Respiration Trial System Using Ventilated Flow-through Method with a Face Mask

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Received October 9, 2000

Abstract

A respiration trial system using a ventilated flow-through method with a face mask was developed at Khon Kaen Animal Nutrition Research Center, Khon Kaen, Thailand in order to study energy metabolism in cattle. It is composed of four components: 1) main air flow component, 2) air sampling component, 3) gas analysis component and 4) data record and calculation component. The programs for data logger and calculation were written in Q-basic for IBM AT/PC-compatible computers. The recovery rate of the whole system was examined by using nitrogen and carbon dioxide gases. The overall average of the recovery rate was 93.3% with small standard deviations, *i.e.* 0.8-1.7% depending on the methods of examination of the rate. As the system is less costly for establishment than that with a hood or a chamber, it could be suitable for conducting studies on energy metabolism of ruminants in developing countries

Key words: cattle, energy metabolism, respiration experimental system

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Introduction

Metabolism trial of energy and protein is an important method to study animal nutrition and nutritive values of feed. In an energy metabolism trial, it is necessary not only to analyze the energy content of the feed, feces and urine, but also to measure respiratory gases, which requires a specific system. The lack of such a system has been one of the constraints on the development of feeding strategies compatible with the availability of local resources and the environments in the tropics.

A face mask technique[2,6] has been used as a readily operational alternative to the respiration chamber[5] for the measurement of energy expenditure in animals. However, the mask for the total collection system has to be tightly sealed around the face of an animal, which may be a cause of stress for the animal, and the Douglas-bag cannot be easily handled. Respiration trial system using a ventilated flow-through method with a face mask, was developed at Khon Kaen Animal Nutrition Research Center, Khon Kaen, Thailand, under the collaborative research project between the Department of Livestock Development (DLD), Thailand, and Japan International Research Center for Agricultural Sciences (JIRCAS) in order to conduct metabolism trials for the nutritional characterization of large ruminant animals, such as cattle and water buffalo, as well as the evaluation of locally available feed resources. This report aimed at describing the structure of the system and at providing the background information on the system. Continuous measurement of respiratory gasses cannot be performed by the mask method. Thus, diurnal changes of carbon dioxide and methane production, and oxygen consumption were examined by the ventilated flow-through method with a hood for setting up an appropriate time schedule of respiration trial using the mask method. The recovery rate of the system was also examined in order to confirm the accuracy and reproducibility of the method.

Materials and Methods

1 Structure of respiration trial system

The structure of the system is depicted in Figs. 1 and 2. The system consists of the following four major components: 1) main air flow component, 2) air sampling component, 3) gas analysis component, and 4) data record and calculation component. The details of each component are listed in Appendix 1.

The programs for data logger and calculation were written in Q-basic for IBM AT/PC-compatible computer. The program is shown in Appendix 2. The

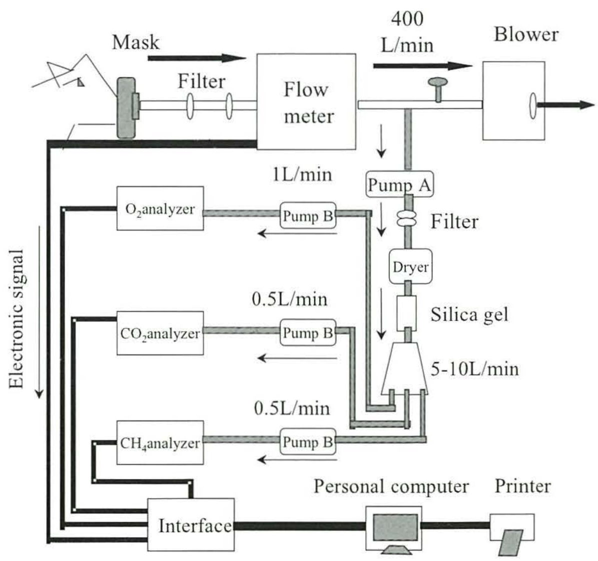

Fig.1. Respiration trial system using a ventilated flow-through method with a face mask.

Fig. 2. Respiration trial system.

respiration trial consists of air analysis and respiration analysis. Air analysis was performed before and after a series of respiration analysis to measure the contents of oxygen, carbon dioxide and methane in the air of the barn where the trial was carried out. The program was written so as to correct the drift of gas analyzers.

2 Time schedule

Diurnal changes of carbon dioxide and methane production, and oxygen consumption were examined in a dry dairy cow given Italian ryegrass wafer (CP 15%) at maintenance level. Feed was given at 09:00 and 16:00. The examination was carried out using a ventilated flow-through method with a hood at the National Institute of Animal Industry, Ibaraki, Japan. The system with a hood is similar to that described in the report of Fujita *et al.*[1].

3 Recovery rate of the system

The gas analyzers were calibrated using standard gases. Two kinds of gas mixtures were used for the calibration, *i.e.* Zero gas and Span gas. Zero gas consisted of O_2 (19.05 %) and N_2 (balance). Span gas consisted of CH_4 (0.19 %), O_2 (20.95 %), CO_2 (1.95 %) and N_2 (balance).

The recovery rate of the whole system was examined by the method of McLean and Tobin[7]. Nitrogen and carbon dioxide gas (>99.9%) were introduced into the 10 L tanks, respectively. The weight of the tanks was measured before the trial. Each gas was individually introduced into the system at the flow level so that air analysis could be performed within a measurable range for about 10 min. Then oxygen consumption and carbon dioxide production were measured for the introduction of carbon dioxide. The oxygen consumption was measured for the introduction of nitrogen. After the trial, the weight of each tank was measured to obtain the total amount of gas introduced into the system.

Recovery rate was calculated by the following equation:

A) Examination of recovery rate by the introduction of nitrogen gas

Recovery rate analyzed from oxygen consumption

$= O_2\ \text{consumption} / ((WN_2/28.013)*22.4*0.2095)$

Where O_2 consumption, WN_2, 28.013, and 0.2095 represent the value of O_2 consumption measured with the system, the weight of nitrogen introduced (g), molecular weight of nitrogen, and oxygen concentration in the air, respectively.

B) Examination of recovery rate by the introduction of carbon dioxide gas

Recovery rate from carbon dioxide production

$= CO_2\ \text{production} / ((WCO_2/44.0098)*22.4)$

Where CO_2 production, WCO_2, and 44.0098 represent the value of CO_2 production measured by the system, weight of carbon dioxide introduced (g), and molecular weight of carbon dioxide, respectively.

Recovery rate from oxygen consumption

$= O_2\ \text{consumption} / ((WCO_2/44.0098)*22.4*0.2095)$

Where O_2 consumption, WCO_2, 44.0098 and 0.2095 represent the value of O_2 consumption measured by the system, weight of carbon dioxide introduced (g), molecular weight of carbon dioxide, and oxygen concentration in the air, respectively.

Results and Discussion

Fig. 3 shows the diurnal changes of carbon dioxide and methane production, and oxygen consumption of dry dairy cows given Italian ryegrass wafer. Oxygen consumption and carbon dioxide production rapidly increased after feeding. The amount of feed given to the animals corresponded to the maintenance level and Italian ryegrass wafer was likely to be more easily consumed than the roughage available in the tropics. Therefore, the increase of oxygen consumption and carbon dioxide production after feeding would be slower in the animals given feed available in the tropics. Itoh[3] examined the properties and magnitude of the experimental error in the measurement of methane production, oxygen consumption and carbon dioxide production by the respiration chamber[5] and reported significant differences in oxygen consumption and carbon dioxide production between day time and night time. It is necessary, therefore, to set the time schedule of the respiration trial with a mask to cover a whole day.

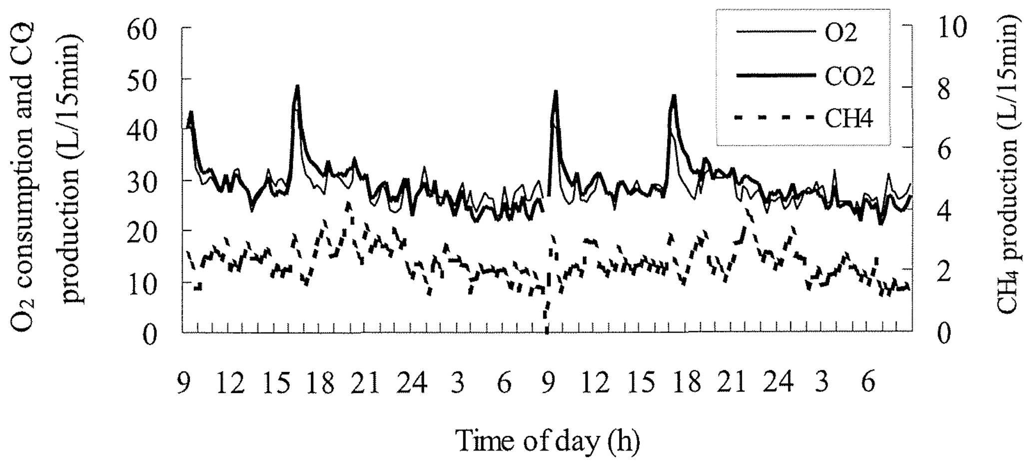

Fig.3. Diurnal changes of methane and carbon dioxide production, and oxygen consumption by dry cows measured by a hood method.
A dry dairy cow was given Italian ryegrass wafer (CP 15%) at maintenance level at 09:00 and 16:00. The trial was carried out with a ventilated flow-through method with a hood at the National Institute of Animal Industry, Ibaraki, Japan.

