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An experimental investigation of the effects of baffles on the agitation and removal of manure solids from a liquid manure holding tank

Frederick Griffin Scholfield

To the Graduate Council:

I am submitting herewith a thesis written by Frederick Griffin Scholfield entitled "An experimental investigation of the effects of baffles on the agitation and removal of manure solids from a liquid manure holding tank." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Biosystems Engineering Technology.

John I. Sewell, Major Professor

We have read this thesis and recommend its acceptance:

B.L. Bledsoe, D.O. Baxter, Summer A. Griffin

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Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

September 10, 1969

To the Graduate Council:

I am submitting herewith a thesis written by Frederick Griffin Scholfield, Junior, entitled "An Experimental Investigation of the Effects of Baffles on the Agitation and Removal of Manure Solids From a Liquid Manure Holding Tank." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Mechanization.

John I. Sewell

Major Professor

We have read this thesis and recommend its acceptance:

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AN EXPERIMENTAL INVESTIGATION OF THE EFFECTS OF BAFFLES ON THE AGITATION AND REMOVAL OF MANURE SOLIDS FROM A LIQUID MANURE HOLDING TANK

A Thesis
Presented to
the Graduate Council of
The University of Tennessee

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

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by

Frederick Griffin Scholfield, Junior

December 1969

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ABSTRACT

Adequate information on which to base efficient designs of internal baffles in liquid manure holding tanks is not available. Laboratory models constructed to one-fifth scale of a prototype liquid manure system were investigated. The agitation nozzle, baffles, and pumping rates were also modeled. Peat moss was used to simulate scaled cow manure. The laboratory test consisted of the following tank arrangements: (1) no baffles, (2) center baffles, (3) side baffles, and (4) side and center baffles. The following conclusions were drawn: (1) the use of the three baffle arrangements decreased the amount of solids left in the tank, and (2) the geometric placement of the agitator nozzle in this study and the use of baffles had a favorable effect on slurry agitation. The least effective was the tank with no baffles, and the most effective treatment was with the side and center baffles.

The results of the test conducted in the model tank were evaluated on the basis of volume of settled solids left in the tank above a slurry base level of 1.5 inches. Based on the volume of solids buildup above the base level, these tests showed that a significant difference in the removal of settled solids existed between each of the four treatments.

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CHAPTER I

THE PROBLEM

I. INTRODUCTION

Confinement of farm livestock and increasing numbers of animals per unit of area have caused inherent problems in the handling and disposal of manure. Highly concentrated rations and confinement have increased the liquid content of animal waste. This change in animal waste consistency has made difficult the handling of manure by conventional manure handling equipment.

Because of the rising cost of labor and the lack of available farm labor, the livestock producer has had to turn to mechanized methods for many farm practices. The producer must try to place some economic value on the liquid manure system. The areas of economic returns in a liquid manure system are: (1) time saved in the handling of manure, (2) nutrients saved, and (3) increased crop production. Johnson (7) states that approximately $4.23 per ton of excrement from dairy cattle can be obtained if liquid manure systems are properly managed. The costs of liquid manure systems are varied. The average cost is approximately $9,000 for an 8,000 cubic foot tank, agitation equipment, and spreading equipment.

Techniques of handling liquid manure on the farm are varied, but the most common system consists of: (1) a holding tank, (2) a means of transporting the manure from the confinement area to the tank which is usually accomplished by washing or scraping the area, (3) a device for mixing and agitating the waste after it is in the tank, (4) a method for the removal of manure from the holding tank, and (5) a method for transporting and spreading the slurry.

Many satisfactory liquid manure agitators and spreaders as well as a few tanks are on the commercial market and available to the producer. However, these systems do have inherent problems; and as these systems are put into operation, it should be noted that they are probably not the final answer to liquid manure handling and disposal. One of the most important problems faced by producers is the agitation of waste in the holding tank (12). The purpose of agitation in the holding tank is to raise the mass of solids from the bottom of the tank and to break up islands of floating material thereby forming a uniform slurry of suspended material which can be pumped from the tank leaving as little settled solids in the tank as possible. Commercially, the most popular type of agitating device is the recirculating centrifugal pump with some type of disintegration tool which allows a steady flow of material to the pump intake opening.

Factors to be considered in the initial design of the holding tank are its shape and obstructions inside the tank such as baffles. Definite information about shape and placement of baffles must be available before an efficient liquid manure system can be properly and adequately designed.

II. SCOPE OF THE STUDY

The objectives of this study were: (1) to determine the effects of various internal baffles on the agitation of manure solids in a rectangular liquid manure holding tank, and (2) to provide information necessary for the most effective placement of internal baffles in a rectangular liquid manure holding tank.

The rectangular tank used in this study was designed by C. R. Mote (8) according to the principles of similtude. In the model studies four conditions were used: (1) no internal baffles, (2) center baffle, (3) side baffles, and (4) side and center baffles. Attempts to eliminate the effect of variables such as nozzle discharge, nozzle location, nozzle rotation, moisture content, viscosity, and time were made throughout the four conditions tested.

CHAPTER II

REVIEW OF LITERATURE

I. THE LIQUID MANURE SYSTEM

In recent years the methods of livestock production have been anything but conventional. The development of mechanical material handling devices and improved means of transportation have made possible the housing of large numbers of animals in confined areas where no more than 100 square feet per dairy cow is allowed. The normal separation that once existed between the rural and populated areas has in many locations disappeared. With current urbanization, odors, the threat of disease and environmental pollution, and public scorn have made the disposal of livestock waste a public problem.

The trends toward confinement of livestock have left the producer with waste material in a form that is not easily handled by conventional manure handling equipment. The producer is now facing the problem of handling manure with a high moisture content which is here referred to as liquid manure. Thus potential savings in labor, flexibility of operations, possibilities for more sanitary conditions, and other economic returns have given rise to much of the current interest in liquid manure systems.

To some producers the liquid manure handling system implies an end to the waste disposal problem. However, to many other persons it implies many new problems to be solved. As simple as the problem of liquid waste disposal may appear, the disposal system must be compatible with the confinement operation. To make a liquid handling system compatible with current economic considerations, the recent labeling of waste as an uneconomical troublesome and worthless byproduct must be changed to approach it as a break-even or a profitable byproduct.

