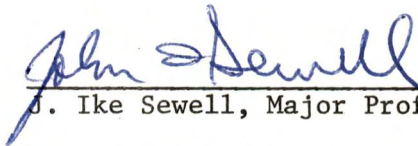
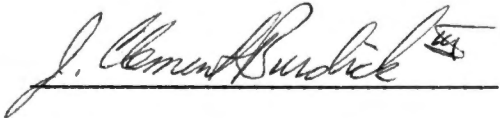


To the Graduate Council:

I am submitting herewith a thesis written by Gary Douglas Miller entitled "Comparative Study of Confinement Beef Finishing Systems During a Summer." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Engineering.


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COMPARATIVE STUDY OF CONFINEMENT BEEF FINISHING
SYSTEMS DURING A SUMMER

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee

Gary Douglas Miller

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ABSTRACT

A two-year study was conducted to evaluate the effects of temperature and pen floor types on the performance of beef cattle fed in a confined, slatted-floor facility in summer. Investigations were also made to develop waste management techniques for a liquid beef manure system and to determine Kjeldahl nitrogen and chemical oxygen demand for liquid beef waste.

During the summer months of 1973, temperatures were recorded in one pen to determine the environmental conditions to which cattle were subjected. During 1974, a comparative study was made among two pens of cattle on concrete slab floors, two pens of cattle on unfanned (natural ventilation) slatted-floors, and two pens of cattle on fanned slatted floors. Temperatures in each of the three pen types were recorded by thermocouples, and cattle performance was evaluated by measuring average daily gains and feed conversion efficiency. The cattle were also scored by University of Tennessee Animal Science Department personnel to determine the effects of temperatures and floor types upon soundness in the animals' knees.

Significant differences in temperatures were found between the three floor types (treatments). Fanning the cattle significantly increased average daily gains and efficiency in feed conversion. The Kjeldahl nitrogen content and chemical oxygen demand of liquid manure samples were comparable to other reported values. Agitation of pit contents by using compressed air was found acceptable.

Swelling in knees of the cattle was affected by treatment, but this did not appear to hinder cattle performance.

A distortion of one type of experimental aluminum slat was observed after more than one year's use. After testing new sections of slat, the distortion was found not to result from a single loading, but most probably to have been caused by repeated stresses.

TABLE OF CONTENTS

CHAPTER	PAGE
I. INTRODUCTION	1
Importance of Study	1
Objectives	3
II. REVIEW OF LITERATURE	5
Confinement Feeding of Beef	5
Animal Waste Characteristics	14
Disposal of Manure on Land	21
III. RESEARCH METHODS AND FACILITIES	27
IV. RESULTS AND DISCUSSION	35
Temperatures and Their Effect on Cattle	35
Slatted Floors and Waste Management	42
Slat Strength	48
V. SUMMARY AND CONCLUSIONS	53
Summary	53
Conclusions	54
Recommendations for Further Study	55
BIBLIOGRAPHY	57
APPENDIXES	66
Appendix A	67
Appendix B	68
Appendix C	69
Appendix D	70
VITA	71

LIST OF TABLES

TABLE	PAGE
1. Mean Temperature for Fanned and Unfanned Slat Pens	37
2. Mean Temperature for Fanned Slat and Unfanned Slab Pens . .	38
3. Mean Scores for Knees of Cattle in Summer of 1974	41
4. Kjeldahl Nitrogen Concentrations and Chemical Oxygen Demands of Liquid Beef Waste	49
5. Mean Temperatures for 1973 Summer Period	67
6. Analysis of Variance for 1974 Summer Temperatures for an Eleven-Day Period	68
7. Beef Cattle Performance Data Summary for 1974 Summer Tests .	69
8. Analysis of Variance of Average Daily Gains for Summer of 1974	70

LIST OF FIGURES

FIGURE	PAGE
1. Layout of Alcoa Barn No. 4	28
2. Experimental Aluminum Slat Designs (Type I on the Left and Type II on the Right) Used in Some Pens of Alcoa Barn No. 4	30
3. Hygrothermograph Location in Pens	33
4. Storage of Manure Scraped from Slabs	43
5. Concrete Slab Pens One Day After Scraping	45
6. Vacuum Tank Spreading Liquid Manure on Field	47
7. Type II Slat Section Showing Deformation After Use	50
8. Deflection and Spread Under Load for Type II Slat	52

LIST OF FIGURES

FIGURE	PAGE
1. Layout of Alcoa Barn No. 4	28
2. Experimental Aluminum Slat Designs (Type I on the Left and Type II on the Right) Used in Some Pens of Alcoa Barn No. 4	30
3. Hygrothermograph Location in Pens	33
4. Storage of Manure Scraped from Slabs	43
5. Concrete Slab Pens One Day After Scraping	45
6. Vacuum Tank Spreading Liquid Manure on Field	47
7. Type II Slat Section Showing Deformation After Use	50
8. Deflection and Spread Under Load for Type II Slat	52

CHAPTER I

INTRODUCTION

I. IMPORTANCE OF STUDY

Ever increasing demands of the world's population on food production facilities have forced modern agriculture to expand and intensify its production practices. Trends continue toward increased herd sizes, confined housing and feeding of animals, and use of concrete lots and hydraulic removal of animal wastes to reduce labor. As a result, in many cases large quantities of lot runoff containing heavy concentrations of animal wastes flowing from small areas must be managed. Meeting current public demands for improved environmental conditions can make this task difficult. Manure disposal from animal confinement operations is complex and demands close supervision.

Management of livestock waste may be separated into four functions: collection, storage, treatment and utilization, and disposal. With current U.S. livestock manure production exceeding 1.5 billion tons per year (Wadleigh, 1968) and as much as 50 percent of this from confinement production (Law and Bernard, 1970), the potential for pollution is an area of intense concern.

The encroachment of urban sprawl into traditionally farm areas has resulted in an influx of people who often do not appreciate the usual farm odors. This results in a rising concern about the

use of some customary waste disposal methods. The solution of such problems could require waste management techniques which incorporate waste utilization and disposal into the total farm management concept in order to save labor, prevent lawsuits, and make proper use of farm resources.

Commercial feedlots are continually coming under tighter restrictions related to enterprise management. Many are required to file plans for controlling runoff from feeding areas for disposal of waste removed from feedlots, and where and when this waste will be applied to land. The legislatures of some Midwestern states have passed laws prohibiting the spreading of livestock wastes on frozen ground, thus making disposal of wastes very difficult during certain seasons. In other areas of the country, such as the Southeast, disposal of wastes is limited by soil trafficability. Even if equipment can get into the fields to spread the wastes, then a strong possibility exists that high runoff rates of water containing waste may still enter streams. Such conditions have, in some areas, led to development and use of covered beef feeding facilities in which storage capacity for several months' manure production is provided.

Significant advances in liquid manure handling systems are taking place with these new systems being, in many respects, more nearly environmentally and economically compatible with society's current requirements. For Tennessee, the possibility of the slatted floor system for beef finishing offers promise. With increasing difficulties in obtaining labor and higher wages imminent, alternatives

to periodic lot scraping and manure hauling are needed to help keep the cost for manure collection and disposal at a minimum while not endangering the environment. The high labor cost for managing waste from feedlots and the additional requirement for timeliness of operations tend to offset the additional fixed cost of the slatted floor system thus suggesting definite possibilities for such systems in Tennessee and other Southeastern states.

II. OBJECTIVES

Because of the relatively new concept of slatted floor feeding of beef cattle, management of such facilities has mostly been on a trial basis. The effects of temperature and humidity on cattle raised in these new facilities have been investigated to a limited extent, especially in the warmer and more humid areas of the Southeast. Further development of waste management techniques for facilities near urban residential areas is needed to preserve harmony between home owners and farm operators while allowing land disposal of wastes for full utilization of the manure.

The specific objectives of this research effort follow:

1. From a study of a slatted-floor beef feeding facility at the University of Tennessee Alcoa Barn No. 4, develop waste management techniques for collecting, storing, and disposing of liquid beef manure stored in a pit beneath slatted floors.

2. Determine possible detrimental effects of temperature and humidity on beef cattle confined on slatted floors.

3. Chemically analyze the liquid manure for fertilizer value and pollutional strength.

CHAPTER II

REVIEW OF LITERATURE

I. CONFINEMENT FEEDING OF BEEF

In the last century, the beef feeding industry has undergone remarkable changes, from raising cattle for slaughter on the open range to confining cattle in metal buildings on slatted floors over pits to collect the wastes. The changes to the new systems of today where thousands of cattle are confined on a small acreage have been gradual. Problems have resulted from these operations because society has been demanding higher environmental qualities and at the same time more beef. Though the two items may not be compatible, both can be obtained, but not without additional cost.

Major causes of problems are associated with waste management. Lawsuits brought by neighbors have resulted from a variety of reasons including noncompliance with zoning regulations, offensive odors resulting from decomposing manure on open lots, and surface water pollution caused by runoff transporting high amounts of organic matter (Willrich and Miner, 1971). Swanson et al. (1971) found that a moderate increase in rainfall intensity causes a much higher solids loss resulting in runoff containing 75 times the phosphorous content, up to 30 times the ammonia nitrogen content, and up to four times the nitrate nitrogen content of that runoff from areas excluding the feedlot. Manges et al. (1971) found feedlot runoff

and manure to be concentrated organic wastes high in nitrogenous compounds which must be prevented from entering streams. The pollution can also spread to underground water sources as Stewart et al. (1968) found the total organic carbon concentration under a feedlot to be five to ten times greater than that of groundwater under adjacent fields.

In order to protect the environment and the feedlot investor, a successful manure management scheme must be developed. Such a scheme generally includes a mechanism to quickly collect the manure, a system to transport the manure, storage facilities, treatment devices, and a disposal method. The livestock operation should be located away from residential areas and at least one-half mile from the nearest house. Feeding areas should be kept dry. The feedlot should be managed to prevent manure from collecting on the animals since manure on the warm bodies yields odors (Miner, 1970). Gilbertson (1970) proposed a set of requirements for an unpaved lot which included the major items as suggested in Miner. His recommendations included: (1) shaping an all weather feed alley; (2) reshaping topography to obtain good drainage; (3) diversion of outside runoff water; (4) providing an area for runoff control facility; and (5) providing an area for disposal of the controlled runoff and manure accumulations.

In heavy rainfall a significant amount of solids as well as liquids flow from the surfaces of feedlots (Gilbertson et al., 1971).⁷ Providing facilities to manage such runoff is expensive. Butchbaker et al. (1972) determined that when land costs reach \$800 per acre,

cold confinement barns with dirt floors become economical when compared with open lots allowing 400 square feet per head. In the Eastern United States where a moisture surplus condition exists, open feedlots would have more runoff and require larger pollution control facilities which would change the economic comparison between cold confinement housing and the open lot.

