THE DEVELOPMENT OF A MECHANICAL CEMENT SPREADER AND ACCESSORIES FOR USE IN SOIL CEMENT CONSTRUCTION

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THE DEVELOPMENT OF A MECHANICAL CEMENT SPREADER AND ACCESSORIES FOR USE IN SOIL CEMENT CONSTRUCTION

SUMMARY

In recent years, it has been found that portland cement combined with certain types of soils produces material suitable for low-cost road and airport construction This type of treatment is referred to as soil-cement stabilization, and numerous civil and military airports have utilized this method in the construction of surfaces and base courses

It has been the general practice to apply the cement to the soil by hand, an operation that, in addition to being slow and labor-consuming, often results in an improper dispersion of the cement

With the approval of the United States Army Air Forces and the endorsement of the Secretary of War, the Technical Development Division of the Civil Aeronautics Administration initiated the project of developing a mechanical cement spreader capable of providing a more speedy and accurate method of applying portland cement to soil that had been prepared for stabilization This project has now been completed and a description of the development and operation of the equipment is contained in this report.

The spreader will give an even distribution of cement over an area 6 feet wide in any controllable amount between 0 3 and 0 75 cubic feet per square yard of surface (approximately 6 to 16 percent by volume of compacted soil for 6-inch thickness) at forward speeds up to 150 feet per minute. The quantity of cement so spread can be controlled within a variation of less than 1 percent based on the volume of compacted soil. The unit is suitable for use with either bulk or sacked cement and is designed to be towed by truck or tractor.

In order that the equipment may be transported to remote combat areas by air, it has been designed so that all units can be broken down into easily assembled parts, each of which will conveniently fit into military transport planes.

INTRODUCTION

The use of soil-cement mixtures for airport paving has been given considerable study by engineers in recent years In this type of construction, the soil to be treated is first prepared by scarifying and pulverizing The required cement is added and the mass thoroughly mixed Water is then added and the soil further mixed, after which the mass is compacted and allowed to cure When the cement hydrates and crystallizes, a new structural material is formed

The soil-cement ratio is different for each type of soil, and it is necessary to determine this relationship by sample tests in the laboratory. In general, an average construction condition will require a cement content of about 10 percent by volume Since depth of treatment is usually 6 inches (thickness of compacted material) there would be required 3 x 3 x 6/12 x 10/100 or 0.45 bags (cu ft) of cement per square yard of surface to obtain a cement content of 10 percent.

Under the present procedure, it is general practice to apply the cement to the ground by hand. This is done by spacing the cement in bags at such transverse and longitudinal intervals as to give the required proportion when spread. For example:

To stabilize a 20-foot roadway to a depth of 6 inches, the requirements per lineal foot for a 10 percent mix would be 20 x 6/12 x 10/100 or 1.00 bag of cement. Therefore, 100 feet of roadway covering 2,000 square feet, would require 100 bags of cement This amount would be proportionately applied by having each sack cover 20 square feet, or one sack should be spotted every 4 feet longitudinally and every 5 feet transversely over the required area

After the bags are in place, they must be broken open, emptied by hand, and the cement spread by garden rakes or by dragging with a spike-tooth harrow. This manual operation is very slow and labor-consuming and, even with painstaking supervision and extended manipulation of the mixture, it was found that under some conditions the resultant distribution of cement did not prove to be uniform, later resulting in pavement failure.

With the increase in airport construction, both civil and military, it was thought necessary to improve and simplify these procedures by the use of a more rapid and accurate method of cement distribution. For this reason the Technical Development Division of the Civil Aeronautics Administration undertook the project of developing a mechanical cement spreader capable of accurately and rapidly applying either bulk or sack cement to the soil in any controlled predetermined proportion. In addition, the entire unit was to be so constructed that, when broken down into easily assembled parts, no one part was to weigh more than 750 pounds and all were to be of such size as to fit into an Army transport plane for shipment by air

Inauguration of this project was approved by Brigadier General L P. Whitten, Director of Base Services, United States Army Air Forces, in a letter dated April 3, 1942, to the Administrator, Civil Aeronautics Administration. Endorsement of the project and certification of its military importance were given by the Secretary of War to the Secretary of Commerce in a letter dated April 21, 1942.

