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ELECTRONIC IDENTIFICATION

October 1, 1978—September 30, 1979

University of California

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by

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ABSTRACT

Livestock field-testing of the electronic identification system has commenced with experiments conducted at the Jornada Experimental Range in Las Cruces, New Mexico. Five other sites which have been selected will be phased in during the coming year. The concept of electronic identification and temperature-monitoring of livestock will then be tested in dairy, feedlot, and open-range environments to demonstrate its commercial application and feasibility. Work at Los Alamos Scientific Laboratory on the identification equipment has been directed toward improving the transponder package design and increasing the sensitivity of the receiver to the reflected transponder signal. Favorable results were obtained from the use of a hobby microcomputer in the electronic identification system. This indicates that the system is compatible with a low budget commercial system affordable to small livestock operations. A considerable amount of work has also been done relating to temperature- monitoring capability of the system because a great deal of difficulty is anticipated in making this a useful tool in the field trials. A radio telemetric physiological monitoring system has been assembled for use in monitoring animal temperature, and biological experiments have been done to test the acceptability of subdermal temperature-monitoring in livestock.

I. INTRODUCTION

This report supplements other reports that have been published in 1979,[1-6] and together, they describe the progress on the Electronic Identification of Animals Project (R-206) during FY 1979.

By 1978 the major technical problems relative to electronic identification of animals had been overcome, so there was little doubt as to whether it was possible to electronically identify animals. The primary interest of the US Department of Agriculture Animal and Plant Health Inspection Service (USDA/APHIS) in electronic identification was for disease control. However, early in the development, it was recognized that its interest would not be served unless there was a concurrent interest serving the livestock industry. The livestock industry supports electronic identification of animals because of potential benefits as a management aid as well as for disease control. Therefore, considerable attention has been directed toward promoting active support of electronic identification throughout the livestock industry by providing benefits to the users that are greater than the costs to them. Thus, the primary functions of the field test were to develop a data base from which cost-benefit analyses could be made and to transmit these data to the various potential users. Hence, there is a converging of interest of the USDA/APHIS and the livestock industry.

Widespread use of electronic identification is necessary for more effective disease control. The feature of electronic identification has the potential for being a strong promotional factor in getting widespread voluntary acceptance by the livestock industry.

Although there have been delays in obtaining a commercial supplier of equipment for field-testing, the work on temperature- monitoring has proceeded with no serious delay. Thus, temperature-monitoring constitutes a significant fraction of this report.

II. NATIONAL LIVESTOCK ELECTRONIC IDENTIFICATION BOARD

The National Livestock Electronic Identification Board (NLEIB, also called the Board) was formed under the auspices of the Livestock Conservation Institute (LCI) to guide the development of electronic identification along the lines that would be acceptable to the livestock industry. The Board has maintained a strong interest in the development of electronic identification and has met at least twice a year since 1975. It normally meets concurrently with the US Animal Health Association (USAHA) in November and with the LCI in May. In FY 1979 the Board met in Buffalo with the USAHA, and in Kansas City with the LCI. At those meetings, the Board firmly endorsed the timely implementation of field-testing with commercial equipment and urged the speedy consummation of the purchase order contract for commercial equipment. It also strongly reaffirmed its position of supporting *voluntary* electronic identification of animals and opposing mandatory electronic identification. At the May meeting concern was expressed over the position of the USAHA Brucellosis Commission where recommended compulsory identification of livestock was necessary for brucellosis eradication. The Board also decided to work with the identification subcommittee of the Brucellosis Commission to minimize differences between the two groups. The Board also agreed to sponsor information exchange meetings where the results of the field-test experiments would be disseminated to interested parties. Thus, the Board constitutes a focal point for coordinating the development of national electronic identification.

III. FIELD-TEST SITES

Visits were made to a large number of potential sites for the field test. These sites are located throughout the United States, and discussions were held at each site to ascertain the extent of their interest, the facilities and manpower available, and the ongoing program at each site. Because of the limited number of systems available, it was decided to locate these systems in places that would have the highest probability of obtaining favorable cost-benefit ratios. From previous analyses, it was determined that dairies and feedlots had the highest potential benefits, so three dairies and two feedlots were chosen. Only research facilities that had a strong practical research program were chosen as test sites because it was felt that the commercial equipment likely to be supplied would not be robust enough and reliable enough for normal commercial operations. The sites chosen were (1) Cornell University (dairy), Ithaca, New York (2) the University of California, Imperial Valley Field Station (feedlot), El Centro, California (3) the University of Illinois at Urbana-Champaign (dairy), Urbana, Illinois (4) the Meat Animal Research Center (feedlot), Clay Center, Nebraska and (5) the University of Michigan (dairy), East Lansing, Michigan. If we are unable to reach agreement with any of the first three dairy sites, an alternate at Utah State University, Logan, Utah, has been selected.

We also chose the Jornada Experimental Range near Las Cruces, New Mexico for demonstrating the LASL-designed system. The Jornada Range is operated by the USDA Science and Education Administration-Agriculture Research (SEA-AR). The main purpose of the system at the Jornada Range is to demonstrate the LASL-designed electronic identification equipment and not to demonstrate all of the possible cost-benefits that can be accrued with electronic identification. It is at a remote site that is normally not attended and where power is generated on-site and stored in batteries. Thus, we think that the problems associated with this site are more severe than those likely to be encountered at the other sites selected.

IV. ELECTRONIC IDENTIFICATION

A. Commercial Equipment

The original request for quotation to produce commercial equipment for the field test presumed that there would be more than one bidder, so the purchase order was designed to enable LASL to buy two sets of equipment from each of two successful bidders. Each company would install one system at a dairy and one at a feedlot. After comparative testing, the additional seven systems (making a total of 11) would be purchased from the company whose equipment performed the best. However, after considerable communication with potential manufacturers, it was found that the specifications based on the LASL design were more stringent than most of the companies were willing to guarantee. As a consequence, only the Raytheon Service Company (RSC), responded firmly to the purchase request.

Raytheon* had indicated that they would supply battery-powered transponders. However, LASL scientists believe that passive transponders (that is, no batteries) better fit the needs of the livestock industry and the Food and Drug Administration (FDA). The NLEIB has approved the battery-powered identifiers.

B. LASL Field-Test Equipment

In discussions with potential suppliers of commercial equipment for the field test it became apparent that the commercial vendors did not appreciate the technical problems that had been surmounted in the development of the LASL-designed equipment. Some commercial suppliers appeared to be producing equipment that could not equal the LASL-designed equipment. Because we believe that the livestock industry needs all the capabilities of the LASL equipment, it was important to demonstrate that we could meet all of the technical specifications that were required of the commercial vendors. This would preclude a possible charge by a commercial vendor that our specifications were beyond the state-of-the-art. We also believed that we could field one of our systems in considerably less time than would be possible by any commercial vendor. By providing a LASL system, we could therefore start collecting some of the experimental data on electronic identification much sooner than if we waited for the first commercial systems. We also thought it was important to be able to compare passive transponders with battery transponders to see if there were distinct advantages of one over the other.

Although most of the creative circuit design work has been completed, there remained some significant technical developments to improve the performance of the system and a considerable amount of hard work to construct the system that works in the real environments where the commercial systems must work. Indeed, one of the primary purposes of testing this equipment in a field situation is to solve the particular problems that present themselves in the livestock environment. Interactions of one piece of equipment with another are commonly necessary and the results of connecting two pieces of equipment are sometimes unpredictable.

Three general areas of equipment modification were addressed to implement the field test. (1) The existing "suitcase" interrogator was modified slightly. (2) The transponder was repackaged to reduce transponder size and decrease pressure necrosis problems. (3) A computer system was purchased for automatic data-recording.

The transponders are 14 cm long, 2.5 cm wide and 1.6 cm thick at their widest parts. Encapsulation is done by a dipping process (rather than cast), resulting in a smooth package with rounded corners. A 2.5 mm circuit board provided a mechanically flexible package. The first units of the new design have been implanted for 4 months with no troubles, indicating that the hermetic sealing problems of earlier units have decreased. Twenty-eight transponders have been implanted at present and another 30 are under construction.

*On February 13, 1980, disagreements over the acceptance tests of the equipment caused negotiations between RSC and LASL to be terminated without the signing of a final contract. This requires a reassessment of the field-test plans. If another source cannot be found, LASL will provide the equipment.

A decision was also made to evaluate the capability of a low-cost "hobby" computer for data-logging and analysis. (Although this type of computer was originally developed for the hobby market, it has proven itself capable in a variety of business, commercial, and research applications.) A Tandy TRS-80 system was selected for a variety of reasons. Considerable effort was devoted to software development for the intended data-logging application. The computer functions well, and Appendix A and B provide details of the software developed.

The TRS-80 computer was found to be reliable and more than adequate for the data-logging tasks.

C. Jornada Range Experiments

The LASL electronic ID system is currently being tested at the Jornada Experimental Range. Open-range conditions were chosen to fully test its reliability while also aiding in grazing-management research. The basic research goal of the experimental range is to improve the productivity of semidesert rangeland and stabilize the rangeland ecosystem. Research is focused on improving rangeland vegetation and developing improved grazing strategies.

Cattle diet, habit and weight-data provide the necessary information for the development of better grazing- management systems on improved and unimproved semidesert range. Automatic weighing of livestock in conjunction with body- temperature sensing provides a tool for improving herd health monitoring and management decision-making.

A field scale study was started during 1976 on the Jornada Experimental Range to determine what effect mesquite (*Prosopis juliflora var. glandulosa*) control would have on the total ecosystem and, in particular, forage and cattle production. A 17 000-acre mesquite duneland was selected for the study. An east-west cross fence was built in 1977 to divide the area into two pastures each comprising approximately 9 000 acres. The north 8 024 acres, designated 2N, has not received chemical herbicide to control mesquite, whereas the south 8 980 acres was treated twice with 2,4,5-T between 1975 and 1978 at a rate of 225 gm active ingredient per acre per treatment. Plant productivity and livestock production/behavior studies have been under way by USDA researchers on both pastures since 1977.

It is difficult to pinpoint the time period and factors that are responsible for significant weight gain or loss in livestock if cause and effect are separated by infrequent weighing. However, an electronic weighing system consisting of a single animal electronic scale, a 21-column printer, a microcomputer, a hand programmer, and a Techtran cassette recorder, all interfaced with the LASL interrogation system, makes it possible to document weight change on a continuous basis. The electronic system is located at the Wagoner Well site, which serves as a common water source for both pastures because it is located on the cross fence line separating pastures 2N and 2S. The electronic system provides date, time of day, animal weight, animal identification and subdermal body temperature in a computer-compatible form that virtually eliminates transposition errors from hand entry of data between collection and statistical analysis.

As part of the livestock production studies, 28 female offspring from both pastures born in 1976 and 1977 of Hereford x Hereford (male x female), Hereford x Santa Gertrudis, and Santa Gertrudis x Hereford were implanted with transponders during 1979. *Bos tarus* (Herefords) and *bos tarus-bos indicus* crosses (Hereford x Santa Gertrudis and their reciprocal) were chosen to evaluate possible differences in subdermal body temperature that might exist due to species differences. Both restrained weighing and automatic weighing are currently being conducted to evaluate equipment performance. Automatic weighing is taking place when animals pass through a one-way maze as they come to drink water at Wagoner Well. As the animal steps onto the scale platform, a photo beam is broken and the electronic system is activated. To insure accurate weights, a pneumatically operated cylinder closes a gate in front of the animal to stop the animal for a minimum of 3 s, during which time the animal is weighed and interrogated.

If the electronic system is operated manually, it is possible to weigh 41% more livestock per hour compared with mechanical weighing. In the automatic mode, it is possible to weigh and interrogate approximately 80% more livestock per hour compared with mechanical manual weighing, with less stress to the animals and virtually no labor requirement except for monitoring the equipment on a daily basis.

In our evaluation of the electronic ID system, our first goal will be to evaluate the cost-benefit ratio of automatic weighing and identification of livestock under field conditions. Consideration of operating costs involving labor and equipment maintenance under remote conditions will be paramount to recommendations concerning this system as a grazing-management tool.

From a research point of view this system makes it possible to obtain data that have previously been impossible to accumulate. Presently, 24 of the original 28 implanted animals are being used to compare weighings at 28-day intervals with continuous weighing. Four of the original animals implanted were culled from the experiment because a pregnancy test in November 1979 indicated the animals were not pregnant. The implants were removed and returned to LASL with tissue samples of the capsule that forms around the implant. Histological studies will be conducted on the tissue samples.

Another aspect of the multifaceted 2N-2S pasture study involves monitoring animal travel with manually read digital pedometers to compare and contrast differences in distance traveled by animals grazing chemically treated and control mesquite dune areas.

During each month, eight consecutive days of animal activity are monitored using vibracorders (clock-operated, 8-day recorders that monitor neck movement). The travel and activity data will be summarized after the July 1980 data have been collected. The information obtained will be used to evaluate energy expended by the animals during grazing.

Future studies will determine how many consecutive days automatic weighing and identification must be carried out to describe accurately and precisely the weight changes occurring within the grazing herd. In addition it will be necessary to determine how many implanted animals are required to describe the weight change occurring in an age class of the grazing herd within acceptable confidence intervals.

Conception rate is the most important limiting economic factor in range-animal grazing management. The monitoring of subdermal body temperature along with ambient weather will be studied to determine if estrus and conception can be accurately predicted within the grazing herd. Also, stress detection through subdermal body-temperature monitoring may be possible. Studies involving methods of gathering animals and periods of weight loss (shrink) will be studied in different seasons.

Cooperative work with the National Aeronautics and Space Administration is under way to develop an electronic pedometer that can be monitored when animals pass over the electronic scales on their way to water. An electronic pedometer incorporated into the automated system would make it possible not only to obtain the weight of the animal, its frequency and time of coming to water, its identity, and its subdermal temperature, but also information on how far the animal has walked since the last interrogation. These data also can be correlated to weather conditions. Automatic collection of data will provide considerably greater accuracy than has been possible in the past with considerably less manpower requirements and less interference with animal behavior.

Tentative results indicate the electronic techniques used to identify animals, to sense subdermal body temperature and to obtain animal weights are sound. Commercial adoption of electronic ID, therefore, should be a reality in the not too distant future.

D. A New Two-Channel Homodyne Receiver

A new two-channel homodyne receiver provides multiple channel signals in a single- antenna homodyne radar system. The receiver is suited particularly for the needs of the LASL electronic ID system. In our ID system, a remote transponder modulates the scattered radio frequency (rf) signal in a coded fashion. This rf signal is received by a homodyne receiver to recover the low- frequency coded portion of the signal. If it is received by a single-channel homodyne receiver, the signal will exhibit "null regions." These null regions are, spaced by a quarter of a wavelength. No coded signal will be output in these regions because the incoming coded rf signal is in phase quadrature with the local reference signal. (Radar speed- measuring devices count these null regions to determine a vehicle's speed.) To eliminate this problem, it is common practice to provide two or more channels using an arrangement of power splitters and mixers. Additionally, present receivers require some means to separate the transmitted and received signals. This can be done by using two antennas, a circular or a directional coupler. Multiple antennas are not usually used because of the resultant increase in bulk. A circulator provides greater sensitivity to the received signal, but it may cause burnout of power splitters and mixers. Since a directional coupler provides greater protection of these components, we have incorporated the coupler into the receiver package. The cost of a two-channel receiver (in use in present systems) is about $700.

The new receiver provides multiple outputs to eliminate "null regions," provides sensitivity equal to or better than the receivers discussed above, is immune to burnout troubles from large reflections, and can be constructed at about 1/50th of the cost of the old receiver. The basic receiver is sketched in Fig. 1.

The transmitted voltage from the rf source is added vectorally to the received voltage coming from the interrogator antenna. (This received voltage may also contain a large unwanted and uncoded component.) The phase between the transmitted and received voltage depends on the position along the transmission line. If signal taps are taken 1/8 wavelength apart, as in Fig. 1, the phase between these two signals will differ by 90° at the two taps. The result is that a coded signal is always present at least on one of the two channels. This concept can be taken further. The circuit shown in Fig. 2 has increased rejection for noise (spurious modulation) on the rf transmitted signal. Other phasing arrangements can be used. For example, Fig. 3 is a three-channel system in which at least two channels always have a coded-signal output.

This receiver can be constructed on printed circuit boards using strip lines as well as using coaxial transmission lines. Also, a filter must be used to prevent rf signal from reaching the output signal channels.

The new development provides superior performance compared with receivers used previously. It provides greater receiver sensitivity and eliminates all of the troubles and complexities of present receivers. It also reduces the receiver cost by about $700. This is significant because the LASL ID system is in the early stages of commercialization and it provides benefits of increased performance and reduced cost.

A receiver patterned after that shown in Fig. 1 was built and installed in the "handheld" interrogator

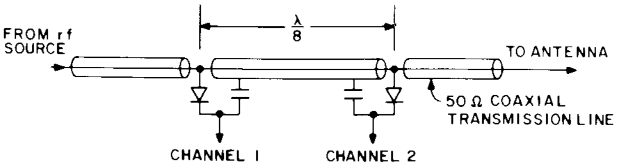

Fig. 1
A simple two-channel homodyne receiver.

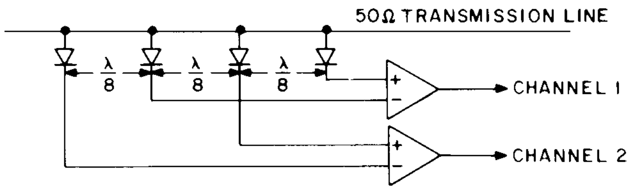

Fig. 2.
A simple two-channel homodyne receiver with noise rejection.

