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Preliminary research with an implantable telemetric system for measuring the body temperature of dairy cows

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Introduction

The automatic collection of data on milk yield and feed intake is already commonplace on many dairy farms. Interest is increasing in the possibility of also automatically registering oestrus and illnesses. One of the reasons for this interest is the increase in average herd size. In the Netherlands, this figure has almost doubled in the last ten years (from 24 to 41). On the farms with larger herds, the animals are commonly kept in loose housing systems. In these systems, individual control of animals is difficult, also because the animals are less accustomed to being restrained for individual control and treatment. Under such conditions the stockman might greatly be helped by the use of some remote controlled system for recording data about the cows' reproductive state and health.

It is well known that illnesses may cause fever, so that they can be detected by measuring body temperature. This still leaves open the question of whether every disease can in practice be detected by monitoring temperature. The same problem arises in the case of oestrus registration on the basis of body temperature. Numerous studies have been done on temperature changes around the oestrus period, (e.g. Rao and Murthy 1971, Lira et al. 1975, Maatje and Rossing 1976, Ball et al. 1978, Nieuwenhuizen et al. 1979, Zartman and DeAlba 1981/1982). Some researchers measured milk temperature automatically in the milk claw (Maatje and Rossing 1976, Ball et al. 1978). This method revealed an increase in milk temperature during oestrus, but other factors also influenced temperature, e.g.: milk flow rate and a high ambient temperature when cows were on the pasture. Because of these problems, the use of temperature transmitters implanted in the cow began to attract interest.

Previous researches have placed temperature transmitters most often in the cervix or vagina (Keener et al. 1977, Nakamura et al. 1983, Zartman et al. 1983, Junge-Wentrup and Holtz, 1984, Araki et al. 1985) or ear (Lira et al. 1975, Seawright et al. 1978, Scott et al. 1983, Wiersma and Stott, 1983), but sometimes also in the jugular vein (Zartman and DeAlba 1981/1982) and in other sites. Some authors reported experiencing problems with the range of transmission when

such methods were used.
To date, the rectum has been the most popular site for measuring body temperature in cows, by whatever technique (Rao and Murthy, 1971, Mostageer et al. 1974, Pau en Wan, 1974, Ball et al. 1978, Kotby et al. 1978, Iketaki et al. 1979, Nieuwenhuizen et al. 1979, Iketaki et al. 1982, Kamada et al. 1984, McLean et al. 1984, Young et al. 1984). Traditionally, rectal temperature was measured with a thermometer, which in practice means that the cow has to be restrained. The need for restraint can be avoided by using a transmitter in the rectum.
When using body temperature to detect oestrus, illness or other relevant events such as the onset of calving, knowledge is needed about the other factors that can influence body temperature. These influences may confuse the results of the temperature registration and raise the risk of wrong conclusions.
The study of body temperature as such has a long history. Much research has been done on the influence of hot, cold (or cooling) and moderate climate e.g.: Gwazdauskas 1975, Brown et al. 1977, Bayer et al. 1980, Kamada et al. 1984, McLean et al. 1984, Araki et al. 1985, Armstrong and Wiersma 1986). Most authors found that in a hot environment the body temperature increases, in a cold environment it decreases and in a moderate climate it is rather stable, but subjected to seasonal (Pharate and Nagpaul, 1984) and daily cycles (Wrenn et al. 1961, Simons et al. 1965, Scott et al. 1983, Young et al. 1984). The results on the effects of ambient temperature on body temperature during oestrus were not consistent: Nieuwenhuizen et al. (1979) found some interaction, Rao and Murthy (1971) found no significant relationship and Ohsaki (1984) found no clear link.
The general level of body temperature is also influenced by several factors. Lactating cows (particularly the high producers) have a higher body temperature than dry cows (Mostageer et al. 1974, Nakamura et al. 1983), because of higher heat production (Boxberger 1983, Curtis 1983). Furthermore, body temperature depends on age (Wrenn et al. 1961, Mostageer et al. 1974) and on the breed of the cow (Mostageer et al. 1974, Kotby et al. 1978).

The objective of the present study was:
a. to continuously record the body temperature of cows using implanted

temperature transmitters and to store the data on computer.
b. to investigate the variation in the continuously recorded body temperature, with the emphasis on the effect of time factors and the behaviour of the cows.

Material and methods

The research was carried out on the experimental farm "De Vijf Roeden" of the Institute of Agricultural Engineering in Wageningen.
The subjects were 10 cows, crosses between Holstein-Friesian and Dutch Friesian. Seven cows were lactating and 3 cows were dry. There was no specific condition for choosing these cows, except that they should be healthy. Milk yield per day averaged 35 kg in the 4 cows that were at the beginning of their lactation and 25 kg in the 3 cows, that were in the middle of their lactation.
All cows were kept in a loose housing system with free stalls for lying, and a common feed gate; the lactating cows in a group of 18 lactating cows; the dry cows in a separate group of about 20 dry cows.
The experimental cows followed the management routine of their own group. The lactating cows were provided with 4-5 kg of maize silage per head and grass silage ad libitum. Fresh feed was supplied at 08.00 and 17.00 hours. At noon and at 23.00 hours, smaller amounts were given. The amount of concentrates that was supplied by an automatic dispenser was related to the milk yield of the cows. Milking was done at 06.00 and 16.00 hours.
Dry cows received a restricted ration per day, up to about 10 kg of wheat silage (straw with grains) at 08.00 hours and 15-20 kg grass silage at 16.00 hours. At the beginning of the "dry" period they were given no concentrates, but later were given 1 kg of mineral mixture per day, plus concentrates from 1 week before expected calving, beginning with 0.5 kg and increasing by 0.5 kg per day up to a maximum of 3 kg per cow.
A telemetric system was used for measuring body temperature. Temperature transmitters were designed and constructed in collaboration with the Institute of Technical and Physical Engineering Research Service in Wageningen. These transmitters were made by chip-wire hybrid technology, and were covered by glass tubing and in a silicone rubber capsule. They were cylindrical: circa 10 cm long and 3.5 cm in diameter. The transmitting frequency of around 30 MHz was chosen on the basis of earlier research with deep implants. The

transmitter had a low power consumption and a transmitting range up to 60 m. The receiving system was fully automatic and could handle 10 transmitters simultaneously. The system was able to record the mean temperature over periods of 5, 10, 30 or 60 minutes, and the minimum and maximum temperatures within these periods. The values were displayed on a small screen, printed on paper tape and stored on a magnetic tape. The overall accuracy of the system was better than 0.1°C.