The equipment, developed and built under contract with the Halliburton Oil Well Cementing Company of Duncan, Oklahoma, is now completed, and after thorough laboratory and field testing it has been accepted by the Civil Aeronautics Administration

The development work was divided into two parts, the development of a special spreader for applying the cement to the ground, and the development of a method of storing and feeding the cement to be applied by the spreader. In this connection, it was necessary to provide for the handling of both bulk and sack cement.

THE CEMENT SPREADER

Development of Spreader

The basic requirement for the cement spreader was that it be able to apply a controlled amount of cement evenly over an area 6 feet wide at a predetermined proportion within an allowable tolerance of plus or minus 1 percent of the volume of compacted base.

It was recognized at the start that the machine should incorporate a method of delivering a metered amount of cement per unit of area regardless of the forward speed After a careful study of several methods of mechanical feeding it was decided that screw conveyors would give a higher degree of accuracy and control for this purpose than any other method It was therefore decided to build the machine around this basic principle

The next step was to determine the proper method of diffusing the cement from the screws in order to obtain an even spread on the ground For this purpose a testing device was set up consisting of a 6-inch feeder screw discharging into a small hopper attached to an inclined chute, as shown in figure 1-A. As the cement was discharged, a piece of canvas was drawn underneath the outlet spout to simulate approximate field conditions of spread The deposited material was then observed in order to note the uniformity of distribution

First tests showed the cement to have a tendency to pile up and fall down the steeper side of the outlet spout, resulting in an uneven spread In order to overcome this condition and to obtain a better diffusion of cement before it reached the outlet spout, a small deflector vane was soldered to the inside of the chute (figures 1-B and 1-C) The results of this arrangement showed a fairly even cross section of spread (figure 1-D)

Tests were then conducted in order to determine the minimum size of the inlet opening of the chute A vane was introduced in the opening allowing the size to be varied during tests The minimum size was found to be 1-1/8 inches, smaller sizes than this causing the cement to bridge across the opening, resulting in uneven feeding

Following these tests, preliminary designs were drawn incorporating this type outlet spout However, it was soon realized that the size spout required when using a single feeder screw was too large for practical field purposes Therefore, the design was modified by replacing the single feeder by a series of smaller screws all feeding from a common hopper box, each of which discharged its material to the ground through individual outlet spouts

To test this design under approximate field conditions, a model machine was built using 4-inch feeder screws powered by a chain drive from sprockets welded to the wheels (figure 1-E) The hopper was filled with cement and the machine pulled over a strip of canvas (figure 1-F) Several runs were made and the spread pattern and operating characteristics were studied, but no attempt was made at this time to test the metering accuracy of the discharge screws The results obtained by these experimental runs gave indications that a spreader built on these lines would be satisfactory

With this preliminary information the first experimental unit was built The machine consisted of eleven 4-inch conveyor screws mounted on a frame built on a truck front-wheel axle Power to operate the screws was obtained from sprockets welded to the wheels running on the axle. In order to make it possible for the machine to operate around corners, curves, etc , five of the screws were powered from one wheel and six from the other by means of a split main shaft Between the wheels and screws were a series of reductions and a P.I.V gear transmission[1], allowing an infinitely variable speed control The driving force was supplied by dual truck wheels using 6 00 x 32 tires. The speed ratio between the metering screws and the driving wheels varied with the P.I V. transmission settings and averaged approximately 24 to 1

This unit was tested on a project at Vernon, Texas, and while the results were not entirely satisfactory from the standpoint of a finished machine, considerable information and general operating experience were obtained and incorporated in subsequent developments. Approximately 108,000 cubic feet of cement were spread during

[1]This control of transmission is made possible by the use of a P I V gear as manufactured by the Link Belt Company of Philadelphia To obtain a desired speed the hand wheel is turned, causing a change in the diameter of two pairs of opposing conical wheels The input shaft turns at a constant speed, but the change in effective diameter over which the P.I V. chain travels causes a change in speed of the output shaft Speed changes are made while the drive is in operation and are continually variable, providing an infinite number of speeds within its operation range without steps The gear uses a positive chain drive, eliminating any possibility of a slippage

this test over an area of about 189,000 square yards While 12 percent cement by volume of compacted base was desired on the job, an over all of 12 7 percent was obtained. However, because of slippage of the driving wheels with the high gear ratio mentioned above, considerable variation in daily averages was encountered In addition, several structural weaknesses were noted

A second model was then designed and constructed to eliminate the objectionable features of the first unit The principal changes were:

1 The number of screws was changed from eleven 4-inch to eight 6-inch

2 Chain drives from sprockets on the driving wheels were eliminated and a differential drive incorporated for the power transmission