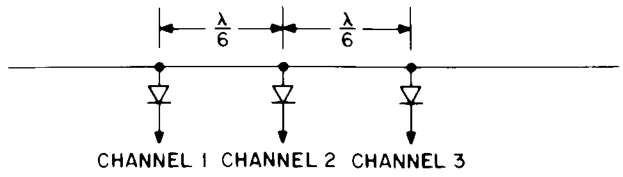

Fig. 3.
A simple three-channel homodyne receiver.

and the performance of the "handheld"unit was improved by the new homodyne receiver.

27-MHz operation. For some applications, a near contact interrogation would be acceptable. To test the present LASL designs for compatibility with this concept, a 100-mW, 27-MHz transmitter was attached to a loop antenna, and a similar loop antenna was attached to the transponder. Successful interrogations could be made at antenna separations up to about 8 in. (This space could be filled with tissue as could be the case in animal implantation.) This test required a minimal effort to perform and required no modifications of the interrogator receiver.

This type of interrogation might be useful for hogs and small animals.

E. Compatibility Tests

LASL was requested by the Federal Communications Commission (FCC), the Spectrum Planning Subcommittee (SPS), and the Department of Energy (DOE) to conduct electromagnetic compatibility tests between the LASL electronic ID system and class A citizens' band equipment. This section summarizes preliminary findings of these tests. The results given here are "worst case" findings since the tests were conducted in an attempt to maximize possible interference. Normally, the LASL signal will be polarized perpendicularly to the class A equipment and will be dispersed because the LASL antenna will direct energy toward the ground or an animal.

We were requested to conduct these tests with the aid of All-Comm, Inc., of Albuquerque, New Mexico. The people at All-Comm were very helpful and friendly. Table I summarizes the characteristics of the equipment used.

The LASL equipment was assigned a splinter channel frequency of 462.6625 MHz. The tests were to determine whether the narrow-band LASL signal would interfere with a normal class A channel, and whether the class A transmission would prevent the LASL system from operating properly. Table II summarizes the test findings.

Since minor interference was seen, it may be necessary to conduct further tests to determine the extent of the interference to be expected if the LASL equipment is set up in its normal configuration (to identify animals), and not setup to maximize interference as was done in this first test.

F. Related Work

LASL has long been interested in non-agricultural applications of electronic identification. During the past year, this interest resulted in construction and installation of a system tailored to electronically identify vehicles as part of a nuclear safeguards program.[7] This system uses a low-power (1-W), 915-MHz interrogator and battery-powered transponders. Data, collected by a Micro-Nova computer, include radiation levels as well as vehicle identification. Experience gained in this system will be useful in the field tests of the livestock electronic ID systems.

V. TEMPERATURE-MONITORING

A temperature-monitoring capability that will complement existing methods has been included in the electronic animal ID system to provide a means for assessing animal health. From the outset, we have believed that a major element in the cost-effectiveness of electronic identification could be this monitoring capability.

An animal's body temperature is controlled by many factors, and many physiological disturbances in livestock can be revealed through changes in body temperature. A number of these disturbances are important to commercial livestock producers. But, while animal temperature is thought to be important in assessing animal health, practical use of the temperature- monitoring feature of the electronic ID system needs more study.

Because the placement of identifiers under the skin of the animal represents a departure from deep body sites for temperature measurements, it will be necessary to define the relationship between skin- and deep-body-temperature events. Also, the system will be used in a wide range of livestock environments from milking parlor to open range. Since much of the research published on animal temperature has been conducted in restricted or controlled environments, its validity must be determined for a wider range of environmental conditions. A considerable amount of work is necessary to apply the basic research conducted in this area to its practical use in the electronic ID system. Accordingly, our field trials will emphasize the investigation of temperature phenomena relating to disease, stress, ovulation, and parturition. Our efforts in this area have mainly been technical ones in preparation for collaborative work with other institutions. However, experiments have been conducted which indicate the problems we may face in monitoring subdermal temperature, and equipment has been assembled that will be used to overcome these problems.

TABLE I
EQUIPMENT CHARACTERISTICS

Station	Frequency[a] (MHz)	Antenna Type	Antenna Gain (Db)	Antenna Height (Ft)	Transmitted Power (W)
All-Comm base 301 Wyoming NE Albuquerque, N.M.	462.6500 t,r 467.6500 t	stacked dipoles	10	~20	~2
All-Comm	462.6500 t	stacked dipoles	5	Sandia Crest ~6000	~10
LASL Mobiles	462.6625 t	Yagi	10	~ 4	~50

[a] t = transmit; r = receive.

TABLE II

PRELIMINARY EMC INTERFERENCE TESTS RESULTS

Distance Between LASL Station and All-Comm Base (ft)	Type of Transmission Path	Interference Seen On	
		LASL Equipment	All-Comm Class A Equipment
1 380[a]	Minimal obstruction	Yes	Yes
3 110	Obstructed by low buildings	No	Barely discernible (not objectionable)
5 840	Partial obstruction by trees and golf course landscaping	No	No
11 370	Minimal obstruction	No	No
21 350	Unobstructed	No	No

[a] Complete interference at this range; operation of both stations interrupted.

A. Physiological Monitoring Systems

Identifiers can measure subdermal temperature but not deep body temperature, and they are likely to produce only a few data points per day from any given animal. Thus, studies on the temperature aspects of the ID system will be best made from a temperature-monitoring system that will remotely monitor the temperature from anywhere in the animal's body to help determine where the identifiers should be located and the best time to interrogate them.

In response to this approach, we have developed a new generation temperature-monitoring system that can acquire continuous temperature data from multiple body sites on several animals at a time. This system consists of independently powered radio transmitters and a monitor to collect and process the data.

In this system, each animal may be instrumented with one or more radio transmitters. Each transmitter has its own frequency and sends out a radio pulse about once a second. The actual time between pulses is proportional to the temperature of the sensor attached to the transmitter. The microcomputer causes the receiver to listen to each transmitter in sequence, converts the time between transmissions to a temperature reading, and stores the information. Radiotelemetric transmitters have a relatively short battery life (1-3 mo) and the number of usable transmitters is limited by the number of transmitter frequencies available (about 2 000). These two factors make this radiotelemetry system unsuitable for a national animal identification program. However, it is well suited to evaluating temperatures at various locations in and on animals as they move about freely.

While the data analysis system was designed as a research tool, the design is intended to simulate future data processing systems for electronically monitoring animal identification and temperature in dairies, feedlots, cow-calf operations and other user environments.

B. Transmitters

The transmitter design developed by LASL is a modification of a commercially available transmitter.* Changes were made to prevent the rf output from feeding back into the circuitry of the transmitter and interrupting the timing circuit. Additional modifications increased the stability of the circuit with respect to battery voltage and transmitter temperature. The latter is not important when transmitters are to be implanted in animals. However, if transmitters are to be used outside the animal with an external probe, any sensitivity of the transmitter circuit to changes in ambient temperature may affect its calibration.

It became expedient to retain the rf portion of the transmitter circuitry and modify the timing circuit by decreasing its sensitivity to the rf output of the transmitter. The modifications involved the substitution of complementary metal oxide semiconductor (CMOS) components for existing components whenever possible to improve circuit stability. Replacements included a 12-stage CMOS binary counter (CD4040B) and a CMOS signal inverter (CD4069). The binary counter sets the pulse rate and is thus one determinant of battery life. Pulse rate selections are available in the binary counter for timing changes in the transmitted interval to extend the battery life if desired (Fig. 4).

In choosing components for the prototype transmitter, tests were run to determine whether the transmitter circuit is affected by temperature and low battery voltage. To determine how stable the transmitter circuit was with changing ambient temperature, a check was made of the sensitivity of the circuit to temperature. This is especially important for ear-mounted transmitters where circuit instabilities could cause the transmitter output to change from its calibration. Calibrations were run on the prototype transmitter with an external probe attached. While the transmitter was maintained at 0 or 40° C, the probe temperature was varied to obtain calibration curves under these two conditions. Results indicated a shift of 12 ms out of an approximate 1000-ms period. This corresponds to a 0.17° C calibration shift for a transmitter held between 0 and 40° C, which is approximately one-half of the shift associated with the unmodified commercial transmitter. Of the 12 ms shift, approximately 2 ms could be attributed to the decrease in battery

*Manufactured by Stuart Enterprises, P.O. Box 2219, Grass Valley, CA 95945.

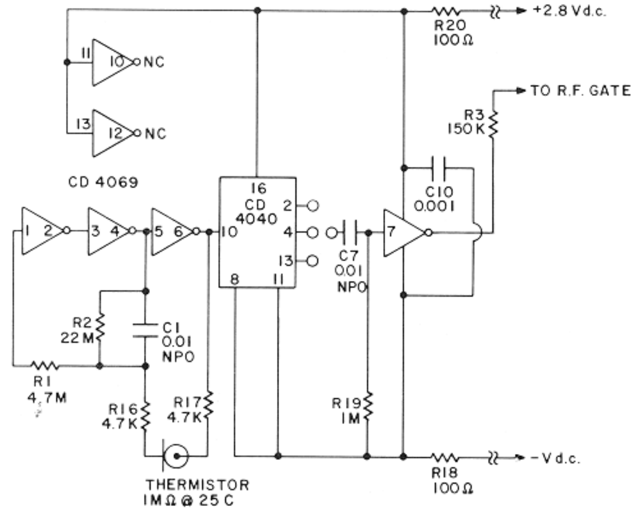

Fig. 4.
CMOS timing circuit portion of the hybrid radio transmitter.

voltage with temperature. Subsequent modifications increased circuit stability with respect to voltage.

Because battery voltage will change slowly as the battery drains, the transmitter must retain a fairly accurate calibration despite some change in battery voltage. The working voltage range of the prototype transmitter is from 2.8 to 2.6 V. Several components were tested and replaced, which decreased the calibration shifts to 4 ms with a change in voltage between 2.8 and 2.6 V. A NPO 0.01-μF capacitor was used in the circuit to further reduce these shifts to 0.2 ms over the voltage range.

Once the basic circuitry was outlined, the circuit was sent for hybridization. By incorporating much smaller chip components, the entire transmitter unit is reduced to a size and shape that can be used for a larger variety of animal applications. The new hybrid transmitter is also designed to use a 2.8-V lithium battery that weighs only ~3 g, offers high service capacity (140 mAh), and is small (23-mm diam, 2.6-mm thick). The battery should provide approximately 3 months of service in normal use.

C. Packaging

While the subdermal transmitter package is encapsulated in an Elvax wax coat[6] and sterilized prior to implantation, a durable protective case is n sary to protect the circuitry. A single basic design is used for both ear-mounted and impla transmitters. Requirements for the case are tl be biocompatible, noncorrosive, transparent to transmission, and durable; have a low water transmission rate, and allow easy battery rep ment.

The package is a cylinder, 1.41 in. in diamete 0.34 in. thick. This shape was chosen becau would have the widest range of application in ar studies. The battery compartment is acces through a threaded O-ring seal that allows the tery to be replaced without moving the transm circuitry. However, if necessary, the entire pac can be disassembled for replacement of parts Fig. 5). For ear-mounting, contacts are mad probe connection through the case and a mac screw is attached on the bottom plate to mount ear tag.

Various packaging materials have been consic for the transmitters. Initial packages have machined to examine the suitability of ce materials for our application. But machining slow and costly process if a large number of un desired. In the future, volume production (100 or more) will be handled best through mold-for techniques. Because of this, materials also had considered according to their ease of handling in injection mold process.

Fig. 5.
The hybrid radio transmitter developed a LASL shown with battery and Kel-F case.

Of the materials machined for the transmitter case, the first was Kel-F,* a thermoplastic. It is used extensively in medicine because of its chemical resistance and inertness. However, it is not easily used in mold processing. Macor, a machinable glass ceramic,** also has many of the properties that would meet our requirements. However, because Macor is more difficult to machine and mold, is quite fragile, and is expensive, we rejected it for our application. Polycarbonate has also been used because of its very high impact strength, easy machinability and molding, and fairly low moisture penetration. However, it does offer less of a barrier to water vapor than the other materials. The best material found so far is Kynar, a polyvinylidene fluoride resin similar to Kel-F and Teflon. It offers high impact strength, low water- vapor transmission, and long term stability in extreme weather conditions and with exposure to ultra-violet light. It also lends itself well to high-production injection molding. Kynar will be used in the future when mold-forming techniques are used.

D. Thermistor Probes

One of the major problems encountered in our application of radiotelemetry is the unreliability of the thermistor probes used in monitoring ear canal temperature. The problem arises because of the necessity of having a delicate electronic component (a thermistor) in a relatively unprotected area. Other researchers in the field of radiotelemetry avoid this type of arrangement for long-term monitoring of physiological parameters, but we must sometimes place the temperature sensor into the ear canal. The two main failures we have found to occur in thermistor probes were the breakage of wires and fluid penetration of the probe encapsulant. Thermistors utilized in the probe are 1 MΩ (at 25°C)thermistors***. These particular thermistors were chosen for two reasons. First, the high probe resistance decreases the current drain on the battery and increases battery life. Secondly, the size of the thermistor is large enough to be easily handled but small enough to minimize animal discomfort. However, with such high electrical resistance, the probe resistance is easily influenced by moisture, which changes the calibration. Also, the wire leads of the thermistor are quite fragile and do not tolerate much flexing. Unfortunately, they are subject to a considerable amount of flex with movement of the ear and when the animal is chewing.

*Produced by the 3M Company, Commercial Chemicals Division, 3M Center, St. Paul, MN 55101.

**Manufactured by Corning Glass Works, Ceramic Products Division, 31501 Solon Rd., Solon, OH 44139.

***Fenwal Electronics, 63 Fountain St., Framingham, MA 01701.

To overcome these problems, it was necessary to construct a probe that has hermetic probe leads that can tolerate long-term flexing, and has a thermistor tip that is immobilized enough to remove the flex from the thermistor leads. Two methods of probe construction were used to fulfill these requirements. For greater strength, both methods use Teflon-coated 32 AWG stainless steel wire* for the main probe leads. These were soldered onto the thermistor leads to make up the main wire assembly.

One design utilized a nonflexing cap to protect the thermistor bead and its fragile leads. The thermistor portion of the wire assembly is sealed within the cap with RTV silastic.** The assembly is then pulled through a section of fluoroelastomer tubing and filled with silastic. The tubing has a low water-vapor transmission rate, and the cap not only serves to protect the probe tip, but also helps to delay the penetration of water vapor. The cap moves the flex to the stainless steel wire, which is able to sustain a considerable amount of flexing. Although the cap increases the diameter of the probe, the silastic filler and tubing allows considerable flexibility, which should reduce animal discomfort.

The second method of probe construction utilizes a hot (rather than cold) method of probe sealing and a reinforced, but not rigid, probe tip. The wire assembly is basically the same. However, it is pulled through a section of oversized polyethylene tubing that is doubled with an insert at one end for reinforcement of the thermistor tip. The polyethylene*** is low-density with a melting point below that of solder. A mold release (Dow Corning silicone lubricant) and a heat-shrinkable polyolefin tubing is slipped over the polyethylene tubing. Using a

*Narco Biomed System, Inc., 7651 Airport Rd., Houston, TX 77017.

**Dow Corning Corp., P. O. Box 592, Midland, MI 48640.

***Clay Adams, Becton Dickinson & Co., Parsippary, NJ 07054.

temperature-controlled hot- air blower regulated just below the melting point of solder, the polyolefin tubing is shrunk around the entire probe. Simultaneously, the heat melts the polyethylene tubing around the wire assembly. Once cooled, the polyolefin tubing is removed from the now completed probe. The polyethylene becomes a uniform conformal coat around the wire assembly, which can be of much smaller diameter than that obtained with other methods.

Many types of encapsulants were considered for use in making the transmitter probe. Polyurethanes, silastic, polyvinyl tubing, parylene, polyvinylidine chloride, Elvax, and Kel-F were all considered. Using polyethylene to encapsulate the probe was decided upon because it simplified the construction of the probe and because of the low cost of the materials. Although polyethylene is not a complete water barrier, it is among the better polymers for preventing water transmission, and its relatively low melting point offers a considerable advantage in probe construction.

In limited tests, performance of the new probe designs has been excellent. Several probes were made and connected to transmitters for animal instrumentation. Transmitter probes have been tested on animals for up to 7 weeks with no probe failures.

While these methods in probe construction have not been fully tested, we believe these probes will give much more reliable performance than others previously used. If there are problems, other options are available, such as using chip thermistors and other forms of polymeric encapsulations. However, these options may add greater bulk or expense to the probe than we feel necessary.

E. Monitoring System

The monitoring system to be used with the LASL transmitter was designed to minimize operator involvement in data collection, but to allow considerable flexibility in analyzing the data that was collected. The software can be easily modified to incorporate temperature-event and pattern-recognition subroutines as soon as basic information from the field trials becomes available. The monitoring system can be used either as a stand-alone computer or with a large main frame computer and can be easily modified for other applications. A special effort was made to produce hardware and software that was directly applicable to electronic identification. We consider the monitoring system to be the forerunner of an on-the-farm, totally automated, temperature-alert system.

Because the system can also be used to monitor telemetered physiological phenomena other than temperature, we refer to it as a "physiological monitor," rather than a "temperature monitor."