Some of the current problems associated with liquid manure systems are installation and equipment cost, availability of land on which to spread the manure, odors and insects after spreading, and problems in agitating and pumping. A satisfactory liquid manure system should provide operational advantages and increased nutritional value for crops. Operational advantages include (1) convenient spreading cycles, (2) reduced time and labor, and (3) improved sanitary conditions. Nutritional gains are (1) more liquid wastes can be retained to spread on crops, (2) leaching losses are lessened, and (3) fields can be covered with the manure slurry when optimum results can be obtained.

Schacht (12) discussed the following two basic types of liquid manure systems: (1) slotted floor storage, and (2) collected manure that is moved to a separate storage area. The first system, with the use of slotted floors, is more suited for swine production; and it is beneficial in development of cleaner animal habits. The second system is more suited for dairy cattle production where the manure is collected and moved to a holding tank.

The components of the liquid manure handling system are equipment for collection, storage, agitation, and removal of manure (11). Collection of feces and urine from the confinement area should be done at regular intervals to prevent nutrient loss, animal diseases, odors and to promote cleaner animal habits (4).

The storage period afforded by the holding tank is the main advantage of a liquid manure system. It allows the operator to store valuable nutrients, reduce odors and disease, and to assist in the control of the manure spreading schedule for the operation. Schacht (12) stated that storage tank size determination is usually based on the following factors: (1) number of animals, (2) amount of waste, (3) equipment limitations, (4) number and type of tanks, (5) storage time and, (6) economical construction. Tank dimensions should not exceed the following limitations. Round, square, or rectangular tanks should have a maximum depth of 12 feet. Roung tanks should not exceed 24 feet in diameter, and rectangular tanks should not exceed an area of 20 feet x 40 feet. These size limitations are necessary because agitation problems may be encountered in larger tanks. All pits should be covered, and the covers should be able to support farm tractor loads. Adequate openings for agitation and scrape-in are a must in every system (12).

Many types of agitators are available to operators of liquid manure systems; however, two types of agitators seemed to have gained acceptance over the others. The first of these is the recirculating centrifugal pump. This type of pump is submerged in the pit, and it usually has a pumping rate of about 2500 gallons per minute. The pump is usually equiped with some type of disintegrating tool which allows for the smooth flow of matted or clumped material into the pump opening. The recirculating pump usually serves a dual purpose of agitating and emptying the pit.

The second method, auger agitation, is best suited for agitation of heavy manure which is manure of lower moisture content than is usually pumped by recirculating pumps. Augers are used to their best advantage when a separate method of emptying the tank is available. Most auger systems contain knives that cut the matted or clumped material found in the tank.

The manure slurry is removed from the holding tank with the agitation pump or a separate pumping system. The spreading or distribution of the slurry on the field is done by two methods. One is by a specially designed sprinkler irrigation system equipped to handle liquid manure. The other system, which is more often used, consists of large mobile tanks equipped with field spreading mechanisms and large low-pressure flotation tires to prevent field compaction. The liquid manure tanks usually range in size from 1000 gallons to 1625 gallons, and they have built-in agitating and pumping systems which are usually power takeoff driven.

II. HOLDING TANK AGITATION

Shaw (14) defined liquid manure as having a moisture content above 95 percent and a simi-liquid slurry as having a range of 88 to 95 percent moisture. In eight dairies using liquid manure systems, the average moisture content of the liquid manure was 91.5 percent on a wet basis, and an average density was 8.5 pounds per gallon (14).

Agitation in a liquid manure system must be efficient so that excessive quantities of solids will not remain in the holding tank after emptying. Holding tank size and percent moisture of manure are two factors that greatly affect recirculation time. The average time required to agitate a 20 foot x 40 foot x 10 foot pit holding 50,000 to 60,000 gallons of manure at 91.5 percent moisture is about four hours (14).

Agitation in the holding tank is greatly affected by proper management before, during, and after the emptying and filling of the tank. Manure reaching the tank will usually have a moisture content of 75 to 80 percent; but under very hot and dry conditions, the moisture content will drop to 50 to 60 percent. Therefore, water must be added in order to have a workable semi-liquid. Peterson (11) recommended that water should be available so that during dry periods the proper consistency of the slurry can be maintained by the adding of water. This water aids in the removal of solids from the scrape-in openings and prevents the filling of the tank to the point that necessary water cannot be added for adequate agitation.

Shaw (14), in his model studies of flow lines in liquid manure agitation, found that the most efficient nozzle position for agitation was one in which the distance to the farthest wall was the shortest. Shaw's models did not employ baffles. He stated that agitation in a rectangular tank was possible from one position if the nozzle were located near the center and the discharge directed against the farthest wall. He also stated that the effective agitation distance for a given pump depended upon the moisture content, density, and viscosity of a manure slurry.

Holding tanks should be designed with economy of construction in mind. Schacht (12) stated that if a tank were round, square, or rectangular, the shape had little effect on the efficiency of a system provided the system was properly designed with reference to columns, baffles, and openings.

Schacht (12) stated that the maximum size for a rectangular tank should be 20 feet x 40 feet x 10 feet. He also reported that round tanks have an advantage over rectangular tanks in agitation efficiency. However, he stated that if a dividing baffle is used in the rectangular tank, the agitation efficiency of the round tank can be approached.

Mote (8) stated that the use of a center baffle in a rectangular tank where the agitation nozzle was located midway between the center of the baffle and one side of the tank greatly impaired the removal of solids from rectangular tanks. He also stated that circular tanks had no apparent advantages over rectangular tanks in agitation efficiency and that continued agitation after the solids were suspended did not increase the quantity of solids removable.

CHAPTER III

LABORATORY MODEL

I. SCALING AND MODELING THEORY

Due to the large sizes of the prototype holding tanks at the experiment stations of The University of Tennessee, it was not possible to conduct full-scale agitation experiments. Therefore, a laboratory sized model of the prototype tank was constructed so that extensive investigations into the effects of baffles on agitation could be conducted in a relatively short period of time.