The development of confined housing is not new, and has been developed and used extensively in Europe. In the U.S., most beef confinement buildings are located in areas where family farms predominate, and they generally feed fewer than 1000 head. They are used in areas where, during certain periods of the year, extremely cold weather could affect the performance or health of the animals (Butchbaker et al., 1971). Butchbaker et al. (1972) felt that confinement feeding of beef in buildings offers better control of flow of wastes and offers advantages over open feedlots in humid areas and in cold areas. Gilbertson (1970) sees confined housing feeding becoming popular with more beef producers as labor shortages and pollution problems increase. In the foreseeable future, all animals might be raised in complete confinement (Moore and Brooker, 1970).

As confinement housing developed, so did ideas for managing wastes such that cattle would remain clean while the handling and removal of wastes would require minimal labor. The idea of raising cattle on a floor where the wastes would fall through cracks in the floor and into a holding pit was developed. Slatted floors have been used for cattle and sheep in Iceland for over a hundred years (Morris, 1963). The modern development of slatted floors resulted

from Norwegian sheep sheds built in about 1930 (Soutar, 1961). In Norway the first barns for cattle built with slatted floors were put into use in 1953, and the idea has spread to all of Europe (Morris, 1963). Slatted floors are now seen in America for a variety of uses in livestock and dairy production. The most popular uses have been with hog production, but they now have begun gaining favor in the beef and dairy production industries.

Moore et al. (1970) promote slatted floors as a way of meeting the demands of society for increased beef production while maintaining environmental protection. Jedele and Andrew (1972) found several advantages of slatted-floor feeding. Surface runoff of waste products is practically eliminated, therefore decreasing the chance of polluting streams. The need for bedding is eliminated and the fertilizer value is maintained, since the manure is protected from sun and rain. Less labor is needed to manage the manure, and the labor can be scheduled around heavy seasonal work loads. Manure exposure to conditions which favor fly production is reduced. Cattle are generally more docile and remain cleaner, often reducing health problems. Because of the cattle remaining indoors, the herdsmen do a better job especially in bad weather. Land requirements are lowered since 18-20 square feet per head have been shown as optimum levels. Baxter and Soutar (1964) considered 20 square feet per head optimum for 11-month old calves, and injuries were negligible; however, some cattle experience swollen knees. Levy et al. (1970) found cattle to have some swelling in the hocks, and later a few permanently swollen hocks, but these conditions had no influence on the rate of gain.

Although results have been variable, some operators have experienced better feeding efficiency for cattle raised on slatted floors than those on ground (Hall and McRoberts, 1968). Klosterman and Roller (1964) found no significant difference among cattle fed on slatted floors and those on ground, although differences in marbling score and quality grade were highly significant. Mahoney et al. (1972) found that cattle on slatted floors with shade and windbreak gained 0.07 pounds per day more than cattle on open lots. Environmental conditions seem to be the governing factors related to efficiency of feed conversion and rate of gain of the cattle.

Because with slatted floors the waste from the animal is separated from the living area of the animal almost as soon as it is excreted, a certain flexibility exists for waste treatment. As pointed out by Leohr (1969), no one process or waste management system will be adequate for all production units, but several more popular methods will be discussed. Mahoney et al. (1972) found slurry handling systems to be used primarily where slatted floor systems have been installed. Two major types prevailed: (1) deep pits for several months' storage and (2) shallow pits for a few days' storage. The few days' storage provided by shallow slurry systems has no advantage over daily scrape and haul systems as related to timeliness of labor scheduling and weather conditions which could prevent disposal in the fields.

Hensler et al. (1970) preferred that anaerobic liquid manure be stored in a concrete tank and spread on or knifed into the soil when conditions were suitable. In choosing this method, Hensler

placed a higher priority on controlling the pollution of surface water, total labor required, flexibility in time, and method of application, while he placed a lower priority on seasonal distribution of labor and investment cost.

After the manure has set for several months, considerable agitation is required to mix solids and liquids. Jedelev and Andrew (1972) found commercially available agitation equipment to effectively mix the contents of the tank. One disadvantage of anaerobic storage is the release of odors and dangerous gases upon agitation before removal. This could be dangerous to livestock and humans near the pit.

Aerated storage of animal waste has also been investigated. Loehr (1971) discussed two systems of oxidation ponds. The usual oxidation pond system includes shallow ponds with large surface areas which furnish the oxygen needed for aerobic degradation of the large quantities of organic matter in animal waste. This system offers potential where large areas of inexpensive land and water are available for use. The area of land needed can be reduced by using a mechanical agitation of the water to provide needed oxygen, but this also increases operating costs.

One of the most popular methods of aerobically treating waste is the oxidation ditch in which the wastes are agitated by paddles. Larson and Moore (1970) found oxidation ditch use to be limited to temporary odorless storage rather than complete treatment. Mahoney et al. (1972) found serious operating problems to be associated with the oxidation ditch. Vanderholm et al. (1974) found that high amounts

of dilution water were required for proper operation to prevent foaming. Jones et al. (1971) found ammonia in the building through the twelfth week of system operation.

Miner (1970) concluded that aerobic treatment of dairy and steer manure was the least desirable treatment with relatively high operating costs and reduced value of manure as fertilizer for corn because of low recovery of plant nutrients. Moore et al. (1970) found the advantages of the oxidation pond concept to be odor control, storage to prevent runoff, partial volume reduction of solids, reduction of the concentration of some plant nutrients, and reduction of pollution strength; however, effluent was still not suitable for discharge into streams. Vanderholm et al. (1974) found that the oxidation ditch, for successful operation, required a significant amount of day-to-day management in addition to routine rotor maintenance and final effluent disposal. The major disadvantage was the requirement for continuous equipment operation which made the oxidation ditch one of the more expensive systems for waste treatment.

The economics of confinement feeding of beef cattle is a topic of considerable discussion. The major disadvantage of confinement buildings is the high initial investment cost. The facility costs may, however, pay for themselves in terms of reduced labor requirements and increased performance of the animals. Also, the pollution potential is less for confinement buildings because the waste is entirely contained, and the possibility exists for controlled treatment, handling, and disposal of the waste.

Butchbaker et al. (1971), in discussing various waste handling systems for confinement buildings, found the solids handling system combined with a solid floor to have the least-cost if bedding costs were not included. The next least cost management system consisted of a cold confinement barn with a deep pit, and it utilized a liquid spreader without soil injection. If bedding costs of \$0.02 per animal day (these costs could be considerably higher) were added to the solid waste management system for solid-floor building, then its cost would be greater than the costs for the slurry handling system for the deep pit. In addition, bedding may be difficult to obtain in some localities, and the costs of handling the bedding must be considered. The problems of odors emitted from the deep pit can be controlled by use of an oxidation ditch, but not without additional cost.

Butchbaker et al. (1971) found the cost per animal per day for a wood frame building with a shed and deep pit to be \$0.0118 per pound of gain. Jones et al. (1971) found the operating cost of the oxidation ditch to be \$0.01 per pound of gain, thus almost doubling the operating cost of feeding cattle not including costs associated with the oxidation ditch since the building and slatted floors would still be needed. With today's electrical costs of \$0.03 to \$0.05 per kilowatt-hour, the operating cost for the oxidation ditch would be almost double that of Jones' figures using \$0.02 per kilowatt-hour energy cost. These costs would make the oxidation ditch uneconomical unless odors were becoming or had become cause for

legal action against the cattle feeding operation.

The climatic effects of temperature on cattle performance have been investigated for several years. Ragsdale et al. (1957) showed that heat had a definite effect on animals when animals raised at a constant 50°F grew much more rapidly than those at 80°F. Even at above 80°F, temperature differences can cause differences in performance. Hellickson et al. (1970) compared performance of cattle in two confinement facilities, a pole barn and an enclosed facility, during a summer. The average daily temperature for a two-week period in the pole barn was 5.4°F higher than the outside temperature and 4.3°F cooler than the enclosed environment barn. Significantly higher average daily gains and feed conversions were found for beef cattle finished in the cooler pole barn.

In order to minimize the effects of heat, various methods of cooling cattle have been tried. Ittner et al. (1957) found increased air movement over the cattle to have potential cooling effects so long as the air temperature was below that of the animal. Wind speeds of 400 feet per minute significantly increased average daily gain of cattle over cattle in pens with wind speeds of 20 feet per minute. Morrison et al. (1970) tried sprinkling cattle with a mist of water to improve feeding efficiency at high temperatures. Sprinkling cattle was significantly better than no sprinkling but not as effective as refrigerated air cooling. Not only was method of cooling the cattle researched for its effectiveness, but length of cooling was also shown to have an effect. Mendell et al. (1971) found that 6 hours

of cooling time during the evening maintained body weight gains equal to those obtained with 12 hours of cooling.

Because of the closer quarters required for confinement beef feeding, the heat can affect the animals to a greater degree. Morrison et al. (1970) found 60 square feet per animal gave significantly better performance than 40 or 20 square feet at high temperatures. In the Southeast, because of high temperature and high relative humidity, the optimum floor facilities could easily require the greater floor space allowances as suggested by Morrison. Also forced-air ventilation of cattle or sprinkling may be necessary to reduce heat stress.

The type of feeding facility chosen, the method of handling waste, and the method of handling the cattle to obtain maximum performance under a variety of climatic conditions will depend upon many factors. Cost, pollution potential, area of land available, and location will certainly be points of most concern. Clawson (1971) best summarized the problem as follows:

Because of varying circumstances, most individual operations will have to be evaluated by themselves technically, politically, and economically. Acknowledgement must be made of the fact that agriculture will be forced to stop pollution and that additional cost of this type of waste management may not be recovered from the value of the waste alone.

II. ANIMAL WASTE CHARACTERISTICS

Animal waste includes excreta (solid and liquid), litter or bedding, cleaning materials, chemicals used for pest control, cleaning water, spilled feeds, and sometimes waste carcasses. The amount and

strength of the wastes produced by an animal depend on the type, breed, sex, age, size, health, and environment of the animal as well as type of feed ingredients and additives in the ration. Environmental factors including temperature, humidity, light, antecedent moisture, rainfall, and age of wastes affect the rate and the extent of degradation of these animal wastes. Relatively stable materials such as lignin and hemicellulose form a large fraction of high-roughage animal feeds. Cattle feces also contains highly stable lignoprotein complexes produced in the digestive tract of the ruminant by the combining of plant lignin with bacterial protein. The lignoprotein complexes are very similar to the humus found in soil. These humus-like compounds may comprise as much as 25 percent of the total dry weight of feces and contain approximately half the total nitrogen in the excrement (Grub et al., 1969).

The chemical properties of cattle feedlot wastes which have been evaluated are those generally associated with fertilizer value of an animal waste, or the amounts of nitrogen (N), phosphorous (P), and potassium (K). Jones et al. (1973) found that the majority of nitrogen in livestock manure exists in the Kjeldahl N form. Although many determinations of the N, P, and K contents have been made, the results are variable due to variations in the treatment of the cattle and rations used which can affect the value (Gilbertson, 1970).

