

Reprinted from

Forage evaluation:

concepts and techniques

edited by

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ELECTRONIC WEIGHING, IDENTIFICATION AND SUBDERMAL BODY
TEMPERATURE SENSING OF RANGE LIVESTOCK

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Abstract

Individual animal weights can be obtained manually or automatically in a computer-compatible format with an electronic scale. If an electronic identification, subdermal body temperature sensing unit is interfaced with an electronic scale, the weight, identification, and subdermal body temperature of individually identified animals can be obtained either manually or automatically, and transcriptional and phonetic errors thus eliminated. Electronics can be used at remote locations despite extreme temperatures, dust, and fluctuation in battery power. For research purposes, daily weight fluctuations, watering behavior, and subdermal body temperature can be recorded continuously. When the system becomes commercially available, increased livestock production at a lower cost will be possible.

INTRODUCTION

Monitoring animal weight change is the most frequently used technique to measure animal response (Johnson and Laycock 1962). Cattle have not been weighed frequently in the past because of labor costs and handling stress to livestock (Matches 1969). Technological advances with semiautomatic scales (Low and Hodder 1976) and now with present day electronic scales (Martin *et al.* 1967; Filby *et al.* 1979; Gross 1980) have made daily weighing possible without high labor requirements and without detrimental handling stress to the animals.

Monitoring individual animal performance requires individual identification. During the late 1960's and early 1970's, electronic identification became a reality (Street 1979). With electronic identification, computer-based individual animal management is now possible (Nott 1979).

Along with electronic animal identification has come subdermal electronic body temperature monitoring. Part of an animal's individuality is expressed in a slightly different mean body temperature,

with perhaps a different diurnal pattern (Seawright et al. 1979). However, health problems may be eminent if temperatures in cattle exceed 39.5 C (Blood and Henderson 1974).

ELECTRONIC WEIGHING

Animal weight data have been taken on individual animals grazing the Jornada Experimental Range since 1958. In the past, the records were kept on index cards and required much hand labor with no suitable method for automation. In 1977, researchers at the Range initiated a computer record system to increase efficiency. To maximize the computer system capabilities, a semiportable electronic scale was purchased in the fall of 1978. The scale unit was built with features for both manual and automatic operation.

For manual operation, a hand-held keyboard with digits between 0 and 9 allows each animal's fire brand to be entered at the time of weighing. With this keyboard, both the Julian date and the military time can also be entered into the scale's clock at the beginning of any weighing cycle. Individual animal weight, a four-digit fire brand for identification, Julian date and military time are recorded on cassette tape in the field for later transfer to a computer file without the need for manual data entry. As a backup system, a 21-column paper tape can be printed in the field at the time the data are collected.

Automatic, unattended operation of the electronic scale is taking place in a remote location where electric power must be generated on site and stored in batteries. Restrained weights are taken every 28 days, and automatic weights are taken in the interim.

The electronic scale, located in a one-way maze, is inside a corral where the animals must come to water. For automatic data acquisition, the animals enter the corral through an entrance bayonet gate, pass through the maze and cross the electronic scale where they are weighed before they reach the water. After the animals water, they leave the corral through an exit bayonet gate.

As an animal steps onto the scale platform, a photo beam is broken. This event triggers a solenoid to release compressed air to two pneumatically operated air rams. One ram closes a wire mesh gate in front of the animal, the other ram secures the gate while it is closed. The automatic gate has a time relay that can be adjusted to

keep the gate closed up to 11 seconds; after this time, air is vented from the rams, and the gate is spring loaded to open. Breaking the photo beam engages the scale electronics to print weight, Julian date and military time on the paper tape, the cassette tape, or on both. An adjustable time relay stops data recording after a predetermined number of prints have been made. This prevents erroneous data acquisition if the photo beam is broken without the animal being on the scale or if the photo beam is not automatically reestablished after an animal leaves the scale.

The electronic scale weighing platform measures 3.0 m by 63.5 cm, with a single load cell in each corner and 1.8-m high, flared solid steel sides with parting sliding doors for manual weighing. The electronic unit can operate on either 110 V.A.C. or 12 V.D.C.; and has a weighing range between 0.45 and 1814.37 kg certifiable at 0.1%. The electronic procedure used to obtain an animal weight does not average consecutive scale readings; therefore, a minimum of 2 to 3 seconds with the animal on the scale platform is required for the scale electronics to reach a stable, accurate weight.