Scaling of the model tank from the prototype gave a length factor of five. The equation for the length factor was $n = L/L_m$ where n is the length factor, L is the prototype length, and L_m is the length of the model. From this equation, all parts of the model were constructed at one-fifth the size of the corresponding parts of the prototype.

Finding a material simulating manure which had a length factor of five was difficult. Although Michigan peat moss did not have a factor of five, it was chosen to simulate manure because of its physical likeness to manure and its shorter fiber length than manure. This failure to exactly satisfy the criteria specified in the above model equation made the model a distorted model.

The water-saturated peat moss selected for use in the model was found to have a viscosity range of 147 to 188 centipoises at temperatures of 79 to 80 degrees Fahrenheit which was similar to the values for dairy cattle manure viscosity found by Mote (8). The peat moss used in the test had a favorable advantage of being able to be used repeatedly and of not giving off noxious odors or harmful gases.

A centrifugal 1.5 inch x 1.5 inch, Gorman-Rupp, solids handling pump (Figure 1) was used because of its capability for handling solids at a low rate of discharge. Froude modeling was used in the calculations of the agitation nozzle size and pump capacity according to $Q_m/Q_p = (L_m/L_p)^{5/2}$ where Q_m is pump discharge for the model, Q_p is the pump discharge for the prototype, L_m is length scale for model and L_p is the length scale for the prototype. The pumping capacity for the prototype Q_p is about 2,500 gallons per minute; and from the above relation where L_m/L_p is 0.2, Q_m was calculated to be 44.5 gallons per minute. The agitator nozzle size in the prototype is 6 inches; and again using n = 5, the model nozzle was constructed 1.2 inches in diameter.

II. PHYSICAL MODEL

The model tank scaled from the prototype according to n = 5 gave the model a practical size of 8 feet x 4 feet x 2 feet deep for laboratory work. The tank depth was increased by 6 inches to prevent overflow of the peat moss slurry during agitation. Mote (8) constructed the model tank of three-fourths inch marine plywood which was glued and nailed to a wooden frame of 2 inch x 4 inch members (Figure 2,3). A non-hardening water-proof caulking compound was used to seal all of the interior seams. A galvanized steel circular tank six feet in diameter was used as a holding tank for the model.

Figure 1. Trash pump used for agitating and emptying of the model tank.

Figure 2. Inside of model tank with no baffles,

Figure 3. Model tank and pumping equipment.

A center baffle 4 feet x 2.5 feet was constructed of three-fourths inch marine plywood. Figure 4 shows the center baffle installed in the model tank. Two side baffles 8 feet x 11.25 inches and constructed of three-eights inch plywood were nailed and caulked to the model tank. Nelson et al, (9) reported that surface velocity in manure agitation should be at least one foot per second. This writer chose to use the side baffles in the model tank to try to increase the surface and sub-surface velocities of the tank thereby increasing the amount of solids being held in suspension. Figure 5 shows the side baffles installed in the tank. Figure 6 shows both the center and side baffles installed in the model tank.

Figure 7 shows the variable-speed motor, Gorman-Rupp 1.5 inch x 1.5 inch centrifugal solids handling pump, and the central valves for the intake and discharge lines. The pump was operated at an average discharge rate of 45 gallons per minute.

The discharge and suction sides of the pump were each connected by flexible hoses to 3-foot lengths of 1.5-inch galvanized pipe. The 3-foot lengths of pipe were fastened to a metal bracket which allowed them to be moved vertically or rotated (Figure 5). The bracket was in turn fastened to a section of angle iron placed laterally across the tank. The bracket could be moved laterally on the angle iron support, and the support could be moved along the long axis of the tank. This arrangement allowed the agitator to be located at any position inside the tank.

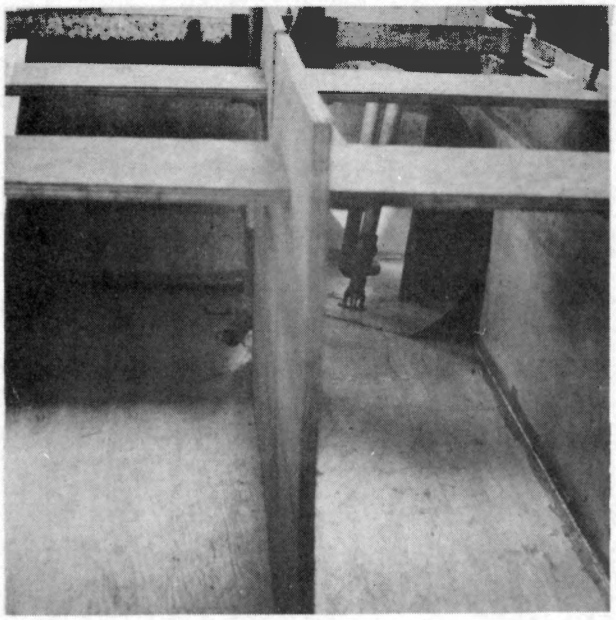


Figure 4. Tank with center baffle.

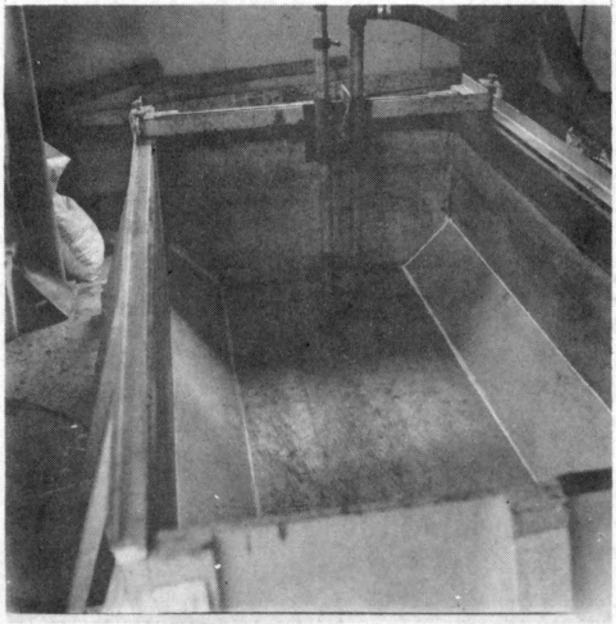


Figure 5. Tank with side baffles and brackets.

