A microcomputer-based system for continuous measurement of rodent food intake

RAY T. STERNER

U.S. Fish and Wildlife Service, Denver Wildlife Research Center, Denver, Colorado 80225

A microcomputer-based system is described for the automatic acquisition, storage, and analysis of rodent food intakes. The feed-o-meter provides reliable, valid measurements of consumption, with minute-by-minute accuracy of ≥ 0.03 g.

Numerous descriptions of equipment for monitoring the continuous eating patterns of rats have been published: (1) strain gauge devices (Armstrong & Coleman, 1979; Le Magnen & Devos, 1970; Le Magnen & Tallon, 1966), (2) contact-type circuits (Beauchamp, Donovan, & Burright, 1972; Fallon, 1965; Morrison & Coffey, 1973; Strohmayer, Silverman, & Grinker, 1980), (3) leverpress systems (Belagura & Coscina, 1969; Kisseleff, 1970; Panskepp, 1973; Thomas & Mayer, 1968), and (4) photocell systems (Davies, 1977; Morrison & Coffey, 1973; Yanura & Suzuki, 1979). To date, however, almost all of these approaches have utilized chart-paper recorders for documentation of response patterns, an approach involving labor-intensive analysis. The contact and photocell systems equate rodent proximity to food cups as consumption, and many of the leverpress systems utilize pellet dispensers, devices that may assess operant or hoarding responses rather than actual ingestive behaviors.

Developments in the electronic and computer industries have yielded hardware applicable to the continuous measurement of food intake by rodents. Modern electronic balances obviate the fabrication of elaborate strain gauge devices (Armstrong & Coleman, 1979; Le Magnen & Tallon, 1966), and increased memory capacities of recent microcomputers (i.e., 24-96 KB), coupled with numerous storage peripherals, make chart-paper recorders obsolete.

In the system described here, dry weights of individual food cups are monitored by means of electronic analog-digital balances that are dedicated to a Z-80A incorporated microprocessor. Times and magnitudes of

weight removals (food consumption) are stored on floppy diskettes for later analyses with auxiliary BASIC language programs or commercial file management/statistical analysis systems.

DESCRIPTION OF THE SYSTEM

The system is composed of two main elements, hardware (which includes microcomputer and peripheral equipment and auxiliary food measurement equipment) and software (see Figure 1). Essentially, remote-sensor electronic balances hold food cups in front of individual rat-housing cages. These are connected by a multiplexer/demultiplexer to a microcomputer having dual floppy diskettes. Peripherals include a CRT display with keyboard, printer, and phone modem. Special cage modifications allow rodents access to one or two food cups while preventing escape of the animals and distortion of sensors. Software governs the automatic collection, storage, and analysis of temporal changes in sensor weights (i.e., food removals).

The system was built to my specifications by Scientech, Inc. (Boulder, Colorado). Several hardware and software modifications were provided by L & L Enterprises (Arvada, Colorado), and a program option for collecting two-choice food-preference data was prepared by Symbolics, Inc. (Lakewood, Colorado).

Microcomputer and Peripheral Equipment

The microcomputer and peripheral equipment consist of six main components: (1) four Scientech 3300-08 analog/digital electronic balances with remote sensors (Scientech, Inc.), (2) a Scientech 303 octaport multiplexer/demultiplexer (Scientech, Inc.), (3) a Northstar HORIZON II microprocessor with floppy diskette storage (North Star Computers, Inc., Berkeley, California), (4) a Hazletine 1500 CRT video display terminal (Hazletine Corporation, Greenlawn, New York), (5) a TI 820-RO printer (Texas Instruments, Inc., Houston, Texas), and (6) an AD-342 Anderson-Jacobson modem (Anderson-Jacobson, Inc., San Jose, California). Specific items were selected because of efficiency, reliability, or cost, but all equipment is RS-232-C compatible.