The temperature transmitters were surgically implanted under local anaesthetic in the left upper part of the abdomen, between the peritoneum layer and the rumen.

Data on body temperature were collected over nearly a one-year period, from October 1985 to July 1986. However, the actual period of recording for an individual cow never exceeded 36 days and this period depended on when the transmitter had been implanted and whether it was working. In 7 of the cows there were gaps between recorded days, because of technical failures (see Table 1).

The data about body temperature of cows with fresh implants were collected from the third day after the implantation, or later. The recording frequency was once per 15 minutes (as mean value for a period of 15 minutes). During behavioural observations it was increased to once per 5 minutes.

The body temperature of the dry cows was also recorded during 7 days on the pasture. Body temperature was also measured in these 3 dry cows before and during calving, when they were kept indoors. The transmitter of one cow stopped working on the day before calving.

While body temperature was being recorded, the following behavioural observations were made:

1. in 4 lactating cows (2 cows at the beginning of their lactation and 2 cows in the middle of their lactation) kept indoors: 11 observations lasting from 08.00 to 16.00 hours, in winter 1986.
2. in 3 dry cows kept indoors: 11 observations from 08.00 to 16.00 hours in August and September 1986.
3. in the same 3 dry cows kept on pasture: 15 observations from 08.00 to 16.00 hours in late August and early September 1986.

The following behaviour was recorded in protocols, rounded to

1 minute: lying, lying + ruminating, standing, standing + eating, standing + ruminating.
The behaviour of cows before and during calving was recorded on video from 3-4 days before calving. Meanwhile, temperature was recorded every 5 minutes.
During the periods that body temperature was being recorded data were also collected about ambient temperature (by thermohydrograph), weather conditions on the pasture and state of health of the cows.
The following statistical tests were performed: analysis of variance, sign-test, correlation coefficients (Conover, 1971), (Snedecor and Cochran, 1973).

Results

1. Body temperature in general

The mean daily body temperature of cows (x) during the observation period was within the range 38.0- 38.5°C for 4 cows and between 38.5-39.0°C for 6 cows (Table 1) and the standard deviations (Sx) varied from 0,06°C to 0.24°C. The smallest standard deviations occured of course in cows with small differences between their minimum and maximum mean daily temperatures and the largest in cows with large differences between these values (Table 1).
On some days, body temperature differed significantly from the mean daily temperature for the whole observation period. At the beginning of the recording period this could be related to effect of implantation of transmitter, but large variations sometimes appeared later, too. Figure 1 shows 2 examples of temperature curves of 2 cows with a 95% confidence interval for the mean temperature in the entire recorded period.
Because insufficient data were obtained on the ambient temperature, the relationship between body temperature and this ambient temperature could not be analysed. However, if ambient temperature did have a strong influence on the body temperature of cows, then a positive correlation could be expected between the mean daily temperature of cows monitored in the same period. In order to test this hypothesis, the body temperature data of 2 groups of 3 cows and 3 pairs of cows, observed on the same days, were compared (Table 2). Only in the case of 2 lactating cows (cows 235 and 346: observation period 24 days) and in the group of 3 dry cows (cows 333, 154 and 117: 18 days) did the temperature data correlate significantly. The curves of the temperature changes of these 5 animals are presented in Figure 2. The temperature changes of the 3 dry cows ran more or less parallel. In the case of the 2 lactating cows, an inverse relation was seen - during all observation period the temperature of one cow increased while that of the second decreased.

2. Fluctuation of body temperature during the day

Figure 3 shows changes in body temperature during the 24 hours of the day. Graph A is the plot of data on 7 lactating cows kept in the cowshed, graph B of the 3 dry cows kept in the cowshed and graph C concerns the same dry cows while they were 7 days on pasture, day and night.

In all 3 situations, body temperature fluctuated during the day, but the fluctuation on the pasture was very large. The difference between maximum and minimum body temperature was 0.3°C in the case of the 7 lactating cows, 0.25°C in the 3 dry cows kept indoors and 0.65°C in the same cows kept outdoors.

The graphs of lactating cows and dry cows kept indoors are similar, except for a slight shift in time during the day. In all cows kept in the cowshed there was a decrease in body temperature below mean day temperature, beginning at 09.00 hours, and lasting until 13.30 hours in dry cows and untill 15.00 hours in lactating cows. Cows observed in the cowshed showed two increases in body temperature: the first in the morning and the second in the afternoon, around the time of main feeding and milking.

In lactating cows, the increase in body temperature in the second part of the day had two peaks. The second peak was possibly related to evening feeding (23.00 hours). However, the minimum daily body temperature occurred during the extra feeding at noon. Strikingly, at milking time, the body temperature of lactating cows was most similar to mean daily temperature, and the standard deviation was smallest.

The plot for the dry cows kept 7 days on the pasture deviated from the plots of cows indoors. Between 09.00 and 21.00 hours the body temperature was higher than the mean for the whole day: for the rest of the day it was lower. The variation in body temperature on the pasture was remarkably high. It can only partly be explained from the shorter recording time (7 days on the pasture versus 25 days in the cowshed). The standard error (S_x) on the pasture was up to 5-6 times larger than in the cowshed, whereas on the basis of the lower number of observations it was expected to be only twice as large ($\sqrt{25}/\sqrt{7} \approx 2$).

