated calf, while consuming three different rations, are summarized in table 3, and the original data are presented in Appendix Table XII. The pH observed when the calf was on an all hay ration was somewhat higher than when on either an all concentrate or a normal ration. The pH values of the latter two rations were quite comparable. During storage the pH generally dropped the first day then leveled off in the all concentrate and all hay ration samples but seemed to increase in the normal ration samples. In view of these data there might be value derived from ruminal pH measurements taken via the esophagus of a normal calf.

TABLE 3

MEANS OF pH DATA FOR RUMINAL FLUID

Ration	Mean pH for Days After Sampling				
	0	1	2	3	4
A[1]	6.4	6.0	6.3	6.7	6.5
B[2]	6.4	5.8	5.7	5.8	5.8
C[3]	6.8	6.6	6.5	6.5	6.6

[1]
[2]Concentrate and hay.
[3]All concentrate.
All hay.

SUMMARY AND CONCLUSIONS

Intra-ruminal temperature, volumetric capacity, and ruminal fluid pH, have been measured in an attempt to develop procedures for rumen development studies.

Ruminal temperature based upon 438 measurements appeared to show a slight decrease in the regression line for temperature on age. There was a slight increase in a regression line for temperature on interval after feeding.

Ruminal-reticular capacity apparently increased at a rapid rate during early age, followed by a period of slower rate of increase which paralleled the growth of the other compartments. Then the rate of increase appeared to become more rapid toward the end of the observation period in this study.

Similar trends were indicated whether the capacities were compared to bodyweight or to age. There appeared to be an interaction between age and bodyweight in relation to compartmental capacity as well as the per cent of total capacity.

The pH of ruminal fluid samples seemed to be slightly higher when the calf was on an all hay ration than when it was fed either concentrates alone or concentrates plus hay. Stored samples revealed a drop in the pH on the day following collection after which there was a rise indicated in the concentrate plus hay ration samples while the pH of the all hay and all concentrate rations appeared to be stable.

On the basis of this study it appears that ruminal temperatures can

be measured effectively with the described procedure. Further work is needed to establish temperature patterns of the rumen with respect to time of eating, with readings taken over a longer period and at shorter intervals than in this study.

Possible relationships between the interaction of age and body-weight and ruminal capacity should be investigated. Experience indicated that a uniform water temperature should be maintained in order to avoid variation in tissue contraction. Further work would be necessary to determine an optimum temperature range. Other refinements in this technique may be desirable.

The measurement of ruminal fluid pH should have value in studying the ruminal development of calves. It would be desirable to adapt pH electrodes in such a way that esophageal penetration could be accomplished in order to make such measurements with normal, intact animals.

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APPENDIX

APPENDIX

TABLE I

GENERAL INFORMATION AND DISPOSITION DATA

Calf No.	Breed	Sex	Date of Birth	Date of Removal	Age in Days	Disposition
28	G	F	9-24-53	6- 3-55	617	Sacrificed
205	G	M	11- 7-53	6- 2-55	572	Sacrificed
27	G	F	12-28-53	6- 1-55	520	Sacrificed
50	H	M	3-12-54	12-20-54	289	Vit. A. Exp.
81	H	M	4- 1-54	12-20-54	265	Vit. A. Exp.
71	H	M	4-16-54	6-28-55	438	Sacrificed
21	G	M	4-29-54	7- 1-55	428	Sacrificed
G29	G	F	9-11-54	12-20-54	110	Vit. A. Exp.
20	J	M	9-15-54	3-24-55	190	Sacrificed
30	G	F	10-12-54	12-20-54	79	Vit. A. Exp.
18	J	M	10-31-54			Fistulated living
29	J	M	1- 1-55	11-12-55	316	Sacrificed
8	G	M	1- 8-55	11- 8-55	304	Sacrificed
64	H	M	1-21-55	11- 2-55	285	Sacrificed
63	J	M	3- 7-55	11- 9-55	247	Sacrificed
95	H	M	6- 4-55	11-11-55	160	Sacrificed
14	H	M	6-23-55	11- 1-55	130	Sacrificed
16	G	M	7-26-55	11- 7-55	103	Sacrificed
5	J	M	10-14-55	11-14-55	31	Sacrificed
3	A	M	11-22-55	11-26-55	4	Sacrificed

TABLE II

TEMPERATURE DATA FOR CALF NO. 205

Calf No.	Date	Age Gp.	Age Da.	Time	Temperature (°F.) Rect.	Rum.	Epid.	Conditions
205								
	Dec.[1]							
	20	14	408	4:00	104.0	104.5	99.0	B.F.
	21	14	409	10:00	101.0	99.0	95.0	B.F.[3]
	21	14	409	11:15	102.5	101.5	86.0	B.F.
	21	14	409	1:45	102.5	101.5	89.0	B.F.
	21	14	409	2:30	102.5	102.5	87.0	A.F. 1/2 hr.
	21	14	409	4:00	102.5	101.5	89.0	A.F. 2 hr.
	22	14	410	4:15	102.5	101.0	92.0	B.F.
	Jan.							
	29	15	448	3:50	100.0	101.5	93.0	A.F. 1/4 hr.
	Apr.							
	11	18	520	4:30	103.0	102.0	96.0	B.F.
	12	18	521	2:30	102.5	102.0	95.0	B.F.
	18	18	527	4:30	103.0	103.0	96.5	B.F.
	19	18	528	4:45	101.5	101.5	95.0	A.F. 3 1/2 hr.
	20	18	529	3:10	102.5	101.0	95.0	B.F.
	21	18	530	4:45	102.5	101.5	95.5	A.F. 1/6 hr.
	22	18	531	4:30	101.0	100.5	95.0	A.F. 1/6 hr.
	26	18	535	8:00	100.5	96.5	91.0	B.F.[4]
	27	18	536	3:30	102.0	100.0	95.0	B.F.
	28	18	537	3:25	103.0	101.5	94.5	B.F.
	29	18	538	3:40	103.0	102.0	96.0	B.F.
	May							
	3	19	542	9:10	101.0	101.5	94.0	B.F.
	3	19	542	10:20	101.0	99.0	95.0	A.F. 1 hr.
	3	19	542	1:45	100.5	101.0	96.0	A.F. 4 1/2 hr.
	3	19	542	3:20	102.0	99.5	95.0	A.F. 1 1/3 hr.[4]
	4	19	543	3:30	102.0	101.0	96.0	B.F.
	5	19	544	10:35	102.0	102.0	96.0	B.F.
	6	19	545	2:35	102.5	102.5	97.0	A.F. 1 1/2 hr.
	30	19	569	4:00	102.0	103.0	95.0	A.F. 1 hr.
	June							
	2	20	572	10:00	101.0	101.0	95.0	A.F. 1/6 hr.