Scientech 3300-08 balances. Each 3300-08 electronic

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Figure 1. Schematic illustration of the rodent feed-o-meter system.

balance is a dual range (i.e., 0-20 g or 0-200 g), analog/digital instrument. The present application uses four balances operating in the 0- to 200-g range with BCD-coded 1-2-4-8 parallel TTL logic (i.e., inclusion of eight balances per octaport is possible). Each balance consists of a chassis (11.4 x 18.7 x 27.9 cm; 5.5 kg; seven-segment, five-character LED digital readout) and a cylindrical remote sensor (5.75 x 3.25 cm in diameter; 1.24 kg). The hard-wired sensor allows automatic monitoring of a food cup up to 8 m from the chassis.

An important feature of the balances is the "weight-averaging" function. This programmable function allows the user to set each balance to compute a mean weight per sampling interval, with an average weight derived from numerous within-interval readings of 1- to 85-sec durations. The advantage of weight averaging is the attenuation of extraneous vibrations.

Sciencetech 303 octaport. The multiplexer/demultiplexer provides an interface between the HORIZON II and Sciencetech balances. The octaport has eight bit-serial connectors and four bit-parallel connectors. The serial connectors have transmit, receive, clear-to-send, and secondary clear-to-send lines as defined by RS-232-C specifications. The serial data rate is selectable from 110 to 9,600 baud, but a uniform baud rate is required among components. Two of the parallel connectors serve as input connectors and have eight input bits, a latch bit, and two output bits; the other two serve as output connectors with eight output bits and four undedicated input bits. Parallel lines are TTL compatible; serial lines are RS-232-C compatible.

HORIZON II microcomputer. The Northstar HORIZON II is the main control unit of the system and utilizes a Z-80A microprocessor. Several important specifications of the computer are: S-100 bus structure, 4-MHz internal clock, two Shugart SA400 minifloppy diskette storage drives (Shugart Associates, Sunnyvale, California), 32-KB fully static memory, and Northstar DOS 4.0 (disk operating system) with an Extended-BASIC language (North Star, Note 1). All software and hardware functions are controlled by the HORIZON II.

Hazletine 1500 video display terminal with keyboard. The Hazletine 1500 CRT with keyboard is the main communications link between the user and other system hardware. The terminal displays up to 24 80-column lines of ASCII-coded characters. All program generation, system operation, and hardware operation are input and monitored by this terminal.

TI 820-RO printer. All printed output is handled by the Texas Instrument 820 receive-only terminal. This is a microprocessor-based impact-type printer (i.e., 9 by 7 matrix/character font; 150 cps).

Anderson-Jacobson AD-342 modem. Telephone transmission of diskette-stored data is possible by means of the Anderson-Jacobson AD-342 modem at selected rates (i.e., 0-450 baud). This device is wired in series with the Hazletine 1500, Sciencetech 303 octaport, and HORIZON II. Rate of transmission is governed by baud switches, but it must be the same among peripherals and agree with JCL specifications of commercial data file management systems.

Auxiliary Food Measurement Equipment

The rat-housing cage and auxiliary equipment are illustrated in Figure 2. Each rat is housed in an individual wire-mesh cage (25 x 20 x 18 cm) supported 25 cm above a table surface by separate mounting stands (30 x 25 x 50 cm). An approximately 10-cm² port is cut in the lower center of each cage front. A Plexiglas cylinder (.3 x 15 x 9 cm in diameter) is mounted to the cage front, with an approximately 10-cm² opening in the Plexiglas aligned directly over the "food port" of the wire cage. The top of this cylinder is sealed with .3-cm Plexiglas (9-cm in diameter). The bottom is fitted with an 8-cm-diameter stainless steel food guard having a concave surface to a 3.3-cm-diameter opening; this guard is held in position by a hose clamp that compresses the bottom of the Plexiglas cylinder. Together, these cage alterations allow each rat access to the food cup but prevent escape and minimize sensor distortion during feeding.

Each sensor holds a cylindrical Pyrex food cup (No. 3140; 5 cm high x 7 cm in diameter). Each cup is glued to a shallow plastic dish (.75 cm deep x 9 cm in diameter) that serves to catch spillage. A laboratory support jack ("Big Jack," Precision Scientific, Chicago, Illinois) holds the sensor and cup beneath the food guard. Each jack rests on a 2.5-cm-thick foam rubber

Figure 2. Detail of the auxiliary food measurement equipment used to position the sensor and food cup in front of the rat-housing cage.

pad to reduce vibration of the sensors. Sensors and cups must be positioned carefully (i.e., avoid contact with other surfaces) to ensure error-free recording. Sizing of the "food port" is also critical to prevent rodents' crawling onto the food guard, thereby distorting the sensors.