3 A more rigid frame was built to carry the working mechanisms

4 A larger P I V transmission was used, replacing the two smaller transmissions used on spreader number 1.

5 Larger tires, 7.00 x 20, were used on the driving wheels in order to obtain better traction

6 A single friction type clutch was used to replace the two sliding jaw clutches of model number 1

7 The discharge tubes were reduced in length from 42 to 24 inches

Upon completion of model number 2, calibration tests were run in the laboratory to check the amount of cement delivered against the amount called for by the various dial settings controlling the P I V gear These tests were performed by filling the hopper with cement and then revolving the screws at a known r p m and weighing the amount of material delivered. From these data operational curves were drawn, showing the percent by volume and cubic feet of cement per square yard delivered by the spreader at forward speeds of 0 5 m.p.h , 1 0 m p h and 1 5 m.p h over the complete range of dial settings on the variable speed transmission.

However, model number 2 did not entirely meet required specifications, so a new machine was built similar to it incorporating the necessary improvements.

The principal changes were.

1 A larger and heavier type of P I V transmission was used, the over-all length being 8 inches more than that used on model number 2

2. The frame was built of lighter but structurally stronger material

3 The length of the outlet spouts was increased from 24 to 32 inches because the frame was raised in order to take care of the larger P I V transmission.

4 Two trailing wheels were mounted on each rear corner of the frame replacing the single center wheel of model number 2

5 A new type hitching mechanism was used, allowing the spreader to be fastened to the framework rather than to the axle of the towing vehicle

6 Curved outlet spouts were used so that the cement when discharged would be traveling in a vertical path rather than on a slope as in spreader number 2

This unit, number 3, represents the final development of the cement spreader and is the machine accepted by the Civil Aeronautics Administration as meeting the design specifications

Description and Operation

The principal parts of the spreader assembly are shown in figure 2 The cement is fed from the hopper by eight conveyor screws through individual outlet spouts to the ground The quantity of cement to be spread is regulated by setting the output control dial (graduated to tenths) which governs the gear ratio between the driving mechanism and the conveyor screws by remote control To set the machine to deliver a certain quantity of cement, reference is made to the calibration curves which indicate the dial setting required to deliver the desired amount of cement These curves will be discussed under "Calibration of the Cement Spreader "

Power to operate the conveyor screws is obtained by the forward rotation of the dual wheels which support the spreader This power is transmitted, by the rotation of the axle, through an automobile differential in such a manner that the rate of turn of the conveyor screws is directly proportional to the forward speed of the spreader The speed ratio between the differential drive and the conveyor screw mechanism is controlled by the P I V gear, a positive type variable speed transmission regulated by the output control dial

The driving mechanism for the conveyor screws is powered by a chain linkage from the transmission gear, as indicated in figure 2 The main drive shaft is 1 inch in diameter and is carried on eight radial ball bearings, one for each miter gear, and a combination radial and thrust roller bearing capable of withstanding an applied thrust of 100 pounds The steel miter gears, which mesh with corresponding gears on the eight conveyor screws, are capable of delivering 0 5 hp at 100 r p m The gears attached to the conveyor shaft are fastened by means of 2-1/4-inch x 1/4-inch soft iron shear pins designed to fail under a shearing force of 1,000 pounds In case some foreign object such as nails, bolts, rocks, etc , should become lodged in the screws, these pins will shear, thus preventing possible damage to some vital part of the machinery

Each conveyor screw is carried on two dust-proof ball bearings The bearings on the discharge end of the screws have a radial capacity of 100 pounds at 100 r p m , while those on the hopper end have a combined radial and thrust capacity of 200 pounds at 100 r p m The screws are 5-3/4 inches in diameter with a 6-inch pitch and operate on a 1-1/2-inch shaft in the conveyor tubes with a clearance of 5/16 inches

The driving mechanism can be engaged or disengaged by means of a built-in friction clutch located between the driving wheels and the P I V variable speed transmission. This clutch has a minimum rating of 3 5 hp at 100 r p m and is operated by a conveniently located shifter lever A hand crank is provided so that the conveyor screws can be operated manually when required

The individual outlet spouts, through which the cement is spread from the conveyor screws to the ground, are all built into one section, easily attached to the outlet openings of the spreader Each spout has an outlet size of 6-1/2 inches wide by 4-1/2 inches deep with a 1-1/8-inch space between openings The bottom of these spouts should be between 4 and 6 inches above ground during spreading operations. This distance can be maintained by raising or lowering the adjustable tail wheels.

