DEVELOPMENT OF A CATTLE ACTIVATED CONTROL SYSTEM FOR A FEED DISPENSER

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1942

Submitted to the Faculty of the Graduate School of
the Oklahoma State University
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
August, 1964

DEVELOPMENT OF A CATTLE ACTIVATED CONTROL SYSTEM

FOR A FEED DISPENSER

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ACKNOWLEDGMENTS

The writer wishes to express sincere appreciation to those who aided him in this investigation.

The writer is indebted to Dr. Gordon L. Nelson for his valuable guidance and encouragement throughout the investigation.

The assistance of Professors E. W. Schroeder, E. R. Daniel and L. O. Roth in developing this report was gratefully appreciated.

The writer is grateful to Dr. L. S. Pope for assistance in reviewing research information and for the facilities in the beef barn. The work of Albert Rutledge in handling the animals was appreciated.

The writer appreciated the guidance of Professor R. L. Heisserman and the work of Martin Block in developing the electronic circuits.

The work of Jack Fryrear and Don McCrakin, Agricultural Engineering drafting department, in preparing the illustrations is gratefully acknowledged.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

There is a need for improving the facilities at the point where feed is consumed by the animal. There are advantages and disadvantages to a system for the self feeding of livestock. The same is true when a timed schedule is followed. There is a need to incorporate the advantages of both systems in a mechanized feeding installation.

This investigation was designed to develop a system for allowing the animal to determine when feed is needed in the trough.

The study includes a review of:

(1) Basic findings and principles in farmstead mechanization.

(2) Applications of electronic circuits in agriculture and industry.

(3) The benefits of multiple feeding of livestock.

(4) Eating patterns of animals.

HYPOTHESIS

The animal has all day and all night to consume the necessary ration. Man time, not animal time, is valuable.

Small equipment capable of delivering fresh feed any time will operate around the clock. Small equipment will do the job economically.

The benefits of multiple feedings are:

1. A minimum of equipment will be required per animal.

2. The cost of equipment per animal will be reduced.
3. A reduction in equipment cost per animal will permit more animals to be put on feed.
4. The animal will consume additional feed during a 24-hour period for greater gains.

Improved controls are needed when small equipment operates around the clock.

OBJECTIVES

The primary objective of this investigation was to develop a control circuit that will contribute toward improved livestock feeding in a mechanized system through multiple feedings around the clock. It was planned to develop a control circuit capable of utilizing a signal from the animal when feed was needed in the trough.

The project was conducted through three phases of investigation

1. Perform an exploratory investigation to obtain information on types and strength of a signal, the animal was capable of controlling, initiating or conducting.
2. Select and test or develop an electronic circuit capable of utilizing the signal from an animal.
3. Analyze the performance of the system.

CHAPTER II

REVIEW OF LITERATURE

There are numerous methods and procedures used in producing beef. Many Oklahoma beef producers operate a cow-calf system. They do not finish out the animals for market. Dry lot feeding is necessary to produce a desirable product for human consumption. Cattle in confinement require labor, good feeding procedures, palatable rations and management. Today labor is expensive and often not available to the livestock producer. Mechanized equipment is needed to improve the feed lot operation. The equipment must be adequately managed and efficiently operated. The equipment must also serve the requirements of the animals on feed.

Work on developing better methods for planning the farmstead layout and developing greater efficiency in farmstead mechanization was reported by McKenzie (1). This work employed the techniques of time and motion study as applied to industry. The flow of materials on the farmstead and methods for selecting equipment and machinery were evaluated. This work was based on the philosophy that man-time be used first to think and last for power. A plan for coordinating the use of buildings, equipment, and work methods with an operating procedure was developed.

Rannfelt (2) analyzed the materials handling procedure on 320 livestock farms in Michigan. His work indicated the need for efficiency and economy in handling the required materials. The magnitude of the problem clearly indicated a definite need for planned systems.

Agricultural Engineers have responded to this need. However, additional research and study are needed to make equipment pay a reasonable dividend on its investment and to increase the value of human effort.

Kelly et al (3) brought out the need for analyzing the mechanized system. Procedures were developed for studying flow charts, for selecting equipment and machinery, for evaluating a preliminary design, and final selection of equipment. Kelly (3) also considered the design of buildings to provide suitable environment for the animals. The coördination of equipment and materials utilizing the shortest distance and least expenditure of power and human labor is the basic philosophy under which a materials handling system must be planned.

Definition of Mechanization and Materials Handling

Hall (4) defined materials handling as labor, methods, equipment, and management required to operate the system. Agriculture materials handling problems are more complex than materials handling in industry. because there are more variables. Man and machine; animal and machine; man and animal; animal products and machine; seasons and machine and the daily variation in weather and machine plus animal are among the necessary factors to consider for improving the mechanized feeding system.

More and more production per man hour of work or increasing the value of human effort is an important function of the system. However other functions are of equal or greater importance. A better return on the investment and on the cost of operation is another important function of the mechanized system.

Mechanization is the transformation of energy by machine, at the decision of the operator, to do work that might formerly have been done by muscle power (Hall (4)). Automation is the application of controls to machines so that they can function without human effort. The forward look goes one step further and makes an application of electronic equipment which is defined here as developing equipment to provide functions and control beyond the realm of human ability.

Automation in Livestock Production

McDonald (5) states that there are powerful motivations toward increased use of automatic machinery and automatic control techniques. Automatic equipment permits operations far more complex than are possible through human effort. In feed lot mechanization, this will mean utilizing low capacity equipment over twelve or twenty-four hour periods. Controls capable of making equipment operate around the clock and without the aid or attention of human hands are needed for complete mechanization. Ordinary machinery reacts in accordance with the laws of mechanics. Automatic machinery is expected to perform a given function irrespective of additional stimuli that it might receive during the operation. Automatic equipment requires a device to sense the need for a change in direction or rotation. It must also sense the results of its action and use its findings to take corrective measures. The completely automated feeding systems will require several sensing devices with adequate controls.

Equipment Economy and Efficiency

Economy of performance is the aim of operations (Thuesen (6)). This means that the equipment should return a reasonable amount to the investor after all costs of operation and of owning the equipment are considered. The cost of owning and of operating the equipment must be calculated when it is purchased. The method for arriving at a reasonable cost for ownership of the system is a matter of business procedure. It is based on a depreciation schedule. The length of service must be estimated at the time of purchase. If the actual life of the equipment is longer than its estimated life, the additional production can be put in the profit column. Equipment must not be allowed to become outdated nor inadequate before sufficient return on the investment is realized. The investment per animal can be comparatively low when small equipment operates around the clock. Continuous operation also reduces the danger of outdated and inadequate equipment.

Efficiency is a factor that must be considered for all processes, operations or activities within a system (Winter (7)). Improvement in one area will have a definite effect on other areas. This effect can be objectionable under some conditions. As an example, if a man watches equipment run after punching the starting button, his time is wasted. The benefits of reducing labor are not fully utilized unless the efforts of man are efficiently used while machine works.

Winter (7) indicates the need for feed lot equipment with capabilities to operate without the attention of man and at the command of the animals.

Electronic Control of Equipment

The investigation of one possible signal from the animal was based upon the report of Bradley (8). The hand to hand resistance of a human body was utilized to control a thyratron vacuum tube. A heavy beam that carried a cutting die was controlled by an electronic circuit that was triggered by the thyratron tube. The heavy beam was instantly stopped if and when the operator's hand was in danger. Many people were measured for hand to hand body resistance to determine the limits for designing the required equipment. Maximum resistance values of all individuals tested was 0.65 megohm for light hand pressure on a steel test bar. The same electronic circuit instantly terminated the cutting stroke when the cutting die completed the circuit between the beam-striking plate and a conductive cutting surface. The precise instant for the stroke termination was after the cutting edge went through the material but before it damaged itself by hitting a termination block.

Electronic equipment now finds limited use in agriculture. John Dobie et al (9) reported the use of a thyratron in developing a device for removing tramp iron from hay. The hay is conveyed at a rapid rate through a weak magnetic field which detects the metal. This magnetic field is in the range of 100 to 150 gauss. The signal was amplified 500 times by a conventional volt amplifier. The thyratron in turn actuated a solenoid which actuated a device for ejecting the hay that contained the metal.

Puckett (10) has reported the use of an electronic controller for an automatic feed grinder. The thyratron detected a change in load through detecting a change in the amperage required to drive the feed grinder. This control reduced the rate of flow of feed into the grinder. It is possible to control the flow of feed into the grinder and thereby make the operation automatic.

Putnam and Davis (13) successfully used photo electric cells, sensitive to variation in light, in a feeding pattern study of steers in a feed lot. The photo electric cells controlled a relay to record the number of times that the animals approached the feed trough per day. The operating principle of the photo tube is as follows: Certain metals have the ability to emit electrons when exposed to light. A cathode of photo electric substance is positioned in a tube with an insulated anode. An electronic potential is created when light falls on the surface of the cathode. The intensity of the light is critical and must be controlled. The photo electric cell may not have sufficient capabilities to be used as a sensing element in the feed trough. It will be useful to activate monitoring controls within the feeding system.

Touch Control Circuits

A contribution has been made to the development of touch controlled circuits by Atkins (11). He reports that a body capacity making contact with a sensing element is used to actuate 30 to 40 watt appliances through solid-state circuits and switches. Novel and useful devices such as lamps, clocks, display systems, safety and alarm units are now being actuated by touch controlled circuits. Touch or proximity control of apparatus is reliable and the cost is low. In the past, the touch control units have been controlled by a radio frequency oscillator detuned or stopped by body capacity and associated body resistances shunting the oscillator tank, resulting in a change of current which operates a relay. Also a thyratron is fired by an a.c. signal coupled to one electrode by means of body capacity. Both of these methods had serious drawbacks. It was difficult to eliminate radio interference. Stray signals affected the operation of the circuit.

Semi-conductor devices overcame most of the objections associated with tube circuitry. Low standby power, freedom from radio frequency interference, compactness, cool operation and long life favor the use of semi-conductors. This system requires the use of self-sustaining oscillators which are fed through a suitable touch control network to a semi-conductor device. A more compact and less expensive system can be provided by using neon lamps. They are used in place of the semi-conductors. They require very little power and are reliable. The circuit is designed to supply negative going pulses when energized from a positive power supply, while the circuit provides a positive going pulse. The positive going and negative pulses from this circuit can be combined so that there is cancellation. The output of the system can be balanced to zero or adjustment can be made to achieve a residual pulse in either direction. Additional capacity is added when a body touches the sensing element. The positive pulses are increased and a relay is activated.

The average adult has a body capacity with respect to ground which usually varies between 50 and 100 $\mu\mu$f.* This value depends upon the amount and location of plumbing, electric wiring or metal furniture in the vicinity of the circuit. The body capacity of a child varies from 25 to 50 $\mu\mu$f. A mouse has a value of about 2 $\mu\mu$f with respect to the ground. Body capacity values for an animal are not available. The electronic circuitry in a touch control unit must be capable of utilizing the body capacity effect over a wide range of values.

* micro-micro farad

This same type of equipment might be utilized in the process of dispensing feed for cattle in the feed lot. The cattle will activate the feed dispenser and the flow of feed will be controlled by the animal's need.

The various segments of industry are utilizing electronic equipment and sensing devices to produce better and more uniform products than ever before known in history. At the same time, the cost per unit has been lowered and the value of human effort has been raised. The application of electronic equipment to agriculture can produce similar results.

Feeding Patterns of Animals

Several studies have been made to learn more about the habits of livestock with emphasis on the consumption of feed. Dwyer's (12) study of cows with calves grazing in an open pasture indicated that they develop definite eating patterns to take advantage of weather conditions and the terrain. The animals grazed an average of 7.96 hours during the day with a major part of the grazing occurring early in the morning and late in the afternoon. The animals desired to graze when the temperature was approximately 85 degrees fahrenheit. At warmer temperatures the animals showed a tendency to rest and stay near the water.

Davis and Putnam (13) indicated that animals, confined to a dry feed lot, feed from 9 to 14 times per 24 hours. Approximately three-fourths of the total time spent at the feeder occurred between 6:00 A.M. and 6:00 P.M. This study also indicated that pre-arranged speed and time of feeding are not significant. The feed must be available when the animal has the desire to eat.

The actions of steers on experimental feeding programs were sampled every 30 minutes for 12 hours per day during a 5-day period. Unpublished data (Pope (14)) gave the following results:

	Ration	Idling	Eating	Ruminating	Other
A	high grain	65.0% *	10.1%	13.9%	10.4%
B	high grain	67.1%	10.7%	11.2%	10.0%
C	low grain	59.7%	11.8%	15.8%	12.2%
D	low grain	60.7%	12.6%	14.0%	11.8%
E	low grain	59.2%	14.6%	15.0%	10.7%

* All percentages are of total time.

A Study of Multiple Feeding for Livestock

Mochrie et al (15) reports on the performance of two groups of four Holstein steers each in a simple-reversal trial of two 6-week periods. The treatments were: feeding the entire daily ration at 7:00 A.M. and 7:00 P.M. (four times per day feeding). The average daily intake of feed for the once per day feeders was 4.0 pounds of grain and 6.3 pounds of hay. The average daily gain on the two comparisons was 1.03 pounds (once per day) and 1.21 pounds (four times per day). This difference in gain of 0.18 was highly significant. At the frequencies studied, frequent feeding of equal daily intakes appeared to increase feed utilization for growth.

Mohrman et al (16) conducted two trials as follows. Trial 1 - Nine Hereford cattle were hand fed two times daily and eight cattle were fed automatically by machine six times daily at 4-hour intervals. The cattle received only the amount of feed that they would clean up in a reasonable time after each feeding. The cattle fed six times daily consumed 17% more feed per head daily and were slightly more efficient in feed conversion than those fed two times daily. They also gained faster than the cattle fed twice per day.

Trial 2 - Three lots of ten yearling steers each were group fed according to three plans as follows: Lot A was fed six times daily, Lot B was fed two times daily, and Lot C was self-fed. After 84 days of a 104-day trial the results were:

	Lot A	Lot B	Lot C
Daily gain	1.95 lb.	1.75 lb.	1.99 lb.
Daily feed consumption	19.5 lb.	18.6 lb.	21.1 lb.
Feed required per pound of gain	10.0 lb.	10.6 lb.	10.7 lb.

The ration for all three groups was 64% ground corn, 25% ground cobs, 10% soybean meal and 1% alfalfa meal.

It is possible that the self-fed animals wasted feed to require 10.7 pounds of feed per pound of gain. The animals fed six times per day significantly out performed the other two groups in gain per pound of feed.

Twenty-two Cheviot ewes were paired and divided into two equal groups which were comparable in age, body-weight and previous history, (Gordon and Tribe (17)). The sheep were penned singly. The same quantity of feed was given to each animal throughout the 18-week experiment. During the first part of the experiment, which lasted for nine weeks, group "A" was fed eight times daily at approximately hourly intervals between the hours of 9:30 A.M. and 5:15 P.M. Group "B" received its daily ration once per day at 9:15 A.M. The treatments were reversed for the second 9-week period. The sheep on multiple feedings showed greater gains with an increase in feed efficiency than the sheep given the same quantity and quality of ration in one feeding per day.

