AN AUTOMATIC ANIMAL WEIGHT RECORDING SYSTEM

by

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ABSTRACT

If range cattle could be weighed frequently, research on relationships between vegetation changes, weather conditions and animal weight would be facilitated. Weighing range cattle would also be beneficial to the rancher in sorting and classing animals for market.

Because of the nature of range cattle, conventional methods for weighing animals are inadequate under range conditions. The required driving and handling of the animals often results in weight losses greater than the weight changes to be measured.

A scale was designed and constructed that will allow remote recording of the weight of range cattle. A watering area was fenced off with the only access being over the scale. As the cattle came for water, their weight was obtained without disturbing the established watering routine.

The scale platform was suspended from a supporting structure by four electrical resistance strain gage load rings. Weight supported by the load rings results in an electrical signal which can be measured by a recording oscillograph. The magnitude of this signal is correlated with animal weight through calibration of the system. This method of weighing cattle proved adequate and reliable.

INTRODUCTION

General Discussion

In 1964 the gross value of Arizona's agriculture was estimated at 523.8 million dollars (1). Of this total, the value of cattle marketed off range and pasture was estimated at 50 million dollars (9).

Range cattle are raised on ranches and sold as calves or yearlings depending on the market prices in the fall of the year. Yearlings sold weigh 500 to 800 pounds and calves 400 pounds or less. These yearlings and calves are put in feedlots and finished to a weight of approximately 1000 pounds (3).

Most ranchers keep herds on a cow and calf basis. Selling calves provides the major part of their income. Stanley (7) states that one of the more important ways to increase income and decrease costs is to market cattle to the rancher's advantage by sorting and classing. Weighing the animals would improve the sorting operation.

Weighing cattle could help further research on the raising of range cattle. Questions such as the following might be answered.

1. At what time of the year do range cattle gain and lose weight?

The answer would probably vary according to any number of conditions. The more important conditions being the type and changes in vegetation and temperatures. If cattle could be frequently weighed, relationships could possibly be determined between amount of weight gain or loss and conditions causing the weight variations.

2. When do calves quit gaining weight in the fall?

The answer to this question would definitely help the rancher who is selling calves. Calves are usually sold by weight. The rancher seeks to determine the time when animal weight and market price will combine to result in maximum returns. Frequent weighing of the calves would establish peak weight periods in the fall and the temporal pattern of animal weights. Calves could then be sold to the rancher's advantage.

If some convenient method for frequent weighing of range cattle were available, these and many other questions could be profitably investigated.

Statement of the Problem

The disposition of range cattle limits the amount of contact the animal should have with man. They are very fearful and suspicious of any change in environment or daily routine. Deviations from daily habits can cause decreased weight gain or even loss of weight. Any system created to weigh the animals should cause no departure from the normal daily habits of the animals.

The purpose of this study was development of a cattle weighing system which would operate under field conditions without affecting the animals rate of weight gain. The study was concerned only with the weighing of range cattle.

Available Weighing Methods

Some feedlots and most stockyards can readily obtain an animal's weight. Scales are usually located in a service alley that is frequented by the animals. When it is necessary to weigh an animal, the service alley is blocked off on one end of the scale and the animal driven on the scale. The other end of the scale is then closed. The operator manually balances the scale, visually reads the animal's weight and records it. The gates are then opened and the animal is released. Figure 1 shows a scale in a service alley of a modern dairy. The scale has a 500 pound capacity and is used to weigh calves.

For animals accustomed to daily handling, this method is adequate, but the system is completely impractical for frequent range use. The range animals would have to be gathered to some convenient corral. This would involve men on horses locating the animals and driving them to the corral. Much mingling with the cattle would then be required

Figure 1. A scale used to weigh calves and conveniently located in a service alley.

to separate the animals and individually weigh each animal. Such an operation would cause considerable fright and terror for the animals and be very undesirable.

Because of the time, labor, and cost, such an operation could only be accomplished at the time of marketing if it were done at all.

Weighing System Requirements

The foregoing discussion leads to five requirements for a range cattle weighing system.

1. The scale should be constructed such that an individual animal can be weighed.
2. In order to accomodate a large number of animals, the actual weighing procedure must be rapid.
3. The weighing of the animals must be accomplished in an area familiar to the animals such as a watering or supplementary feeding area.
4. The operation of the weighing system must not disturb the normal routine of the animals.
5. Any instrumentation must be suitable for operation in remote areas.

DESIGN AND CONSTRUCTION OF THE SCALE

Weighing Method

A platform and supporting structure was designed and constructed. The platform was suspended from the supporting structure by four electrical resistance strain gage load rings. Weight supported by the load rings results in a signal which can be detected by a recording oscillograph. The magnitude of this electrical signal can be correlated to animal weight by proper calibration of the system.

Design Criteria

The animals of interest weigh 900 pounds or less. Consideration was given to the range bulls that will also use the scale and weigh 2000 pounds or more. The dead load of the platform was estimated as 400 pounds. Thus the total design load for the load rings is 2400 pounds. Each ring was designed to carry 800 pounds. This allowed for a margin of safety of 200 pounds per load ring or 800 pounds total load. The 200 pound excess capacity is necessary because as the animals walk, there is an impact factor which increases the load.

The length of the platform must allow one and only one animal to be entirely on the scale for about two steps before moving off. The width of the platform must be narrow enough to restrict the animals from turning around.

The system must be capable of recording an animal's weight as the animal moves across the scale without stopping. Because of the necessity for fast response in the weighing procedure, an electrical method was investigated.

The Rocky Mountain Forest and Range Experiment Station, who will use the pilot model, specified that the scale should weigh an 800 pound cow within 20 pounds of her true weight. Thus the accuracy of the scale should allow any animal's weight to be obtained with no greater error than 2.5 percent.

Load Ring Design and Construction

Electrical resistance strain gages electrically wired in the familiar Wheatstone bridge were used. Figure 2 shows a Wheatstone bridge circuit with E the excitation voltage, I_g the current through the galvanometer G, and R_i, $i = 1, 2, 3$ or 4, the resistances of the strain gages. The equation for the current, I_g, through the galvanometer G is (5)

$$(1)\quad I_g = \frac{E(R_2R_4 - R_1R_3)}{R_2(R_1+R_4)\ (R_g+R_3+R_4) + R_1R_3R_4 - R_2R_4^2 + R_gR_3(R_1+R_2)}$$

The current I_g is a function of the resistances in the bridge, R_i, and the excitation voltage E. To achieve maximum sensitivity or produce maximum current, I_g, for a given load, the greatest difference in the products of the resistances R_1R_3 and R_2R_4 is necessary as seen from equation 1.

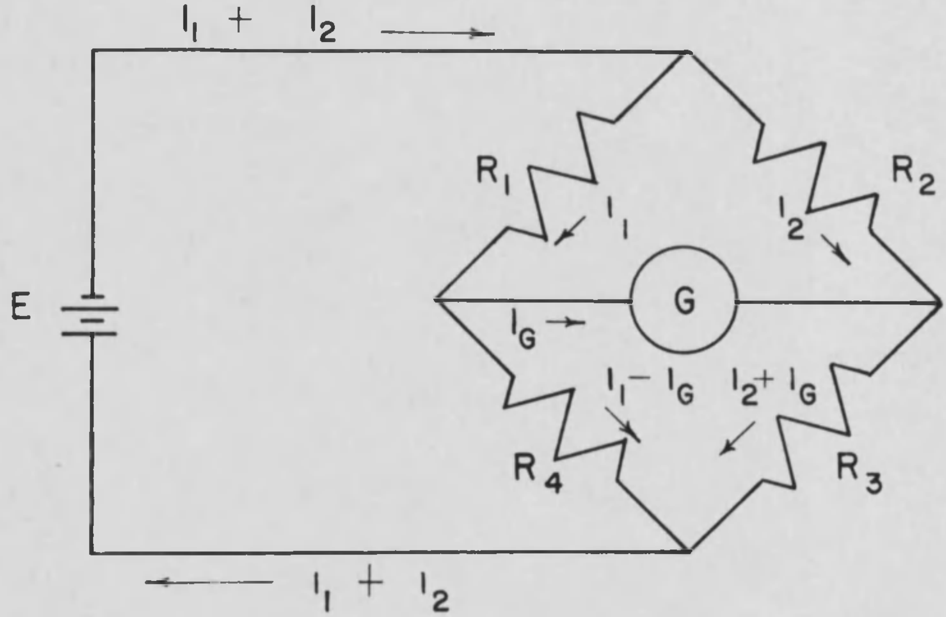

Figure 2. Wiring diagram and flow of current in a Wheatstone bridge circuit.

When a ring is loaded as in Figure 3, the outer surface at the strain gage location is in compression and the inner surface at this location is in tension. Figure 3 shows the load ring with the strain gages mounted in their places with gages R_1 and R_3 in compression and gages R_2 and R_4 in tension when the ring is loaded as shown. Figure 4 shows the electrical connections of the ring of Figure 3.

