HEAT TOLERANCE STUDIES ON CATTLE
IN THE WET TROPICS


Part II. Preliminary studies on a field technique for the quantitative assessment of sweating in cattle.

by

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Part I

Water relationship studies,
with special reference to
water intake of Zebu-Holstein heifers.
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INTRODUCTION

The importance of water in the physiology of farm animals has been emphasised by various workers including Bonsma (1939), Leitch and Thompson (1944), and French (1956). Within the last 10 to 15 years there has been a marked increase in the attention paid to the ability of animals to withstand the high ambient temperatures of tropical environments. This interest in heat tolerance has been stimulated largely by the need for greater production of animal products in the tropics and the fact that unadapted temperate stock have often proved unsatisfactory under these conditions. The part played by water in the thermoregulatory mechanisms of cattle is now widely appreciated and it is in this light that water intake and excretion have come to the fore.

Thompson et al. (1949), using psychrometric faces at Missouri Experimental Station, found that both European and Zebu type cattle increased their water consumption at temperatures above 50°F. This was, however, subject to considerable individual variation, as one animal increased hay water intake from 11 gallons per day at 50°F to 15 gallons at 100°F. Another animal in the same trial, reduced consumption from 12.3 gallons at 50°F to 10.6 gallons at 100°F. The authors pointed out the very considerable direct cooling effect of the large amount of water taken by the Zebu animals. This was accompanied by an almost equal increase in excretion of urine of lower specific gravity.

Mullick et al. (1959) worked out an experiment in India which (in the absence of humidity psychrometric rooms) compared
REVIEW OF LITERATURE

In many water intake experiments, especially those carried out in the field, no account has been taken of the water in the feed. The importance of this source is clearly demonstrated by Leitch and Thompson (1944), who quote an experiment involving three dairy cows of approximately the same yield. In addition to a basal ration of hay and grain, one animal received 26 lbs. of silage, the second 81.7 lbs. of turnips, and the third 115.7 lbs. of turnips per day. The animal receiving silage drank nearly 6.5 gallons of water whilst the cow on the 115.7 lbs. of turnips drank no free water. In spite of this, the third animal had a greater total water intake. This example is perhaps rather extreme and may be criticized on the grounds that the dry matter content of the rations was not constant, the silage ration containing some 4 lbs. less dry matter. However, its implication is clear.

Thompson et al. (1949), using psychrometric rooms at Missouri Experimental Station, found that both European and Zebu type cattle increased their water consumption at temperatures above 50°F. This was, however, subject to considerable individual variation, as one animal increased her water intake from 11 gallons per day at 50°F to 43 gallons at 100°F. Another animal, in the same trial, reduced consumption from 12.3 gallons at 50°F to 10.6 gallons at 100°F. The authors pointed out the very considerable direct cooling effect of the large amount of water taken in by the former animal. This was accompanied by an almost parallel increase in output of urine of lower specific gravity.

Mullick et al. (1952), carried out an experiment in India which (in the absence of elaborate psychrometric rooms) compared
water intakes (water drunk, feed water, and metabolic water) in the four different seasons of the year. The mean temperature ranged from 64°F in winter to 98°F in summer, and the water intake increased from 20.9 lbs. in winter to 33.3 lbs. in summer. The dry matter consumption remained more or less constant in all seasons. In contrast to the work of Thompson et al. (1949) they noted no significant increase in urine output and no significant change in the specific gravity of the urine. The additional water consumed was, therefore, presumably evaporated through the respiratory tract and skin, thus reducing the heat load on the animals. Unlike the temperate bred animals used by Thompson et al., the cattle used were Zebu stock and the authors suggested that they occupy an intermediate position between European cattle and man in their ability to sweat. The view that Zebu cattle lost more water through the skin is supported by Rhoad (1940), but Thompson et al. (1951) found that the vaporization per unit surface area of Brahman cattle was less than that of European animals. They attributed the greater heat tolerance of the Brahman to their lower metabolic rate and their greater surface area per pound body weight. Further evidence that Zebu cattle sweat more than temperate breeds has been given by Ferguson and Dowling (1955), who showed that Zebu x Jersey cattle lost nearly six times as much water through the skin as pure bred Ayrshire animals when subjected to an air temperature of 118°F at 28% R.H. Winchester and Morris (1956) have presented figures to show that Zebu cattle had a lower water intake per pound of dry matter ingested than temperate breeds at comparable ambient temperatures. French (1956) working in East Africa also found that Zebu (Masai) cattle drank considerably less water than 3/4 bred Ayrshires under the same conditions. These findings taken together might suggest that Zebu animals are relatively more efficient at utilising water for evaporative cooling than European type cattle in that they
drink less water and pass a smaller volume of urine but sweat more.

Thompson et al. (1949) noted that in general, the greater the water consumption, the smaller the rise in rectal temperatures of dairy cattle when subjected to increasing ambient temperatures. Payne and Hancock (1957), however, carried out an experiment with 6 sets of identical Jersey twins, in which one twin of each set was kept in New Zealand while the co-twin was taken to Fiji, where they were kept under nearly similar conditions of management. The major environmental difference was climatic. They stated that there was a highly significant positive correlation between water consumption and rectal temperature which disagrees with the findings of Thompson et al. (1949). They pointed out, on the other hand, that rectal temperature was not really a satisfactory method of assessing heat tolerance. One of the twins, which had a lactation record almost equal to its New Zealand co-twin and therefore might be considered heat tolerant, actually had an higher rectal temperature than any of the animals in the trial. She also had the highest water consumption.

Rhoad (1940), however, has shown that the diurnal range in rectal temperature is a better guide to heat tolerance than absolute temperature alone. Payne and Hancock's (1957) experiment can, therefore, be criticized on the grounds that rectal temperature was measured once daily and the diurnal fluctuation in temperature cannot be assessed.

The work carried out to date seems to suggest that the relationship between water intake and heat tolerance is exceedingly complex and highly subject to the individuality of the animals. Many of the findings on this aspect are conflicting and there is a great need for further data from which a clearer picture might emerge.
OBJECT

The College has embarked upon a series of heat tolerance studies, which includes an investigation into the water relationships of cattle in the tropics. Chalmers and Jackson (1958) studied the water intake of crossbred stock, taking into account both free water drunk and the water obtained from the grass. The results from this trial differed somewhat from water intake patterns observed by previous workers and it was considered necessary to repeat this experiment taking various precautions to secure greater precision.