Footnotes used consistently throughout the temperature data tables are as follows:
[1]December, 1954 dates. All other months are 1955.
[2]Underlined time is P.M. All other time is A.M.
[3]Low reading due to thermocouple trouble.
[4]Low reading due to consumption of water prior to the measurement.
[5]Readings were made after fistulation, in the normal manner.

TABLE III

TEMPERATURE DATA FOR CALF NO. 71

Calf No.	Date	Age Gp.	Age Da.	Time	Temperature (°F.) Rect.	Rum.	Epid.	Conditions
71	Dec.[1]							
	21	9	249	3:15	103.5	103.0	86.0	A.F. 1 3/4 hr.
	22	9	250	5:15	102.5	102.0	91.0	B.F.
	30	9	258	5:10	102.0	102.0	88.0	B.F.
	Jan.							
	29	10	288	3:10	102.0	103.5	92.0	A.F. 1/4 hr.
	Apr.							
	11	12	360	4:00	102.5	103.5	95.0	B.F.
	12	13	361	4:00	102.5	101.5	95.0	B.F.
	14	13	363	4:00	102.5	102.5	95.0	B.F.
	18	13	367	4:15	102.5	101.5	98.0	B.F.
	19	13	368	4:35	102.0	101.0	97.0	A.F. 3 1/3 hr.
	20	13	369	3:00	102.0	101.5	96.5	B.F.
	21	13	370	4:35	102.5	101.0	96.0	B.F.
	22	13	371	4:15	103.0	101.5	95.5	A.F. 1/6 hr.
	26	13	375	8:10	102.0	101.5	94.5	B.F.
	27	13	376	3:00	102.5	102.0	96.0	B.F.
	28	13	377	3:35	102.5	100.0	96.0	B.F.
	29	13	378	3:50	102.5	102.5	97.0	B.F.
	May							
	3	13	382	9:00	101.0	101.0	95.0	B.F. 1 hr.
	3	13	382	10:10	101.5	101.5	95.0	A.F. 1 hr.
	3	13	382	1:35	101.0	101.0	97.0	A.F. 4 1/2 hr.
	3	13	382	3:10	102.5	103.0	98.0	A.F. 1 hr.
	4	13	383	3:20	102.5	101.5	97.5	B.F.
	5	13	384	10:25	102.0	102.0	96.5	B.F.
	6	13	385	2:25	103.0	102.0	97.0	B.F.
	June							
	21	15	431	3:45	101.5	102.5	97.5	B.F.
	22	15	432	10:25	101.5	102.0	96.0	B.F.
	22	15	432	3:50	101.5	102.5	97.5	B.F.
	23	15	433	9:00	101.5	101.5	96.0	B.F.
	23	15	433	11:00	102.0	101.5	95.0	A.F. 2 hr.
	23	15	433	12:00	101.5	101.5	96.0	A.F. 3 hr.
	23	15	433	2:00	101.5	102.5	96.5	A.F. 5 hr.
	23	15	433	3:00	101.5	101.5	96.0	A.F. 6 hr.
	24	15	434	11:15	102.0	102.0	96.5	B.F.
	24	15	434	12:00	102.0	101.0	96.0	A.F. 1/2 hr.[4]
	25	15	435	9:30	101.5	101.5	96.0	B.F.
	27	15	437	9:00	101.5	101.5	97.0	B.F.
	27	15	437	11:15	101.0	102.0	96.0	A.F. 2 hr.
	27	15	437	1:15	101.5	102.0	96.0	A.F. 4 hr.
	27	15	437	3:15	102.0	102.0	96.0	A.F. 6 hr.
	28	15	438	8:45	101.5	101.5	96.5	A.F. 1 1/2 hr.