As previously indicated each ring was designed to carry 800 pounds. The rings were short lengths of standard weight black pipe. Baumeister and Marks (2) specify that the minimum strength of standard weight pipe is 45,000 pounds per square inch. Thus the rings were selected such that at 800 pounds the critical section of the rings approached the allowable stress.

With reference to Figure 5, the stress at section $A_1 - A_2$ is approximated by (6),

$$(2)\ \sigma_A = 1/2\ \frac{P}{a} + \frac{M_A}{aR}\left(1 + \frac{1}{Z}\left[\frac{y}{R+y}\right]\right)$$

and the stress at section $B_1 - B_2$ is approximated by,

$$(3)\ \sigma_B = \frac{2M_A + PR}{2aR}\left(1 + \frac{1}{Z}\left[\frac{y}{R+y}\right]\right)$$

Where σ = stress

P = load

a = cross sectional area of the ring

R = mean radius of the ring

y = distance from the center of the section to the point in which the stress is desired

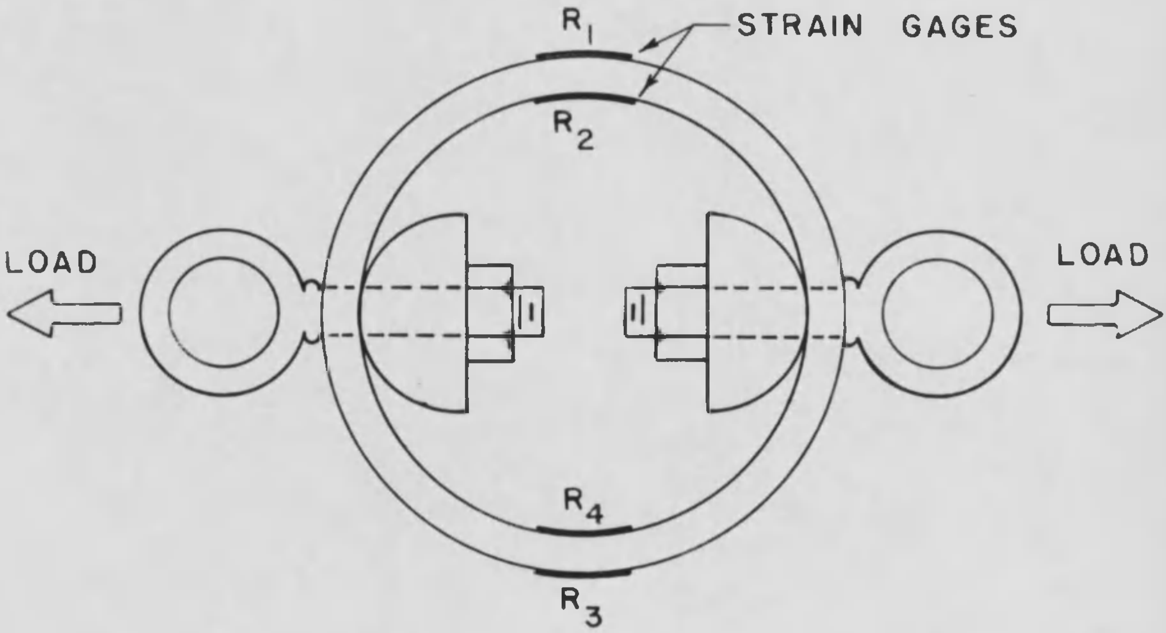

Figure 3. Load ring showing the location of strain gages and direction of load.

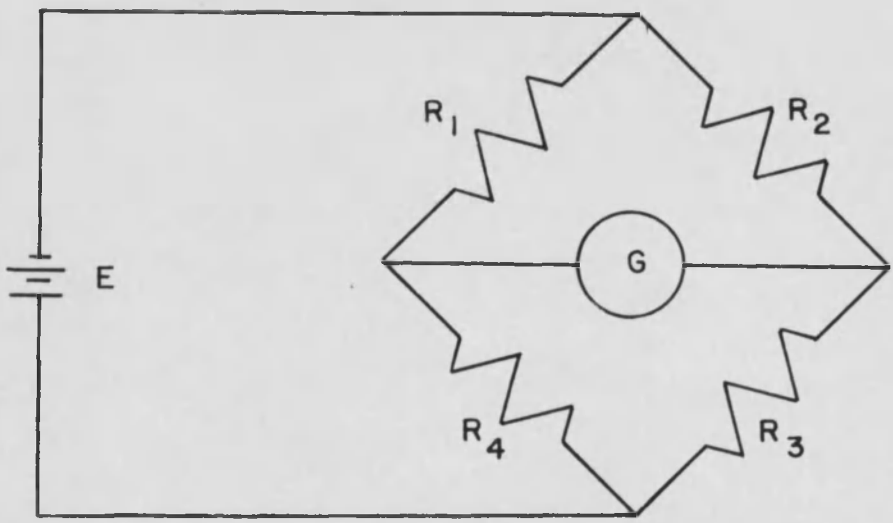

Figure 4. Location of strain gages in bridge circuit with reference to Figure 3.

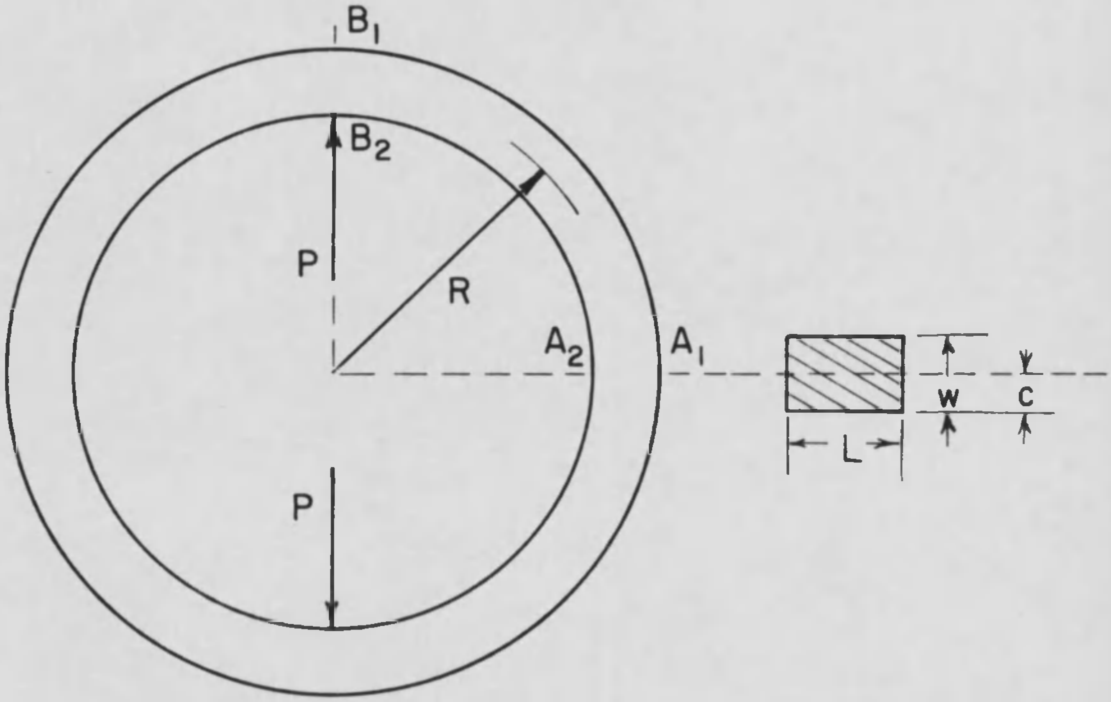

Figure 5. Loading of a ring, for stress calculation at sections A_1-A_2 and B_1-B_2.

Z = influence due to curvature

M_A = bending moment

and M_A is defined as follows,

$$(4) \quad M_A = 1/2 \; PR \left(\frac{2}{\pi} - 1 \right)$$

and Z is defined as follows,

$$(5) \quad Z = 1/3 \; (C/R)^2 + 1/5 \; (C/R)^4 + 1/7 (C/R)^6 + \text{---}$$

and C is defined as half the thickness of the ring.

Appendix A contains the design calculations for the rings selected. The stresses at section $B_1 - B_2$ are larger than those at Section $A_1 - A_2$, therefore section $B_1 - B_2$ is the critical section of the ring and governs the ring size. Sections of standard 5-inch diameter black pipe 2 inches long with wall thickness of .258 inches were selected for the load rings. This resulted in a maximum stress section $B_1 - B_2$ of 42,000 pounds per square inch compared to the 45,000 pounds per square inch allowable stress.

Instrumentation

As previously mentioned, the current is a function of the resistance of the bridge circuitry. As the bridge resistance, R_1, changes, the current I_g, from equation 1, changes. To measure the current I_g, a Sanborn model 321 oscillograph recorder was used. This recorder has a 5 millisecond delay from excitation of the bridge to signal which is more than adequate to meet the time requirements for this study. The recorder is designed for use with a transducer having an equivalent resistance between 100 and 5000 ohms. The strain gages selected have a resistance of 1000 ohms and a gage factor of 3.41. The equivalent resistance of each ring electrically connected as in Figure 4 is 1000 ohms and when the rings are all connected in parallel in the completed unit, the equivalent resistance is 250 ohms. Figure 6 shows the wiring diagram for the rings all electrically connected.