Figures 3 through 8 show the progressive assembly of the cement spreader All units are bolted or otherwise attached in such a manner as to be easily taken apart and reassembled No hoisting equipment is required since all parts are light enough to be handled manually The heaviest units are the assembly, consisting of the conveyor tubes and hopper box - 740 pounds, the P I V gear and sub-frame - 650 pounds, and the main frame - 470 pounds. Other parts range in weight from 200 pounds down to 10 pounds

The assembled cement spreader, shown in figure 9, weighs 3,800 pounds when empty and in over-all dimensions measures 46-1/2 inches high, 97-7/8 inches wide, and 88 inches long. It is supported on dual wheels using 7.00 x 20 tires The spreader has a discharge capacity range of 25 to 75 sacks of cement per minute over a maximum width of spread of 6 feet. This width can be reduced progressively by blocking off any required number of conveyor screws in the hopper bottom by means of metal covers designed for this purpose (figure 8-D) The spreader can be attached to various sized towing trucks by means of an adjustable hitch having 12 inches of vertical and 9 inches of horizontal adjustment

ACCESSORY EQUIPMENT

Since the specifications required that the spreader be designed to handle both bulk and sacked cement, it was necessary to provide methods for storing and feeding the material for each of these conditions In order to obtain a compact combination of units it was decided to mount this equipment on the towing truck ahead of the spreader.

A collapsible convoy unit with mechanically operated feeder screws was designed to handle the bulk cement, and a manually operated cutting table and feeding chute were devised for use with sacked cement Both methods are suitable for mounting on standard flat bed trucks. The convoy container is built to mount on the truck bed as a unit, while the cutting table and chute are attached to the rear edge of the truck bed leaving ample room for storing sack cement ahead of it. Each method offered separate problems of design

Collapsible Convoy

The principal requirements for the convoy unit were that it be a collapsible container having a minimum storage capacity of 150 sacks of cement, and that it be capable of discharging the cement into the spreader hopper at a rate of not less than 25 sacks per minute No unit part was to be larger than 92 x 65 x 60 inches or weigh more than 750 pounds

From past experience by the Halliburton Oil Well Cementing Company in the handling of bulk cement by large convoy operation, it was decided that the cement should be fed from the storage container into the spreader hopper by means of conveyor screws powered either by a separate motor or by gear arrangements from the supporting truck axle After careful consideration of weight, size limitation, and ease of handling with various sized trucks, it was decided to use a four-cylinder air-cooled gasoline engine for this purpose

Since bent or distorted parts would be hard to take apart and assemble, it was necessary that the unit be built more ruggedly than if it were designed for permanent mounting only To meet these requirements, and at the same time keep within the weight restrictions, it was decided to use corrugated metal welded to flat sheets for the construction Extensive tests were conducted to determine the strength and properties of these fabrications since information on this type structure was extremely meager As a result of the tests it was found that 18-gage corrugated steel welded to a like thickness of flat sheet would be entirely satisfactory

With this information, it was decided to build the convoy unit to consist of a container having removable sides, mounted on a divided hopper composed of two symmetrical halves and containing two motor-driven screw feeders with suitable discharge spouts attached Figures 10 and 11 illustrate the principal parts of the assembly.

The hopper is divided into two symmetrical parts held together by an L-shaped pin at each end and four bolts passing horizontally through the middle cover strip The bottom of each hopper is shaped like a rounded V and carries one conveyor screw and part of the control linkage The sides and ends of each hopper consist of 18-gage corrugated and 20-gage flat steel riveted together with stiffeners placed around the top edge and rigid bracing at the bottom. The V-shaped portion of the hopper consists of a curved 10-gage steel bottom, riveted to 20-gage flat sloping sides, and all welded to stringer bracing Receptacles are provided in the stiffeners around the top edge to receive retaining pins from the convoy side and end panels

As a result of tests and studies of various sized conveyor feeders it was decided that 9-inch screws operating at about 55 r p m. would be most satisfactory Variable pitch screws were used in order to get an even flow of cement, the flight varying from one-half standard pitch at the motor end to double standard pitch at the discharge end Each screw feeder is carried on two self-aligning ball bearings, of the combined radial and thrust type, having a radial load capacity of 1,675 pounds at 100 r p m. All bearings are adequately sealed against cement dust The screws are mounted in the hopper bottom with a minimum clearance of 1/2 inch Baffles are placed at equal intervals above the screws in order to evenly distribute the cement and also to serve as structural members