Software

Data acquisition, storage, and reduction is governed by an Executive Program (MENU) that offers a choice of seven user options: (1) parameter-file maintenance, (2) collect data, (3) print data, (4) graph data, (5) two-choice data, (6) convert data, and (7) transfer data to modem. All of these programs are written in an interactive mode, and the user specifies a set of parameters with the Hazletine 1500. A short description of each routine follows.

Executive program (Menu). Menu is a 38-line control program that governs the loading of seven optional data collection, conversion, and analysis programs into memory. A copy of Menu is listed in Part 1 of the appendix. Lines 70-130 inclusive show the PRINT statements displayed as seven options for the user. Following depression of the numbered option on the Hazletine 1500 keyboard, Menu "CHAINS" to the selected program, and, upon completion, each program "CHAINS" back to Menu.

Parameter-file maintenance (Option 1). This is a 300-line program that stores data identifiers (header information) on the data diskette. Ten identifiers are requested and stored: password (i.e., ≤ 10 characters used for file security), title (i.e., ≤ 20 characters of descriptive information about the study), date (i.e., MM/DD/YY numeric code for date), scan interval (i.e., ≤ 2 -digit numeric that specifies the number of minutes elapsing between scans of the balances), min/

max change-in-state criteria (i.e., numeric values that specify the minimum and maximum weight, in grams, difference used to record food consumption), low/high graph value (i.e., numeric values that specify the minimum and maximum weight differences used as bounds of the abscissa by the graph program), and light-on/off times (i.e., two HH:MM times that specify the diurnal light-dark schedule used during data collection).

No real-time clock functions are available. Scan intervals accurate to 1 min (i.e., range = 1-60 min) are handled by counter circuits. Numerous error-detection loops and diagnostics are included; these account for much of the program's length.

Collect data (Option 2). The data collection program is a 314-line program that compares and stores weight differences occurring for each balance (sensor) at specified scan intervals. Functions of this program include addressing of the octaport (Scientech 303) and data handling (i.e., serial/parallel bit conversion and test), monitoring of time (i.e., scan interval), and comparing of balance weights to prior weights and the change-in-state criterion.

Collect data also offers the user three subroutines: collect, wait, and exit to Menu. The collect subroutine (see Part 2 of the appendix) specifies that each balance will be scanned for the remaining weight after a specified interval obtained from parameter-file maintenance. This weight is then subtracted from the previous lowest recorded weight and compared to the change-in-state criterion entered in the parameter file. If this difference exceeds criterion, the time, sensor, and magnitude of difference (in milligrams) are stored onto the data diskette; otherwise, no new data are recorded, but time is updated and scan interval is reinitiated. The wait subroutine simply precludes read/write operations until collect is reinitiated, a useful function to allow care of animals. Exit to Menu is self-explanatory.

Print data (Option 3). This is an 89-line program that prints the data recorded by the collect data program. Output includes (1) select header information, (2) spurious data entries, (3) times and amounts of food consumption (in milligrams) recorded for each balance, and (4) sums of the weight differences recorded for each balance.

Graph data (Option 4). This is a 101-line program that generates a histogram plot of the food-intake profile for each rat. The abscissa is specified in equal increments bounded by the minimum and maximum weights (in milligrams) cited in the parameter-file program. The ordinate represents numbers of scan intervals during which weight differences of specified magnitudes were recorded.

Two-choice data (Option 5). This 240-line program controls the collection and printing of food-intake measurements during a two-choice preference test. Change-in-state data are stored for two sensors representing a single rodent.

Convert data (Option 6). The convert data program

is a 96-line program designed to reorder data collected using two-choice preference. Data for each sensor are copied to a "scratch disk" for printing in the collect data mode.

Transfer data to modem (Option 7). The modem option loads a 52-line program into memory that addresses the octaport to the Anderson-Jacobson modem. Data are transmitted at 300 baud by means of phone line for subsequent analysis or storage using commercial data file/statistical systems (e.g., SAS, SPSS).