Scale Construction

Measurements of typical animals were necessary to correctly dimension the scale. Design criteria allowed for one animal entirely on the scale at a time and restricted the animal from turning around on the scale. The dimension for width was taken from a large Hereford bull and the dimension for length was taken from a cow weighing approximately 900 pounds. The width of the scale was dimensioned for a bull because he must be able to cross the scale. The cow was walked through sand and a measurement was taken from the cow's hind feet past her front feet two steps. From this measurement the length of the scale was selected to be 90 inches. The width of the bull was measured as 36 inches and the width of the scale was selected to be 42 inches.

The material used in the construction of the platform and supporting structure was selected to give adequate self-supporting strength. This was necessary because the scale

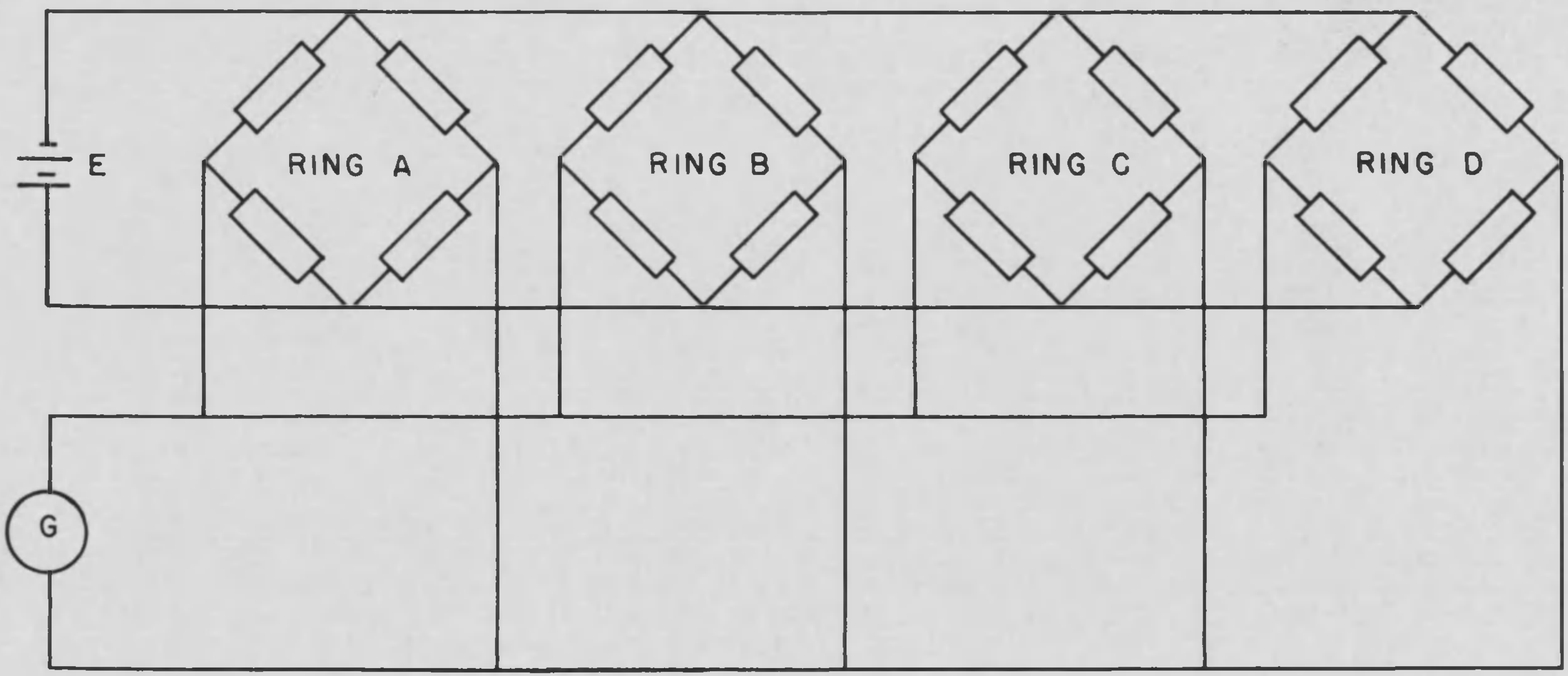

Figure 6. Wiring diagram for the four load rings.

was to be moved at least twice. The supporting structure was constructed from 6-inch channel iron and 3-inch I-beam. The platform was constructed from angle iron and 2-inch by 8-inch wood planks. The platform rests on the supporting structure when the load rings are not in place. Hooks located on the platform and supporting structure permit the load rings to be easily inserted thus raising the platform off the supporting structure. Figure 7 shows the load rings and hooks on the scale. Figure 8 shows the completed scale with the load rings in place. Lateral movement of the platform is restricted by four links attached to the platform and supporting structure as shown in Figure 9. They allow sufficient vertical movement of the platform by no horizontal movement.

Figure 7. A load ring and hooks on the platform and supporting structure.

Figure 8. The complete assembled scale.

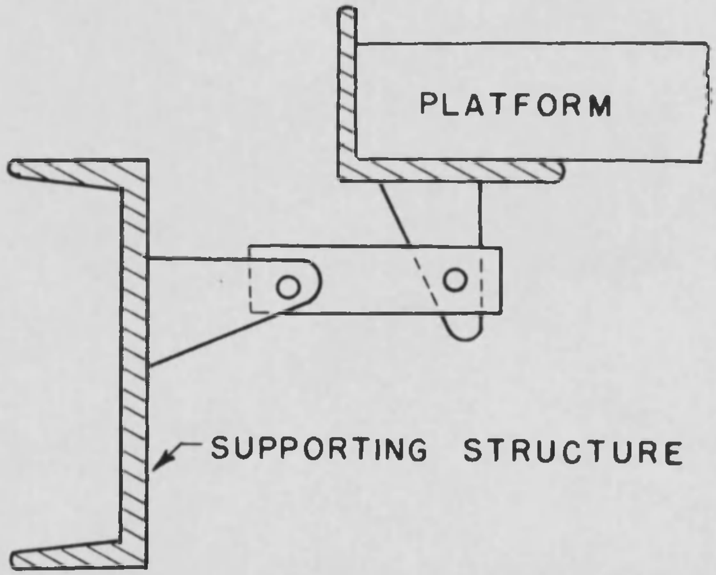

Figure 9. Method used to restrict any lateral movement of the platform.

CALIBRATION

General Discussion

It is necessary for the sensitivity of the load rings to be as nearly the same as possible. This will allow a given load to be applied at any location on the scale platform and result in the same signal output. Sensitivity of a transducer is defined as the number of microvolts of signal output from the transducer per volt of excitation signal to the transducer per unit load applied to the transducer.

The calibration circuit for the instrument used inserts a 40 microvolt per volt signal in series with the transducer. The writing arm of the instrument can be adjusted to some number of divisions of deflection in response to this signal. This number of divisions deflection is referred to as calibration divisions. It then requires, when the transducer is in use, 40 microvolts per volt to give a deflection equal to the number of calibration divisions. To obtain the output in microvolts per volt for a given load and a given number of divisions of writing arm deflection, the following formula is used:

$$(6) \quad T.O. = \frac{Cal. V. \times Div.}{Cal. Defl.}$$

Where T. O. = Transducer output in microvolts per volt for a load

Cal. V. = calibration voltage

Cal. Defl. = number of calibration divisions

Div. = number of writing arm divisions deflection for the load

Individual Load Rings

For identification purposes the rings were labeled A, B, C and D. Each ring was connected to a hydraulic press and a 500 pound dynamometer. Figure 10 illustrates the calibration equipment used. The hydraulic press was used to load the rings in 100 pound increments to 400 pounds and unload in the same manner. An oscillograph record was made of the loading of each ring. The oscillograph record was load in terms of the number of writing arm divisions deflection. It is then necessary to convert to microvolts per volt by equation 6. The number of calibration lines for all four rings was 30.5 lines. This specified number of calibration divisions was determined by loading the rings and adjusting the writing arm to give approximately 5 pounds per line, thus permitting easier interpretation of the oscillograph traces. Graphs of microvolts per volt versus load were plotted from the data. The equation for each curve was determined by a least-square analysis (8). The

Figure 10. Equipment used for the calibration of the load rings.

slope of each curve is the transducer sensitivity of the load ring and the units are in microvolts per volt per pound. The transducer sensitivity of each ring was compared with the other rings. The load ring with the greater sensitivity was used as the control. The transducer sensitivity of the other rings was increased by shaving off from the length of each ring in a lathe in approximately .003-inch increments. A sensitivity change was noticeable with this slight change in length. The procedure of loading each ring, comparing sensitivities and correcting was repeated until all four rings had as near the same sensitivity as achievable by this method. The final sensitivity of each ring is shown in Figure 11.

