# FETAL ELECTROCARDIOGRAM IN DAIRY CATTLE
## V FINDINGS AT PARTURITION*1

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In the field of obstetrics in large domestic animals, there has been little information on various physiological conditions of the fetus during parturition; although maternal clinical symptoms during parturition are described in detail in many text books. Undoubtedly, knowledge of fetal physiology at parturition, particularly on fetal heart condition, is very important and necessary in obstetrics for resolving parturition mechanism and saving the fetus from death during parturition, as has been already proven in the case of human fetuses[2,4].

The main purpose of this work is to obtain electrocardiographical information concerning fetal and maternal heart activities during and immediately after parturition in dairy cattle.

## MATERIALS AND METHODS

Six pregnant cows at full term, 4 Holsteins and 2 Guernseys, were the subjects in this experiment. Clinical data on the cows including age, number of partus, gestation period, etc. are listed in table 1. Parturition in 4 cases was almost normal, but in the remaining two cases labor pains were rather weak and the time for expulsion of the fetus was prolonged. In all cases the presentation of the fetus was normal, showing the anterior longitudinal presentation and dorso-sacral position. The newborn calves, five females and one male, were entirely normal and healthy.

Recording of fetal electrocardiogram (F-ECG) started 2~3 days before the expected date of parturition, and the recordings were made several times at different intervals until the appearance of symptoms of parturition. When the symptoms appeared, F-ECG were recorded

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TABLE 1 *Clinical data of materials*

| CASE NO. | COW NO. | BREED | AGE | NO. OF PARTUS | GESTATION PERIOD | TIME OF EXPULSION* | LABOR PAINS | SEX OF CALF |
|---|---|---|---|---|---|---|---|---|
| | | | yr | | days | min | | |
| 1 | H-610 | Holstein | 9 | 5 | 276 | 17 | Normal | ♀ |
| 2 | M- 12 | Guernsey | 8 | 1 | 289 | 21 | " | " |
| 3 | G-296 | " | 6 | 2 | 297 | 28 | " | ♂ |
| 4 | H-627 | Holstein | 6 | 3 | 282 | 60 | " | ♀ |
| 5 | H-654 | " | 3 | 0 | 289 | 115 | Weak | " |
| 6 | H-630 | " | 6 | 3 | 282 | 230 | " | " |

Note: * Time of expulsion was calculated from recognition of the initial rupture of "water bag" to expulsion of the fetus through the vulva.

continuously from 1~2 hours prior to the rupture of the "water bag" (fig. 8) to 10~50 minutes after the fetus was expelled.

Techniques and equipment used in this experiment were the same as those described previously[8]; a bipolar lead between the right flank and the right lower abdomen (1-3 lead) usually applied, but supplementarily several other leads were sometimes used. In order to record ECG of newborn calves, the routine bipolar lead was employed, but in this instance the electrode positions varied with the cases, because it was difficult to make the positions uniform for actively moving newborns.

Heart rates in fetuses and dams during and immediately after parturition were calculated by the number of QRS spikes as a time-series average heart rate. Heart tones in dams and newborns were also auscultated in order to make it easy to distinguish fetal heart rates (F-HR) from maternal ones (M-HR).

## RESULTS

### 1 Changes of fetal heart rate (F-HR)

#### 1) Normal parturition group

Four cases (Nos. 1~4) belonged to this group.

In case No. 1 (H-610), 1~10 hours before rupture of the bag, the F-HR was 92~106. Immediately after rupture of the bag, F-HR elevated to 114 then decreased to 78~86 for 11~13 minutes after rupture. During the last five minutes of expulsion stage, the recording of F-ECG was disturbed by maternal electromyogram.

In case No. 2 (M-12), at 96 and 57 hours prior to rupture of the bag, F-HR was 114 and 108 respectively. For 30 minutes, immediately before rupture, it was 102~120. For 7 minutes after rupture, F-HR was counted at 108~120 and then it decreased slightly to 90~180 for the following 8~16 minutes. For the last 5 minutes, no clear F-ECG was obtained.

In case No. 3 (G-296), at 52 hours before rupture, F-HR was 120. During 1~17 hours before rupture, F-HR decreased to 78~106. At 9 minutes prior to rupture, it was 90. At 3, 5, and 11 minutes after rupture, it showed 78, 96 and 72, respectively. F-HR then increased to 108 at 20 minutes after rupture of the bag, and 90 at 24 minutes. The changes of the

heart rates of the fetus and the dam in this case are in plate II.

In case No. 4 (H-627), 47 hours before rupture, F-HR was 114, and then it decreased to 108 within 2 hours before rupture. At 60 minutes before rupture, F-HR showed 114~120, but at 40 minutes it decreased to 84. For 25 minutes prior to rupture it returned to 114~120 and immediately before rupture it decreased to 102. At 15, 20 and 30 minutes after rupture, F-HR was 120, 96 and 120, respectively. At 35 minutes after rupture, it became 78, being minimized throughout the whole course of parturition, and then it gradually increased to 114 until the expulsion of the fetus.