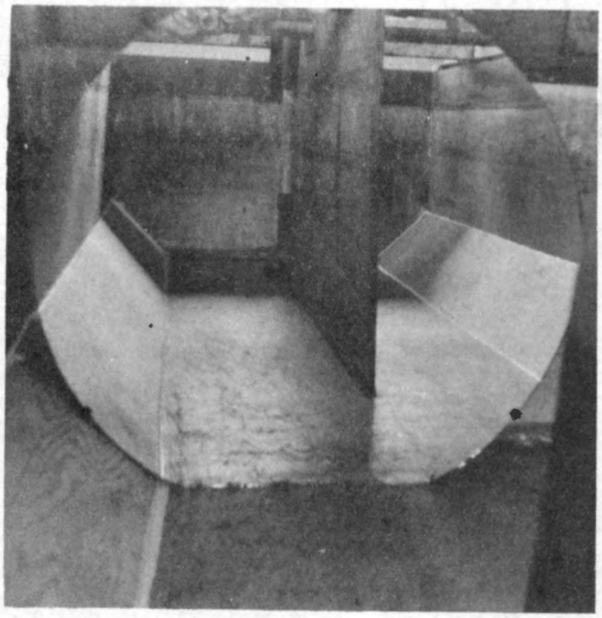


Figure 6. Side and center baffles installed in tank.

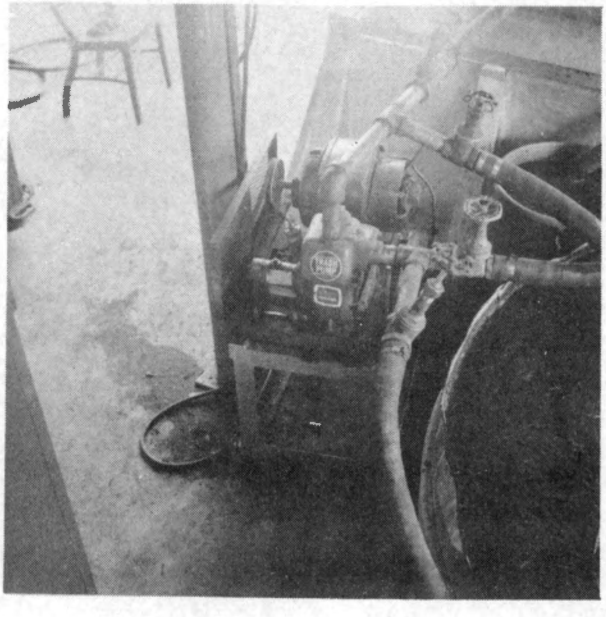


Figure 7. Pump and control valves.

A 90-degree elbow was fastened to the discharge pipe, and the elbow was fastened to the scaled nozzle which provided a discharge stream parallel to the bottom of the tank. Two valves were placed in both the suction and the discharge lines so that at the end of agitation periods, the discharge could be diverted into a holding tank where it could be stored until the next experiment.

CHAPTER IV

PROCEDURE

I. AGITATION TESTS

For each series of tests run, the agitator was located 73 inches from the farthest end and 22 inches from the right side of the 4 foot x 8 foot tank. The intake nozzle was located six inches to the left and four inches to the rear of the agitation nozzle. Shaw (14) stated that, based on his studies of flow lines in model tanks, the most efficient agitation in liquid manure holding tanks could be obtained by placing the agitation nozzle so that the distance to the farthest wall of the tank was as short as possible. The agitation nozzle was placed 1.5 inches above the bottom of the tank, and the intake nozzle was placed on the bottom of the tank. The variable-speed electric motor driving the pump was set to maintain as nearly as possible an average discharge rate of 45 gallons per minute. The discharge rate was calibrated by measuring the volume collected for a known period of time.

The model tank was loaded with 300 pounds of dry matter, and water was added until a volume of 479 gallons was obtained. The initial mixture was thoroughly agitated and allowed to settle. A settling time of four hours before unloading was used as a minimum time between replications.

Each agitation period was for thirty minutes. The initial direction of the slurry flow was counter clockwise with the agitation nozzle directed at the right side of the tank at a point 24 degrees from the center line of the agitation nozzle position. The nozzle was left in that position for nine minutes, then the nozzle was rotated 307 degrees in a clockwise direction. This rotation was accomplished in one minute. The nozzle was left in the new position for nine minutes, then a reversal of the first rotation was done to place the direction of flow back in its original position. The nozzle was left in the original position for the remaining ten minutes of the agitation period.

Moisture and viscosity samples were taken in the main stream of discharge from the agitator after 29 minutes of agitation. After removal of material from the tank by pumping, final moisture and viscosity samples were taken. Before taking these samples, the settled material was agitated with a shovel.

At the end of the agitation period, the slurry was pumped into a holding tank at a maximum rate of 55 gallons per minute. Measurements of buildup in the model tank were made by a template (Figure 8). The depth of the slurry left in the tank after each cycle was measured, and the weight and volume measurements were calculated. The percent of total dry matter left in the tank was derived from volume and weight calculations which will be described later.

II. MOISTURE EVALUATION

The moisture content of the peat moss slurry was determined by taking two samples of the slurry, in the main stream of discharge from the agitator, at 29 minutes into the agitation cycle. Moisture samples

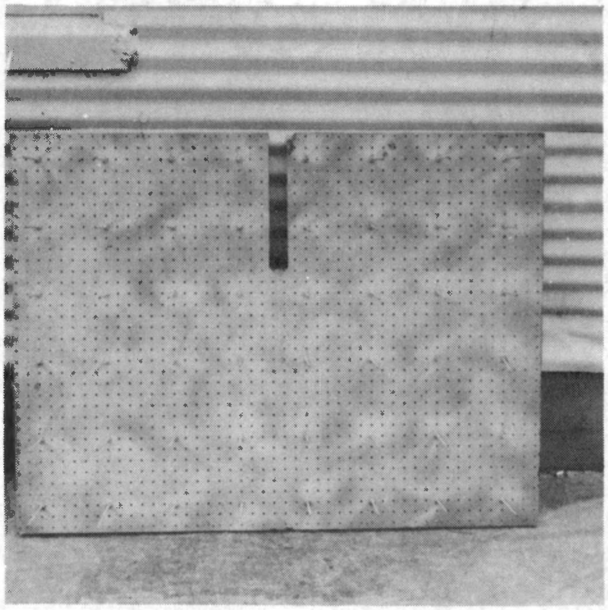


Figure 8. Templet used to measure solid deposition.