A statistical analysis has shown that these differences are highly significant. The possible reasons for these differences are discussed by Gordon (17) as follows:

1. "It may be that when a ration is divided into several small feeds spread over a long period of time the total surface area open to attack by micro-organisms in the rumen might be larger and/or available for a longer time per unit of microbial activity than when the same quantity and quality of food is given as one meal. In this way a more efficient coefficient of digestibility might be obtained."

2. "Since food material passes into the abomasum from the reticulum at a constant and not too rapid rate throughout the day, and since during a meal the heavier and more finely divided portion of the ration rapidly reaches the reticulum, then under a system of small feeds this portion will pass on and into the abomasum in a short period of time. Therefore the loss of energy due to a fermentation process will be minimized. If a large amount of food is ingested at one time it probably remains longer in the rumino-reticular cavity, and this disproportionately greater delay will result in large energy losses."

3. "A completely different aspect is suggested by the third possibility. The even supply of substrate and the supposedly even production of metabolites that may occur under the frequent feed system may (a) give rise to an alimentary environment better suited to the growth and metabolism of micro-organisms, and (b) it may enable the animal to utilize the metabolites more efficiently than under the single feed system where there may be a more rapid flooding of the tissues than is compatible with an optimal rate of utilization."

4. "It is possible that the length of time spent ruminating by the animal under the two systems of management may be different and might, by the consequent differences in mechanical action upon the food, result in differences in digestibility. Continuous observations were made on the ruminating behaviour of four sheep, two from each group, over a 72 hour period. The total time spent ruminating by the two frequently fed sheep was 2534 minutes whereas the two single fed sheep spent 3483 minutes ruminating. Further work is continuing along these lines."

Gordon (17) explains further that additional studies are needed in this area. The basic information signifies that an increased live weight gain and an increased efficiency of feed utilization are obtained when sheep are fed a small portion of their daily ration numerous times per day.

Summary of Pertinent Information

The work of Putnam and Davis (13) indicated that animals on free choice of feed around the clock used from 7 to 12 feeding periods per day. The assumption here was that frequent feedings prevent hunger stress and rapid rates of eating. The animal spends only a few moments Sampling per feeding at the trough when it has free choice of feed; therefore, the length of feed trough per animal can be shortened. The precise length of trough per animal must be determined by research.

The search of literature clearly indicates that when animals eat once or twice per day, less feed is consumed per animal and the feed conversion ratio is not as desirable as animals on multiple feedings per day.

A summary of information from Mochrie et al (15), Thomas and Mochrie (18), Mohrman et al (16) and Pope's (14) experience indicated the following hypothesis. It is possible that if an animal will consume one additional pound of feed above maximum present consumption, a twenty percent increase in gain of weight can be expected.

Feed consumed by the animal is utilized as follows: (Animals on full feed)

41% - heat and body functions
(to maintain weight)

11% - lost through the urine

30% - lost in undigestible residue

18% - gain in body weight

Most of the extra one pound of feed consumed per animal is utilized in gaining weight.

Factors involved in increasing the feed conversion ratio are as follows: Hughes et al (19)

(1) The components of the ration.

(2) Inherited ability of animal to gain weight.

(3) Physical condition of the feed.

"The true value of feed is a measure of what it accomplishes and not a measure of what it contains". Tillman (20).

Then these factors are important too:

(1) Environmental temperature and conditions.

(2) Rate at which feed is consumed.

(3) The amount of feed consumed per animal per day.

Future Development

The search of literature on feeding livestock revealed that research workers agree upon the beneficial effect of multiple feeding periods for animals in the feed lot. Multiple feedings per day provide for better feed conversion ratios and often greater feed consumption per animal. Research indicates that greater daily feed intake provides a greater margin of nutrients above the maintenance requirements of the animal. This margin of nutrients is available for additional production. A better method needs to be developed for making the ration available around the clock. Equipment can be developed to serve the needs of livestock for multiple feedings.

CHAPTER III

INVESTIGATION OF SIGNAL SOURCES AND REQUIRED CIRCUITS

This part of the project was designed as an exploratory study. Its purpose was to determine the type of signal and the control system capable of detecting the need for fresh ration to flow into the feed trough.

Types of Systems Considered for This Study

A system of pressure switches could be developed to signal a controller when the animals emptied the trough. The system would be based upon a variation in weight of the trough. Mechanical difficulties would develop if moisture condensed and froze on the pressure points. The accumulation of dust and rough treatment from the animals would also be a source of failure. The pressure switch system was not studied for these reasons.

The photo electric cell was considered because of Putnam's (13) work. Photo electric cells were successfully used to signal instrumentation for recording the number of times animals approached a feed trough.

A light sensitive cell could be placed in the bottom of the trough. It would signal a controller for a feed dispenser when the animal removed the feed from its surface. The photo electric cell was not selected for this study because (1) the animal would become a mechanical device to make and break the light beam. It might learn to operate the system when feed was not needed in the trough. (2) The light sensitive cell will require a certain level of intensity. Variations due to dust and moisture could cause interruptions in the performance of the equipment.

The exploratory area selected for investigation was the application of an electronic controller capable of utilizing a signal to be originated, controlled or directed by the animal. The methods selected for study were:

(1) A low voltage circuit utilizing mouth to neck resistance in the animal to control a thyratron vacuum tube in an electronic circuit was considered. This method was based upon the report by Bradley (8) on how hand to hand human body resistance was used to trigger a switch through a thyratron to control a cutting machine.

(2) The capacitive effect of the animal's body for controlling an electronic circuit. This idea was based upon Atkin's (11) report. The method is commonly known as "a touch control circuit".

An exploratory study was made first on the low voltage circuit designed to utilize the mouth to neck resistance of the animal.

Experimental Equipment

The experimental equipment consisted of:

1. The experimental feeder with adjustable trough. Figures 1 to 3.
2. Instrumentation and equipment to be discussed later in this section. Figure 4.
3. Feeder animals ranging in size from 300 lbs. to 900 lbs. A total of 15 Herefords and Black Angus steers and heifers

were made available by the Oklahoma State University Animal Science Department for all experiments in this investigation.

The investigation was made in the Animal Science Department feeder barn. It is a long structure with gable roof and opened to the south. Rain did not reach the feeder during the study; however, moist air and wind were often present.

Feed Trough and Circuits

The adjustable feature in the feed trough was necessary to accommodate the various sizes in animals. The feed was measured in inches from a leveled surface to the bottom of the trough. Later in the study feed was measured in grams. Approximately 240 grams of feed was placed in each compartment. The analysis of performance was based upon the amount of feed in grams remaining in the trough.

The electric circuit from trough to recording and amplifying equipment was alternately A.W.G.#12 T.W.* and A.W.G.#18 T.W. wire. The sensing conductor in the trough was made by removing the insulation from a portion of the wire and attaching it to the bottom of the trough. The length of the sensing conductor varied as indicated throughout the record of the investigation. The performance of the sensing station was studied at various locations in the trough (Figure 2). The bottom of the trough was adjusted to four inches.

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* A.W.G. - American wire gauge

T.W. - Thermo-plastic for use in wet locations.

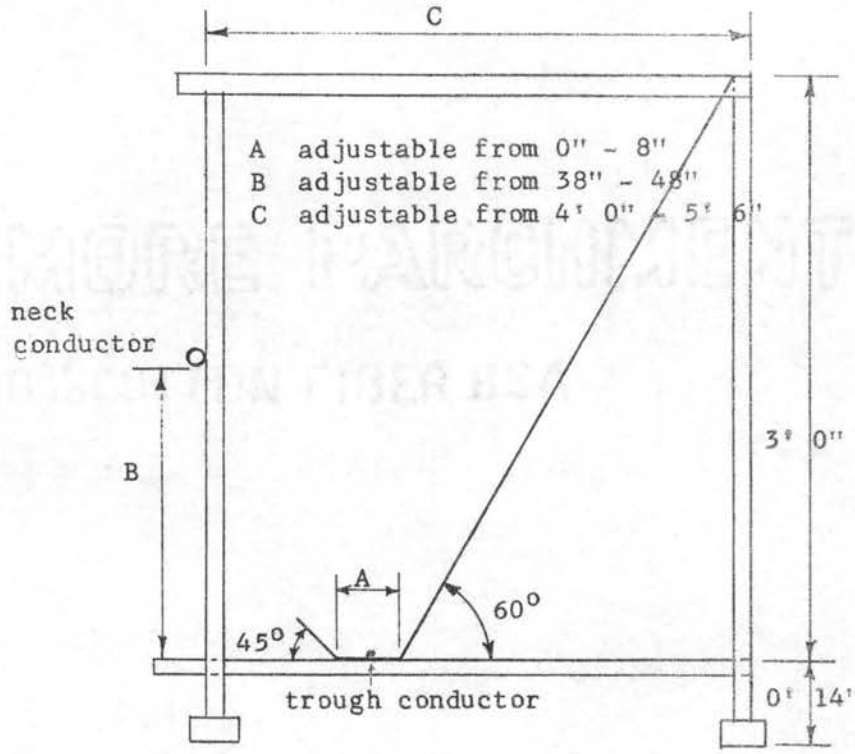

Figure 1. Experimental trough and feeder.

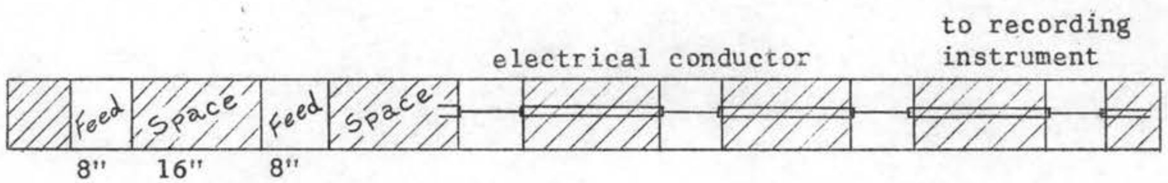

Figure 2. Feed trough - wired for exploratory test.

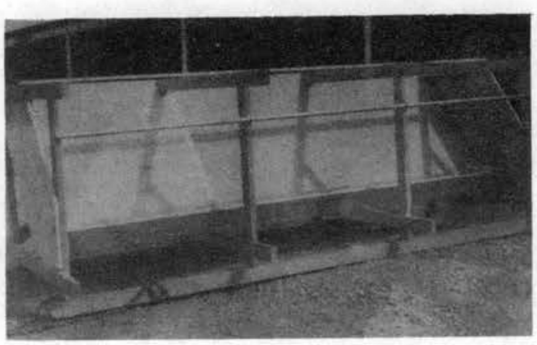

Figure 3. Feed and animal - closed circuit.

Explanation of Instruments and Equipment

The instruments and equipment required to study the performance of the mouth to neck resistance signal were assembled in the Electronics Laboratory of the Oklahoma State University under the supervision of Professor R. L. Heiserman, Head, Electronics Technology Department, Technical Institute. See Figure 4. The closed circuit is illustrated in Figure 5.

1. Resistance decade box: Resistance increases from zero to one megohm by a factor of 10 for each control.
2. Power pack or battery eliminator: Supplied d.c. voltage for the circuit. The circuit was tested from six through twelve volts.
3. Recording instrument by Brush Instruments, Model Mark II. The recorder was equipped with an oscillograph and an amplifier. Chart speeds range from 1 to 125 mm. per second. A 10 millivolt input signal produced a pen deflection of one chart line. It has an amplitude and frequency range from zero to 100 cycles per second. When the sensitivity control is in the first or XI position, the recorded signal is equal to the product of pen deflection in chart lines times volts per chart line.
4. Substitution box - variable in standard values of capacitance. The box contained various sized capacitors with a rotating switch to give a variation in capacitive values. The variable resistor and capacitor together

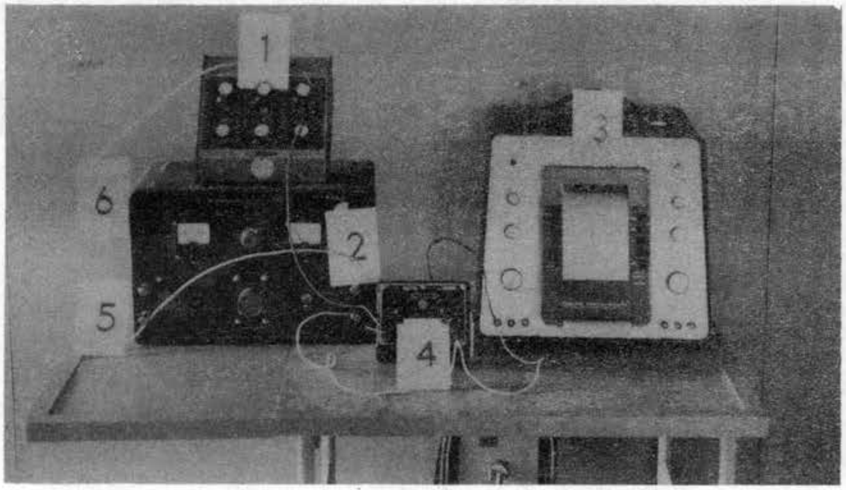

Figure 4. Test equipment in closed circuit.

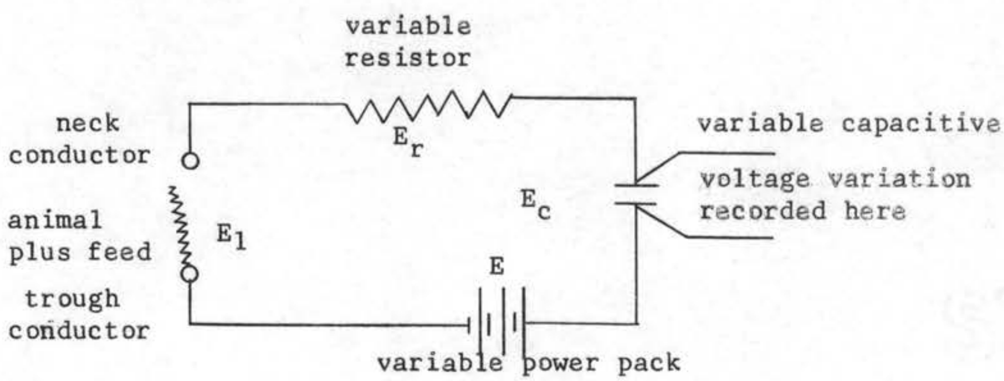

Figure 5. Closed circuit showing relationship of equipment.

act as an R.C.* integrator. The pen on the recorder cannot react to the extremely high frequency of the signal. The R.C. integrator reduced the frequency of the signal to less than 100 cycles per second, or within the range of the recording instrument.

5. Circuit to trough conductor.
6. Circuit to neck conductor.

Explanation of Symbols

An explanation of symbols from Figure 5 is as follows:

E - Power supply - converts a.c. power to d.c.

E_1 - Drop in potential from trough conductor through animal and feed to neck conductor.