Variations in laboratory techniques employed in an analysis of wastes account for some differences. (Loehr (1967) determined the daily waste production of a 900-pound steer to be 43 pounds feces and 17 pounds urine. Laak (1970) and Taiganides (1964) found

beef manure to be very similar in content: 10.2 to 10.4 percent total solids; total N and K to be 3.7 percent and 3.0 percent of total solids, respectively; and P to be 1.1 percent N. The National Association of Agricultural Scientists (1963) found a range for N to be 0.24 to 0.60 percent, P to be 0.09 to 0.25 percent, and K to be 0.14 to 0.28 percent. Research on manure slurries at feedlots by Pioneer Hi-Bred Corn Company (1967) showed a ton of beef manure slurry to contain 6.4 pounds N, 4.6 pounds P_2O_5 , and 7.2 pounds K_2O or 0.37, 0.23, and 0.36 percent, respectively. The results, although somewhat variable, show that manure does have a chemical content to which a price for fertilizer value can be attached.

Morris (1971) recognized that a range for the fertilizer nutrients could be calculated. In 1966 the range was determined to be \$0.36 to \$0.87 per ton, while in 1971 this value dropped to \$0.29 to \$0.69 per ton of liquid manure. This drop in price is directly related to the drop in the price of commercial nitrogen prices due to the more economical artificial processes then available in 1971. Today, because of the energy shortage, the values of fertilizer elements have doubled to tripled giving the manure a much higher value, ranging from \$0.83 to \$2.01 per ton of liquid manure according to the Tennessee Farmer's Co-op.

Just as plants can receive beneficial effects from the chemical content of manure, mismanagement of this resource can lead to environmental pollution--especially of water. Pollution has been defined as any factor which adversely affects the historical beneficial or subsequent legitimate water use (Okey et al., 1969). The potential

pollution characteristics of animal waste and runoff from feedlots have been recorded by Henderson (1962), Taiganides (1963), Willrich (1966), and Loehr (1968).

Beef manure, because it is a waste from a warm-bodied animal and from a ruminant in which the major digestive processes depend upon bacterial action, contains a variety of microorganisms. Among the bacteria, the enterococci and coliforms are very numerous with relative orders of microbial magnitude per milliliter of manure suspension of total count, 10^8 ; anaerobes, 10^5 to 10^6 ; *Escherichia coli*, 10^5 ; enterococci, 10^4 to 10^6 ; and total fungi, 10^3 to 10^6 (Barker, 1973). The coliform group is defined in Standard Methods (1971, p. 662) as including "all the aerobic and facultative anaerobic, Gramnegative, nonspore-forming, rod-shaped bacilli which ferment lactose with gas formation within 48 hours at 35°C." The coliform group includes organisms that differ in biochemical characteristics and natural habitats. *Escherichia coli* is a facultative anaerobe which inhabits human and animal intestines and is present in fecal discharges. The presence of fecal coliform organisms (*E. coli*) indicates recent and possibly dangerous pollution of waters.

When manure is mixed with water, the free oxygen is removed from the water so quickly that the initially present oxygen has no significant effect on the anaerobic bacteria which were growing in the manure prior to its discharge from the animal. The first stage of anaerobic biological degradation of organic matter in water consists of hydrolysis of high molecular weight organic compounds and conversion of simpler soluble organics to organic acids by acid-

forming bacteria. During this phase as the pH drops below 5.5, microbial activity slows, and only the acid-forming bacteria continue metabolism. If the pH of the manure does not drop below 6.0, the second stage of anaerobic degradation is the gasification of organic acids to methane and carbon dioxide by methane forming bacteria. It should be noted that the acid-forming bacteria merely hydrolyze the biodegradable components of organic manures resulting in no change in the biochemical oxygen demand (BOD) or chemical oxygen demand (COD) of the waste.

BOD and COD reductions occur when the methane bacteria convert the soluble organics to methane, an insoluble gas that is discharged to the atmosphere. Nye et al. (1971) concluded that a definite change in the rate of decomposition of COD and volatile solids seems to occur between 48°F and 56°F. If the water-diluted manure contains nitrates or sulfates, the bacteria, while oxidizing the organic matter, will reduce the nitrates to nitrogen gas, or they will reduce the sulfates to sulfides. Both nitrates and sulfates will be reduced before methane will be formed. Aerobic bacteria tend to break down simple sugars much faster than the more complex carbohydrates such as lignin, lignoprotein complexes, and hemicellulose commonly found in manures.

Studies have shown that routinely employed analyses such as the five-day BOD test, as outlined in Standard Methods (1971, pp. 489-495), for the characterization of sewage and municipal wastewater cannot be indiscriminately used for the characterization of agricultural wastes and wastewaters. Municipal sewage is comprised

of large quantities of water contaminated by relatively small quantities of wastes; whereas, agricultural wastewaters generally consist of high concentrations of organics diluted with small amounts of water. The BOD is a bioassay subject to any interferences that will affect biological activity.

Variations of BOD values from animal wastewaters can be attributed to possible inhibitory effects of feed additives such as antibiotics, copper, zinc, and other toxic metals. Humenik (1971) reports that more attention should be directed to the COD and total organic carbon (TOC) tests as more reliable measures of the pollutional potential of animal wastes. The COD test measures the amount of oxygen required for the chemical oxidation of waste to carbon dioxide and water; while in the TOC analysis, a relationship exists between the amount of oxygen utilized by microorganisms and the amount of organisms metabolized.

As with nitrogen content, the COD values which have been determined are variably dependent on the animal, the feed, and the environment. Gilbertson (1969) found, for a cattle stocking rate of 100 square feet per head, the COD for manure ranged from 10,900 to 190,000 parts per million (ppm); and for a cattle stocking rate of 200 square feet per head, the COD value for manure ranged from 12,400 to 286,000 ppm. Townshend (1969) determined the COD for beef waste to average 316,000 ppm. For runoff from a feedlot, the values are much more variable depending upon slope of lot, intensity of rainfall, whether lot is paved, and exposure of the manure to the factors previously mentioned.

Another type of water pollution can be caused by conversion of nitrogen compounds in manure into nitrates which are water soluble and move into the ground-water table, thus constituting a health hazard if the nitrates are ingested via drinking water. The U.S. Public Health Service has set a nitrogen standard of 10 parts per million as nitrate nitrogen to be the maximum nitrogen content of raw surface water supplies for safe drinking water. Drinking water with excessive amounts of nitrate nitrogen can contribute to the illness known as infant methemoglobinemia (Standard Methods, p. 233, 1971). Livestock can be affected adversely and exhibit poor growth characteristics due to high nitrate content in drinking waters. Stewart et al. (1968) showed that nitrates can move through the soil and into ground water supplies under feedlots and that such nitrogen content was higher under feedlots than adjacent irrigated fields. Rademacher (1969) reported in a Missouri study that 42 percent of more than 6000 water supplies had greater than 5 ppm nitrate as nitrogen, and in northwestern Missouri, 50 percent of water samples had sufficient nitrogen to be of concern.

Possibly one of the most frequent complaints from animal feeding units is not from water pollution but from air pollution and the odor released by stored manure. Identification of the various gaseous compounds associated with odor has been made by several investigators including Burnett (1969), Merkel et al. (1968), and White (1971). Over 40 compounds in 10 groups have been identified with indole, skatole, mercaptans, and sulfides as the most powerful odorants

(Barth, 1974). The odors in many cases are not simply due to the presence of gases, ammonia and hydrogen sulfide, or even to one or two odorous organic compounds and odorous gases, but they result from combinations of all (Burnett, 1969). Most odor production is dependent upon the pH of the manure in storage with production increasing drastically if the pH is either too basic or too acidic.

III. DISPOSAL OF MANURE ON LAND

With any industry the disposal of waste products is a time consuming and perplexing problem, and the cattle feeding industry is no exception. Several methods for the disposal of manure have been researched. These varied from burning it for fuel to making it into brick for buildings. Anthony (1971) has had success with feeding beef cattle waste back to the cattle, and some success was reported by Sneed (1939) in feeding cattle waste to hogs. Generally waste treatment plants such as those used by municipalities are not feasible for cattle feeding operations because the characteristics of feedlot wastes are different from wastes of municipalities (Butchbaker et al., 1971). The strength of cattle feedlot wastes alone makes the use of municipal treatment systems expensive since a 100,000-head feedlot would require a treatment system equivalent to that of a city of a million population (Viets, 1968). Thus, the costs of such facilities may also be prohibitive.

The land has been and will continue to be the ultimate disposal point for animal wastes from agricultural operations (Loehr, 1971). Taiganides and Hazen (1966), Loehr (1969), Klausner (1971), Pratt

et al. (1971), Robbins et al. (1971), Buttbaker et al. (1972), and Ross et al. (1972) have encouraged the disposal of feedlot wastes onto agricultural land when the land is available. Webber (1970) found that the biological, chemical, and physical properties of soil provide a treatment facility for biodegradable wastes which is far superior to any treatment system devised by man.

Previously mentioned methods for treating animal wastes may be used to reduce the volume or quantity requiring disposal, but the land remains the disposal point for most of the treated and untreated wastes. Several critics, as pointed out by Loehr (1969), found land disposal less economical than in the past due to increased cost of transporting wastes to suitable sites, the large land areas required, limited time for spreading, and availability of inexpensive chemical fertilizers. They contend that no profitable method of livestock manure utilization has been developed and the discovery of one is unlikely. The much higher costs of chemical fertilizers in 1974 have caused renewed interest in the utilization of animal manures for their fertilizer value.

The amount of land needed for proper waste disposal varies. Many states have standards which regulate the amount of waste applied by setting limits on the number of animals to be served per acre of land. Such limits were proposed in the Tennessee Legislature and established by the Tennessee Public Health Department, Division of Water Quality Control (1973). The standards vary depending upon the type of wastes applied and the chemical and biological changes which occur to the wastes when applied to the land.

Studies by Klausner et al. (1971) have shown that the addition of organic matter increased soil aggregation which resulted in increased water infiltration. This is supported by Cross and Fishbach (1972) in their studies which showed that initial infiltration rates were greatly increased, although water holding capacity was reduced. Such an increased rate of infiltration reduces losses of soil and water due to erosion and runoff. Other studies have confirmed that applying animal wastes to soil not only increases organic matter but also increases carbon, nitrogen, available phosphorous, exchangeable potassium, chlorides, calcium and magnesium, soluble zinc, and salinity of soils affected. Two of the major elements of concern resulting from the addition of animal wastes, from a soil and water pollution standpoint, are nitrogen and phosphorous. Nitrogen can have several mineral forms including ammonium cations (NH_4), Nitrate (NO_3^-), nitrite (NO_2^-), elemental N (N_2), Nitrous oxide (N_2O), nitric oxide (NO), and nitrogen dioxide (NO_2) in soil. The nitrate form of N is the most soluble and is of greatest concern from the standpoint of leaching losses and movement into water supplies.

Leaching is generally greatest during cool seasons when precipitation exceeds evaporation, while downward movement of nitrates in summer is usually restricted to periods of heavy rainfall. Nitrate, under suitable conditions, is lost rapidly from the soil by bacterial denitrification. The ability to reduce nitrate to N gases is limited to those organisms which can utilize the oxygen of nitrate as a suitable substitute for molecular oxygen in conventional metabolism. The following pathway represents the probable mechanism of bacterial

denitrification through microbial transformations: $\text{organic-N} \rightarrow \text{NH}_4^+ \rightarrow \text{NO}_2^- \rightarrow \text{NO}_3^-$ under aerobic conditions.