In spite of all the above-mentioned differences between plots, the common feature of all of them was that body temperature peaked at about the same time - at 17.00 hours.

In order to check the significance of differences in body temperature during consecutive days and within the day and between periods (4 periods of 6 hours were considered), an analysis of variance was performed for data on 3 cows obtained during the same 9 days. In all cases, the temperature between days and between periods within the day differed significantly, and the day x period interactions were also significant in the statistical sense (Table 3).

3. Body temperature and behaviour

In our study it appeared that a change in body position from standing to lying and vice versa was directly followed by a change in body temperature: an increase after lying down, a decrease after standing up (Tables 4 and 5, Figures 4 and 5). The mean lying and standing times during the observation period in relation to the magnitude of body temperature change in 7 cows are given in Table 4. In cows observed in the cowshed, temperature increased during lying and it decreased during standing. This phenomenon was most pronounced in lactating cows. In the dry cows, this relation was not found on the pasture (Table 4).

The magnitude of increase (or decrease) of body temperature in relation to the duration of the lying (or standing) episode in the group of lactating cows is presented in Figure 4. The mean duration of a lying episode was 55 minutes and the mean temperature increase was 0.15°C. The corresponding figures for a standing episode were 52 minutes and a temperature decrease of 0.19°C. There were individual cases deviating from the positive or negative relationship (Figure 4). The sign-test confirmed the significance of the increase in temperature during lying ($T = 30.89$, $p \leq 0.01$) and the decrease of temperature during standing ($T = 29.13$, $p \leq 0.01$) (Conover, 1971).

An analysis of variance was done in order to compare the magnitude of body temperature change during lying (or standing) in two parts of the observation period, treating the lactating and dry cows kept in the cowshed separately (Table 5). The daily observation period was divided into two subperiods on the basis of general fluctuation of body temperature during the day (Figure 3). As Figure 3 showed, during 08.00–13.00 hours in lactating cows (08.00–12.00 hours in dry cows) the body temperature decreased and during 13.00–16.00 hours in lactating cows (12.00–16.00 hours in dry cows) it increased.

The objective was to examine the relation between daily fluctuation in body temperature and changes in body position. The magnitude of temperature change per 5 minutes lying (or standing) was used in order to diminish the influence of the length of the lying (standing) period. The analysis of variance proved there was a significant difference between body temperature change during lying and standing for lactating cows ($F = 66.90$, $p \leq 0.01$) and also for dry cows ($F = 15.24$, $p \leq 0.01$) over all the 8 hours of observation. Simultaneously, this relationship was confirmed in a comparison of subperiods ($F = 4.07$, $p \leq 0.01$ in lactating cows, $F = 5.54$, $p \leq 0.01$ in dry cows), but only in lactating cows was there a significant interaction between subperiods and change in body temperature ($F = 4.08$, $p \leq 0.05$).

Figure 5 presents one example of a body temperature curve of an lactating cow during 8 hours of observations. The troughs and peaks of the graph run more or less parallel to changes from lying to standing. The behaviour performed in a particular body position, e.g. rumination during lying or standing, or eating while standing did not appear to have an effect on body temperature.

4. Body temperature before and during calving

In Figures 6 and 7 data about body temperature before and during calving are presented. The general tendency was that on the day of calving and one day before, the temperature was lower than in the preceding days (Figure 6). On the other hand, the temperature 2–3 days before calving was higher than the mean reference temperature of these cows (Table 1) (cow 333 – mean reference temperature 38.76°C, mean body temperature 2–3 days before calving 39.14°C; cow 154 - 38.95°C and 39.38°C; cow 117 - 38.47°C and 38.79°C).

During calving (assuming that this began with symptoms of visible unrest and ended with the expulsion of the placenta) a large fluctuation of temperature was observed (Figure 7). The difference between maximum and minimum body temperature in this period was 1.00°C in cow 333 and 0.65°C in cow 117. A smaller drop in body temperature was seen between the start of unrest and the appearance of the front legs of the calf in the vulva. During the drawing of the calf, the temperature of the mother's body increased. The largest drop in body temperature was observed after the extraction of the calf (both calves were drawn out). The rate of temperature decrease in this period averaged 0.10°C per 5 minutes, but even reached the rate of 0.20°C per 5 minutes. The influence of body position on body temperature during calving was not clear.

Discussion

1. Body temperature in general

In our study, the difference between the mean body temperatures of the 10 cows was no more than 1°C. Comparison of data on individual cows did not reveal any relation between temperature and reproductive status, age and milk production. However, it must be added that the cows were not all observed in the same season, so that various factors may be responsible for the lack of correlation. In most cows, the mean daily body temperature fluctuated strongly, so that there were significant differences between days. These differences between days even existed after the data from the 10 first days after the transmitters had been implanted were removed from the analysis. (During these 10 days the cows might have had fever as a consequence of infection after the surgery.)
At present we cannot fully explain the day-to-day differences. The data were recorded over one year, during which the mean daily ambient temperature ranged between 0° and 20°C. However, the data per individual cow were always collected within a period of two months, which in practice meant that the maximum difference in ambient temperature was 10°C within the recording period. Whether this fluctuation in ambient temperature contributed to the day-to-day variation in body temperature was not clear. The correlations between the body temperature of cows observed during the same period did not reveal an overruling effect of ambient temperature (Table 2, Figure 2). Also here it should be admitted that the data had shortcomings. The study was done over a period of about one year, but there was a lack of data on cows recorded over an extended period, and therefore seasonal effects might have become important.
As the technology of transmitters improves and the techniques of monitoring implanted transmitters are refined, the amount and quality of data collected in such research will improve.