Table 1. Recovery rate of the respiration trial system

Gas analyzed by the system	Gas introduced into the system	Recovery rate Average	Standard deviation
Oxygen consumption	Nitrogen	0.924 [1]	0.008
Carbon dioxide production	Carbon dioxide	0.933 [2]	0.011
Oxygen consumption	Carbon dioxide	0.943 [2]	0.017

[1] n=3
[2] n=4

Terada *et al.*[8] examined variances of 3 factors, which were considered to influence the accuracy of the measurement of methane production, *i.e.* individual animal, daily difference, and diurnal changes, in the results with respiration trial with a hood. The variance related to diurnal change was the largest among the three factors. It was suggested, based on this analysis, that a respiration trial should be carried out for 2-3 days, 4-6 times a day when four animals are utilized for the trial. The following schedule of the respiration trial with a mask is recommended so that the data taken at some points during a day could represent the results of a whole day. It is also recommended that the trial be repeated for 4 days, should unexpected circumstances arise.

07:00 Respiration analysis
08:00 Feeding
10:00 Respiration analysis
13:00 Respiration analysis
16:00 Respiration analysis
17:00 Feeding
19:00 Respiration analysis
22:00 Respiration analysis
01:00 Respiration analysis

The results of the recovery analysis using the two methods described above are shown in Table 1. The overall average of recovery was 93.3% with a small standard deviation, *i.e.* 0.8-1.7%. Although all of the gas analyzers were calibrated using the standard gases, the flow cell was not calibrated, which may account for the fact that the recovery was slightly less than 100 %. However, the standard deviation was smaller than that in the system reported by Itoh *et al.*[4], presumably due to the simplicity of the system in the present study. It was confirmed, therefore, that the reproducibility of the method was sufficient to measure quantitatively oxygen consumption and the production of carbon dioxide and methane by cattle and water buffalo.

The ventilated flow-through method with a face mask is an alternative system for respiration trial to that with a hood or a chamber. The cost for establishment is much lower and the management of the system is relatively easy. Therefore, the system could be suitable for the research environment in developing countries.

Acknowledgements

The authors express their appreciation to all the staff members of the DLD and JIRCAS for their cooperation. This study was carried out under the collaborative research project between DLD and JIRCAS.

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Appendix 1.

Structure of the system

The system consists of the following components:

1) Main air flow component

(1) Mask

The mask was originally manufactured by Sanshin Kogyo Ltd., Japan. As the body of the mask, which had been originally made of plastic was damaged, an aluminum bucket was modified to replace the body.

(2) Flow cell

The value of the flow rate should be expressed as 0 ℃ 1 STP(standard temperature and pressure).

Thermal flow cell, Japan Flow Cell Ltd.

Type:	FHW-N-S
Diameter:	40A
Orifice diameter:	15.3 mm
Flow range:	50-500 l/min(ntp)
Output:	4-20mADC
Electricity:	100V/200VAC 50/60Hz
Power consumption:	less than 15 VA

(3) Blower

A vacuum cleaner can be used as a blower. A vacuum cleaner, with a switch to adjust its power, is recommended. It can be a small/medium-size home-use vacuum cleaner to obtain 500 l/min air flow. The one used in this system is:

Type:	National NC4760
Power:	1300VA

(4) Pipe and valve

The main pipe connected to the flow cell from the cattle crate is slightly flexible and made of plastic with a diameter of 6 cm. The pipe connecting the main pipe with the mask is very flexible and made of plastic, which is similar to the flexible pipe of a vacuum cleaner.

A two-layer nylon stocking cloth was inserted as a filter at three junctions of the pipes to remove dust.

One valve was installed before the blower in order to adjust the flow rate, around 400 l/min.

2) Air sampling component

(1) Pump

A diaphragm type dry vacuum pump is required to take sample gas from the main air flow component and to introduce the gas into the gas analysis component. The one used in the system is:

Diaphragm type dry vacuum pump

Sinku Kiko Co., LTD.

Type:	DAL-10S
Pumping speed:	10 l/min (50Hz)
Ultimate pressure:	180 torr
Motor:	Single phase 100 V, 10W, 4 Poles, Condenser run
Weight:	1.7 kg
Ambient operation temp:	7-40 ℃

(2) Filter

An air filter is needed to remove fine dust in the sample gas. The filter and filter holder used in the system are as follows:

Glass Microfibre Filters, Wattman International LTD.

Type:	GF/A
Diameter:	4.7 cm

Filter Holder

Diameter:	4.7 cm
Maximum pressure:	4.2 kg/cm^2

(3) Air dryer

The air dryer is one of the key components to obtain stable and reliable gas analysis data, especially for oxygen analysis. In this system, two kinds of air dryer units were installed. One is a membrane air dryer unit. The other is silica gel packed in a plastic holder.

a) Membrane air dryer unit

The unit consists of two membrane air dryers, a filter and a compressor. One membrane air dryer is used for the sample gas. The other membrane dryer is used for producing dry air to purge the dryer for the sample gas. The compressor is used for the membrane dryer to purge the gas.

Membrane air dryer for sample gas

Sunsep-W membrane air dryer, Asahi Glass Company

Type:	SWF-M06-400
Air flow:	5-25 l/min
Air pressure:	< 8.5 kgf/cm^2

Membrane air dryer for purging gas

Sunsep-W membrane air dryer, Asahi Glass Company

Type:	SWC-01-150
Air flow:	20-200 l/min
Air pressure:	< 8.5 kgf/cm^2

Pump

Oil-less compressor, GAST

Type:	RAA-P103-EB

(4) Pipe and valve

Sample air is introduced through a silicone tube. The purge gas is introduced by N_2 tube. Any air leaking into the sample gas in this component produces a large error in the results of the respiration analysis. Care must be taken in this aspect.

3) Gas analysis component

(1) Oxygen analyzer

Xentra 4100, Servomex

Power supply:	100V (350VA)
Analog output:	4-20mA
Analysis range:	19.000-21.000%
Sample gas requirement:	70-210 kPa
	(Sample flow is automatically adjusted 250 ml/min in the analyzer)
Moisture:	Dew point 5 ℃ below lowest ambient operating temperature

(2) Carbon dioxide analyzer

Infra-red gas analyzer, Horiba

Type:	VIA 300
Power supply:	100V (150VA)
Analog output:	0-100 mV

Analysis range: 0-2 %
Sample gas requirement: 0.5-1.5 ml/min

(3) Methane analyzer

Infra-red gas analyzer, Horiba

Type: VIA 300
Power supply: 100V (150VA)
Analog output: 0-100 mV
Analysis range: 0-0.2 %
Sample gas requirement: 0.5-1.5 ml/min

(4) Pumps

Pump for oxygen analyzer

Diaphragm type dry vacuum pump, Enomoto Micro Pump MFG. Co., Ltd.

Type: GA380
Pumping speed: 8-10 l/min
Ultimate pressure: 1.0 kg/cm^2
Electricity: 100V (15W)
Weight: 2.2 kg
Ambient operation temp: 0-40 ℃

Pump for carbon dioxide and methane analyzers

Diaphragm type dry vacuum pump, Iwaki Air pump

Type: APN-085VX-1-07
Pumping speed: 5-6 l/min
Ultimate pressure: 0.8 kg/cm^2
Electricity: 100V (35/38W)

4) Data record and calculation component

(1) Recorder

Hybrid Recorder, Chino Co. LTD.

Type: AH560-RNN
Input range: 6 or 12 ranges
Electricity: 81-264V(60VA)
Option: RS232C

(2) Computer

IBM PC/AT compatible Computer

Q-basic program should be available in DOS.

(3) Cable

RS232C cable (Cross-over)

(4) Printer

For this system, NEC Pinprinter P1200 is used.

5) Electric supply component

Three UPSs (two 1kw and one 0.5kw) are installed to obtain a stable supply of electricity.