Before rupture of the water bag, the F-HR generally maintained a level of 100 beats per minute or showed a little decreasing tendency, but after rupture, at approximately the middle of the stage of expulsion, a marked fall of F-HR was characteristic in all cases.

2) Group with weak labor pains

Two cases (Nos. 5 & 6) belonged to this group. The stage of expulsion in this group was prolonged.

In No. 5 (H-654), 61~62 hours before rupture, F-HR was 102~108. At 15 and 5 minutes before rupture it showed 104 and 96 respectively. Immediately before rupture, it was counted as 108. For 44 minutes after rupture, F-ECG could not be recorded clearly. At 45~57 minutes after rupture it was 104~108, but then it decreased to 85. The final F-HR, in the stage of expulsion, at 105 minutes after rupture, was 120.

In case No. 6 (H-630), at 7, 38 and 57 hours before rupture, F-HR showed 96, 108 and 128 respectively. For 2 hours prior to rupture, it maintained a rate of approximately 108. Immediately after rupture, F-HR was 96. For 40 minutes after rupture it was 96~108. Then, F-HR showed an alternate increase and decrease within a range from 120 to 206 during the subsequent 150 minutes.

Thus, these 2 cases showed a similar tendency in F-HR change as that of normal parturition cases before rupture, but after rupture, one of them showed a gradual increase in F-HR until the middle of the stage of expulsion then alternate increase and decrease in rate occurred until expulsion of the fetus.

## 2 Heart rate of newborn (NB-HR)

The heart rate of newborn calves was calculated by means of newborn electrocardiogram and by direct auscultation within 1~11 minutes after expulsion. A comparison was made

TABLE 2 *Final fetal heart rate (F-HR) and newborn's heart rate (NB-HR)*

| CASE NO. | FINAL F-HR | INITIAL NB-HR | TIME AFTER EXPULSION | RANGE OF NB-HR | RECORDING LENGTH |
|---|---|---|---|---|---|
| | | | min | | min |
| 1 | 90 | 136 | 1 | 108~144 | 10 |
| 2 | 96 | 132 | 4 | 120~138 | 40 |
| 3 | 90 | 144 | 11 | 120~196 | 45 |
| 4 | 114 | 90 | 1 | 114~174 | 17 |
| 5 | 120 | 66 | 5 | 108~120 | 13 |
| 6 | 210 | 180 | 1 | 162~198 | 45 |

between the NB-HR and the final F-HR. This data is listed in table 2. In 3 cases with normal labor pains, the NB-HR showed a higher level than the final F-HR. While, in the remaining case of the normal parturition group and 2 cases of the other group, the NB-HR was rather lower than the level of the final F-HR. In case No. 5 the NB-HR maintained a marked lower level than other cases for 13 minutes. In case No. 4 the NB-HR elevated within a short time. In case No. 6, however, the NB-HR maintained a higher level but did not exceed the level of the final F-HR for 45 minutes after expulsion.

In conclusion, when the final F-HR remained at rather lower levels, the initial NB-HR showed a rapid elevation within a short time after delivery, while when the final F-HR was high, the initial NB-HR generally decreased immediately after delivery. However, after 10 minutes or so, there was a tendency to maintain a high level of NB-HR in all cases.

## 3 Maternal heart rate (M-HR)

Respective values of M-HR before rupture of the bag, immediately after rupture, at term and after expulsion are shown in table 3. Variation of M-HR throughout the above course was more slight than that of F-HR. It tended to increase from the middle phase to termination of expulsion and also after expulsion. During rupture, in 2 cases, M-HR was higher than before rupture, and in 1 case it was a little lower. In the remaining 3 cases M-HR was almost the same as before rupture. Therefore, rupture of the bag did not seem to give any significant effect on maternal heart rhythm.

TABLE 3 *Changes of maternal heart rate*

| CASE NO. | BEFORE RUPTURE*1 | IMMEDIATELY AFTER RUPTURE*2 | TERMINATION OF EXPULSION*2 | AFTER EXPULSION |
|---|---|---|---|---|
| 1 | 98~108 | 90~95 | 98~102 | 104~110 |
| 2 | 72~ 98 | 84~90 | 98~102 | 78~100 |
| 3 | 78~ 84 | 90~94 | 108~114 | 108~132 |
| 4 | 84~ 86 | 90~94 | 90~102 | 102*3 |
| 5 | 84~ 90 | 78~96 | 96~120 | — |
| 6 | 78~102 | 90~96 | 96~114 | 136*3 |