EXPERIMENTAL USE OF THE SYSTEM

Eight tests were conducted to determine the operating characteristics and effectiveness of the system. Each balance was calibrated at the start of tests by using standard laboratory weights; the weight-average function of balances was suppressed throughout these procedures.

Validity (Tests 1 and 2)

Tests 1 and 2 were each 4-h validation tests conducted to verify that data stored on floppy diskette (i.e., collect data) were valid measurements of the weight removed from system balances. For both tests, balances were zeroed and the sensors were loaded with cups containing about 150 g of dried sand. Next, the collect data program was initiated at a scan interval of 1 min; the change-in-state criterion was .01 and .05 g for respective tests. Fifty times throughout each test small quantities of sand (Test 1: mean = .11 g, SD = .06 g, range = .03-.32 g; Test 2: mean = .12 g, SD = .05 g, range = .03-.26 g) were removed from each cup. The time and amount of each removal were recorded by the investigator onto a data sheet.

Differences between the data stored on the diskette and those recorded by the investigator were tabulated for each test (Table 1). As shown, 96% and 99% of these measurements were $\leq .02$ g discrepant in Test 1 and 2, respectively. Moreover, with the exception of seven removals that were $< .05$ g (Test 2) and eight removals that occurred at the time balances were scanned, times of removals were recorded correctly on the diskette. These results validate both hardware and software functions associated with data acquisition.

Stability and Accuracy (Tests 3-7)

Three observations relevant to system accuracy were made during Tests 1 and 2. First, recording changes of .01 g yielded 103 false positive and 81 false negative fluctuations (see Table 1). This instability of measurements was attributed to uncontrolled electronic (e.g., heat, voltage), mechanical (e.g., vibration), and meteorological (e.g., humidity, air currents) factors. Although fluctuations generally occurred as alternate .01-g increases and decreases in weight, several .02- to .03-g fluctuations also occurred. Additionally, minor "drift" of balance weights accrued from these fluctuations (i.e., $\leq .08$ g/4-h test). Second, no spontaneous fluctuations were recorded during Test 2 (i.e., .05 g change in state). This result showed that spontaneous fluctuations of balance weights could be overridden by appropriate programming. Third, removing weight from balance sensors during the approximately 5-sec scanning period caused eight data values to be combined into the subsequent scan interval (i.e., delayed 1 min).

Based on these observations, Tests 3, 4, 5, 6, and 7 were conducted to better quantify the system's stability and accuracy during a 24-h period. Standard weights of approximately 150 g of dried sand were placed on each

Table 1
Summary of Validation Data

Balance	Investigator- and System-Recorded Agreement					Fluctuation	
	Equal	$\pm .01$ g	$\pm .02$ g	$\pm .03$ g	$\pm .09$ g	.01-g FP	.01-g FN
Test 1: .01 g Δ -state							
1	20	23	5	2		25	23
2	31	13	3	3		17	9
3	28	21	1	0		28	24
4	13	23	10	4		33	25
Σ	92	80	19	9		103	81
%	46	86	96	100			
Test 2: .05 g Δ -state							
1	22	19	4	1	1	0	0
2	24	10	4	0		0	0
3	33	13	3	0		0	0
4	19	20	10	0		0	0
Σ	98	62	21	1	1	0	0
%	54	80	99	99	100		

Note—FP = false positive, FN = false negative; % = cumulative percentage. Removals for Test 2 do not sum to 50 per balance. This is due to three, two, one, and one removals of $< .05$ g occurring for Balances 1, 2, 3, and 4, respectively. These data are not lost, but they are combined into the subsequent scan interval, in which a total removal of $\geq .05$ g is detected.

sensor, and the collect data program initiated. All of these tests involved a 1-min scan interval, whereas change-in-state criteria were designated at .01, .02, .03, .04, and .05 g during respective tests.