F. Functional Specifications

The hardware and software were designed to meet a list of functional specifications that were derived from our experience with temperature telemetry at LASL, at the National Veterinary Services Laboratories (NVSL) in Ames, Iowa, and with our concept of system requirements in dairies, feedlots, and other user sites. The specifications are as follows

1. Reliable
2. User oriented
3. Totally automated physiological monitoring of multiple animals
4. Modification of software on-site by user
5. Data storage
   a. Approximate equivalent capacity
      1) 100 cows
      2) hourly measurements
      3) 2 months
   b. Format
      1) date/time
      2) cow number/body site
      3) pulse interval and temperature data
      4) transmitter frequency
      5) pulse interval-to-temperature conversion coefficients
6. Data display
   a. Cathode-ray tube
   b. Hard copy
   c. Overlay more than one data set
7. Computations
   a. Conversion of pulse interval-to-temperature
   b. Computation of means
      1) individual or groups
      2) total experiment to date
      3) segmented time intervals within experiment (hourly, daily, etc.)

c. Independent of separate computer facility
8. Compatibility with large computer
    a. Telephone link to large computer.
    b. Software also usable on large computer.
9. Error flags
    a. Temperature window
    b. Too large a temperature change/time
    c. Power failure
10. Editing
    a. Change Points
    b. Delete points
11. Transmitter replacement on a single animal without reinitializing the entire group
12. User-generated event markers
13. User-generated comment file
14. Protection from lightning/power-outage failure
15. Individuals or experimental group scanned as often as once per minute.

Three physiological monitoring systems are being assembled at LASL. The systems are identical except one system will have extended capabilities. Each system acquires telemetric data in an automated fashion without operator intervention, requiring only standard ac power and the proper initialization by the operator. Each of the three physiological monitors are capable of independently collecting and storing temperature data as they are transmitted from various transmitters in the field. The data are stored on floppy disks to minimize the risk of data loss in the event of power failure. Floppy disks are nonvolatile media (that is, the information stored on disk remains after the power has been turned off). The parameters governing the data collection process are easily changed by issuing the appropriate command to the computer. The data can be displayed in either table or plot format, with each format including markers that identify notable events that occurred during the data-acquisition run. Once the data have been collected, the computer can be commanded to perform certain statistical and data-editing functions to aid in trend analysis. The function of each monitor is to (1) communicate to the operator through an "intelligent" operating system, (2) acquire and store transmitted data, (3) perform calculations on the data, (4) edit the data, and (5) display the data. The extended system has software development capabilities in addition to the five basic capabilities.

G. System Configuration

Each physiological monitoring system is housed in a standard 19-in. rack with an overall height of 23 in. The monitor requires a maximum of 1 kW of power provided by a standard 60-Hz, 115-V outlet. The ac line voltage can vary up to ±15% with no effect on the operation. Lightning protection is also provided in addition to the line regulation.

The major system components are shown in Fig. 6. All hardware is commercially available except the LASL-designed interface between the processor and the telemetric equipment. An expense list is presented in Appendix C for a detailed itemization of the commercially available items used in the system. The telemetric equipment consists of a receiver and a pulse interval meter. Receiving the pulse interval data from the transmiters is a Telonics TR-2 receiver. This receiver operates at 150 to 152 MHz. Within this range, the receiver can select 2000 discrete frequencies in 1-kHz increments. Because it was designed to track game animals from an airplane, the TR-2 can receive relatively long-range transmissions with the apppropriate antenna. The Telonics TDP-1 pulse interval meters accepts the data from the receiver and processes them in a form acceptable by the computer.

Figures 7 and 8 illustrate the actual hardware used. The main item, the computer, is a DEC LSI-11/2 central processing unit (CPU) with 32 kbytes of memory. Mass storage is provided by a Data

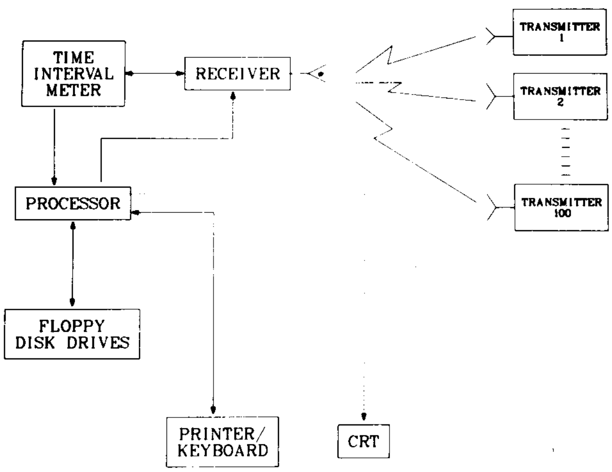

Fig. 6.
Diagram of the physiological monitor.

Fig. 7.
Hardware used in the extended physiological monitor. A. Microcomputer with DEC LSI-11/2 central processing unit. B. Data Systems dual floppy-disk drive. C. DEC VT-100 video terminal. D. Telonics TR-2 receiver. E. Telonics TDP-1 processor.

Fig. 8.
Teletype Model 43 keyboard/printer (basic monitor). printer.

Systems dual floppy-disk drive. The disk drive accepts either single- or double-density floppy disks. The inexpensive floppy disk is easily inserted and removed from a disk drive, and is portable because of its 8- by 8- by 1/16-in. dimensions.

The CPU uses the Teletype model 43 keybord/printer to communicate with the operator. The printer types 30 characters/s on a 132-column format, printed on 8-1/2- by 11-in. paper. The extended monitor also includes a DEC VT-100 video terminal. The terminal can display and send information at a much higher speed than the teletype. This is an important feature for a software development facility, where an extensive amount of information is being passed between the operator and the computer.

H. Data Acquisition and Storage

The monitor computer controls the frequency of the receiver. Each selected frequency corresponds to a particular transmitter and its associated temperature probe. The transmitter broadcasts pulses with the time between pulses corresponding to the temperature of the temperature probe. The receiver passes these data on to the pulse-interval meter. The pulse-interval meter processes the data into a form acceptable to the computer. The computer then reads the data, converts the raw data to a temperature, then continues on with the frequency-scanning process.

The scanning process is set by the operator during the initialization sequence at the beginning of a data- acquisition run. The parameters set during an initialization sequence are (1) scan rate, (2) transmitter frequencies to be scanned, (3) frequency-to-cow-number correlation, (4) time-interval-to-temperature conversion coefficients, (5) temperature error bounds, and (6) current time and date.

During data acquisition, the frequencies selected are scanned at a fixed rate. The scan rate can be in 1-min increments anywhere from 1 to 1440 minutes (24 h). During each scan, all transmitters are monitored in the sequence that was specified during initialization. The transmitter "location" is specified in terms of the cow number and where the temperature probe is located on the cow. This information is included when the operator requests a display of the temperature data received during a data-acquistion run. To convert the raw time-interval data from each transmitter into their corresponding temperature values, a coefficient query is included in the initialization sequence. The coefficients specify a quadratic equation that converts time-interval data for a particular transmitter into temperature values. The temperature values can be checked to determine transmitter failure by specifying error bounds on the data received. The error bounds include a check of the maximum temperature change allowable between successive data points.

If the computer does not receive any data at all for a particular transmitter, a "search" routine is entered. The monitor assumes the transmitter has drifted from the proper frequency, thus frequencies near the prescribed frequency are examined for data. When the correct frequency is found, the monitor updates the old transmitter frequency with the correct one, then continues the scanning sequence. After an unsuccessful search, it moves onto the next frequency.

After each scan, the temperature data is stored on a floppy disk. Along with the temperature data, all of the parameters governing the data acquisition run are stored on disk. This implies that a power failure will not destroy the results of the run. Furthermore, when ac power is restored, the monitor goes back into operation without operator intervention.

I. Operating System

The operating system is responsible for communicating with the operator and implementing the commands issued by the operator. There is a specific set of commands that the physiological monitoring system recognizes. The commands specify and control the operations of the monitor. Commands that specify monitor operations result in sentence-structured questions being asked by the monitor that must be answered by the operator.

When the monitor is turned on, the operator receives a short message and then a prompt. The prompt indicates that the monitor is ready for a command. A command, such as an initialization request, will cause the monitor to query the operator about the data-acquisition parameters necessary for a run (scan rate, transmitter frequencies, temperature conversion coefficients, etc.). Each response by the operator is checked for format and to see that it is within prescribed limits before the monitor will accept it. All of the commands can be issued while a data-acquisition run is in progress. This enables the operator to observe the data collection results as they are occurring.

The operating system error checks the pulse interval as it is received to determine if any transmission errors have occurred. The transmission error bounds are set in the initialization sequence and include the upper and lower temperature values that are considered valid and the maximum change in temperature value that is likely to occur from the previous value to the current value. When an "error" is detected, the operating system notifies the operator of the likely error condition in all subsequent temperature data printouts. In addition to an error marker being placed in the data printouts, a time-referenced log is kept of all the transmission errors occurring during the data-acquisition run. This log can be observed by the operator at any time, with the appropriate command.

The operator can also place markers in the data printouts. These markers are meant to be a general purpose aid to flag those events the operator decides are significant. For example, a marker may be set for a particular cow when it is vaccinated if the operator suspects this will affect the next temperature reading. The researcher is then alerted to this situation on subsequent data printouts and can interpret the data accordingly.

In addition to the transmission error markers and operator-generated markers, is the power failure/restart marker. This marker is handled and displayed in a similar manner to the other markers, and indicates when power failed and was restored.

The operating system was developed at LASL for the physiological monitor. To facilitate future improvements on the operating system, the program is fully commented and uses the widely known high-level FORTRAN IV programming language.

J. Data Processing

Data processing includes any mathematical operations done on the temperature data. The operator has a choice of four data-processing commands: two for data conversion and two for statistical functions. The commands invoke the following functions (1) time-interval-to-temperature conversion, (2) temperature-to-time-interval conversion, (3) statistical mean over time period, and (4) interval mean over time period.

The statistical functions are included as trend recognition aids to the researcher. The calculation of a statistical mean over a given time period makes use of all of the data points included in the given time period. The time period is specified by the operator in terms of a start and stop time. The calculation of the interval mean makes use of a group of mean values over the time period of interest. The overall time period is divided into equally spaced intervals, and the mean value is calculated for each (daily mean values could be calculated over the course of a month, for example). For the interval mean, the operator specifies the interval time period and the overall time period. The statistical function commands can be applied to a single transmitter or all transmitters. Any data point that is associated with a transmission error will not be included in the statistical calculations.

K. Data Display

There are two formats that can be used to display data, plot format and table format. An example listing of the table format is given in Fig. 9. A table listing will display the data from a maximum of 100 transmitters whether the data are time interval, temperature, or statistical data. All of the listed data are time referenced, and includes any system-generated or operator-generated markers. Each page begins with a header and is followed by the columns of time and date entries. The page header includes the time and date of the listing, the page number, the cow number, and transmitter location.

For an up-to-date account of the data-acquisition scan parameter, an information header can be listed at any time. The information header consists of the time and date of the listing, the scan rate, the cow number, the transmitter-location-to-transmitter-frequency correlation, a list of the quadratic coefficients for each transmitter, the data-acquisition run start time, and the present status of the run. Included in the run status is an estimate of the amount of time remaining until the monitor must abort the run for lack of storage space for data.

Plots are available in the form of data versus time. The data can be temperature data or statistical means. The operator has the choice of plotting the data from a single transmitter or from several transmitters on the same plot.

For the general use of the operator, the physiological monitor provides a "scratch pad" area within the computer. This area can be used by the operator to log comments pertinent to the data-acquisition run. The comment log can be displayed at any time by issuing the appropriate command.

L. Data Editing

Data editing has been implemented on the physiological monitor so the operator can change or zero a data point. Data editing can only be done on the temperature data. Editing can be done on any transmitter data that was recorded at any time during a data-acquisition run. A data point that is edited to zero will not be included in any subsequent statistical calculations.

M. Temperature-Monitoring Experiments

While the major portion of the experiments on animal temperature is being planned in collaboration with researchers at other institutions, experiments have been conducted at LASL to obtain information that would be useful in preparing for the electronic identification field test. Studies have been started to evaluate the suitability of the present location of the transponder in the animal for monitoring animal temperature. This location is behind the withers, near the backbone. The location for the transponder was chosen for its ease of interrogation, its lesser susceptibility to infection and its lesser chance for damage to transponder circuitry. It must be determined if this location is also suitable for monitoring animal temperature. To do this, the relationships between deep body temperature, subdermal temperature, ambient temperature, exercise, fever and social stress need to be determined.

1/14 15:17:25 PAGE 1

BODY TEMPERATURES AT EACH CHANNEL
(CHANNEL INDENTIFIED BY COW I.D. # AND TRANSMITTER LOCATION LETTER)

TIME OF SCAN M/D	H:M	913E	913B	913R	7392E	5348B	6543E	4930R	76E	534E	91B
1/14	14: 9	38.38	38.38	38.38	38.41	38.38	38.43	38.38	38.45	38.38	38.32
1/14	14:11	38.38	38.47	38.38	38.46	38.38	38.46	38.38	39.56	38.38	38.45
1/14	14:13	39.12	38.45	38.38	38.45	39.05	38.45	38.37	38.45	38.38	38.45
1/14	14:15	38.37	38.46	38.37	38.46	38.37	38.46	38.37	38.45	36.60	38.47
1/14	14:17	38.37	38.46	38.37	38.46	38.37	40.96	38.36	38.47	38.39	38.47
1/14	14:19	38.37	38.48	38.36	38.48	38.36	38.48	38.36	38.48	38.36	38.45
1/14	14:21	38.36	38.32	38.36	38.49	38.37	35.93	38.36	38.50	38.36	38.50
1/14	14:23	38.36	38.50	38.36	38.50	38.94	38.51	38.36	38.51	38.35	38.51
1/14	14:25	38.36	38.52	38.36	38.52	42.51	38.54	38.36	38.54	38.36	38.54
1/14	14:27	38.36	38.55	38.36	38.55	38.36	38.57	38.35	38.56	38.36	38.56
1/14	14:29	38.35	38.54	38.35	38.56	38.35	92.65	38.35	36.48	38.35	38.57
1/14	14:31	38.35	38.57	38.35	38.55	38.35	38.56	38.84	38.55	38.35	38.56
1/14	14:33	38.33	38.63	38.84	38.55	38.35	38.55	38.36	38.55	38.35	38.55
1/14	14:35	38.35	38.55	38.35	38.55	38.35	38.57	38.55	38.56	38.35	38.55
1/14	14:37	38.35	38.56	38.35	38.55	38.35	38.63	38.35	38.54	38.35	38.56
1/14	14:39	38.35	38.56	38.35	38.56	38.35	38.57	38.52	38.56	38.35	38.57
1/14	14:41	38.33	38.57	36.51	38.56	38.35	38.56	38.35	36.38	38.35	38.55
1/14	14:43	38.35	38.55	38.35	38.56	38.35	38.56	38.35	38.57	38.35	36.48
1/14	14:45	38.84	38.57	38.35	38.58	38.35	38.49	38.35	38.57	38.35	38.58
1/14	14:47	38.35	38.58	38.35	38.58	38.33	38.90	38.35	38.58	38.35	36.51
1/14	14:49	38.35	38.56	38.35	38.56	38.35	38.55	38.84	38.56	38.35	38.56
1/14	14:51	36.49	38.57	38.35	38.54	38.35	38.57	38.81	38.57	38.35	38.57
1/14	14:53	38.35	38.57	38.35	38.85	38.35	38.57	38.35	38.58	38.35	92.80
1/14	14:55U	38.35	38.56	38.35	38.56	38.35	38.55	38.35	92.19	38.35	0.00
1/14	14:57	38.35	38.57	38.34	38.57	38.35	38.57	38.35	38.57	38.35	38.57
1/14	14:59	38.78	38.56	38.46	38.58	38.46	38.58	38.35	38.58	38.46	38.58
1/14	15: 1	38.35	38.57	38.34	38.57	38.35	92.65	38.35	38.57	38.35	38.57
1/14	15: 3	38.35	38.56	38.35	38.54	38.34	38.56	38.35	38.56	38.35	38.56
1/14	15: 5	38.35	38.76	38.35	38.56	38.74	92.19	38.35	38.56	38.35	38.56
1/14	15: 7	40.15	38.56	38.35	38.55	38.46	38.56	38.35	38.57	38.74	38.55
1/14	15: 9	38.35	38.55	38.34	38.55	38.34	38.55	38.34	38.54	38.34	38.55
1/14	15:11	38.35	38.56	38.34	38.56	38.35	38.57	36.46	38.57	38.35	38.55

Fig. 9.
Table format listing of temperature data.

One consideration of a subdermal implant site is the amount of subdermal insulation present and its position relative to the transponder. The pattern of adipose (fatty) tissue distribution may greatly affect the measurement of body temperature. Animal fat insulates against body heat loss and may hinder or enhance the temperature sensing capability of the transponder, so measurements of fat distribution provides data which are important to transponder placement.

To determine fat distribution, beef cattle were examined following slaughter (Schwartzman Packing Co.). Measurements were taken over the half carcasses of six animals. It was found that beef animals have a tendency to accumulate fat at the implant site behind the withers, along the back, rump and ventral surfaces. The ability of the transponder to detect changes in deep body temperature depends upon its position relative to fatty tissue and blood circulation patterns. If the unit is implanted in beef calves which are subject to fatty weight gain, its temperature monitoring capability may change with animal growth . If fat is laid down beneath the transponder, the fat will effectively insulate the transponder from deep body and decrease its sensitivity to deep body temperature. If fat is laid down around the transponder to form a pocket, the insulation may enhance the transponder's ability to monitor deep body temperature. In the withers, this is a consideration which must be kept in mind. Thus, if the transponder is located in areas subject to fat accumulation, animal growth may significantly affect the transponder's role in monitoring animal temperature.