E_r - Drop in potential across resistor.

E_c - Drop in potential across capacitor.

The sum of the voltage potential in this closed circuit must equal zero.

$$E - (E_1 + E_r + E_c) = 0$$

Factors Affecting the Flow of Current

Factors affecting the flow of current in this circuit were:

1. Resistance of the hair and impurities on the animal's neck. Figure 3.
2. Variation in pressure between the animal's neck and the neck conductor. Figure 3.
3. Resistance in the feed. Figure 2.

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* R.C. - Resistor capacitor.

4. Variation in resistance between the mouth and the trough conductor.

Testing of Closed Circuit

Exploratory research was required to establish the characteristics of the mouth to neck resistance signal. There was no way to get a verbal response from the animals. The known values for the hand to hand resistance in a human would not apply to the animals. The basic objective was to isolate a signal that could be controlled by the animal.

The closed circuit was assembled as follows:

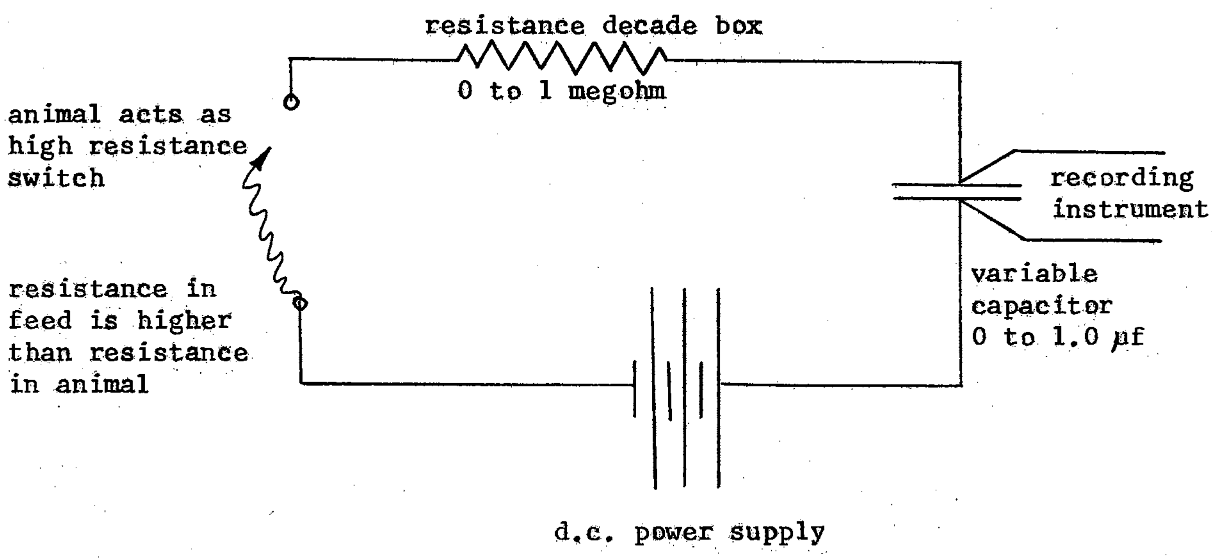


Figure 6. Instrumentation in the circuit.

The voltage variation at the capacitor in the circuit was recorded because the extremely high frequency of the signal was controlled at this point. The resistance in the circuit was varied as needed to keep the marking pen on the chart.

Six Hereford steers weighing about 500 lbs. each were used for these tests. They were fed as individuals and in groups of two, four and six. A number 12 solid copper conductor was installed the entire length of the 12 ft. trough. The neck conductor was adjusted to make contact with the back of the animal's neck. Figure 3. Each compartment in the trough held sufficient ration per feeding to satisfy the animal's appetite. The animals were allowed to eat long enough to get readings on the chart for each trial; then they were driven away from the feed. The feed was leveled to three inches and the animals returned to the trough. The feed was leveled the third time at one or two inches above the bottom of the trough. Several recordings were made on each animal during each feeding. A total of 140 tests were made of animals eating under varying conditions. Variables evaluated were (1) number of animals eating simultaneously, (2) depth of feed, (3) impressed voltage on closed circuit, (4) size and shape of trough, and (5) eating habits of animals.

These preliminary trials were made with the trough adjusted to a bottom width of 4 inches. The variable resistor and capacitor were set at 400,000 ohms and .03 microfarads respectively. The recording instrument was set at .1 volt per chart line with a speed of 5 mm. per second. The reproduction of the chart line, Figures 7 through 9, is a record of the changing voltage at the capacitor in the closed circuit. The voltage increased as the amount of feed in the trough decreased. The recorded voltage also varied as the animal's head moved in the trough during the eating process.

The voltage varied from zero when the animal's head was out of trough, to maximum voltage when the animal made contact with the trough conductor in the bottom of the trough. The circuit was completed between the animal's tongue in the trough and the back of its neck at the neck conductor, Figures 2 and 3. A definite change in voltage was desired because the response of electronic equipment will be based upon a change in the signal.

Values for Various Stations in the Closed Circuit

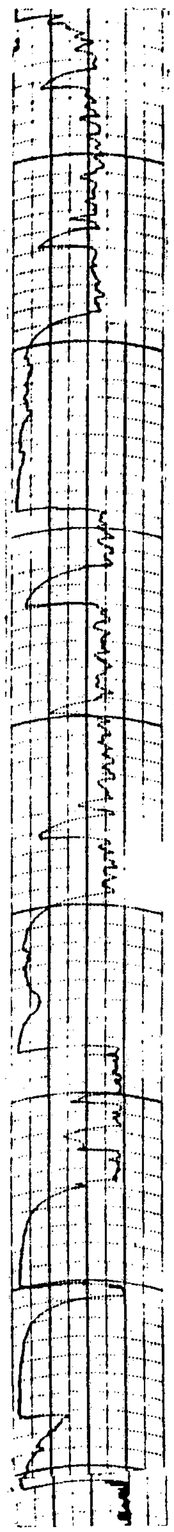
There was a voltage drop at each junction in the circuit. The voltage was recorded at the capacitor. The benefit of the RC integrator was realized at this point. The potential in voltage is recorded in the chart below. See Figure 5 for the location of various stations. The computations are based upon Ohm's Law $I = E/R$.

TABLE I

CALCULATIONS FOR CLOSED CIRCUIT

Volts				Amount of Feed in Trough	Resistance from Trough Conductor to Neck Conductor
E	E_1	E_r	E_c		
6	2.868	.232	2.9	0 inches	4.96 meg ohm
6	3.732	.168	2.1	5 inches	8.86 meg ohm
9	4.788	.312	3.9	0 inches	8.26 meg ohm
9	6.526	.184	2.3	5 inches	14.26 meg ohm
12	7.918	.302	3.8	0 inches	10.48 meg ohm
12	8.978	.224	2.8	5 inches	16.08 meg ohm

ONE ANIMAL EATING



Animal started eating
2.1 volts

5" feed

2.3 volts

Animal out to level feed to 3 inches

2.4 volts

2.7 volts

2.7 volts

Animal out to level feed

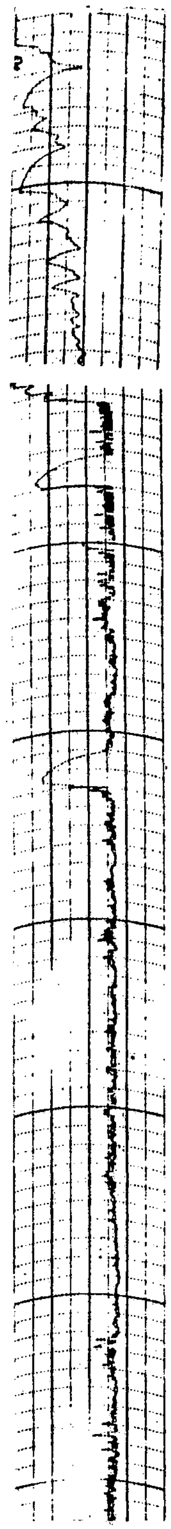
one inch of feed

2.9 volts

Empty trough

3.0 volts

(no significant change in voltage)



Animal started eating
1.9 volts

5 inches feed
2.4 volts increase

4 inches feed

3 inches feed
4 animals eating
2.8 volt change

When four animals eat, pen deflection is more rapid resulting in a smoother signal.

2 inches feed

2.78 volts

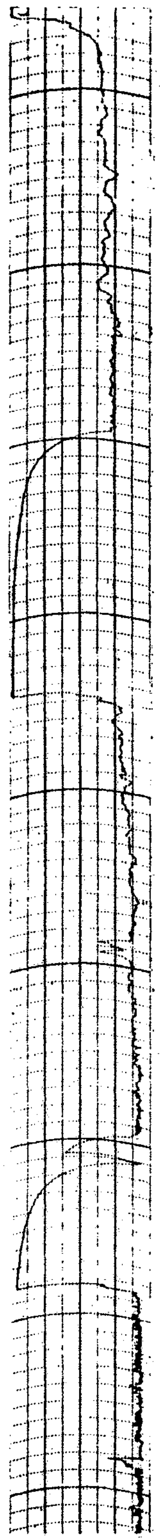
2.8 volts

1 inch feed

2.8 volts
Empty feed trough

Figure 7. Voltage variation produced in test circuit by eating activities of the animal - six volts impressed in circuit.

SIX ANIMALS EATING



Animals started eating

2.8 volts

5" feed

3.2 volts

4" feed

Animals out to level and reduce feed to 3" of feed

The signal indication on the chart was less jagged than with one or two animals because of distribution of animal eating time. Two to four animals eating at all times.

3.7 volts

3.8 volts

Animal lifted head

Animals out of trough

Leveled to 1" of feed

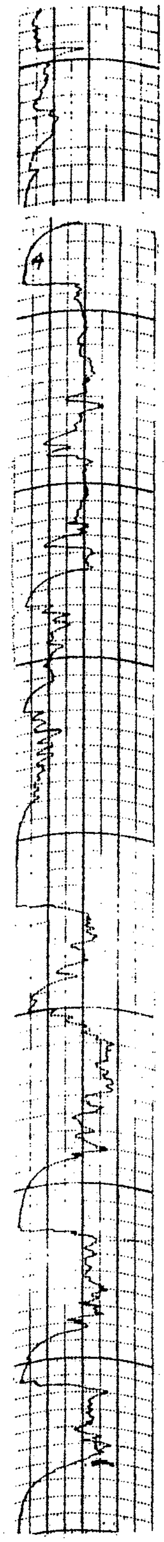
3.8 volts

Empty trough

3.9 volts

10-23-63

ONE ANIMAL EATING



Animals started eating
1.8 volts

5" feed

Animal removed head from trough

4" feed

2.3 volts

Animals out to level feed to 3".

Animal's head out temporarily.

2.7 volts

Leveled to 1" of feed

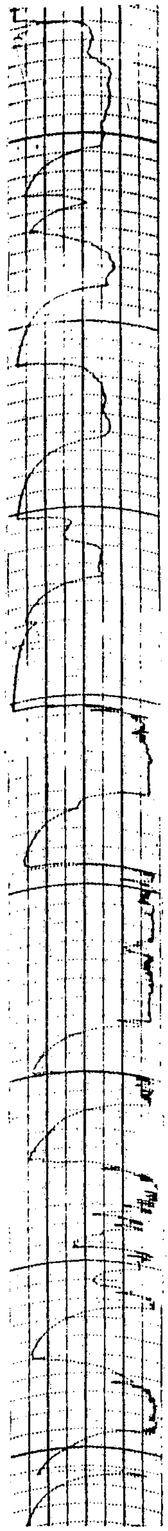
2.7 volts
Empty trough

3.0 volts

10-24-63

Figure 8. Voltage variation produced in test circuit by eating activities of the animal - nine volts impressed in circuit.

ONE ANIMAL EATING



Animals started eating.

2.8 volts

5" feed

2.78 volts

Animal removed head from trough.

Animal removed head from trough.

2.5 volts

Leveled to 3" feed animal out

2 animals eating.

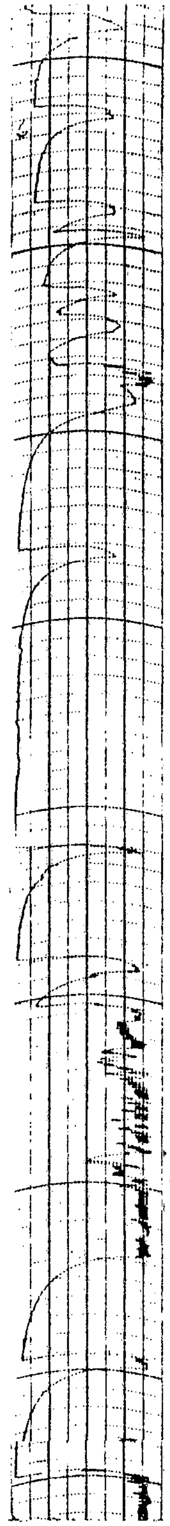
2" feed
3 animals eating

3.7 volts

3.8 volts

Empty trough.

3.8 volts



Animal started eating.

2.7 volts

5" feed
Animal took bite or two and lifted head.

3.5 volts

4" feed

Animal out to level and adjust feed to 2".

2 animals eating
2" feed

3.7 volts

Both animals backed away from trough then returned for another bite of feed.

Animals out to level feed.
1" feed, 3.76 volts

Figure 9. Voltage variation produced in test circuit by eating activities of the animal - twelve volts impressed in circuit.