TABLE IV

TEMPERATURE DATA FOR CALF NO. 21

Calf No.	Date	Age Gp.	Age Da.	Time	Temperature (°F.) Rect.	Rum.	Epid.	Conditions
21								
	Dec.[1]							
	21	8	236	3:30	102.5	101.5	90.0	A.F. 2 hrs.
	22	8	237	5:00	102.5	103.0	90.0	B.F.
	Jan.							
	29	10	275	3:30	100.0	101.5	95.0	A.F. 1/4 hr.
	Apr.							
	11	12	347	3:15	104.0	103.0	96.0	B.F.
	12	12	348	3:30	104.0	103.5	98.0	B.F.
	14	12	350	4:15	103.0	104.0	96.0	B.F.
	18	12	354	4:00	103.5	103.0	97.0	B.F.
	19	12	355	4:25	102.5	102.5	97.0	A.F. 3 hrs.
	20	12	356	2:40	104.0	101.5	96.0	B.F.
	21	12	357	4:25	103.0	103.0	96.0	B.F.
	22	12	358	3:40	103.0	102.0	97.0	B.F.
	26	13	362	8:25	100.5	102.0	95.0	B.F.
	27	13	363	3:15	102.5	99.0	97.0	B.F.
	28	13	364	4:00	103.0	104.0	97.0	B.F.
	29	13	365	4:05	102.5	102.5	97.0	B.F.
	May							
	3	13	369	8:45	101.5	102.0	95.0	B.F.
	3	13	369	10:00	102.0	102.5	96.5	A.F. 1 hr.
	3	13	369	1:25	102.0	102.0	97.0	A.F. 4 1/2 hr.
	3	13	369	3:00	103.0	103.0	98.0	A.F. 1 hr.
	4	13	370	2:20	102.0	101.5	96.0	B.F.
	5	13	371	10:15	101.5	101.0	96.5	B.F.
	6	13	372	2:15	102.5	103.0	97.0	B.F.
	June							
	21	14	418	3:30	103.5	103.0	99.0	B.F.
	22	14	419	9:25	101.5	102.0	96.0	B.F.
	22	14	419	3:25	102.5	104.0	99.5	B.F.
	23	14	420	8:30	101.5	102.0	97.0	B.F.
	23	14	420	9:50	101.5	102.0	96.5	A.F. 1 1/3 hr.
	23	14	420	11:20	101.5	102.0	96.0	A.F. 2 2/3 hr.
	23	14	420	1:30	101.5	102.5	98.0	A.F. 5 hr.
	23	14	420	2:30	101.5	101.5	97.0	A.F. 6 hr.
	24	15	421	11:00	101.5	102.0	98.0	B.F.
	24	15	421	11:45	101.5	100.5	98.0	A.F. 1/2 hr.[4]
	25	15	422	9:15	102.0	103.0	98.5	B.F.
	27	15	424	8:45	102.0	102.0	97.0	B.F.
	27	15	424	11:00	102.0	102.0	96.5	A.F. 2 hr.
	27	15	424	1:00	103.0	102.5	97.0	A.F. 4 hr.
	27	15	424	3:00	102.5	103.0	98.0	A.F. 6 hr.
	July							
	1	15	428	1:15	103.0	103.0	98.0	A.F. 5 1/4 hr.

TABLE V

TEMPERATURE DATA FOR CALF NO. 8

Calf No.	Date	Age Gp.	Age Da.	Time	Temperature (°F.) Rect.	Rum.	Epid.	Conditions
8								
	Jan. 31	1	23	3:40	103.0	104.0	95.0	B.F.
	Mar. 22	3	73	3:30	103.0	102.0	91.0	B.F.
	Aug. 11	8	215	1:00	103.0	103.0	98.5	B.F.
	11	8	215	2:10	102.5	102.5	98.5	A.F. 1 hr.
	11	8	215	3:10	100.5	100.0	99.0	A.F. 2 hr.
	12	8	216	10:45	101.0	101.5	97.0	B.F.
	12	8	216	12:15	101.0	101.0	97.0	A.F. 1 hr.
	12	8	216	1:15	101.0	101.5	97.0	A.F. 2 hr.
	17	8	221	10:45	102.5	102.0	98.5	B.F.
	17	8	221	12:15	102.5	103.0	99.0	A.F. 1 hr.
	17	8	221	1:15	102.0	103.0	99.0	A.F. 2 hr.
	18	8	222	8:30	101.0	101.5	97.0	B.F.
	18	8	222	10:00	102.0	103.0	99.0	A.F. 1 hr.
	18	8	222	11:00	102.0	103.0	99.5	A.F. 2 hr.
	23	8	227	9:45	102.0	103.0	99.0	B.F.
	23	8	227	12:00	102.5	103.5	100.0	A.F. 2 hr.
	24	8	228	8:45	102.5	102.5	98.5	B.F.
	24	8	228	10:30	102.5	104.0	99.5	A.F. 1 hr.
	24	8	228	11:30	103.0	104.0	100.0	A.F. 2 hr.
	25	8	229	8:15	101.0	103.0	97.0	B.F.
	25	8	229	10:00	102.0	104.5	98.5	A.F. 1 hr.
	25	8	229	11:00	102.5	104.5	100.0	A.F. 2 hr.
	26	8	230	8:30	101.0	101.5	98.0	B.F.
	26	8	230	10:00	103.0	103.5	100.0	A.F. 1 hr.
	26	8	230	11:00	103.0	103.5	100.0	A.F. 2 hr.
	27	8	231	8:30	101.0	102.0	97.5	B.F.
	27	8	231	10:00	102.5	104.0	99.5	A.F. 1 hr.
	27	8	231	11:00	102.5	103.5	99.5	A.F. 2 hr.
	29	8	233	8:30	102.0	102.0	97.5	B.F.
	29	8	233	10:30	103.0	105.0	101.0	A.F. 1 hr.
	29	8	233	11:30	102.5	102.5	99.0	A.F. 2 hr.
	30	8	234	8:30	101.5	102.5	98.0	B.F.
	30	8	234	10:00	103.0	103.5	99.5	A.F. 1 hr.
	30	8	234	11:00	101.5	102.0	100.0	A.F. 2 hr.
	31	8	239	8:30	101.5	102.0	97.0	B.F.
	Sept. 7	9	242	9:00	101.0	101.0	96.0	B.F.
	7	9	242	10:30	102.5	104.5	100.0	A.F. 1 hr.
	7	9	242	11:30	102.0	105.0	98.0	A.F. 2 hr.
	8	9	243	10:45	101.5	103.5	99.0	A.F. 1 hr.