Weights from the electronic display unit > 0.0 and < 0.5 kg are displayed and recorded as 0.0 kg whereas weights > 0.5 and < 1.0 kg are displayed and recorded as 0.5 kg. Response time is adjustable to give as many as four weights per second to a damped response giving one weight per two seconds. Both an automatic zero and a manually operated tare button are available. To exclude recording data if more than one animal enters the scale at a time, engineers built an adjustable upper bound into the microprocessor. If this feature is used, weights in excess of the preset amount are not passed to the paper tape printer or cassette recorder.

ELECTRONIC IDENTIFICATION AND SUBDERMAL BODY TEMPERATURE SENSING

The United States Department of Agriculture, Animal Plant Health Inspection Service in conjunction with the Department of Energy funded the development of an electronic identification and temperature monitoring system for use in animal disease control through improved disease detection and traceback (Holm 1977). The work began in 1972 at Los Alamos Scientific Laboratory (LASL), Los Alamos, New Mexico; and by the fall of 1973, the theory of operation had been proved

technologically feasible (Baldwin et al. 1973). However, not until the fall of 1976 was a subdermal transponder having both temperature-measuring capability and three digits of identification, demonstrated (Holm 1976). Bobbett et al. (1977) have documented the technical aspects of electronic identification and temperature monitoring.

The experimental transponder unit, 14 cm long, 2.5 cm wide, and 1.6 cm thick, contains an antenna and an approximately 1 cm³, hermetically sealed microcircuit (Araki et al. 1980). For encapsulation, the unit is dipped in silicone rubber to give the transponder smooth rounded corners to reduce pressure necrosis when implanted subdermally, parallel with the backbone on the animal's left side behind the shoulder blade. With additional development, reduction in transponder size will allow the use of an implant gun rather than surgery.

Above the place of interrogation, an antenna sends a microwave beam of 462 MHz toward the transponder. The beam penetrates the animal's skin with sufficient strength to power the transponder circuitry. The transponder, in turn, sends back to the antenna an encoded identification number and subdermal body temperature that is decoded with appropriate filters and digital electronics. The transponders used in the field test have a 13-bit memory with three digits each for identification and subdermal body temperature sensing, accurate to within ± 0.5 C (Holm et al. 1979). Erroneous readings are essentially eliminated because the receiver circuitry requires that the identical coded signal be received three successive times before it is accepted as a correct signal. Temperature reproducibility is within ± 0.1 C between temperatures of 30 and 45 C with interrogation time less than 0.5 seconds with no erroneous readings for animals moving up to 24 km/hour (Holm et al. 1979). Electromagnetic radiation levels are kept within the U.S. health standards.

THE ELECTRONIC SYSTEM

The interface of electronic weighing with the LASL electronic identification and subdermal body temperature sensing unit was first attempted in Albuquerque, New Mexico, in August 1977 during an International Brand Conference. During the fall of 1979, the first field test of electronic weighing, identification, and subdermal body temperature sensing began on the Jornada Experimental Range.

Presently, continuous monitoring of cattle weight change, watering frequency, and subdermal body temperature is being investigated. The cattle grazing a 3,320-ha, unimproved, semidesert range pasture are weighed and interrogated at a corral location, where frequency of the cattle to water dictates the amount of data collected per unit of time. Time and date of watering are recorded for each animal as it crosses the electronic scale; however, not all individual weights are identified because only 65% of the herd is transponder identified.

Two extra data locations for input from the electronic identification and subdermal body temperature sensing unit were provided in the electronic scale's cassette tape and paper tape recording components. With automatic unattended operation, those animals having transponders are individually identified along with their subdermal body temperature at the time their weight is taken. The interface between the electronic scale and the LASL system (Fig. 1) has required several special interface units that function in timing the sequence of events so data are properly recorded on the cassette tape or the paper tape, or both.