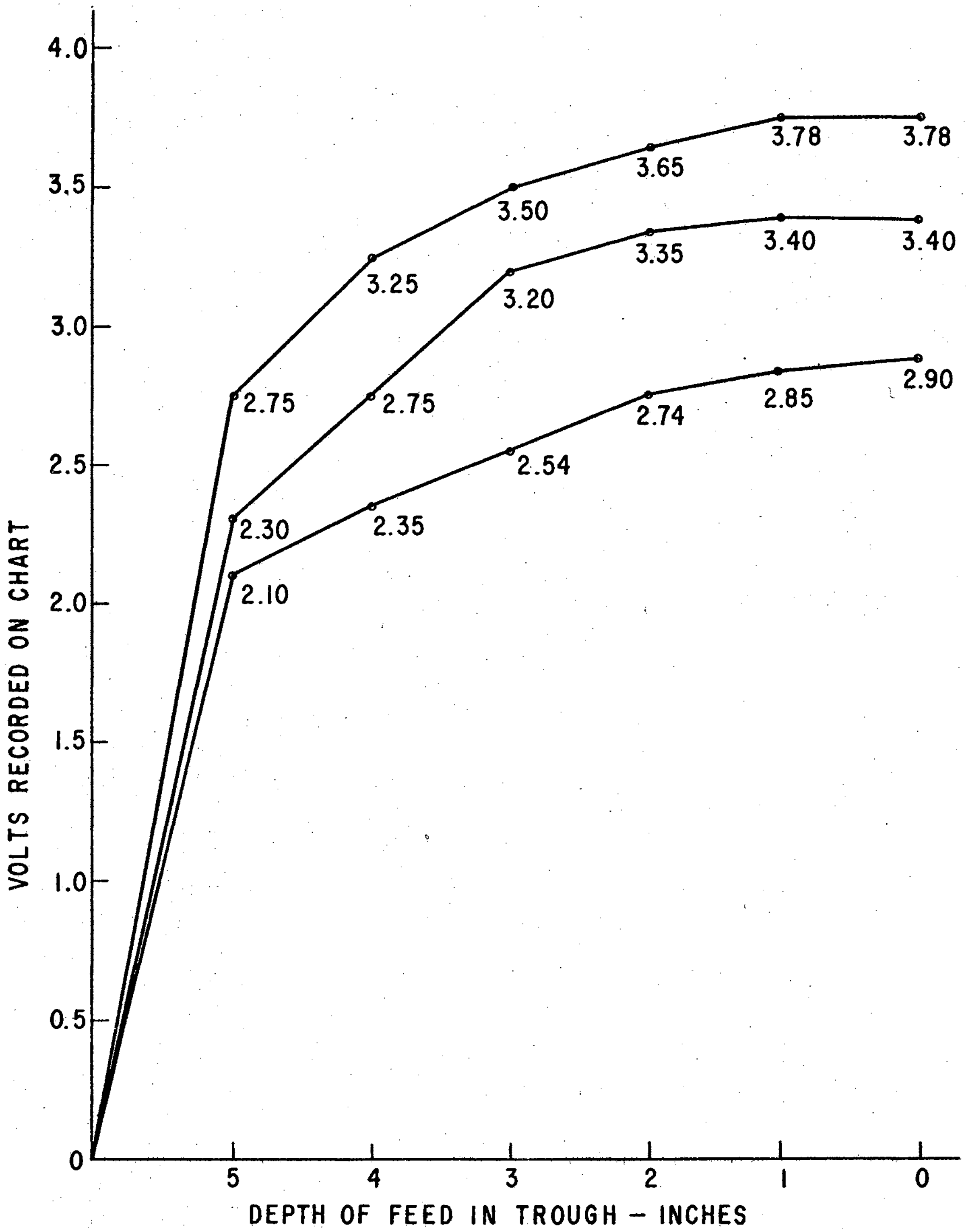


Figure 10. The voltage response in the recording instrument.

Test Circuit Operated at Zero Voltage

At zero impressed voltage in the closed circuit Figures 4 and 5, a definite change in voltage or change in characteristic of the signal was detected when an animal touched the trough conductor with its tongue. The neck conductor was no longer needed because there was no flow of current. There was no longer a need for a closed circuit. The power source was removed and the trough conductor became a sensing conductor. The amplifier in the recording instrument was detecting a signal from the animal's body. The instrumentation in the detecting circuit was:

1. Resistance decade box. Figure 6.
2. Recording instrument. Figure 6.
3. Variable capacitor. Figure 6.

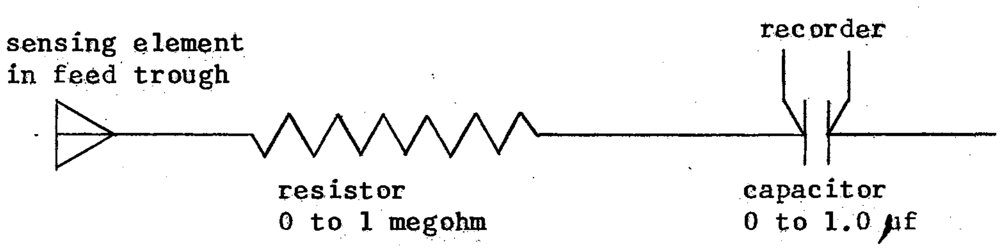
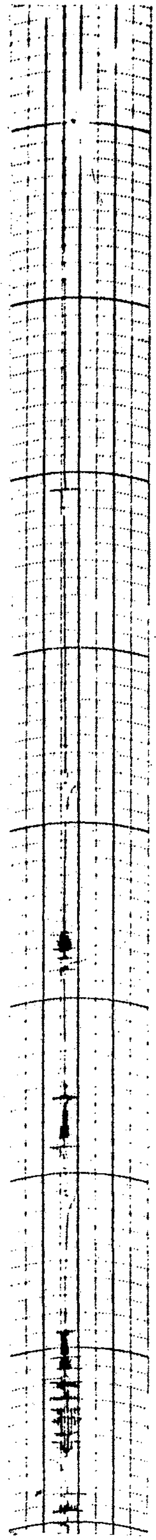


Figure 11. Instrumentation for circuit operated at zero voltage.

The bottom of the trough was adjusted to two inches in width because the first trials indicated that this adjustment gave better performance than the 4-inch width. Six inches of eating space were allowed per animal (Figure 3). The smaller eating compartment required less feed. It was no longer leveled at specified depths. An A.W.G. #18 solid copper conductor was alternately used with an A.W.G. #12 solid copper conductor as a sensing

TWO ANIMALS AT THE TROUGH



11-29-63, 6:30 A.M.

Temperature 28° F.
R.H. Dry

3" feed in trough

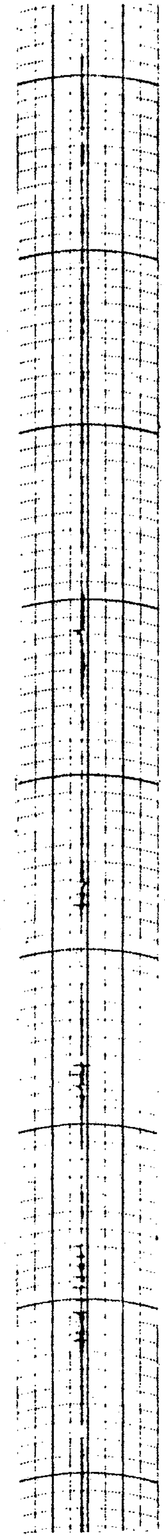
Sensing conductor six inches of #18 solid conductor

78 seconds to first impulse

Animal striking sensing element with tongue

Good signal for firing thyratron or for any type of control equipment.

.1 volt/chart line



12-7-63, 5:00 P.M.

Animals started with 4" feed

Sensing conductor six inches of #12 solid conductor

Weak signal at 50 seconds after start.

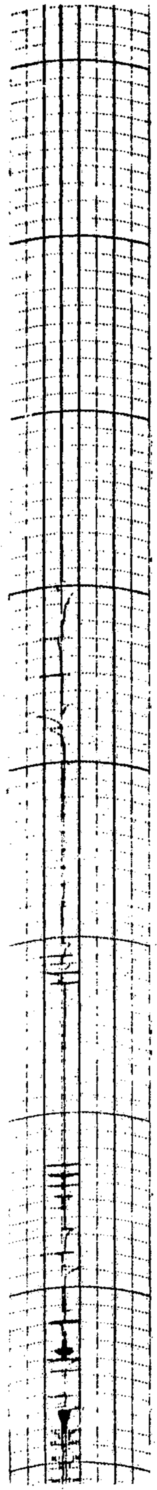
Signal through 1" feed

Poor impulse

Signal is not weak because recording instrument is set on .5 volt/chart line.

Figure 12. Chart record when circuit was operated at zero voltage.

TWO ANIMALS AT THE TROUGH



Temperature 62° F.

R.H. 62%

Two animals started eating with 3" feed in trough.

Sensing conductor 3" of #18 solid conductor

Trough 2" wide at bottom

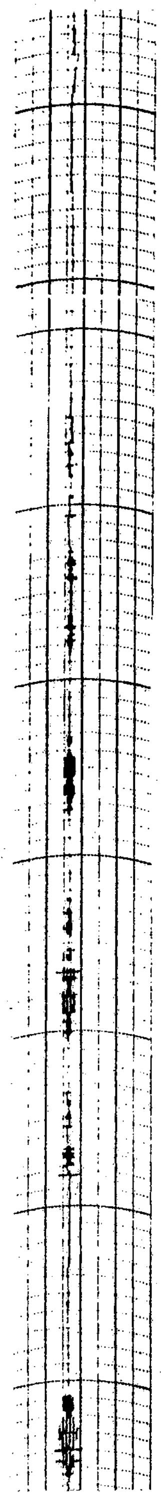
Animal's tongue strikes sensing conductor.

Equipment should be adjusted to ignore the first signals.

Animal would impulse relay several times here.

Trough almost empty. Animal is striking element with tongue. A good signal.

.1 volt/chart line



Instrument records signal from animal at 3" of feed.

Animals started eating with 4" of feed in trough.

Sensing conductor 3" of #12 solid conductor

.5 volt per chart line

Trough 2" wide at bottom

4" feed in trough at start

The recording instrument picked up signal before animal made contact with sensing conductor.

First impulse came in at 20 seconds after animal started eating.

A relay nor a thyratron would respond properly to this signal.

Empty trough

.5 volt/chart line

Figure 13. Chart record when the circuit was operated at zero voltage - 2nd trial.

conductor. Each sensing station was made by removing the insulation from the portion of the electrical wire which was under each feed compartment. This electrical conductor was 30 inches long but only 6 or 12 inches of it was exposed. See chart notation on the following pages for its length. Only 3 inches of feed was placed in each compartment at the beginning of each trial.

The two 550 lb. Black Angus steers were used for these tests. Both animals ate simultaneously. The resistance and capacitance were set at 554,555 ohms and .53 μf respectively. The chart speed was 5 mm. per second. See Figures 12 and 13 for performance of this sensing circuit.

Nature of Signals

A further search of information revealed that there was a 60 cycle per second electromagnetic field radiating from the central station alternating current that travels on the electric power lines. A definite signal could be detected from this field. The change in signal, Figures 12 and 13, could have been due to the animal's body acting as an antenna to collect the signal from the atmosphere or it was coming in on the recording instrument. However, the animal was definitely controlling the signal when it touched the electrical conductor in the feed trough.

"The average adult has a body capacity with respect to ground which usually varies between 50 and 100 μf," Atkins (11). It is assumed that the average animal also has a body capacity with respect to ground of proportionate magnitude. It was impossible to determine the effect of this body capacity to ground in the signal as noted in Figures 16 and 17.

This study indicates that a usable signal can be controlled by the animal. It is electronic in nature. Therefore, an electronic circuit will be required to utilize the signal.

The animals were no longer available. The test equipment was returned to the laboratory.

CHAPTER IV

DEVELOPMENT OF ELECTRONIC CIRCUIT

This part of the experiment was designed to develop equipment capable of utilizing the signal as noted in the previous chapter and to test the reliability of the circuit. The size of the trough and the location and size of the sensing conductor were continuously studied throughout the experiment. Five electronic circuits were tested at the feed trough. Data were taken on the last three circuits as listed below:

Circuit "A" - Touch control or oscillating. Figure 14.

The following circuits were designed and built in the electronics laboratory at Oklahoma State University by Martin Block under the supervision of Professor H. L. Heisermann, Head of the Electronics Technology Department of the Technical Institute.

Circuit "B" - First test circuit. Figure 16.

Circuit "C" - First operating circuit. Figure 17.

Circuit "D" - Circuit "C" plus a .25 μf capacitor.

Circuit "E" - Circuit "D" plus a variable resistor on control circuit. Figure 18.

Circuit "A"

Atkins (11) originally reported on an oscillating circuit. It is also known as a touch or proximity control circuit. The touch control unit, as discussed in this report, was purchased. The touch control "T1" in the circuit, Figure 14, was connected to the sensing conductor in the feed trough, Figure 2. Pulse energy, originating with the neon oscillator, was fed to the animal's body when it contacted the sensing station. In this manner the control relay in the circuit was activated. The control relay activated a 150 watt light bulb for these trials.

After each impulse the circuit remained in the "on" position until the operator furnished the "off" touch. The circuit could have been rebuilt to reactivate itself in the "on" position. The results of these trials appeared to be too erratic for continuous use of a touch control circuit. No further work was done with this circuit.

Test Equipment

The test equipment for circuits "B", "C", "D", and "E" consisted of the following:

1. Amplifier or electronic circuit and step relay. See Figure 15. The amplifier was connected to the step relay through a plate relay. The step relay required 12 volts d.c. Each impulse advanced the relay counter 1 step. The stations were labeled in increments of two from zero through 24.
2. Variable d.c. power pack or battery eliminator for the amplifier. The voltage to the plate on the pentode tubes and to the plate relay was varied from 100 to 150 volts in increments of 5 volts. Various circuits were operated at voltages as indicated in this report.

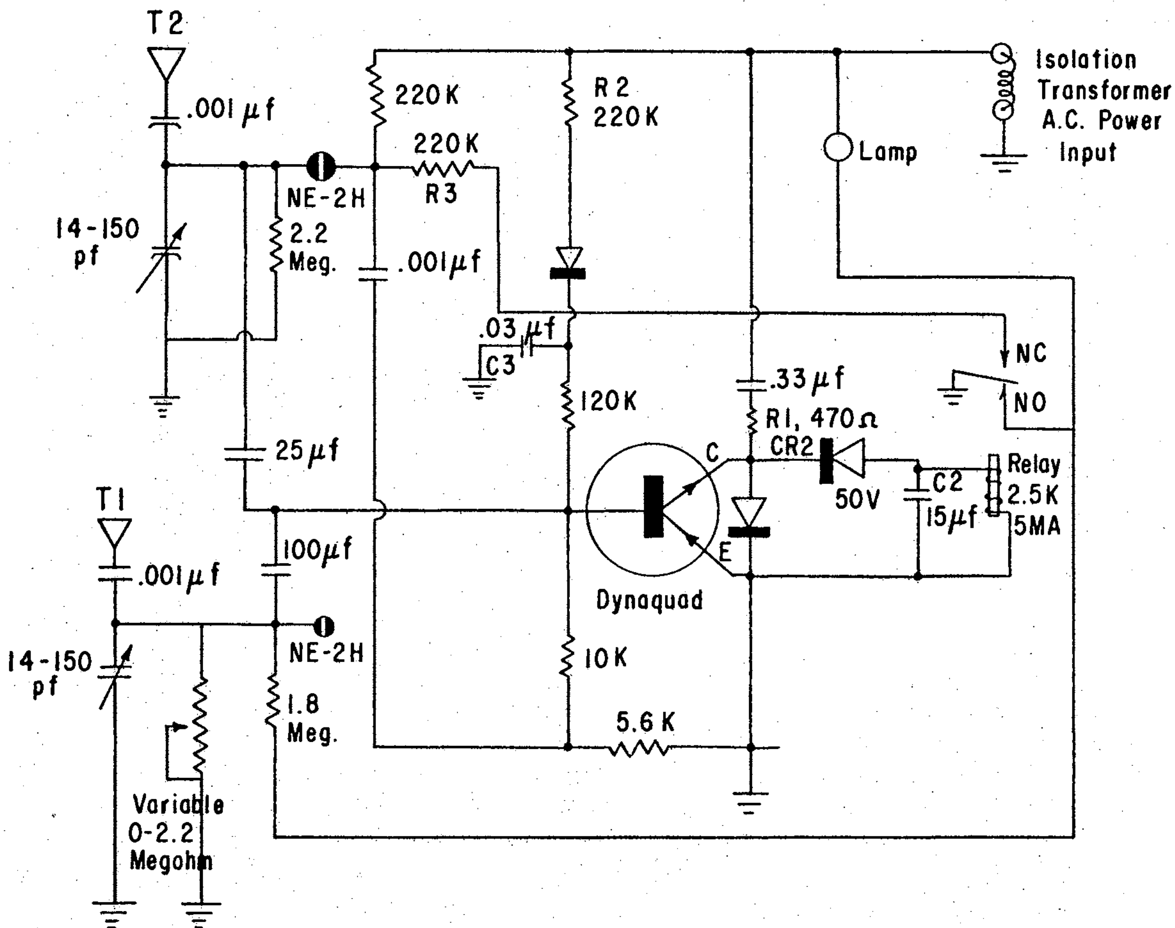


Figure 14. Circuitry for Dynaquad Touch Control Switch.