Soil nitrate can also be microbiologically denitrified under anaerobic conditions to N_2 or N_2O gaseous forms and escape to the atmosphere. Denitrification can be considered a desirable process when it occurs below the rooting zone because it reduces the nitrate content of groundwater. Microbial decomposition of organic nitrogen compounds also releases nitrogen as ammonia under aerobic as well as anaerobic conditions, and this process is most active at temperatures above 60°F . Ammonium cations are held tightly by the soil and organic colloids; thus, they are relatively immobile in the soil. When phosphorous contained in animal wastes is added to an aerated soil, it is converted rapidly to water insoluble forms and becomes extremely immobile. Phosphorous reduction results from chemical activity of the clay fraction near the soil surface. Phosphate ions become fixed to the soil particles and are relatively insoluble thereafter; consequently, 95 percent of the phosphate losses from runoff (van Schilfgaarde, 1972) appear to be associated with movement of soil. These phosphate losses are primarily inorganic orthophosphate.

The amount of nitrogen used by crops would appear to be a limiting factor in obtaining maximum benefit from the manure applied to soil. Adriano (1971) reported that crops recycle N by absorbing nitrate and ammonia and converting it to proteins in plant tissues. The efficiency of nitrogen utilization by plants seldom exceeds 75 percent and may be as low as 30 percent. The amount of manure

required for plant toxicity is debatable. Mathers (1970) found in the High Plains of Texas that exceeding 112 tons per hectare (45.3 tons per acre) reduced yields. Hensler (1970), in Wisconsin, found that increasing amounts of manure (0-270 tons per acre) for both unlimed and limed soils increased nutrient recovery in all cases; and he concluded that, at high rates of application, manure nutrients can be used in crop production and soil improvement with little danger of toxicity to livestock resulting from excess nutrients in plants. Taiganides (1970) indicated that crop production begins to decrease as salt concentrations (sodium chloride, sulfates, and magnesium bicarbonate) exceed 900 milligrams per liter (ppm) and is stopped when irrigation water contains more than 5,000 milligrams per liter of salts. Mathers and Stewart (1971) found at Bushland, Texas that soil salinity could be a problem with high rates of manure application when sufficient leaching does not occur. Manges et al. (1971) concluded that the ratio of land needed for disposal of feedlot wastes to feedlot area is governed by the permissible accumulation of nitrogen and salts in the soil profile. Tennessee usually has sufficient rainfall such that accumulation of salts in the soil profile has not been a problem as related to plant growth.

Animal wastes which are properly applied to land produce a minimum of odors and result in few, if any, complaints. Robbins et al. (1971) suggested that land spreading, when coupled with good soil and water conservation practices, is an effective means for preventing pollution. The added nutrients are utilized by vegetative

cover which inhibits erosion and may result in less stream enrichment than that from watersheds devoid of farm animal wastes. For control of odors, Nordstedt and Taiganides (1971) suggested meteorological control as a potentially effective concept with diffusion conditions and wind speed as the most critical factors. Bartlett and Marriott (1971) found advantages in subsurface disposal of beef manure including: (1) covered material does not present unsightly appearance associated with surface spreading, (2) runoff is prevented since the manure is retained by the crops, (3) odors are not emitted, and (4) the nutrient content is retained for maximum fertilization and not lost to the atmosphere. Gumerman and Carlson (1969) support the control of odors by subsurface disposal since they found that sterile loam soil possesses the capacity to remove H_2S , ethyl and methyl mercaptal, but not methane. These three compounds have previously been identified as part of the more volatile components of animal waste which contribute to odors. There is no substitute for good management, and proper site selection together with an attitude of being a good neighbor helps to minimize problems and complaints resulting from land spreading of animal waste.

CHAPTER III

RESEARCH METHODS AND FACILITIES

A slatted-floor beef finishing facility was constructed in the fall of 1971 at the University of Tennessee Aluminum Company of America (Alcoa) farm. An existing barn with a concrete-slab floor was remodeled to include aluminum slats and reinforced-concrete slats installed over reinforced-concrete manure pits in half the barn (six pens), while the slab was left intact in the other half (six pens). During the summer of 1972, the barn was enlarged to include more slatted-floor pens over reinforced-concrete manure pits with four additional pens on either side of the barn (Figure 1).

In the 1971 renovation, the experimental aluminum slats installed were approximately 3 1/2 inches deep with a top width of 6 inches. The slats, fabricated by Alcoa, weighed approximately two pounds per foot of length. Different surface roughness patterns to minimize slippage of animals were used in the design. The reinforced concrete slats purchased had a top width of 4 1/2 inches, were 5 1/2 inches deep, and had a bottom width of 3 inches. Both types of slats were designed to support a 250-pound load per linear foot of slat across an eight-foot span. The spacings between the aluminum and concrete slats were 1 3/4 and 1 1/2 inches, respectively. The 1972 addition to the barn contained experimental aluminum slats 4 1/2 inches deep and 6 inches wide which had been extruded by Alcoa. The slats weighed approximately 2 pounds per linear foot and were

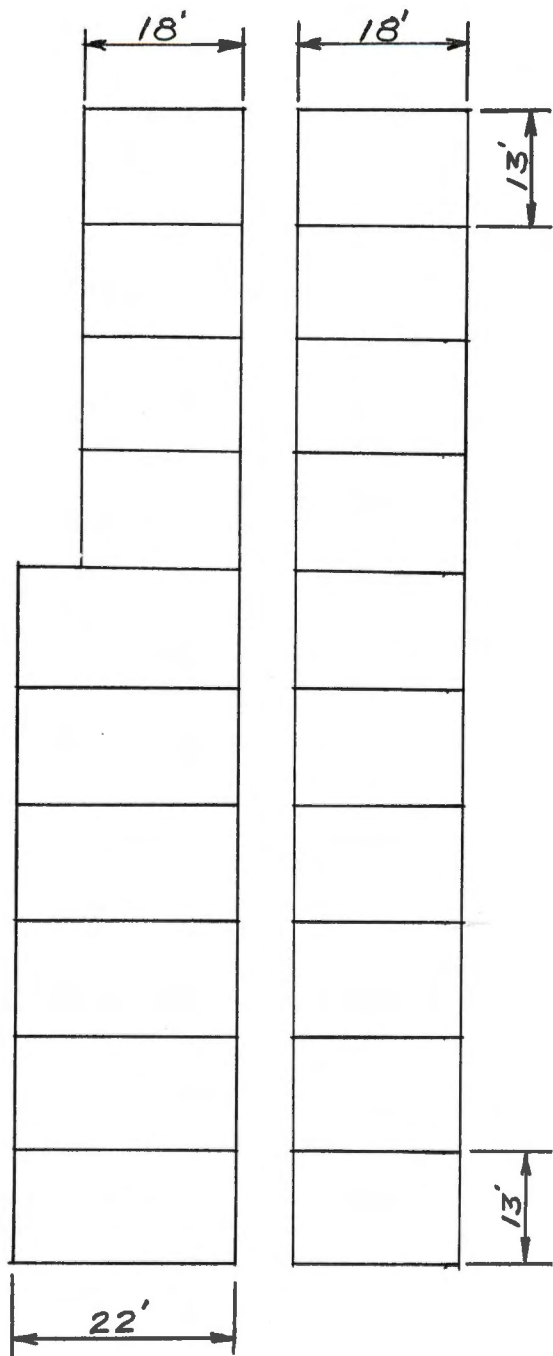


Figure 1. Layout of Alcoa Barn No. 4

installed with 1 3/4 inch crack spacings. The latter slat type incorporated two different grid designs to reduce slippage by the cattle. The two types of aluminum slats are shown in Figure 2.

The inside dimensions of the concrete pits in the barn renovated in 1971 were 16 feet wide, 4 feet deep and 36 feet long. The floors in the pit were flat. The pits constructed in 1972 were 16 feet wide, 4 feet deep, and 48 feet long. These pits were equipped with floors sloping toward a sump in the center of the pit to facilitate pit emptying. The concrete and reinforcement were designed according to accepted reinforced-concrete procedures. An 8-inch by 6 1/2-inch, wide-flange steel girder was placed along the entire length of the center of the pits to support the slats designed for an eight-foot span. The girder was supported by reinforced concrete columns on 13-foot centers. Pit construction details are given by Sewell and McLaren (1973).

Before cattle were initially placed on the slats and immediately after each pit emptying, approximately 6 inches of water was placed in the pit so the manure would not dry. Dry manure is known to create difficult agitation problems. The only liquids entering the pit between emptyings were urine and a small quantity of spillage from the cattle waterers. The manure was removed from the pits at four- to six-month intervals, and agitation was done only during pit emptyings when the cattle had been moved.

Cattle were initially placed in the barn during the fall of 1971 with very few problems developing. Because of the relative newness of feeding cattle under confinement in the Southeast,

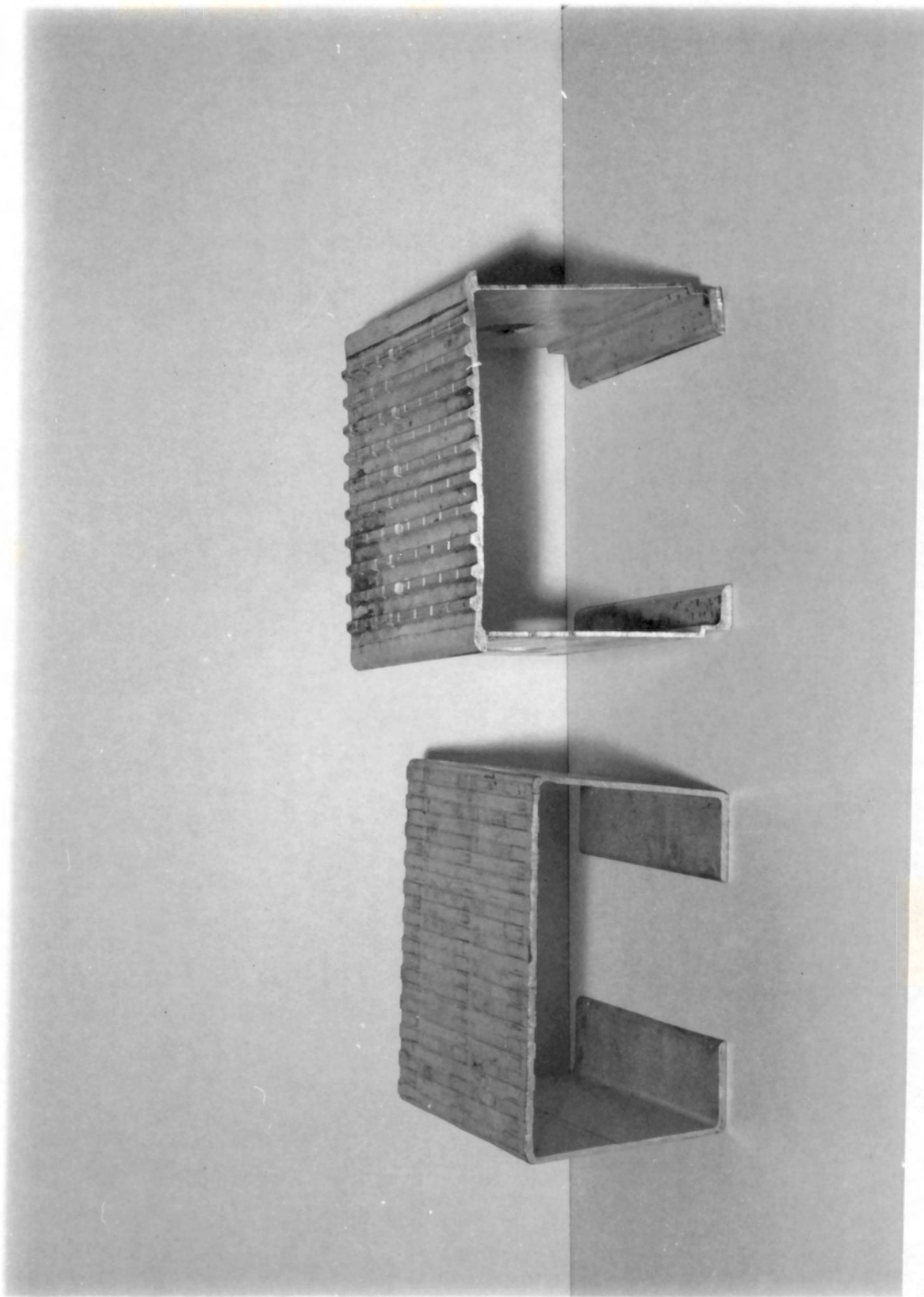


Figure 2. Experimental aluminum slat designs (Type I on the left and Type II on the right) used in some pens of Alcoa Barn No. 4