TABLE V (Continued)

Calf No.	Date	Age Gp.	Age Da.	Time	Temperature (°F.) Rect.	Rum.	Epid.	Conditions
8								
	Sept.							
	8	9	243	10:45	101.5	103.5	99.0	A. F. 1 hr.
	8	9	243	11:45	102.0	103.5	99.0	A. F. 2 hr.
	9	9	244	10:00	102.0	102.5	97.5	B. F.
	9	9	244	11:30	102.5	104.0	99.0	A. F. 1 hr.
	9	9	244	12:30	102.5	104.0	99.0	A. F. 2 hr.
	14	9	249	8:35	100.0	102.0	95.0	B. F.
	14	9	249	10:05	102.5	104.0	99.0	A. F. 1 hr.
	14	9	249	11:05	102.0	103.5	98.0	A. F. 2 hr.
	30	9	265	8:35	102.5	103.5	96.0	B. F.
	30	9	265	10:15	102.0	104.5	99.0	A. F. 1 hr.
	30	9	265	11:15	100.0	103.5	96.0	A. F. 2 hr.
	Oct.							
	3	9	268	8:50	102.0	103.0	97.0	B. F.
	3	9	268	10:30	101.0	103.0	97.0	A. F. 1 hr.
	3	9	268	11:30	101.5	102.5	98.0	A. F. 2 hr.
	19	10	284	9:10	101.5	102.5	96.0	B. F.
	19	10	284	10:40	101.0	102.5	96.5	A. F. 1 hr.
	19	10	284	11:40	101.0	103.5	98.0	A. F. 2 hr.
	21	10	286	8:25	101.0	102.5	96.0	B. F.
	21	10	286	9:55	101.0	103.0	98.0	A. F. 1 hr.
	21	10	286	10:55	100.5	102.0	96.0	A. F. 2 hr.
	22	10	287	8:55	102.0	103.0	96.0	B. F.
	22	10	287	10:25	100.5	103.0	98.0	A. F. 1 hr.
	22	10	287	11:25	100.0	103.0	95.5	A. F. 2 hr.
	Nov.							
	8	11	304	1:30	101.0	103.0	95.5	B. F.

TABLE VI

TEMPERATURE DATA FOR CALF NO. 29

Calf No.	Date	Age Gp.	Age Da.	Time	Temperature (°F.) Rect.	Rum.	Epid.	Conditions
29								
	Jan. 31	2	331	3:15	102.0	104.0	90.0	B.F.
	Mar. 22	3	381	3:00	102.0	102.0	93.5	B.F.
	Aug. 11	8	223	12:50	102.0	101.0	97.5	B.F.
	11	8	223	1:50	101.5	103.0	99.0	A.F. 1 hr.
	11	8	223	2:50	101.0	101.0	98.5	A.F. 1 hr.
	12	8	224	10:30	99.5	101.0	97.0	B.F.
	12	8	224	12:00	100.5	101.0	97.0	A.F. 1 hr.
	12	8	224	1:00	100.5	101.0	97.5	A.F. 2 hr.
	17	8	229	10:30	101.5	101.5	98.0	B.F.
	17	8	229	12:00	101.0	103.0	98.0	A.F. 1 hr.
	17	8	229	1:00	102.0	103.0	98.5	A.F. 2 hr.
	18	8	230	8:15	101.5	101.5	98.0	B.F.
	18	8	230	9:45	102.0	103.0	100.0	A.F. 1 hr.
	18	8	230	10:45	102.0	103.0	99.0	A.F. 2 hr.
	23	8	235	9:30	101.0	101.0	99.0	B.F.
	23	8	235	11:45	101.5	102.5	98.5	A.F. 2 hr.
	24	8	236	8:30	101.0	102.0	99.0	B.F.
	24	8	236	10:15	102.5	103.5	100.0	A.F. 1 hr.
	24	8	236	11:15	102.5	103.5	100.0	A.F. 2 hr.
	25	8	237	8:00	101.0	101.5	97.0	B.F.
	25	8	237	9:45	101.0	103.0	100.0	A.F. 1 hr.
	25	8	237	10.45	103.0	103.5	101.5	A.F. 2 hr.
	26	8	238	8:15	100.5	100.5	98.5	B.F.
	26	8	238	9:45	103.0	104.0	100.0	A.F. 1 hr.
	26	8	238	10:45	103.0	103.0	100.0	A.F. 2 hr.
	27	8	239	8:15	101.0	101.0	97.0	B.F.
	27	8	239	9:45	102.0	103.0	98.5	A.F. 1 hr.
	27	8	239	10:45	102.0	102.0	99.0	A.F. 2 hr.
	29	9	241	8:15	101.5	101.5	99.0	B.F.
	29	9	241	10:15	102.0	102.0	99.0	A.F. 1 hr.
	29	9	241	11:15	102.5	102.5	100.0	A.F. 2 hr.
	30	9	242	8:15	101.5	101.0	96.0	B.F.
	30	9	242	9:45	102.0	104.0	97.0	A.F. 1 hr.
	30	9	242	10:45	101.0	101.0	97.0	A.F. 2 hr.
	31	9	243	8:15	101.0	101.0	96.0	B.F.
	Sept. 7	9	250	8:45	100.5	101.5	96.0	B.F.
	7	9	250	10:15	102.0	103.5	98.5	A.F. 1 hr.
	7	9	250	11:15	101.5	103.0	99.0	A.F. 2 hr.
	8	9	251	9:00	101.5	102.0	96.0	B.F.

TABLE VI (Continued)