Appendix 2

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10 '***************************************************************************
20 '* ENERGY METABOLISM DATA LOGGING PROGRAM FOR 4 CHANNEL DATA *
30 '*            PROGRAM NAME "ENELOG ver2.1"              *
40 '*       ORIGINALLY PROGRAMMED BY M. SHIBATA (1994-12-09)        *
50 '*   NATIONAL INSTITUTE OF ANIMAL INDUSTRY, TSUKUBA, JAPAN      *
52 '*     TRANSLATED INTO QBASIC BY T. KAWASHIMA (1997-11-21)       *
54 '*JAPAN INTERNATIONAL RESEARCH CENTER FOR AGRICULTURAL SCIENCES *
60 '***************************************************************************
70 '
80 'EXAMPLE OF 2ch DATA
90 'B01,891018132136,011200000 1.605,021200000 1.615B
100 '
110 DEFINT I-N
120 DIM A$(200), ITIME$(200), ICH(200, 4), IST(200, 4), DATAI(200, 4), NTIME$(200), NCH(200, 4),
NST(200, 4), DATAN(200, 4)
130 ' DEFINITION OF CODE
140 STX$ = CHR$(2): ETX$ = CHR$(3): ACK$ = CHR$(6): NAK$ = CHR$(21)
150 OPEN "COM2:9600,N,8,1,LF" FOR RANDOM AS #1
160 ON COM(2) GOSUB 1040 'SINPUT
170 COM(2) ON
180 NFLG = 0: NP = 1: LP = 0: N% = 0
190 CLS : INPUT "INPUT TITLE OF MEASUREMENT"; TITLE$
200 '
210 'KEY INPUT TREATMENT
220 CLS
230 PY$ = ""
240 LOCATE 3, 4: PRINT "PLEASE INPUT COMMAND !"
250 LOCATE 6, 6: PRINT "1: AIR ANALYSIS  (MAXIMUM 15 MINUITS) ........ 1"
260 LOCATE 7, 6: PRINT "2: RESPIRATION ANALYSIS ...................... 2"
270 LOCATE 8, 6: PRINT "3: MEASUREMENT END !! (FOR DATA PRINTOUT)..... 3"
280 LOCATE 11, 30: INPUT ITREAT
290 IF ITREAT < 1 OR ITREAT > 3 GOTO 240
300 PRINT : PRINT : PRINT "INPUT TREATMENT = "; ITREAT
310 PRINT : PRINT "TREATMENT IS OK?  (Y/N)"
320 INPUT TREAT$
330 IF TREAT$ = "Y" GOTO 350
340 GOTO 240
350 ON ITREAT GOTO 360, 400, 440
360 FOR L = 1 TO 100
370 ITIME$(L) = ""
380 FOR M = 1 TO 4: ICH(L, M) = 0: IST(L, M) = 0: DATAI(L, M) = 0!: NEXT M
390 NEXT L
400 FOR L = 1 TO 200
410 NTIME$(L) = ""
420 FOR M = 1 TO 4: NCH(L, M) = 0: NST(L, M) = 0: DATAN(L, M) = 0!: NEXT M
430 NEXT L
440 IF ITREAT = 3 GOTO 1260
450 J = 0: FOR I = 1 TO 100: A$(I) = "": NEXT I
460 CLS : PRINT : INPUT "STORE THE DATA IN HARD DISK ? (Y/N)"; DK$
470 IF DK$ <> "Y" AND DK$ <> "N" GOTO 460
480 IF DK$ = "N" GOTO 570
490 '
500 'DATA ARE SAVED UNDER DIRECTORY C:\GASDATA\
510 'FILE NAME: AIR DATA IS XXXX.ADT AND RESPIRATION DATA IS XXXX.RDT
520 '
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```
530 PRINT : PRINT : PRINT "INPUT FILE NAME (NO EXTENSION(.XXX) ONLY FILE NAME, WITHIN 8 CHARACTERS)"
540 IF ITREAT = 1 THEN INPUT BFNM$: BFNM$ = "C:\GASDATA\" + BFNM$ + ".ADT"
550 IF ITREAT = 2 THEN INPUT BFNM$: BFNM$ = "C:\GASDATA\" + BFNM$ + ".RDT"
560 OPEN BFNM$ FOR OUTPUT AS #2
570 KY$ = "ST": GOSUB 900 'SOSHIN
580 CLS : LOCATE 17, 2: PRINT "HIT ANY KEY WHEN PROCEED TO NEXT TREATMENT !!"
590 PY$ = INKEY$
600 IF PY$ = "" GOTO 590
610 CLOSE #2: N% = 0
620 OC$ = "DS"
630 OC$ = STX$ + OC$ + ETX$
640 PRINT #1, OC$: L = 0
650 CLS : PRINT "DATA COMMUNICATION STOP"
660 IF ITREAT = 2 GOTO 800
670 '
680 'DATA SELECTION AND TRANSFORM CHARACTER TO NUMERAL FOR AIR DATA
690 NDATAA = NDATA
700 FOR L = 1 TO NDATA
710 ITIME$(L) = MID$(A$(L), 5, 12)
720 ICH(L, 1) = VAL(MID$(A$(L), 18, 2)): IST(L, 1) = VAL(MID$(A$(L), 26, 1)): DATAI(L, 1) = VAL(MID$(A$(L), 27, 6))
730 ICH(L, 2) = VAL(MID$(A$(L), 34, 2)): IST(L, 2) = VAL(MID$(A$(L), 42, 1)): DATAI(L, 2) = VAL(MID$(A$(L), 43, 6))
740 ICH(L, 3) = VAL(MID$(A$(L), 50, 2)): IST(L, 3) = VAL(MID$(A$(L), 58, 1)): DATAI(L, 3) = VAL(MID$(A$(L), 59, 6))
750 ICH(L, 4) = VAL(MID$(A$(L), 66, 2)): IST(L, 4) = VAL(MID$(A$(L), 74, 1)): DATAI(L, 4) = VAL(MID$(A$(L), 75, 6))
760 NEXT L
770 GOTO 880
780 '
790 'DATA SELECTION AND TRANSFORM CHARACTER TO NUMERAL FOR RESP. DATA
800 NDATAR = NDATA
810 FOR L = 1 TO NDATA
820 NTIME$(L) = MID$(A$(L), 5, 12)
830 NCH(L, 1) = VAL(MID$(A$(L), 18, 2)): NST(L, 1) = VAL(MID$(A$(L), 26, 1)): DATAN(L, 1) = VAL(MID$(A$(L), 27, 6))
840 NCH(L, 2) = VAL(MID$(A$(L), 34, 2)): NST(L, 2) = VAL(MID$(A$(L), 42, 1)): DATAN(L, 2) = VAL(MID$(A$(L), 43, 6))
850 NCH(L, 3) = VAL(MID$(A$(L), 50, 2)): NST(L, 3) = VAL(MID$(A$(L), 58, 1)): DATAN(L, 3) = VAL(MID$(A$(L), 59, 6))
860 NCH(L, 4) = VAL(MID$(A$(L), 66, 2)): NST(L, 4) = VAL(MID$(A$(L), 74, 1)): DATAN(L, 4) = VAL(MID$(A$(L), 75, 6))
870 NEXT L
880 GOTO 220
890 '
900 'SOSHIN
910 '*****  SEND DATA REQUEST COMMAND  *****
920 NFLG = 1: ' DATA RECEIVE FLAG SET
930 OC$ = KY$
940 OC$ = STX$ + OC$ + ETX$
950 PRINT #1, OC$;
960 GOSUB 980 'JK: GOTO 580
970 '
980 'JK
990 '*****  WATCH DATA RECEIVE  *****
1000 FOR I = 0 TO 1000: NEXT I
```