information about the desirability and feasibility of confined feeding of cattle during the summer was desired. During the summer of 1973, bulls weighing from 450 to 560 pounds each were placed into six slatted-floor pens to determine the cause and severity of swelling in the knee joints which had been observed during the previous summer's feeding trials. These cattle remained on a full finishing ration as described by McLaren and Sewell (1973) until they weighed approximately 950 pounds. Feed consumption and weight gains were measured by the personnel of the University of Tennessee Animal Science Department. During the 1973 summer test, a continuous temperature recording device was placed in one pen to record temperature variations at six locations within the pen. Weekly observations of the condition of the cattle and the slats were made and recorded. At the end of the feeding period, the cattle were removed from the barn area and the manure was removed from the pit.

In the summer of 1974, a study was begun to determine the effects of fan cooling of cattle on slatted floors especially as related to swelling in the knees of cattle. Six pens of cattle were included in the study with two slatted-floor pens being fanned, two slatted-floor pens being unfanned, and two concrete slab-floor pens being unfanned. Thus, three treatments were established. Initial weights of the cattle, three pens of bulls and three pens of steers, were recorded; and periodic checks of weight gains were recorded. Seven cattle were allotted to each slatted-floor pen and six to each slab-floor pen with one pen each of steers and bulls in each treatment. Cattle on slatted floors were allowed 34 square feet

per animal while the cattle on concrete slab pens were allowed 57 square feet per animal. The type and amount of feed consumed by the cattle was recorded daily. Recording hygrothermographs were installed between the two pens making up each of the three categories of pens (treatments) as shown in Figure 3. Cattle behavior was also observed and recorded during various periods of the day.

The two fanned slatted-floor pens were each equipped with a commercially available ventilation fan which directed air movement downward on the cattle. The 36-inch wall fans were rated at $3/4$ horsepower, and their specified delivery rates were 9400 cubic feet per minute (cfm) at $1/8$ inch static pressure. With seven animals per pen, the design ventilation rate was about 1300 cfm per animal. This compares with 2400 cfm per animal used by Ittner et al. (1957) in California and 200 cfm per 1000 pound animal plus additional pit ventilation recommended by Midwestern Plan Service (1973).

Agitation of solids prior to removal was achieved using a commercial air compressor equipped with a long, hand-held nozzle for agitation of the pit contents. Removal of manure from the pits and its disposal into fields was achieved using two commercially available vacuum tank spreaders with capacities of 1100 gallons and 1500 gallons. The vacuum tanks were pulled by tractors of at least four-plow capacity.

When the pits were emptied during the summers of 1973 and 1974, man-hours required for removal and disposal of the waste were recorded. Also samplings of loading times, distances traveled, travel times, and amount of waste removed were made and recorded. Performance of

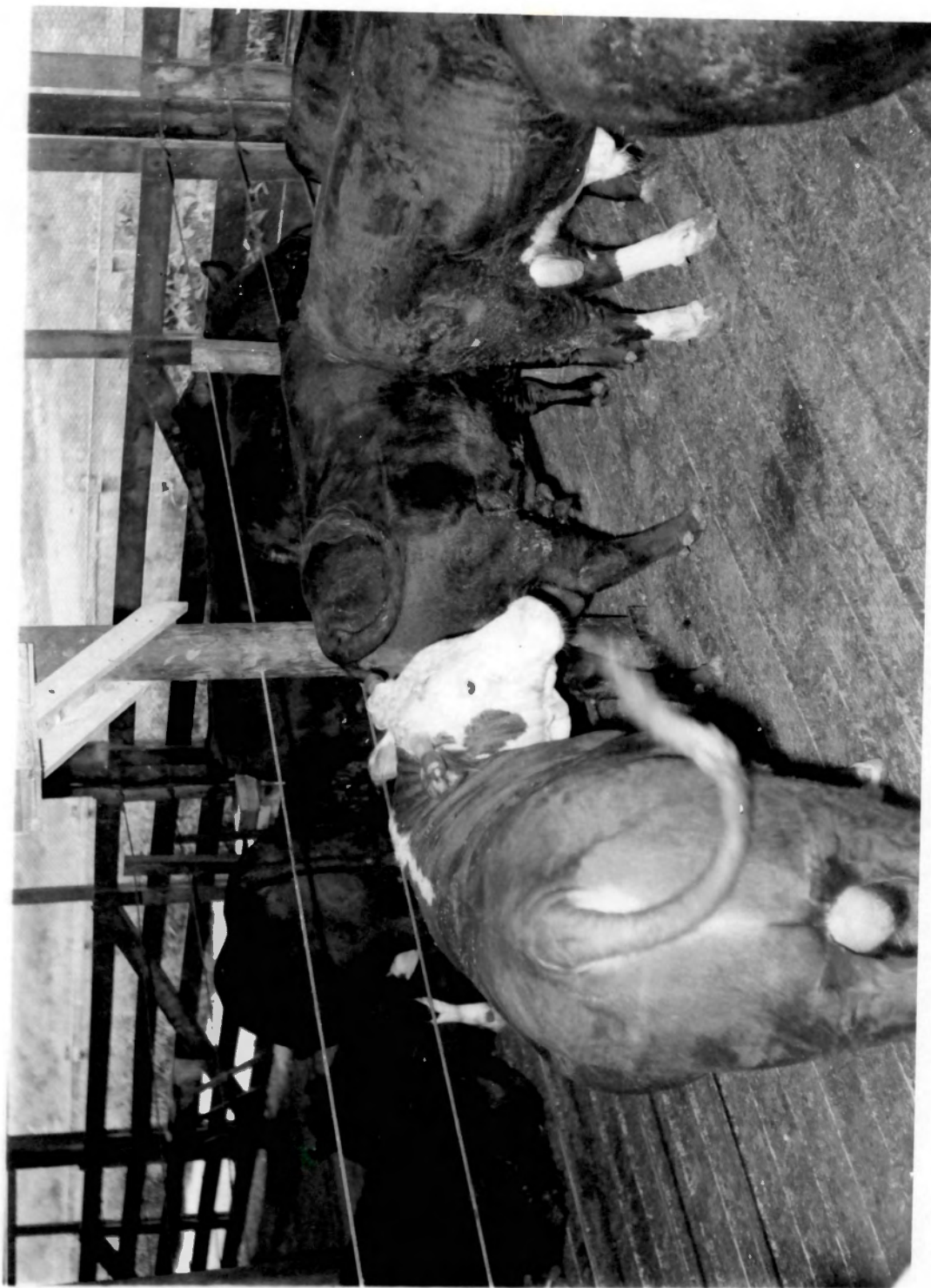


Figure 3. Hygrothermograph location in pens

equipment and suitability of waste disposal methods on land were also determined.

Samples of the wastes were obtained from the pits at the time of removal in order to evaluate the wastes for Kjeldahl nitrogen and chemical oxygen demand (COD). Kjeldahl nitrogen was determined according to McKenzie and Wallace (1954). COD determinations were performed using the dichromate reflux method outlined in Standard Method for the Examination of Water and Wastewater (1971, pp. 495-499). The samples were blended in a laboratory blender and diluted as necessary to afford determination within the limits available for the test procedure.

Because of changes in the cross section of one slat design over a period of time, a strength test was performed on two slat patterns to determine if the slats were easily deformable. The tests were performed using standard materials testing procedures on a standard testing machine. Dial indicators were placed at the midpoint of an eight-foot section of slat to measure both the spread and deflection of the slat under load.

CHAPTER IV

RESULTS AND DISCUSSION

I. TEMPERATURES AND THEIR EFFECT ON CATTLE

The profitable management of any beef finishing system is based upon the provision of suitable environmental conditions for maximum efficiency of feed conversion by the beef animal. Because this was one of the first slatted floor facilities in the Southeast, data were desired on the environmental conditions which might be expected to be present during the summer period. The temperature data from the initial study in 1973 are given in Appendix A. This temperature data, although for only one slatted-floor pen, offers substantial information about the possible temperatures which could affect the cattle. The average maximum temperature outside the barn was obtained from the U.S. Weather Bureau Station one mile from the feeding site. In the summer of 1973, these maximum temperatures both inside and outside the barn averaged more than 80°F, a critical temperature expressed by several previous investigators. Maximum temperatures inside the barn were somewhat higher than the maximum temperatures outside the barn during July and substantially higher during August.

Some swelling occurred in the knee joints of the cattle during the 1973 summer. Because of the knee problems and the high temperatures encountered during July, further study was conducted in 1974.

In analyzing data for the summer period of 1974, several temperature differences were discovered between the three floor systems and the hall (Figure 1, page 27). Generally the coolest period of the day was between 6 and 8 AM, while the highest temperatures were recorded between 4 and 6 PM. Temperatures for 11 days were analyzed using a balanced design. Floor types were found to have a significant difference in temperatures at $p < 0.01$. The difference in temperatures from day to day was also significant. The analysis of variance is shown in Appendix B. The temperature of the unfanned slat floor pen is shown in Table 1 to vary from 1°F cooler than to approximately 3.5°F warmer than the fanned slat pen. The temperature of the unfanned slat pen was usually higher than that of the fanned slat pen.

The major reason for the pattern of temperatures between the two types of slatted floors was the effect of the fans. The fans, because they were angled downward and drawing air from near the roof, would tend to heat the pens as the heat would build up under the roof during the morning hours. The fans would also tend to cool the pens quicker during the early evening after sunset. This would tend to explain the negative difference shown in Table 1 during the late morning hours and the increasing positive differences during the early evening.