The Zebu/Holstein (approximately 1/4 Zebu, 3/4 Holstein) heifers weighing in the region of 750 lbs. were used in the experiment. These were virgin at the time of selection, but the majority were served before the end of the trial. (Appendix III)

These same animals were used to carry out a grass intake trial using chronic oxide, which ran concurrently with the cage method of estimation. The chronic oxide technique is fully described by Addison and MacDougall (1959).

The amount of free water drunk by the two animals was recorded and the method used is described on page 47.
The experiment was carried out at the Government Stock Farm, St. Joseph, Trinidad, during the periods 5th November to 10th November, 1958 in the wet season and 24th February to 2nd March, 1959 in the dry season.

The fields chosen for the wet season trial were Captain I and Captain III since of the fields available these two had the most uniform sward of Pangola grass (*Digitaria decumbens*). The western end of Captain III had a high proportion of Savanna grass (*Axonopus compressus*) so this section was not used in the trial. In the dry season it was found necessary to incorporate a third field (Gregg's Pasture). This was also under Pangola pasture but there were extensive bare patches which were avoided as far as possible during the trial.

Ten Zebu/Holstein (approximately 1/4 Zebu, 3/4 Holstein) heifers weighing in the region of 750 lbs. were used in the experiment. These were virgin at the time of selection, but the majority were served before the end of the trial. (Appendix III)

These same animals were used to carry out a grass intake trial using chromic oxide, which ran concurrently with the cage method of estimation. The chromic oxide technique is fully described by Addison and MacDonald (1959).

The amount of free water drunk by the ten animals was recorded and the method used is described on page 17.
THE DETERMINATION OF HERBAGE CONSUMPTION BY GRAZING STOCK USING THE MOVABLE CAGE TECHNIQUE

Klingman et al. (1943) have suggested two further sources of error that are relevant even when the cages are moved frequently. In this experiment the grazing by stock will tend to increase the variation in the grazed portions of the field.

**REVIEW OF LITERATURE**

The use of movable cages to determine the productivity of pastures has received much attention in the past. Less attention, however, has been paid to the use of the technique to estimate specifically the herbage consumption of the grazing animal, although of course there is much in common between the two aims. In this experiment it was intended to investigate day to day variations in herbage and water intake as well as seasonal differences. With this in mind, movable cages may have an advantage over the indigestible tracer methods such as the chromic oxide technique used by Chalmers and Jackson (1958), as with the latter the time of passage through the animal is rather indeterminate. Some of the tracer may appear after 20 hours whilst it may continue to be excreted for 4 to 5 days. (Moore and Winter, 1934). It is therefore unreliable to assume that fluctuations in the excretion of chromic oxide are due to feed intake differences of the previous day or the penultimate day.

Two major criticisms of the cage technique have been pointed out by various workers (Colishaw, 1951; Brown, 1954; Castle, 1955). The first of these being that the grass protected by the cages will tend to grow faster than the surrounding sward since the herbage does not suffer defoliation. Secondly, due to the relatively tall growth within the cages, there will be microclimatic differences between the two areas and consequently the rate of growth will be affected. These two disadvantages may be neglected under conditions where the cages are moved daily
to a fresh site. For example, using cages in conjunction with strip grazing.

Klingman et al. (1943) have suggested two further sources of error that are relevant even when the cages are moved frequently. In the first place selective grazing by stock will tend to increase the variation in the grazed portions of the field. Green (1949) after carrying out trials with sheep disagreed with this and stated that with samples of 18 sq. ft. the effect of selectivity in grazing was insignificant. On the other hand figures presented by Lineham and Lowe, (1946) suggested that the variation in the grazed sward was considerably greater. The coefficient of variation for the caged areas being 26% while that for the grazed portion was 58%. The use of close strip grazing might be expected to reduce this source of error. The second factor suggested by Klingman et al. being the initial variability of the pasture due to soil and fertility differences. Lynch (1947), attempted to reduce this variation by trimming the pasture with a mower before placing the cages, but this has no application where the cages are moved daily. Green (1949) has shown that this error tends to be greater on low yielding pasture, which may be significant in relation to the dry season in Trinidad. Certainly the pastures appeared more uneven in the dry season.

The question whether the sample areas from the grazed portion of the field should be chosen at random or selected for similarity in growth and composition to the caged areas has also given rise to controversy. Jolly (1950), stated that any form of selection by the operator may give rise to bias. Klingman et al. (1943) compared the errors of the two alternatives and found that the standard deviation of the selected sites was 134 lbs. dry matter per acre, whilst those chosen at random gave a figure of 378 lbs. They found that the advantage remained in favour of the selected
sites even when 'unskilled' workers were used to choose the sites. A further suggestion has been that the grazed sample should be taken from the area immediately adjacent to the cage, and in this way reduce the initial difference between the two sites. Donald (1946) has stated, and our own observations have shown, that animals tend to graze more heavily round the margins of the cage. This would tend to overestimate the amount of herbage consumed in the locality of the cage.

The cage method of estimating pasture consumption depends on the cages being movable, and hence the size of sampling unit has largely been governed by ease of handling. Fuelleman and Burlisson (1939) and Klingman et al. (1943) used four feet square cages whilst Lineham and Lowe (1946) used larger cages, covering 11 feet x 5 feet, from which an area of 11 feet x 3 feet was harvested. At the Grassland Research Station, Stratford-on-Avon, cages covering a 9 feet x 4 feet area have been found satisfactory. These were semi-circular in cross-section and thus had the advantage of being easy to store. (Colishaw, 1951)

Green (1949) has investigated the statistical aspects of cage size and within a one acre field he compared sample areas ranging from one square foot to thirty square feet. He concluded, that the error fell rapidly to a cage size of ten square feet, but fell more slowly to the thirty square feet samples. He recommended that from a statistical point of view increasing the number of samples was preferable to enlarging the sample area. Under the conditions at Stratford-on-Avon he noted that eight three feet square cages per acre were capable of achieving standard errors of 10% or less. Lineham and Lowe (1946) carried out cage experiments in Northern Ireland and compared herbage intake figures from the cage technique with those computed from liveweight increments of the grazing stock. They used ten 11 feet x 5 feet cages in an area of some 33.1 acres of reseeded
pasture, and the stock remained in the field for some 12 days before moving to a similar field. This was continued throughout the growing season and the overall results of the cage technique agreed closely to the computed figures, the former estimating some 6.8% higher than the animal production method. The difference between the two techniques was more variable in the individual 12 day grazing periods, the highest being 34.3%.