The four load rings were then electrically connected, illustrated in Figure 6, as they would be on the scale and each ring individually loaded with the hydraulic press. All four rings become part of one transducer and variation in transducer sensitivity as influenced by each individual ring was investigated. The number of calibration divisions was 35.5 lines, which, when the transducer was in use, gave approximately 20 pounds per line of writing arm deflection. Equation 6 was used to convert to microvolts per volt. Curves of microvolts per volt versus load were plotted and equations obtained. Figure 12 shows the curves and variability in transducer sensitivity as affected by each load ring.

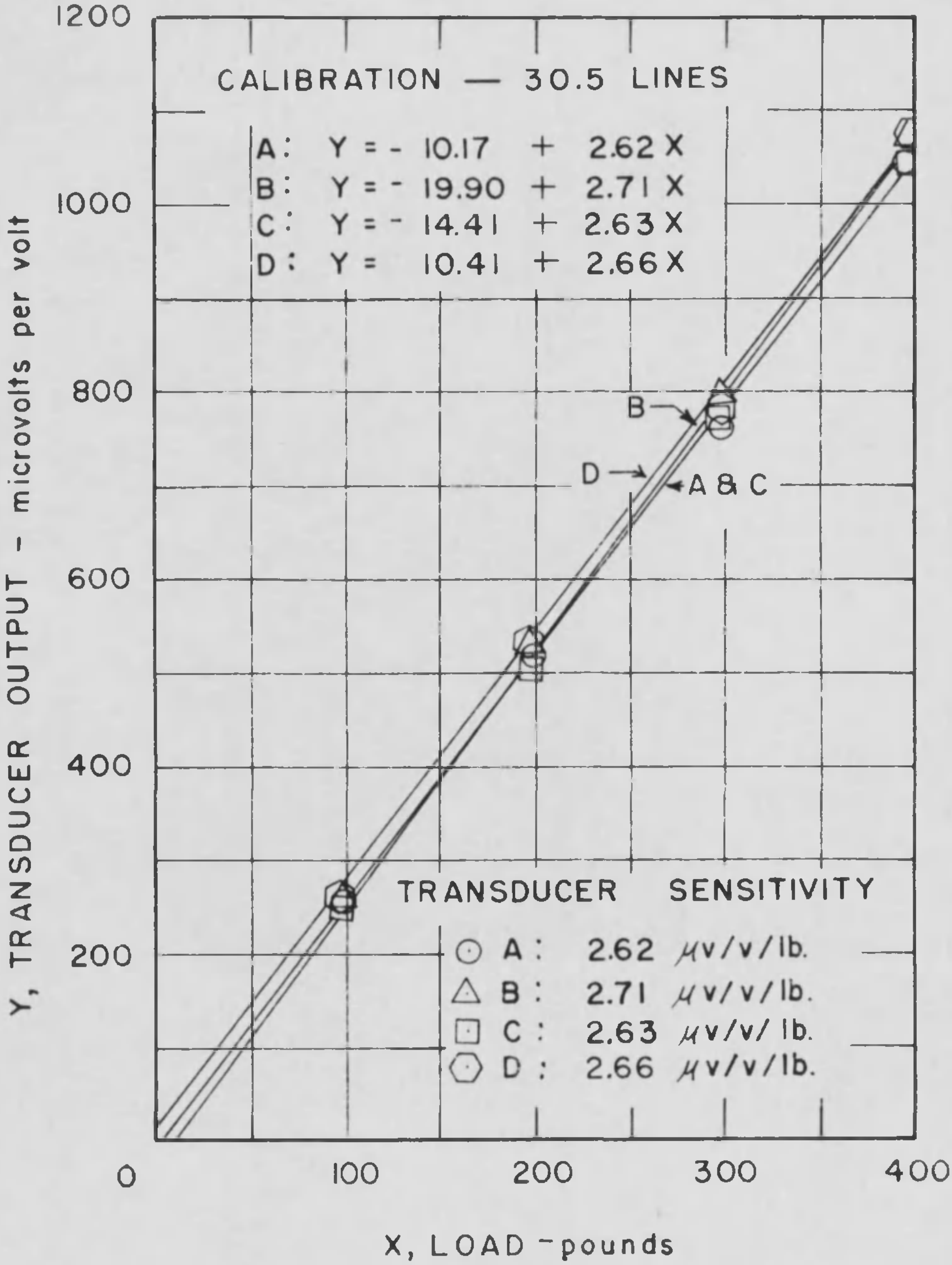

Figure 11. Output versus load for each individual load ring.

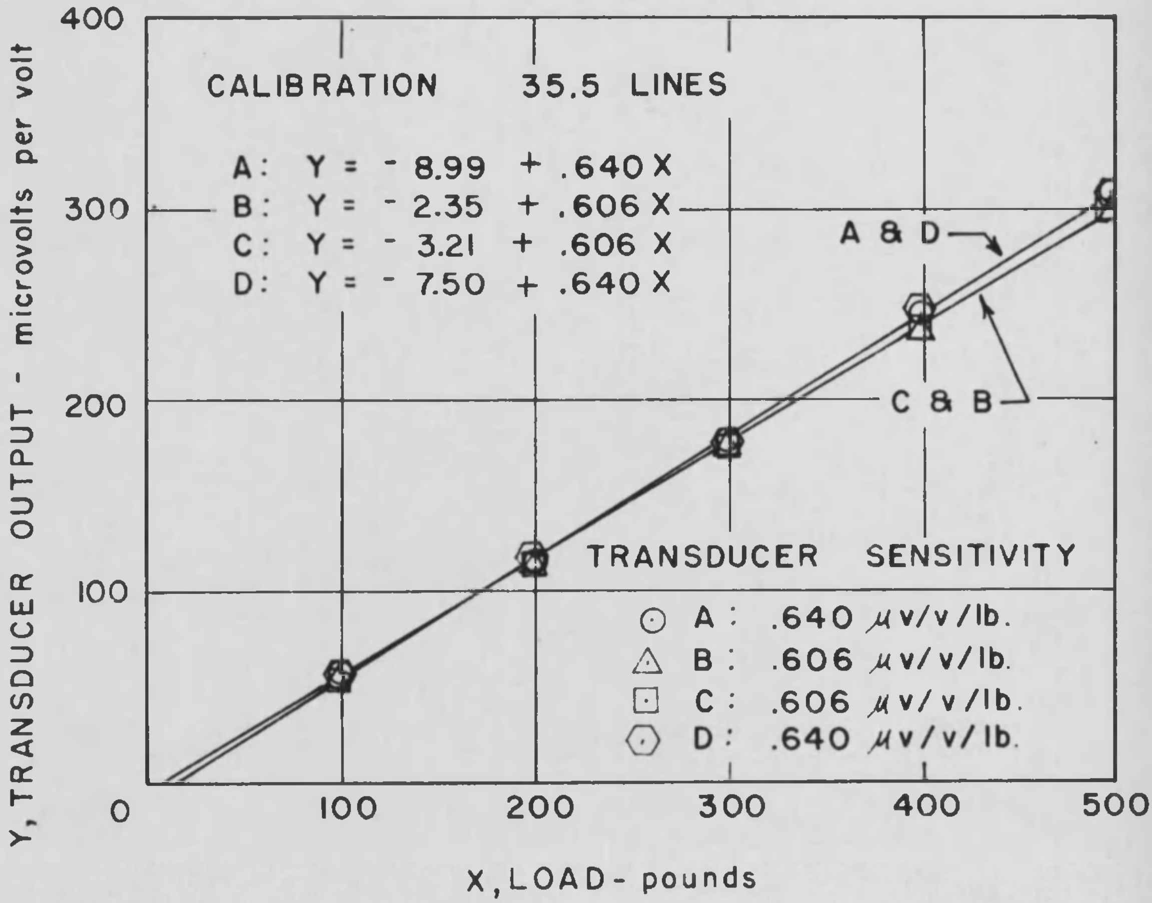

Figure 12. Output versus load for all load rings electrically connected but individually loaded.

With the four load rings connected in parallel as in Figure 6, the equivalent transducer resistance is one-fourth of the equivalent resistance of one ring. Therefore, when load is applied to a four-ring transducer, the sensitivity may be expected to be about one-fourth that of the rings operated as individual bridges. This relationship is born out by the relationship between the sensitivities shown in Figures 11 and 12.

Completed Scale

The scale was installed at the Campbell Avenue Farm of the University of Arizona for calibration. After the rings were individually calibrated, they were inserted on the scale. Fifty pound sand bags were used to dead load the scale in increments to 900 pounds. From this, the transducer sensitivity of the scale and load rings as a unit was obtained. The method used was as previously used and it was necessary, by equation 6, to convert to microvolts per volt. The number of calibration lines was again set for 35.5 lines. Figure 13 is the graph of signal output versus load for the completed scale.