The fanned slat pen was consistently warmer than the unfanned slab, as shown in Table 2. This difference was minimal during the early morning hours and greater during the afternoon. Orientation of the barn is most likely the reason for these discrepancies, since

TABLE 1. MEAN TEMPERATURE FOR FANNED AND UNFANNED SLAT-PENS

Time	Unfanned Slat ^a	Fanned Slat	Difference ^b
2 AM	69.0	66.8	2.2
4 AM	65.9	64.7	1.2
6 AM	63.2	61.4	1.8
8 AM	63.3	59.9	3.4
10 AM	69.7	70.4	-0.7
12 Noon	79.2	77.8	1.4
2 PM	87.7	88.8	-1.1
4 PM	90.7	91.7	-1.0
6 PM	92.7	91.6	1.1
8 PM	88.1	86.5	1.6
10 PM	79.6	77.2	2.4
12 Midnight	72.1	71.1	1.0

^aFor a 35-day period beginning in the first week in July, 1974.

^bDifference equals unfanned minus fanned, degrees F.

TABLE 2. MEAN TEMPERATURE FOR FANNED SLAT AND UNFANNED SLAB PENS

Time	Fanned Slat ^a	Unfanned Slab ^a	Difference ^b
2 AM	66.9	65.9	1.0
4 AM	64.6	63.0	1.6
6 AM	61.8	60.9	0.9
8 AM	61.6	60.6	1.0
10 AM	68.9	66.1	2.8
12 Noon	78.0	74.7	3.3
2 PM	86.2	83.5	2.7
4 PM	89.9	86.6	3.3
6 PM	90.5	86.3	4.2
8 PM	86.1	82.3	3.8
10 PM	76.6	74.5	2.1
12 Midnight	71.0	69.4	1.6

^aFor a 42-day period in the summer of 1974.

^bDifference equals fanned slat minus unfanned slab, degrees F.

the slab-floor pens receive little of the warmer afternoon sun while the slat-floor pens receive almost all the afternoon sun.

Air movement had a significant effect on the average daily gain of the cattle (steers and bulls) as the pens with the fans had significantly higher average daily gains at the $p < 0.10$ level, as seen in Appendixes C and D. In addition, the fanned cattle had excellent efficiency in feed conversion as determined by the University of Tennessee Animal Science Department. The steers in the fanned-slat pen equalled the feed conversion efficiency of those steers in the unfanned slat pen, and the unfanned slatted floor steers excelled in efficiency of feed conversion over the steers on the slab floor by 1.5 pounds of feed per pound of gain. The bulls on the fanned slats exceeded those bulls on both unfanned slats and the conventional concrete slab in feed conversion efficiency and rate of daily gain. These comparisons support the data of Ittner et al. (1957).

Just as performance can be adversely affected by high environmental temperatures, so can an animal's health. During the summer of 1973, several animals were found to have one or more swollen knees and/or hocks. The degree of swelling varied, although it generally appeared to occur more often and more severely in the knee that the animal used to push itself up when moving into a standing position. Also, temperature was thought to be a factor in the degree of swelling; however, no data were available to support this idea. Neither were the effects of swelling on the performance of the cattle known. Older cattle in 1973 had been placed in pens adjacent to the younger cattle, and they showed no knee damage.

During the summer of 1974, the cattle in each group were periodically evaluated for swelling in the knees and scored by personnel of the University of Tennessee Animal Science Department and rated from one to five depending on the severity of swelling (Table 3). An analysis of variance employing missing plot techniques was used to determine the effects of floors and sex on swelling scores. The effects of floor types and sex were not significant at the $p < 0.16$ level; however, no conclusion can be logically drawn from such data. By floor types, the fanned slats had slightly higher mean scores than the fanned slats, and the slabs had the lowest mean scores. However, with only six or seven cattle per pen, one animal with severe swelling could markedly affect the mean. Although fanning did not reduce swelling, fanning was shown to have a beneficial effect on rate of daily gain for bulls and steers (Appendix C). Bulls on test showed better feed conversion efficiency on fanned slatted floors than on the unfanned slatted floors. Thus knee swelling did not appear to adversely affect performance.

Periodic observations were made during the late afternoon hours to determine if differences in the activity of the cattle on the fanned and unfanned slats could be observed. Mr. J. Newt Odom, Superintendent of Farms, University of Tennessee at Knoxville, felt that there was a definite difference in behavior. The unfanned cattle were usually more restless and got up and down more often, while those cattle being fanned seemed to be more contented. The animals on the unfanned slats moved about more than either the animals

TABLE 3. MEAN SCORES FOR KNEES OF CATTLE IN SUMMER OF 1974

Floor	Sex	Number of Animals	Observations	Mean Score ^a
Fanned slats	Steers	7	2	1.86
Fanned slats	Bulls	7	2 & 4	1.79
Unfanned slats	Steers	7	4	1.79
Unfanned slats	Bulls	7	4	1.61
Concrete slab	Steers	6	4	1.50
Concrete slab	Bulls	6	4	1.57
Fanned slats	All cattle			1.82
Unfanned slats	All cattle			1.70
Concrete slab	All cattle			1.54
All floors	Steers			1.71
All floors	Bulls			1.65

^aScores were defined as follows:

- 1 Normal--no swelling
- 2 Slight swelling, one knee
- 3 Slight swelling, both knees
- 4 Severe swelling, one knee
- 5 Severe swelling, both knees

on the concrete-slab pen or the fanned slats. Mr. Jackie Martin, Manager of the University of Tennessee Alcoa Farm, felt that the temperatures only aggravated a preexisting condition in the type of cattle present. Because the cattle were being tested for performance, they gained weight at rates faster than would be normal; and as a result, greater strain was placed on the knees; they became tender and tended to bruise easier. This would appear feasible since older cattle under the same environmental conditions showed no adverse effect in the summer of 1973.

Based on observations during 1973 and 1974, the knee swelling problems appear to be associated with summer temperature since cattle fed during the other three seasons of the year did not, during the tests, exhibit knee swelling. During 1973, some cattle exhibited knee swelling to such a degree that they were removed from pens and placed on pasture. Most of these cattle fully recovered. In the summer of 1974, no cattle were removed from any pens during test.

II. SLATTED FLOORS AND WASTE MANAGEMENT

The advantages and disadvantages of slatted floors in the feeding of cattle in the Southeast have been debatable. The cattle on feed at the Alcoa farm have performed well on the slatted floors as shown by the daily gain data previously discussed. The cattle also remained noticeably cleaner on the slatted floors than the cattle on the slabs. The concrete slab pens were scraped at least once and usually twice a week with the manure being stockpiled as shown in Figure 4 until suitable weather permitted disposal on fields.

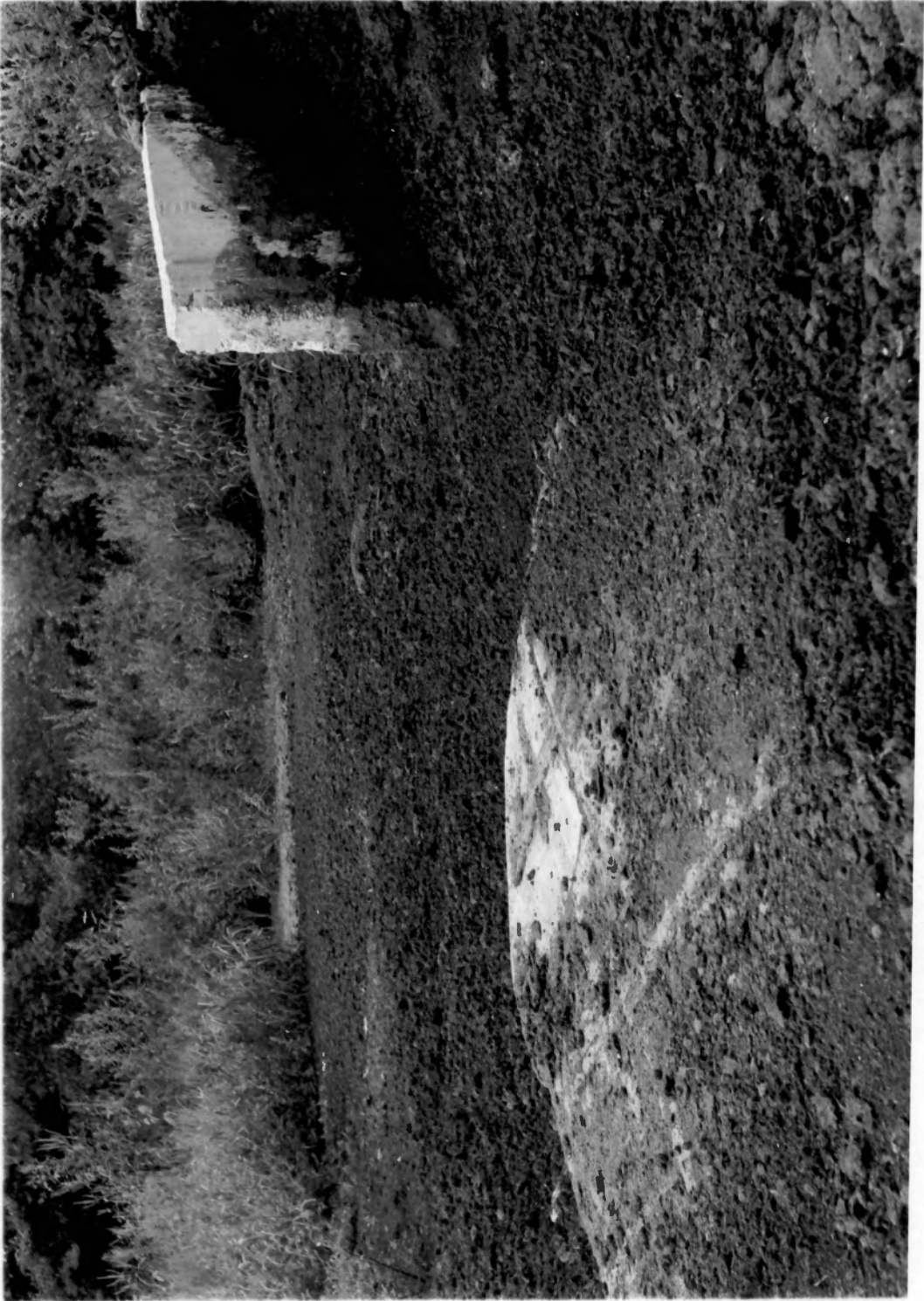


Figure 4. Storage of manure scraped from slabs

Even then, the cattle pens with slab floors, after one day's time, had manure accumulations as shown in Figure 5. The conditions in the immediate vicinity of the slab floors are decidedly unsanitary during most of the year, and the maximum fertilizer value of the manure is lost due to seepage in storage.

With slatted floors and pits underneath for storage of manure, the cattle remained cleaner and less fertilizer value of the manure was lost. The manure from the pits was removed two or three times a year and placed on fields where corn silage was grown. In 1973 and 1974, this was done in the spring before corn was planted and in the fall after harvest and before a cover crop was planted. Because of the available manure storage capacity, the timeliness of manure spreading operations facilitates labor requirements and scheduling.