The methods of harvesting the sample areas have varied considerably with the different workers in this field. There is no necessity to cut a sample approximating to that which the animal actually eats provided that the two areas are cut to the same height. Brown (1954) has suggested a metal frame to assist in judging the correct heights of the cuts but this problem may also be overcome by cutting the herbage very close to ground level with hand shears. Cutting with shears, however, is tedious and mechanical means have been tried. Lineham and Lowe, (1946) used an 'Allen' motor scythe which proved satisfactory under their conditions. The Grassland Research Station have modified a mower to cut very close to ground level. However, with stoloniferous (or rhizomatous) grasses such as Pangola (Digitaria decumbens) the use of the mower is liable to induce large errors. This is due to the grazing animals lifting the stolons off the ground and hence within reach of the mower blade. In the caged areas, on the other hand, the stolons remain at ground level and are not cut by an ordinary mower. The United States Department of Pasture Research recommends that such stoloniferous grasses should be plucked by hand, but this is very time consuming and appears to offer no particular advantage to the cage technique since this depends on the differences between two cuts. Brown (1954) also pointed out that the plucking method is also open to bias by the operator.
Construction of Cages

Most workers in this field have emphasised the need for durability in the construction of cages since cattle rub against them and try to reach the grass inside the enclosure. It was felt, that a frame of 1½ inch 'Dexion' slotted angle iron would be sufficiently strong to withstand the depredations of the animals.

A five feet square was used as the top of the cage and legs, each 2 feet 6 inches long, were bolted to the corners. These were cut obliquely at their lower end so that the resulting point could be easily driven into the ground to provide firm anchorage for the cage. With the rather high cost of 'Dexion' in mind, it was thought that an economy might be effected by using 2 x 1 inch timber for the lower rungs of the cage. These were attached to the legs 7 inches from the points by wood screws. During the course of the experiment several of these rungs were broken and they did not lend adequate rigidity to the structure. The top and sides of the frame were covered with 1½ inch wire mesh.

Method

The animals were strip grazed using an electric fence which was moved daily to offer fresh pasture. During the wet season these fields were each used to provide three days grazing, but in the dry season this was reduced to two days due to the smaller amount of available grass.

The animals were moved from the pasture at 1630 hours to the crush pen where faecal grab samples, for the chromic oxide trial, were taken. During this time the five cages were
randomly placed in the area allotted to the cattle for the following 24 hours. The following day at 1630 hours the ungrazed sample areas were cut and weighed. On the first day of the trial an 'Allen' motor scythe was tried, but it proved unsatisfactory, due to the cutter-bar being excessively worn. Hand shears were used to cut the plots for the remainder of the experiment.

For the first three days of the experiment the grazed sample was taken from an area immediately adjacent to the cage, but following the observation that animals tended to trample round the cages it was decided to follow the recommendations of Klingman et al. (1943). The samples representing the grazed areas were, therefore, selected on the basis of similarity to the caged area to which they referred.

For the first three days two 5 feet x 5 feet grazed plots were cut for each ungrazed plot, but since this amount of hand-clipping prevented the operation being completed before nightfall this was subsequently reduced to one grazed plot per ungrazed plot.

The results of the wet season trial suggested that the apparent herbage consumption for a particular day, appeared to be related to the area grazed on that day. In the wet season the area allocated was very variable, and it was thought that this might account for the great variability in the herbage estimate. Consequently, in the dry season, it was decided to allow an equal area of grazing each day, and this was standardized at 12,000 sq. ft. (0.28 acres).

The grass was sampled at 0600 hours and 1800 hours each day, and moisture content determined. The sampling technique involved cutting the herbage from various parts of the field at a height representative of that actually grazed by the cattle.
The grass was immediately placed in a weighed polythene bag, taking care to retain as much surface water (dew or rain) as consumed by the stock. The bag was sealed with a rubber band and reweighed in the laboratory.

Figures for the proportion of total grazing time spent during the two periods 0000 hours to 1200 hours and 1200 hours to 2400 hours were obtained from Northwood (1959), who observed these animals during the trial. The amount of water taken in with the grass could thus be more accurately determined by weighting the appropriate grass moisture content figure with the intensity of grazing during that period.
**RESULTS**

A summary of the results obtained from cage technique trial

<table>
<thead>
<tr>
<th>Day</th>
<th>WET SEASON</th>
<th></th>
<th>DRY SEASON</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Herbage eaten per 10 heifers</td>
<td>Water in grass</td>
<td>Area grazed</td>
</tr>
<tr>
<td></td>
<td>lbs.</td>
<td>lbs.</td>
<td>sq. ft.</td>
</tr>
<tr>
<td>1</td>
<td>706.1</td>
<td>589.7</td>
<td>4739</td>
</tr>
<tr>
<td>2</td>
<td>1686.0</td>
<td>1365.9</td>
<td>16027</td>
</tr>
<tr>
<td>3</td>
<td>701.3</td>
<td>600.7</td>
<td>4340</td>
</tr>
<tr>
<td>4</td>
<td>1168.4</td>
<td>978.9</td>
<td>7647</td>
</tr>
<tr>
<td>5</td>
<td>1648.8</td>
<td>1405.7</td>
<td>14062</td>
</tr>
<tr>
<td>6</td>
<td>735.1</td>
<td>700.1</td>
<td>5853</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td><strong>1107.0</strong></td>
<td><strong>940.0</strong></td>
<td><strong>8778</strong></td>
</tr>
</tbody>
</table>

Since the cages were moved daily the errors due to differences in the growth rate of the grass in the caged and uncaged plots can be ignored. Also the error incurred due to differences in height of clipping in the ungrazed and grazed plots would be kept to a minimum by either increasing the frequency of grazing or by selecting a grass species with a low growth rate.
DISCUSSION

These results show a very wide day to day variation and some of the estimates of intake are unrealistic, as it is extremely unlikely that a heifer would eat more than 120 lbs. of green herbage per day. These results were compared with the figures obtained using the chromic oxide technique but no correlation was apparent. In making these comparisons it was assumed that the rate of passage of the tracer through the animal was either one or two days. (Moore and Winter, 1934).

It can be seen from the above table that in the wet season the estimate of grass intake varied almost directly with the area grazed. This may, at first sight, appear to agree with the findings of Johnstone-Wallace and Kennedy (1944), who showed that cattle on pasture consumed an amount proportional to the available herbage. The paper, however, referred to the amount of grass present per acre rather than the total amount offered to the animals. An indication of the density of the herbage offered on any particular day may be obtained by using as samples the five caged areas in each strip. This does not represent the grass available for grazing since the plots were cut to ground level, but should indicate any large differences in the density of the sward. The table (Appendix II) shows that there is no relationship between the figures obtained for the amount grazed and the total herbage per acre. In addition the results obtained in the dry season again showed very wide variation but in this case similar areas were grazed each day.