of 50 grams were weighed and oven dried at 80 degrees centrigrade for eight hours and at 105 degrees centigrade for one hour. Moisture samples were also taken of the material left in the model tank. These samples were taken after the material was agitated by the operator with a shovel to obtain a uniform slurry of settled solids left in the tank. The moisture content for this study was maintained at 92.5 percent which is equivalent to a dry matter content of 7.5 percent by weight. Moisture calculations were made by dividing the weight of the dry matter plus water weight into the weight of the dry matter.

III. VISCOSITY EVALUATION

Viscosity values were determined with a Mac Michael viscosimeter equipped with a 30-gauge centrified torsion wire, a one-centimeter cylindrical plunger, and a 185-mililiter sample cup filled to a depth of 4 centimeters. The rotation speed of the sample cup was 54 revolutions per minute. Viscosity values for the slurry in the model tank were maintained between 147 and 188 centipoises. Viscosity values of 144 to 175 centipoises were found in manure slurry by Mote (8). Viscosity tests conducted on the peat moss slurry used in the study were determined by taking a sample of the slurry at 29 minutes into the agitation cycle.

The temperature of the peat moss slurry was determined by placing a thermometer in the slurry for five minutes before viscosity samples were taken for both the initial and final viscosity samples.

CHAPTER V

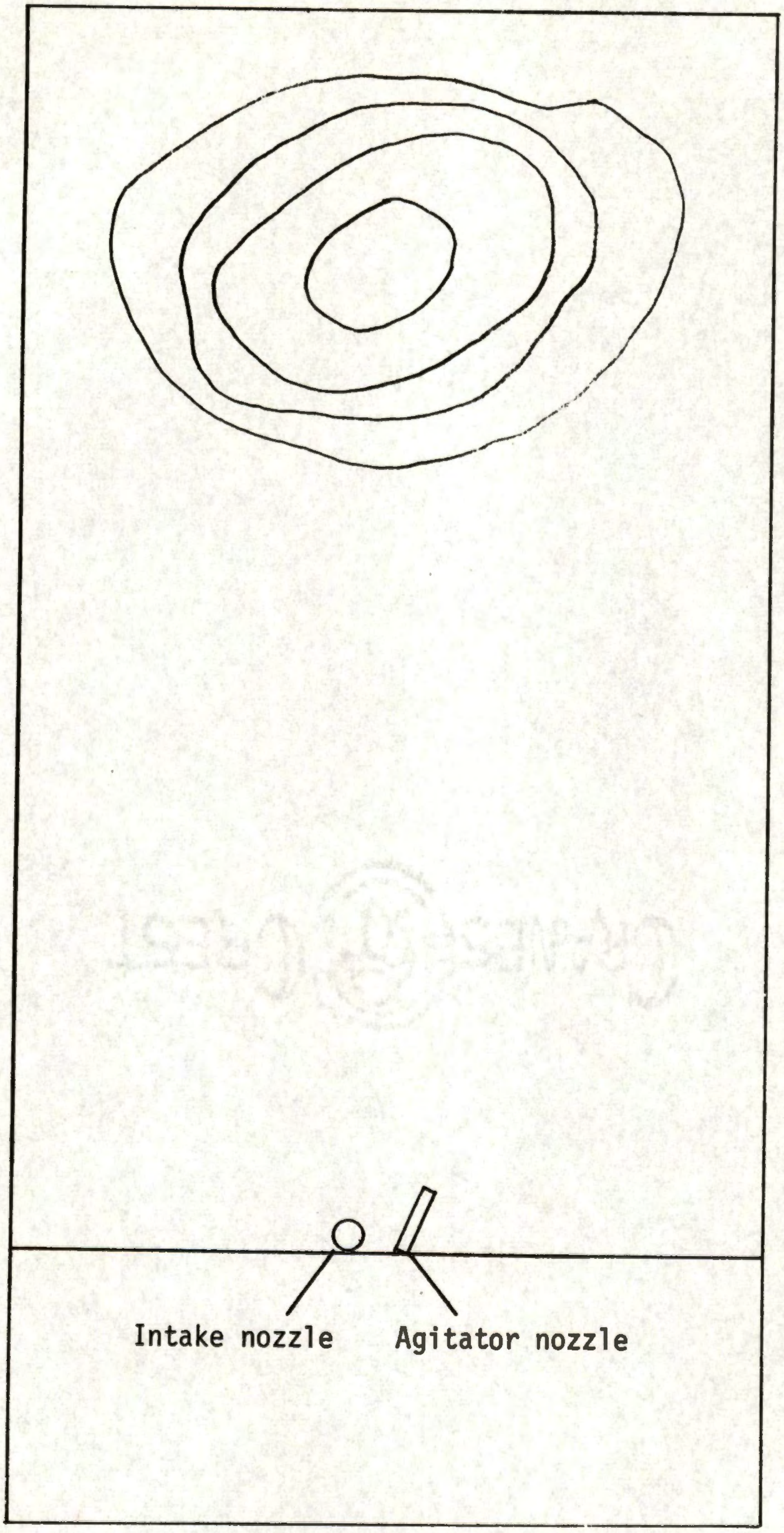
RESULTS AND DISCUSSION

I. LABORATORY TESTS

Little difference was observed between replications of the same treatment on the deposition of solids in the model tank. The topography and the percent of dry matter were relatively constant between replications of the same treatment. The treatments were: (1) no baffles, (2) center baffles, (3) side baffles, and (4) side and center baffles.