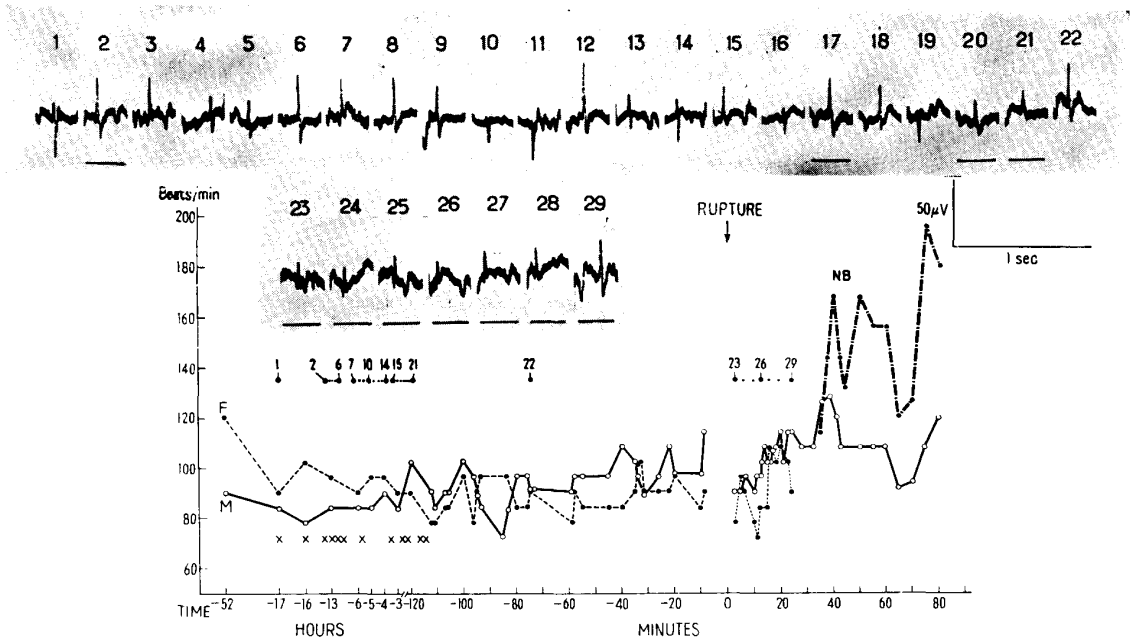
Notes: *1 Range before rupture
*2 Range within approximately 3 minutes after rupture or expulsion
*3 Values in short time recordings
— No maternal electrocardiogram could be recorded.

## 4 Change in fetal QRS (F-QRS) pattern

F-QRS pattern was recorded by lead 1–3 throughout the entire course of this experiment.

In 4 cases (Nos. 1, 2, 5, & 6), no change in polarity of the initial deflection of F-QRS (Rs type) was recorded, but in QRS amplitude, a slight variation was noted. In the remaining 2 cases (Nos. 3 & 4), 2 types of F-QRS patterns, Rs and rSr′, were recorded, a reversal change of F-QRS, Rs⇄rSr′, frequently occurred before rupture of the bag without relation to maternal position. After rupture, F-QRS pattern always showed Rs type, although the

FIGURE 1 *Changes in fetal QRS pattern (case No. 3)*




Notes Each number in the above electrocardiogram (1~29) corresponds to that of the below figure, meaning each recording period.
Nos. 1~22 are before rupture and Nos. 23~29 are after rupture.
Underlined fetal QRS indicates that of recording at lying position of the dam and QRS without underline at standing position.
All fetal electrocardiogram were recorded by lead 1-3.

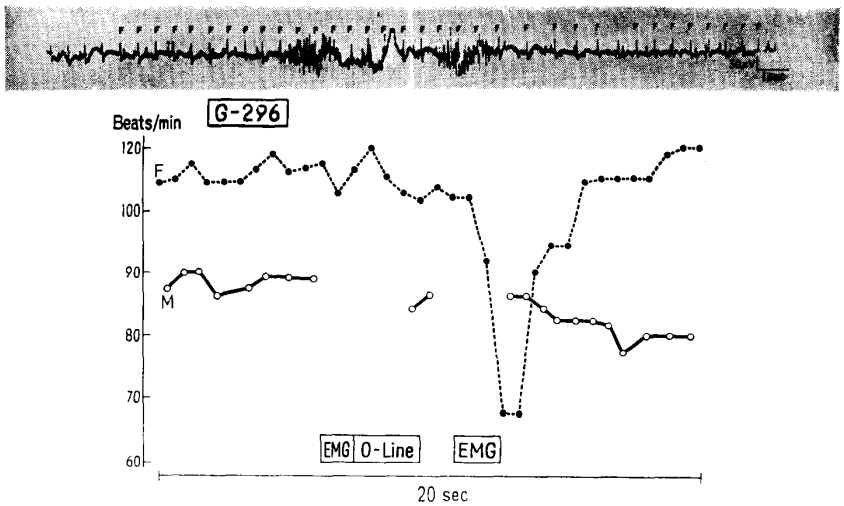
F (dotted line): Fetal heart rate
M (full line): Maternal heart rate
X : Fetal arrhythmia
NB (wave line): Heart rate of newborn calf

amplitude varied. An example of F-QRS changes throughout the whole course examined is shown in figure 1.

## 5 Fetal arrhythmia

During the recording of F-QRS, fetal arrhythmia was frequently observed before and/or after rupture of the bag; in 4 cases, arrhythmia occurred both before and after rupture. Such fetal arrhythmia was characterized by sinus bradycardia together with irregular R-R (Q-Q) intervals, recurring several times within several seconds and being reversible without changing QRS pattern. Fetal arrhythmia was generally observed immediately after maternal electromyogram as shown in figure 2, or several seconds prior to electromyogram as shown in figure 3. Furthermore, in cases in which fetal arrhythmia occurred after rupture, it seemed to be related to labor pains as shown in figure 4. Exact relations between fetal arrhythmia and postnatal condition of the newborn, however, could not be clarified in this experiment. More detailed analysis of fetal arrhythmia in the course of parturition will be necessary in the future.