Since the cages were moved daily the errors due to differences in growth rate of the grass in the caged and uncaged plots can be ignored. Also the error incurred due to differences in height of clipping in the ungrazed and grazed plots would be kept to a
minimum by cutting to ground level. (Brown, 1954). This leads one to conclude that the major part of the error is due to natural variation in the sward, which is increased in the grazed plots by selective grazing of the stock. The coefficient of variation for the caged areas in the wet season was 32% and in the dry season 56.2%, agreeing with Green (1949), who claimed that variability was greater in pastures of low productivity.

A comparison between the wet and dry season results reveals that whereas the estimates of herbage consumption in the wet season tend to be somewhat higher than one would expect, the dry season figures are consistently lower. An explanation that may account for part of this difference is that in the wet season the tall grass under the cages held more rain water or dew than the grass which had been disturbed by grazing and trampling. During the dry season trial, on the other hand, there was no surface water on the grass when it was clipped.

In conclusion it can be stated that whereas the use of cages has given satisfactory results under temperate conditions, with comparatively uniform swards (Lineham and Lowe, 1946), the method has no application under the conditions of this experiment. This is mainly due to the fact that the swards of Pangola grass used were very uneven. It is true that a better estimate of consumption may be obtained by increasing the number of cages used. It would, however, be very laborious to cut more than five cages and their corresponding grazed areas by hand, and if a motor mower were used the errors resulting from uneven cutting would have to be taken into account.
MEASUREMENT OF FREE WATER DRUNK

Method

Wet Season

The method and equipment was the same as that used by Chalmers and Jackson (1958).

Eight troughs were made by longitudinally bisecting four 44 gallon oil-drums. These were laid lengthways in two parallel rows on flat ground and secured by wooden stakes driven into the ground.

Each trough was filled with 15 gallons of water and the level marked at the beginning of the trial. After 24 hours the amount of water drunk was computed by measuring the volume of water required to restore the water in the troughs to the original level. One trough was covered with coarse wire mesh and used as a control to enable correction for loss or gain due to evaporation or rain to be made.

Dry Season

Experience in the wet season indicated that the method described gave a reasonable estimate of water drunk, but was very laborious to operate and move from field to field.

More manoeuvrable troughs were, therefore, used in the dry season. These consisted of entire drums with a panel removed from the side. These had a capacity of about 35 gallons each, and were fitted with legs, thus not requiring staking.

Measurement of water drunk was effected in a similar manner to that already described.
RESULTS

A summary of the results, using the Chromic Oxide method of assessing dry matter intake

<table>
<thead>
<tr>
<th>Season</th>
<th>Betts &amp; Bond 1958/9</th>
<th>Chalmers &amp; Jackson 1957/8</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WET</td>
<td>DRY</td>
</tr>
<tr>
<td>Rainfall in inches</td>
<td>0.34</td>
<td>0.00</td>
</tr>
<tr>
<td>Rel. Humidity % 0800 hrs.</td>
<td>89</td>
<td>81</td>
</tr>
<tr>
<td></td>
<td>86</td>
<td>64</td>
</tr>
<tr>
<td>Rel. Humidity % 1600 hrs.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature °F maximum</td>
<td>87</td>
<td>88</td>
</tr>
<tr>
<td></td>
<td>71</td>
<td>68</td>
</tr>
<tr>
<td>Temperature °F minimum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sunshine hours</td>
<td>5.2</td>
<td>7.6</td>
</tr>
<tr>
<td>Av. weight of heifers in lbs.</td>
<td>732.7</td>
<td>779.9</td>
</tr>
<tr>
<td>Water drunk per day</td>
<td>19.3</td>
<td>52.8</td>
</tr>
<tr>
<td>lbs/heifer</td>
<td>2.6</td>
<td>6.8</td>
</tr>
<tr>
<td>lbs/100 lbs L.W.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry matter consumed per day</td>
<td>14.3</td>
<td>15.6</td>
</tr>
<tr>
<td>lbs/heifer</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>lbs/100 lbs L.W.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moisture % of grass 0600 hrs.</td>
<td>85.5</td>
<td>81.9</td>
</tr>
<tr>
<td>1800 hrs.</td>
<td>84.6</td>
<td>72.4</td>
</tr>
<tr>
<td>Mean</td>
<td>85.1</td>
<td>77.2</td>
</tr>
<tr>
<td>Grass consumed per day</td>
<td>96.6</td>
<td>68.8</td>
</tr>
<tr>
<td>lbs/heifer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water obtained from grass per day</td>
<td>82.3</td>
<td>53.2</td>
</tr>
<tr>
<td>lbs/heifer</td>
<td>11.2</td>
<td>6.8</td>
</tr>
<tr>
<td>lbs/100 lbs L.W.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total water consumed per day</td>
<td>101.6</td>
<td>106.0</td>
</tr>
<tr>
<td>lbs/heifer</td>
<td>13.8</td>
<td>13.6</td>
</tr>
<tr>
<td>lbs/100 lbs L.W.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ratios:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water drunk</td>
<td>1.5</td>
<td>3.4</td>
</tr>
<tr>
<td>Dry matter consumed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water from grass</td>
<td>5.8</td>
<td>3.4</td>
</tr>
<tr>
<td>Dry matter consumed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total water</td>
<td>7.1</td>
<td>6.8</td>
</tr>
<tr>
<td>Dry matter consumed</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Time of sampling not stated, but other information indicated sampling at approx. 1300 hrs.*
DISCUSSION

It can be seen from the present results that the heifers drank about 2.5 times as much water in the dry season as they drank in the wet season. They also ingested slightly more dry matter, and the total water intake was slightly higher in the dry season. The contribution of water from the grass to this total was, however, less in the dry season, reflecting its lower moisture content.

The herbage consumption in the wet season may have been influenced by the failure to allow an equal area for grazing each day. It should be pointed out, that from the appearance of the sward after grazing, there seemed to be no shortage of grazing even on the smallest area.

Examination of the climatological data shows that the major differences between the wet and dry season trials were daily rainfall, humidity and sunshine hours. There seems to be no reference in the literature pertaining to the direct effect of rainfall on cattle, but it was noticed during the trial, that heavy rain caused the animals to stop grazing and face away from the prevailing wind. In the wet season, when these showers were frequent, the interruption in grazing may have reduced the intake slightly. On the other hand, Wilson and Lutara (1955) noted that rain falling at night when the animals are resting will cause them, firstly to stand up, and secondly to start grazing as soon as the rain has abated. This may increase total grazing.