Calf No.	Date	Age Gp.	Age Da.	Time	Temperature (°F.) Rect.	Rum.	Epid.	Conditions
29								
	Sept.							
	8	9	251	10:30	102.0	103.0	97.0	A.F. 1 hr.
	8	9	251	11:30	102.0	103.0	98.0	A.F. 2 hr.
	9	9	252	9:45	101.5	102.0	97.0	B.F.
	9	9	252	11:15	102.5	103.5	100.0	A.F. 1 hr.
	9	9	252	12:15	101.5	104.0	99.0	A.F. 2 hr.
	14	9	257	8:25	102.0	103.0	96.0	B.F.
	14	9	257	9:55	102.5	103.0	97.0	A.F. 1 hr.
	14	9	257	10:55	103.0	103.0	99.5	A.F. 2 hr.
	30	10	273	8:25	101.0	102.0	96.0	B.F.
	30	10	273	10:05	102.5	104.0	96.5	A.F. 1 hr.
	30	10	273	11:05	101.5	103.0	96.5	A.F. 2 hr.
	Oct.							
	3	10	276	8:40	101.5	102.0	95.0	B.F.
	3	10	276	10:20	102.0	102.5	96.5	A.F. 1 hr.
	3	10	276	11:20	102.0	103.0	96.0	A.F. 2 hr.
	19	10	292	9:00	102.0	103.0	96.0	B.F.
	19	10	292	10:30	101.5	103.5	96.0	A.F. 1 hr.
	19	10	292	11:30	101.5	102.5	97.5	A.F. 2 hr.
	21	10	294	8:15	101.0	102.5	94.0	B.F.
	21	10	294	9:45	102.0	102.5	97.0	A.F. 1 hr.
	21	10	294	10:45	102.5	104.5	96.5	A.F. 2 hr.
	22	10	295	8:45	101.0	102.0	95.0	B.F.
	22	10	295	10:15	101.5	102.5	95.0	A.F. 1 hr.
	22	10	295	11:15	101.5	101.5	97.0	A.F. 2 hr.
	Nov.							
	12	11	316	9:15	101.0	102.0	94.0	B.F.

TABLE VII

TEMPERATURE DATA FOR CALVES NO. 95 AND NO. 14

Calf No.	Date	Age Gp.	Age Da.	Time	Temperature (°F.) Rect.	Rum.	Epid.	Conditions
95								
	Sept.							
	14	4	102	8:55	101.0	102.0	97.0	B.F.
	14	4	102	10:25	102.0	103.0	98.0	A.F. 1 hr.
	14	4	102	11:25	103.0	103.0	100.0	A.F. 2 hr.
	30	4	118	8:55	100.5	101.0	96.0	B.F.
	30	4	118	10:35	101.0	103.0	97.0	A.F. 1 hr.
	30	4	118	11:35	101.5	103.0	96.5	A.F. 2 hr.
	Oct.							
	3	5	121	9:10	101.5	102.5	97.0	B.F.
	3	5	121	10:50	103.0	103.5	98.0	A.F. 1 hr.
	3	5	121	11:50	101.0	102.5	97.0	A.F. 2 hr.
	19	5	137	9:40	101.5	101.5	96.0	B.F.
	19	5	137	11:10	101.5	102.5	97.0	A.F. 1 hr.
	19	5	137	12:10	101.0	102.5	97.5	A.F. 2 hr.
	21	5	139	8:55	101.0	102.5	96.5	B.F.
	21	5	139	10:25	101.5	102.5	97.5	A.F. 1 hr.
	21	5	139	11:25	101.5	102.0	95.0	A.F. 2 hr.
	22	5	140	9:25	101.0	101.0	95.5	B.F.
	22	5	140	10:55	102.0	102.0	95.0	A.F. 1 hr.
	22	5	140	1:55	102.0	102.5	95.0	A.F. 2 hr.
	Nov.							
	11	5	160	9:15	100.5	101.5	94.0	B.F.
	Oct.							
14								
	19	4	118	9:50	101.0	102.0	96.0	B.F.
	19	4	118	11:20	102.0	103.5	97.0	A.F. 1 hr.
	19	4	118	12:20	103.0	105.0	100.5	A.F. 2 hr.
	21	4	120	9:05	101.5	101.5	94.0	B.F.
	21	4	120	10:35	102.0	103.0	96.0	A.F. 1 hr.
	21	4	120	11:35	102.0	102.5	98.0	A.F. 2 hr.
	22	5	121	9:35	101.5	101.5	95.5	B.F.
	22	5	121	10:05	100.0	102.5	95.0	A.F. 1 hr.
	22	5	121	12:05	102.0	103.0	98.0	A.F. 2 hr.
	Nov.							
	1	5	130	1:00	102.0	103.0	97.0	A.F. 3/4 hr.

TABLE VIII

TEMPERATURE DATA FOR CALVES NO. 27 AND NO. 18

Calf No.	Date	Age Gp.	Age Da.	Time	Temperature (°F.) Rect.	Rum.	Epid.	Conditions
27								
	Apr.							
	11	16	469	5:00	102.5	103.0	95.0	A.F. 1/6 hr.
	12	16	470	2:45	101.0	99.5	95.0	B.F.
	14	16	472	3:30	101.5	102.5	95.0	A.F. 1 1/2 hr.
	18	16	476	3:15	101.5	102.0	96.0	A.F. 2 hr.
	19	16	477	4:00	102.0	102.0	95.0	A.F. 2 3/4 hr.
	20	16	478	2:00	101.5	101.5	93.0	B.F.
	21	16	479	4:00	102.0	101.0	93.5	A.F. 1/6 hr.
	22	16	480	3:20	101.5	102.0	95.0	A.F. 1/6 hr.
	25	17	483	4:35	101.5	101.0	94.0	A.F. 1/2 hr.
	27	17	485	3:45	102.0	103.0	95.0	A.F. 2 1/2 hr.
	28	17	486	2:35	101.5	101.5	94.0	B.F.
	29	17	487	3:00	101.0	101.0	94.0	A.F. 2 hr.
	May							
	3	17	491	1:50	101.0	101.0	94.0	B.F. [4]
	3	17	491	3:45	102.0	97.5	95.0	A.F. 1 1/6 hr.
	4	17	492	2:40	101.5	101.0	95.0	B.F.
	6	17	494	2:50	101.0	102.5	95.0	A.F. 2 hr.
	30	18	518	3:30	101.5	102.5	95.0	A.F. 3 hr.
	June							
	1	18	520	2:30	100.5	102.0	95.5	A.F. 1 1/2 hr.
	Dec.[1]							
18	30	2	60	2:40	102.5	103.5	92.0	B.F.
	Jan.							
	21	3	90	4:20	101.5	103.5	92.0	A.F. 1/4 hr.
	31	4	92	3:50	101.0	104.0	95.0	B.F.
	Oct.							
	19	12	353	10:00	101.0	102.0	99.0	B.F.[5]
	21	12	355	9:15	101.0	100.5	99.0	B.F.[5]
	22	12	356	9:45	101.0	101.5	97.5	B.F.[5]