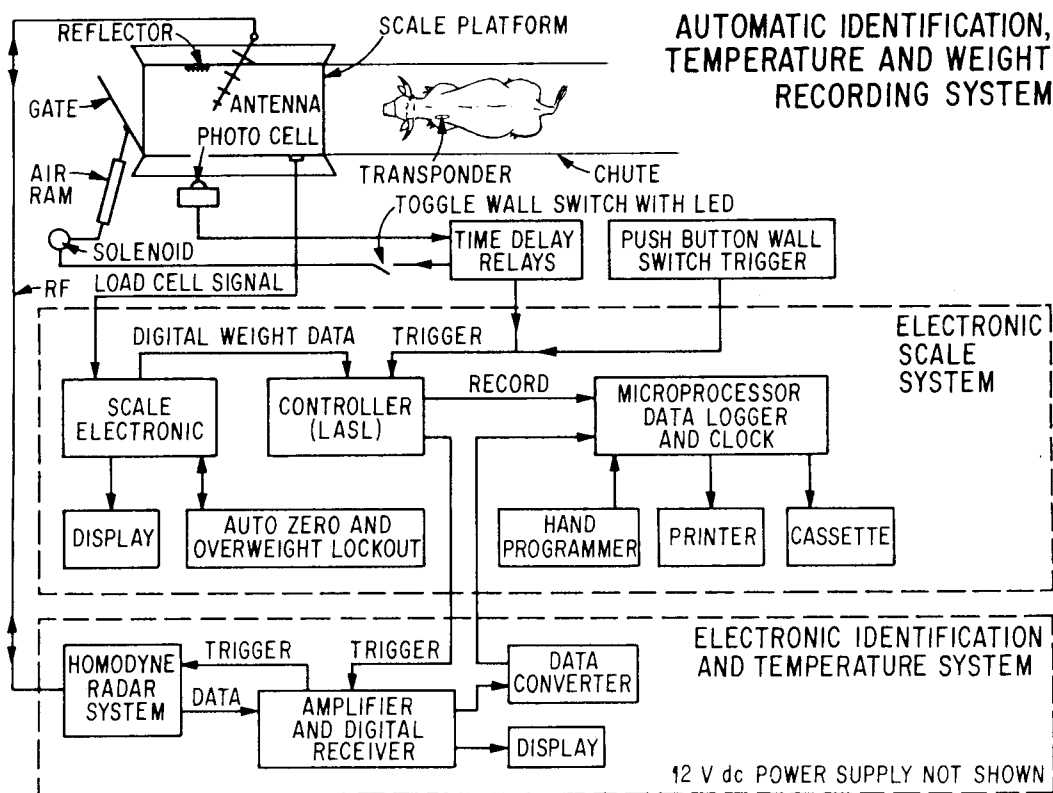


Fig. 1. Block diagram of a single-animal scale and electronic components for manual and automatic weighing, identification, and subdermal body temperature sensing of cattle.

The interfacing of the two electronic units into a working system has met with several problems. The most important problems are: 1) the failure of commercial equipment to perform in accordance with manufacturer's specifications; 2) environmental problems affecting the electronics, especially extremes in temperature and dust; 3) interface timing problems between the LASL equipment and the electronic scale; and 4) some erroneous weights that must be discarded because animals are not always spaced so that only one animal enters the scale when the system is operating automatically and unattended. Extremes in ambient temperature above 37 C are very difficult to control under remote situations and still pose a problem to the electronics. However, raising the ambient temperature around the electronics above 0 C during the winter has been adequately corrected with a thermostatically operated propane space heater. Sealing the doors and windows in the equipment trailer with weather stripping and caulking has substantially reduced dust accumulation.

A total of 42 transponders were surgically implanted beginning in June of 1979. Of the original transponders, four were surgically removed, two because the animals were culled from the herd for management reasons and two because the transponders ceased to function. Ten other nonfunctioning transponders have not been surgically removed from the herd and probably have ceased to function because body fluids entered the transponder and caused electronic failure. Of the 27 transponders still working, one has been in place for 389 days.

DISCUSSION AND CONCLUSIONS

With manual electronic weighing, 86 head of livestock can be efficiently weighed per hour at a remote location. This weighing represents a 41% savings in time over that with single animal mechanical weighing and compares favorably with results in previously reported studies (Filby et al. 1979). Transcriptional and phonetic errors are eliminated with computer speed and precision during data acquisition and summarization. Continuous, unattended, automatic weighing adds the positive benefit of reduced handling stress and also eliminates the labor required for gathering and manual weighing. By interfacing electronic weighing with electronic identification and subdermal body temperature sensing, automatic unattended data acquisition on an individual animal basis is possible. Transponder-

identified animals can be interrogated at frequently visited locations such as water and salt, if the investigator wants to document diurnal use patterns. The temperature-sensing capability of the transponder will allow temperature-related stress and disease phenomena to be investigated. Timely management decisions related to the reproductive cycle of range livestock may also be possible through the monitoring of subdermal body temperature.