FIGURE 2 *Fetal arrhythmia observed before rupture (case No. 3)*




Notes Fetal electrocardiogram (F: fetal spikes) and number of heart rate culculated from it
EMG: Electromyogram of dam
0-line: 0-line movement

FIGURE 3 *Fetal arrhythmia observed after rupture (case No. 3)*

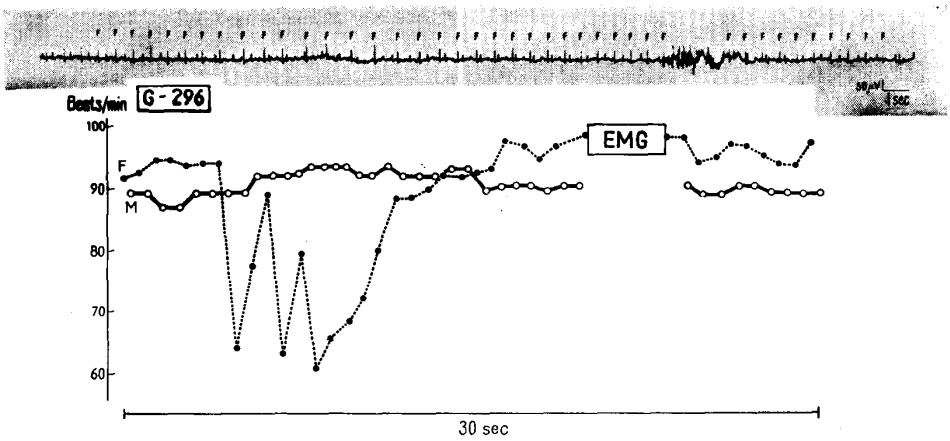
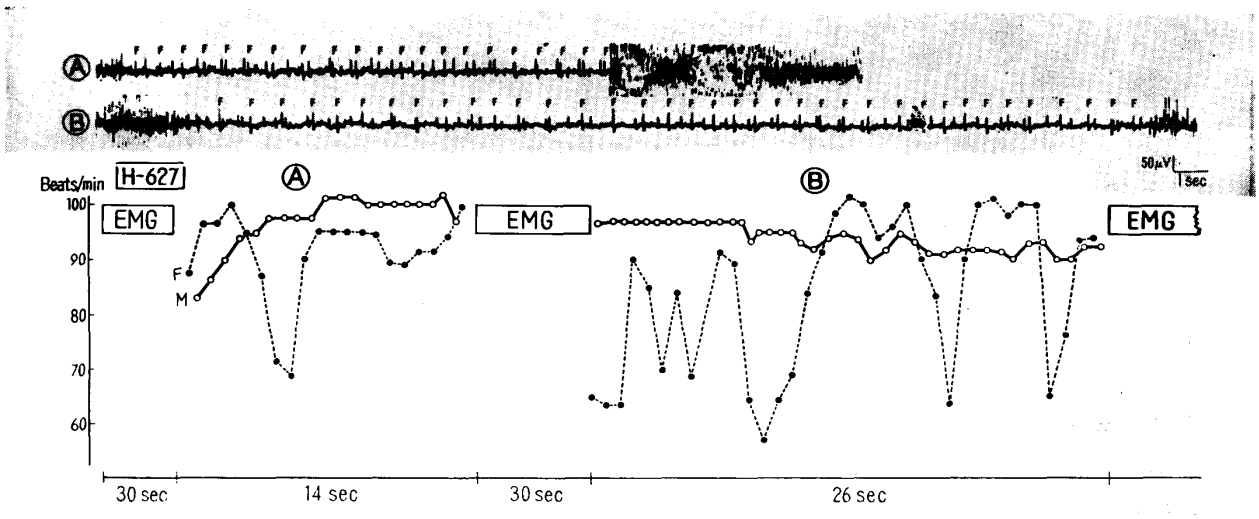


FIGURE 4 *Fetal arrhythmia observed after rupture (case No. 4)*




## DISCUSSION

On the basis of recent investigations about fetal physiology in man[2,4] and experimental animals[5,7], changes of the fetal heart rhythm during parturition can be classified into 2 types. One includes bradycardia of "late onset"[2], bradycardia between uterine contraction[6], "type II dip"[4] and bradycardia paradoxa[1]. These are fundamentally the same phenomenon and can be explained as a sign of abnormal hypoxic fetal distress. The other is called rapid dynamic deceleration[1], "type I dip"[4], or bradycardia of "early onset"[2]. This type of change in the fetal heart rhythm is considered to be physiologically normal and may be due to a compensatory or adaptive mechanism against compression of the umbilical cord or of the fetal head.