```
1010 IF NFLG = 1 THEN PRINT #1, OC$
1020 RETURN
1030 '
1040 'SINPUT
1050 '*****  DATA RECEIVE TREATMENT  *****
1060 IF LOC(1) < 2 THEN RETURN
1070 LINE INPUT #1, L$
1075 L$ = MID$(L$, 2, 81)
1080 CLS : LOCATE 17, 2: PRINT "HIT ANY KEY WHEN PROCEED TO NEXT TREATMENT !!"
1082 LOCATE 18, 1: PRINT "DATA IS BEING SAVED IN THE FILE:"
1084 LOCATE 18, 35: PRINT BFNM$
1085 LOCATE 19, 1: PRINT "TYPE OF DATA:": LOCATE 19, 15: PRINT MID$(L$, 2, 2)
1088 LOCATE 20, 1: PRINT "NO OF RECORD:": LOCATE 20, 15: PRINT N%
1090 LOCATE 21, 1: PRINT "Present Data are as follows:                    "
1100 LOCATE 22, 1: PRINT L$
1110 'SCAN BUSY CHECK
1120 IF MID$(L$, 2, 2) <> "01" THEN GOTO 1230
1130 IF DK$ = "N" GOTO 1230
1140 IF N% > 0 GOTO 1180
1150 PRINT #2, L$: CLOSE #2
1160 OPEN BFNM$ FOR APPEND AS #2
1170 N% = N% + 1: GOTO 1220
1180 PRINT #2, L$: N% = N% + 1
1190 IF N% < 60 GOTO 1220
1200 N% = 1: CLOSE #2
1210 OPEN BFNM$ FOR APPEND AS #2
1220 J = J + 1: A$(J) = L$: NDATA = J
1230 NFLG = 0
1240 RETURN
1250 '
1260 'PRINT OUT PROCEDURE
1270 CLS : INPUT "PRINT OUT DATA ? (Y/N)"; PO$
1280 IF PO$ <> "Y" AND PO$ <> "N" THEN GOTO 1270
1290 IF PO$ = "N" GOTO 1850
1300 IF NP > 1 GOTO 1430
1310 IF LP < 57 GOTO 1330
1320 LPRINT CHR$(12): LP = 0
1330 LPRINT "ENERGY METABOLISM DATA LOGGING SYSTEM (ENELOG)": LPRINT
1340 LPRINT "CHANNEL    ITEM                    UNIT"
1350 LPRINT "  1     OXYGEN (O2)                 mV"
1360 LPRINT "  2     CARBON DIOXIDE (CO2)        -"
1370 LPRINT "  3     METHANE(CH4)                mV"
1380 LPRINT "  4     FLOW RATE                   V (ORIGINAL mA, 250 OHM RESISTANT ATTACHED)"
1390 LPRINT "STATUS  0:NORMAL, 1:OVER RANGE, 2:UNDER RANGE": LPRINT : LPRINT : LPRINT
1400 NP = NP + 1: LP = LP + 11
1410 IF LP < 59 GOTO 1430
1420 LPRINT CHR$(12): LP = 0
1430 LPRINT "TITLE OF MEASUREMENT: "; : LPRINT TITLE$: LPRINT : LP = LP + 2
1440 CLS : INPUT "AIR DATA PRINT OUT ? (Y/N)"; AIR$
1450 IF AIR$ <> "Y" AND AIR$ <> "N" THEN GOTO 1430
1460 IF AIR$ = "N" GOTO 1620
1470 LPRINT "AIR GAS CONCENTRATION DATA (NO TRANSFORMATION)": LPRINT
1480 LPRINT "TIME:YYMMDDHHMMSS  CH STS   DATA  CH STS   DATA  CH STS   DATA  CH STS
DATA"
1490 LPRINT "-----------------------------------------------------------------------------": LP = LP + 4
1500 FOR L = 1 TO NDATAA
1510 LPRINT SPC(5); : LPRINT USING "& &"; ITIME$(L);
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```
1520 FOR M = 1 TO 4
1530 LPRINT USING "####"; ICH(L, M); IST(L, M);
1540 LPRINT USING "###.###"; DATAI(L, M);
1550 NEXT M
1560 LPRINT : LP = LP + 1
1570 IF LP < 63 GOTO 1590
1580 LPRINT CHR$(12): LP = 0
1590 NEXT L
1600 LPRINT "-------------------------------------------------------------------------------": LP = LP + 1
1610 LPRINT : LPRINT : LPRINT : LP = LP + 3
1620 PRINT : PRINT : INPUT "RESPIRATION DATA PRINT OUT ? (Y/N)"; RES$
1630 IF RES$ <> "Y" AND RES$ <> "N" THEN GOTO 1620
1640 IF RES$ = "N" GOTO 1810
1650 IF LP < 59 GOTO 1670
1660 LPRINT CHR$(12): LP = 0
1670 LPRINT "RESPIRATION GAS CONCENTRATION DATA (NO TRANSFORMATION)": LPRINT
1680 LPRINT "TIME:YYMMDDHHMMSS  CH STS   DATA  CH STS   DATA  CH STS   DATA  CH STS   DATA"
1690 LPRINT "-------------------------------------------------------------------------------": LP = LP + 4
1700 FOR L = 1 TO NDATAR
1710 LPRINT SPC(5); : LPRINT USING "& &"; NTIME$(L);
1720 FOR M = 1 TO 4
1730 LPRINT USING "####"; NCH(L, M); NST(L, M);
1740 LPRINT USING "###.###"; DATAN(L, M);
1750 NEXT M
1760 LPRINT
1770 IF LP < 63 GOTO 1790
1780 LPRINT CHR$(12): LP = 0
1790 NEXT L
1800 LPRINT "-------------------------------------------------------------------------------"
1810 LPRINT CHR$(12): LP = 0
1820 PRINT : INPUT "PRINT OUT AGAIN ? (Y/N)"; PO$
1830 IF PO$ <> "Y" AND PO$ <> "N" THEN GOTO 1820
1840 IF PO$ = "Y" GOTO 1300
1850 CLS : INPUT "CONTINUE MEASUREMENT (Y) OR END (E)"; ANS$
1860 IF ANS$ <> "Y" AND ANS$ <> "E" THEN GOTO 1850
1870 IF ANS$ = "E" GOTO 1890
1880 CLOSE : GOTO 150
1890 CLOSE : SYSTEM
```

```
10 '*********************************************************************
20 '* ENERGY METABOLISM CALCULATION PROGRAM FOR 4 CHANNEL DATA *
30 '*              PROGRAM NAME "ENECAL" ver2.1                *
40 '*   ORIGINALLY PROGRAMMED BY M. SHIBATA (1994-12-16)        *
50 '*   NATIONAL INSTITUTE OF ANIMAL INDUSTRY, TSUKUBA, JAPAN    *
52 '* REVISED AND TRANSLATED INTO QBASIC BY T. KAWASHIMA (1997-12-18) *
54 '* JAPAN INTERNATIONAL RESEARCH CENTER FOR AGRICULTURAL SCIENCES *
60 '*********************************************************************
70 '
80 DEFDBL I-N
90 DEFSTR A
100 DEFDBL D
110 DIM ATIME(200), IYEAR(200), IMTH(200), IDAY(200), IHOUR(200), IMIN(200), ISEC(200), ICH(200, 4), IST(200, 4), DATAI(200, 4), ANTIME(200), NYEAR(200), NMTH(200), NDAY(200), NHOUR(200), NMIN(200), NSEC(200), NCH(200, 4), NST(200, 4), DATAN(200, 4), DO2(200), DCO2(200), DCH4(200)
120 DIM DSSA(200), DSSB(200), DO2STD(200), DCO2STD(200), DCH4STD(200), DSS(200)
130 '
140 IICH = 0
150 CLS : LOCATE 3, 5: PRINT "GAS CALIBRATION DATA INPUT"
160 LOCATE 5, 7: PRINT "INPUT NEW STANDARD DATA................1"
170 LOCATE 7, 7: PRINT "USE OLD DATA (IN FILE C:\CALIB.DAT).....2"
180 INPUT ISTD
190 PRINT : PRINT : INPUT "INPUT NUMBER IS OK (Y/N)"; ANS$
200 IF ANS$ <> "Y" GOTO 150
210 ON ISTD GOTO 220, 590
220 CLS : INPUT "INPUT O2 ZERO CONCENTRATION (%)"; C(1)
230 INPUT "INPUT O2 ZERO VOLTAGE (mV)"; V(1)
240 INPUT "INPUT O2 SPAN CONCENTRATION (%)"; C(5)
250 INPUT "INPUT O2 SPAN VOLTAGE (mV)"; V(5)
260 IF IICH > 0 GOTO 430
270 INPUT "INPUT CO2 ZERO CONCENTRATION (%)"; C(2)
280 INPUT "INPUT CO2 ZERO VOLTAGE (mV)"; V(2)
285 CV = V(2) / 100: GOSUB 4220: V(2) = CV
290 INPUT "INPUT CO2 SPAN CONCENTRATION (%)"; C(6)
300 INPUT "INPUT CO2 SPAN VOLTAGE (mV)"; V(6)
305 CV = V(6) / 100: GOSUB 4220: V(6) = CV
310 IF IICH > 0 GOTO 430
320 INPUT "INPUT CH4 ZERO CONCENTRATION (%)"; C(3)
330 INPUT "INPUT CH4 ZERO VOLTAGE (mV)"; V(3)
335 CV = V(3) / 100: GOSUB 4250: V(3) = CV
340 INPUT "INPUT CH4 SPAN CONCENTRATION (%)"; C(7)
350 INPUT "INPUT CH4 SPAN VOLTAGE (mV)"; V(7)
355 CV = V(7) / 100: GOSUB 4250: V(7) = CV
360 IF IICH > 0 GOTO 430
370 INPUT "INPUT FLOW ZERO RATE (NL/MIN)"; C(4)
380 INPUT "INPUT FLOW ZERO VOLTAGE (V)"; V(4)
390 INPUT "INPUT FLOW SPAN RATE (NL/MIN)"; C(8)
400 INPUT "INPUT FLOW SPAN VOLTAGE (V)"; V(8)
410 PRINT : INPUT "INPUT DATA OK ? (Y/N)"; ANS
420 IF ANS = "Y" GOTO 500
430 CLS : LOCATE 3, 5: PRINT "INPUT WHICH ITEM TO BE CHANGED ?"
440 LOCATE 5, 7: PRINT "OXYGEN (O2)......................1"
450 LOCATE 7, 7: PRINT "CARBONE DIOXIDE (CO2)............2"
460 LOCATE 9, 7: PRINT "METHANE (CH4)....................3"
470 LOCATE 11, 7: PRINT "FLOW RATE (NL/MIN)...............4"
480 INPUT IICH: IF IICH = 0 GOTO 500
490 ON IICH GOTO 220, 270, 320, 370
```