Balance recordings were "smoothed" as the change-in-state criteria increased. Mean (and standard deviation) spontaneous fluctuations across the four balances were 274.5 (88.8), 14.8 (20.9), 1 (1.2), 1 (2), and 0 (0) during the .01-, .02-, .03-, .04-, and .05-g criterion tests, respectively. Average (and standard deviation) "drift" of balance weight was .03 (.02), .06 (.05), 0, 0, and 0 for these tests. Of 1,095 recorded fluctuations in the five tests, 91% occurred in Test 3 (i.e., .01-g criterion). Only four fluctuations occurred using the .03- and .04-g criteria, with "drift" cancelled over the 24-h period. As in Test 2, fluctuations were eliminated by using the .05-g criterion, as well as with the .04-g value (i.e., Tests 6 and 7). Thus, the programmed change-in-state parameter overrides system instabilities, allowing minute-by-minute measurement accuracy of $\geq .03$ g.

Effectiveness (Test 8)

Test 8 was conducted to demonstrate the operational use of the "feed-o-meter." Briefly, I monitored the minute-by-minute food intakes of eight male Sprague-Dawley albino rats (Charles River Laboratories, Wilmington, Massachusetts) for 3 consecutive days. The procedure involved single-choice presentation of ground Purina Rat Chow. Test cages were in a partially sound-proof, temperature-controlled (20°C-23°C) room. A 12:12 h light-dark schedule (i.e., 0800-1959 h and 2000-0759 h, respectively) was maintained before and during the test. Rats were allowed 4 days adaptation to test cages. Ad-lib feeding patterns were measured during consecutive 23-h periods daily (i.e., 0900-0759 h), with maintenance of rats and data files occurring between 0800-0859 h. Sensors were loaded daily with a glass food cup containing approximately 150 g of chow, and the collect data program was initiated using a scan interval of 1 min with a change-in-state criterion of .05 g.

Mean (and standard error) daily food intake was 20.5 g (.24) and occurred during a daily average of 92.9 min (4.1) of eating. As expected, a strong nocturnal effect was evident; 74% of the 3-day consumption and 80% of all ingestion times (in minutes) were recorded during the "dark" segments of the light schedule. Spillage was monitored by weighing the daily amounts of food in the "catch plates" (see Figure 2); this averaged .53 g (SE = .12, range = .09-1.75) per day, values that minimally affected eating patterns.

Figure 3A shows the minute-by-minute food consumption patterns of the eight rats, and Figure 3B is an enlargement of the 2200- to 0130-h portion of Rat 1's record for Day 1. Note the distinct "meals" characterizing these data. Data for Rats 1-4 show consistent intakes of several 20- to 60-min meals during the dark period,

Figure 3. (A) Minute-by-minute food-intake patterns of eight albino rats during the 3-day ad-lib feeding test (i.e., Rat 1 = top . . . Rat 8 = bottom). (Note—The dashed portion of each abscissa refers to the 1-h maintenance period between 0800 h and 0859 h daily; no food consumption measurements were recorded during this period.) (B) Enlargement of the consumptions by Rat 1 between 2200 h and 0130 h of Day 1.

whereas patterns of Rats 5-8 indicate more frequent, shorter meals.

Numerous prior studies have shown that rats are not random feeders (Belagura & Coscina, 1969; Le Magnen & Devos, 1970; Le Magnen & Tallon, 1966; Levitsky, 1970; Panskepp, 1973). Data for albino rats have indicated that 60%-70% of daily food intake is ingested as 6-12 meals during the nocturnal portion of the circadian cycle (Belagura & Coscina, 1969; Kisseleff, 1970). Although definitions of "meals" vary among investi-

gators, the observed nocturnal and meal-eating patterns agree sufficiently with earlier reports (i.e., Kisseleff, 1970; Le Magnen & Tallon, 1966; Panskepp, 1973) to confirm efficacy of the system.