In this experiment, using cattle fetuses, fall of F-HR was mainly seen during the middle period of the stage of expulsion after rupture. The slowing of F-HR is not the same category as that of human fetuses, because the F-HR in cattle fetuses was obtained as a time-series average heart rate and thereby it probably means an averaged F-HR which includes all kinds of temporary fetal arrhythmia as described above. Therefore, a comparison between changes in the heart rate of human fetuses and those of cattle fetuses could not be made. However, the fall of the F-HR during the middle period of the stage of expulsion probably means that an elevation of intra uterine pressure caused by uterine contraction before rupture does not cause any important effect on the fetal heart rhythm, but uterine contraction after rupture produces a slowing of the fetal heart rhythm. The condition of the umbilical cord and fetal presentation in the birth canal when slowing of F-HR occurred could not be clearly confirmed in this study. Further-

more, in cases with weak labor pains, an increasing tendency of F-HR was noticed instead of a falling of F-HR. This also means that weak pressure on the fetus does not make the F-HR slow. Therefore, the following factors may be suggested as causes: fetal hypoxia caused by disturbances in maternal-fetal circulation, compression of the fetal head in the birth canal, vagal effect to the fetal heart, and a fall of the $PO_2$ value in the central nervous system of the fetus. These factors may be interrelated and may act on the fetus simultaneously or independently under certain maternal and fetal conditions during delivery. In order to confirm the physiological significance of these factors ond changes of the heart rhythm of bovine fetuses, further experimentation will be needed.

In the course of this study, fetal arrhythmia with temporary slowing of F-HR was recorded. This type of slowing should not be considered an abnormal feature, because these fetuses were born alive, the newborn calves were entirely normal and healthy, and such arrhythmia disappeared immediately after delivery. However, a marked descent of the F-HR and prolongation of fetal undoubtedly be dangerous to fetal life, particularly in cases where these phenomena bradycardia may are associated with severe dystocia, since such disorders would diminish the cardiac output, thus reducing the blood supply to the fetal tissues.

A reversal change of F-QRS pattern, Rs⇄rSr', was frequently recorded before rupture in a limited number of cases. A similar change of F-QRS, Qr⇄Rs, was observed in a fetus at 180 days of pregnancy, and the possible cause in this case was discussed in the previous paper[9]. In the former case, however, the mechanism seems to be somewhat different from the present cases. The Rs⇄rSr′ change may be due to some change in fetal presentation which may be caused principally labor pains before rupture of the bag. It is assumed that when the forelegs of the fetus pass through the cervical canal, the head portion enters tightly into the cervical canal and rupture of the bag has already occurred, no reversal change is observed and the QRS pattern always shows only the Rs type. In order to make this assumption decisive, however, much more information concerning changes of fetal presentation during parturition will be required.

In human subjects, the level of the heart rate of the newborn is comparatively low at birth but it elevates until the 4th day post-partum[4]. In cattle, on the other hand, there hitherto was no information concerning the heart rate of the newborn, although it was reported that the heart rate of calves of 2～60 days post-partum ranged 110～134. In this experiment,, it became certain that the heart rate of newborn calves is more rapidly accelerated after delivery than that of human newborns.

The reasons for such acceleration of the heart rate of newborns both in man and cattle may be due to the sudden commencement of pulmonary circulation,

a sudden release from predominant vagus control during fetal life, respiratory effect, gases in blood, exercise of newborns and abrupt enviromental change, etc.[3)]

Slight elevations of M-HR were recorded during parturition; rupture of the water bag and labor pains have little effect in elevating the M-HR. This gives a good contrast in comparison to the changes of the maternal heart rhythm during parturition in a mare, in which a clear A-V block was recorded[10)].

## SUMMARY

This experiment was attempted to obtain electrocardiographical information about fetal and maternal heart activities during and after parturition in dairy cattle. Six pregnant cows were submitted to this experiment. The results are summarized as follows:

1) In 4 cases of normal parturition, the change in fetal heart rate was not so great before rupture of the bag, but after rupture a marked fall of fetal heart rate was characteristic in all cases at approximately the middle of the stage of expulsion. While, one of 2 cases with prolongation of the expulsion stage due to weak labor pains, showed a gradual increasing tendency of the heart rate until the middle of the stage of expulsion, and showed an alternate increase and decrease until termination of expulsion.

2) In the majority of cases, the heart rate of newborns was rapidly accelerated after expulsion and maintained a higher level for 10～50 minutes post-partum. No irregular QRS of the newborn was observed.

3) A reversal change of the fetal QRS, Rs⇄rSr′, was observed before rupture of the bag in 2 cases. After rupture, however, the pattern always showed Rs type only.

4) Fetal arrhythmia such as sinus bradycardia was recorded within several seconds before and/or after rupture. Fetal arrhythmia was generally observed immediately after or prior to maternal electromyograms, thus it seemed to be related to attacks of labor.

5) Variation of the maternal heart rate was smaller than that of fetal one throughout the whole course of parturition. Slight elevation of the maternal heart rate was recorded at the terminal stage of parturition.