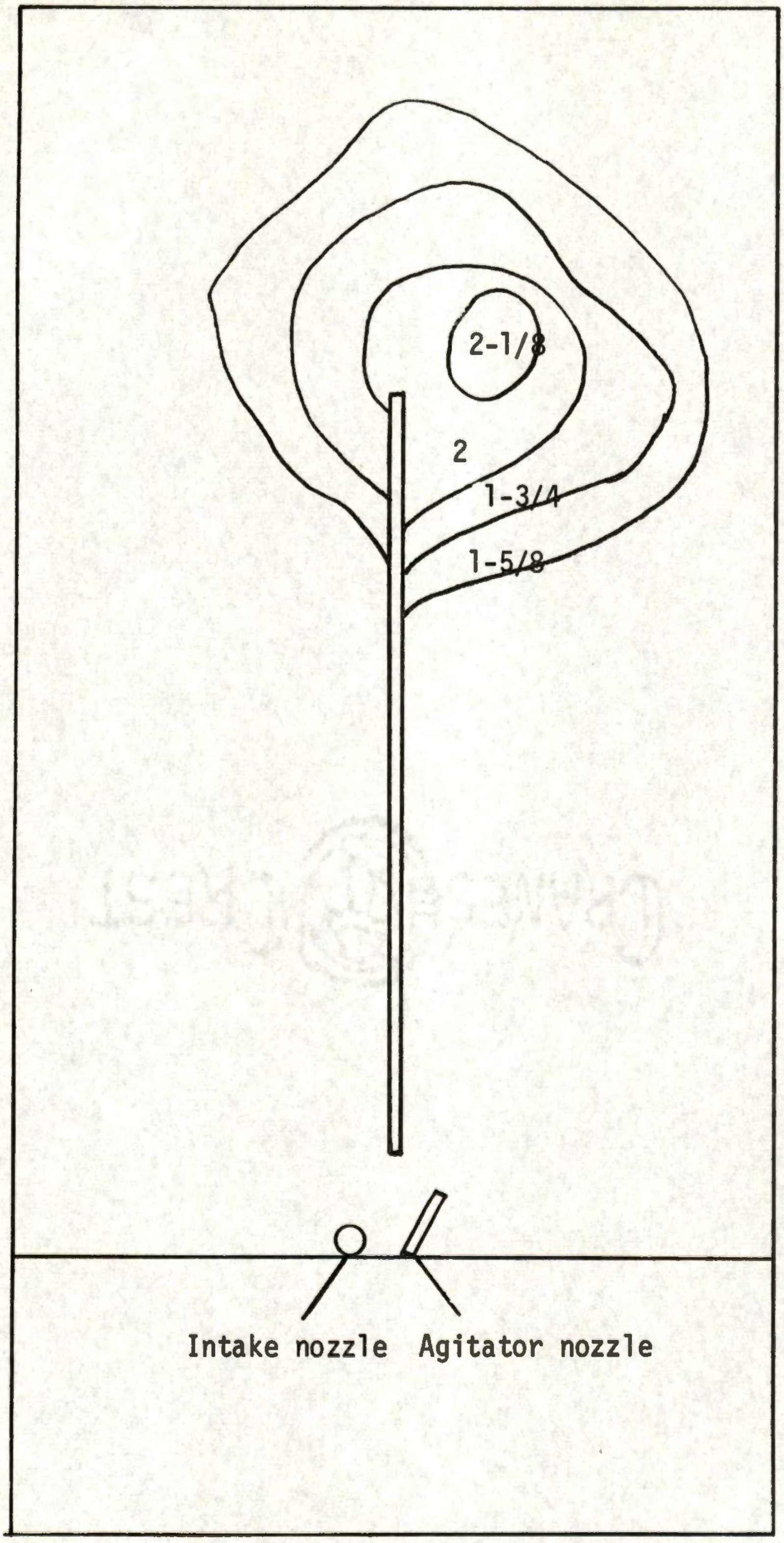
Observation of the topographic sketches shows the general topography and position of the settled solids in all of the treatments studied except the one with side and center baffles where no deposition of solids remained in the model tank. The buildup of solids in the first, second and third treatments was found to accumulate at the end of the tank farthest from the agitator (Figures 9, 10, 11).

In the sketch without baffles (Figure 9), it can be observed that the buildup of solids is located at the end of the tank farthest from the agitator nozzle. During agitation of the peat moss slurry, a counter clockwise surface swirl was observed above the solids buildup. The use of a center dividing baffle significantly decreased the solids buildup; however, the surface swirl was decreased but not eliminated. The solids buildup was again located at the farthest end of the tank from the agitator nozzle (Figure 10). The results of the study with the center