TABLE IX

TEMPERATURE DATA FOR CALVES NO. 28, NO. 50, NO. 81, and NO. 16

Calf No.	Date	Age Gp.	Age Da.	Time	Temperature (°F.) Rect.	Rum.	Epid.	Conditions
28								
	Apr.							
	11	19	564	5:30	102.5	101.5	94.0	A.F. 1/6 hr.
	12	19	565	3:15	101.0	101.5	93.0	B.F.
	14	19	567	3:00	101.5	102.0	93.5	A.F. 1 1/2 hr.
	18	20	571	3:30	102.0	102.0	95.0	A.F. 1/6 hr.
	19	20	572	4:15	101.5	101.0	94.5	A.F. 3 hr.
	20	20	573	2:20	101.5	101.0	94.5	B.F.
	21	20	574	4:15	102.0	101.0	93.0	A.F. 1/6 hr.
	22	20	575	3:30	102.0	101.0	94.0	A.F. 1/6 hr.
	25	20	578	4:50	101.5	101.0	94.0	A.F. 1/2 hr.
	27	20	580	4:00	102.0	102.0	95.0	A.F. 3 hr.
	28	20	581	2:45	101.5	100.0	94.0	B.F.
	29	20	582	3:30	100.0	100.0	93.0	A.F. 2 1/2 hr.
	May							
	3	20	586	2:00	101.0	100.5	94.0	B.F.
	3	20	586	4:00	101.0	100.0	94.5	A.F. 1 1/4 hr.
		20	587	3:00	101.5	102.0	94.0	B.F.
	6	20	589	3:05	102.0	102.0	95.0	A.F. 2 hr.
	30	21	613	3:45	102.0	103.0	95.0	A.F. 3 1/4 hr.
	June							
	3	21	617	9:00	101.0	101.5	97.0	B.F.
50								
	Dec.[1]							
	20	10	283	4:30	102.5	102.5	98.0	A.F.
	21	10	284	11:30	101.0	101.5	83.0	A.F. 3 hr.
	21	10	284	2:15	102.0	101.0	88.0	B.F.
	21	10	284	2:45	102.0	101.0	86.0	A.F. 1/2 hr.
	21	10	284	4:30	102.5	101.5	89.0	A.F. 2 1/4 hr.
	22	10	289	4:35	102.0	101.0	90.0	B.F.
81								
	Dec.[1]							
	21	9	264	3:00	102.5	101.5	90.0	A.F. 1 1/2 hr.
	22	9	265	5:30	103.0	102.5	92.0	B.F.
16								
	Oct.							
	19	3	85	10:20	102.0	103.0	98.0	B.F.
	22	3	88	9:55	102.0	102.5	100.0	B.F.
	Nov.							
	7	4	103	9:40	101.0	102.0	95.0	B.F.

TABLE X

TEMPERATURE DATA FOR CALVES NO. 64 AND NO. G29

Calf No.	Date	Age Gp.	Age Da.	Time	Temperature (°F.) Rect.	Rum.	Epid.	Conditions
64								
	Mar. 22	3	61	3:45	100.0	101.5	93.5	B.F.
	June. 21	6	151	4:00	101.0	102.0	96.5	B.F.
	Aug. 11	7	202	12:30	102.0	102.0	98.0	B.F.
	11	7	202	1:45	102.0	103.0	98.0	A.F. 1 hr.
	11	7	202	2:45	100.0	101.0	98.0	A.F. 2 hr.
	12	7	203	10:15	100.5	101.0	97.0	B.F.
	12	7	203	11:45	100.5	101.5	96.5	A.F. 1 hr.
	12	7	203	12:45	101.0	101.0	97.0	A.F. 2 hr.
	17	7	208	10:15	102.0	102.0	98.0	B.F.
	17	7	208	11:45	101.5	102.0	99.0	A.F. 1 hr.
	17	7	208	12:45	101.5	103.0	98.0	A.F. 2 hr.
	18	7	209	8:00	101.5	101.5	97.0	B.F.
	18	7	209	9:30	101.5	103.0	98.0	A.F. 1 hr.
	18	7	209	10:30	102.0	103.5	99.5	A.F. 2 hr.
	23	8	214	9:15	101.5	102.0	98.0	B.F.
	23	8	214	11:30	101.5	102.0	98.0	A.F. 2 hr.
	24	8	215	8:15	102.5	102.5	98.0	B.F.
	24	8	215	10:00	102.0	103.0	98.0	A.F. 1 hr.
	24	8	215	11:00	102.5	103.0	99.0	A.F. 2 hr.
	25	8	216	7:45	101.0	102.00	97.5	B.F.
	25	8	216	9:30	102.0	103.0	99.0	A.F. 1 hr.
	25	8	216	10:30	101.5	103.5	99.0	A.F. 2 hr.
	26	8	217	8:00	101.0	101.5	97.0	B.F.
	26	8	217	9:30	102.0	103.5	99.0	A.F. 1 hr.
	26	8	217	10:30	102.5	103.0	98.5	A.F. 2 hr.
	27	8	218	8:00	100.5	101.5	96.5	B.F.
	27	8	218	9:30	102.0	103.5	99.0	A.F. 1 hr.
	27	8	218	10:30	102.0	103.0	98.0	A.F. 2 hr.
	29	8	220	8:00	101.5	101.5	98.0	B.F.
	29	8	220	10:00	102.5	103.0	99.0	A.F. 1 hr.
	29	8	220	11:00	101.5	103.0	99.0	A.F. 2 hr.
	30	8	221	8:00	101.5	101.5	96.5	B.F.
	30	8	221	10:30	101.5	102.5	97.0	A.F. 2 hr.
	31	8	222	8:00	101.0	101.5	95.5	B.F.
	Sept. 7	8	229	8:30	101.0	101.5	96.0	B.F.
	7	8	229	10:00	101.5	103.0	98.0	A.F. 1 hr.
	7	8	229	11:00	102.0	104.0	99.0	A.F. 2 hr.
	8	8	230	8:45	102.0	102.0	97.0	B.F.
	8	8	230	10:15	102.0	104.0	97.0	A.F. 1 hr.