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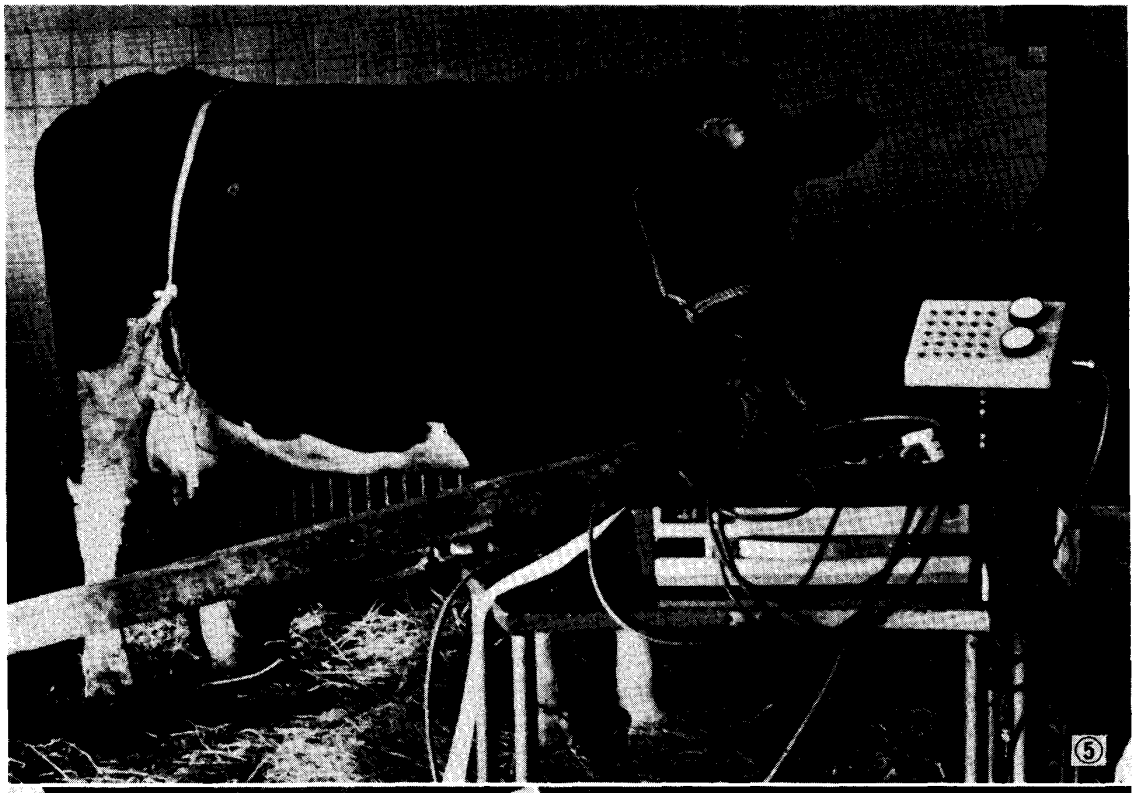
## EXPLANATION OF PLATES

### PLATE I

Fig. 5 General appearance of fetal electrocardiogram recording before delivery of a cow

Fig. 6 An example of skin electrode application during parturition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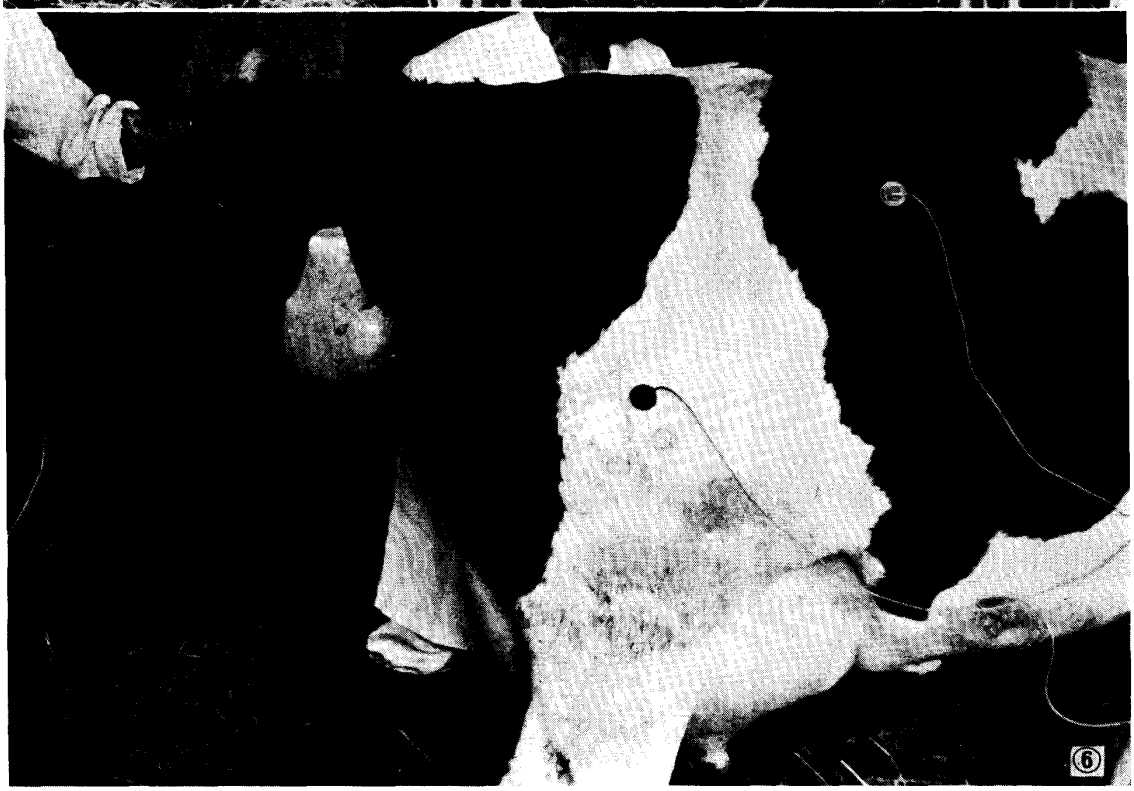
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PLATE II