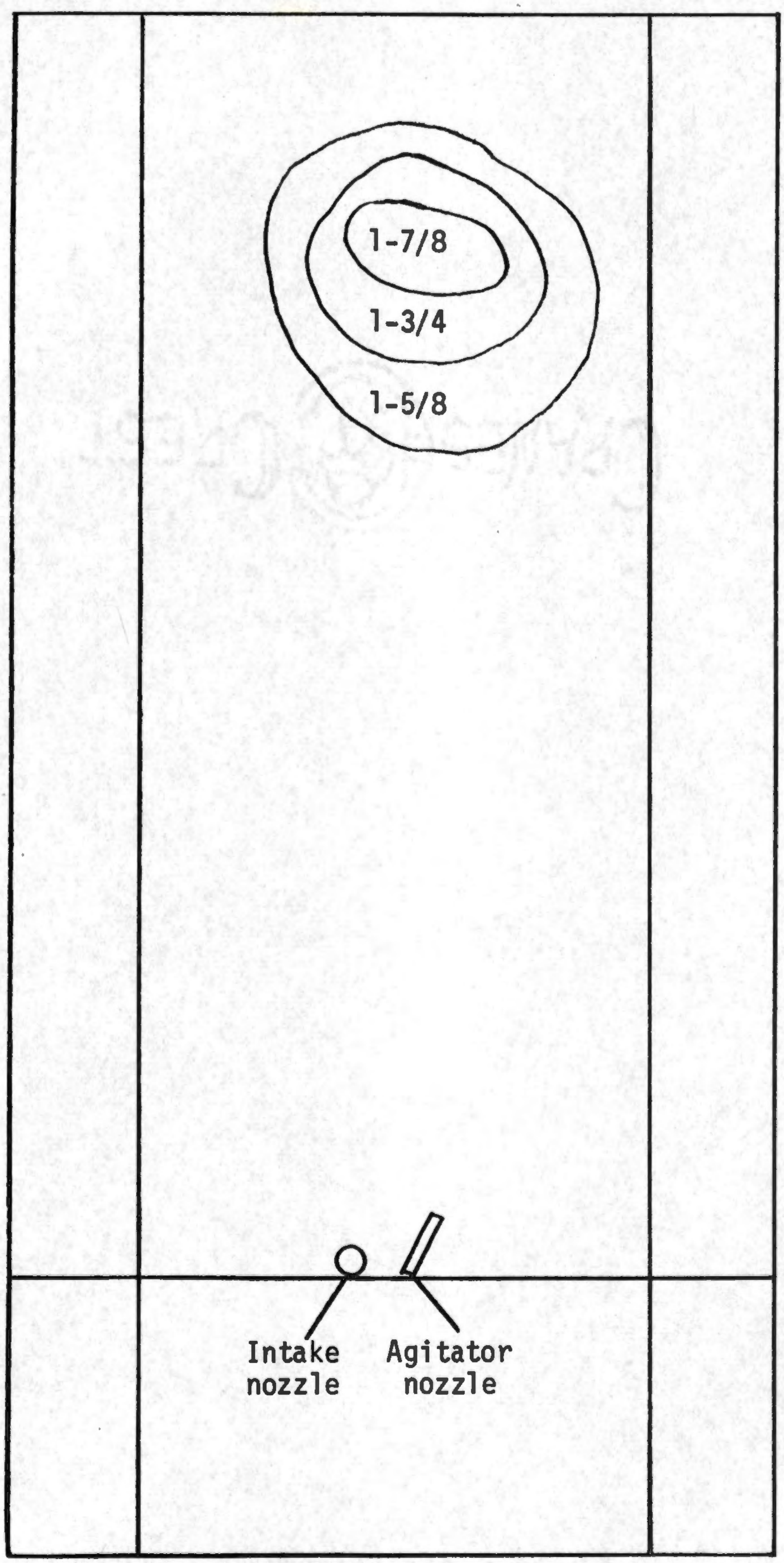
Legend: ----2.0----depth in inches of sediment

Figure 9. Typical topographic sketch of solids deposition above the base level in the tank with no baffles.



Legend: ----2.0----depth in inches of sediment

Figure 10. Typical topographic sketch of solids deposition above the base level in the tank with a center baffle.



Legend: ----15/8----depth in inches of sediment

Figure 11. Typical topographic sketch of solids deposition above the base level in the tank with side baffles.

dividing baffle would tend to suggest that elimination of the counter clockwise swirl in the tank arrangement without baffles (Figure 9) would also markedly decrease solids buildup.

The use of side baffles in the model tank (Figure 10) significantly decreased the solids buildup (Table I); but again, the surface swirl was not eliminated. The surface velocity of the entire tank was noticeably increased. In the fourth treatment of side and center baffles (Figure 11), the surface swirl was eliminated; and a marked increase in surface turbulence was observed by the operator. A significant reduction (Table I) in the solids left in the model tank as compared to the other treatments of the study was observed.

The findings indicate that when more than one agitator opening is to be provided in a tank, the agitator openings should be placed at opposite ends of the tank when tank geometries are similar to those of treatments one, two and three. Periodic rotation of the agitator from one position to another would probably decrease the solids deposition in the holding tank under these conditions.

An analysis of variance of the volume of settled solids above the base level of 1 1/2-inches was conducted. The 1 1/2-inch base level was determined by measuring the pumping level of the intake nozzle of the recirculating pumping system. The analysis of variance table for the four treatments is presented in Table II. Raw data for the table is given in Table I.

In the investigation of the effects of the internal obstructions on solids removal, the difference between replications was insignificant.

TABLE I

VOLUME OF PEAT MOSS REMAINING IN THE TANK ABOVE THE BASE LEVEL

Test Conditions[a]	Rep. 1	Rep. 2	Rep. 3	Mean[c]
1	0.97[b]	0.98	1.01	0.99
2	0.47	0.39	0.49	0.45
3	0.16	0.10	0.14	0.13
4	0.00	0.00	0.00	0.00

[a]1, tank without baffles; 2, tank with center baffle; 3, tank with side baffles; 4, tank with side and center baffles.

[b]Volume of settled solids in cubic feet above the base slurry depth of 1.5 inches remaining in the tank.

[c]The least significant difference between means is 0.062 cubic feet at the 0.05 level.

TABLE II

ANALYSIS OF VARIANCE

Source	DF	SS	Variance	F Test
Total	11	1.744		
Treatments	3	1.732	.5773	444.08**
Replications	2	.004	.002	1.538
Error	6	.008	.0013	

**Indicates significance at the 0.01 level.

However, a significant difference was found between treatments as shown by an "F" test taken at the 0.01 level of probability (Table II).

A test for the least significant difference in means was run to compare means of Table I at the 0.05 probability level and a significant difference was found between the means of all of the treatments. The results of this test differ with the findings of Mote (8) in that he found a center baffle to impair the removal of solids from a rectangular tank. The difference between Mote's findings and those of this study is probably due to the geometrical location of the nozzle and nozzle design. In Mote's study, the nozzle was located midway between the center of the baffle and one side of the tank rather than in the end of the tank and approximately in line with the baffle as in this study.

The differences between the results produced by the three treatments with baffles and the treatment without baffles were significant based on the deposition of solids after pumping. The test indicated that side or center baffles used under conditions of these tests will improve the ability of the agitator to put larger amounts of settled solids into suspension during agitation. The use of side and center baffles together greatly increased the removal of solids from the model tank. These results on the use of a center baffle are in agreement with the proposal of Schacht (12) that a center baffle would improve agitation in a rectangular tank.

III. FIELD INVESTIGATION

The liquid manure tanks at The University of Tennessee's Experiment stations at Lewisburg and Spring Hill were examined on April 22, 1969.