During periods of manure removal from the pits, vacuum tank spreaders removed the liquid manure and transported it to fields. Before the pit unloading began, a section of slats was removed and the contents of the pit were agitated for one hour using a commercial air compressor with a capacity of 100 cubic feet of air per minute (cfm). During the removal process, two men were required: one to operate the air compressor and agitate the pit, and one to operate the vacuum spreader tank.

Agitation was found to be critical in the successful removal of the manure from the pits. One pit was partially emptied without prior agitation. Serious problems were encountered with the removal of the heavier solids in the bottom of the pit. Forcing compressed

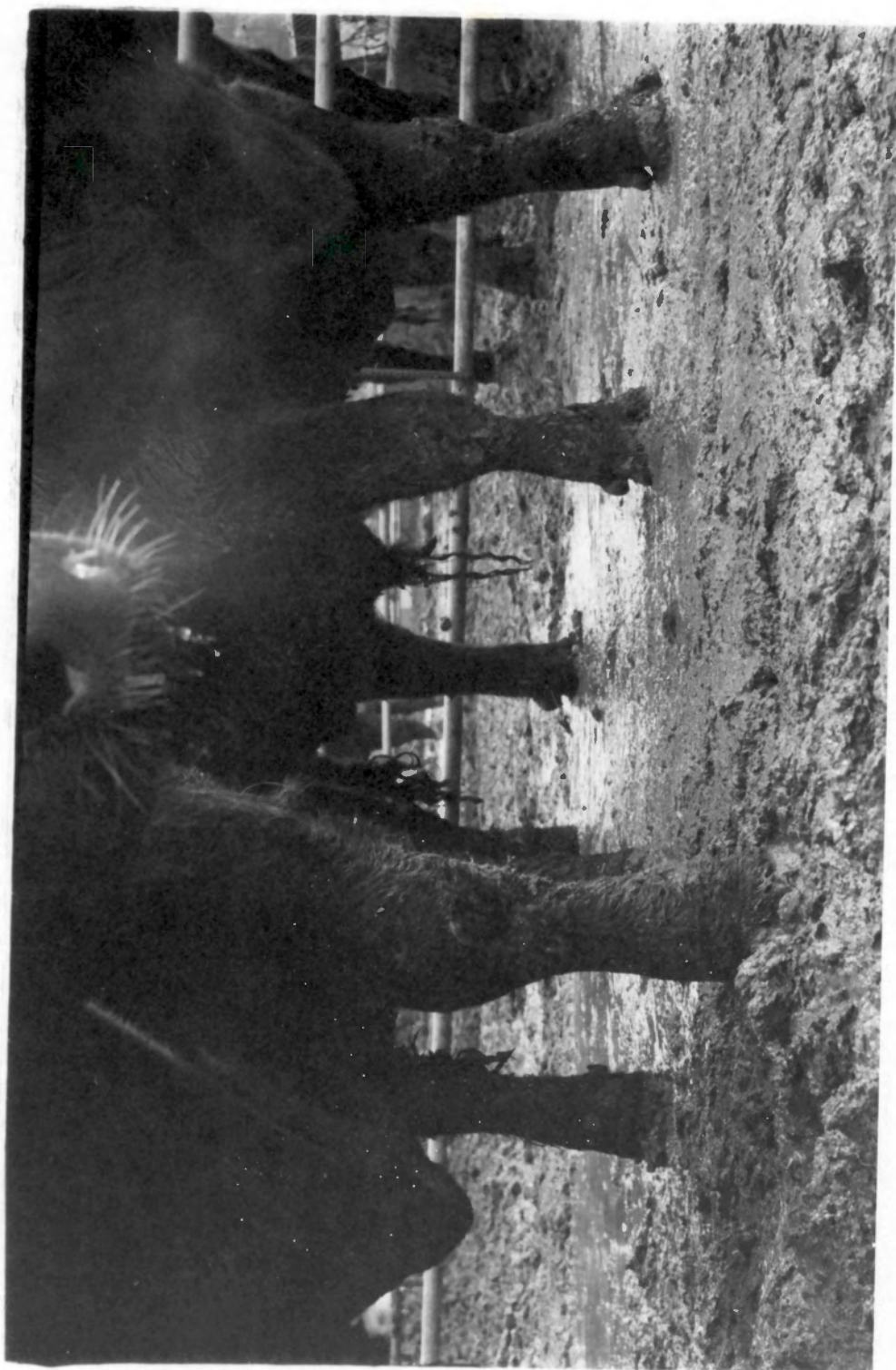


Figure 5. Concrete slab pens one day after scraping

air from the spreader tanks was not sufficient to allow removal by vacuum. After several attempts to remove the solids, including the addition of water, emptying was abandoned and the pit was allowed to refill. No further attempts were made to remove manure from the pits without prior agitation.

When the liquid manure was removed in the fall of 1973, two men removed 33 loads (1100 gallons per load) of manure with an average labor requirement of 1.87 man-hours per load. With two spreader tanks and three men working during the spring of 1974, the average load time was reduced to 1.40 man-hours per load. The distance required for travel to and from the field for disposal was a major factor in this large time requirement. Road travel time (one-way) varied from 14.4 to 15.5 minutes. This time was measured from the barn to the point where the vehicle turned off the road and into the field. Unloading time requirements varied from 4 to 16 minutes depending on the distance required to travel across the field to the disposal area. No problems were encountered during the spreading process as shown in Figure 6. Loading times varied from 5.0 to 16.5 minutes depending upon where the hose was placed in the pit and the consistency of the waste. During the early loadings from a pit, the hose was kept near the top to remove chunks of dried manure which floated on top of the liquid. Substantial amounts of air entered the vacuum tank, resulting in longer loading times.

The manure was placed in fields for use as fertilizer for corn production. Samples were obtained from two pits and analyzed for Kjeldahl nitrogen and for chemical oxygen demand. The results



Figure 6. Vacuum tank spreading liquid manure on field

of these tests are shown in Table 4. Kjeldahl nitrogen ranged from 3360 parts per million (ppm) to 4930 ppm, or from 0.34 percent to 0.49 percent. These values are within the ranges reported by the National Association of Agricultural Scientists (1963). Because of the large dilutions required and the micro-method used, the repeatability was lacking to some degree, although the results appear to be satisfactory. Chemical oxygen demand also varied, and again the large dilution required was most likely a major cause. Sample A ranged from approximately 97,100 to 118,400 ppm oxygen demand while sample B ranged from 162,200 ppm to 173,000 ppm oxygen demand. Both samples fall into ranges within which previous investigators have found. These tests tend to confirm that liquid manure is a valuable fertilizer if properly managed and a great source of pollution if mismanaged.

III. SLAT STRENGTH

During the period of manure removal in the spring of 1974, deformation of sections of the Type II slat (Figure 1, page 27) was observed. Although no deformation was obvious when viewing the slatted floors from the top, a substantial decrease in the spacing between slats had occurred due to spreading of the lower parts of the slats as shown in Figure 7.

Sections of the slats, seven feet long, were tested using a standard testing procedure where a point load was applied to the center of the slat. Deflections for the two types of beams were measured and recorded as were the amounts of spread. Results for

TABLE 4. KJELDAHL NITROGEN CONCENTRATIONS AND CHEMICAL OXYGEN DEMANDS OF LIQUID BEEF WASTE

Sample	Kjeldahl Nitrogen (ppm)	Chemical Oxygen Demand (ppm)
A1	3,870	97,100
A2	3,420	118,400
A3	4,880	103,500
A4	4,930	
Mean of A	3,530 4,275	106,300
B1	4,480	173,000
B2	3,810	162,200
B3	3,360	164,400
B4	4,260	
Mean of B	3,980	166,500
Mean of A and B	3,750	136,400

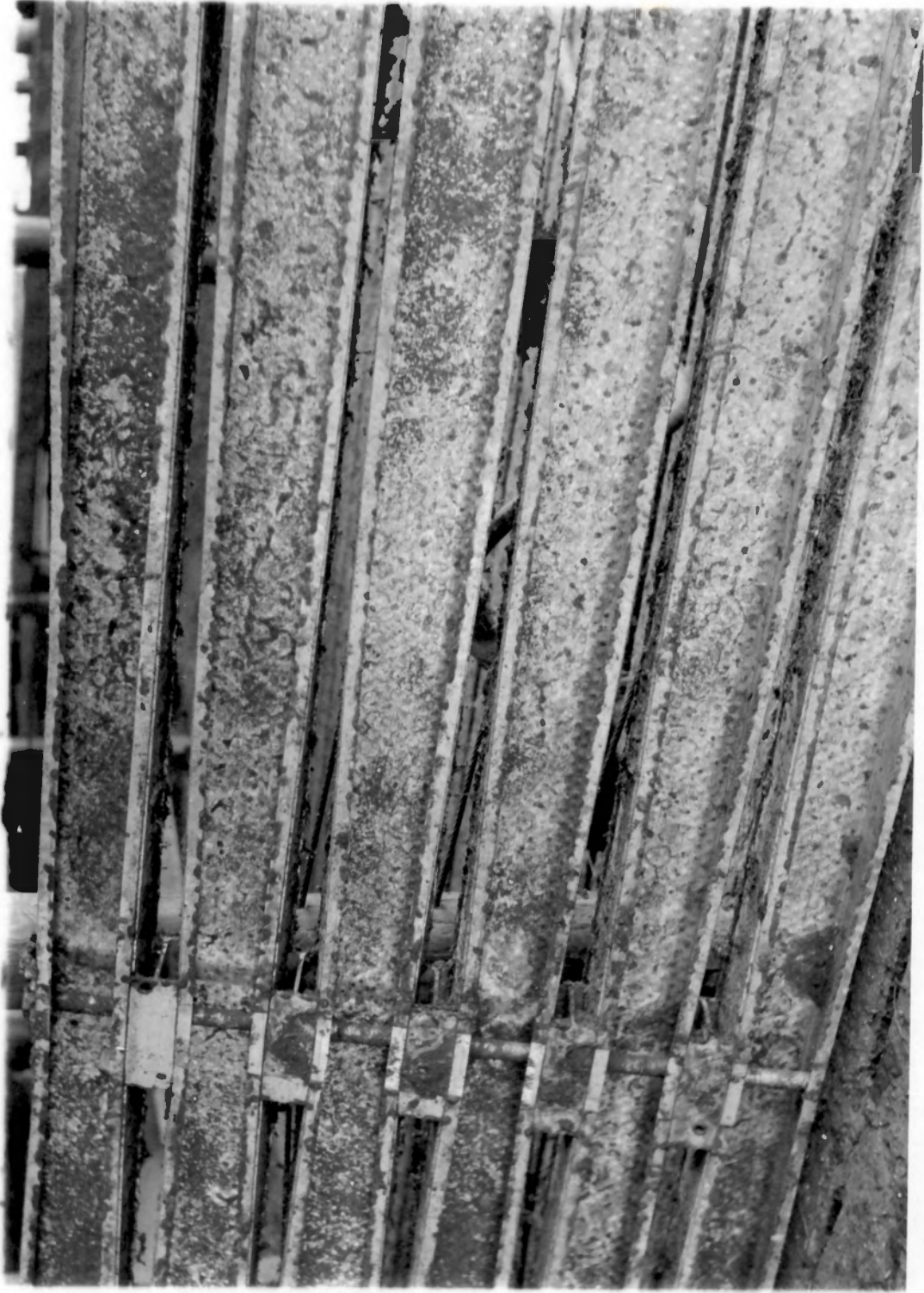


Figure 7. Type II slat section showing deformation after use

slat Type II are shown in Figure 8. Similar data were determined for slat Type I. From Figure 8, one can see that a point load of up to 800 pounds did not produce permanent deformation. Therefore, one might think that the spread is a result of fatigue rather than an instantaneous loading. Although the spreading is not of immediate concern in safety failure, it does reduce the space through which manure droppings can fall. Some problems developed as manure dried between the slats and clogged the crack spaces. Because of this, the cattle remained dirtier and the pens were not so clean as those with the Type I slat. Also, because the manure was often dry before it fell into the pit, dried and floating chunks formed which tended to clog the vacuum spreader tanks' discharge valves.