3. Battery eliminator for the 12 volt d.c. step relay. See Figure 15 for equipment in the circuit.

4. Isolation transformer. The isolation transformer was placed in the circuit to prevent the possibility of a ground loop existing through the power supply. It could produce premature triggering in the circuit before the animal touched the sensing conductor.

5. Feed trough. Individual trough sections were constructed. A sensing conductor was placed in each trough section. Each section was individually connected to the amplifier. The bottom of the trough was varied from 5/8 to 2-1/2 inches in width. Figure 2.

6. Sensing conductor. An A.W.G. #18 solid conductor copper wire was located in the bottom of the trough at 3 locations. It was varied in length from 5/8 to 2-1/2 inches.

Preliminary Testing of Circuit

The circuit or amplifier was developed and tested in the electronics laboratory in the Technical Institute. A preliminary test run was needed to make the required adjustments for reliable performance of the circuit in the feed trough. Circuit "B", Figure 16, was connected to the test equipment, Figure 15, at the feeder. Two Black Angus steers weighing about 500 lbs. each were used for these tests. The bottom of the trough was adjusted to 2.5 inches in width. The 2 inch sensing conductor was a #18 bare solid wire. It was installed in the bottom of two compartments in the feed trough. At the beginning of each trial 2.3 lbs. of feed were placed in

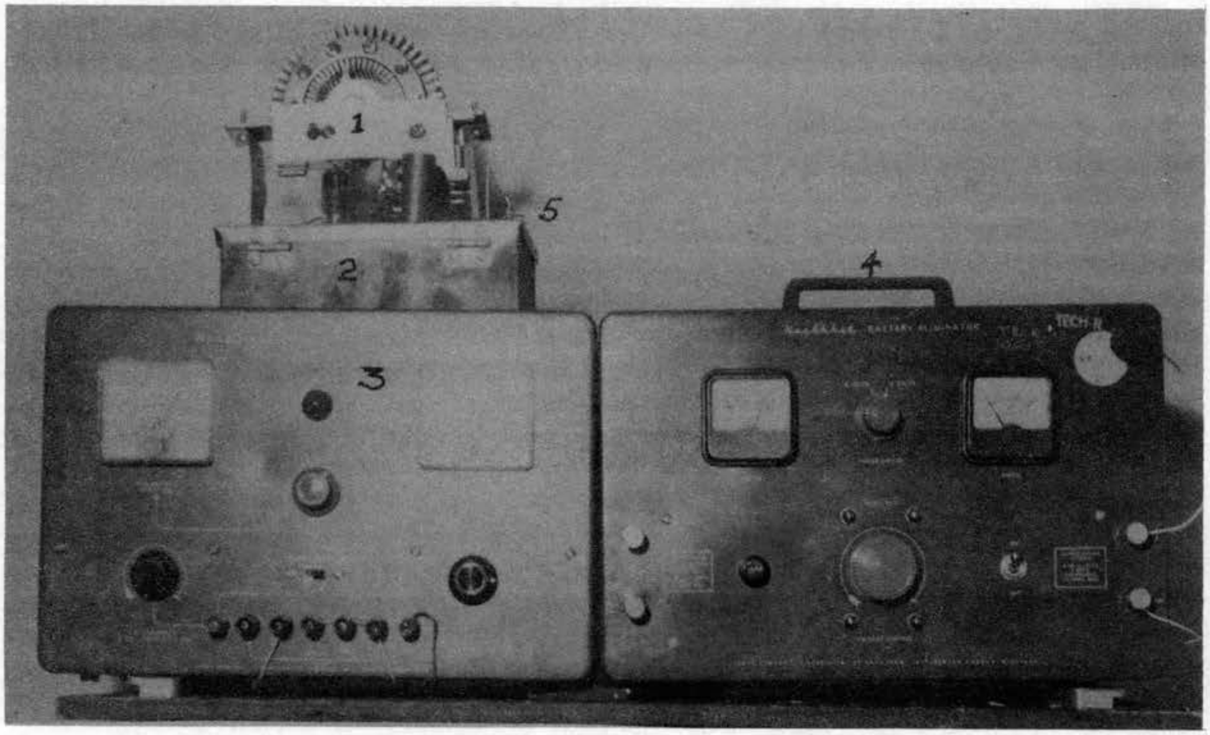


Figure 15. Test equipment for electronic circuit.

1. Step relay - 12 volts.
2. Amplifier or electronic circuit.
3. Variable power pack - 100 to 130 volts d.c.
4. Battery eliminator for step relay - 12 volts d.c.
5. Connection for sensing station in feed trough.
6. Isolation transformer - not pictured.

the trough. The amount of feed, measured in grams, that remained after the scheduled number of impulses on the step relay was recorded.

The voltage impressed upon the plate in the pentode tube varied from 100 to 130 volts.

The performance of this amplifier was too erratic and the readings were not recorded. Adjustments were made in the grid leak and bias resistors to develop Circuit "C", Figure 17.

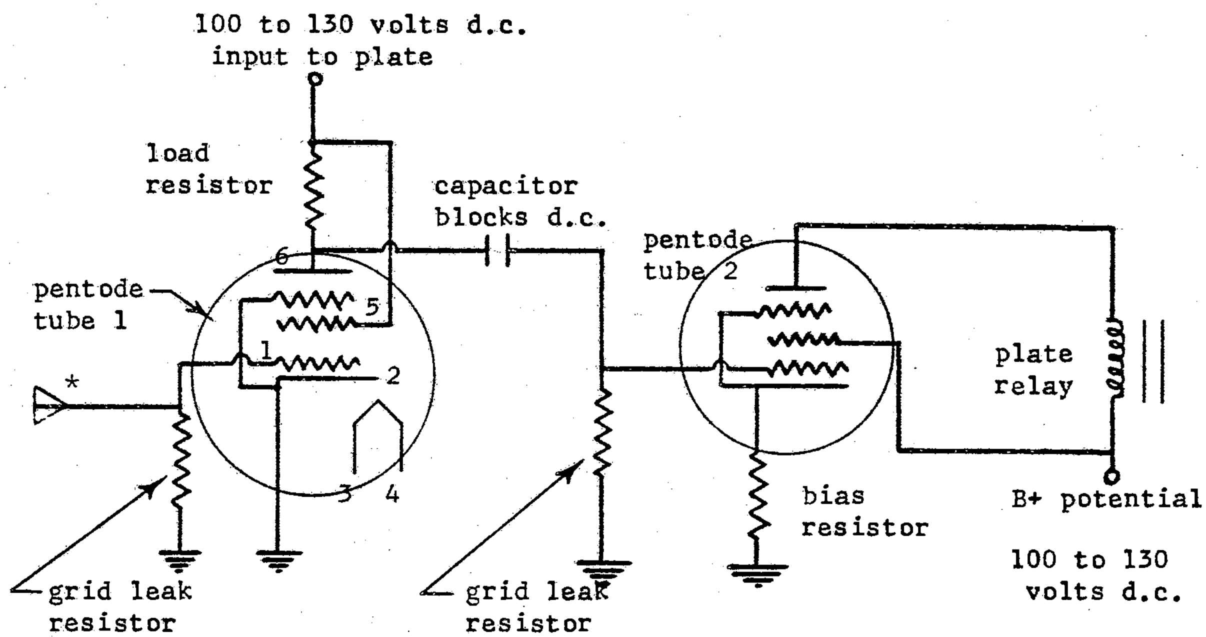
Circuit "C"

This circuit was tested with the same animals, trough, and electrical connections as for Circuit "B". It utilized the 60 cycle signal from the electrical power lines. The signal was picked up by the animal's body, acting as an antenna, and amplified by the pentode tubes. The animals were activating the step relay through the electronic circuit.

Apparently the capacity to ground effect inherent in the animals affected the operating point of the circuit. After several trials, it was discovered that the hum signal was also being introduced into the system by the feed trough. This circuit was also too erratic for continuous operation.

Two changes were necessary to develop a satisfactory operating amplifier labeled as Circuit "D".

1. A .4 μf capacitor shunting the plate relay circuit was installed at "b", Figure 17.
2. Insulating plastic was installed across the bottom and on the sides of the trough for the purpose of isolating the sensing stations. It prevented the feed trough from introducing the hum signal into the system.

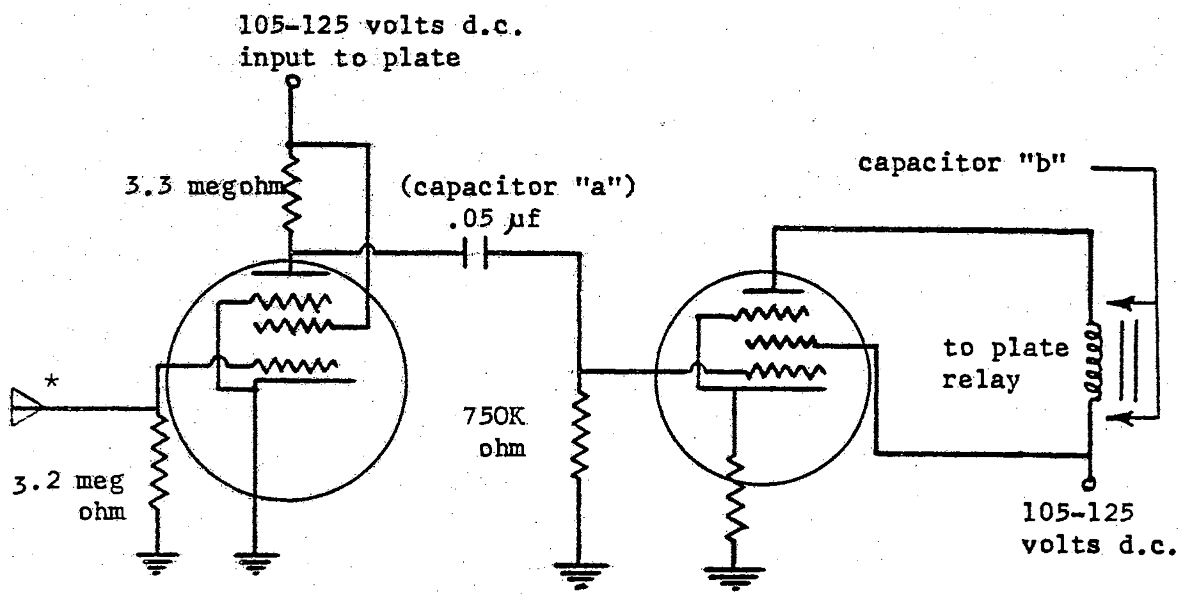


Identification of electrical contacts in pentode tube.
1. Control grid (input from animal).
2. Cathode.
3. & 4. Filaments (heaters).
5. Screen grid.
6. Plate.

* Sensing conductor in the feed trough.

Figure 16. Diagram of electronic circuit and test circuit "B".

Figure 17. Operating circuits.



Test Circuit "C"

Circuit "D" was developed by shunting the plate relay circuit with a .4 µf capacitor in Circuit "C". The value of the grid resistor for the input circuit to the control grid in the first pentode tube was reduced to 2.2 megohms. Circuit "D" is not pictured.

* Sensing conductor in the feed trough.

Circuit "E"

The final amplifier to be developed and tested was Circuit "E". A variable resistor replaced the 2.2 megohm grid leak resistor on the control grid that detected the signal from the animal. See Figure 18.

Operation of Electronic Circuit "E"

The animal, acting as an antenna in the electromagnetic field, induced a voltage pulse on the control grid in the first pentode tube each time its tongue made adequate contact with the sensing conductor in the bottom of the trough, Figure 16. The resulting signal was amplified and pulsating d.c. signal was sent to the second pentode tube. The circuit normally passed sufficient d.c. current through the plate relay coil to hold the relay point open. A test of the circuit indicated that 1.24 microamperes of current were required to activate the plate relay. The signal from the animal caused the current flow and the voltage to rise above that required to activate the plate relay, See Figure 19. When the animal disengaged its tongue from the sensing conductor, a sudden voltage drop occurred in the plate relay circuit. The tendency of capacitor "b", Figure 17, to recharge after this sudden voltage drop caused the current in the relay coil to drop momentarily below its drop out value. A test of the circuit indicated that the plate relay dropped out at .195 microampere. Instantaneously the points on the plate relay closed momentarily which passed the electrical energy in another circuit to the step relay. This action advanced the step relay one station.

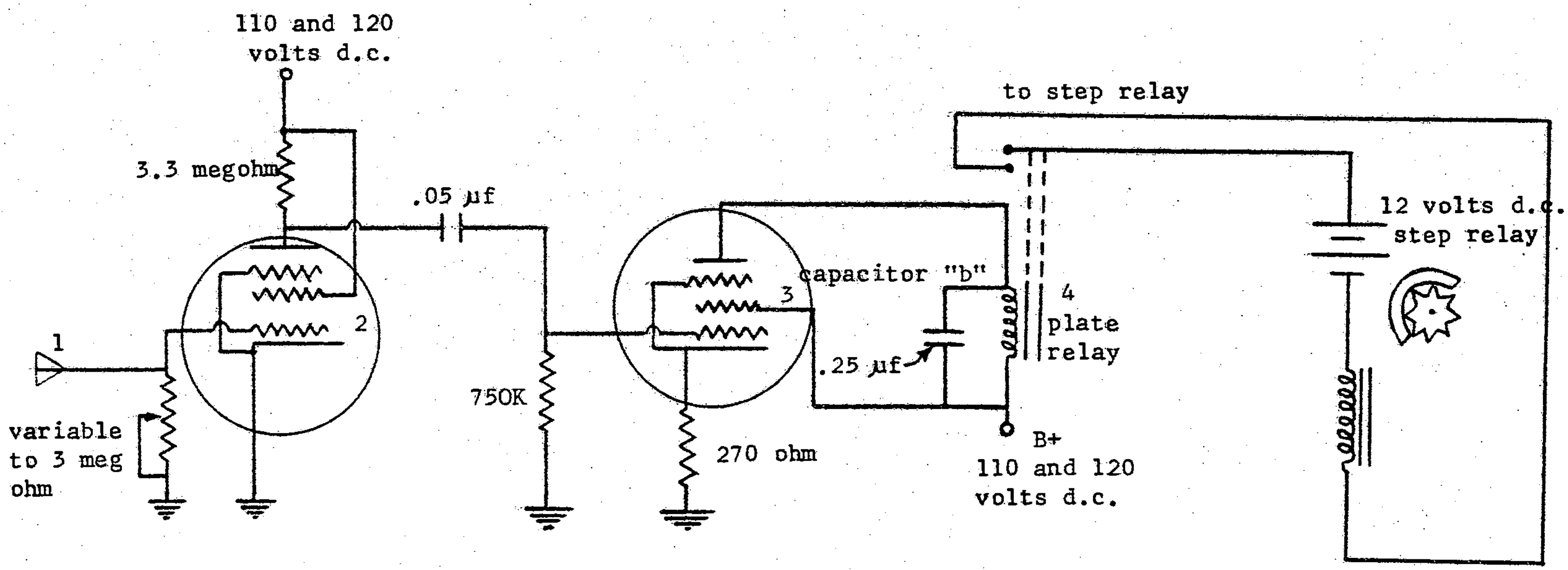


Figure 18. Operating unit - Circuit "E".