The difference in total water intake between the wet and dry season is small. This is not surprising since the temperature, which has been shown to have a marked effect on water intake, was approximately the same in the two seasons. Henderson and Teague (1933) compared two groups of cattle, one on a ration of wet sugar beet pulp, and the other receiving dry pulp;
this corresponds to a certain extent to the fodder conditions in the wet and dry seasons. Both groups were allowed water ad lib., and their results showed that both groups had approximately the same total water intake. This agrees with the results of the present trial.

Ragsdale et al. (1953) have shown, however, that high humidity tends to reduce the total water intake in Brown Swiss and Holstein animals at ambient temperatures above 75°F. In the present work, however, the higher humidities of the wet season seem to have had little effect. It is true that the total water intake per beast was slightly higher in the dry season, but it must be remembered that the animals had put on weight and in terms of pounds of total water consumed per 100 lbs. liveweight there was virtually no difference between the two seasons.

The greater amount of radiation in the dry season, as indicated by the sunshine records, also had little effect, although Brody et al. (1954) noticed that Brahman cattle increased their water consumption under high radiation intensities. Under the conditions of the present trial there was ample shade in all pastures, and the animals could readily retreat from the direct rays of the sun.

The most marked difference between the wet and dry season trial was the source of water in the two periods. In the wet season the grass supplied 81% of the total water intake, while in the dry season only 52.4% was obtained from grass. This emphasises the need to consider feed-water in water intake trials. A quite erroneous picture would have been obtained if only the free water drunk had been determined.

The results of the present trial (expressed in terms of pounds of total water intake per pound dry matter eaten) have
been compared with figures obtained by other workers, and there is general agreement. Mullick et al. (1952), found this ratio to be 5.1 : 1 under summer conditions in India. This is slightly narrower than either the wet or dry season ratio obtained in the present trial, in spite of the somewhat higher temperatures experienced in India. They were using pure Zebu stock which have been shown by French (1956) and Winchester and Morris (1956) to have a lower water requirement.

Winchester and Morris have calculated the ratio of total water intake to dry matter consumption for numerous classes of stock under a wide range of ambient temperatures. The figure they obtained for Zebu animals, at 80°F, was 4.8 which agrees closely with the ratio of 4.5 found by Mullick et al (1952) for Zebus during the spring season in India (mean temperature 86°F). They stated that this ratio for European type cattle, at 80°F, was 6.2 which closely parallels the figure of 6.8 for the dry season in the present trial.

It is interesting to note that Winchester and Morris (1956) also stated that, at a temperature of 80°F, European heifers of 800 lbs. require a total water intake of 106 lbs. per day. This agrees very closely with the results of the present trial in which heifers of mainly European type and similar weight were used. It would, therefore, be very interesting to obtain water intake data for cattle of varying proportions of European blood under Trinidad conditions.

In view of the large variation between the present results, and those obtained by Chalmers and Jackson (1958) under rather similar conditions, it was decided to make a detailed comparison between the two trials.

The climatic conditions existing during both trials were very similar, although Chalmers and Jackson recorded a slightly
higher figure for sunshine hours in both seasons. They made no reference to the availability of shade in the pastures, but an inspection by the present workers revealed that there was very little shade available. Since there was ample shade in the present trial it can be considered that the animals used by Chalmers and Jackson (1958) were subjected to direct sunlight for longer periods each day.

Management differed in the two trials. Chalmers and Jackson used a day and night paddock system on which the animals were allowed unrestricted grazing throughout the trial. They noted that the night paddock was poor in the wet season and practically unproductive in the dry season. In spite of this, their results indicate that the animals consumed 82% more dry matter in the dry season. In the present trial, where grazing was relatively plentiful in the dry season, the increase in the dry season was only 9%.

The major discrepancy in the two sets of results lies in the derived figure for water obtained from fodder. This is deduced from the dry matter intake and the moisture percentage of the grass. Chalmers and Jackson claimed that the moisture content of the grass was almost similar for the wet and dry seasons although this seems contrary to popular belief, and indeed to the present determinations. Also their moisture content percentages for both seasons were much lower than the present figures. They did not describe their sampling method, but other information has indicated three factors which have undoubtedly contributed to their lower figures.

They collected rather more of the plant than is normally grazed by the stock. They included stems and stolons which have a lower moisture content than the leaf, which comprised the bulk of the present sample.
Secondly, they did not sample grass at different times of the day; an important factor, especially during the dry season. Their single sample was actually collected soon after mid-day, at which time the moisture content is at a minimum.

Finally, they failed to retain any free water present on the leaves when taking their sample. This is important because much of this water is undoubtedly consumed by the stock during grazing.

The differences between the two trials in terms of water obtained from grass are very pronounced. Chalmers and Jackson (1958) claimed that 114% more water is obtained from the grass in the dry season than in the wet season. This reflects their low figure for intake of dry matter in the wet season, and also the comparatively low moisture content of the wet season herbage. Present results, however, show that 54.9% less water was obtained from grass in the dry season than in the wet season.

With reference to total water intake Chalmers and Jackson showed an increase of 123% in the dry season as compared with the present figure of only 4%. It seems unlikely that with comparatively similar temperatures in both seasons that there would be such a marked increase in total water intake. It is interesting to note that their results of the dry season trial agree closely with the present results, especially in respect to total water intake.
CONCLUSIONS

In reviewing water intake studies in cattle, attention was drawn to the relationship between the heat tolerance of animals, and their total water intake. The results of the present trial indicate very small differences in total water intake between wet and dry seasons, and also that climatic factors were very similar for both seasons. This would suggest, from a heat tolerance standpoint, that seasonal comparisons in Trinidad are of little value.

If water intake is any criterion for assessing heat tolerance, it could be used to compare the tolerance of different breeds or to assess the discomfort suffered under different management systems. Also allied with any water intake trial it is felt that some investigation into the utilization of the water, particularly the evaporative loss of water from the skin, should be conducted.


REFERENCES


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<tr>
<td>% grazing 1200 - 2400 hrs.</td>
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**Northwood (1959)**

## Addison and MacDonald (1959)
A table comparing the amount of grass grazed, (as determined by the cage technique) with the total amount of herbage available.

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<th>Date</th>
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## APPENDIX III

Details of heifers used in trial.

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<td>Dry Season Trial</td>
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Part II

Preliminary studies on a field technique for the quantitative assessment of sweating in cattle.
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INTRODUCTION AND REVIEW OF LITERATURE

In consideration of the adaptability of cattle to conditions of high temperature some workers hold that the non-production of heat is a basic factor enabling an animal to withstand high ambient temperatures. Be that as it may, it cannot be denied that the ability of an animal to cool itself is an additional faculty enabling it to withstand high external temperatures.