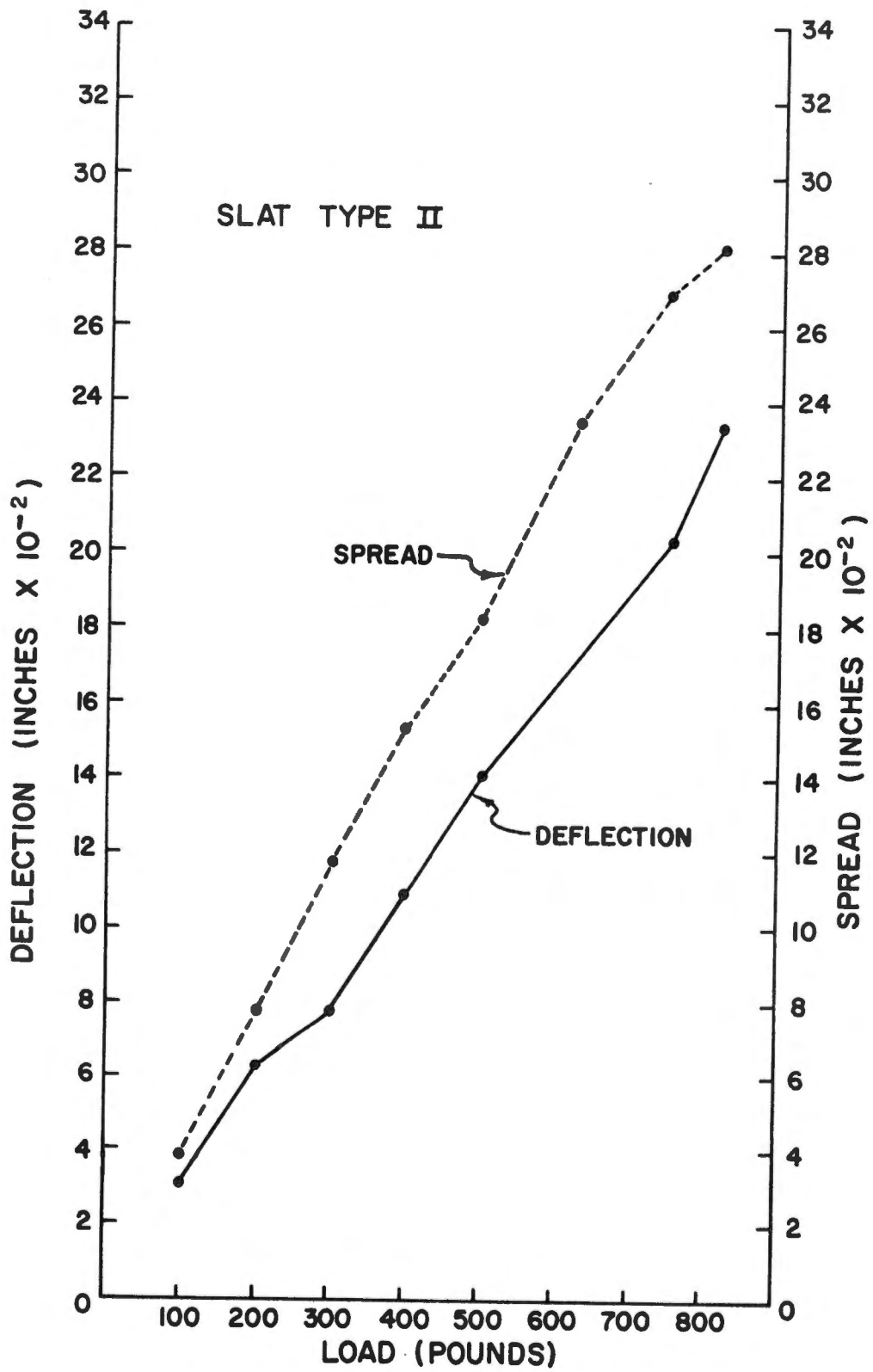


Figure 8. Deflection and spread under load for Type II slat

CHAPTER V

SUMMARY AND CONCLUSIONS

I. SUMMARY

From the study during the summer of 1974, fanning was shown to have a significant beneficial effect on the average daily gains of the cattle. This supports the work by Ittner et al. (1957) in climates warmer than 80°F. For the same time period, a significant difference in temperatures was found for different floor types with slatted floors being warmer than concrete slab floors. Orientation of the barn could have influenced this difference since the side of the barn with slatted floors received most of the afternoon sun.

The cattle in the fanned slatted pens appeared more alert and were not so restless during late afternoon observation periods. A significant statistical difference was found between floor types and severity of swelling in the knees with cattle on slats exhibiting slightly more swelling than cattle on slabs. These knee problems did not adversely affect average daily gain and feed conversion efficiency.

Agitation of pit contents was found to be a necessary part of the pit cleaning process for the easy removal of all materials in the pit. Satisfactory removal was accomplished by use of vacuum tank spreaders with two spreaders and three men being more efficient than one spreader and two men. High labor requirements were partially due to the long haul distances required.

Manure was placed on the fields for its fertilizer value. Kjeldahl nitrogen determinations of liquid manure samples showed the manure to have values of approximately 3750 ppm which compare favorably with those determined by other investigators. Possible pollution potential was determined by finding the chemical oxygen demand of the waste. These values, approximately 130,000 ppm, also were within the values as determined by other investigators.

During one cleaning period, a deformation in one type of experimental aluminum slats was observed. This deformation was apparently due to the spread of the slat under repeated loading. The deformation prevented the manure from properly falling through slat spacings and into the pit below. Laboratory tests on two types of slats revealed no permanent deformation with point loads up to 800 pounds at the center of an eight-foot unsupported length of slat.

II. CONCLUSIONS

1. Statistically significant differences in pen temperatures occurred between slatted floors and concrete slabs, but orientation of the building could have affected this.
2. Differences occurred in the degree of knee swelling between concrete slabs and slat-floor pens with slightly more swelling occurring on the slat floors. Knee swelling had little effect on the average daily gains of the cattle.
3. Fanning cattle significantly increased the efficiency of feed conversion and the average daily gain of cattle.

4. Agitation of liquid manure by using compressed air was an acceptable means of liquefying the contents of the pits.
5. Nitrogen content and COD values of samples obtained from the manure pits were comparable to other reported values.
6. Distortion of experimental aluminum slats was not due to a single loading but probably due to repeated stresses resulting in fatigue.

III. RECOMMENDATIONS FOR FURTHER STUDY

To obtain the maximum return on an investment in a slatted floor facility, the facility must be used at maximum capacity for the entire year. The cattle must also perform well with no adverse effects to gain maximum return. Because of the uncertainty in the seriousness of the swelling of the knees during previous summer periods, further tests requiring a greater number of animals would appear justified. The 1974 test was limited because of the small number of animals available. Therefore, results were of limited value since the power of the test was only 50 percent. To offset this, additional tests with a larger number of animals and over several years' duration would be desirable.

The study should include fanned slat and fanned concrete slab pens. The effect of orientation of the barn should be reduced by using slatted pens on the same side of the barn as the concrete slab pens. The study should include cattle on fanned slats and slabs, as well as cattle on unfanned slats and slabs. Additional measures

to reduce the amount of heat trapped in the roof gable of the barn should be included. These measures could include venting of the roof at the peak and/or painting the outside of the roof white to reflect the heat away from the roof. By making these additional studies, the feasibility of summertime feeding of cattle in the Southeast could be determined.

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APPENDIXES

APPENDIX A

TABLE 5. MEAN TEMPERATURES FOR 1973 SUMMER PERIOD

Month	Temperature (°F)	
	Mean Maximum in Barn	Mean Maximum ^a Outside Barn
June	81.0	82.3
July	86.0	84.0
August	92.6	86.1

^aTemperatures obtained from U.S. Weather Bureau Climatological Data, 1973.

APPENDIX B

TABLE 6. ANALYSIS OF VARIANCE FOR 1974 SUMMER TEMPERATURES FOR AN ELEVEN-DAY PERIOD

Source	Degrees of Freedom	Mean Squares	F-Value
Floor	3	18.3	15.6**
Observation	10	36.0	30.7**
Floor by Observation	30	1.2	

**
p < 0.0001

APPENDIX C

TABLE 7. BEEF CATTLE PERFORMANCE DATA SUMMARY FOR 1974 SUMMER TESTS

	Treatment					
	Conventional		Unfanned		Fanned	
	Concrete Slab		Slatted Floor		Slatted Floor	
	Bulls	Steers	Bulls	Steers	Bulls	Steers
Total weight gain ^a	256	260	265	275	292	278
Average daily gain ^b	2.51	2.55	2.60	2.69	2.78	2.73
Feed conversion	8.0	10.1	7.8	8.6	7.2	8.6

^aAll data provided by Dr. J. B. McLaren, University of Tennessee, Knoxville, Animal Science Department; pounds gain.

^bPounds per day.

^cPounds feed per pound gain.

APPENDIX D

TABLE 8. ANALYSIS OF VARIANCE OF AVERAGE DAILY GAINS FOR SUMMER OF 1974

Source	Degrees of Freedom	Mean Squares	F-Value
Treatment ^a	2	0.2417	1.79 [†]
Sex	1	0.0002	1
Treatment by Sex	2	0.0506	1
Within	34	0.1351	

^aConventional concrete slab, unfanned slatted floor, or fanned slatted floor.

[†]_p < 0.10

VITA

Gary Douglas Miller was born in Newport, Tennessee on December 1, 1950. He attended elementary school in that city and was graduated from Cocke County High School in 1968. The following September he entered the University of Tennessee; and in August, 1972, he received the Bachelor of Science Degree in Agricultural Engineering. In the fall of 1972 he accepted a research assistantship with the University of Tennessee Agricultural Experiment Station and began study toward the Master of Science Degree in Agricultural Engineering. He received this degree from the University of Tennessee in March, 1975. He is a member of Phi Eta Sigma, Alpha Zeta, Gamma Sigma Delta, and Tau Beta Pi honorary societies and a student member of the American Society of Agricultural Engineers.