2. Fluctuation in body temperature during the day

As regards variation of body temperature within the day, the results

were very clear, particularly the data from lactating and dry cows in the cowshed. There was a diphasic pattern, with temperature peaks in the morning and evening. This confirmed the earlier work of Wrenn et al. (1961) and Simons et al. (1965).
Various authors have reported in some way about differences in body temperature between different periods of the day. According to Kotby et al. (1978), Curtis (1983), Krzymowski (1975), Nieuwenhuizen et al. (1979) temperature is generally lower in the morning and higher in the afternoon or the evening. It is thought that there is a Circadian rhythm in body temperature, because the cycle has also appeared in an absolute constant ambient temperature (Scott et al. 1983). But the actual cycling is also influenced by the ambient temperature (Kotby et al. 1978, Scott et al. 1983) and corresponds to husbandry activities in the cow's environment during the day, e.g. milking (Nieuwenhuizen et al. 1979). Some authors suggested that there is a shift in body temperature that follows 3-6 hours (Kamada et al. 1984) or 6 hours (Gwazdauskas, 1975) after changes in ambient temperature. In our study, the maximum body temperature was recorded around 17.00 hours in all groups of cows: this agrees with most other studies. Only Nieuwenhuizen et al. (1979) indicated 22.00 hours as the time of maximum body temperature. The lowest temperature in our research appeared in the second half of the night and at noon. Wrenn et al. (1961) mentioned 10.25 hours as the time of lowest body temperature.
The daily differences between maximum and minimum body temperature obtained by different authors were: between 0.20-0.65°C (in our study, in the 3 different groups of cows), 0.5°C (Wrenn et al. 1961), 0.9° C (Seawright et al. 1978) and 0.35°C (Junge-Wentrup and Holtz, 1984). The magnitude of this variation is almost the same as the temperature changes that appear during oestrus. This complicates the use of body temperature as a factor for the detection of oestrus. The problem might be resolved if temperature measurements for oestrus detection were restricted to the time of the day that has a small variation in body temperature (e.g. milking time).
In our study, a remarkable variation in body temperature appeared in the 3 dry cows on the pasture. The same cows observed in the cowshed showed a fairly constant diphasic diurnal pattern in body temperature.

The increased variability on the pasture may be the result of factors such as the absence of fixed feeding times, and the changing weather.

3. Body temperature and behaviour

It was found that in the cows kept in cowshed the body temperature increased during lying and decreased during standing. These changes were in the order of +0.20°C for a period of about one hour of lying and -0.20°C for about one hour of standing.
Curtis (1983) reported on behavioural thermoregulation in animals. This mechanism is particularly important in an environment where the ambient temperature is above or below the thermoneutral zone for the animal. Furthermore certain behaviour can itself have consequences for heat balance. During standing, metabolic conversion is larger (extra 1 Kcal hr^{-1} kg^{-1}) because energy is required to resist gravity (Curtis, 1983). In lying the need for energy is lower. It seems that at the beginning of lying there is a surplus of heat that is gradually returned to the environment. Lasson (1977) and Boxberger (1983) measured heat flow given by lying cow to the stall floor. They found that the flow rate diminished with the time of lying. During lying, heat loss by conductivity is generally higher because a large part of body surface is in contact with floor. The type of floor and its temperature also influence the conductivity (Curtis, 1983). Armstrong and Wiersma (1986) observed that during the hot weather in Arizona, cows remained standing when the ground was dry, but lay down when it was wet. Boxberger (1983) reported that cows lay less frequently on cool surfaces.
In lactating cows, the sum of all temperature changes in lying and standing was greater than in dry cows. This is related to the higher heat production of lactating cows (Lasson 1977, Boxberger 1983, Curtis 1983). No relationship between body position and change in body temperature was found in cows on the pasture. During our observation on the pasture the weather was changeable, with some periods with much rain and wind. The cows lay on the pasture for a relatively short time: 21% of the observation period in comparison with 52% of time in lactating cows and 37.5% in dry cows in the cowshed (Table 4). It is

possible that in this way the cows on the pasture avoided the excessive loss of heat, that would have taken place while lying on the wet grass. Curtis (1983) reported large energy expenditure on pasture and Krzymowski (1975) mentioned large heat losses during rain.
In our study, the influence of eating on body temperature was not clear. In cows kept in the cowshed, the two peaks in daily body temperature coincided with the two main feeding periods. Nevertheless, in individual cows no increase of body temperature was seen when the cow started eating. The same was true for rumination. Other authors (Simons et al. 1965, Kamada et al. 1984, Young et al. 1984) reported an increase of body temperature in cows after eating. Possibly the different locations of temperature measurement inside the body influences the results of the effect of eating. Simons et al. (1965) indicated a large difference of body temperature (in the range of a few degrees Celcius) after eating and drinking, but in their experiment the transmitter was implanted in the reticulum.

4. Body temperature and calving

Body temperature decreased during the last two days before calving, this is consistent with the reports of other authors (Iketaki et al. 1979, Iketaki et al. 1982, Ohsaki 1984, Pharate and Nagpaul, 1984). During the day of calving, body temperature decreased during the outflow of fluids and especially after the drawing of the calf. Monitoring the temperature data of highly pregnant cows seems to offer the possibility of predicting the precise time of parturition and of controlling the whole process of calving.

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Table 1: Survey of data on experimental cows kept indoors.