TABLE X (Continued)

Calf No.	Date	Age Gp.	Age Da.	Time	Temperature (°F.) Rect.	Rum.	Epid.	Conditions
64								
	Sept.							
	8	8	230	11:15	102.5	104.0	98.5	A.F. 2 hr
	9	8	231	9:30	101.5	103.0	97.0	B.F.
	9	8	231	11:00	102.5	104.5	98.0	A.F. 1 hr.
	9	8	231	12:00	103.0	103.5	100.0	A.F. 2 hr.
	14	8	236	8:15	102.0	102.5	95.5	B.F.
	14	8	236	9:45	101.5	103.0	96.0	A.F. 1 hr.
	14	8	236	10:45	102.0	103.0	99.0	A.F. 2 hr.
	30	9	252	8:15	101.0	102.5	96.5	B.F.
	30	9	252	9:55	102.0	103.0	97.0	A.F. 1 hr.
	30	9	252	10:55	102.0	103.0	96.0	A.F. 2 hr.
	Oct.							
	3	9	255	8:30	102.0	102.5	96.0	B.F.
	3	9	255	10:10	101.5	103.0	96.5	A.F. 1 hr.
	3	9	255	11:10	102.0	102.5	95.0	A.F. 2 hr.
	19	10	271	9:20	101.5	103.0	95.0	B.F.
	19	10	271	10:50	101.5	103.0	97.0	A.F. 1 hr.
	19	10	271	11:50	101.5	102.5	96.0	A.F. 2 hr.
	21	10	273	8:35	101.5	102.5	97.0	B.F.
	21	10	273	10:05	101.5	102.5	95.0	A.F. 1 hr.
	21	10	273	11:05	101.0	103.0	95.0	A.F. 2 hr.
	22	10	274	9:05	101.5	102.0	96.5	B.F.
	22	10	274	10:35	100.5	102.5	98.0	A.F. 1 hr.
	22	10	274	11:35	100.5	102.0	95.0	A.F. 2 hr.
	Nov.							
	2	10	285	1:00	100.0	102.0	90.0	A.F. 3 hr.
G29								
29	Dec.[1]							
	30	4	110	4:50	101.5	103.0	91.0	B.F.

TABLE XI

TEMPERATURE DATA FOR CALVES NO. 63, NO. 30, NO. 20, NO. 5, AND NO. 3

Calf No.	Date	Age Gp.	Age Da.	Time	Temperature (°F.) Rect.	Rum.	Epid.	Conditions
63								
	Aug.							
	12	6	158	11:00	100.5	101.0	98.0	B.F.
	12	6	158	12:30	100.5	100.5	98.0	A.F. 1 hr.
	12	6	158	1:30	101.0	100.5	97.0	A.F. 2 hr.
	17	6	163	10:00	102.0	102.0	99.0	B.F.
	17	6	163	12:30	101.0	102.5	99.0	A.F. 1 hr.
	17	6	163	1:30	102.0	102.0	98.0	A.F. 2 hr.
	18	6	164	8:45	100.5	100.5	97.0	B.F.
	18	6	164	10:15	101.0	102.0	100.0	A.F. 1 hr.
	18	6	164	11:15	100.0	102.5	99.0	A.F. 2 hr.
	23	6	169	10:00	102.0	102.0	99.0	B.F.
	23	6	169	12:15	102.5	103.5	99.0	A.F. 2 hr.
	24	6	170	9:00	101.0	102.0	99.0	B.F.
	24	6	170	10:45	102.0	104.0	100.0	A.F. 1 hr.
	24	6	170	11:45	102.5	103.5	100.0	A.F. 2 hr.
	25	6	171	8:30	101.0	101.5	97.0	B.F.
	25	6	171	10:15	102.5	103.5	101.0	A.F. 1 hr.
	25	6	171	11:15	102.5	103.5	100.0	A.F. 2 hr.
	26	6	172	8:45	101.0	100.0	96.5	B.F.
	26	6	172	10:15	102.5	102.5	99.0	A.F. 1 hr.
	26	6	172	11:15	102.0	103.5	100.0	A.F. 2 hr.
	27	6	173	8:45	101.0	101.5	97.5	B.F.
	27	6	173	10:15	101.5	102.0	99.0	A.F. 1 hr.
	27	6	173	11:15	101.5	101.5	98.0	A.F. 2 hr.
	29	6	175	8:45	101.5	101.5	98.5	B.F.
	29	6	175	10:45	102.5	103.5	101.0	A.F. 1 hr.
	29	6	175	11:45	102.0	103.0	100.0	A.F. 2 hr.
	30	6	176	8:45	101.0	101.0	98.0	B.F.
	30	6	176	10:15	102.0	102.5	98.0	A.F. 1 hr.
	30	6	176	11:15	101.5	102.5	99.0	A.F. 2 hr.
	31	6	177	8:45	101.5	101.5	97.0	B.F.
	Sept.							
	7	7	184	9:15	101.0	101.5	96.5	B.F.
	7	7	184	10:45	102.5	103.5	100.0	A.F. 1 hr.
	7	7	184	11:45	102.0	103.5	99.0	A.F. 2 hr.
	8	7	185	9:30	101.5	102.0	97.0	B.F.
	8	7	185	11:00	102.0	103.5	98.0	A.F. 1 hr.
	8	7	185	12:00	102.0	104.0	99.0	A.F. 2 hr.
	9	7	186	10:15	101.0	102.0	97.0	B.F.
	9	7	186	11:45	102.0	103.0	98.5	A.F. 1 hr.
	9	7	186	12:45	102.0	102.5	99.5	A.F. 2 hr.
	14	7	191	8:45	101.0	102.0	95.0	B.F.
	14	7	191	10:15	102.0	103.5	98.0	A.F. 1 hr.