1. Sensing conductor in the feed trough.
2. First pentode tube detected the hum signal that was picked up by the animal acting as an antenna.
3. The second pentode tube further refines and amplifies the signal.
4. The plate relay was activated by the signal from the second pentode tube. The step relay was impulsed when the animal released its tongue from the sensing conductor in the feed trough.

If the current received a spurious signal from additional sources, the drop in current flow or voltage drop caused by the licking action of the animal might not have created sufficient voltage drop to let the relay coil points close. The plate relay became inactive and would not impulse the step relay.

The trough and the structure that held the trough were capable of acting as an antenna to collect the signal. Therefore, the sensing stations had to be isolated from the feed trough.

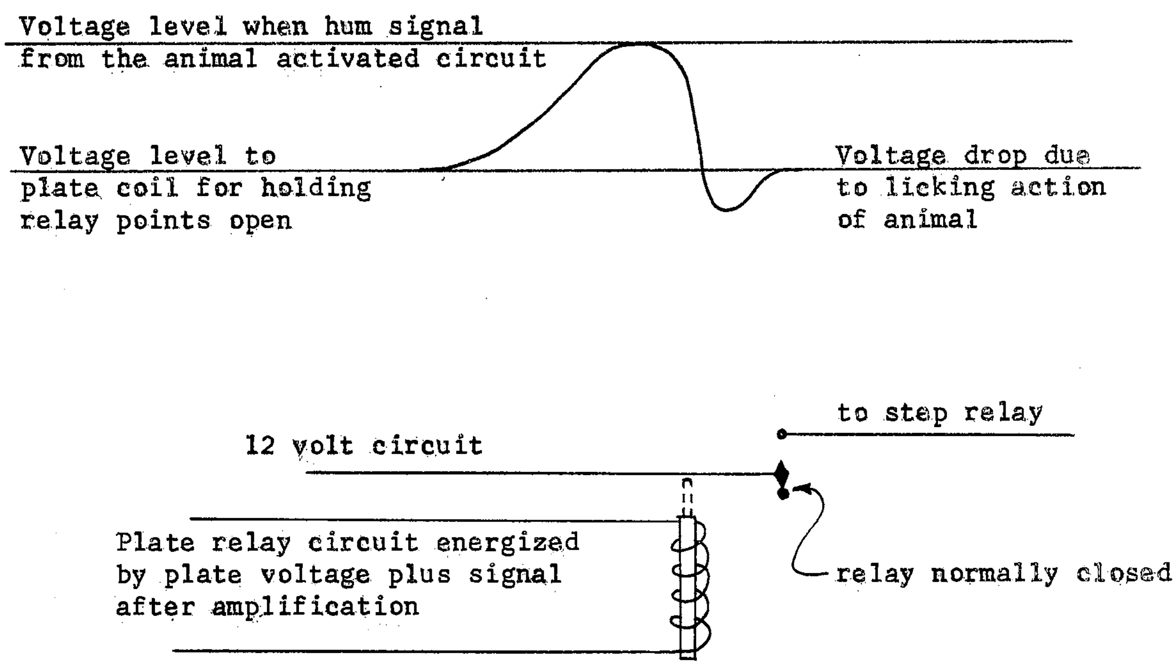


Figure 19. Operating principle of the circuit.

New Design of Feed Trough

Apparently the design of the feed trough and the size of the sensing conductor were important for the successful operation of this system. The strongest and most reliable signal came through when the animal's tongue made contact with the sensing conductor in the bottom of the trough. If the animal used its tongue too much, an excessive amount of saliva was left in the trough. The saliva was objectionable because it made the feed unpalatable and it altered the operation of the electronic circuit. The trough design, size and location of the sensing conductor were studied as the experiment progressed.

Other Variables to be Studied

1. Voltage impressed upon the pentode tube plate.
2. The size of the animals.
3. The number of impulses on the step relay that should be required before fresh feed falls into the trough.

Other important variables are:

1. Relative humidity in the air.
2. Moisture in the feed.
3. Physical shape and content of the feed.
4. Strength of the signal from the electromagnetic field.

New Scheduled Trials

On February 15, 1964, the feeder was started with Circuit "D" (Figure 17). Four Black Angus heifers and two Hereford steers were made available by the Animal Science Department. They were identified as follows:

A_1 Black Angus 325 pounds heifer

A_2 Black Angus 345 pounds heifer

A_3 Black Angus 345 pounds heifer

A_4 Black Angus 360 pounds heifer

A_5 Hereford 425 pounds steer

A_6 Hereford 425 pounds steer

The animals were fed twice per day for five days to adjust the equipment and to get the animals eating properly before a record was taken. Six compartments were made in the trough. The first four were 5 inches long to accommodate the heifers. The last two were 6 inches long for the steers. See Figure 2. The procedure for taking samples of feed was the same as in the preliminary trials. The bottom of the trough was adjusted to two inches in width. The sensing conductor was two inches long.

A series of tests were made to determine the variation in the performance of each section of the trough. The animals were rotated from section to section at various feedings. There was no significant difference in the amount of feed left in the trough when the same animal was fed in the various trough sections.

The data for Circuit "D" were recorded and analyzed (Table II). The circuit was operated at voltage settings of 105, 110, 115, 120 and 125. The schedule of impulses for each voltage setting was 5, 10, 15 and 20. The amount of feed, in grams, remaining in the trough after the scheduled number of impulses was recorded.

Circuit "E" (Figure 18) was developed by replacing the 3 megohm grid leak resistor on the part of the circuit that connected the control grid in the first pentode tube to the sensing station in the feed trough with a variable resistor. The system was operated with the resistance setting at 1.75, 1.25 and 0.75 megohms with 110 volts impressed upon the circuit. A second set of trials was made with the same resistance settings with 120 volts on the circuit. The data were recorded in Table IV.

CHAPTER V

PRESENTATION OF DATA AND ANALYSIS OF VARIANCE

Presentation of Data from Circuit "D"

The data in Table II are the average sample size, in grams, from three replications per animal from all four animals in the test when the electronic circuit was operated at five equally spaced voltage settings on the input to the amplifier for Circuit "D", Figure 17. The variation was from 105 through 125 volts. The variation on the step relay ranged from 5 through 20 impulses in increments of 5. A sample was obtained by weighing the amount of feed remaining in the trough after the scheduled number of impulses were made on the step relay.

Figure 20 is a graph of the relationship of voltage variation to the average sample size.

The analysis of variance, Table III, is based upon five equally spaced treatments or voltages. This analysis was made to determine the nature of a response curve when the voltage increased from 105 to 125. It is a statistical procedure that can be used in place of a standard regression analysis for determining the effect of one factor. The two factors considered were impulses and voltage. Each of the individual sums of squares for the voltage increments were tested by means of the impulse by voltage error term.

TABLE II

SUMMARY OF DATA FROM CIRCUIT "D"

Impulses	105 Volts	110 Volts	115 Volts	120 Volts	125 Volts	
5	133.7	79.0	62.7	32.0	49.0	356.4
10	106.3	62.7	54.3	51.3	35.3	309.9
15	99.0	50.3	40.0	24.7	30.7	244.7
20	82.7	61.0	33.7	33.7	30.0	241.1
Total	421.7	253.0	190.7	141.7	145.0	1,152.1
$\bar{y}$	105.6	63.25	47.7	35.4	34.2	

The above table is the average feed sample, in grams, from 3 replications on 4 animals.

TABLE III

A COMPARISON OF IMPULSES BY VOLTS - CIRCUIT "D"

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square or Estimate of Standard Deviation	F Test	Frequency Level
Total Mean	20 1	82,745.57 66,252.71			
Impulses	3	1,960.54	653.51	8.19	99%
Volts	4	13,574.86	4,524.95	56.71	99%
1st degree	1	11,079.50		138.86	99%
2nd degree	1	2,279.96		28.57	99%
3rd degree	1	673.22		8.44	97.5%
4th degree	1	62.32		.78	50%
Error	12	957.46	79.79		

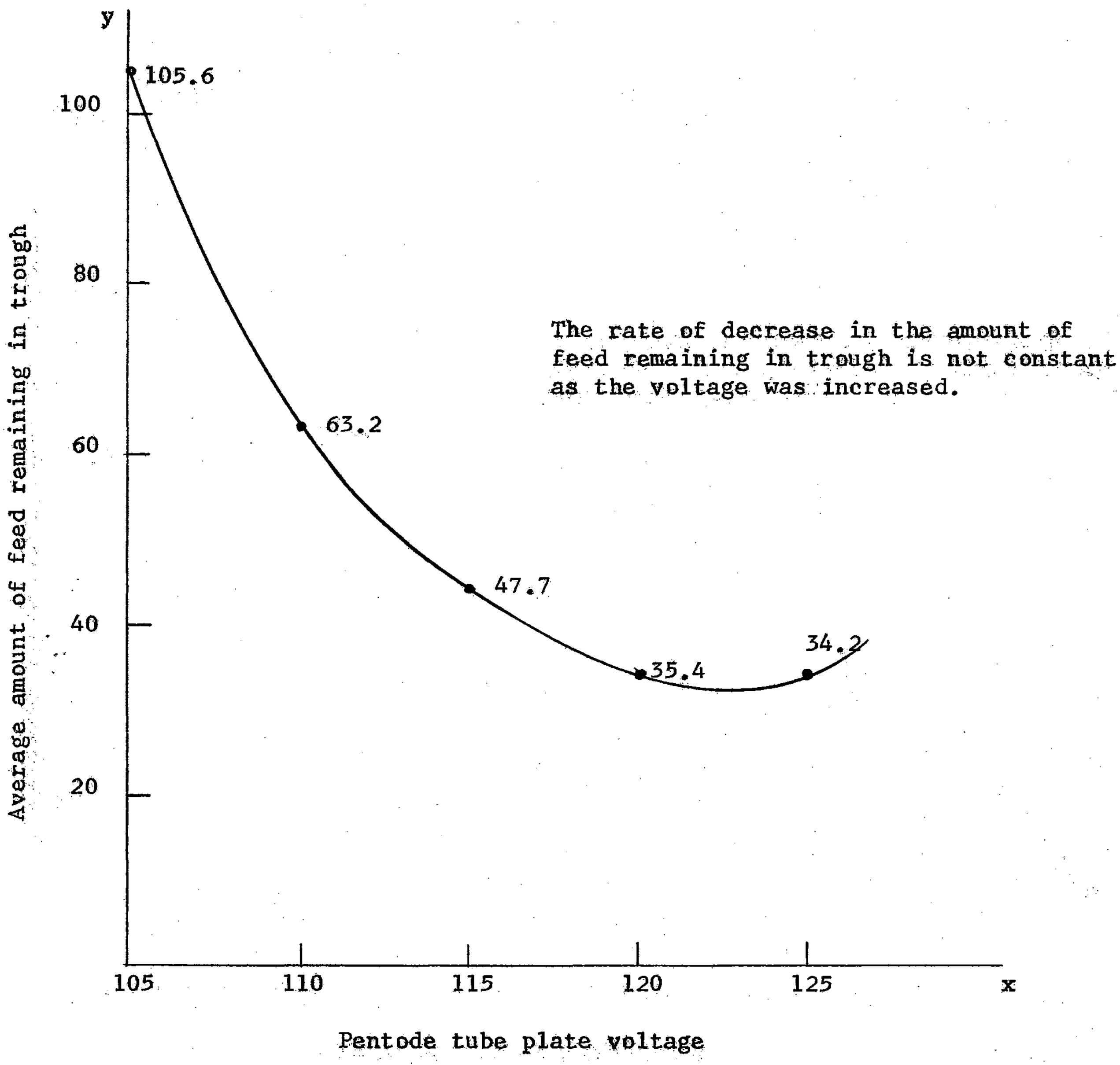


Figure 20. The relationship of voltage variation in Circuit "D" to the sample.

Presentation of Data from Circuit "E"

Table IV is a record of 216 readings or samples with the control circuit operating at 110 and 120 volts. The sample of feed remaining in the trough was taken at each combination of resistance, impulse and voltage. The weight of the sample was recorded in grams.

The variable grid leak resistor in the amplifier circuit that connected the sensing station in the trough with the control grid in the first pentode tube was varied 1.75, 1.25, and 0.75 megohms. The step relay was scheduled at 2, 5, and 10 impulses. The sample variance, based upon three replications, was calculated. Figure 23 is the relationship of this variance taken over the range of impulses as compared to the variation in resistance.

The data were studied as a factorial experiment. The design was 4 X 3 X 3 X 2 with 3 readings or replications. Table V is an analysis of variance due to the four main effects and due to the second and third order of interactions. The main effects were animals, resistance, impulses and voltage.