```
500 CLS : INPUT "SAVE THE NEW CALIBRATION DATA IN CALIB FILE ? (Y/N)"; ANS
510 IF ANS <> "Y" GOTO 630
520 OPEN "C:\CALIB.DAT" FOR OUTPUT AS #1
530 AG(1) = "O2 ZERO": AG(2) = "CO2 ZERO": AG(3) = "CH4 ZERO": AG(4) = "FLOW ZERO"
540 AG(5) = "O2 SPAN": AG(6) = "CO2 SPAN": AG(7) = "CH4 SPAN": AG(8) = "FLOW SPAN"
550 FOR I = 1 TO 8
560 PRINT #1, AG(I); ","; C(I); V(I)
570 NEXT I
580 CLOSE #1
590 CLS : PRINT "READ CALIBRATION DATA FILE !"
600 OPEN "C:\CALIB.DAT" FOR INPUT AS #1
610 FOR I = 1 TO 8: INPUT #1, AG(I), C(I), V(I): NEXT I
620 CLOSE #1
630 CLS : PRINT : PRINT : PRINT "READ NEW AIR COMPOSITION DATA FILE ? (Y/N)"
640 INPUT " YOU MUST INPUT AT 1ST CALCULATION !!"; ANS
650 IF ANS = "Y" OR ANS = "N" GOTO 660 ELSE GOTO 630
660 IF ANS = "N" THEN GOTO 2830 ELSE GOTO 680
680 AADATA = "C:\GASDATA\" + "*.ADT"
690 CLS : INPUT "INPUT AIR DATA FILE NAME BEFORE THE TRIAL"; ATITLE
700 CLS : PRINT "AIR DATA FILES ARE AS FOLLOWS:": PRINT : FILES AADATA
710 PRINT : INPUT "PLEASE INPUT AIR DATA FILE NAME (NO EXTENSION(.XXX) ONLY FILE NAME";
AAFNM: AAFNM = "C:\GASDATA\" + AAFNM + ".ADT"
720 OPEN AAFNM FOR INPUT AS #1
730 ATIME = ""
740 FOR L = 1 TO 200
750 IYEAR(L) = 0: IMTH(L) = 0: IDAY(L) = 0: IHOUR(L) = 0: IMIN(L) = 0: ISEC(L) = 0: DSSA(L) = 0
760 FOR M = 1 TO 4
770 ICH(L, M) = 0: IST(L, M) = 0: DATAI(L, M) = 0!
780 NEXT M
790 NEXT L
800 FOR M = 1 TO 4: DMEAN(M) = 0!: NEXT M
810 L = 1: NDATAA = 1
820 NDA1 = 1: NDA2 = 1: NDA3 = 1: NDA4 = 1: IER = 0: NDA5 = 1: DSSA = 0
830 INPUT #1, A1, A2, A3, A4, A5, A6
840 IER = 0: NDATAA = NDATAA + 1
850 ATIME(L) = A2: IYEAR(L) = VAL(MID$(A2, 2, 2)): IMTH(L) = VAL(MID$(A2, 4, 2)): IDAY(L) =
VAL(MID$(A2, 6, 2))
860 IHOUR(L) = VAL(MID$(A2, 7, 2)): IMIN(L) = VAL(MID$(A2, 9, 2)): ISEC(L) = VAL(MID$(A2, 11, 2))
870 ICH(L, 1) = VAL(MID$(A3, 1, 2)): DATAI(L, 1) = VAL(MID$(A3, 10, 6)): IST(L, 1) = VAL(MID$(A3, 9,
1))
880 DATAI(L, 1) = (DATAI(L, 1) - V(1)) * ((C(5) - C(1)) / (V(5) - V(1))) + C(1)
890 ICH(L, 2) = VAL(MID$(A4, 1, 2)): DATAI(L, 2) = VAL(MID$(A4, 10, 6)): IST(L, 2) = VAL(MID$(A4, 9,
1))
895 CV = DATAI(L, 2) / 100: GOSUB 4220: DATAI(L, 2) = CV
900 DATAI(L, 2) = (DATAI(L, 2) - V(2)) * ((C(6) - C(2)) / (V(6) - V(2))) + C(2)
910 ICH(L, 3) = VAL(MID$(A5, 1, 2)): DATAI(L, 3) = VAL(MID$(A5, 10, 6)): IST(L, 3) = VAL(MID$(A5, 9,
1))
915 CV = DATAI(L, 3) / 100: GOSUB 4250: DATAI(L, 3) = CV
920 DATAI(L, 3) = (DATAI(L, 3) - V(3)) * ((C(7) - C(3)) / (V(7) - V(3))) + C(3)
930 ICH(L, 4) = VAL(MID$(A6, 1, 2)): DATAI(L, 4) = VAL(MID$(A6, 10, 6)): IST(L, 4) = VAL(MID$(A6, 9,
1))
940 DATAI(L, 4) = (DATAI(L, 4) - V(4)) * ((C(8) - C(4)) / (V(8) - V(4))) + C(4)
950 DSSA(L) = IHOUR(L) * 3600 + IMIN(L) * 60 + ISEC(L)
960 DSSA = DSSA + DSSA(L)
970 NDA5 = NDA5 + 1
980 IF IST(L, 1) = 0 GOTO 1000
990 DATAI(L, 1) = 99.999: IER = IER + 1: GOTO 1010
```

```
1000 NDA1 = NDA1 + 1: DMEAN(1) = DMEAN(1) + DATAI(L, 1)
1010 IF IST(L, 2) = 0 GOTO 1030
1020 DATAI(L, 2) = 99.999: IER = IER + 1: GOTO 1040
1030 NDA2 = NDA2 + 1: DMEAN(2) = DMEAN(2) + DATAI(L, 2)
1040 IF IST(L, 3) = 0 GOTO 1060
1050 DATAI(L, 3) = 99.999: IER = IER + 1: GOTO 1070
1060 NDA3 = NDA3 + 1: DMEAN(3) = DMEAN(3) + DATAI(L, 3)
1070 IF IST(L, 4) = 0 GOTO 1090
1080 DATAI(L, 4) = 99.999: IER = IER + 1: GOTO 1100
1090 NDA4 = NDA4 + 1: DMEAN(4) = DMEAN(4) + DATAI(L, 4)
1100 IF IER > 0 THEN ATIME(L) = "* " + ATIME(L)
1110 IF EOF(1) THEN 1130 ELSE 1120
1120 L = L + 1: GOTO 830
1130 NDA1 = NDA1 - 1: NDA2 = NDA2 - 1: NDA3 = NDA3 - 1: NDA4 = NDA4 - 1: NDATAA = NDATAA - 1:
NDA5 = NDA5 - 1
1140 DMEAN(1) = DMEAN(1) / NDA1
1150 DMEAN(2) = DMEAN(2) / NDA2
1160 DMEAN(3) = DMEAN(3) / NDA3
1170 DMEAN(4) = DMEAN(4) / NDA4
1180 DSSA = DSSA / NDA5
1190 CLOSE
1200 CLS : LOCATE 3, 5: PRINT "AIR DATA PRINT OUT AND/OR SAVE TO HARD DISK ?"
1210 LOCATE 5, 7: PRINT "NO OUTPUT FOR AIR....................0"
1220 LOCATE 7, 7: PRINT "PRINT OUT ONLY.......................1"
1230 LOCATE 9, 7: PRINT "SAVE TO HARD DISK ONLY...............2"
1240 LOCATE 11, 7: PRINT "BOTH PRINT OUT AND HARD DISK.........3"
1250 INPUT IOT
1260 LOCATE 16, 5: INPUT "INPUT NUMBER IS OK ? (Y/N)"; ANS$
1270 IF ANS$ <> "Y" GOTO 1200
1280 IF IOT = 0 GOTO 1700
1290 ON IOT GOTO 1300, 1530, 1300
1300 LPRINT "ENERGY METABOLISM MEASUREMENT CALCULATION SYSTEM (ENECAL)": LPRINT
: LPRINT : LP = LP + 3
1310 LPRINT "TITLE OF MEASUREMENT: "; : LPRINT ATITLE: LPRINT : LP = LP + 2
1320 LPRINT "AIR GAS CONCENTRATION DATA (%) *** STS=1,2 AND DATA 99.999 IS ABNORMAL
DATA": LPRINT
1330 LPRINT "TIME:YYMMDDHHMMSS  CH STS    O2   CH STS   CO2   CH STS   CH4   CH STS  FLOW"
1340 LPRINT "--------------------------------------------------------------------------------": LP = LP + 4
1350 FOR L = 1 TO NDATAA
1360 LPRINT SPC(3); : LPRINT USING "& &"; ATIME(L);
1370 FOR M = 1 TO 3
1380 LPRINT USING "####"; ICH(L, M); IST(L, M);
1390 LPRINT USING "###.###"; DATAI(L, M);
1400 NEXT M
1410 LPRINT USING "####"; ICH(L, 4); IST(L, 4);
1420 LPRINT USING "####.##"; DATAI(L, 4)
1430 LP = LP + 1
1440 IF LP < 63 GOTO 1460
1450 LPRINT CHR$(12): LP = 0
1460 NEXT L
1470 LPRINT : LPRINT "     MEAN CONC"; : LPRINT SPC(2);
1480 FOR I = 1 TO 3: LPRINT USING "###########.###"; DMEAN(I); : NEXT I
1490 LPRINT USING "###########.##"; DMEAN(4): LP = LP + 2
1500 LPRINT "--------------------------------------------------------------------------------": LP = LP + 1
1510 LPRINT : LPRINT : LPRINT : LP = LP + 3
1520 IF IOT = 1 GOTO 1700
```