To a great extent, animals regulate body temperature by altering heat loss through the skin. Certain body regions are more actively involved in regulating body temperature than others, to conserve heat when cold and release heat when hot. Temperatures in these regions fluctuate more than in other areas. Also, certain body regions may have more local muscle activity than others and this may cause large changes in local tissue temperature. If transponders were implanted in these areas it would be difficult to obtain readings which could be used to estimate an animal's true body temperature. It is important then to determine if some site other than the withers will provide a more accurate measure of deep body temperature. Such studies are best carried out with multiple-body-site monitoring through radiotelemetry. However, since reliable equipment was not available at the time, an alternative, indirect method was employed.

Body sites were compared utilizing a quick scanning technique called infrared thermography. In principle, all objects above 0 K radiate infrared radiation. Thermography measures the intensity of infrared radiation and this is correlated to surface temperatures. In thermography, a TV-type picture is generated that indicates surface temperatures. It can be photographed to give a permanent record of comparative temperatures of various body sites.

Thermography scans were made on a steer with a winter coat of a uniform black color. Comparisons were made between a low ambient temperature of 8°C and a warm ambient temperature of 28°C. Measurements were made of surface coat temperatures and shaved-skin temperatures to obtain an idea of the relative skin temperatures and coat insulation. Hair coat samples also were taken over a 25.8-cm^2 area to rank coat densities. Six areas compared with withers, neck, pelvis, dulap, thorax, and abdomen. Thermography showed that coat surface temperatures were influenced greatly by coat insulation when comparisons were made between coat and skin surface measurements. Of the areas compared through thermography, the withers appeared to have the greatest coat insulation and warmest shaved-skin temperature. When coat densities were compared, the withers showed the greatest density at 0.041 g/cm^2 and the dulap showed the lowest density at 0.009 g/cm^2.

Results are only preliminary as they are based on one animal and offer no direct measure of subdermal temperature. A multiple monitor of subdermal temperatures is necessary for firm conclusions to be made, and this is being planned for the future with the new LASL radiotransmitters. However, through the use of thermography, the withers do appear to be among the best of the sites compared. Because the heavy coat insulation of the withers in wintered animals offers protection from the elements, a transponder would not be affected by ambient temperature there as much as in other regions. The site also does not appear to be affected by thermoregulatory adjustments.

It was previously shown that in a controlled environment, the withers subdermal temperature tracks deep body temperature very well.[6] Within the confines of the experiment, this is further indication that the withers is a good area for the monitoring of body temperature. However, it must still be determined if similar results can also be obtained in uncontrolled environments. Because the electronic ID transponders will be used in a wide variety of environments from field ranges to dairy milking parlors, (and field testing will encompass all these areas) a look at subdermal temperature in uncontrolled environments is necessary to anticipate problems that may arise during the field trials. Such an experiment was done at LASL using three calves of Brahma-Angus mix. Each animal was instrumented with a subdermal temperature transmitter implanted behind the withers and an ear-mounted transmitter to monitor tympanic temperature. Radiotransmitters were also used to measure ambient temperature and black globe temperature. Black globe temperature is the temperature at the center of a black metal sphere and is the net result of a variety of environmental effects including air temperature, sunlight, wind, and precipitation. Because it is the result of environmental variables that have similar influences on the animals, it provides a more accurate estimate of the effect of environmental conditions on the implanted temperature unit.

Temperatures were monitored in an uncontrolled indoor environment as might be encountered in a dairy and in an uncontrolled outdoor environment as might be encountered in a feedlot. Measurements were taken once every five minutes using an Intel 8010-based microprocessor system. Hardware and software components for the system were assembled through the cooperative effort of LASL and APHIS personnel. Data were stored on cassette tape at the animal facility. They were then transferred through telephone lines to the LASL central computer facility for data analysis.

Results are shown in Fig. 10 of the indoor monitoring period. Within this period indoor temperature varied between 15.2 and 26.4°C. Fairly rhythmic fluctuations occurred in subdermal temperature which were much more pronounced than tympanic temperature. These diurnal rhythms also varied among animals, with animal 207 showing much greater variability.

After animals were transferred to the outdoor area, temperatures were again monitored. Outdoor temperatures were 13.1 to 27.0°C during this period. The effect of the uncontrolled environment on the animals is graphically represented in Fig. 11. Here black globe temperature is also represented along with ambient temperature. In the outdoor environment, the pattern of subdermal temperature is quite different from that obtained indoors. Large spikes are evident here that did not occur previously. These apparently are due to the effects of sunlight. It should be noted that during these spikes, subdermal temperature was often greater than tympanic temperature. With rain or snow, large depressions in the graph are possible that may be accompanied by much smaller depressions in deep body temperature.

While outdoors, the animals were also vaccinated with Brucella abortus (strain 19) vaccine at an estimated 8.5×10^{10} infectious units per dose. The effect of the vaccination is shown in Fig. 12. Again, large deviations can be seen in subdermal temperature, which appear to cloud the effects of the vaccination.

Examination of the data indicates that environmental conditions do have significant effects on subdermal temperature. These effects have a large impact on the use of subdermal temperature in the electronic indentification system, and major corrections appear necessary to relate subdermal temperature to deep body temperature.

However, Table III shows a statistical comparison of body temperature means among the various conditions. It can be seen that during the three periods, no significant change in ambient temperature occurred. This simplifies the comparison. As one would expect, significant differences appear in the deep body temperature of all animals between prevaccination and postvaccination periods. However, a statistical difference is also seen in subdermal temperature between these two periods. Such results indicate that although some clouding of the temperature response does occur in the outdoor environment, these differences are not completely obscured by ambient factors.

But, statistical significance does not mean that such differences can be seen from one day to the next or that smaller changes in body temperature can be discerned. A major part of these experiments is to develop correction schemes for subdermal temperature. Attempts are now under way to make such corrections to subdermal temperatures so they will correlate more closely with deep body

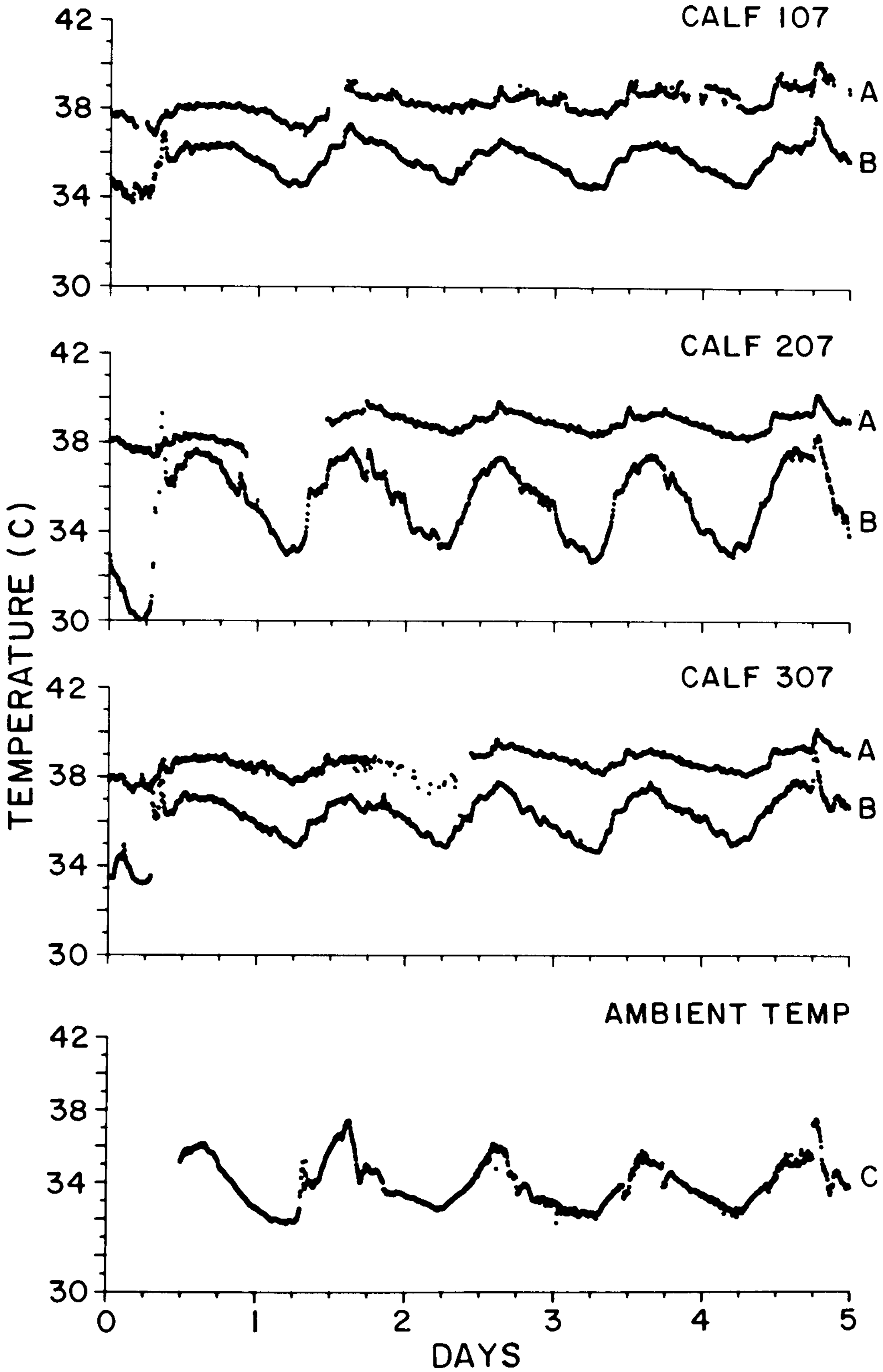

Fig. 10.
Temperature patterns of three calves maintained in an uncontrolled indoor environment. A. Ear canal temperatures. B. Subdermal temperatures. C. Environmental temperatures.

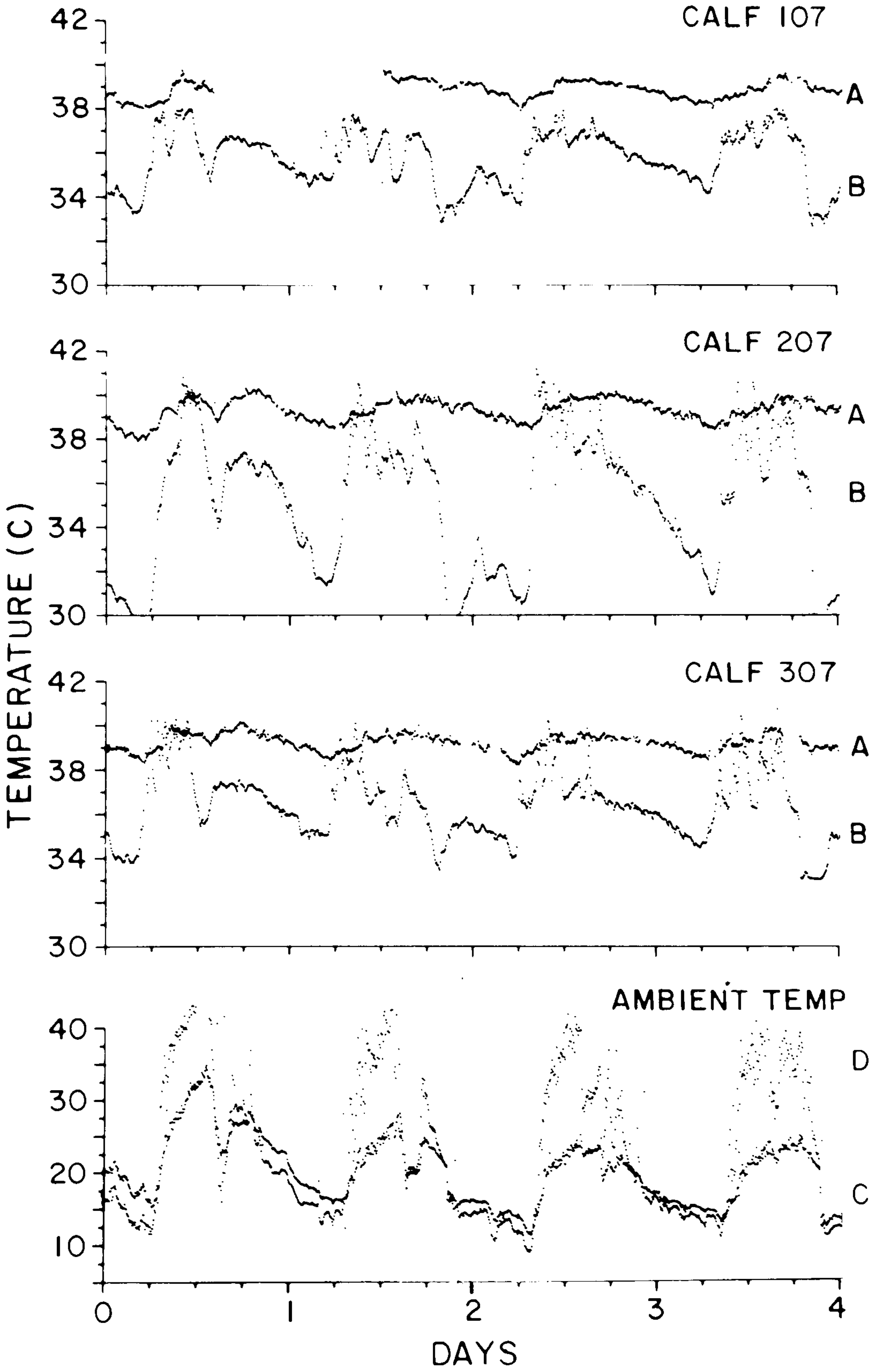

Fig. 11.

Temperature pattern of three calves maintained in an uncontrolled outdoor environment. A. Ear canal temperatures. B. Subdermal temperatures. C. Environmental temperatures. D. Black globe temperatures.

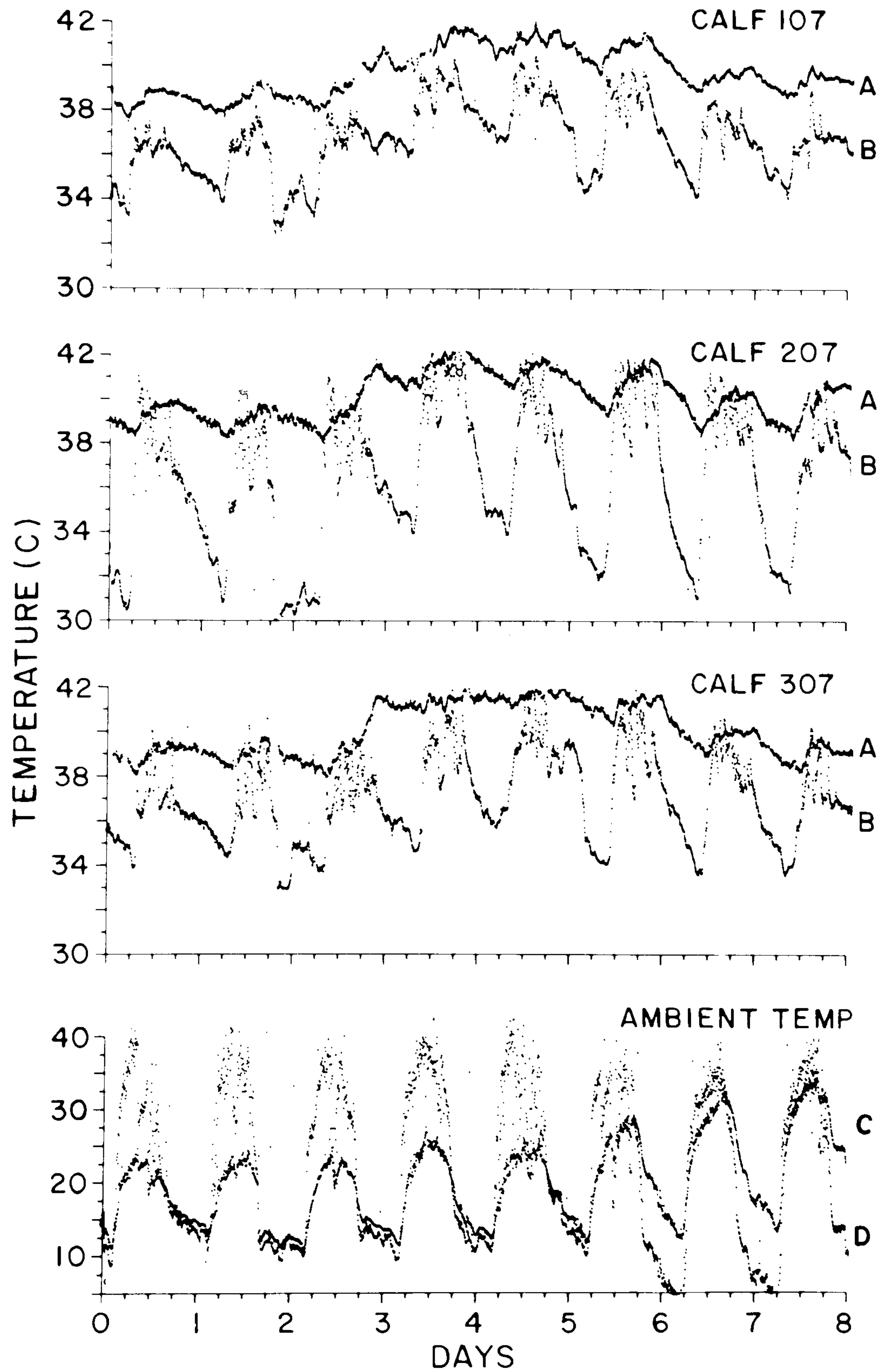

Fig. 12.