Cow no.	No. of (L) lactation or gestation (G)	Stage of lactation	No. of recording days	Months/year of recording	Daily body temperature (°C) mean $\bar{x}$	minimum min (x)	maximum max (x)	standard deviation Sx
103	5 L	middle	9	X, XI, 85	38.18	38.07	38.28	0.06
257	2 L	beginning	28	I, II, 86	38.68	38.53	39.04	0.14
104	6 L	middle	30	I, II, 86	38.34	38.21	38.49	0.08
88	6 L	middle	36	I, II, 86	38.33	37.94	38.62	0.20
234	3 L	beginning	27	I, II, 86	38.74	38.27	39.14	0.23
235	3 L	beginning	28	IV, V, 86	38.96	38.59	39.57	0.23
346	1 L	beginning	28	IV, V, 86	38.71	38.35	39.20	0.24
333	2 G	dry	24* +	VIII, IX, X 86	38.76	38.49	39.07	0.18
154	3 G	dry	29* +	VIII, IX, X 86	38.95	38.70	39.27	0.15
117	6 G	dry	21* +	VIII, IX, X 86	38.47	38.27	38.59	0.07

* In addition there were 7 recording days on pasture

\+ Excludes 5 days before calving

Table 2: Correlation coefficients between daily body temperature of cows recorded during the same series of days (compare Figure 2)

Cows	Period	r	p
103/104	9 days	+ 0.11	> 0.10
104/88		+ 0.09	> 0.10
103/88		+ 0.19	> 0.10
104/88	8 days	+ 0.65	0.08
257/234	19 days	− 0.46	0.05
235/346	24 days	− 0.74	< 0.01
333/154	18 days	+ 0.87	< 0.01
154/117		+ 0.69	< 0.01
333/117		+ 0.63	< 0.01

Table 3: Differences in the body temperature between days and periods within the day.

Source of variation		Cow 88		Cow 103		Cow 104	
	df	F	P	F	P	F	P
Day	8	2.82	0.008	15.98	< 0.001	21.56	< 0.001
Period of day	3	5.11	0.002	21.97	< 0.001	21.56	< 0.001
Interaction	24	5.12	< 0.001	9.23	< 0.001	7.71	< 0.001
Residual	108						

Table 4: Mean total lying and standing time of the cows during the observation period (08.00–16.00 hours) and the total change of body temperature during these lying and standing positions.

Groups of cows	No. of observations	Time spent in lying/standing position and change of body temperature			
		lying		standing	
		min.	°C	min.	°C
4 lactating cows in cowshed	11	250	+ 0.70	230	- 0.84
3 dry cows in cowshed	11	180	+ 0.47	300	- 0.33
same dry cows on pasture	15	100	+ 0.01	380	+ 0.36

Table 5: Change of body temperature per 5 min. lying and standing time (taking into account entire observation period and two subperiods) in cows kept indoors.

Group of cows	No. of periods observed	Periods and subperiods	Mean temperature change per 5 min.			
			during lying		during standing	
			n	°C	n	°C
Lactating cows	11	08.00-16.00 h.	59	+ 0.020	62	- 0.019
		within:				
		08.00-13.00 h.	35	+ 0.020	34	- 0.028
		13.00-16.00 h.	24	+ 0.020	28	- 0.009
Dry cows	11	08.00-16.00 h.	36	+ 0.013	45	- 0.002
		within:				
		08.00-12.00 h.	12	+ 0.006	18	- 0.006
		12.00-16.00 h.	24	+ 0.017	27	0.000

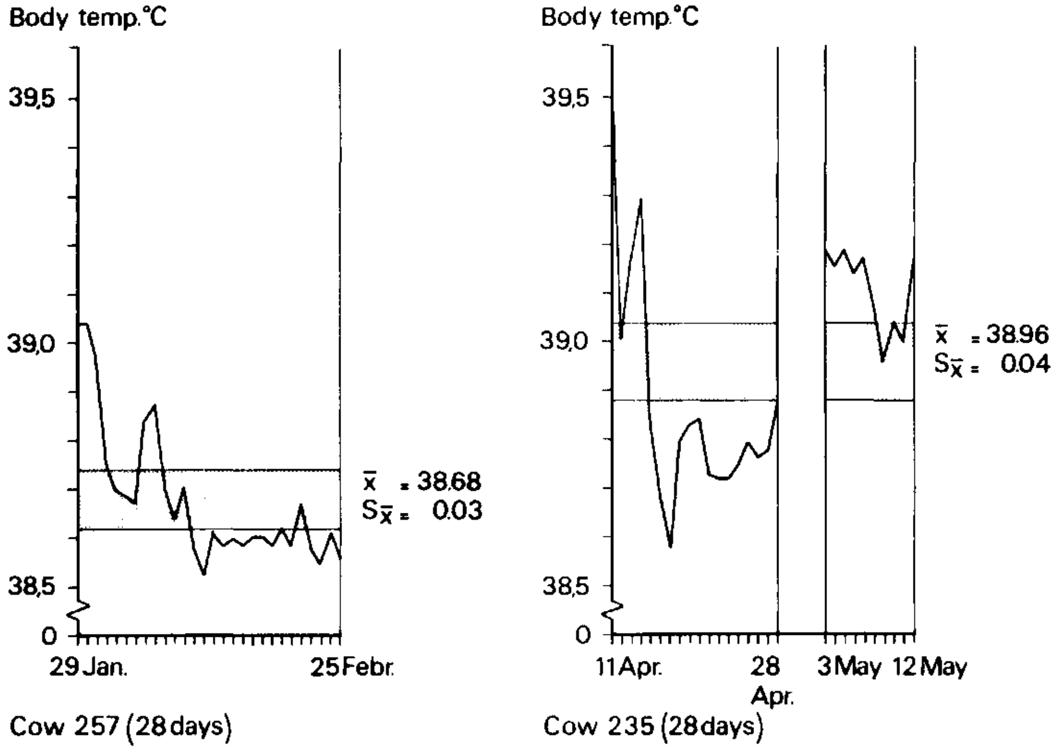


Fig. 1 Course of body temperature during the recording days for two cows (implantation of transmitter on 27 Jan. in cow 257 and on 8 Apr. in cow 235), and the 95 % confidence area of the mean temperature (marked).