Animals can dissipate heat in two main ways. Firstly, by non-evaporative cooling by conduction, convection and radiation and secondly, by evaporative means. The latter process occurring by way of the respiratory tract and also by evaporation of water secreted from the sweat glands on to the skin.

Many workers have attempted to measure the amount of water evaporated from the skin surface by various techniques, all of which have suffered from certain drawbacks. Probably the first worker to attempt to make such a measurement was Sanctorius, a doctor who in 1614 described in his book Medica Satica an experiment to determine the perspiration of a man, by seating him on a chair that was suspended from a balanced steelyard and observing the man's loss in weight over a period of time. The principle of this method has been employed by modern workers, but by weighing animals in psychrometric chambers. In these, the temperature, humidity and air movement can be regulated as required. The faeces, urine and drooled saliva are collected in vessels and the respired air is collected by means of a mask. All these products are weighed and the difference in weight between this total and the overall loss in weight is attributed to sweat loss. This type of trial has been carried out by Riek and Lee (1948), Knapp and Robinson (1954) and Taneja (1958) in Australia and by Thompson, McCroskey and Brody (1951) in the United States. The method has been shown to give good results,
but its major drawbacks are that the apparatus is very expensive, it cannot be used on animals under natural field conditions, and it cannot measure sweating from localized areas of skin surface.

In making an actual collection of sweat for qualitative experiments on the sweat of humans, Robinson et al. (1941), Mickelson and Keys (1943) and Ladell (1947), loosely ensheathed an entire limb in an airtight bag attached firmly at the upper part of the arm or thigh of the subject and drained off the sweat exuded into the bag from a tube at the bottom of the bag. This technique has not been adapted for use in quantitative sweating on cattle, presumably because of several apparent obstacles. The bag would set up an unnatural microclimate round the limb, the apparatus would be difficult to attach and it would cause the animal considerable inconvenience.

All other methods that have been used to obtain a quantitative assessment of sweating have attempted to measure the degree of sweating of small localized areas of the animal's surface. While this type of experiment cannot give an accurate assessment of overall sweating by an animal from its entire surface, it can be useful in the execution of trials designed to compare sweating of different areas of an animal's skin, to compare the rates of sweating while an animal is subjected to different conditions and to compare sweating differences between similar loci on different types of animal.

The methods of measuring the amount of sweat exuded from small areas of skin surface fall into two categories. The first is aimed at collecting sweat by some means from a given area of skin, for a given period and weighing the amount collected. The second method is based on the differential rate of colour change of certain chemicals when moistened.

Freeborn, Regan and Berry (1934) and Rhoad (1940) employed a gravimetric method which involved placing 10 cm. diameter
Petri dishes containing weighed pieces of blotting paper, impregnated with anhydrous calcium chloride over a closely clipped patch of skin over the ribs and attaching the Petri dishes to the animal with a simple harness. After an hour the dishes were removed and the blotting paper weighed. The main disadvantage of this method lies in the fact that the calcium chloride is extremely hygroscopic and will absorb water-vapour from the air during the periods when the blotting paper is exposed directly to the air, immediately prior to application and after removal from the animal's skin. This absorption from the atmosphere could perhaps be accounted for to some extent by the use of a 'control' Petri dish not placed in contact with the sweating skin but similar in all other respects to the sweat-absorbing dish. No reason is given for the clipping of the coat over the test areas but it would appear that this procedure would result in an unnatural condition existing around the sweat glands. Ferguson and Dowling (1955) also employed this technique, their only modification being that the dishes were hand-held to the clipped surface for only five minutes.

Mickelson and Keys (1943) in the course of their qualitative experiments on human sweating actually obtained quantitative results by applying gauze bandages to the skin surface. The difference in weight before and after absorption being used to represent the amount of sweat collected. This method satisfied the experimenters, but it was noted that practice was needed to apply and remove the bandages. However, they failed to evaluate the probability of absorption of water-vapour from the atmosphere during application and removal, and so their results probably gave an exaggerated estimate of sweating.

A different approach to the gravimetric method was made by McDowell, Lee and Fohrman (1954) who followed the principle employed by Kuno (1927) and Pinson (1942) in the measurement of
sweating by humans. The method of Kuno and Pinson consisted of attaching a small capsule to the skin of the subject and drawing measured amounts of dried air through the capsule and over the covered skin and then through absorbers containing sulphuric acid. The weight increase of the absorbers represented the weight of sweat collected from the area covered by the capsule. When McDowell, Lee and Fohrman adopted this principle for the measurement of sweating by cattle they realized that by drawing dried air over the skin they would expose the skin to conditions quite different from the ambient atmospheric conditions. They overcame this problem to a certain extent, by keeping the test area exposed to virtually natural but measured conditions of humidity. These workers did not clip the hair over the test areas, but only in rings around the test areas, so that the flange of the capsule could be firmly cemented to the skin of the animal. This method appears to be capable of giving very accurate results, but suffers from the disadvantage of requiring rather large and cumbersome apparatus which is connected to the animal by pipes, thus rendering it unsuitable for field work with animals under natural conditions.

The colorimetric methods that have been used are based on the rate of colour change of certain substances when hydrated by sweat. Berman (1957) used filter papers impregnated with anhydrous cobalt chloride. These were placed in glass cups which were applied to the skin of the animal. The time taken for the cobalt chloride to change from violet to red was recorded on a stop-watch. This time was considered to be inversely related to the evaporation rate from the skin. Berman also showed that the sweating rate of shaven skin was significantly greater than that of unshaven skin. Ferguson and Dowling (1955) used the same principle but used a suspension of bromothymol blue and sodium carbonate in liquid paraffin as the testing substance.
This method may suffer from the fact that the indicators probably absorb varying amounts of atmospheric water-vapour during the pre-application period and also, the human error factor involved in assessing colour changes is quite considerable. While this method could be used to carry out comparative experiments on the basis of time elapsed, absolute results in terms of amount of sweat produced would be difficult to attain with any degree of accuracy.

An electrical method used widely in soil moisture studies could be considered. This consists of measuring the resistivity of a porous plaster block when permeated with varying amounts of moisture. Its major deficiency, from the sweat assessment stand-point, lies in the fact that the variable concentration of salts in sweat would also cause differences in the resistivity of the block and so a measure of resistivity could not, therefore, be directly correlated with moisture absorption.

A universal disadvantage of all these methods lies in the fact that they all entail the attachment of some device to the skin of the animal, thus subjecting the areas covered to an environment that differs from the natural.