These two tanks were of the same type concrete construction with concrete supporting columns. The tank at Spring Hill had just been emptied, and five to six days of scrapings were in the tank. The depth of solids settled in the tank was measured with a probe and was found to be 4 to 6 inches. The tank at the time held about 2 3/4 feet of liquid. The tank at Lewisburg was being emptied, and a probe of settled solids was taken when the tank was almost full. Settled solids were found only under one drop opening and in a very small area farthest away from the agitation nozzle. The depth of the deposit was five inches. Samples of settled material from the Lewisburg and Spring Hill tanks were taken to determine the amounts of rock and gravel by volume in the tanks. The Lewisburg sample had no rock or gravel, but the Spring Hill tank had 5.8 percent rock and gravel by volume.

The rock and gravel found in the sediment of the Spring Hill tank probably came from the construction of new concrete lots at the station. Steps should be taken to minimize the introduction of this type of material into the tank because of possible damage to pumping and agitation equipment. A continuance of rock or gravel buildup in the tank would suggest the need for employing measures to reduce rock and gravel intake.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Many progressive livestock farmers in recent years have gone to confinement feeding of livestock. This type of operation produces large quantities of manure on a small area. Public demands for better sanitation and waste removal as well as farmers' desire for improved efficiency and labor saving management techniques have given rise to greater popularity of the liquid manure disposal system. One of the major problems in designing a liquid manure holding tank is locating the agitator openings and deciding whether or not to use a baffle; and if one is used, what size it should be. Many questions as to the effects of internal baffles on agitation have caused concern in the minds of prospective liquid manure system owners.

The effects of internal obstructions in a model manure holding tank were studied experimentally by using peat moss to simulate cow manure. The model of the prototype tank was scaled to 1/5 the prototype size. The agitator nozzle and nozzle discharge were also scaled to 1/5 prototype size and $(1/5)^{5/2}$ prototype discharge, respectively.

The tests were run with four different baffle arrangements: (1) no baffles, (2) center baffles, (3) side baffles, and (4) side and center baffles. An analysis of variance of the volume of settled solids above the base levels of the slurry was made.

Based on the model studies of the effects of internal obstructions on the removal of settled solids from a liquid manure holding tank, the following conclusions were drawn: (1) the use of a center baffle decreased the amount of solids left in the tank when the agitator nozzle was located just off the end of the baffle and directed the flow down the side of the baffle, (2) the use of the two side baffles increased the amount of solids held in suspension by agitation, (3) the combined use of side and center baffles decreased the deposition of solids significantly over that of the center or side baffles alone, and (4) the geometric placement of the agitator nozzle and the use of baffles had a favorable effect on slurry agitation.

Schacht (12) stated that the use of a dividing center baffle increased the effectiveness of agitation. Mote (8) in agitation studies where the nozzle was placed midway between the center of the baffle and one side of the tank, found that the use of a center baffle impaired agitation. The difference in the conclusions of Schacht and Mote may be resolved by the conclusions drawn from this research. These disagreements could have been caused by differing geometric location of the nozzles and nozzle design in the two studies.

Further study should be done on the deposition of solids in slurries at higher dry matter contents. Also, the effect of shorter agitation periods on solids deposition should be investigated. By studying shorter agitation periods, optimum time intervals of agitation might be found thereby suggesting a more efficient management program. In future studies the use of an animal manure rather than peat moss should be beneficial.

LIST OF REFERENCES

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1. Giles, R. V., Hydraulics and Fluid Mechanics. New York: Schaum Publishing Company, 1956.

2. Hart, S. A., "The Management of Livestock Manures." Transactions of the ASAE, Vol. 3, No. 2, 1960.

3. Hart, S. A., "This Spreading of Slurried Manures." Transactions of the ASAE, Vol. 7, No. 1, 1964.

4. Hazen, T. E., "The Wiles of Wet Waste." American Society of Agricultural Engineers Paper No. 68-556, 1968.

5. Herum, F. L., G. W. Isaacs, and R. M. Peart, "Flow Properties of Highly Viscous Organic Pastes and Slurries." Transactions of the ASAE, Vol. 9, No. 1, 1966.

6. Johnson, C. A., "Disposal of Dairy Manure." Transaction of the ASAE, Vol. 8, No. 1, 1965.

7. Johnson, H. K., "Streamlined Manure Handling the Liquanine Way." Harvestore Farmer, Vol. 4, No. 1, 1965.

8. Mote, C. R., "An Experimental Investigation of Conditions Affecting the Agitation and Removal of Manure Solids from a Liquid Manure Holding Tank." Unpublished Masters Thesis, The University of Tennessee, December 1968.

9. Nelson, G. L., J. J. Kolega, Ubba Agena, Quintin Graves, and George Hoffman, "Basic Performance Parameters for Oxygenation and Liquid Circulation in Rotor-Aerated Liquid Waste Systems." American Society of Agricultural Engineers Paper No. 68-932, 1968.

10. Ostrander, C. E., "Poultry Manure Disposal." Transactions of the ASAE, Vol. 8, No. 1, 1965.

11. Peterson, C. L., Planning a Liquid Manure Handling System. Idaho Agricultural Extension Service Bulletin No. 478, October, 1966.

12. Schacht, Carroll, "Development of Liquid Manure Handling Equipment." American Society of Agricultural Engineers Paper No. MC-66-204, 1966.

13. Sewell, J. I., and C. R. Mote, "Model Studies of Agitation in Liquid Manure Tanks." Unpublished Paper Presented to the American Society of Agricultural Engineers, February 3-5, 1969.

14. Shaw, R. H., and J. S. Boyd, "Effects of Manure Characteristics and Shape of Tank on Agitation in Liquid Manure Tanks." American Society of Agricultural Engineers Paper No. 68-931, 1968.

15. Speigel, M. R., Theory and Problems of Statistics. New York: Schaum Publishing Company, 1961.

16. Steel, R. G. C., and J. H. Torrie. Principles and Procedures of Statistics. New York: McGraw-Hill Book Company, Inc., 1967.

17. Taiganides, E. P., and R. K. White, "The Menace of Noxious Gases in Animal Units." American Society of Agricultural Engineers Paper No. MC-66-204, 1966.

18. Wolf, D. C., "Developments in Hog-Manure Disposal." Transactions of the ASAE, Vol. 8, No. 1, 1965.

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