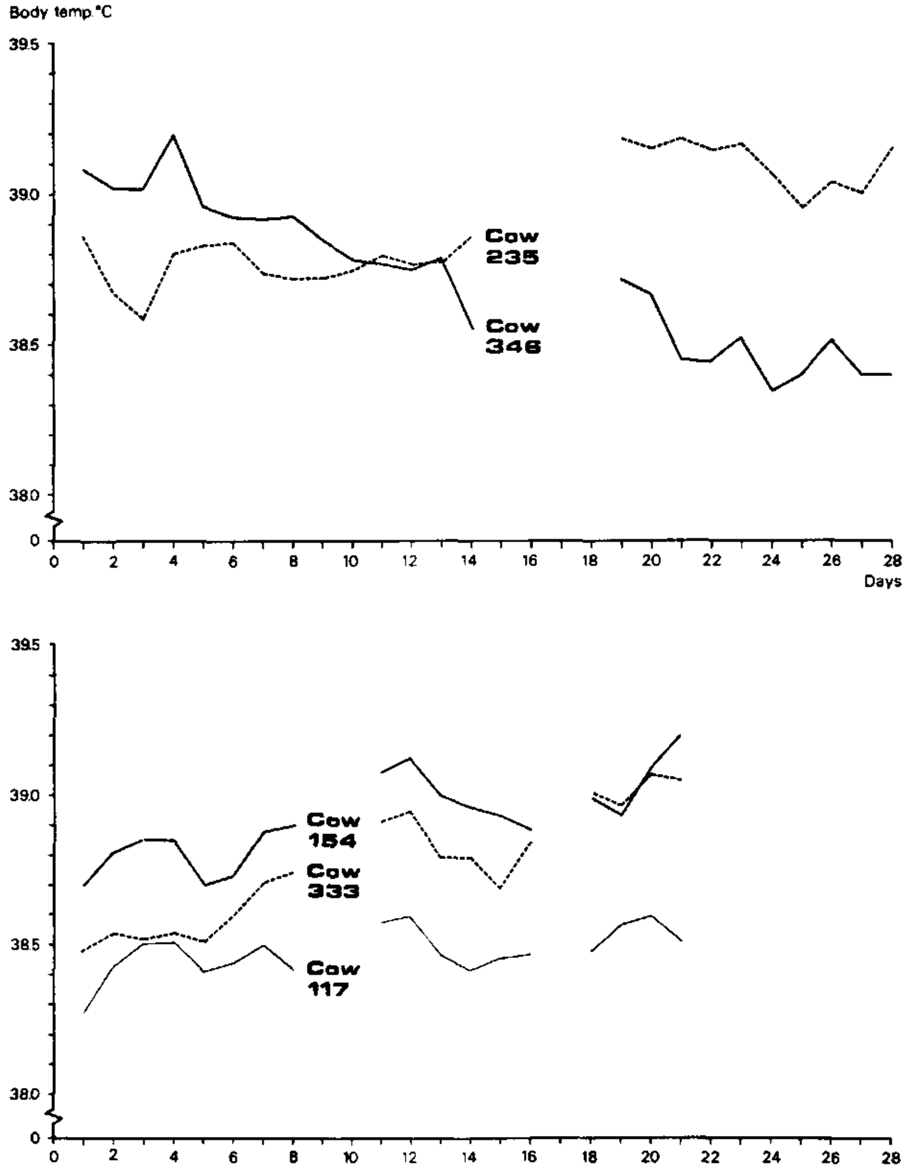


Fig. 2 Course of mean daily body temperature of 2 lactating cows (above) and 3 dry cows (below) recorded together (Compare Table 2)

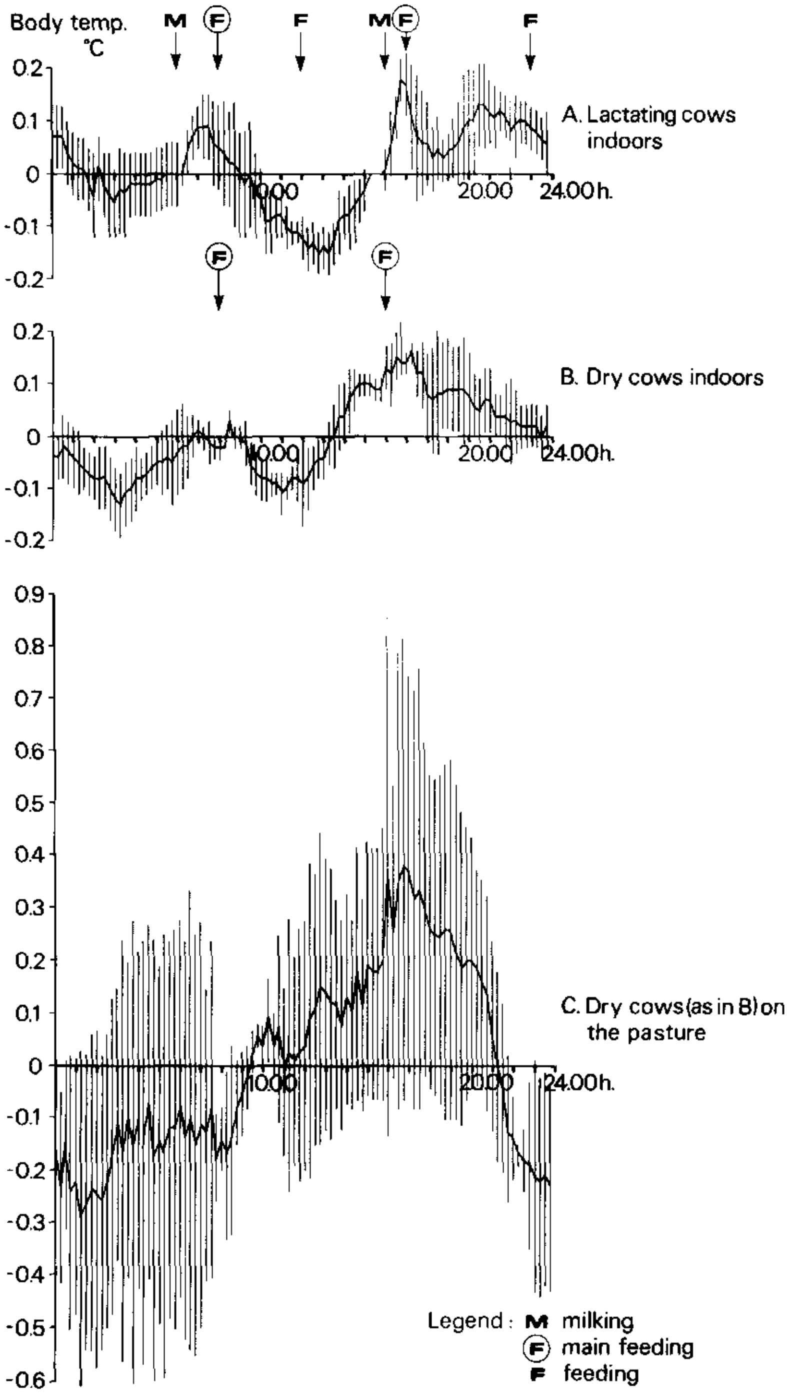
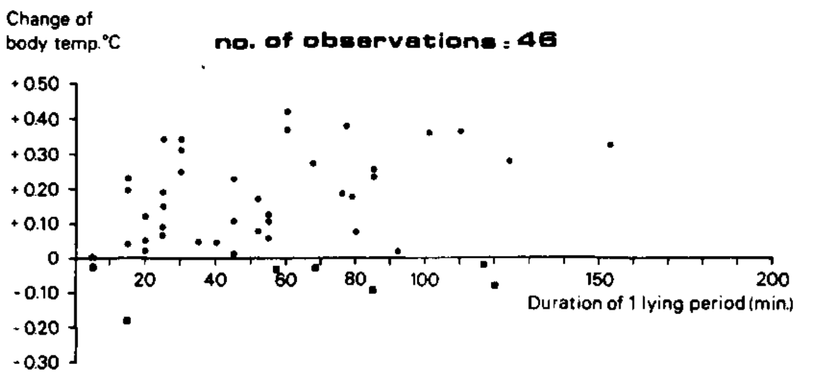