In the design of accurate methods of sweat assessment in the field, at reasonable cost, certain considerations must be made. Macrogravimetric methods requiring the use of psychrometric rooms are to be discounted. Therefore, some device must be attached to the animal, but this must be small and light and not cause the animal to deviate from its normal behaviour. Also the animal should be free to walk without the encumbrance of attached pipes and wires. With these conditions and the merits and demerits of previous experiments in mind, the following apparatus and technique was devised.
EXPERIMENTAL

The method is based on the gravimetric measurement of sweat collected from small areas of the animal's surface for a given period, and is similar to the method used by Freeborn, Regan and Berry (1934), Regan and Richardson (1938), Rhoad (1940) and Mickelson and Keys (1943), and considered by Findlay (1950) to be the most promising.

Certain modifications, however, were considered necessary. Firstly, it was desired to use an absorbent of similar texture to the animal's coat, that would readily absorb liquid water by surface tension and capillarity forces from the unshaven surface of the animal, but not absorb water hygroscopically from the atmosphere. Cellulose fibre, in the more convenient form of cotton-wool, was considered, following the favourable report by Mickelson and Keys (1943) on gauze bandages. The cotton-wool was tested by cutting pads 15 cms. by 8 cms. from a roll of the material. Each pad was placed in a light aluminium screw-top container (fig. 3) and oven-dried for 24 hours, then cooled in a desiccator. Whilst in the desiccator the lids of the containers were screwed down to effect an air-tight enclosure. The containers, with pads, were weighed on a chemical balance. They were then opened and the pads lifted on to the tops of the containers with forceps in order to expose them to the atmosphere. At timed intervals after the initial exposure the weight of the pads and containers was recorded and the Relative Humidity percentage measured. This was continued for up to 24 hours on three pads, which were initially exposed at different times on the 24 hour cycle.

The absorption curves of the cotton-wool (fig. 1) plotted from these measurements show the percentage weight increase of
the pads against time after initial exposure, and the R.H.% at the time of each weighing. From the three plotted curves (which cover a fairly wide humidity regime, 58 to 84 R.H.%), three further curves for constant R.H. of 65%, 75%, and 85% were deduced (fig. 2). These are found to follow a similar pattern, characterized by a rapid increase in weight of 4% to 6% over the first two hours of exposure, and thereafter a more gradual weight increase of about 0.25% per hour over the next 22 hours.

The absorption of liquid water by cotton-wool from a wet surface was also investigated. This was done by saturating a piece of filter paper in a Petri dish, and then lightly pressing a cotton-wool pad upon it. The pad was successively weighed and the filter paper resaturated until the water appeared to have permeated right through the pad. At this point, the pad had absorbed 17.4% of its own weight of water. From these observations it was concluded that the cotton-wool pad could be expected to absorb, and firmly retain, up to its own weight of water.

These results indicated that surgical cotton-wool was a suitable absorbent for further investigation, provided that certain precautions were taken.

Firstly, in order to make some correction for the inevitable absorption of water-vapour from the atmosphere by the cotton-wool, it was decided to use two pads per trial. A 'test' pad to absorb the sweat and a 'control' pad treated in an exactly similar manner to the 'test' pad, except that it is placed in direct contact with the surface of the animal under test. Instead, it is placed in contact with a piece of cured, unshaven hide attached to the animal.

Secondly, it has been observed that dry cotton-wool rapidly absorbs up to 6% of its own weight upon exposure to the atmosphere, even at fairly low humidities, and thereafter, its
rate of absorption drops to a low level. This fact suggests that both pads should be pretreated by oven-drying, and then exposed to the atmosphere for 4 to 6 hours before use. This procedure leaves both pads in a similar condition and their subsequent rate of absorption of water vapour from the atmosphere remains at a very low level (0.25% by weight per hour).

Apparatus

The apparatus is made up in the following manner. The two pads, 5.5 cms. square (p), are held in a capsule (Appendix I, fig. 4) which consists of two trays of a rigid plastic material, each 5.5 cms. square internally and 0.6 cm. deep. The two trays are fixed together, base to base, to form the capsule.* Two elastic loops are secured to the capsule for attachment purposes.

The capsule is held to the test area of the animal's surface by means of a capsule-carrier (figs. 3 and 5). This consists of a strip of cured, unshaven hide 32 cms. long, 11 cms. wide at the middle and tapered at each end to a width of 2.5 cms. An heavy gauge wire rectangle, 2.5 x 1.0 cm. is fitted to each end (a). At the widest portion of this hide, on the coat side, a small dress-makers hook is stapled to each margin (b). These serve as the attachment points for the rubber band which is affixed to the capsule.

The capsule-carrier, is affixed to the animal by means of a 1 inch wide elastic strap (d), one end of which is fastened to the wire ring at one end of the capsule-carrier. To the other end of the strap a hook is attached (e) which can be rapidly

* The prototype capsule was made from a cigarette packet holder manufactured by the Tupper Corporation, Farnumsville, Mass., U.S.A.
coupled and uncoupled to the wire ring at the other end of the capsule-carrier. The length of the elastic strap is variable and should be adjusted to hold the capsule-carrier comfortably and firmly in position. This adjustment should be done during a preliminary conditioning period, during which the apparatus without pads, is applied to the animal in order to accustom it to wearing the apparatus. The length of the conditioning period depends upon the temperament of the animals.

Method

A quantitative sweating test, using this apparatus, is carried out in the following manner. The capsule-carrier, capsule, elastic strap and two aluminium containers, one marked 'T' (test) and another marked 'C' (control) are dried in a desiccator. Two similar pads, treated as prescribed (page 8, line 1), are placed in the capsule by means of forceps (fig. 4). The capsule is placed on the coat side of the capsule-carrier and its elastic loops fixed to the two marginal hooks (fig. 3). The capsule-carrier is rolled, coat side innermost, and placed in a dry polythene bag together with the two marked containers and the elastic strap. The bag is closed and taken to the field.

The portion of the surface of the animal to be tested is lightly mopped with a piece of cotton-wool, in order to remove excess moisture, but leaving residual moisture on the coat and skin similar in amount to that which will be left when the cotton-wool 'test' pad is finally removed from the animal.

The assembled apparatus is then removed from the bag and secured to the animal as shown in fig. 5, with the coat side of the carrier and the 'test' pad in contact with the mopped surface of the animal. At the moment of contact a stopwatch is started.
The animal is left free for a suggested period of one hour, whilst subjected to the test conditions. At the termination of this period the apparatus is detached. The two pads are removed by forceps and enclosed in their respective containers. The containers, holding the pads, are then weighed on an accurate chemical balance. With covers loosened, they are dried in an oven for 24 hours, cooled in a desiccator and reweighed. From these four weighings, abbreviated as shown below, the amount of liquid water collected from the test area of 5.5 cm$^2$ during the hour can be deduced by subtraction.