Short periods of automatic unattended operation have revealed some of the capabilities of the system. In Table 1, daily weights of 2-year old heifers grazing unimproved semidesert range reveal their daily weight fluctuations. Too often, money and labor constraints placed upon researchers result in few animals being weighed infrequently, in efforts to evaluate treatment effects. Data in Table 1 show that within-animal variability was less than between-animal variability during 8 consecutive days for the 10 transponder-identified heifers. If this trend is consistent continuous automatic electronic animal weighing offers a precise, alternative method to the investigator when production (weight change) is to be obtained for small numbers of animals.

Table 1
Mean weight (kg) obtained automatically over 8 consecutive days from 6 to 13 August, 1980 for 10, two-year-old transponder-implanted heifers grazing unimproved semidesert rangeland.

Animal No.	Mean Weight†								\bar{X}	+S.D.†††
	8/6	8/7	8/8	8/9	8/10	8/11	8/12††	8/13		
949	273	—	257	—	291	275	281	—	275	12
950	281	310	—	—	307	—	—	—	299	16
962	—	360	—	374	370	—	364	—	367	6
963	420	—	428	—	474	—	—	—	441	29
971	331	358	—	355	355	—	350	—	350	11
972	304	311	311	—	329	319	—	—	315	10
973	329	332	342	346	333	343	—	—	338	7
978	372	—	368	—	364	359	—	—	366	6
979	387	369	374	—	364	—	—	350	369	14
984	—	296	—	—	299	—	295	—	297	2
\bar{X}	337	334	347	358	349	324	323	350		
+S.D.	52	29	59	14	53	37	41	0		

† — indicates that animal did not enter corral and cross over weighing platform.
 †† Rained intermittently during the 24-hour period.
 ††† S.D. = standard deviation.

From Table 1 the pattern of watering frequency was unique for individual animals. Rain that fell on 12 August was probably

responsible for reducing the animal's need to enter the corral for water on 13 August. Between 6 and 13 August, all transponder-identified animals moved through the corral between 0800 and 2300 hours (Mountain Standard Time); activity peaked between 1300 and 1500 hours.

Ambient air temperature (C) sensed near the interrogation location and subdermal body temperature (C) were recorded concurrently between 6 and 11 August 1980 for animal 973, a 2-year old Santa Gertrudis X Hereford crossbred heifer. Subdermal body temperatures were consistently higher and less variable than ambient air temperatures. The range in subdermal body temperature of the 2-year old heifer (37.0 - 40.3 C) for 6 consecutive days was less than the range in ambient air temperatures (21.1 - 38.9 C). Because of the proximity of the transponder to the skin surface and insulation of the transponder by adipose deposition, corrections for ambient temperature will be necessary to detect physiological changes within the animal (Araki *et al.* 1980).

As a range research tool, electronic weighing, identification, and subdermal body temperature sensing offer a means of collecting accurate data in a precise computer-compatible format that can be rapidly summarized. Both labor and animal stress are reduced and increased efficiency thus results. With automatic operation, the possibility that the "observer" affects the "measurement" is eliminated.

To the livestock producer, electronic identification will mean individual record keeping on animal location, health, and production with fast, accurate computer precision. With minicomputers, even the small operator will be able to automate many activities that currently require time and labor, such as opening and closing gates for sorting animals and dispensing feed to individual animals. The end result should be increased production at a lower cost because management decision can be based on long-term individual records rather than a herd average.

ACKNOWLEDGMENTS

A special thanks is extended to Dr. Dale Holm, Project Leader, and his coworkers at Los Alamos Scientific Laboratory for the dedicated hours of support so willingly given.

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DISCUSSION

Recorder: C.C. BOSWELL

HORN asked if the device would register all the animals if a group of cattle were to enter the sensor area at one time. ANDERSON replied that engineers from the Physical Science Laboratory of the University of New Mexico were presently solving this problem. A simple low-powered animal separator which allowed only one cow or calf to proceed onto the scale at a time had been developed. The system works on a time delay principle. In the identification system, an animal must be directly under the low power microwave beam before a record is made. There is no interference from animals outside the scale.

HORN asked if free-ranging cattle had to be separated from a mob in order to obtain the identification and temperature record. ANDERSON felt that the beam is sufficiently narrow and the power sufficiently low to obtain individual records from a group of cattle at range as long as the recorder is aimed close enough to individual animals.

In reply to a question from RIEWE, ANDERSON considered that where an AC power supply was available it was technologically possible to open a series of gates to sort several different groups of animals back into their correct treatment paddocks using the animals' identification numbers.