Fig. 3 Fluctuation of mean body temperature of cows during the day (together with the marked 95 % confidence interval area) for the lactating cows (A), the dry cows (B) and the dry cows on the pasture (C). "0" is the relative base level (i.e. mean cow temperature)



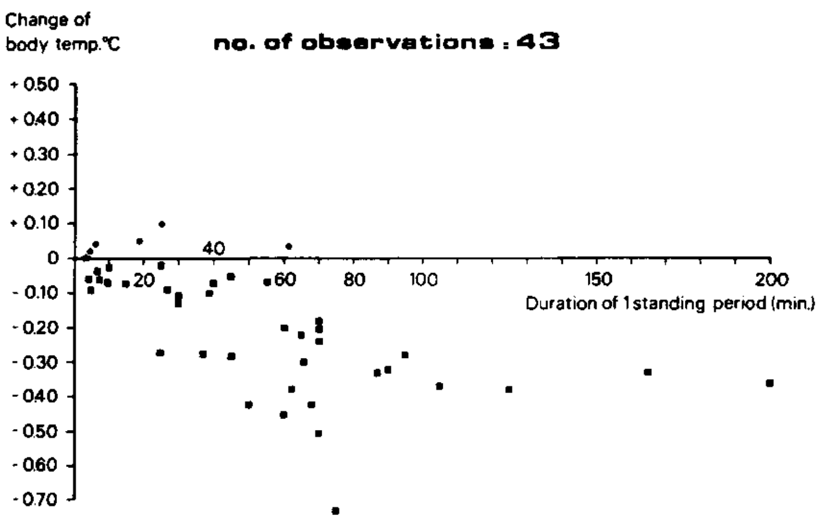


Fig. 4 Duration of lying and standing periods in relation to change of body temperature during these periods in 4 lactating cows