REFERENCE NOTE

1. North Star. *System software manual* (North Star Computers Soft-Doc Revision 2.1). Berkeley, Calif: Author, 1979.

REFERENCES

- ARMSTRONG, S., & COLEMAN, G. A strain gauge device for measuring feeding or drinking in laboratory rats. *Physiology & Behavior*, 1979, **23**, 1153-1156.
- BEAUCHAMP, J., DONOVICK, P. J. & BURRIGHT, R. G. An automated system for long term and continuous computer compatible recording of feeding, drinking and general activity behaviors of rodents. *Physiology & Behavior*, 1972, **8**, 765-768.
- BELAGURA, S., & COSCINA, D. V. Influence of gastrointestinal loads on meal-eating patterns. *Journal of Comparative and Physiological Psychology*, 1969, **69**, 101-106.
- DAVIES, R. F. Long- and short-term regulation of feeding patterns in the rat. *Journal of Comparative and Physiological Psychology*, 1977, **91**, 574-583.
- FALLON, D. Eatometer: A device for continuous recording of free-feeding behavior. *Science*, 1965, **148**, 977-978.
- KISSELEFF, H. R. Free feeding in normal and "recovered lateral" rats monitored by a pellet-detecting eatometer. *Physiology & Behavior*, 1970, **5**, 163-173.
- LE MAGNEN, J., & DEVOS, M. Metabolic correlates of the meal onset in the free food intake of rats. *Physiology & Behavior*, 1970, **5**, 805-814.
- LE MAGNEN, J., & TALLON, S. La periodicite spontanee de la prise d'aliments ad libitum du rat blanc. *Journal de Physiologie (Paris)*, 1966, **58**, 232-349.
- LEVITSKY, D. A. Feeding patterns of rats in response to fasts and changes in environmental conditions. *Physiology & Behavior*, 1970, **5**, 291-300.
- MORRISON, S. D., & COFFEY, N. F. Feeding activity and feeding efficiency as distinct modes of change in food intake. *Journal of Applied Physiology*, 1973, **34**, 268-270.
- PANSKEPP, J. Reanalysis of feeding patterns in the rat. *Journal of Comparative and Physiological Psychology*, 1973, **82**, 78-94.
- THOMAS, D. W., & MAYER, J. Meal taking and regulation of food intake by normal and hypothalamic-hyperphagic rats. *Journal of Comparative and Physiological Psychology*, 1968, **66**, 642-653.
- STROHMAYER, A. J., SILVERMAN, G., & GRINKER, J. A. A device for the continuous recording of solid food ingestion. *Physiology & Behavior*, 1980, **24**, 789-791.
- YANURA, S., & SUZUKI, T. Eating pattern of morphine dependent rats. *Japanese Journal of Pharmacology*, 1979, **29**, 753-762.

Appendix

Part 1

```
10 REM ***** MENU *****
20 DIM M$(80)
30 GOTO 50
40 !CHR$(7)
50 ERRSET 88,L,E GOSUB 250
60 !
70 !5=25 H5=19 V5=9 M$="1 = enter parameter file maintenance" GOSUB 330
80 H5=19 V5=10 M$="2 - collect data from balances" GOSUB 330
90 H5=19 V5=11 M$="3 - print collected data" GOSUB 330
100 H5=19 V5=12 M$="4 - graph data collected" GOSUB 330
110 H5=19 V5=13 M$="5 - print report of 2-choice data" GOSUB 330
120 H5=19 V5=14 M$="6 - change data form of 2-choice" GOSUB 330
130 H5=19 V5=15 M$="7 - transfer data from diskette to modem" GOSUB 330
140 !5=31 H5=28 V5=6 M$="ENTER FUNCTION" GOSUB 330
150 N$=INCHAR$(0) N=VAL(N$) IF N<1 THEN 170 IF N>7 THEN 170
160 ON N GO TO 180, 190, 200, 210, 220, 230, 240
170 !CHR$(7), GO TO 140
180 CHAIN "PARM"
190 CHAIN "COLLECT"
```

```
200 CHAIN "PRINT"
210 CHAIN "GRAPH"
220 CHAIN "2-CHOICE"
230 CHAIN "DATAFORM"
240 CHAIN "MODEM"
250 REM***** SET UP SCREEN *****
260 !CHR$(126),CHR$(28), !CHR$(126),CHR$(25),
270 !TAB(23), "ANIMAL DATA COLLECTION SYSTEM"
280 !TAB(17), "U S FISH & WILDLIFE, DENVER, COLORADO" !
290 !CHR$(126),CHR$(31),TAB(16), "***** A E N U *****"
300 RETURN
310 REM ** POSITION CURSOR & PRINT M$ **
320 !CHR$(126),CHR$(15),
330 !CHR$(126),CHR$(17),CHR$(H5-1),CHR$(V5-1),M$," ",
340 D=EXAM(10769)+(EXAM(10770)*256) FILL 0,0
350 IF E=0 THEN 370 IF !5=31 THEN 370 E=0 H5=62 M$="
360 GO TO 330
370 RETURN
```