The scale was then dead loaded with the sand bags at each corner to obtain the variability of the transducer sensitivity for the scale as influenced by each ring. Figure 14 shows the curves of signal output versus load for each

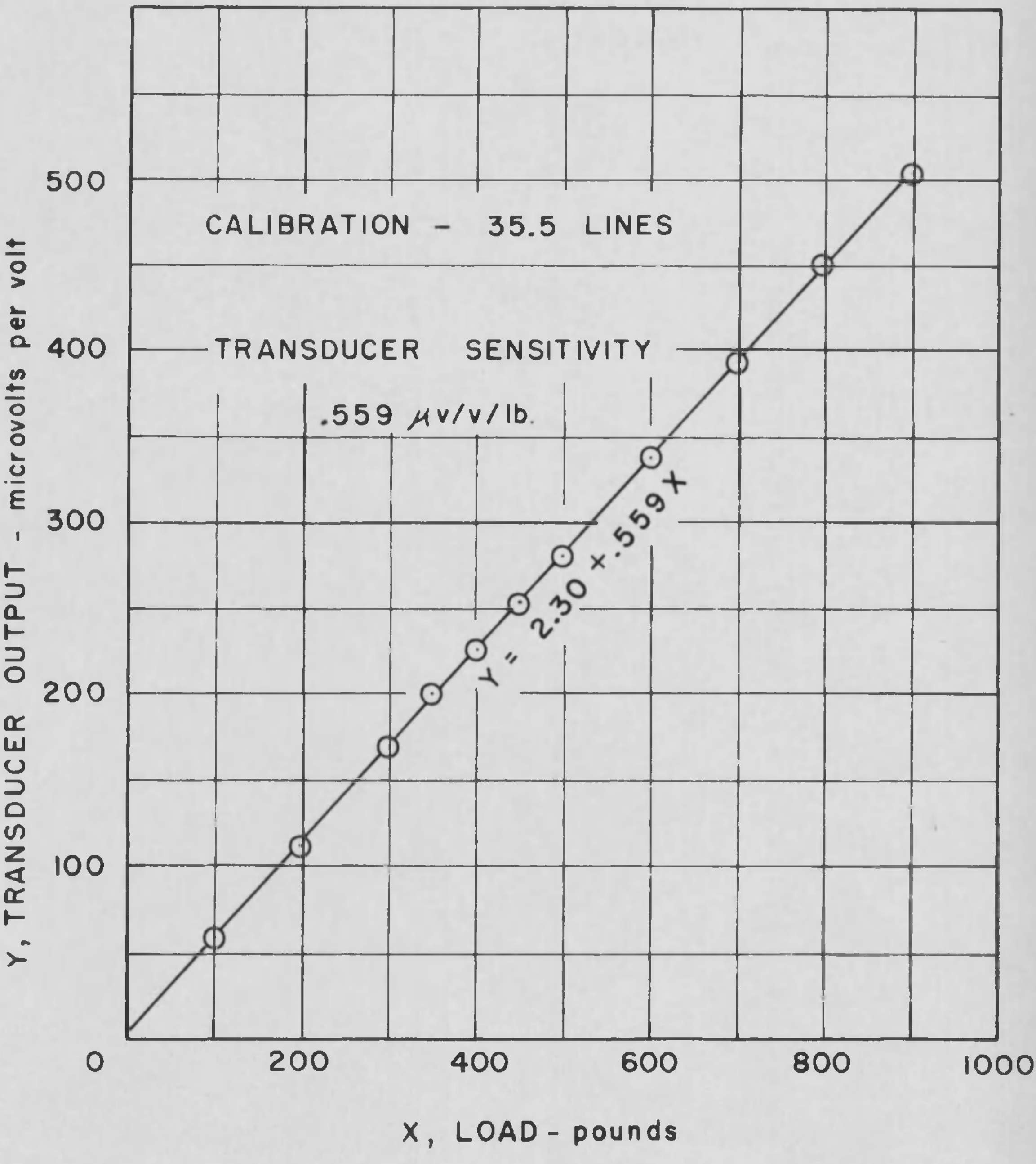

Figure 13. Output versus load for the complete scale.

corner in which the load was applied. The various slopes of the curves for each corner illustrates how the transducer sensitivity of the scale changes with load location.

The variability of the transducer sensitivity, as influenced by the individual load rings, Figure 12, is 2.73 percent from the mean of the four transducer sensitivities. For Figure 14, where the scale was loaded at each corner, the maximum variability of the transducer sensitivity was 1.54 percent from the mean. Thus it is seen that the variation in sensitivity among the load rings is not as serious when they are loaded through the scale platform as it is when they are directly individually loaded. This is largely because it is impossible to cause one ring to carry the entire load when loading through the platform.

Steers of known weight were then led across the scale to observe the oscillograph traces that would be obtained with live loads. Figure 15 shows the type of graph obtained for a steer as it crossed the scale. The true weight of the steer is indicated where it stood still on the scale. Figure 16 shows the record of weight of two more steers. Their walking and standing oscillograph traces are overlaid to show that by averaging the peaks from the oscillograph traces adequate interpretation of weight is obtained.

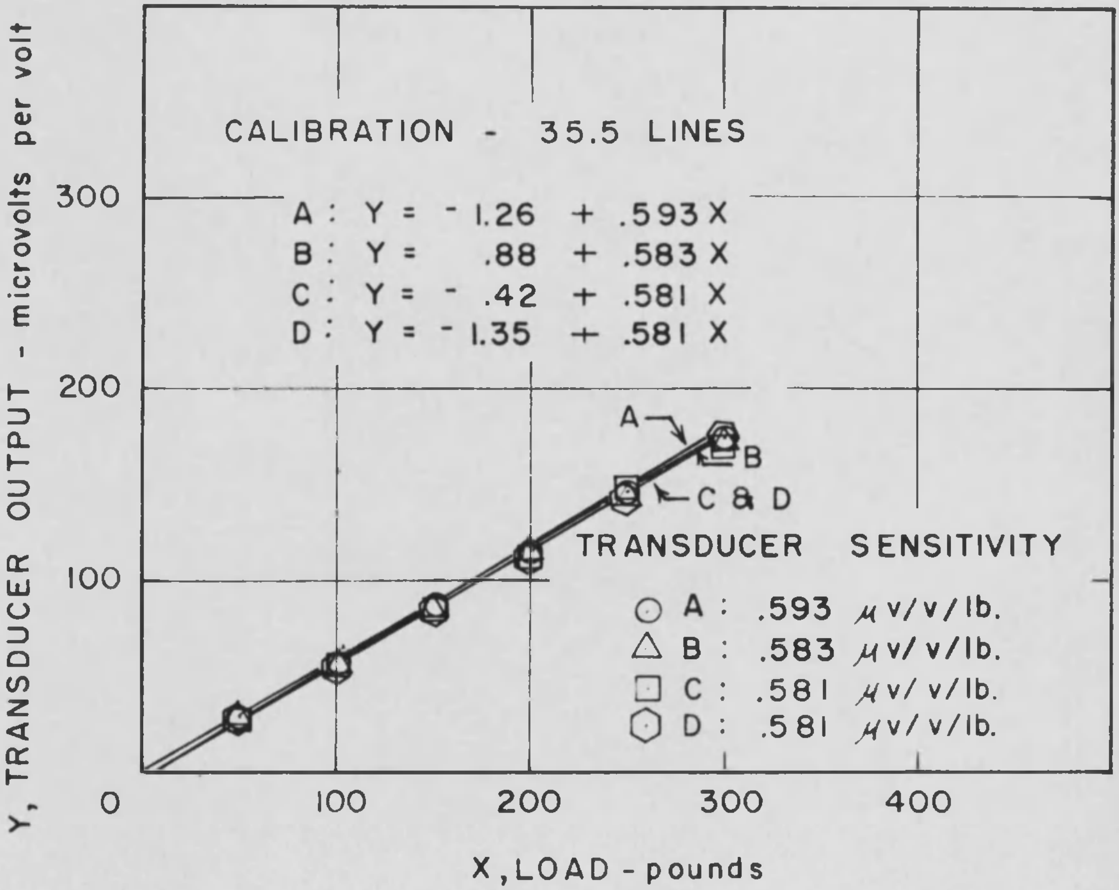

Figure 14. Output versus load for individual corner loading.