TABLE IV

DATA FROM CIRCUIT "E"

Impulse	Resistance	A_1 110	A_1 120	A_3 110	A_3 120	A_4 110	A_4 120	A_5 110	A_5 120	Total
		Feed samples - in grams								
	1.75	94	74	87	56	92	44	34	63	
		89	82	84	54	88	51	60	51	
		92	76	86	64	91	56	109	37	
	Total	275	232	257	174	271	151	203	151	1714
		86	48	76	30	87	36	106	31	
2	1.25	84	31	80	64	88	54	92	20	
		87	38	87	56	85	48	116	42	
	Total	257	117	243	150	260	138	314	93	1572
		82	58	76	53	67	42	80	24	
	0.75	78	47	72	38	63	31	84	14	
		81	62	75	42	52	38	83	18	
	Total	241	167	223	133	182	111	247	56	1360
Total		773	516	723	457	713	400	764	300	4646
	1.75	74	64	60	58	82	72	8	14	
		82	79	61	30	73	52	38	39	
		78	44	42	21	96	55	77	18	
	Total	234	187	163	109	251	179	123	71	1317
		64	22	98	48	39	34	98	18	
5	1.25	76	39	62	37	42	28	71	6	
		71	32	73	42	44	26	80	28	
	Total	211	93	233	127	125	88	249	52	1178
		74	31	92	53	54	46	72	13	
	0.75	67	36	89	41	71	41	59	23	
		42	48	86	54	52	36	63	7	
	Total	183	115	267	148	177	123	194	43	1250
Total		628	395	663	384	553	390	566	166	3745
	1.75	44	42	37	43	55	16	61	12	
		94	13	42	12	62	27	9	28	
		73	20	59	14	52	12	28	6	
	Total	211	75	138	69	169	55	98	46	861
		74	26	36	42	32	18	95	42	
10	1.25	67	8	63	16	46	21	82	16	
		42	12	48	21	39	43	68	8	
	Total	183	46	147	79	117	82	245	66	965
		74	74	51	11	32	28	63	4	
	0.75	43	16	23	48	46	23	56	9	
		38	27	38	26	29	32	51	11	
	Total	155	117	112	85	107	83	170	24	853
Total		549	238	397	233	393	220	513	136	2679

TABLE V

ANALYSIS OF VARIANCE FOR CIRCUIT "E"

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square or Estimate of Standard Deviation	F Test	Frequency Level
Total	216	710,018			
Mean	1	567,337.5			
Corrected total	215	142,680.5			
Main Effects					
Animal	3	4,289.09	1,429.7	1.074	<70%
Impulse	2	26,931.69	13,465.85	10.119	99%
Resistance	2	1,291.08	645.54	0.485	<70%
Voltage	1	53,518.52	53,518.52	40.220	99%
Readings or Replication	2	388.69	194.35	1.134	<70%
Error (a)	3	3,991.93	1,330.64		
First order interactions					
A x I	6	1,765.94	294.32	0.652	<70%
A x R	6	8,162.32	1,360.39	3.012	99%
A x V	3	3,991.93	1,330.64	2.946	95%
I x V	2	596.06	298.03	0.66	<70%
R x I	4	2,081.72	520.43	1.161	<70%
R x V	2	2,304.45	1,152.23	2.555	90%
Error (b)	48	21,681.98	451.708		
Error (c)	142	24,335.29	171.375		

CHAPTER VI

OPERATION OF ELECTRONIC CIRCUIT IN FIELD TEST OF CONTROL SYSTEM

The observations on the following pages were taken to evaluate the performance of the control system in the feed trough under operating conditions. A 60 inch portion of the trough was used for this study. Four Black Angus heifers weighing from 325 to 365 pounds were fed twice per day. They were kept hungry to make them eat when observations were taken on the performance of the system.

Description of Electrical System and the Trough

Electronic circuit "E", Figure 16, was used in the control system for these trials. Four sensing stations were located in the bottom of the trough as indicated in Figure 21. The A.W.G. #18 solid wire was used for the sensing conductor. Its length varied as indicated in the record of observations. Each station was independently connected to the amplifier through a switch. The impulse to the step relay, Figure 21, was clearly audible. Each station was identified on the feeder and on the trough. When the animal's mouth approached a station, the corresponding switch was closed to connect that station to the amplifier. When the animal triggered a station the second time during each trial, that station's circuit remained open until the next trial started. The animal often triggered one station several times per feeding but only two impulses were received by the step relay. In this manner it was possible to study the operation of the system in controlling a set of step relays.

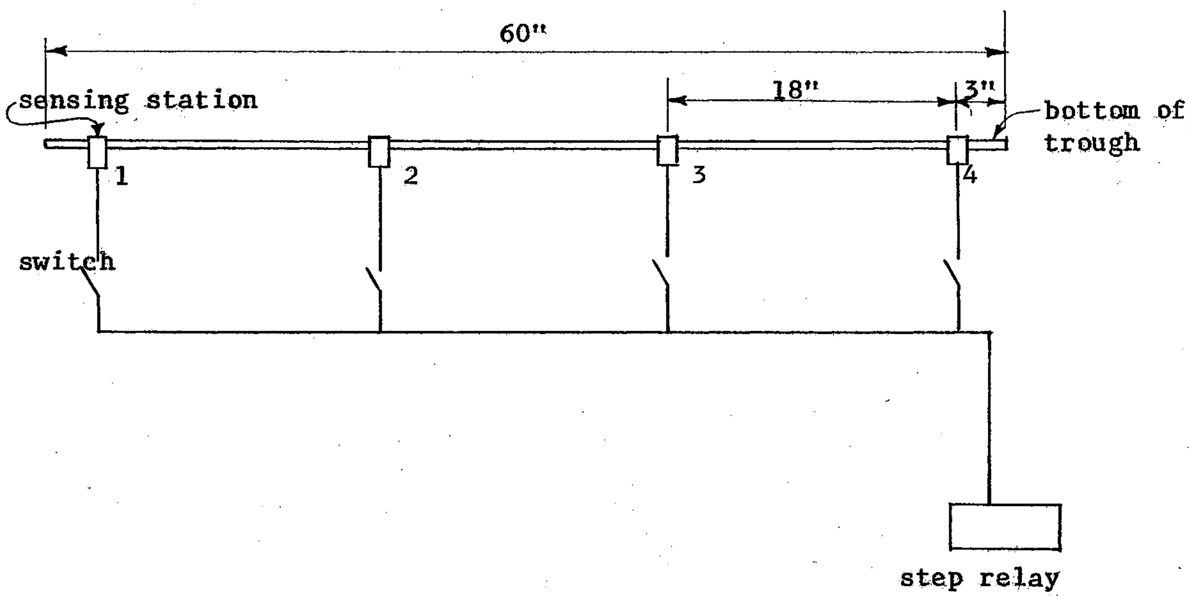


Figure 21. Control system in a 60-inch section of the trough.

The following log is a record of observations taken from March 1 through March 8, 1964. A total of 42 observations were made. Only the observations that were significantly different or contributed towards new information were recorded here.

Observation No.	Sensing Conductor	Trough Adjustment	Performance of Animal	Results or Remarks
1	$1\frac{1}{2}$"	$1\frac{1}{2}$"	Animal vigorously scoops feed with mouth and licked bottom of trough.	All four sensing stations were triggered. Considerable saliva deposit.
2	$1\frac{1}{2}$"	$1\frac{1}{2}$"	Animals ate feed from center of trough first. Animals move up and down the trough leaving feed packed at each end.	Sensing stations number 2 & 3 each tripped the relay twice. There was no saliva deposit left in trough but only two sensing stations were activated (Figure 21).
3	$1\frac{1}{2}$"	$1\frac{1}{2}$"	Three animals were eating at trough. The animals were allowed to eat until all four sensing stations were each tripped twice.	There was some saliva deposit in the trough. The sensing conductor was shortened to 5/8" and the bottom of the trough adjusted to 5/8".
5	5/8"	7/8"	First trial at new feeding hour. Animals cleaned up the feed before the relays were tripped.	It appeared that the animals were skipping over the electrode in the bottom of the trough. Considerable saliva in the trough.
10	2"	7/8"	Three animals ate without pushing and fighting one another for the feed.	All four sensing stations were activated. Saliva was deposited in the trough.
11	2"	1-1/8"	Animals had a tendency to eat the feed that was readily accessible before licking bottom of trough. Licking action caused a strong impulse on each sensing station.	Animals left a little saliva because of licking action. More saliva was left in trough when animals tripped the relay at fourth station than when they tripped the relay at only three stations.

Observation No.	Sensing Conductor	Trough Adjustment	Performance of Animal	Results or Remarks
16	1-3/4"	1-1/4"	Three animals emptied the 60" trough and triggered 3 of the 4 sensing stations.	No evidence of saliva. Animal did not lick feed until trough was almost empty. 116 grams of feed left in trough.
17	1-3/4"	1-1/4"	Animals were allowed to eat in trough until all four sensing stations were activated.	There were only 80 grams of feed left in trough. Excess saliva was also left in trough.
19	1-3/4"	1-1/4"	All four animals triggered four relays. Animals in center of trough had a tendency to empty the trough first. They either licked the bottom of the trough or pushed the animal away from the end of the trough where feed remained.	Excessive saliva was deposited for about 35" through the center of the trough.
22	1-3/4"	1-1/4"	Four animals were eating in the trough. They impulsed 3 sensing stations.	The animals left 132 grams of feed in the trough. There was little or no evidence of saliva.

Four additional observations were taken with the conditions described in observation number 22. The animals readily tripped the relay twice at three of the four stations. The amount of feed left in the trough was not significant. The animals cleaned up the feed before leaving a deposit of saliva when the bottom of the trough was adjusted to 1-1/4 inches and the sensing conductor was 1-3/4 inches long.

Feed Compaction Test

Ration "A" - 80% cracked milo and 20% cotton seed hulls by weight.

Ration "B" - 40% cracked milo and 60% cotton seed hulls by weight.

Ration "C" - 5% animal fat and 98% ground grain, no bulk.

The hum pick up signal readily traveled through all three rations when the feed was packed down by hand. Immediately upon loosening the material, the signal was blocked until the animal made contact with the sensing conductor in the feed trough. The animals packed ration "A" while eating in the small compartment. They did not pack this ration in the 60-inch trough. Ration "C" was extra dense because of the high grain and animal fat content. It did not perform well in the trough. The feed dispenser should agitate the ration and drop it loosely a short distance into the trough. Pelleted feed and complete rations will probably perform best in this system. The compaction rate went up considerably when moisture was added to the feed. The touch control signal was altered by a small percent of moisture in the feed. When the moisture content of the ration was below 18% there appeared to be no effect in the hum signal as long as the feed remained loose. The investigation indicated that a cattle activated electronic circuit can be developed to control a system of relays for operating a feed dispenser motor.

A Study of Saliva Build-up

The amount of saliva on the feed increased as the scheduled number of impulses increased. It was caused by too much licking by the animal in the trough. Ration "A" was used for this observation. It was composed of 80% cracked milo and 20% cotton seed hulls by weight. In the sack Ration "A" contained 11.3% moisture based upon dry matter. The feed sample was taken after the scheduled number of impulses on the step relay and tested for moisture content.

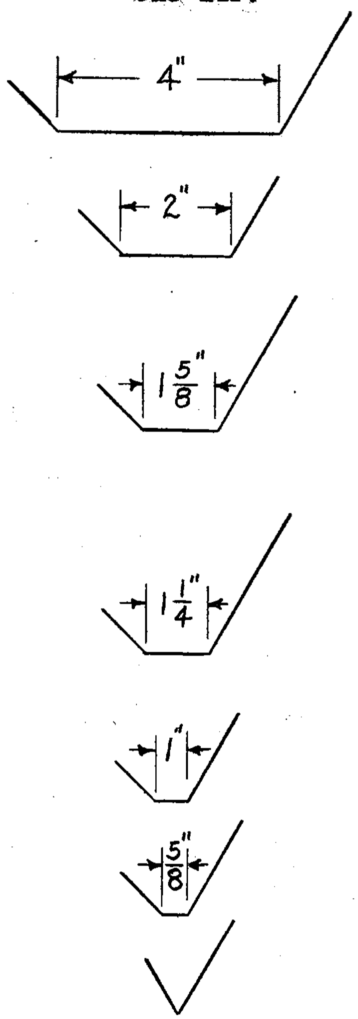
Number of Impulses	Percent of Moisture Based Upon Dry Matter
5	11.8%
20	28.1%
10	14.6%
10	15.2%
5	11.3%
5	13.7%
10	13.8%
5	12.6%
8	12.0%
15	21.2%
6	12.5%
10	18.3%
5	11.3%
5	12.1%
20	26.8%
15	17.4%
10	13.8%
5	11.9%
5	12.1%
10	13.8%
15	18.2%
20	19.8%

Trough Size Study

This study began during the investigation of signal sources and ended during the observations of the system.

Objective: Design trough to accommodate the sensing conductor for the electronic controller.

Design trough to conserve feed and incite animal to consume desired amounts of feed. Little feed should be exposed to the air.



4" trough too wide - animal ate feed out of middle - made contact with sensing conductor too soon. Too much feed exposed.

2" trough - still too wide for the 300 to 350 pound animal. An 800 pound animal might need this size - not tested.

1-5/8" trough - worked best for the 450 pound animals. If trough is too small animal licks too much with tongue and creates saliva deposit. The most desirable design requires the animal to use its tongue when the feed is near the bottom of the trough.

1-1/4" trough - right size for the four animals weighing from 300 to 350 pounds each. Sensing conductor placed in center of trough 1-1/2" in length.

1" trough - worked well on four animals. Saliva built up often before controller tripped the relay 5 times.

5/8" trough - too narrow. Objectionable saliva was always deposited in the trough.

No favorable results .....

Figure 22. Variation in trough size.

CHAPTER VII

DISCUSSION OF DATA AND RESULTS

Data in Table II

This part of the experiment was planned to determine the nature of a response when the voltage impressed upon the circuit and the required impulses increased increments of five from 105 through 125 volts and from 5 through 20 impulses, respectively. The analysis of variance due to the interaction volts by impulses was made to estimate the significance of the voltage variation on the performance of the control system. See Table III. The variation due to voltage was highly significant and approximately seven times greater than the variation due to the impulses. The analysis of variance further indicated that the effect of voltage change decreased as the voltage decreased from 105 to 125 volts. The variations from 105 to 110 and 110 to 115 were significant above the 99% level. The change from 115 to 120 volts was significant at the 95% level. The change from 120 to 125 volts was not significant at the 50% level.

The graph, Figure 20, shows the voltage variation on the X axis and the average sample size or the average amount of feed remaining in the trough, in grams, on the Y axis. It is another study of the variation due to voltage. The relationship is non-linear.

The analysis indicated that the variation due to voltage was too great for proper or accurate performance of the control circuit. The amplifier unit needed to be capable of utilizing the signal within a range of various voltages without affecting the sample size. A variable resistor was placed in the circuit to ground that connected the sensing station to the control grid in the first pentode tube in the amplifier unit. See Circuit "E" in Figure 18.

Discussion of Table IV

The investigation started with nothing known about the validity of this method for testing the performance of the signal. Unknown and untested discrepancies were present. Climatic conditions, consistency of the feed and type of animal were possible sources of variation. The error terms in the analysis of variance, Table V, includes all of these unknown variables.

The analysis was made from 216 samples of feed with the control system operating at varying adjustments as indicated in the presentation of data in Table III.

Discussion of the Analysis of Variance in Table V

The variation due to the main effect of the animal was significant at the 70% level. Therefore, the variation in the sample size due to the animal could have been caused by chance and not because of the animal. The trough was adjusted to accommodate the animals and there should not have been a variation due to the animals. The variation due to the effect of the impulse schedules and due to the voltage was significant at the 99% level. These two main effects could have caused a variation in the sample size.

The relationship of impulse to the standard deviation of the sample size is illustrated in Figure 23. When the circuit was scheduled for two impulses, the sample size varied the least. The relatively large variations in the sample size from A_1 and A_5 accounted for the large mean square or the estimate of the standard deviation for the effect due to the impulse. As the number of impulses increased, the performance of the circuit became more erratic. In the laboratory, the amplifier functioned from 100 to 130 volts. When it was put in the control circuit, the voltage appeared to become more critical. The amplifier should operate in the control circuit with either 110 or 120 volts impressed upon the pentode tube plate and the B+ terminal on the plate relay. During the trials the voltage was maintained at either 110 or 120 with a battery eliminator, Figure 15. It appears that a voltage regulator will be needed for field operations.