Temperature pattern of three calves vaccined with Brucellosis abortus (strain 19) vaccine while maintained in an uncontrolled outdoor environment. A. Ear canal temperatures. B. Subdermal temperatures. C. Environmental temperatures. D. Black globe temperatures.

TABLE III

MEAN BODY TEMPERATURES OF THREE CALVES

Mean Deep Body Temperatures (°C ± 1 S.D.[a])

Calf	Indoor	Outdoor	Outdoor Fever
1	38.34 ± 0.48	38.36 ± 0.39[b]	40.19 ± 0.46[b]
2	38.85 ± 0.46	38.97 ± 0.48	41.01 ± 0.65
3	38.72 ± 0.38	39.04 ± 0.38	41.43 ± 0.38

Mean Subdermal Temperatures (°C ± 1 S.D.[a])

Calf	Indoor	Outdoor	Outdoor Fever
1	35.78 ± 0.64	35.57 ± 1.21	37.83 ± 1.39[b]
2	35.47 ± 1.49	34.84 ± 3.08	37.52 ± 2.88
3	36.27 ± 0.77	36.26 ± 1.51	38.12 ± 1.92

Mean Ambient Temperatures (°C ± 1 S.D.[a])

Indoor	Outdoor	Outdoor Fever
19.74 ± 3.19	19.57 ± 4.71	19.72 ± 4.92

[a]S.D. = standard deviation.

[b]Significance at $P < 0.01$.

temperatures. One obvious approach is to correct for the effects of ambient conditions on subdermal temperature. In the previous graph of indoor temperature monitoring (Fig. 10), larger swings are evident in subdermal temperature than in deep body temperature. An obvious relationship exists between subdermal temperature and ambient temperature. One could assume that if physical parameters (animal insulation, animal health) and emotional parameters remained unchanged, a regression analysis of subdermal temperature and ambient temperature would provide an accurate measure of the effect of ambient temperature on subdermal temperature. This in turn could be used to correct subdermal temperature to a "constant" ambient temperature. With the application of such a correction and a replotting of the original data, corrected subdermal temperatures are obtained as shown in Fig. 13. A considerable reduction in the amplitude of the diurnal variation occurs and seems to eliminate much of the effects of ambient temperature. Figure 13 shows the best type of correction possible, since the correction was made on the same points used in determining the regression line. Still, it can be reasoned that if the regression curve was constructed from data obtained from an animal in normal state, any subsequent deviation is the result of factors not considered in the regression (such as a change in deep body temperature, a change in local physiological parameters — blood flow during stress or a change in an unmeasured environmental parameter).

Ambient temperature can also be used as a correction factor in the outdoor environment and does reduce the fluctuation in subdermal temperature. However, ambient temperature does not correct for other factors such as sunlight, which could be equally significant. A more acceptable correction factor may be found by using black globe temperature. When such a correction is made, the results are as shown in Fig. 14 . Again, a considerable reduction occurs in subdermal temperature variability, which may prove advantageous in analyzing subdermal temperature data. One obvious difficulty in applying such a correction is that if the animal moves between sun and shade, corrections applied to the original data may be in error and may magnify the discrepancy.

It was noted previously that the diurnal variation in the subdermal temperature of animal 207 was much more pronounced than that of the other animals. A comparison of the variances associated with the means shown in Table III indicated a significant difference between this animal and the others. While data have not been pooled to obtain a common regression equation and tested statistically, it would appear that problems may arise to prevent the use of a single correction factor for all animals. However, it is possible that animals will be placed in one of several categories for analysis rather than utilizing each animal as its own control.

This form of a temperature correction may be used alone or may also serve as a preliminary data treatment for subsequent forms of analysis through which temperatures can be flagged. One form of analysis

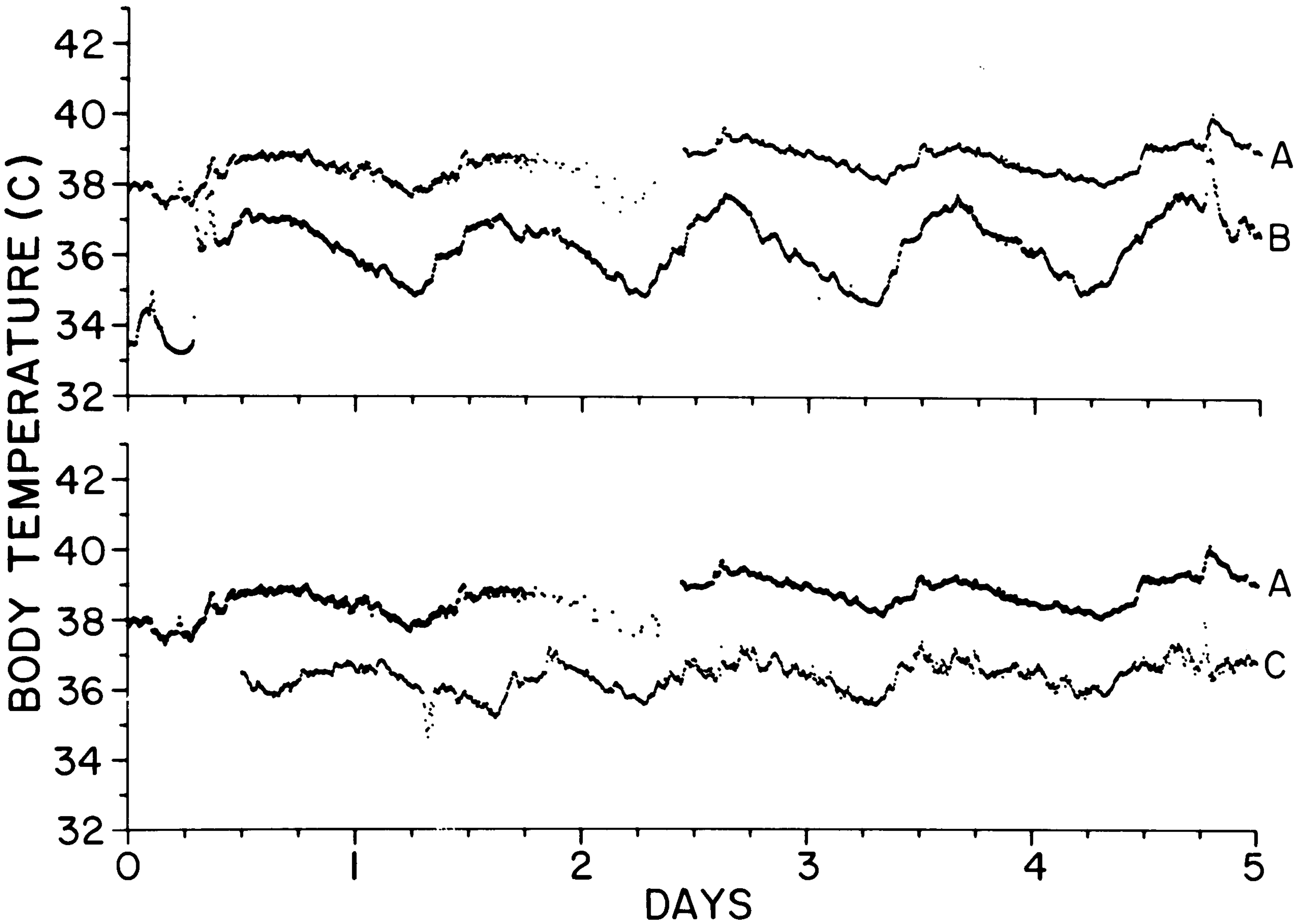

Fig. 13.

A comparison of ambient temperature (A) with uncorrected subdermal temperature (B, upper plot) and with results of an environmentally corrected subdermal temperature (C, lower plot). Corrections were made on data obtained during the indoor period (see Fig 10).

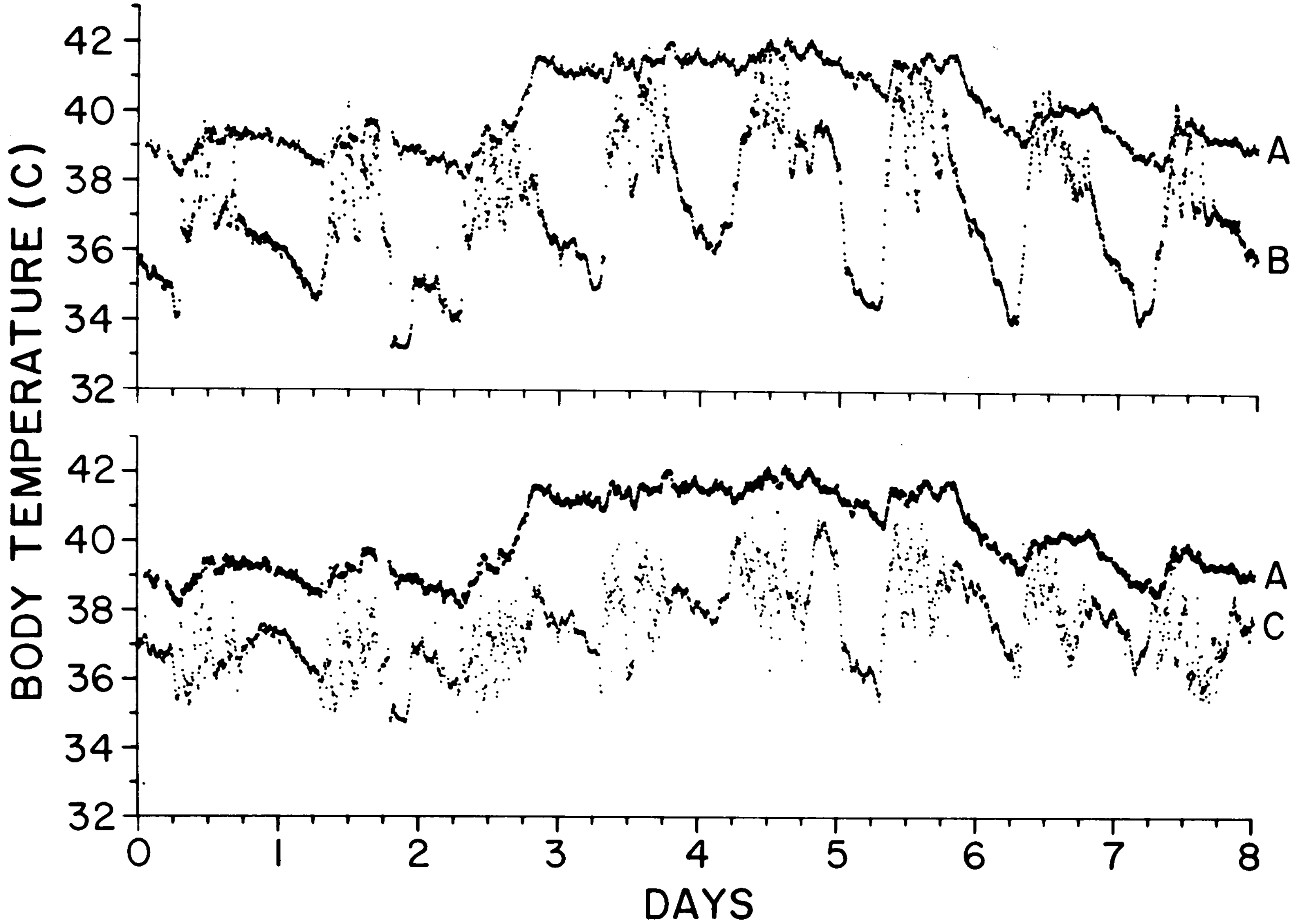

Fig. 14.
A comparison of subdermal temperatures during fever. The upper plot shows the uncorrected subdermal temperature data (B) and the lower plot shows the subdermal temperature corrected for black globe temperature (C).

that may be of considerable use is the determination of an average herd temperature from animals within a certain period of time. Each temperature included in this average may then be compared to the average to produce a ranking of animals relative to the herd average. If all animals are exposed to the same environmental conditions, we may be able to assume that animal temperatures will remain in the same position relative to the herd average or shift positions in predictable fashion. Any unexplained shifts in position may then be flagged for possible caretaker intervention. This, however, requires a statistically significant sampling of a herd or a section of a herd near in time to any individual temperature reading. This type of data gathering is easily possible in dairy herds at milking time. It may also be adapted to range and feedlot conditions. However, preliminary correction factors, such as those mentioned above, may need to be applied before calculating the herd average.

In the experiments completed to date, it appears that the withers is an acceptable location for the implantation of the transponder units. With appropriate forms of correction, acceptable data may be obtained that could alert livestock managers of health problems. However, since sunlight appears to be a major source of pertubation it is still worthwhile to consider the use of alternative implantation sites that may obviate the need for extensive data manipulation. Such considerations would be necessary only where sunlight is encountered and different optimum implant locations may be found for beef and dairy cattle. Whether the use of different implant sites is possible must be determined during the field trials.

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APPENDIX A

LOGGING ANIMAL ID DATA USING THE TRS-80 MICROCOMPUTER

by
J. A. Landt

The following equipment was used for data-logging using the TRS-80 microcomputer: (1) a standard 16K RAM Level II BASIC TRS-80 microcomputer, (2) an expansion interface with 32K RAM, (3) an RS-232 board, and (4) a "quick" printer.

I. SET UP

The TRS-80 microcomputer manuals are fairly complete. The system is easy to set up but could take 4 to 8 h if one had no previous familiarity with this type of equipment. Several problems do surface in the set-up procedure that require particular attention.

The expansion interface manual has an error on page 6, first line, concerning the arrangement of the cassette cables. The correct arrangement is shown on page 7, Fig. 5 of the manual. Cassette cable #1 should be wired to the port nearest the minidisk port, cassette cable #2, the middle, and the keyboard patch cord closest to the power cords.

The "dummy plug" should not be put in the microphone jack CTR-80 cassette recorders. This is mentioned in a small, easily overlooked addendum.

The RESET button is hidden and does not seem to function properly. If the computer gets hung up (on problems in a tape read, for example), the keyboard power should be turned off and then back on. This erases everything in RAM, but there appears to be no other way.

II. USE OF CASSETTE AND TAPES

The real-time clock works well. However, for 32K RAM in the expansion interface, the addresses are slightly different than given in the manual. Also, the real-time clock must be turned off to use the cassette. Otherwise, data transferred to and from the cassette is filled with noise. To account for the lost time, the real-time clock can be updated each time data are recorded on the cassette.

Only about six lines of data can be placed on the cassette tape with a single command, and it takes a long time (about 9 s). The maximum output is 255 characters (preceeded by a long leader). In comparison, the Techtran cassette writes in blocks of 256 characters in < 1 s. There should be some way around this slow recording.

System tapes go on cassette #1 for loading. CLOAD and CSAVE should be used with care. Mistaken use of CLOAD when CSAVE was desired is disastrous. A CLOAD with an improper volume-level setting on the cassette requires a complete restart (turn the power off then back on). A backup tape should be kept so you do not have to start from scratch if a program is lost because of a computer "hangup."

III. USE OF THE RS-232 INTERFACE WITH LEVEL II BASIC

A. General Considerations

The RS-232 interface can be used with the standard Level II BASIC. The manuals have all of the required information, but do not explain how to use the RS-232 with Level II BASIC commands. Assembly language may execute faster, but the BASIC commands are adequate for the electronic identification demostration (EID) data-logging needs at 300 baud. At higher baud rates, very little can be done with the RS-232 interface using BASIC programming because of timing problems. For high-speed data transfer applications, the RS-232 interface is more useful when driven by a machine language program. This requires assembly language or FORTRAN programming. Machine language routines can be loaded from tape or from coding placed in a BASIC code. Execution can be from the System mode or through a subroutine system call in BASIC. The nondisk Level II BASIC supports only one such subroutine call; therefore, the real-time clock and the RS-232 cannot both be controlled by a subroutine call. Once the machine language codes are generated, no exceptional programming skill is required to use them.

The program TERM can be used to check out the RS-232 interface. (This program is supplied with the RS-232 board from Tandy Corporation.) TERM is initialized by setting the switches on the RS-232 board corresponding to the external equipment requirements. Data coming from the external equipment are interpreted as ASCII characters and displayed on the screen.

Use of the RS-232 interface hinges on two BASIC commands (1) OUT X, Y and (2) Z = INP(X), where X is a port address (decimal) and Y and Z are data to be output to the port or read from the port, respectively. Two steps are required (1) to set the RS-232 interface in the desired configuration, and (2) to input or output the desired data. With Level II BASIC, the second of the two required steps is accomplished by using the data provided in the manual along with number conversions from hexadecimal to decimal, binary to decimal, etc. Similar coding can be done in assembly language or FORTRAN. An example is provided in Sec. D.

B. Hardware Setup

Install the RS-232 board according to the instructions in the manual. Set the TERM/COMM switch to TERM.