Part 2

```
460 REM MISCELLANEOUS FILE-LOCATING AND RECORD-KEEPING
470 REM STEPS PRECEDE THE COLLECT DATA SUBROUTINE
480
490 *** COLLECT DATA ***
500 M1$="COLLECTING DATA"
510 M2 = M1 REM INTERVAL COUNTER, SAMPLE INTERVAL
520 IF M2 >= M1 THEN GOSUB 790
530 GOSUB 2160 REM SAMPLE KEYBOARD & UPDATE TIME
540 IF Z9$="W" THEN RETURN ELSE 520
550
560 **** TURN REMOTE POWER ON/OFF ****
570 S$="A" O = 0
580 FOR I = 1 TO 10
590 IF T < T(I,0) THEN 610
600 B = T(I,1) B1 = T(I,2)
610 NEXT I
620 RETURN
630
640 ***** SET INTENSITY, POSITION CURSOR, & PRINT M$
650 !CHR$(126),CHR$(15)
660 !CHR$(126),CHR$(17),CHR$(H5-1),CHR$(V5-1),M$,
670 FILL 0,0
680 IF E=0 THEN 700 IF !5=31 THEN 700 E=0 H5=62 M$="
690 GO TO 650
700 RETURN
710
720 **** INTERVAL ****
730
740 REM GET DATA FROM BALANCES
750 D(F1,0,0) = PRESENT DATA
760 D(F1,0,1) = PREVIOUS DATA
770 D(F1,1,0) = REFERENCE DATA
780 D(F1,1,1) = PREVIOUS OVER LIMIT (=1)
790 M2=0
800 FOR F1=0 TO S8
810 IF S(F1,1) = 0 THEN 870 REM SKIP UNSPECIFIED STATIONS
```

```
820 O = INT (F1/8)
830 R = (F1-8*O)
840 GOSUB 1460 REM GET DATA
850 D(F1,0,1) = D(F1,0,0) REM SAVE LAST INPUT
860 D(F1,0,0) = VAL (C1$) REM LOAD NEW INPUT
870 GOSUB 2160 REM UPDATE CLOCK
880 NEXT F1
890
900 REM WRITE CHANGES TO FILE
910 GOSUB 2160 REM UPDATE CLOCK
920 FOR F1 = 0 TO S8
930 IF P1=1 THEN 1040
940 IF S(F1,1) = 0 THEN 1050 REM SKIP UNSPECIFIED STATIONS
950 IF D(F1,0,0) = 999.99 THEN 1130
960 IF ABS(D(F1,1,0) - D(F1,0,0)) < C THEN 1050 REM LESS THAN MINIMUM
970 IF D(F1,1,0) - D(F1,0,0) < 0 THEN 1100 REM QUESTIONABLE DATA
980 IF D(F1,1,0) - D(F1,0,0) > C1 THEN 1100 REM GR THAN MAX
990 IF T2 = F0 THEN WRITE #0,"T",T T2=TO
1000 WRITE #0,"",F1+1,D(F1,1,0)-D(F1,0,0)
1010 M$=STR$(F1+1)+""+STR$(T)
1020 !5=25 H5=10 V5=F1+15 GOSUB 650 REM PRINT CHANGE TIME
1030 ! " LAST",D(F1,0,1)," ", "NEW",D(F1,0,0)," ", "REF",D(F1,1,0),
1040 D(F1,1,1)=F0 D(F1,1,0)=D(F1,0,0) REM RESET REFERENCE
1050 NEXT F1
1060 P1 = 0
1070 GOSUB 2160 REM UPDATE CLOCK
1080 T2=F0
1090 RETURN
1100 IF D(F1,1,1) = 0 THEN 990
1110 D(F1,1,1) = 0 GO TO 1050
1120 ***** OVERLOAD WRITE *****
1130 WRITE #0,"O",F1+1,D(F1,0,0)
1140 GO TO 1050
1150 REM !CONTINUE WITH PROGRAM)
```