(aT) Weight of container T, 'test' pad, absorbed water-vapour and absorbed liquid water (sweat).
(bT) Weight of container T, and 'test' pad (dried).
(aC) Weight of container C, 'control' pad and absorbed water-vapour.
(bC) Weight of container C and 'control' pad (dried).

**Subtraction** (example in Appendix II, Table I)

Weight of liquid water absorbed (sweat) from 5.5 cms.$^2$

\[
= (aT - bT) - (aC - bC) \text{ grams}
\]

\[
= fT - fC \text{ grams}
\]

\[
= g \text{ grams}
\]

This figure can be converted to a more convenient expression\(^{(h)}\) of grams/square metre/hour by multiplying by a factor of 330.58. It must be noted, however, that conversion to this form does not represent the amount of liquid water that would have been absorbed from any particular square metre of the animal's surface.
PRELIMINARY TRIAL OF APPARATUS AND METHOD

The apparatus was used in the prescribed manner on two Zebu-Holstein heifers at the Government Stock Farm at St. Joseph on Sunday 1st. March, 1959 at 1500 hours and at 1630 hours.

The animals did not appear to be disturbed by the presence of the apparatus and permitted its application and removal while standing free. It was observed that other animals in the herd tended to investigate, by smell and taste, the apparatus worn by the animal under test. Therefore, the capsule-carrier and elastic strap were treated with ethylhexanediol* which prevented further interference.

Results

Measurements taken from these two tests are presented in Appendix II, Table 1. It can be seen from these that the amount of water-vapour absorbed from the atmosphere by the control pads amounted to 6.6% and 4.6% of the weight of the pads. These figures are in agreement with the absorption curves shown in Appendix I, figs. 1 and 2. Also the 'test' pads absorbed considerably more overall than the 'control' pads (86.0% and 100.0%).

A subsidiary test was conducted on a trotting horse to determine whether the pads could absorb profuse sweating. In this case the test pad was applied to the withers for only twelve minutes, during which period its weight increased 64%.

The sweating rate of the horse was calculated to be 1732 grams/square metre/hour. This is almost three times as great as the maximum sweating rate of cattle, found to be 550 grams/

* Manufactured by Northrop, Lyman & Co. Ltd., Toronto, Canada.
DISCUSSION

The results of the trials indicate that water is absorbed from the coat of the heifers.

Previous workers, notably Riek and Lee (1948), have indicated that water-vapour escapes through the skin by simple diffusion and also, that liquid water is secreted by the sweat glands on to the surface of the skin. Should this be so, in the interpretation of the results from these trials, it must be determined which of these components is collected by the pads.

The preliminary tests on cotton-wool showed that its absorption of water-vapour was low. Also, since both pads were subjected to similar air conditions during the sweating trial it can be assumed that any vapour diffused through the skin of the animal would have permeated both pads to a similar extent during the test-hour. Any difference in weight gain can, therefore, be attributed mainly to the collection of liquid water by surface tension and capillary forces of the 'test' pad.

It is this liquid water component, presumably only secreted by the sweat glands, that is of major interest in heat tolerance studies. The evaporation of liquid water from the surface of the animal causes a heat loss of 580 calories/gram evaporated.

A subsidiary test was conducted on a trotting horse to determine whether the pads could absorb profuse sweating. In this case the test pad was applied to the withers for only twelve minutes, during which period its weight increased 64%.

The sweating rate of the horse was calculated to be 1732 grams/square metre/hour. This is almost three times as great as the maximum sweating rate of cattle, found to be 660 grams/square metre/hour by McDowell et al. (1954). This indicates that the apparatus could easily absorb the most profuse sweating
of cattle, but care must be taken to adjust the duration of application of the pad to suit the degree of sweating to be measured. This is important since the pad can only be considered to absorb and firmly retain up to its own weight of moisture.

While this apparatus appears to offer a possible means of measuring the secretion of liquid water on to the skin, it suffers from certain limitations in its present form. It can only be attached satisfactorily to a limited number of areas on the animal's surface. The apparatus itself is very simple and inexpensive, but it requires the use of certain expensive ancillary equipment i.e. an oven and a very accurate balance. These items, however, are generally already available in most laboratories.

Should it be desired to make a full analysis of the composition of the animals sweat, any non-aqueous components could be collected by washing out the test pad with hot water and alcohol.
CONCLUSION

The described apparatus and method offers an apparently accurate, simple and inexpensive means of assessing the secretion of liquid water on to the surface of the skin. The results of the two trials indicate that further consideration of the method should be given for its use in a comparative sweating trial. The results of this should be statistically analysed in order to determine whether the method is capable of giving valid results.
REFERENCES


APPENDIX II

Table 1
Preliminary Sweating Trial Results

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<td>Govt. Stock Farm St. Joseph</td>
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<td>1 / 3 / 1959</td>
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<td>Zebu-Holstein heifer H 1</td>
<td>Zebu-Holstein heifer H 29</td>
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<td>TEST AREA</td>
<td>Left fore-rib</td>
<td>Right hind-rib</td>
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<tr>
<td>AIR TEMPERATURE</td>
<td>85°F</td>
<td>78°F</td>
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<td>RELATIVE HUMIDITY %</td>
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<td>approx. 59</td>
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<th>C</th>
<th>T</th>
<th>C</th>
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<td>(a) Container + pad (wet)</td>
<td>48.572</td>
<td>48.054</td>
<td>48.388</td>
<td>47.600</td>
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<td>(b) Container + pad (dry)</td>
<td>48.335</td>
<td>47.927</td>
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<td>(c) Container (dry) **</td>
<td>46.640</td>
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<td>(d) Pad (wet) (a-c) **</td>
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<td>(e) Pad (dry) (b-c) **</td>
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<td>(f) Weight increase (a-b) or (d-e)</td>
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| (g) Sweat/5.5 cm. \( ^2 \) /30 min. (\( \text{ft}^2-\text{FG} \)) | 0.110  | 0.078  |

| (h) Sweat/metre\(^2\)/hour (g x 330.58 x 2) | 72.8 grams | 51.4 grams |

** Not necessary for calculation of (h)
ACKNOWLEDGEMENTS

The writers wish to express their gratitude to Dr. O. Gonzalez for permission to conduct the trials at the Government Stock Farm, St. Joseph and to the farm staff, especially Messrs Dominique and Gregg, for their co-operation throughout the trials.

Further our thanks are due to Dr. M. C. Bennett for information on the absorbent properties of cotton wool and finally to Dr. P. N. Wilson, our supervisor, for his guidance during the experiments.

27th April, 1959. R.D.W.B. and R.S.B.