For logging data on the standard 25-pin connector, pin 7 is ground, pin 3 is data input, and either pin 4 or 20 can be used to indicate that the interface is ready.

C. Commands and Conventions

Tables A-I through A-VI provide all the data needed to use the RS-232.

D. Example

The easiest way to show how to use the RS-232 interface is by example.

Consider a signal with the following conventions: 300 baud, 8 bits of data, 2 stop bits, 1 start bit, and no parity. The example is outlined in Table A-VII.

The Y variable in step 5 is the decimal character that was received by the RS-232 interface and is available for processing. Data can be held off by setting D1 to 1 (step 3). The remainder of the control character is the same as in Step 3, and the command would then be OUT 234,250. The coding provided in Table A-VIII below turns the EID data on and off and prints the numbers on the video display. Further processing is required to convert the numbers to ID numbers and temperature.

IV. DATA-LOGGING

The data-logging program (Appendix B) logs the EID data on the line printer and cassette tapes. Program variables are listed in Table A-IX and subroutine functions are given in Table A-X. Figure A-1 shows the flow diagram of the program. This program operates the RS-232 interface at 2400 baud. As a result, the FORTRAN data-logging program (in Appendix B) accesses the interface. The compiled FORTRAN program is loaded automatically by the BASIC program (lines 500 to 584).

A. Initialization

To run the program, follow the instructions given below (this explanation assumes operating knowledge of the TRS-80 system):

Level III BASIC* is the recommended operating system. If Level III BASIC is not used, the real-time clock will not function.

Capital letters are system prompts. Underlined capital letters are necessary operator commands.

1. Connect cables; turn power on.
2. MEMORY SIZE? <u>60000 ENTER</u>, (the enter key)

*GRT Corp., Consumer Computer Group, 1286 N. Lawrence Station Rd., Sunnyvale, CA 94086.

TABLE A-Ia

SENSE SWITCH CONVENTIONS FOR THE RS-232 BOARD

Position	Binary State
Closed	0
Open	1

TABLE A-Ib

CONTROL SIGNAL CONVENTIONS FOR THE RS-232

Voltage Level	Binary State
High (3.5 to 12)	0
Low (-12 to -3.5)	1

TABLE A-II

PIN DESIGNATIONS AND SIGNAL DESCRIPTION FOR THE RS-232 CONNECTOR

Pin Number	Abbreviation	Description
1	PGND	Protective Ground
2	TD	Transmit Data
3	RD	Receive Data
4	RTS	Request-to-Send
5	CTS	Clear-to-Send
6	DSR	Data Set Ready
7	SGND	Signal Ground
8	CD	Carrier Detect
20	DTR	Data Terminal Ready
22	RI	Ring Indicator

TABLE A-III

OPERATION OF SENSE SWITCHES[a] ON THE RS-232 BOARD

Baud Rate	S6	S7	S8
110	Closed	Closed	Closed
150	Closed	Closed	Open
300	Open	Closed	Closed
600	Open	Closed	Open
1200	Closed	Open	Closed
2400	Closed	Open	Open
4800	Open	Open	Closed
9600	Open	Open	Open

Parity	S4
Enabled	Closed
Disabled	Open

Stop Bits	S5
1	Closed
2	Open

Word Length	S2	S3
5-bit word	Closed	Closed
6-bit word	Closed	Open
7-bit word	Open	Closed
8-bit word	Open	Open

Parity Select	S1
Odd parity	Closed
Even parity	Open

[a] Sense switch abbreviated "S" with identifying number following.

TABLE A-IV

MAPPED MEMORY ALLOCATION OF THE RS-232

Address			
Decimal	Hexadecimal	Out (I/O Port Write)	In (I/O Port Read)
232	E8H	Master Reset (Any Data)	Modem Status Register
233	E9H	Baud Rate Select	Configuration Sense Switches
234	EAH	UART[a] Control Register and Handshake Latch	UART Status Register
235	EBH	Transmit Data Register	Received-Data Register

[a] Universal Asynchronous Receiver Transmitter.

TABLE A-V

SUMMARY OF BAUD RATE GENERATOR (BRG) PROGRAMMING FOR THE RS-232

Nibble Loaded (H)	Transmit or Receive Baud Rate	10x Clock Freq (kHz)	% Error	Switch-Selectable
0	50	0.8	0	No
1	75	1.2	0	No
2	110	1.76	0	Yes
3	134.5	2.1523	0.016	No
4	150	2.4	0	Yes
5	300	4.8	0	Yes
6	600	9.6	0	Yes
7	1 200	19.2	0	Yes
8	1 800	28.8	0	No
9	2 000	32.081	0.253	No
A	2 400	38.4	0	Yes
B	3 600	57.6	0	No
C	4 800	76.8	0	Yes
D	7 200	115.2	0	No
E	9 600	113.6	0	Yes
F	19 200	316.8	3.125	No

TABLE A-VI

BIT ALLOCATIONS FOR REGISTERS AND LATCHES ON THE RS-232

Bit Value (Decimal)	Data Bit	Modem Status Register	Configuration Sense Switches	UART[a] Control Register and Handshake Latch	UART Status Register
128	D7	Clear to send; Pin 4, DB-25[b]	Even Parity Enable; 1=even, 0=odd	Even Parity Enable; 1=even, 0=odd	Data Received; 1=Condition true
64	D6	Data Set Ready; Pin 6, DB-25	Word length; select 1	Word length; select 1	Transmitter Holding; Register Empty; 1=Condition true
32	D5	Carrier detect; Pin 8, DB-25	Word length; select 2	Word length; select 2	Overrun Error; 1=Condition true
16	D4	Ring Indicator; Pin 22, DB-25	Stop bit select; 1=2 bit, 0=1 bit	Stop bit select; 1=2 bit, 0=1 bit	Framing error; 1=Condition true
8	D3	Unused	Parity inhibit; 1 disables parity	Parity inhibit; 1 disables parity	Parity error; 1=Condition true
4	D2	Unused	Baud Rate 3	Break	Unused
2	D1	Receiver Input; UART, P20	Baud Rate 1	Request to send; Pin 4, DB-25	Unused
1	D0	Unused	Baud Rate 2	Data Terminal Ready; Pin 20, DB-25	Unused
		In OE8H (232)	In OE9H (233)	Out OEAH (234)	In OEAH (234)

[a] Universal Asynchronous Receiver Transmitter.

[b] DB-25 is the standard 25-pin RS-232 connector (Table A-II).

TABLE A-VII

INSTRUCTIONS FOR USING THE RS-232 INTERFACE WITH AN EXAMPLE

Step	Function	Basic Command
1	Master reset.	OUT 232,0
2	Set the baud rate. 300 = 5 H from Table A-V So transmit = receive baud rate = 300 is 55 H = 85 decimal (16 x 5 + 5). Table A-IV gives address of Baud Rate Select of 233.	OUT 233,85
3	Set UART[a] control register. By using the signal characteristics listed above, Table A-III and Table A-VI, the control character is:	

Bit	State	Explanation
D7	1	Even parity, not really used
D6	1	8-bit word=S2 & S3 open (T. A-III)
D5	1	= D6 = D5 =1 (T. A-Ia).
D4	1	2 stop bits.
D3	1	Disabled parity.
D2	0	Not used.
D1	0	Apply +12 V to pin 20; ask for data.
D0	0	Not used.

Step	Function	Basic Command
	The control character is 11111000; binary or 248 decimal.	OUT 234,248
4	See if data received. Data received if D7 = 1 or if X > 127.	X = INP (234)
5	Get data. When X > 127 or D7 = 1, get data. This automatically resets D7 to 0.	Y = INP (235)

[a] Universal Asynchronous Receiver Transmitter.

TABLE A-VIII

A PROGRAM TO READ DATA FROM THE RS-232

Code		Comments
10	OUT 232,0	Master reset.
20	OUT 233,85	Baud rate = 300.
30	OUT 234,248	Sets UART and turns EID data on.
40	X = INP (234)	See if data received.
50	If X > 127 GO TO 70	If D7 of X = 1 (X $\geq$ 128), data received.
60	GO TO 40	Try again.
70	OUT 234,250	Hold off future EID data.
80	X = INP(235)	Read data.
90	Print X	Output data.
100	GO TO 30	Proceed to next data.
110	END	

TABLE A-IX

EID CASSETTE DATA-LOGGER PROGRAM VARIABLES, VERSION 2.1

Variable	Use
TO	10-element array used to accumulate data.
TA	7-element array used for clock initialization.
TZ	12-element array used for labels.
D	8-element array of data (1 through 7 are used).
A	8-element array; the address part of D.
N	8-element array; the data part of D.
TB	Temporary storage of string data.
I3	I3=1 if Level III BASIC is loaded, 0 otherwise.
TP	"CLOCK INOPERATIVE" if I3=0 or TP=actual time if I3=1.
IP	IP = 1 if line printer output is desired, 0 otherwise.
IR	IR = 1 if data is recorded on cassette, 0 otherwise.
IN	Meant to count data numbers; not implemented.
IM	The number of strings of TO that have been filled.
IS	A temporary integer used for timing and cassette output.
ID	The number of filled positions in D.
IO	The total number of triggers seen; not presently used for anything.
TU	The previous EID data string.
I	A temporary integer; used for simple short loops, etc.
TC	A string containing a comment.
IL	The length of string TC.
IC	The number of blocks of 25-character strings in TC.
I2	A temporary integer used in comment subroutines. I2=1 signals that TC is a new comment. I2=0 signals that part of TC has been output.
IA	The number of unused TO strings.
II	A temporary integer.
TT	Used at the beginning of comment blocks; TT="*" or " ". Also used in reinitializing the clock and for time and old identification number in data read subroutine.
I9	Used for control of screen output.
I8	Used for control of screen output.
DS	The integer number of seconds required for a cassette save.
S	Seconds.
M	Minutes.
H	Hours.
E2	Number of seconds since 12:00 midnight.
LH	Temporary; used for string length.
Y	Temporary; used to test status of UART.
FL	An error flag FL = 0 means no errors, FL = 1 means errors found.
X	Accumulates N for a quick test of a trigger.
TN	The new or present EID data string.
TD	The identification number portion of the string TN.
II	A temporary integer.
TV	The time string printed on the screen.

TABLE A-X

DATA-LOGGING SUBROUTINES

Subroutine	Function
GOSUB 502	Load RS-232 program machine language.
GOSUB 1010	Clock initialization. Returns I3=1 if Level III BASIC is loaded.
GOSUB 2010	Initializes output device controls; resets UART and variables.
GOSUB 3010	Keyboard scan and comment recorder. Fills array TC so that length is a multiple of 25 characters.
GOSUB 4010	Interrogates UART and decodes data. Fills the array TN with data.
GOSUB 5010	Updates screen display time.
GOSUB 5210	Fills the TO array from the comment string TC. Calls for cassette output if 9 TOs are filled. Also prints comments.
GOSUB 5710	Fills TO array with data in TN. Prints data and calls for cassette output if 9 TOs are filled.
GOSUB 6010	Sends data to cassette. Assumes that TO(1) through TO(9) are filled with data or comments. Turns off system clock while cassette is running and automatically reinitializes the clock.
GOSUB 7010	Fills unused TOs with filler and sends the data to cassette.
GOSUB 8010	Fills TZ array with labels.
GOSUB 9010	Calls GOSUB 7010 so that data in memory is not lost, then permits reading of tapes.
GOSUB 9510	Cleans up the top of the screen after comments, etc.

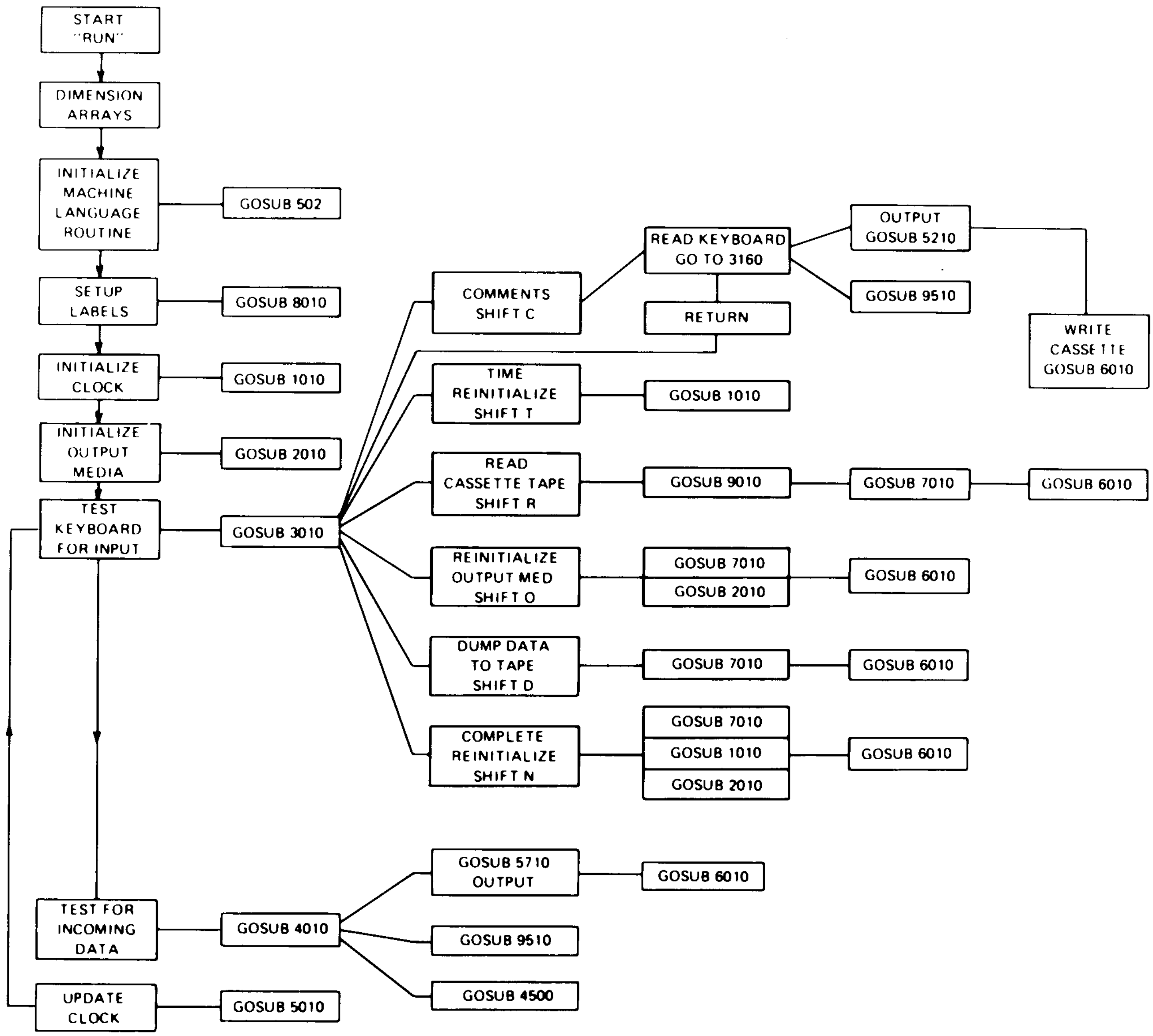

Fig. A-I.
EID cassette data-logger program flow diagram.

3. Place EID program tape on cassette #1 and prepare for reading.
4. READY
   <u>SYSTEM ENTER</u>
5. ? <u>LEV3 ENTER</u>
6. Wait for tape to load. See the TRS-80 manuals if troubles occur. Proper loading is occurring when one asterisk is steady and the other flashes slowly in the upper right corner of the screen.
7. ? <u>/ENTER</u>
8. G2 LEVEL III BASIC
   •
   •
   •
   READY
   <u>LOAD#-1, ENTER</u>
9. READY
   Remove program tape from cassette #1.
10. <u>RUN ENTER</u>
11. Answer the questions and supply the data the program asks for. If the program dies, type in RUN again (or reload the program).

12. When "PRESENT TIME AND DATE" and the time is displayed, the program is running and waiting for data.

B. Controls

The user can control the program, change modes, and add comments by using the shift key in conjunction with other keys. The controls presently in the program are

1. Shift C: Program pauses and allows comments to be typed in.
2. Shift R: For reading data tapes. Program dumps any data stored in memory to the cassette first so that no data are lost. The clock must be reinitialized after this control is used.
3. Shift D: Dumps any data stored in memory to cassette. Typically used if one wants to change cassette tapes.
4. Shift O: Changes output devices (that is, can turn off line printer, etc.).
5. Shift T: Reinitializes the clock. Used for resetting the time.
6. Shift N: Complete new initialization.

C. Notes About the Data-Logging Program

The data-logging program is running smoothly and has been checked out. The progam does not process the data. Software additions could be made to calculate running averages, etc. Other control features could be added as well. Future software modifications are anticipated to increase its utility.

Following are some of the quirks of the TRS-80 system and how these quirks affect this program. Software was required so that commas, colons, and slashes could be used in comments. Quotes are converted to apostrophes.

The timing between the TRS-80 and the EID equipment is fairly critical. Care should be used when changing the program in the areas of accessing the RS-232 interface.

To make full use of the cassette, data are "packed." The data are broken into blocks of 26 characters. Each block is treated as a string. Data on the transponder number, temperature, and the time and date are contained in a single block. Comments are also broken up into blocks of 26 characters. The first block of a comment contains an asterisk in the first character. Continuation blocks for the same comment contain a blank in the first character. When nine blocks have been accumulated (ID numbers and comments intermixed), one long string is formed by summing the nine blocks. To avoid unwanted interaction, quotation marks are added at the ends of the long string before it is recorded. All of this was required to utilize the cassette fully and to avoid unwanted responses prompted by commas, colons, etc., in the comment strings.