```
1530 PRINT : INPUT "PLEASE INPUT FILE NAME TO BE SAVED (NO EXTENSION(.XXX) ONLY FILE NAME)"; AAFILE
1540 AAFILE = "C:\HPDATA\" + AAFILE + ".RES"
1550 OPEN AAFILE FOR OUTPUT AS #1
1560 IE = 9999
1570 PRINT #1, "TITLE OF MEASUREMENT: "; ATITLE
1580 PRINT #1, "TIME    "; ","; "  O2"; ","; "  CO2"; ","; "  CH4"; ","; " FLOW"
1590 FOR L = 1 TO NDATAA
1600 PRINT #1, ATIME(L); ",";
1610 FOR M = 1 TO 3
1620 PRINT #1, DATAI(L, M);
1630 NEXT M
1640 PRINT #1, DATAI(L, 4)
1650 NEXT L
1660 PRINT #1, "       MEAN CONC";
1670 FOR I = 1 TO 3: PRINT #1, DMEAN(I); : NEXT I
1680 PRINT #1, DMEAN(4)
1690 CLOSE #1
1700 CLS : INPUT "INPUT TITLE OF MEASUREMENT(AIR DATA FILE AFTER THE TRIAL)"; ATITLEB
1710 AADATA = "C:\GASDATA\" + "*.ADT"
1720 CLS : PRINT "AIR DATA FILES ARE AS FOLLOWS:": PRINT : FILES AADATA
1730 PRINT : INPUT "PLEASE INPUT AIR DATA FILE NAME (NO EXTENSION(.XXX) ONLY FILE NAME"; AAFNM: AAFNM = "C:\GASDATA\" + AAFNM + ".ADT"
1740 OPEN AAFNM FOR INPUT AS #1
1750 ATIME = ""
1760 FOR L = 1 TO 200
1770 IYEAR(L) = 0: IMTH(L) = 0: IDAY(L) = 0: IHOUR(L) = 0: IMIN(L) = 0: ISEC(L) = 0: DSSB(L) = 0!
1780 FOR M = 1 TO 4
1790 ICH(L, M) = 0: IST(L, M) = 0: DATAI(L, M) = 0!
1800 NEXT M
1810 NEXT L
1820 FOR M = 1 TO 4: DMEANB(M) = 0!: NEXT M
1830 L = 1: NDATAA = 1
1840 NDA1 = 1: NDA2 = 1: NDA3 = 1: NDA4 = 1: IER = 0: NDA5 = 1: DSSB = 0
1850 INPUT #1, A1, A2, A3, A4, A5, A6
1860 IER = 0: NDATAA = NDATAA + 1
1870 ATIME(L) = A2: IYEAR(L) = VAL(MID$(A2, 2, 2)): IMTH(L) = VAL(MID$(A2, 4, 2)): IDAY(L) = VAL(MID$(A2, 6, 2))
1880 IHOUR(L) = VAL(MID$(A2, 7, 2)): IMIN(L) = VAL(MID$(A2, 9, 2)): ISEC(L) = VAL(MID$(A2, 11, 2))
1890 ICH(L, 1) = VAL(MID$(A3, 1, 2)): DATAI(L, 1) = VAL(MID$(A3, 10, 6)): IST(L, 1) = VAL(MID$(A3, 9, 1))
1900 DATAI(L, 1) = (DATAI(L, 1) - V(1)) * ((C(5) - C(1)) / (V(5) - V(1))) + C(1)
1910 ICH(L, 2) = VAL(MID$(A4, 1, 2)): DATAI(L, 2) = VAL(MID$(A4, 10, 6)): IST(L, 2) = VAL(MID$(A4, 9, 1))
1915 CV = DATAI(L, 2) / 100: GOSUB 4220: DATAI(L, 2) = CV
1920 DATAI(L, 2) = (DATAI(L, 2) - V(2)) * ((C(6) - C(2)) / (V(6) - V(2))) + C(2)
1930 ICH(L, 3) = VAL(MID$(A5, 1, 2)): DATAI(L, 3) = VAL(MID$(A5, 10, 6)): IST(L, 3) = VAL(MID$(A5, 9, 1))
1935 CV = DATAI(L, 3) / 100: GOSUB 4250: DATAI(L, 3) = CV
1940 DATAI(L, 3) = (DATAI(L, 3) - V(3)) * ((C(7) - C(3)) / (V(7) - V(3))) + C(3)
1950 ICH(L, 4) = VAL(MID$(A6, 1, 2)): DATAI(L, 4) = VAL(MID$(A6, 10, 6)): IST(L, 4) = VAL(MID$(A6, 9, 1))
1960 DATAI(L, 4) = (DATAI(L, 4) - V(4)) * ((C(8) - C(4)) / (V(8) - V(4))) + C(4)
1970 DSSB(L) = IHOUR(L) * 3600 + IMIN(L) * 60 + ISEC(L)
1980 DSSB = DSSB + DSSB(L)
1990 NDA5 = NDA5 + 1
2000 IF IST(L, 1) = 0 GOTO 2020
```

```
2010 DATAI(L, 1) = 99.999: IER = IER + 1: GOTO 2030
2020 NDA1 = NDA1 + 1: DMEANB(1) = DMEANB(1) + DATAI(L, 1)
2030 IF IST(L, 2) = 0 GOTO 2050
2040 DATAI(L, 2) = 99.999: IER = IER + 1: GOTO 2060
2050 NDA2 = NDA2 + 1: DMEANB(2) = DMEANB(2) + DATAI(L, 2)
2060 IF IST(L, 3) = 0 GOTO 2080
2070 DATAI(L, 3) = 99.999: IER = IER + 1: GOTO 2090
2080 NDA3 = NDA3 + 1: DMEANB(3) = DMEANB(3) + DATAI(L, 3)
2090 IF IST(L, 4) = 0 GOTO 2110
2100 DATAI(L, 4) = 99.999: IER = IER + 1: GOTO 2120
2110 NDA4 = NDA4 + 1: DMEANB(4) = DMEANB(4) + DATAI(L, 4)
2120 IF IER > 0 THEN ATIME(L) = "* " + ATIME(L)
2130 IF EOF(1) THEN 2150 ELSE 2140
2140 L = L + 1: GOTO 1850
2150 NDA1 = NDA1 - 1: NDA2 = NDA2 - 1: NDA3 = NDA3 - 1: NDA4 = NDA4 - 1: NDATAA = NDATAA - 1:
NDA5 = NDA5 - 1
2160 DMEANB(1) = DMEANB(1) / NDA1
2170 DMEANB(2) = DMEANB(2) / NDA2
2180 DMEANB(3) = DMEANB(3) / NDA3
2190 DMEANB(4) = DMEANB(4) / NDA4
2200 DSSB = DSSB / NDA5
2210 CLOSE
2220 CLS : LOCATE 3, 5: PRINT "AIR DATA PRINT OUT AND/OR SAVE TO HARD DISK ?"
2230 LOCATE 5, 7: PRINT "NO OUTPUT FOR AIR....................0"
2240 LOCATE 7, 7: PRINT "PRINT OUT ONLY.......................1"
2250 LOCATE 9, 7: PRINT "SAVE TO HARD DISK ONLY...............2"
2260 LOCATE 11, 7: PRINT "BOTH PRINT OUT AND HARD DISK.........3"
2270 INPUT IOT
2280 LOCATE 16, 5: INPUT "INPUT NUMBER IS OK ? (Y/N)"; ANS$
2290 IF ANS$ <> "Y" GOTO 2220
2300 IF IOT = 0 GOTO 2720
2310 ON IOT GOTO 2320, 2550, 2320
2320 LPRINT "ENERGY METABOLISM MEASUREMENT CALCULATION SYSTEM (ENECAL)": LPRINT
: LPRINT : LP = LP + 3
2330 LPRINT "TITLE OF MEASUREMENT: "; : LPRINT ATITLEB: LPRINT : LP = LP + 2
2340 LPRINT "AIR GAS CONCENTRATION DATA (%) *** STS=1,2 AND DATA 99.999 IS ABNORMAL
DATA": LPRINT
2350 LPRINT "TIME:YYMMDDHHMMSS  CH STS   O2  CH STS  CO2  CH STS  CH4  CH STS  FLOW"
2360 LPRINT "----------------------------------------------------------------------------": LP = LP + 4
2370 FOR L = 1 TO NDATAA
2380 LPRINT SPC(3); : LPRINT USING "& &"; ATIME(L);
2390 FOR M = 1 TO 3
2400 LPRINT USING "####"; ICH(L, M); IST(L, M);
2410 LPRINT USING "###.###"; DATAI(L, M);
2420 NEXT M
2430 LPRINT USING "####"; ICH(L, 4); IST(L, 4);
2440 LPRINT USING "####.##"; DATAI(L, 4)
2450 LP = LP + 1
2460 IF LP < 63 GOTO 2480
2470 LPRINT CHR$(12): LP = 0
2480 NEXT L
2490 LPRINT : LPRINT "     MEAN CONC"; : LPRINT SPC(2);
2500 FOR I = 1 TO 3: LPRINT USING "##########.###"; DMEANB(I); : NEXT I
2510 LPRINT USING "###########.##"; DMEANB(4): LP = LP + 2
2520 LPRINT "----------------------------------------------------------------------------": LP = LP + 1
2530 LPRINT : LPRINT : LPRINT : LP = LP + 3
2540 IF IOT = 1 GOTO 2720
```