Fetal, maternal and newborn's electrocardiograms at parturition (case No. 3)

1–3 and 1–13 indicate lead methods employed.

F : Fetal QRS

M : Maternal QRS

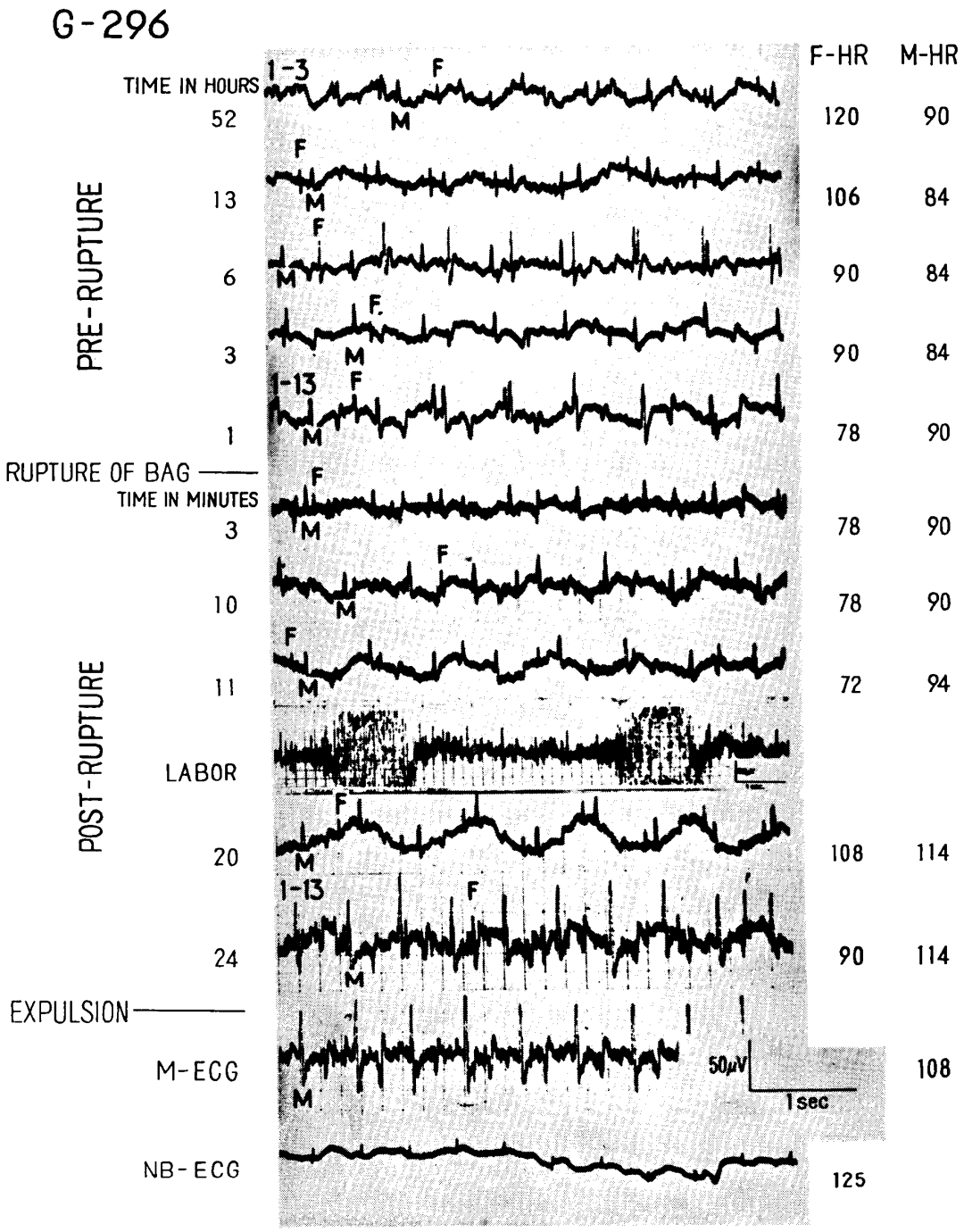
Labor : Labor pains

Expulsion : Expulsion of fetus

Rupture of bag : The first rupture of bag

M-ECG : Maternal electrocardiogram

NB-ECG : Electrocardiogram of newborn calf


G-296
TIME IN HOURS
F-HR
M-HR
PRE-RUPTURE
52
120
90
13
106
84
6
90
84
3
90
84
1
78
90
RUPTURE OF BAG
TIME IN MINUTES
3
78
90
10
78
90
POST-RUPTURE
11
72
94
LABOR
20
108
114
24
90
114
EXPULSION
M-ECG
108
50μV
1 sec
NB-ECG
125

## PLATE III

Fetal, maternal and newborn's electrocardiograms at parturition (case No. 6)

1–3 indicates lead method.