The system clock is turned off and reinitialized automatically for the cassette output.

Interrogation is initiated by a "trigger" signal. This signal turns on the EID equipment and sends an ID number 0 and a temperature reading 0 to the data-logging equipment. The data- logging program recognizes this sequence as a new trigger, and does not record the data. Other incoming data are checked for errors and recorded if no errors are found. Additionally, identical sequential ID numbers are not recorded to conserve paper and magnetic tape.

The program has not been optimized to reduce memory requirements or running time. About three readings per second can be processed.

V. SUMMARY

Data-logging on the standard cassette is very slow and cannot be done with the clock on. The disk system works very well for data-logging (only slight modification of the program in Appendix B is required to use the disk system). Cassette-recording time could be reduced by using the RS-232 interface and a digital cassette drive such as the Techtran Model 817. For efficiency, the use of a disk system is best. The only major constraint is control of the environment of the TRS-80. Extreme heat, cold, humidity, or dust are not tolerated well. Additional input/output (I/O) channels are not presently available to record other data.

APPENDIX B

DATA-LOGGING PROGRAM

```
5 REM **** MACHINE LANGUAGE DATA AQUISITION SUBROUTINE
10 REM EID DATA LOGGER VERSION  5.2 11-19-79 J LANDT
15 REM ***  FOR 2400 BAUD
20 REM HAS CHOICES FOR SCREEN, LINE PRINTER, AND CASSETTE
30 CLEAR 2000
40 DEFSTR T
50 DIM T0(10),TA(7),TZ(12)
55 DEFSNG E
60 DEFINT I,O,N,F,D,A,H,M,S,L,Y
70 DIM D(8),A(8),N(8)
71 Y3=0:YO=0:YI=0:YD=-528:READ YP:READ YQ
72 POKE 16526,176:POKE 16527,250
73 GOSUB 502
75 GOSUB 8010
80 REM INITIALIZE AND SETUP
90 GOSUB 1010
100 GOSUB 2010
110 REM TEST INKEY FOR KEYBOARD INTERACTION
120 GOSUB 3010
130 REM TEST FOR INCOMMING DATA AND PROCESS
140 GOSUB 4010
150 REM UPDATE SCREEN CLOCK
160 GOSUB 5010
170 GOTO 120
180 REM END SESSION
200 CLS
210 PRINT "TERMINATION NOT IMPLEMENTED YET"
220 PRINT "ENTER A NUMBER OF COMMENTS TO GET"
230 PRINT "ALL OF THE LAST DATA ON TAPE"
240 PRINT " "
250 PRINT "   PROGRAM WILL RESUME"
260 GOTO 120
500 REM **** MACH LANGUAGE INITIALIZATION
501 DATA -1360,-535
502 DATA  33,  0,  0, 34,  4,254, 33,  0,  0, 34
503 DATA   6,254, 33, 59,252,205,148,252, 50,  2
504 DATA 254,214,127, 23,159, 50,  8,254,183,194
505 DATA 229,250, 33, 61,252,205,148,252, 50,  1
506 DATA 254, 17, 63,252, 33, 59,252,205,164,252
507 DATA 195, 51,251, 17, 63,252, 33, 59,252,205
508 DATA 164,252, 33,  1,  0, 34,  9,254, 33, 59
509 DATA 252,205,148,252, 50,  2,254,214,127, 61
510 DATA 214,127,159, 50,  8,254,183,194, 42,251
511 DATA  42,  9,254, 35, 62,100,149, 62,  0,156
512 DATA 242,241,250, 17, 65,252, 33, 59,252,205
513 DATA 164,252, 17, 53,252, 33, 67,252,205,143
514 DATA 252,201, 33, 61,252,205,148,252, 50,  1
515 DATA 254, 58,  1,254,111, 23,159,103,235, 33
516 DATA  16,  0,205, 71,252, 34, 11,254, 41, 41
517 DATA  41, 41,235, 58,  1,254,111, 23,159,103
518 DATA 123,149,111,122,156,103,175,149,111,156
519 DATA 149,103,125, 50,  3,254, 42, 11,254,235
520 DATA  42,  4,254,123,149,111,122,156,103,125
521 DATA   7,181,230,127,180,214,  1,159, 50,  8
522 DATA 254,183,194,198,251, 33,  0,  0, 34,  6
523 DATA 254, 42, 11,254, 43,125,  7,181,230,127
524 DATA 180,214,  1,159, 50,  8,254,183,194,198
525 DATA 251, 42, 11,254,125,  7,181,230,127,180
526 DATA 214,  1,159, 50,  8,254,183,194,189,251
527 DATA  17, 65,252, 33, 59,252,205,164,252, 17
528 DATA  69,252, 33, 67,252,205,143,252,201, 33
529 DATA   1,  0, 34,  4,254,195,238,250, 42,  6
530 DATA 254,235, 58,  3,254,111, 23,159,103, 25
531 DATA  34,  6,254, 42, 11,254, 35, 34,  4,254
532 DATA  42, 11,254, 17,241,253, 25, 34, 11,254
533 DATA  17,  3,254, 33, 11,254,205,143,252, 42
534 DATA   4,254, 17,249,255, 25,125,  7,181,230
535 DATA 127,180, 23,159, 50,  8,254,183,194,238
536 DATA 250, 17, 65,252, 33, 59,252,205,164,252
537 DATA  17, 57,252, 33, 67,252,205,143,252, 42
538 DATA   6,254,125,  7,181,230,127,180,214,  1
539 DATA 159, 50,  8,254,183,202, 43,252,201, 17
540 DATA  55,252, 33, 67,252,205,143,252,201,  2
541 DATA   0,  1,  0,  0,  0,234,  0,235,  0,248
542 DATA   0,250,  0,240,253,  3,  0,235,122,179
543 DATA 202,106,252,122,183, 66,252,110,252,124
544 DATA 168, 71,124,181,200,124,183,235,252,110
545 DATA 252,197,205,192,252,241,183,252,110,252
546 DATA 235,201,205,244,252,137,175, 79,147, 95
547 DATA 121,154, 87,201, 33,223,255,126, 47,119
548 DATA 175,111,144, 71,125,155, 95,125,154, 87
549 DATA 125,153, 79,201, 94, 35, 86, 26,201,205
550 DATA 181,252,115,201,  1,219,255, 62,219,  2
551 DATA   3,126,  2,  3, 62,201,  2,195,219,255
552 DATA   1,219,255, 62,211,  2,  3,126,  2,  3
553 DATA  62,201,  2, 26,195,219,255,126, 35,102
554 DATA 111,235,126, 35,102,111,235,201,124, 47
555 DATA  71,125, 47, 79,  3, 33,  0,  0, 62, 17
556 DATA 245,183,195,219,252,245,229,  9,219,218
557 DATA 252,241, 55, 62,225,123, 23, 95,122, 23
```

```
558 DATA  87,125, 23,111,124, 23,103,241, 61,194
559 DATA 209,252,124,183, 31,103,125, 31,111,201
560 DATA 225,126, 35,229,183, 23,245, 79,  6,  0
561 DATA  33, 70,253,  9, 94, 35, 86,235, 34, 17
562 DATA 254, 33, 13,254, 54, 13, 35, 54, 10, 35
563 DATA  54, 42, 35, 54, 42, 35, 35, 35, 54, 42
564 DATA  35, 54, 42, 35, 54, 13, 35, 54, 10, 33
565 DATA  13,254,  6, 10,197,126,205,173,253,193
566 DATA   5, 35,194, 42,253, 58, 23,254, 60, 50
567 DATA  23,254,254, 20,210,151,253,241,208,195
568 DATA 151,253, 73, 68, 70, 48, 77, 80, 73, 82
569 DATA  70, 87, 73, 84, 69, 88, 68, 79, 77, 76
570 DATA  68, 90, 76, 71, 83, 81, 73, 66, 84, 76
571 DATA  79, 66, 68, 69, 73, 83, 66, 69, 73, 78
572 DATA  79, 86, 67, 78, 71, 76, 71, 83, 83, 78
573 DATA  65, 58, 73, 79, 68, 84, 66, 73, 82, 67
574 DATA  69, 70,175, 50, 23,254, 50, 24,254, 33
575 DATA 150,253, 34, 25,254, 42, 73, 64,249, 96
576 DATA 105,233,201, 33,159,253,229, 42, 25,254
577 DATA 233, 62, 13,205,173,253, 62, 10,205,173
578 DATA 253,195, 45, 64,201,254, 10,200,197,213
579 DATA 229,245,205, 51,  0,194,  0,  0,241,225
580 DATA 209,193,201,229, 42, 27,254,126,254, 13
581 DATA 204,212,253,183,204,212,253, 35,126, 34
582 DATA  27,254,225,201,197,213,  6, 80, 33, 29
583 DATA 254,205, 64,  0,120,183,202,214,253, 33
584 DATA  28,254,209,193,201,255
700 CLS:PRINT CHR$(23):PRINT "WAIT-----"
705 PRINT@ 384, "MACHINE LANGUAGE SUBROUTINE "
710 PRINT "IS BEING LOADED"
715 FOR I=YP TO YQ
720 READ II
725 POKE I,II
730 NEXT I
735 CLS
740 RETURN
1000 REM *******  INITIALIZATION SUBROUTINE FOR CLOCK *********
1010 CLS
1020 PRINT "IS LEVEL III BASIC LOADED IN?"
1025 PRINT "  ":PRINT "ANSWER Y OR N :  ";
1030 TB=INKEY$
1040 IF TB="" GOTO 1030
1050 PRINT TB
1060 IF TB="Y" GOTO 1090
1070 IF TB="N" GOTO 1270
1080 GOTO 1010
1090 ON ERROR GOTO 1500
1091 TV=TIME$
1093 PRINT "  ":I3=1
1095 LSET RESET
1100 PRINT "FOLLOW FORMAT OF EXAMPLE IN ENTERING DATA"
1110 PRINT "A 24-HOUR CLOCK IS USED"
1120 PRINT "TO INITIALIZE CLOCK, TYPE IN MONTH DAY YEAR HOUR";
1130 PRINT " MINUTE SECOND"
1140 PRINT "FOLLOWED BY HITTING THE 'ENTER' BAR"
1150 PRINT "THE CLOCK IS STARTED WHEN THE 'ENTER' BAR IS HIT"
1160 PRINT " "
1170 PRINT "EVERY NUMBER MUST CONTAIN 2 AND ONLY 2 DIGITS, AND"
1180 PRINT "SEPARATE NUMBERS BY A SINGLE SPACE"
1190 PRINT "EXAMPLE:  JULY 19, 1979 AT 5 MINUTES 33 SECONDS"
1200 PRINT "AFTER 3 O'CLOCK PM IS:";
1210 PRINT "        07 19 79 15 05 33ENTER"
1220 PRINT "NOW ENTER THE PRESENT TIME: ";
1230 INPUT TB
1235 ON ERROR GOTO 1600
1240 CMD "R", TB:TP=TIME$
1250 CLS
1255 ON ERROR GOTO 0
1260 GOTO 1280
1270 TP="CLOCK INOPERATIVE":I3=0
1275 ON ERROR GOTO 0
1280 PRINT "    "
1290 PRINT TP
1295 IF IP=1 LPRINT CHR$(30);"INITIALIZATION TIME:    ";TP
1300 PRINT "  "
1310 RETURN
1500 CLS
1502 PRINT CHR$(23);"TRIED TO FOOL ME HUH ??"
1504 PRINT "  "
1506 PRINT "LEVEL III IS NOT IN"
1508 PRINT "RESIDENCE.  THE CLOCK"
1510 PRINT "WILL BE INOPERATIVE"
1512 PRINT "  "
1514 PRINT "HIT THHE 'C' KEY TO CONTINUE : ";
1516 TB=INKEY$
1518 IF TB="C" GOTO 1522
1520 GOTO 1516
1522 CLS
1524 RESUME 1270
1600 CLS
1602 PRINT CHR$(23);"TRIED TO FOOL ME HUH ??"
1604 PRINT "  "
1606 PRINT "DATA WAS NOT IN THE RIGHT FORMAT"
1608 PRINT "THE CLOCK WILL BE RESET TO 0"
1610 PRINT "  "
1612 PRINT "HIT THE 'C' KEY TO CONTINUE : ";
1614 TB=INKEY$
1616 IF TB="C" GOTO 1620
1618 GOTO 1614
```

```
1620 TB="00 00 00 00 00 00"
1622 CMD "R",TB
1624 RESUME 1250
2000 REM *******  INITIALIZATION SUBROUTINE FOR OUTPUT ********
2010 CLS
2015 PRINT "IF LINE PRINTER IS NOT AVAILABLE BUT IS REQUESTED,"
2020 PRINT "THIS PROGRAM WILL DIE........."
2030 PRINT " "
2040 PRINT "IS LINE PRINTER HARD COPY DESIRED"
2050 PRINT "AS DATA IS TAKEN?":PRINT " ":PRINT "  ANSWER Y OR N: ";
2060 IP=0
2070 TB=INKEY$
2080 IF TB="" GOTO 2070
2090 PRINT TB
2100 IF TB="N" GOTO 2220
2110 IF TB<>"Y" GOTO 2010
2120 IP=1
2130 PRINT " "
2140 PRINT "IS LINE PRINTER READY?":PRINT " ":PRINT "  ANSWER Y OR N: ";
2150 TB=INKEY$
2160 IF TB="" GOTO 2150
2170 IF TB<>"Y" CLS:GOTO 2010
2172 FOR I=1 TO 2: LPRINT " ":NEXT
2174 LPRINT CHR$(31);"      ";TZ(1)
2176 LPRINT STRING$(6," ");TZ(2)
2178 LPRINT " "
2180 LPRINT CHR$(30);"    ";TZ(3);" ";TZ(11)
2182 LPRINT " "
2184 LPRINT STRING$(17," ");TZ(4)
2186 LPRINT "    ";TZ(5);"ORATORY"
2188 LPRINT STRING$(13," ");TZ(6)
2190 LPRINT STRING$(10," ");TZ(7)
2192 LPRINT " "
2194 LPRINT STRING$(7," ");TZ(8)
2196 LPRINT " "
2198 LPRINT STRING$(7," ");TZ(9)
2200 LPRINT STRING$(7," ");TZ(10)
2202 FOR I=1 TO 3:LPRINT " ":NEXT
2204 LPRINT CHR$(29);"INITIALIZATION DATE AND TIME IS   ";TP
2206 LPRINT " "
2208 LPRINT CHR$(30);"ID  TEMP   DATE    TIME"
2220 CLS:PRINT "IS PARALLEL OUTPUT TO WEIGH-RIGHT SCALE DESIRED?":PRINT "   ":PR
INT "ANSWER Y OR N :  "
2221 TB=INKEY$
2222 IF TB="" GOTO 2221
2223 IF TB<>"Y" GOTO 2225
2224 IP=2:GOTO 2230
2225 IF TB<>"N" GOTO 2220
2230 CLS:PRINT "DATA CAN BE RECORDED ON CASSETTE AS IT IS TAKEN"
2240 PRINT " "
2250 PRINT "DATA IS RECORDED IN BLOCKS OF 9 RECORDS"
2260 PRINT "A RECORD IS A STRING OF 26 CHARACTERS"
2270 PRINT "DATA AND COMMENTS ARE INTERMIXED"
2280 PRINT "IT TAKES ABOUT 9 SECONDS TO RECORD ONE BLOCK"
2290 PRINT " "
2300 PRINT "DO YOU WANT DATA RECORDED AS IT IS TAKEN?"
2305 PRINT " "
2310 PRINT " ANSWER Y OR N: ";
2320 IR=0
2330 TB=INKEY$
2340 IF TB="" GOTO 2330
2350 IF TB="N" GOTO 2440
2360 IF TB<>"Y" GOTO 2220
2370 IR=1:CLS
2380 PRINT "DATA IS RECORDED ON CASSETTE # 1"
2390 PRINT "IS CASSETTE # 1 READY FOR RECORDING?"
```

```
2395 PRINT " "
2400 PRINT "ANSWER Y OR N: ";
2410 TB=INKEY$
2420 IF TB="" GOTO 2410
2430 IF TB<>"Y" GOTO 2220
2440 CLS
2450 PRINT "COMMENTS PERTAINING TO A READING WILL BE ACCEPTED"
2460 PRINT "ONLY BETWEEN DATA READINGS.  PROGRAM LIMITS"
2470 PRINT "A SINGLE COMMENT TO 225 CHARACTERS"
2480 PRINT " ":PRINT "HIT THE 'SHIFT' KEY AND THE 'C' KEY"
2490 PRINT "SIMULTANEOUSLY TO OBTAIN A PROMPT FOR COMMENTS"
2500 PRINT " "
2510 PRINT "NEXT :  UART WILL BE INITIALIZED AUTOMATICALLY"
2520 PRINT "CONNECT DATA LINE"
2530 PRINT " "
2540 PRINT "IS EVERYTHING OK?":PRINT " ":PRINT "  ANSWER Y OR N: ";
2550 TB=INKEY$
2560 IF TB="" GOTO 2550
2570 IF TB<>"Y" GOTO 1010
2580 OUT 232,0  'MASTER RESET
2590 OUT 233,170 'TRANS=REC BAUD RATE =2400
2600 OUT 234,250 'HOLD OFF DATA
2610 IN=0
2620 IM=0
2630 IS=0
2640 ID=0
2660 I0=0
2665 I9=0
2666 CLS
2670 GOSUB 9510
2680 TU=STRING$(26," ")
2690 FOR I=1 TO 8
2700 D(I)=0
2710 N(I)=0
2720 A(I)=0
2730 NEXT I
2740 RETURN
3000 REM ****** KEYBOARD CONTROL SUBROUTINE *********
3010 I=0 ' TEST KEYBOARD FOR INPUT
3020 TB=INKEY$
3030 IF TB="" GOTO 3270
3040 IF TB="c" GOTO 3160
3050 IF TB="t" GOSUB 1010:CLS:PRINT CHR$(23):RETURN
3060 IF TB="r" GOSUB 9010:RETURN
3070 IF TB="o" GOSUB 2010 :RETURN
3075 IF TB="d" GOSUB 7010:CLS:PRINT CHR$(23):RETURN
3080 IF TB<>"n" GOTO 3120
3085 GOSUB 7010
3090 GOSUB 1010
3100 GOSUB 2010
3110 RETURN
3120 RETURN
3150 PRINT TB;:PRINT " ";:PRINT TB;
3151 IL=IL-1:IF IL=0 GOTO 3160
3152 TC=LEFT$(TC,IL)
3154 GOTO 3168
3160 PRINT@ 0, "HIT THE  'ENTER'  KEY AT END OF"
3161 PRINT "COMMENT.   ENTER COMMENT NOW : ":PRINT ">";
3162 TC=""
3164 IL=0
3168 TB=INKEY$
3170 IF TB="" GOTO 3168
3171 IF TB=CHR$(8) GOTO 3150
3172 IF TB=CHR$(13) GOTO 3220
3173 IF TB=CHR$(34) THEN TB="'"
3174 IL=IL+1
```

```
3176 PRINT TB;
3178 TC=TC+TB
3180 IF IL<225 GOTO 3168
3220 IF IL=0 GOTO 3265
3221 IC=IL/25
3222 I2=IL-25*IC
3224 IF I2=0 GOTO 3230
3226 IC=IC+1
3230 I2=IL-(IC-1)*25
3240 I=25-I2
3250 TC=TC+STRING$(I," ")
3255 I2=1
3260 GOSUB 5210
3265 GOSUB 9510
3270 RETURN
3280 GOSUB 9510
4000 REM *******   DATA REDUCTION AND TEST SUBROUTINE   ******
4010 Y1=USR(0)
4020 Y3=PEEK(YD)
4030 IF Y3=0 GOTO 4110
4040 IF Y3=1 GOTO 4140
4050 RETURN
4110 I0=I0+1
4120 YO=0
4125 IF IP=2 GOSUB 4500
4130 GOTO 4010
4140 IF I3=1 THEN TP=TIME$
4150 YI=PEEK(YD+4)+10*(PEEK(YD+3)+10*PEEK(YD+2))
4160 IF YI=YO GOTO 4220
4165 IF IP=2 GOSUB 4500
4170 YO=YI
4180 TN=RIGHT$(STR$(YI),3)+" "+RIGHT$(STR$(PEEK(YD+5)),1)+RIGHT$(STR$(PEEK(YD+6)
),1)+"."+RIGHT$(STR$(PEEK(YD+7)),1)+" "+TP
4190 GOSUB 5710
4200 GOSUB 9510
4210 TU=TN
4220 RETURN
4499 REM *****  TO OUTPUT PARALLEL DATA ON LINE PRINTER PORT
4500 POKE 14312,255
4510 POKE 14312,0
4520 FOR I=1 TO 3
4530 YX=PEEK(YD+8-I)+16*PEEK(YD+5-I)
4540 POKE 14312,YX
4550 NEXT I
4560 RETURN
5000 REM *******   CLOCK DISPLAY UPDATE SUBROUTINE   *********
5010 IF I3=1 GOTO 5040
5020 PRINT@ 0, STRING$(32," ")
5030 RETURN
5040 IF TIME$<>TV GOTO 5060
5050 RETURN
5060 TV=TIME$
5070 PRINT@ 0, "PRESENT       DATE     TIME    "
5075 PRINT STRING$(12," ");TV
5090 RETURN
5200 REM ******   OUTPUT COMMENTS SUBROUTINE   *************
5210 PRINT@ 0, "WAIT -- OUTPUTTING COMMENTS";STRING$(20," ")
5220 IA=9-IM
5230 IF IC<IA GOTO 5340
5240 I1=IM+1
5250 IM=9
5260 FOR I=I1 TO IM
5262 TT=" "
5264 IF I2=1 THEN TT="*"
5266 I2=0
5270 T0(I)=TT+LEFT$(TC,25)
```

```
5271 I9=I9+1
5272 IF I9>10 THEN I9=10
5273 I8=384+(I9-1)*64
5274 PRINT@ I8, "    ";T0(I)
5275 IF IP=1 LPRINT CHR$(30);"    ";T0(I)
5280 IC=IC-1
5290 TC=RIGHT$(TC,25*IC)
5300 NEXT I
5310 GOSUB 6010
5320 IF IC>0 GOTO 5340
5330 RETURN
5340 I1=IM+1
5350 IM=IM+IC
5360 FOR I=I1 TO IM
5362 TT=" "
5364 IF I2=1 THEN TT="*"
5366 I2=0
5370 T0(I)=TT+LEFT$(TC,25)
5371 I9=I9+1
5372 IF I9>10 THEN I9=10
5373 I8=384+(I9-1)*64
5374 PRINT@ I8, "    ";T0(I)
5375 IF IP=1 LPRINT CHR$(30);"    ";T0(I)
5380 IC=IC-1
5390 IF IC=0 THEN IC=1
5400 TC=RIGHT$(TC,25*IC)
5410 NEXT I
5420 IF IM=9 GOTO 5450
5430 RETURN
5450 GOSUB 6010
5460 PRINT@ 0, STRING$(27," ")
5470 RETURN
5700 REM *****   OUTPUT DATA SUBROUTINE   **************
5710 I9=I9+1
5715 IF I9>10 THEN I9=10
5720 I8=384+(I9-1)*64
5725 PRINT@ I8, TN
5730 IF IP=1 LPRINT CHR$(30);TN
5740 IN=IN+1
5750 IM=IM+1
5760 T0(IM)=TN
5770 IF IM=9 GOTO 5790
5780 GOTO 5800
5790 GOSUB 6010
5800 RETURN
6000 REM *********  OUTPUT TO CASSETTE SUBROUTINE  *******
6010 IM=0
6020 IF IR=1 GOTO 6040
6030 GOTO 6380
6040 PRINT@ 0, "WAIT -- WRITING TO CASSETTE";STRING$(20," ")
6042 TB=""
6044 FOR I=1 TO 9
6046 TB=TB+T0(I)
6048 NEXT
6049 TB=CHR$(34)+TB+CHR$(34)
6050 IF I3=0 GOTO 6360
6060 TP=TIME$
6070 FOR I=1 TO 6
6080 IS=(I-1)*3+1
6090 TA(I)=MID$(TP,IS,2)
6100 NEXT I
6130 DS=9 ' ADJUST -- HERE SET FOR 9 SECONDS TO RECORD
6140 S=VAL(TA(6))
6145 M=VAL(TA(5))
6150 H=VAL(TA(4))
6155 E2=S+60*(M+60*H)
```

```
6160 E2=E2+DS
6165 IF E2>86399 GOTO 6060 '  LOOP AROUND DAY END TROUBLE
6170 S=S+DS
6175 IF S<60 GOTO 6190
6180 S=S-60
6185 M=M+1
6190 IF M<60 GOTO 6220
6195 M=M-60
6200 H=H+1
6220 TA(4)=STR$(H)
6230 TA(5)=STR$(M)
6240 TA(6)=STR$(S)
6250 FOR I=4 TO 6
6260 LH=LEN(TA(I))
6270 IF LH>2 GOTO 6290
6280 TA(I)="0"+RIGHT$(TA(I),1)
6290 TA(I)=RIGHT$(TA(I),2)
6300 NEXT I
6310 TT=TA(1)
6320 FOR I=2 TO 6
6330 TT=TT+" "+TA(I)
6340 NEXT I
6350 IF I3=1 CMD "T"
6360 PRINT #-1, TB
6370 IF I3=1 CMD "R", TT
6380 FOR I=1 TO 9
6390 T0(I)=STRING$(25," ")
6400 NEXT
6410 RETURN
7000 REM *********  DUMP MEMEORY TO CASSETTE ADD END OF FILE  *
7010 IF IR=0 RETURN
7015 PRINT@ 0, "DUMPING DATA IN MEMORY AND WRITING END OF FILE"
7020 IM=IM+1
7030 FOR I=IM TO 9
7040 T0(I)=STRING$(26,"#")
7050 NEXT I
7060 GOSUB 6010
7070 CLS
7080 RETURN
8000 REM *******  LABELS SETUP SUBROUTINE  *****
8010 TZ(1)="L A S L"
8020 TZ(2)=" E I D "
8030 TZ(3)="ELECTRONIC IDENTIFICATION"
8040 TZ(4)="OF THE"
8050 TZ(5)="LOS ALAMOS SCIENTIFIC LAB"
8060 TZ(6)="P.O. BOX 1663"
8070 TZ(7)="LOS ALAMOS, NM 87544"
8080 TZ(8)="FOR MORE INFORMATION, CALL"
8090 TZ(9)="D.M. HOLM   (505) 667-4047"
8100 TZ(10)="J.A. LANDT  (505) 667-7558"
8105 TZ(11)="SYSTEM"
8110 CLS
8120 PRINT CHR$(23)
8130 PRINT STRING$(12," ");TZ(1)
8140 PRINT STRING$(12," ");TZ(2)
8150 PRINT "  "
8160 PRINT "   ";TZ(3)
8170 PRINT STRING$(13," ");TZ(11)
8180 PRINT STRING$(13," ");TZ(4)
8190 PRINT "   ";TZ(5)
8200 PRINT STRING$(9," ");TZ(6)
8210 PRINT STRING$(6," ");TZ(7)
8220 PRINT "  "
8230 PRINT "   ";TZ(8)
8240 PRINT "  "
8250 PRINT "   ";TZ(9)
8260 PRINT "   ";TZ(10)
8280 INPUT "HIT THE 'ENTER' BAR TO CONTINUE ";TB
8290 RETURN
9000 REM *** SUBROUTINE TO READ CASSETTE TAPES  *******
9010 CLS:PRINT "THIS SUBROUTINE WILL READ DATA TAPES"
9020 PRINT "  "
9030 PRINT "FIRST, EXISTING DATA IS DUMPED TO CASSETTE"
9040 PRINT "IF YOU WANT TO RETURN TO THE MAIN PROGRAM"
9050 PRINT "WITHOUT PROCEEDING WITH THIS PROCESS,"
9060 PRINT "HIT THE 'R' KEY.  OTHERWISE THE 'C' KEY : ";
9070 TB=INKEY$
9080 IF TB="" GOTO 9070
9085 CLS
9090 IF TB="R" CLS:PRINT CHR$(23):RETURN
9100 IF TB<>"C" GOTO 9010
9110 GOSUB 7010
9120 CLS
9130 PRINT "REWIND THE CASSETTE TAPE.  HIT THE 'C' KEY"
9140 PRINT "TO CONTINUE :  ";
9150 TB=INKEY$
9160 IF TB="" GOTO 9150
9170 IF TB<>"C" GOTO 9120
9175 IF I3=1 CMD "T"
9177 CLS:PRINT "READING TAPE"
9180 INPUT #-1,TB
9190 CLS
9200 PRINT "ID TEMP   DATE     TIME"
9210 FOR I=1 TO 10
9220 II=(I-1)*26+1
9230 PRINT MID$(TB,II,26)
9240 NEXT I
9250 TT=RIGHT$(TB,3)
9255 PRINT "  ":PRINT "  "
```

```
9260 PRINT "HIT THE 'R' TO STOP AND RETURN TO DATA COLLECTION"
9270 PRINT "HIT THE 'C' TO CONTINUE"
9280 TB=INKEY$
9290 IF TB="" GOTO 9280
9300 IF TB="R" GOTO 9355
9310 IF TB<>"C" GOTO 9280
9320 IF TT<>"###" GOTO 9177
9330 CLS:PRINT "END OF FILE FOUND IN PREVIOUS RECORD"
9340 PRINT "RETURNING......"
9350 FOR I=1 TO 1000:NEXT
9355 GOSUB 1010
9360 CLS:GOSUB 9510:RETURN
9370 END
9500 REM ****  SUBROUTINE TO CLEAN UP TOP OF SCREEN  *****
9510 PRINT CHR$(23);:PRINT@ 0, "  "
9520 FOR I=1 TO 4:PRINT "  ":NEXT
9530 PRINT "ID  TEMP   DATE     TIME";
9540 RETURN
```