```
2550 PRINT : INPUT "PLEASE INPUT FILE NAME TO BE SAVED (NO EXTENSION(.XXX) ONLY FILE NAME)"; AAFILE
2560 AAFILE = "C:\HPDATA\" + AAFILE + ".RES"
2570 OPEN AAFILE FOR OUTPUT AS #1
2580 IE = 9999
2590 PRINT #1, "TITLE OF MEASUREMENT: "; ATITLEB
2600 PRINT #1, "TIME    "; ","; "  O2"; ","; "  CO2"; ","; "  CH4"; ","; " FLOW"
2610 FOR L = 1 TO NDATAA
2620 PRINT #1, ATIME(L); ",";
2630 FOR M = 1 TO 3
2640 PRINT #1, DATAI(L, M);
2650 NEXT M
2660 PRINT #1, DATAI(L, 4)
2670 NEXT L
2680 PRINT #1, "      MEAN CONC";
2690 FOR I = 1 TO 3: PRINT #1, DMEANB(I); : NEXT I
2700 PRINT #1, DMEANB(4)
2710 CLOSE #1
2720 FOR L = 1 TO 4
2730 PRINT DMEAN(L)
2740 PRINT DMEANB(L)
2750 NEXT L
2760 PRINT DSSA
2770 PRINT DSSB
2780 PRINT "GO TO THE END? (Y/N)"
2790 INPUT ANS$
2800 IF ANS$ = "Y" THEN END
2810 CLS : PRINT : PRINT "READ RESPIRATION DATA FILE "
2820 ARDATA = "C:\GASDATA\" + "*.RDT"
2830 CLS : PRINT "RESPIRATION DATA FILES ARE AS FOLLOWS:": PRINT : FILES ARDATA
2840 PRINT : INPUT "PLEASE INPUT RESPIRATION DATA FILE NAME (NO EXTENSION(.XXX) ONLY FILE NAME)"; ARFNM: ARFNM = "C:\GASDATA\" + ARFNM + ".RDT"
2850 OPEN ARFNM FOR INPUT AS #1
2860 CLS : INPUT "INPUT TITLE OF MEASUREMENT"; ANTITLE
2870 ANTIME = ""
2880 FOR L = 1 TO 200
2890 NYEAR(L) = 0: NMTH(L) = 0: NDAY(L) = 0: NHOUR(L) = 0: NMIN(L) = 0: NSEC = 0
2900 FOR M = 1 TO 4
2910 NCH(L, M) = 0: NST(L, M) = 0: DATAN(L, M) = 0!
2920 NEXT M
2930 NEXT L
2940 NDATAR = 1: NER = 0
2950 INPUT #1, A1, A2, A3, A4, A5, A6
2960 NST(NDATAR, 1) = VAL(MID$(A3, 9, 1)): IF NST(NDATAR, 1) <> 0 GOTO 3130
2970 NST(NDATAR, 2) = VAL(MID$(A4, 9, 1)): IF NST(NDATAR, 2) <> 0 GOTO 3130
2980 NST(NDATAR, 3) = VAL(MID$(A5, 9, 1)): IF NST(NDATAR, 3) <> 0 GOTO 3130
2990 NST(NDATAR, 4) = VAL(MID$(A6, 9, 1)): IF NST(NDATAR, 4) <> 0 GOTO 3130
3000 ANTIME(NDATAR) = A2
3010 NYEAR(NDATAR) = VAL(MID$(A2, 1, 2)): NMTH(NDATAR) = VAL(MID$(A2, 3, 2)): NDAY(NDATAR) = VAL(MID$(A2, 5, 2))
3020 NHOUR(NDATAR) = VAL(MID$(A2, 7, 2)): NMIN(NDATAR) = VAL(MID$(A2, 9, 2)): NSEC(NDATAR) = VAL(MID$(A2, 11, 2))
3030 NCH(NDATAR, 1) = VAL(MID$(A3, 1, 2)): DATAN(NDATAR, 1) = VAL(MID$(A3, 10, 6))
3040 NCH(NDATAR, 2) = VAL(MID$(A4, 1, 2)): DATAN(NDATAR, 2) = VAL(MID$(A4, 10, 6))
3050 NCH(NDATAR, 3) = VAL(MID$(A5, 1, 2)): DATAN(NDATAR, 3) = VAL(MID$(A5, 10, 6))
3060 NCH(NDATAR, 4) = VAL(MID$(A6, 1, 2)): DATAN(NDATAR, 4) = VAL(MID$(A6, 10, 6))
3070 DATAN(NDATAR, 1) = (DATAN(NDATAR, 1) - V(1)) * ((C(5) - C(1)) / (V(5) - V(1))) + C(1)
```

```
3075 CV = DATAN(NDATAR, 2) / 100: GOSUB 4220: DATAN(NDATAR, 2) = CV
3080 DATAN(NDATAR, 2) = (DATAN(NDATAR, 2) - V(2)) * ((C(6) - C(2)) / (V(6) - V(2))) + C(2)
3085 CV = DATAN(NDATAR, 3) / 100: GOSUB 4250: DATAN(NDATAR, 3) = CV
3090 DATAN(NDATAR, 3) = (DATAN(NDATAR, 3) - V(3)) * ((C(7) - C(3)) / (V(7) - V(3))) + C(3)
3100 DATAN(NDATAR, 4) = (DATAN(NDATAR, 4) - V(4)) * ((C(8) - C(4)) / (V(8) - V(4))) + C(4)
3110 NDATAR = NDATAR + 1
3120 GOTO 3140
3130 NER = NER + 1
3140 IF EOF(1) THEN 3150 ELSE 2950
3150 CLOSE
3160 NDATAR = NDATAR - 1
3170 'GAS CONSUMPTION/PRODUCTION CALCULATION FOR EVERY SCAN DATA
3180 DTO2 = 0!: DTCO2 = 0!: DTCH4 = 0!: INTSEC = 0
3190 FOR I = 1 TO 200: DO2(I) = 0!: DCO2(I) = 0!: DCH4(I) = 0!: NEXT I
3200 FOR I = 1 TO NDATAR - 1
3210 IF I + 1 > NDATAR GOTO 3450
3220 NDSE = NSEC(I + 1): NDSS = NSEC(I)
3230 IF NDSE < NDSS THEN NDSE = NDSE + 60
3240 NDSEC = NDSE - NDSS
3250 '
3260 DSS = NHOUR(I) * 3600 + NMIN(I) * 60 + NSEC(I)
3270 DSE = NHOUR(I + 1) * 3600 + NMIN(I + 1) * 60 + NSEC(I + 1)
3280 DO2STD = DMEAN(1) - (DMEAN(1) - DMEANB(1)) * (DSS - DSSA) / (DSSB - DSSA)
3290 DO2STE = DMEAN(1) - (DMEAN(1) - DMEANB(1)) * (DSE - DSSA) / (DSSB - DSSA)
3300 DO2S = (DO2STD / 100 - (DATAN(I, 1) / 100)) * (DATAN(I, 4) / 60)
3310 DO2E = (DO2STE / 100 - (DATAN(I + 1, 1) / 100)) * (DATAN(I + 1, 4) / 60)
3320 DO2(I) = (NDSEC * (DO2S + DO2E)) / 2: DTO2 = DTO2 + DO2(I)
3330 DCO2STD = DMEAN(2) - (DMEAN(2) - DMEANB(2)) * (DSS - DSSA) / (DSSB - DSSA)
3340 DCO2STE = DMEAN(2) - (DMEAN(2) - DMEANB(2)) * (DSE - DSSA) / (DSSB - DSSA)
3350 DCO2S = ((DATAN(I, 2) / 100) - DCO2STD / 100) * (DATAN(I, 4) / 60)
3360 DCO2E = ((DATAN(I + 1, 2) / 100) - DCO2STE / 100) * (DATAN(I + 1, 4) / 60)
3370 DCO2(I) = (NDSEC * (DCO2S + DCO2E)) / 2: DTCO2 = DTCO2 + DCO2(I)
3380 DCH4STD = DMEAN(3) - (DMEAN(3) - DMEANB(3)) * (DSS - DSSA) / (DSSB - DSSA)
3390 DCH4STE = DMEAN(3) - (DMEAN(3) - DMEANB(3)) * (DSE - DSSA) / (DSSB - DSSA)
3400 DCH4S = ((DATAN(I, 3) / 100) - DCH4STD / 100) * (DATAN(I, 4) / 60)
3410 DCH4E = ((DATAN(I + 1, 3) / 100) - DCH4STE / 100) * (DATAN(I + 1, 4) / 60)
3420 DCH4(I) = (NDSEC * (DCH4S + DCH4E)) / 2: DTCH4 = DTCH4 + DCH4(I)
3430 INTSEC = INTSEC + NDSEC
3440 NEXT I
3450 'CALCULATION FOR PER 1 HOUR
3460 DTO2 = (DTO2 * 3600) / INTSEC: IF DTO2 < 0 THEN DTO2 = 0
3470 DTCO2 = (DTCO2 * 3600) / INTSEC: IF DTCO2 < 0 THEN DTCO2 = 0
3480 DTCH4 = (DTCH4 * 3600) / INTSEC: IF DTCH4 < 0 THEN DTCH4 = 0
3490 IF DTO2 = 0 THEN GOTO 3500 ELSE GOTO 3510
3500 RQ = 0: GOTO 3520
3510 RQ = DTCO2 / DTO2
3520 'FROM McLEAN'S EQUATION(HPMC=KCAL/HR, HPMJ=KJ/HR)
3530 DHPMC = DTO2 * 4.89: DHPMJ = 4.184 * DHPMC
3540 'FROM BROUWER'S EQUATION(HPBC=KCAL/HR, HPBJ=KJ/HR)
3550 DHPBC = DTO2 * 3.866 + DTCO2 * 1.2 - DTCH4 * .518: DHPBJ = 4.184 * DHPBC
3560 CLS : LOCATE 3, 5: PRINT "RESPIRATION DATA PRINT OUT AND/OR SAVE TO HARD DISK ?"
3570 LOCATE 5, 7: PRINT "NO OUTPUT FOR RESPIRATION DATA.........0"
3580 LOCATE 7, 7: PRINT "PRINT OUT ONLY.........................1"
3590 LOCATE 9, 7: PRINT "SAVE TO HARD DISK ONLY.................2"
3600 LOCATE 11, 7: PRINT "BOTH PRINT OUT AND HARD DISK...........3"
3610 INPUT IOT
3620 LOCATE 16, 5: INPUT "INPUT NUMBER IS OK ? (Y/N)"; ANS
```