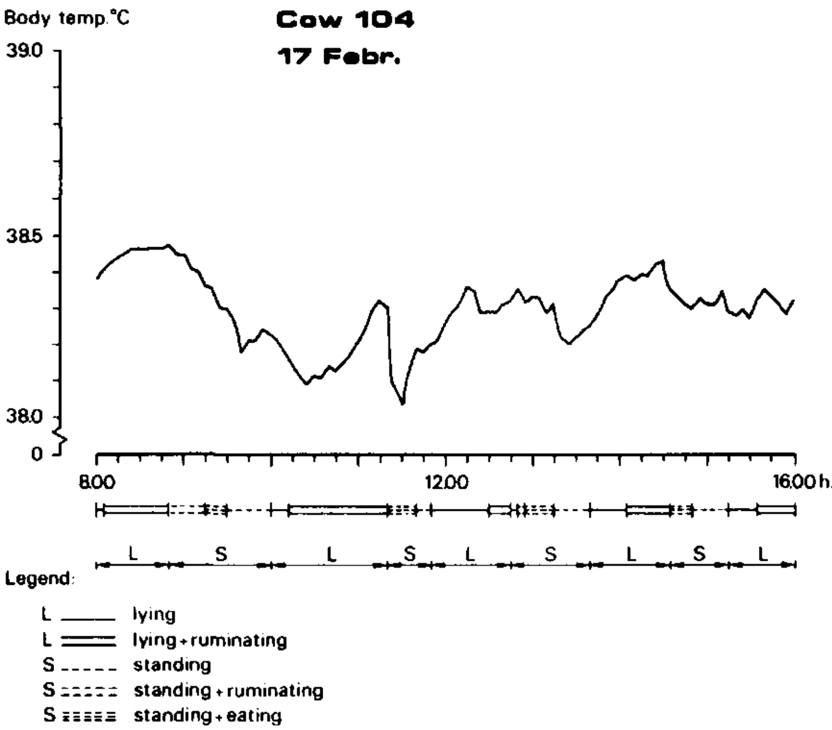


Fig. 5 Body temperature of one cow in relation to her behaviour

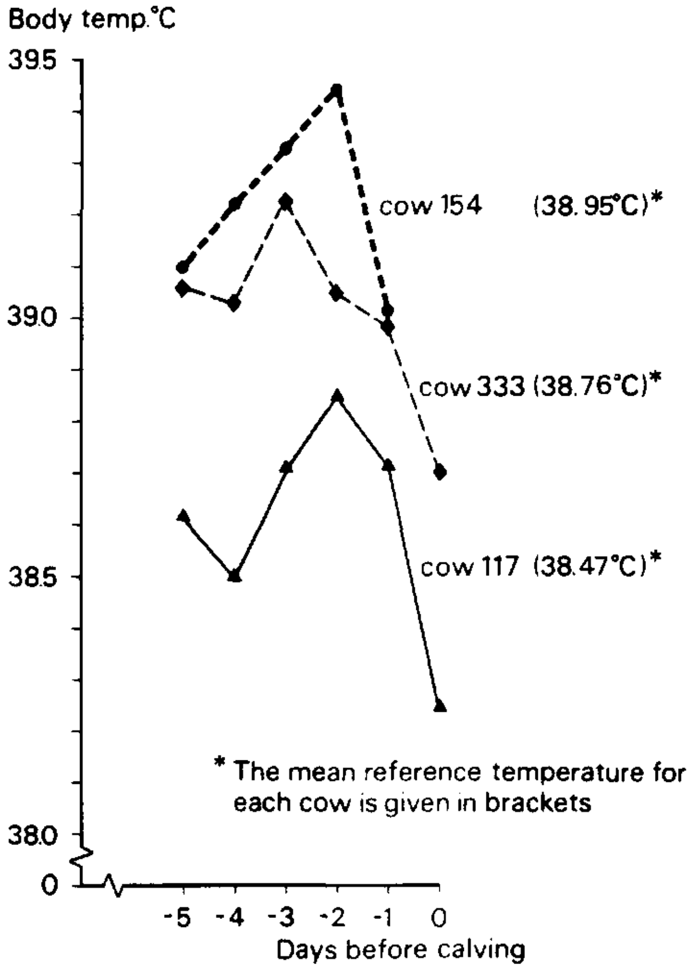


Fig. 6 Mean daily body temperature in the last days before calving

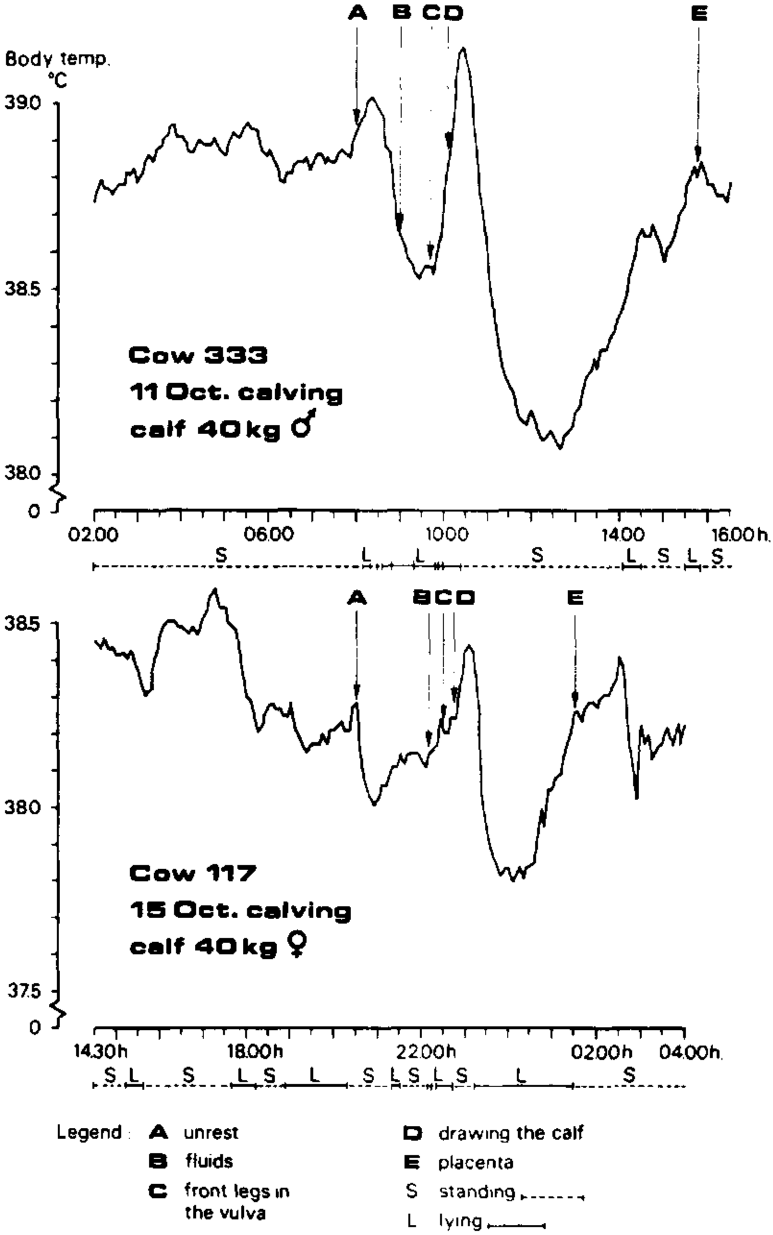


Fig.7 Body temperature data (beginning 6 hours before visible unrest symptoms) and delivery stages and body position