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```
      SUBROUTINE UART
C
C  A FORTRAN SUBROUTINE THAT RESULTS IN A MACHINE
C  LANGUAGE ROUTINE TO READ THE ELECTRONIC ID DATA
C  COMING IN THE FACTORY RS-232 PORT OF THE TRS80
C
C  LOAD AS FOLLOWS:
C
C  PROGRAM STARTS AT  FAB0H    ENDS AT  FDE9H
C  DATA    STARTS AT  FE00H    ENDS AT  FFE5H
C
C  I/O TO BASIC PROGRAM IN BETWEEN, FROM FDF0H TO FDF5H
C
C  DEFUSR=&HFAB0 IN BASIC PROGRAM (OR -1360)
C  CALL BY USING USR FUNCTION
C
C  ANSWER MEMORY SIZE BY 64175 OR LESS
C
      INTEGER*1 I2,I4,JD
      I=0
      I3=0
      I4=INP(234)
      IF(I4.LT.127) GO TO 10
      I2=INP(235)
      CALL OUT(234,240)
      GO TO 50
   10 CALL OUT(234,240)
   20 DO 30 J=1,100
      I4=INP(234)
      IF(I4.GT.127) GO TO 40
   30 CONTINUE
      CALL OUT(234,250)
      CALL POKE(-528,2)
      RETURN
   40 I2=INP(235)
   50 JA=I2/16
      JD=I2-16*JA
      IF(JA.EQ.1) GO TO 70
      I3=0
      IF(JA.EQ.1) GO TO 70
      IF(JA.EQ.0) GO TO 60
      CALL OUT(234,250)
      CALL POKE(-528,3)
      RETURN
   60 I=1
      GO TO 20
   70 I3=I3+JD
      I=JA+1
      JA=JA-527
      CALL POKE(JA,JD)
      IF(I.LT.7) GO TO 20
      CALL OUT(234,250)
      CALL POKE(-528,0)
      IF(I3.EQ.0) RETURN
      CALL POKE(-528,1)
      RETURN
      END
```

APPENDIX C

PHYSIOLOGICAL MONITOR COMPONENT BREAKDOWN

by
R. R. Brown

The hardware for the physiological monitor system was assembled from components produced by several manufacturers. Component costs are those incurred in March 1979. Because the computer industry is rapidly changing, hardware configurations may be altered and greater sophistication had with equivalent expense.

Item	Manufacturer	Cost	Qty	Total
NPI 11/03H Microcomputer	NETCOM	$ 2,200.00	1	$ 2,200.00
NDLV11 Serial line unit	NETCOM	225.00	1	225.00
WL-550 EIA data cable	NETCOM	55.00	1	55.00
H-150 Rack mounting kit	NETCOM	45.00	1	45.00
NDRV11 Parallel line interface unit	NETCOM	210.00	1	210.00
KEV-11 Arithmetic chip	NETCOM	175.00	1	175.00
TRV11 Bus terminator	NETCOM	85.00	1	85.00
DSD 440 Flexible disk system	Data Systems Inc.	2,500.00	1	2,500.00
in-5004, 32K RAM memory	INTEL	1,225.00	1	1,225.00
Model 43, printer/keyboard	Teletype Corp.	1,200.00	1	1,200.00
Acoustic Coupler	ZENTEL	300.00	1	300.00
MLSI-WWB1 Wire wrap module	MDB Systems Inc.	49.00	1	49.00
TCU-50D Timing unit	Digital Pathways	300.00	1	300.00
1KVA Line regulator	SOLA	385.00	1	385.00
RT[2] software	DEC	100.00	1	100.00
TR-2 Receiver	Telonics	878.00	1	878.00
TDP-1 Digital processor	Telonics	448.00	1	448.00
RA-6 Antenna	Telonics	62.00	1	62.00
LA-1 Lightning arrestor	Telonics	40.00	1	40.00
M984-BA cabinet	DEC	300.00	1	300.00
Miscellaneous				800.00
TOTAL COST				$11,582.00

EXTENDED PHYSIOLOGICAL MONITOR SYSTEM

Item	Manufacturer	Cost	Qty	Total
Basic monitor		$11,582.00	1	$11,582.00
NDLV11 Serial line unit	NETCOM	225.00	1	225.00
WL-550 EIA data cable	NETCOM	55.00	1	55.00
VIT-100-AA CRT	DEC	2,000.00	1	2,000.00
Advanced video option (for VT-100)	DEC	270.00	1	270.00
RT-11 version 3B software	DEC	1,000.00	1	1,000.00
FORTRAN IV version 2.1 (for RT-11)	DEC	800.00	1	800.00
Miscellaneous				100.00
Less RT[2] software				- 100.00
TOTAL COST				$15,932.00

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