```
3630 IF ANS <> "Y" GOTO 3560
3640 IF IOT = 0 GOTO 4080
3650 ON IOT GOTO 3660, 3920, 3660
3660 LPRINT "TITLE OF MEASUREMENT: "; : LPRINT ANTITLE: LPRINT : LP = LP + 2
3670 LPRINT "RESPIRATION GAS CONCENTRATION DATA (%) *** ABNORMAL DATA SKIPPED": LPRINT
3680 LPRINT "TIME:YYMMDDHHMMSS CH STS   O2  CH STS  CO2  CH STS  CH4  CH STS  FLOW"
3690 LPRINT "-----------------------------------------------------------------------------": LP = LP + 4
3700 FOR L = 1 TO NDATAR
3710 LPRINT SPC(3); : LPRINT USING "& &"; ANTIME(L);
3720 FOR M = 1 TO 3
3730 LPRINT USING "####"; NCH(L, M); NST(L, M);
3740 LPRINT USING "###.###"; DATAN(L, M);
3750 NEXT M
3760 LPRINT USING "####"; NCH(L, 4); NST(L, 4);
3770 LPRINT USING "####.##"; DATAN(L, 4): LP = LP + 1
3780 IF LP < 63 GOTO 3800
3790 LPRINT CHR$(12): LP = 0
3800 NEXT L
3810 LPRINT "-----------------------------------------------------------------------------": LPRINT : LP = LP + 2
3820 IF LP < 55 GOTO 3840
3830 LPRINT CHR$(12): LP = 0
3840 LPRINT "      O2 Cons(l/hr)   CO2 Prod(l/hr)   CH4 Prod(l/hr)            RQ": LPRINT SPC(3);
3850 LPRINT USING "############.##"; DTO2; DTCO2; DTCH4; RQ
3860 LPRINT : LPRINT "   Heat Production                   kcal/hr     KJ/hr"
3870 LPRINT "     by McLean's Equation        "; : LPRINT USING "######.###"; DHPMC; DHPMJ
3880 LPRINT "   Heat Production                   kcal/hr     KJ/hr"
3890 LPRINT "     by Brouwer's Equation       "; : LPRINT USING "######.###"; DHPBC; DHPBJ
3900 LPRINT CHR$(12): LP = 0
3910 IF IOT = 1 GOTO 4080
3920 OPEN AAFILE FOR APPEND AS #1
3930 PRINT #1, "TITLE OF MEASUREMENT: "; ANTITLE
3940 PRINT #1, "TIME    "; ","; "  O2"; ","; "  CO2"; ","; "  CH4"; ","; " FLOW"
3950 FOR L = 1 TO NDATAR
3960 PRINT #1, ANTIME(L); ",";
3970 FOR M = 1 TO 3
3980 PRINT #1, DATAN(L, M);
3990 NEXT M
4000 PRINT #1, DATAN(L, 4)
4010 NEXT L
4020 PRINT #1, "O2 Cons(l/hr)"; ","; "CO2 Prod(l/hr)"; ","; "CH4 Prod(l/hr)"; ","; " RQ"
4030 PRINT #1, DTO2, DTCO2, DTCH4, RQ
4040 PRINT #1, "Heat Production"; ","; "kcal/hr"; ","; " KJ/hr"
4050 PRINT #1, "  by McLean's Equation"; ","; : PRINT #1, DHPMC, DHPMJ
4060 PRINT #1, "Heat Production"; ","; "kcal/hr"; ","; " KJ/hr"
4070 PRINT #1, "  by Brouwer's Equation"; ","; : PRINT #1, DHPBC, DHPBJ
4080 CLOSE #1
4090 CLS : PRINT , "TITLE OF MEASUREMENT: "; ANTITLE
4100 PRINT "      O2 Cons(l/hr)   CO2 Prod(l/hr)   CH4 Prod(l/hr)            RQ": PRINT SPC(3);
4110 PRINT USING "############.##"; DTO2; DTCO2; DTCH4; RQ
4120 PRINT : PRINT "   Heat Production                   kcal/hr     KJ/hr"
4130 PRINT "     by McLean's Equation        "; : PRINT USING "######.###"; DHPMC; DHPMJ
4140 PRINT "   Heat Production                   kcal/hr     KJ/hr"
4150 PRINT "     by Brouwer's Equation       "; : PRINT USING "######.###"; DHPBC; DHPBJ
4160 INPUT "CONTINUE CALCULATION (Y) OR END (E)"; ANS
4170 IF ANS <> "Y" AND ANS <> "E" GOTO 4160
4180 IF ANS = "E" GOTO 4200
```

```
4190 GOTO 630
4200 SYSTEM
4210 PRINT , DATAN(L, 4)
4220 'LINEARIZATION OF CO2 VOLTAGE DATA
4230 CV = ((.0776 * (CV ^ 3) + .2723 * (CV ^ 2) + .6545 * CV)) * 100
4240 RETURN
4250 'LINEARIZATION OF CH4 VOLTAGE DATA
4260 CV = ((.1087 * (CV ^ 3) + .1647 * (CV ^ 2) + .7265 * CV)) * 100
4270 RETURN
```

フェースマスクを用いた開放式呼吸試験システム

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摘　要

牛におけるエネルギー代謝を研究するため、タイ国コンケン市にあるコンケン家畜栄養研究センターにフェースマスクを用いた開放式呼吸試験システムを構築した。このシステムは１）通気部、２）サンプルガス採取部、３）ガス分析部、４）データ集録部から構成されている。データ取り込みと計算用プログラムはそれぞれIBM互換機コンピュータ用Ｑベーシックで書かれている。システムの回収率を窒素ガスと炭酸ガスをそれぞれ用いて検定した。回収率の全体的な平均は93.3%で、標準偏差は用いた方法により0.8-1.7%であった。本システムは構築のための費用がヘッドケージ法やチャンバー法に比べ小さく、発展途上国における反芻家畜の代謝試験実施に有効であると考えられる。

キーワード；牛、エネルギー代謝、呼吸試験装置

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