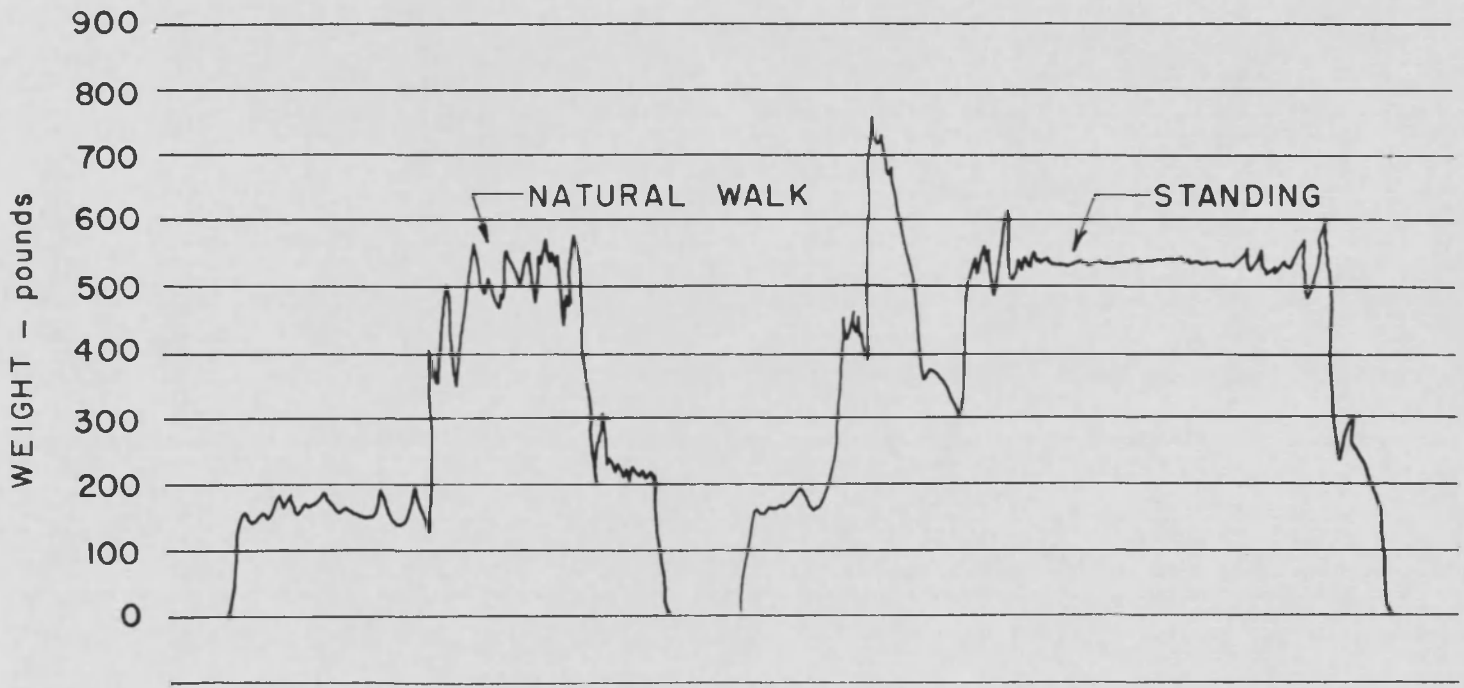

Figure 15. A reproduction of oscillograph traces taken as animals were led across the scale during calibration.

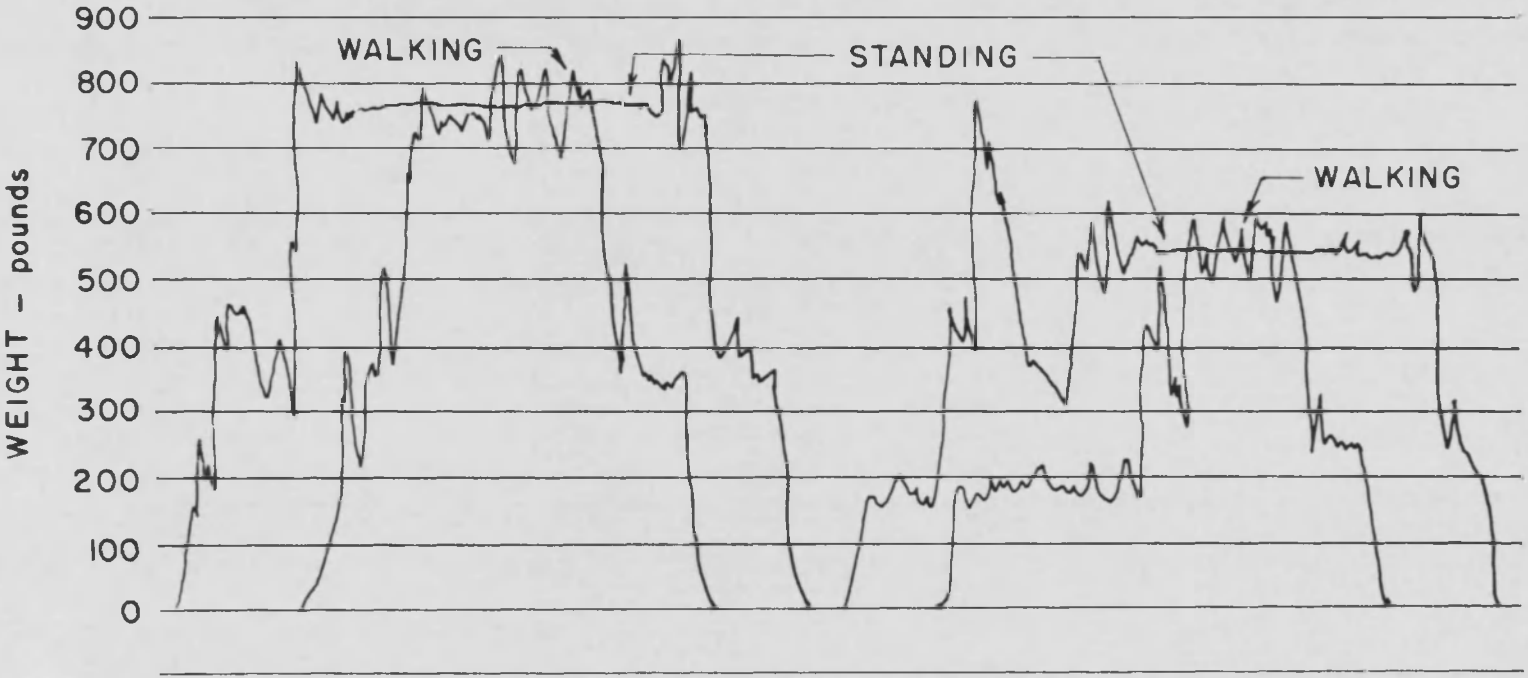

Figure 16. Oscillograph traces taken from walking and standing animals, overlaid to demonstrate how charts can be interpreted.

During calibration, it was observed that sunlight hitting the load rings caused considerable drift of the zero load line on the oscillograph. By shading the load rings, this effect was eliminated.

FIELD EVALUATION

Field Procedures

After calibration, the scale was moved to the Santa Rita Experimental Range south of Tucson. The experimental range, operated by The United States Department of Agriculture for research purposes, is divided into individual fenced pastures. For each two pastures one watering source is available and the fence straddles the watering tank as shown in Figure 17. To insure that all the animals in a given pasture are weighed, the watering area was fenced off with access and exit through one-way gates. The cattle get to water through an approach alley in which the scale was installed. Figure 18 shows the scale being assembled at Santa Rita. After the cattle cross the scale, they go through a one-way gate and have access to the water tank. When they leave the watering area through the other one-way gate, they cannot return without crossing the scale again.

A chute was constructed to confine the animals to the scale. Figure 19 shows the construction of the chute and one-way gates.

The load rings were completely covered so that no sunlight could reach them as shown in Figures 20 and 21.