TABLE XI (Continued)

Calf No.	Date	Age Gp.	Age Da.	Time	Temperature (°F.) Rect.	Rum.	Epid.	Conditions
63								
	Sept.							
	14	7	191	11:15	102.5	104.0	98.0	A.F. 2 hr.
	30	7	207	8:45	101.5	103.0	96.0	B.F.
	30	7	207	10:25	102.5	103.0	97.5	A.F. 1 hr.
	30	7	207	11:25	100.5	103.0	99.0	A.F. 2 hr.
	Oct.							
	3	7	210	9:00	102.0	103.0	97.0	B.F.
	3	7	210	10:40	102.0	102.0	97.0	A.F. 1 hr.
	3	7	210	11:40	101.0	103.0	96.0	A.F. 2 hr.
	19	8	226	9:30	101.0	101.5	97.0	B.F.
	19	8	226	11:00	102.0	103.0	96.0	A.F. 1 hr.
	19	8	226	12:00	102.0	102.5	97.0	A.F. 2 hr.
	21	8	228	8:45	102.0	103.0	95.5	B.F.
	21	8	228	10:15	101.0	104.0	96.0	A.F. 1 hr.
	21	8	228	11:15	100.5	102.0	95.0	A.F. 2 hr.
	22	8	229	9:15	101.0	102.0	96.0	B.F.
	22	8	229	10:45	101.0	102.0	95.0	A.F. 1 hr.
	22	8	229	11:45	100.5	103.0	97.5	A.F. 2 hr.
	Nov.							
	9	9	247	9:30	100.5	101.5	96.0	B.F.
30								
	Dec.[1]							
	30	3	79	3:20	101.0	102.0	88.0	B.F.
20								
	Mar.							
	24	7	190	8:20	101.0	102.0	93.0	B.F.
5								
	Nov.							
	14	2	31	9:15	101.5	100.5	97.0	B.F.
3								
	Nov.							
	26	1	4	3:30	103.0	104.0	97.0	B.F.

TABLE XII

pH DATA ON RUMINAL FLUID SAMPLES

Sample No.	Ration	Day after Sampling				
		0	1	2	3	4
1	Conc.	6.5	5.9	6.4	6.5	6.5
2	and	6.0	5.6	7.1	7.1	7.2
3	Hay	6.4	6.7	6.6	6.6	---
4	"	6.4	5.9	5.8	---	5.9
5	"	6.6	6.4	---	6.5	6.9
6	"	6.6	---	6.6	6.5	7.2
7	"	6.6	6.5	6.7	7.1	7.2
8	Conc.	6.0	5.6	5.7	5.6	5.6
9	only	6.5	6.2	6.2	6.5	6.7
10	"	6.3	6.1	6.1	6.6	6.9
11	"	6.2	5.3	5.4	5.6	5.4
12	"	6.4	5.8	5.7	5.8	5.8
13	"	6.5	5.8	5.5	5.6	5.6
14	"	6.4	5.7	5.5	5.5	5.6
15	"	6.3	5.6	5.5	5.7	5.8
16	"	6.6	5.7	5.5	5.7	6.1
17	"	6.3	5.7	5.6	5.5	6.0
18	"	6.4	5.6	5.6	5.7	5.7
19	"	6.4	5.7	5.7	6.0	6.0
20	"	6.4	6.1	5.8	5.9	5.9
21	"	6.9	5.8	5.5	5.4	5.6
22	"	6.7	6.5	6.3	6.4	6.5
23	"	6.7	5.9	5.9	6.3	6.2
24	"	6.7	6.2	6.3	6.9	6.3
25	"	6.9	6.5	6.8	6.5	6.6
33	Hay	6.7	6.4	6.2	6.5	6.6
34	Only	7.0	6.4	6.4	6.4	6.5
35	"	6.9	6.6	6.8	6.6	6.7
36	"	6.7	6.5	6.2	6.3	6.5
37	"	6.8	6.4	6.1	6.3	6.2
38	"	6.8	6.5	6.6	6.8	6.9
39	"	6.9	6.8	6.7	6.6	7.0
40	"	6.8	6.5	6.6	6.6	6.7
41	"	6.8	6.5	6.5	6.6	6.6
42	"	7.2	6.8	6.8	6.7	7.0
43	"	6.9	6.8	6.9	6.8	7.0
44	"	6.7	6.5	6.4	6.5	6.5
45	"	6.8	6.5	6.4	6.4	6.4
46	"	6.6	6.6	6.2	6.4	6.4
47	"	6.9	6.7	6.5	6.6	6.7
48	"	6.8	6.6	6.5	6.5	6.8
49	"	6.9	6.8	6.5	6.5	6.7
50	"	6.9	6.4	6.6	6.5	6.6
51	"	6.9	6.7	6.6	6.6	6.7
52	"	6.9	6.6	6.4	6.4	6.3
53	"	6.9	6.7	6.6	6.4	6.5

VITA

Roy J. Wilson

Candidate for the Degree of

Master of Science

Thesis: RUMEN STUDIES

Major: Dairy Production

Biographical:

Personal data: Born November 1, 1928. Wyandotte, Oklahoma

Undergraduate Study: Northeastern Oklahoma A & M College Miami, Oklahoma 1947-49. Oklahoma A & M College Stillwater, Oklahoma 1949-51.

Graduate Study: Oklahoma A & M College 1954-56

Experience: U. S. Army, 1951-54.

Member of: American Dairy Science Association, Red Red Rose.

Date of Final Examination: April 2, 1956

THESIS TITLE: RUMEN STUDIES

AUTHOR: Roy James Wilson

THESIS ADVISER: Dr. Magnar Ronning

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TYPIST: Twyla D. Milligan