F : Fetal QRS

M : Maternal QRS

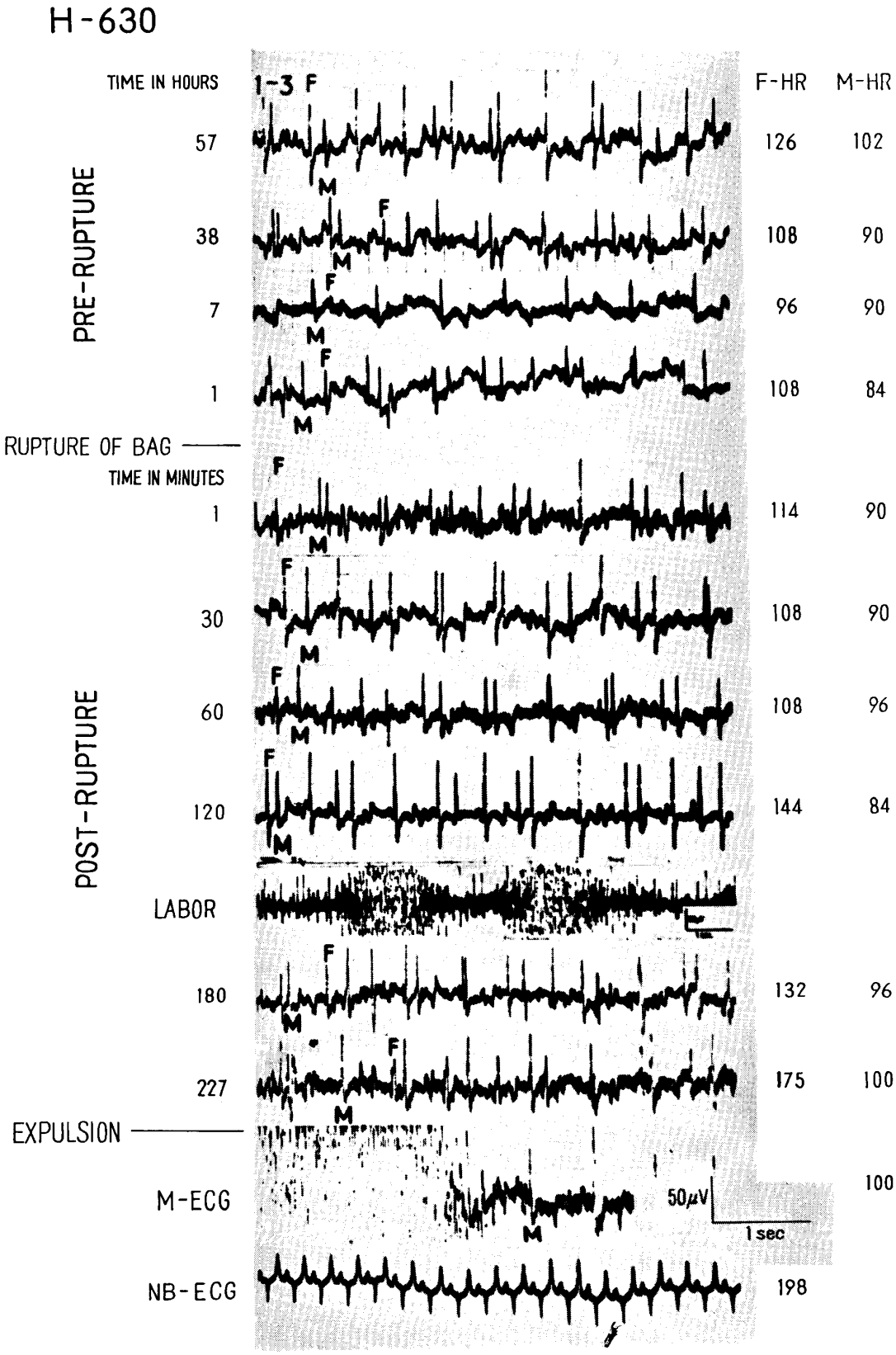
Rupture of bag : The first rupture of bag

Labor : Labor pains

Expulsion : Expulsion of fetus

M-ECG : Maternal electrocardiogram

NB-ECG : Electrocardiogram of newborn calf


H-630
TIME IN HOURS
1-3 F
F-HR
M-HR
PRE-RUPTURE
57
126
102
38
108
90
7
96
90
1
108
84
RUPTURE OF BAG
TIME IN MINUTES
POST-RUPTURE
1
114
90
30
108
90
60
108
96
120
144
84
LABOR
180
132
96
227
175
100
EXPULSION
M-ECG
50μV
1 sec
100
NB-ECG
198