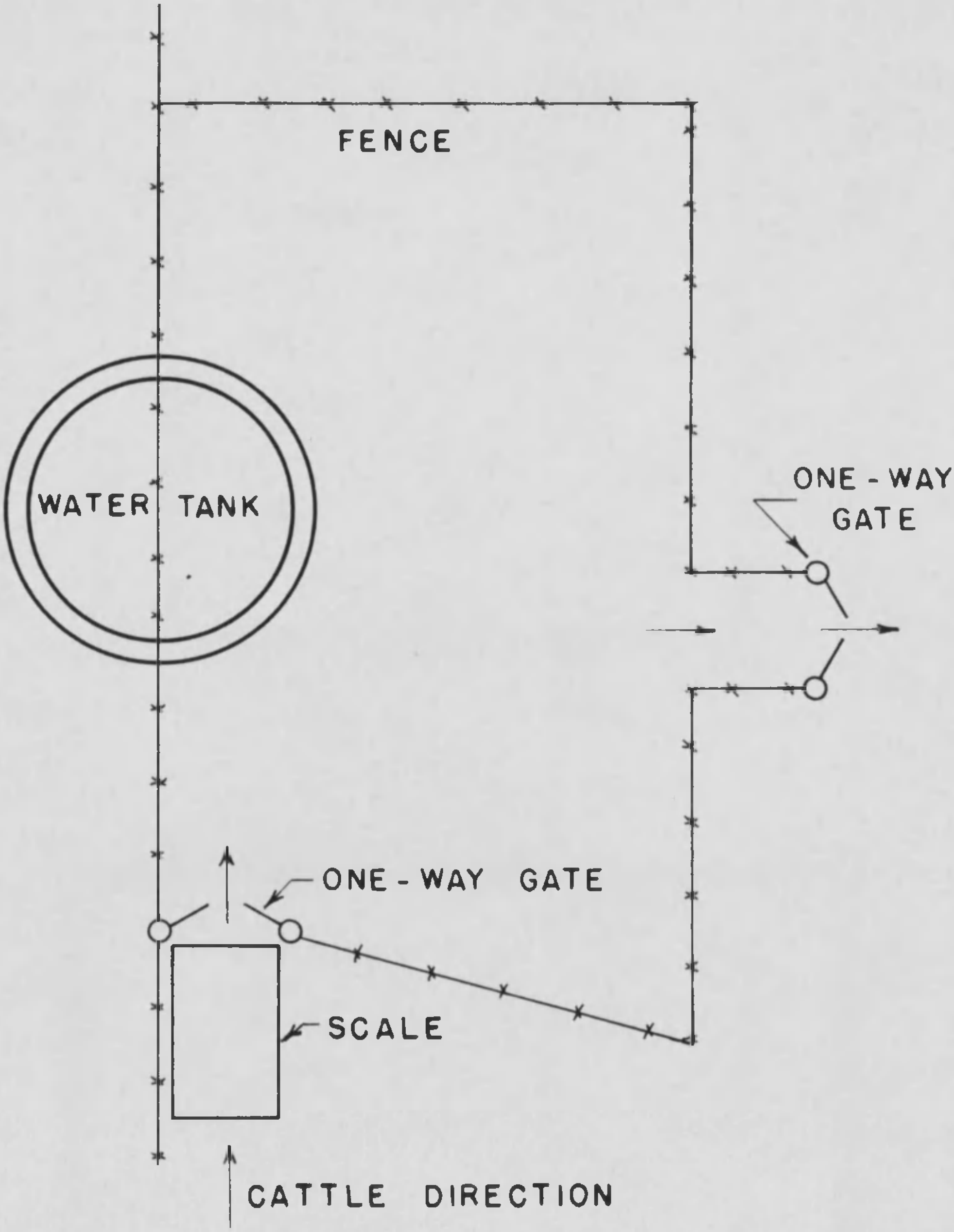

Figure 17. Plan view of scale site at Santa Rita Experimental Range.

Figure 18. Assembling of the scale at Santa Rita Experimental Range.

Figure 19. Completed scale assembly and one-way gate at Santa Rita Experimental Range.

Figure 20. Shade boxes for load rings, open for insertion and removal of load rings at Santa Rita Experimental Range.

Figure 21. Shade Boxes for load rings, closed when scale is in use at Santa Rita Experimental Range.

The scale platform was covered with about one inch of soil so that the cows would not hesitate to cross the scale because of the wood floor. After several days the soil was removed. For several days thereafter no attempt was made to weigh the cattle until they became conditioned to the scale platform and crossed naturally. The load rings were then inserted and readings started. The recorder was placed in a pickup truck approximately 50 feet from the scale to prevent scaring the animals.

Experimental Results

When the weighing of the cattle was first attempted, some of the animals were still hesitant to cross the scale. When these animals did cross, the charts obtained were sometimes uninterpretable because the animal ran across the scale. A longer conditioning period seems to be required for some animals.

For most animals, interpretable charts were obtained. The oscillograph traces were comparable to those obtained from the calibration studies. Figure 22 shows a cow crossing the scale. Figure 23 is a reproduction of a chart obtained of three animals crossing the scale at Santa Rita Experimental Range. The first and third weights are of cows and the middle weight is of a calf. The first cow's weight would

Figure 22. A cow crossing the scale at Santa Rita Experimental Range.

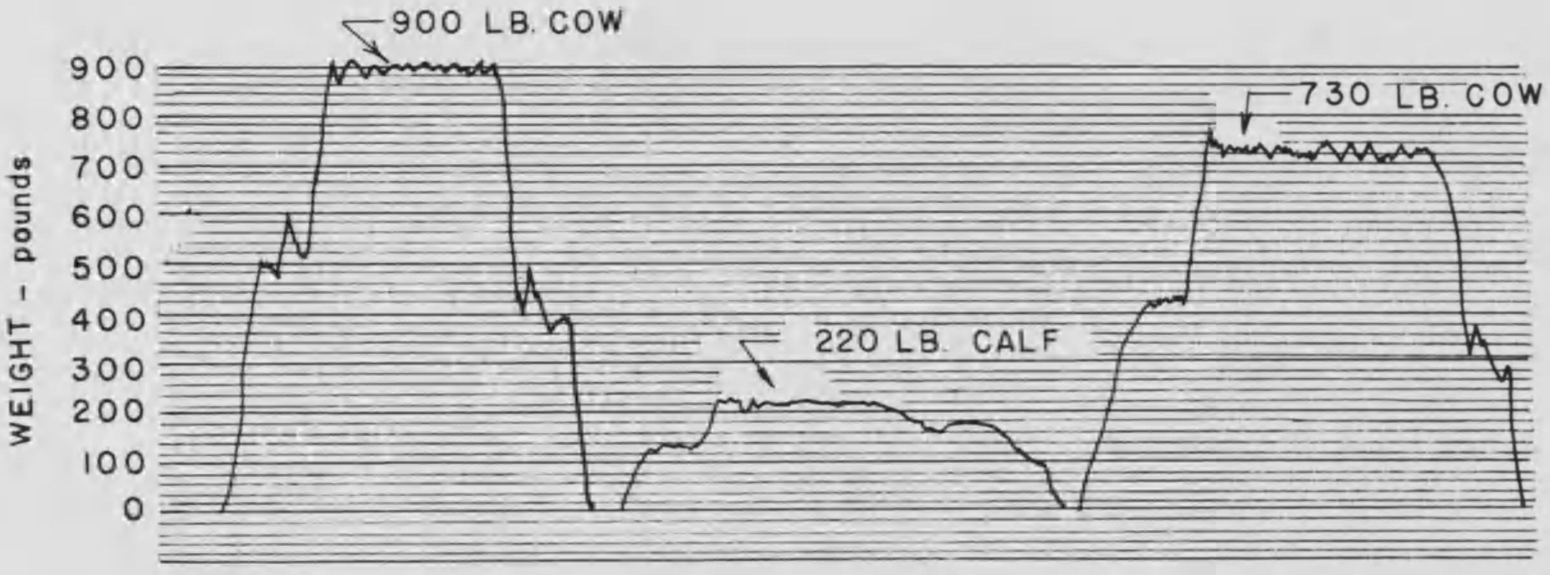

Figure 23. Oscillograph traces obtained as two cows and a calf each crossed the scale.

be read as 900 pounds, the calf as 220 pounds and the third animal as 730 pounds. The cattle weighed in the field crossed the scale at a more leisurely walk than those cattle that were led across the scale during the calibration at the Campbell Avenue Farm. This can be seen by comparing Figure 22 with Figures 15 and 16. The peaks of the oscillograph traces of Figures 15 and 16 have a wider range than those from Figure 22.

Field Calibration

It was considered necessary to check the calibration of the scale because the scale had been moved since the original calibration and had been in use for a period of time. The field calibration was accomplished by using five people and some 20 pound weights. Various numbers of the individuals would walk across the scale with one, two or no weights. The individuals, with their respective additional weights, were weighed on a portable scale at the scale site.

The load that was measured by the load rings shall be load in terms of the original calibration. The applied load shall be the load as measured by the portable field scale. The mean percent difference between measured load, weight according to the original calibration, and the applied load, weight according to the portable field scale, was 2.10 percent with the range of differences from zero to 5.45 percent.

Figure 24 is a graph of measured load versus applied load. It is seen that the measured load is always heavier than the applied load. Because of this, the portable field scale and the scale used to weigh the sandbags used in calibrating the load rings on the scale were compared. Given loads were weighed on both scales to determine if any difference existed between the two scales. Both scales weighed given loads the same. This indicated that the load ring scale is weighing too heavy.

Two alternatives are possible to correct the heavy readings of the scale. The first would be to recalibrate the scale by dead loading it. The second would be to use Figure 24 as a calibration curve by taking measured loads and using Figure 24, obtain actual load. If the first alternative is used, it is recommended that a field calibration curve using live loads, such as was obtained in Figure 24 be obtained to insure correct interpretation of the oscillograph traces in terms of load.