The variance due to the resistance was significant at the 70% level. However, the interaction of animal by resistance revealed that the effect was significant at the 99% level. It indicated that under those conditions the resistance should have varied with the size of the animal. The data in Table IV shows that the sample variance was less at 0.75 megohm for A_5 (425 pounds) than at 1.75 megohms. The sample from A_1 (325 pounds) and A_4 (360 pounds) appeared to have less variance at 1.25 megohms. The samples from the 345 pound animal (A_3) indicated a relatively narrow variation at 1.75 and 0.75 megohms for two impulses. The larger animal required a reduction in the resistance setting as noted in Figure 21.

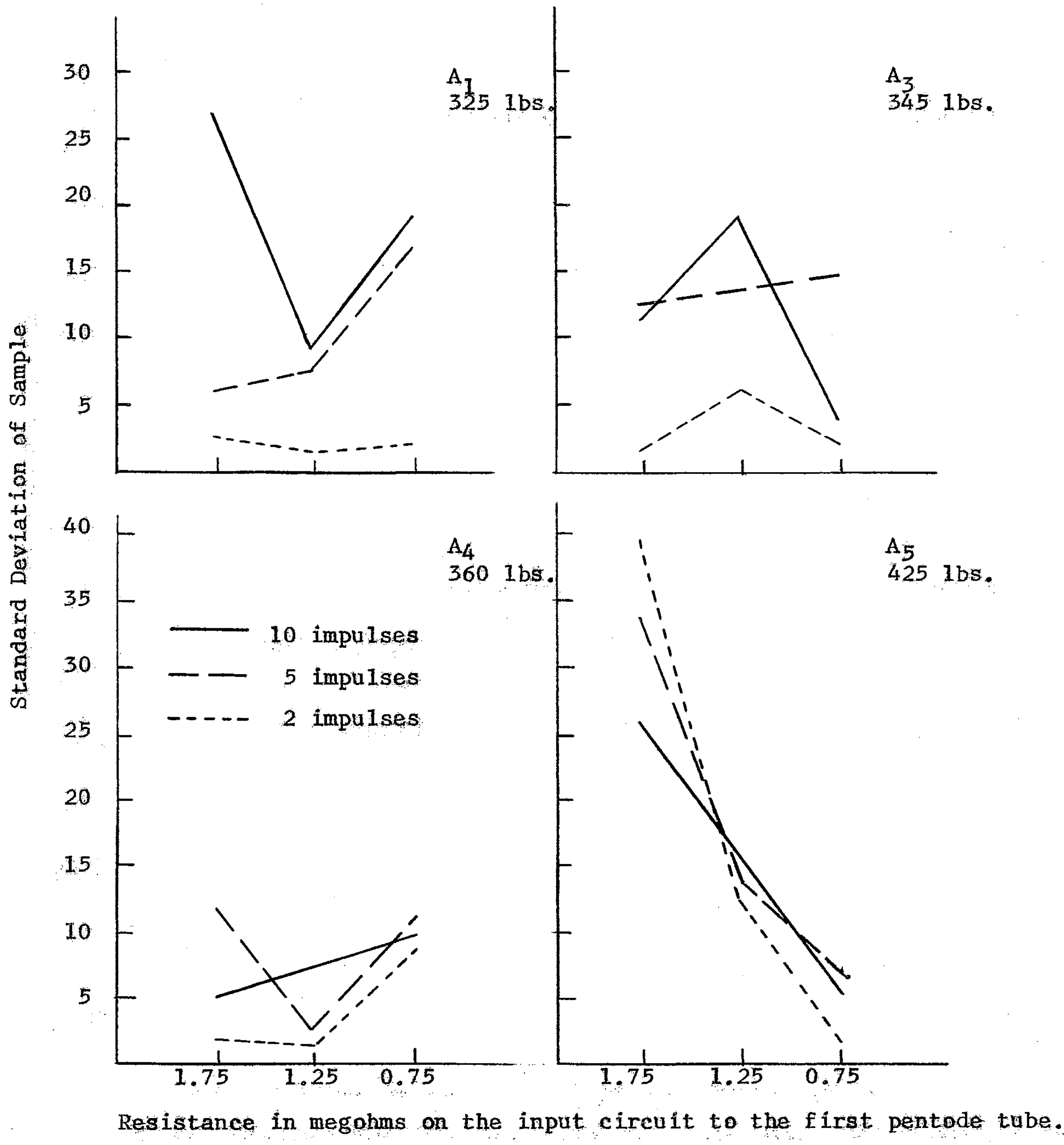


Figure 23. A comparison of the sample standard deviation to the variation in scheduled impulses on the step relay.

The lower resistance setting allowed more of the signal to go to ground before it reached the control grid in the pentode tube. See Figure 18.

The variation in the following interactions could have been due to chance because it was significant at the 70% level:

Animal by impulse

Impulse by voltage

Resistance by voltage.

The variance due to the interaction of animal by voltage was significant at the 95% level and resistance by voltage at the 90% level. Therefore, part of the variation in the sample size could have been caused by these two interactions.

The variation due to the readings or the replications was significant below the 70% level. This evidence showed that the control system would operate on any day at any time because the readings were randomly taken morning, noon and night under varying climatic conditions.

Discussion of Results from Study of Additional Variables

The trough used in this investigation is pictured in Figures 1 and 2. Its shape and adjustable features were selected after a study of existing equipment. The trough must be designed to force the animal to use its tongue to get the feed that is near the bottom. When the trough was set too narrow at the bottom, objectionable saliva was deposited in the trough because of the licking action of the animal. When the animal reached the bottom of the trough with its mouth, a weak signal was often received by the amplifier. The system operated best when the animal was forced to make contact with the sensing conductor through its tongue.

See Figure 22.

The results of this study indicated that the sensing conductor can act as an antenna for picking up the hum signal. When the animal's body was the only factor in controlling the in-coming signal, the amplifier performed satisfactorily without the variable resistor. The circuit was isolated to prevent the spurious signals as much as possible. If complete isolation of all circuits can be accomplished, it is possible that an operating amplifier will not need the variable resistor as pictured in Circuit "E". It is highly possible that bistable ferromagnetic cores could be designed to replace the step relay. Ferromagnetic cores are easily magnetized and can store binary information. They are small, rugged and they are reliable.

The feed compaction study indicated that the feed dispenser should agitate the ration as it falls into the trough. The study further indicated that a pelleted ration would have contributed toward a satisfactory performance of the control system.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

Summary

An exploratory investigation was made to determing the possibility for improving the process of feeding livestock through the application of electronic circuitry. In developing this investigation it was necessary to study:

1. Existing systems
2. Eating patterns of animals
3. Types and strength of signals the animal was capable of controlling, initiating or conducting
4. Feed trough design.

Three types of signals that could be controlled or conducted by the animal were tested:

1. Mouth to neck resistance of the animal in a closed circuit that would be detected by a thyratron vacumm tube.

2. Capacitive effect of the animal to be detected through a sensing conductor in the feed trough by a touch control circuit.

3. The 60 cycle per second signal from the electromagnetic field from the electric power lines. The signal was controlled by the animal when it made contact with a sensing conductor in the bottom of the feed trough. The signal was amplified until it was capable of impulsing a

plate relay in the electronic circuit, Figure 18. The plate relay was capable of controlling other relays as needed to control the flow of feed into the trough.

Four animals varying in weight from 325 to 425 pounds were used in testing an operating circuit designed to utilize the 60 cycle hum signal. The circuit in the control system was operated at 110 and 120 volts; 0.75, 1.25, and 1.75 megohms of resistance in the first grid leak resistor (Figure 18) and 2, 5, and 10 impulses were scheduled on the step relay. The effects of the variation due to the animals, voltage, impulse schedule, and resistance adjustment were analyzed. A factorial design was used for this analysis. It was indicated that the variation due to impulse and voltage was significant at the 99% level. Three first order interactions were also highly significant. They were animal by resistance, animal by voltage, and resistance by voltage.

Other variables in the studies were:

1. Size and shape of the feed trough.
2. Size and length of the sensing conductor.
3. Compaction of the feed.

After the circuit was tested for reliability and for consistency of action, it was tested under feeding conditions. A 60 inch portion of the trough and four heifers were used for these trials.

Conclusions

The following conclusions were drawn from the experiment.

1. The exploratory investigation of three basic signals indicated that the 60 cycle per second electromagnetic field signal from the electric

power line performed with the least variation in sample size.

2. Circuit "E" (Figure 18) conducted and adequately amplified the signal to impulse a plate relay for a series of 216 trials during the experimental phase of this work.

3. The size and shape of the trough were significant. The trough design must require the animal to use its tongue in getting the feed on the bottom of the trough. The tests indicated that the trough (Figure 2) gave best results when the bottom width was adjusted to 1-1/4 inches for the 325 to 360 lb. animals. The 425 lb. animal required a 1-1/2 inch adjustment.

4. The bottom of the trough should be adjusted to fit the animal.

5. The length and size of the sensing conductor were significant. The trials indicated that a 1-3/4 inch length of #18 A.W.G. wire was a desirable size. A larger size of wire became an effective antenna and picked up spurious signals.

6. The sensing stations and the electronic circuit should be completely isolated.

7. The number of sensing stations in the trough were significant. The analysis of variance shows that the variation due to the impulse is highly significant. It was concluded that this evidence shows a real difference among the treatment means for the various impulse settings. Four sensing stations were used in the 60-inch portion of the trough to feed four animals.

8. The feeding equipment should be activated after two impulses on the step relay.

9. The size of the animal had an effect upon the strength of the

signal that was picked up by the amplifier.

10. The larger animal required a reduction in the resistance on the grid leak resistor in the amplifier circuit that connected the sensing station to the control grid. Under these conditions the control system functioned with the least variation in the sample size when the resistance was set at 0.75 megohms for the large animal and 1.75 megohms for the small animal.

11. A circuit can be developed to utilize the signal from a wide range of animal sizes and eliminate the variable resistor.

12. The analysis of variance indicated that under these conditions the voltage should be controlled and kept constant.

13. The physical condition of the feed was significant. A compacted feed had a tendency to conduct the signal. The ration must fall loosely into the trough.

14. Moisture in the atmosphere did not appear to affect the performance of Circuit "E".

15. Performance of the circuit was altered when the moisture content of the feed exceeded 18% based upon dry matter.

16. A cattle activated electronic circuit can successfully control a system of relays for operating a feed dispenser motor.

Suggestions for Further Study

Additional study is suggested to determine

1. The maximum number of sensing stations that can control one system of relays.
2. The maximum spacing between sensing stations in the trough.

3. The desirable material, size and shape for the sensing conductor.

4. The method and materials required to isolate the sensing station and the electronic circuit.

Develop design equations for a system of relays to control the signal from a varying number of sensing stations.

Design a circuit using ferromagnetic cores and other semi-conductors for controlling the signal from the animal.

Investigate the benefits of multiple feedings with a cattle activated controller on the feed dispenser.

SELECTED BIBLIOGRAPHY

1. McKenzie, Bruce, Thesis Report, Michigan State University, "The Development of Grain Feed Storage and Handling Systems for Livestock Farms", Purdue listing 1958, Vol. 3:11.

2. Rannfelt, Carl A., Thesis Report, Michigan State University, "Materials Handling on the Farmstead, Analysis Approach", Purdue listing 1958, Vol. 3:1.

3. Kelly, C. F. & T. E. Bond, "Engineering Design of a Livestock Physical Plant", Ag. Eng. J., Vol. 34:601-607.

4. Hall, Carl W., "Theoretical Considerations in Materials Handling Systems, Ag. Eng. J., Vol. 39 (9):524-529 S '58.

5. McDonald, Patrick H., Jr., "Role of Feedback in Automatic Machinery", Ag. Eng. J., Vol. 42:420-2, Aug. 61.

6. Thuesen, H. G., "Engineering Economy" Second Edition, Englewood Cliffs, N. J., Prentice-Hall, Inc., 1958.

7. Winter, Frederick C., "An Approach to Efficiency Studies", Ag. Eng. J., Vol. 37:482-487.

8. Bradley, Robert W., "Thyratrons Control Dye-Cutting Machine", Electronics, Vol. 30: Part 1 p. 162-5, Jan. 1, 1957.

9. Dobie, John B., Fredric C. Jacob, & Leroy C. Kleist, "Electronic Detection and Removal of Tramp Iron From Chopped Hay", Ag. Eng. J., Vol. 34:377-381.

10. Puckett, H. B., "Electronic Controlled for an Automatic Feed Grinder", Exp. Sta. B 615, University of Illinois, August 1957.

11. Atkins, C. E., "Latest Advances in Touch Control", Electronics World, M 1963 Vol. 69 No. 5, p. 34.

12. Dwyer, Don D., "Activities and Grazing Preferences of Cows With Calves in Northern Osage County Oklahoma", Exp. Sta. Bul. 588, Oklahoma State University, Oct. 1961.

13. Putnam, P. A. & R. E. Davis, "Ration Effects on Drylot Steer Feeding Patterns", ARS Beltsville, Journal of Animal Science, Vol. 21(4): 1962 p. 1009.

14. Pope, L. S., Professor and Head of Animal Science Department, Oklahoma State University, Unpublished Work.

15. Mochrie, R. D., W. E. Thomas & H. L. Lucas, "Influence of Frequency Feeding Equalized Intakes on Animal Response", Journal of Animal Science, Vol. 15:1256, 1956.

16. Mohrman, R. K., W. W. Albert, A. L. Neuman & G. E. Mitchell, "The Influence of Hand-feeding, Self-feeding, and Frequent-interval Feeding on Performance and Behavior of Beef Cattle," Journal of Animal Science, Vol. 18:1849, 1959.

17. Gordon, J. G. & D. E. Tribe, "The Importance to Sheep of Frequent Feeding", British Journal of Nutrition, Vol. 6 p. 89, 1952.

18. Thomas, W. E. & R. D. Mochrie, "Effect of Frequency of Feeding Equalized Intake on Growth of Dairy Heifers", Proceedings of Assoc. of So. Agri. Workers, P. 129, 1956.

19. Hughes, Joe, S. A. Ewing, L. S. Pope & Eldon Nelson, "Factors Influencing Feed and Energy Intake of Steers Fed Conventional and High Concentrate Rations", Progress Report, 1963-64, Oklahoma State University Agr. Exp. Sta.

20. Tillman, Allen D., "An Evaluation of Energy Feeding Standards", Feedstuffs, December 13, 1963.

21. Arsdall, R. Van, "Automation in Your Cattle Feedlot", Ill. Ag. Exp. Sta. Ill. Res., Vol 2:8-9, Sum. '60, also American Livestock Breeders Gazette, Vol. 125:10-11, Jan. 1960.

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