Reasons for variation in difference between measured load and applied load, Figure 24, and the variation in transducer sensitivity comparisons of Figures 11, 12, 13 and 14 may be attributable to any of the following:

1. For calibration and use of the scale, the gain was set at 35.5 lines. The gain can only be positioned to the nearest half line. For any two weighing periods, where it is necessary to

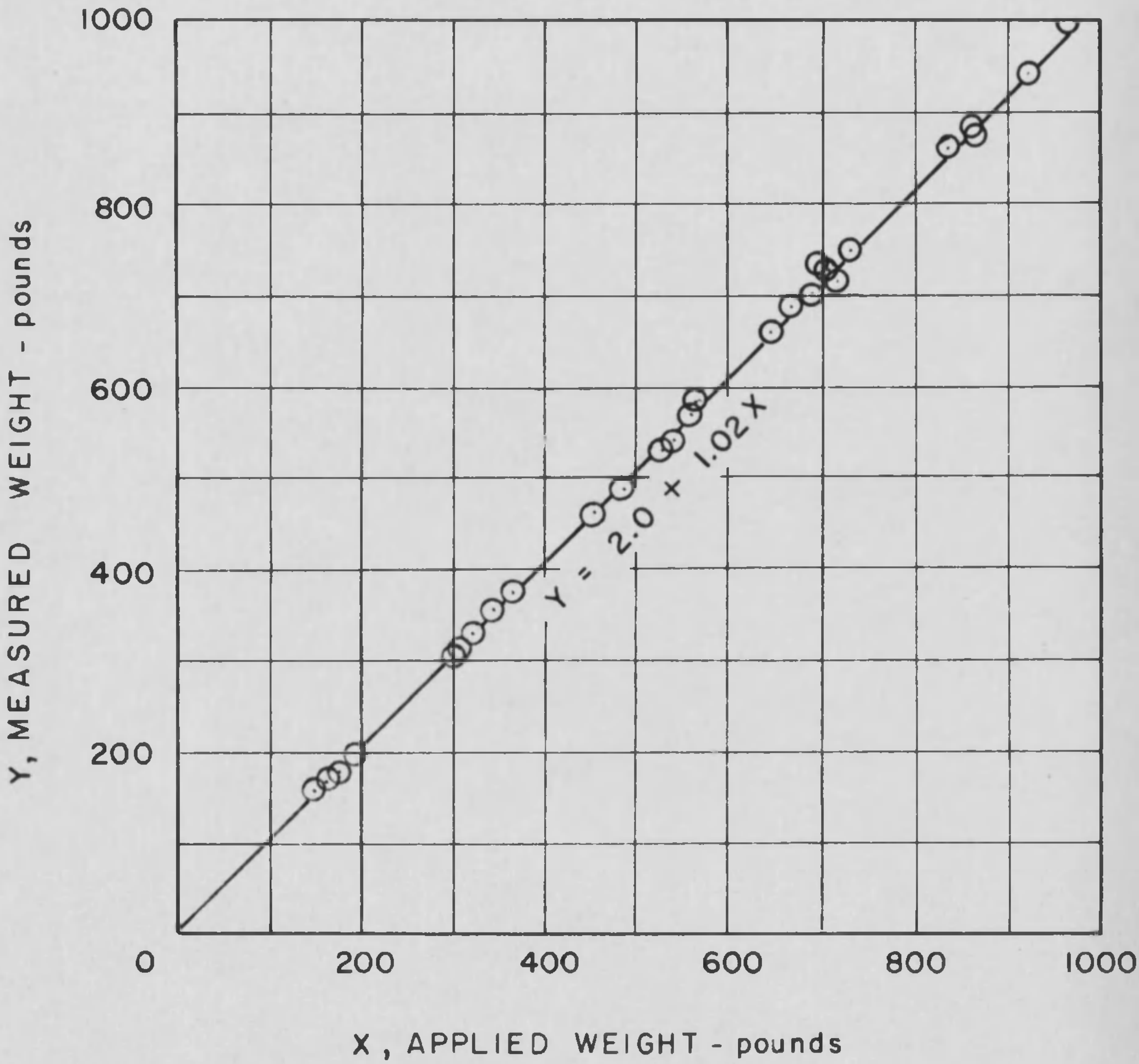

Figure 24. Measured weight versus applied weight.

adjust the gain, it is possible to have a 1.41 percent difference before any weights are obtained by not positioning the calibration divisions to the identical base position each time.

2. The interpretation of the oscillograph traces during use of the scale can only be read to the nearest 10 pounds because of the requirement of a full scale deflection of 900 pounds. For example, if 305 pounds were put on the scale to be weighed, the chart could be interpreted as 300 pounds or 310 pounds, with a decision as to whether the trace was closer to the 300 or 310 pound division. The same decision may not be made for two identical weights. For animals less than 200 pounds, the error could be greater than the specified 2.5 percent only because of the limitation of the chart.

CONCLUSIONS

General

The results demonstrate that by using load rings or an equivalent transducer and recording system, range cattle can be weighed without disturbing the normal routine of the animals. The weighing procedure does not require elaborate preparation. One person can insert the load rings and prepare the instrument for recording. It would be very convenient to know at approximately what time of day the animals came for water. Sufficient time could then be alloted to prepare the scale and the cattle could be weighed with a minimum waiting period.

Any relationship between measured weight and the true weight of range cattle was not investigated, other than by the original calibration, because of the inability to weigh the range cattle by some other method. It is reasonable to assume that the oscillograph traces can be interpreted for cattle with the same consistency as for the field calibration studies, as the oscillograph traces were simiiliar. Thus with a field calibration curve such as Figure 24, true weight can be obtained for range cattle.

Suggestions for Improvement

After completing the construction and instrumentation of the scale and observing the scale in use, the following suggestions for improvement are made.

1. The supporting structure could be constructed from lighter material. This would reduce cost and allow for easier handling.
2. A method of damping the scale oscillations would permit easier interpretation of the oscillograph traces. This could be accomplished by some mechanical means.
3. A method to momentarily stop the animal on the scale, while weighing, would eliminate the oscillating traces and weights would be obtained more accurately. However, this method must not disturb the animals.

APPENDIX A

Design calculations for ring selected.

5" Nominal pipe

5.563" Outside diameter

5.047" Inside diameter

.258" Thickness = w

Variables as defined in text and Figure 5.

$$R = \frac{5.563 + 5.047}{4} = 2.65 \text{ inches}$$

$$C = \frac{.258}{2} = .129 \text{ inches}$$

$$C/R = .129/2.65 = .0488$$

$$Z = 1/3\ (C/R)^2 + 1/5\ (C/R)^4 = .00079$$

$$1/Z = 1265$$

$$M_A = 1/2\ PR \left(\frac{2}{\pi} - 1 \right)$$

$$= 1/2\ P\ (2.65) \left[.636 - 1 \right] = -.482P$$

$$\sigma_A = 1/2\ \frac{P}{a} + \frac{M_A}{aR} \left(1 + \frac{1}{Z}\ \frac{y}{R+y} \right)$$

$$\sigma_{A_1} = \frac{P}{2(.258)} - \frac{.482\ P}{.258(2.65)\ (L)} \left[1 + 1265 \left(\frac{.129}{.129 + 2.65} \right) \right]$$

$$= 1.94\ P/L - .705\ P/L \left(1 + 58.4 \right)$$

$$= 1.94\ P/L - 41.6\ P/L = -39.6\ P/L$$

$$\sigma_{A_2} = 1.94\ P/L - .705\ P/L \left[1 + 1265 \left(\frac{-.129}{2.65 - .219} \right) \right]$$

$$= 1.94\ P/L - .705\ P/L\left[\ 1 - 64.7\ \right]$$

$$= 1.94\ P/L + 45.0\ P/L = 46.94\ P/L$$

$$\sigma_B = \frac{2M_A + PR}{aR}\left(\ 1 + \frac{1}{Z}\,\frac{y}{R+y}\ \right)$$

$$\sigma_{B_1} = \frac{-2(.482P) + 2.65P}{2(.258)\ (2.65)\ L}\left(\ 59.4\ \right)$$

$$\sigma_{B_2} = \frac{1.686\ P}{1.365\ L}\left(\ -63.7\ \right) = -78.7P/L$$

Load P of 800 pounds and length, L, of 2 inches.

$$\sigma_{A_1} = -39.66\ P/L = -39.66\ \left(\frac{800}{2}\right) = -15,900 \text{ psi.}$$

$$\sigma_{A_2} = 46.94\ P/L = 46.94\ \left(\frac{800}{2}\right) = 18,700 \text{ psi.}$$

Because of the .5 inch hole, the effective length, L, at section BB is 1.5 inches.

$$\sigma_{B_1} = 73.2\ P/L = 73.2\ \left(\frac{800}{1.5}\right) = 39,00 \text{ psi.}$$

$$\sigma_{B_2} = 78.7\ P/L = 78.7\ \left(\frac{800}{1.5}\right) = -42,000 \text{ psi.}$$

LIST OF REFERENCES

1. "Arizona Agriculture 1965", Arizona Cooperative Extension Service and Agricultural Experiment Station, Bulletin A-38.

2. Baumeister, T. and Marks, L. S., Mechanical Engineers Handbook, McGraw-Hill, New York, 6th. ed., 8-165, 1958.

3. Lane, A. M. and Stanley, E. B., "Cattle Feeding in Arizona", Arizona Agricultural Extension Service, Circular 131, November 1959.

4. Lee, G. H., An Introduction to Experimental Stress Analysis, John Wiley and Sons, Inc., New York, 6th printing, 1963.

5. Perry, C. C. and Lisner, H. R., The Strain Gage Primer, McGraw-Hill, New York, 1955.

6. Seely, F. B. and Smith, J. C., Advanced Mechanics of Materials, John Wiley and Sons, Inc., New York, 2nd edition, 7th printing; 177 - 183, 1962.

7. Stanley, E. B. and Rigden, J. T., "The Cattle Ranching Industry in Arizona", Arizona Agricultural Experiment Station, Mimio #54, March 1943.

8. Steel, R. G. D., and Torrie, J. H., Principals and Procedures of Statistics, McGraw-Hill, New York, 1960.

9. Stubblefield, T. M., Professor of Agricultural Economics, University of Arizona, Unpublished data.