The conveyor screws carry the cement from the convoy through the discharge spouts into the spreader hopper The discharge spouts consist of two tubes fastened together as a unit by two spacers (figure 11) The tubes have an inside diameter of 10 inches and carry bearings for the screw feeders at the discharge ends The spouts slip over the screw extensions and are bolted to the end panel of the hopper bottom It is necessary that the convoy be mounted forward of the rear axle of the supporting truck; otherwise the front wheels may be raised from the ground For this reason two lengths of discharge spouts and extension screws are provided so that the convoy can be adapted to various sized trucks When the long spouts are used they must be braced by a cable from the rear panel

Bolted to the hopper bottoms are the walls of the convoy which consist of two side and two end panels These are constructed of 18-gage corrugated metal, with corrugations running parallel to the ground, welded to 18-gage flat sheet metal The smooth surface is placed on the inside to offer less resistance to the flow of cement The panels are reinforced by four equally spaced vertical stiffeners and by horizontal stiffeners along the bottom and top edges These stiffeners are made of 10-gage metal and are bolted in place Each vertical support contains a free sliding retaining pin which fits into a corresponding receptacle in the hopper bottom An overhanging canvas flap is fastened to the inside of the bottom of the panels to prevent leakage of cement along the joining edges Folding handles are provided on the outside of the sections for ease in handling during assembly The sides are held together against the outward thrust of the cement by tie rods, 12 through the sides and 9 through the ends

The unit is covered with a canvas top attached to the convoy sides by rope lacing running through 3/4-inch hooks projecting from the top edges of the side and end panels The covering is made to slope toward the edges by means of two supports running across the top of the unit

The motor used to power the conveyor screws is a four-cylinder air-cooled engine rated at 13 8 hp at 1800 r p m In order to keep the engine away from cement dust as much as possible it is mounted ahead of the convoy The mounting is formed of high tensile steel channel and carries, in addition to the motor, the gasoline tank, battery box, chain and sprocket reduction, and part of the control linkage. The mounting is attached firmly to the assembled hopper bottoms by four pins (figure 11)

The driving power is transmitted through the chain reduction to the conveyor shaft by means of a flexible coupling that can be easily separated The chain reduction is well housed and protected from dust. Each gear shaft operates on ball bearing pillar blocks The output sprocket on the final chain drive is attached to a jaw clutch which floats on the shaft carrying the motor half of the coupling These jaw clutches permit the selective engagement of the screw feeders and are controlled by levers attached to the motor mount Remote control linkage is provided so that the engagement of the conveyor screws, the main motor clutch for the engine, and the throttle, can all be controlled from the rear of the convoy by the operator standing on the floor of the spreader This control linkage is divided into three parts, one carried by the motor mounting, one by the hopper bottoms, and the other between the discharge spouts The latter two parts are merely extension rods and can be easily disengaged Figures 12, 13, and 14 show the progressive assembly of the convoy All unit parts are bolted together in such a manner that they can be easily taken apart and reassembled No hoisting equipment is necessary since all parts can be handled by hand The heaviest units are the motor mounting - 575 pounds, the hopper sections - 560 pounds each, and the motor - 330 pounds The side and end panels weigh 238 and 158 pounds, respectively, while other parts range from 150 to 4 pounds The total weight of the convoy is 3,225 pounds.

The assembled unit, shown in figure 15, has a capacity of 160 sacks of cement with a minimum discharge rate of 25 sacks per minute. In over-all dimensions the convoy and motor assembly is 104 inches long, 46 inches wide, and 72 inches high The discharge spouts are furnished in two lengths, 24 and 42 inches, depending on the size truck to be used When not in use the spouts are covered by thin metal plates to prevent leakage of cement. The covers are removed and replaced by canvas socks when operations are begun (figure 14-D) When mounted on the truck the convoy should be tied down firmly to the truck bed by chains in such a manner that the discharge spouts will maintain the proper relation to the spreader hopper.

Collapsible Cutting Table and Chute

In order to adapt the spreader to the use of sacked cement, a special chute and sack cutting table were developed This equipment, shown in figure 16, consists of a manually operated circular saw mounted on a collapsible table with an adjustable chute feeding into the spreader hopper The chute is designed to be clamped to the rear edge of a flat bed truck by means of two screw clamps and can be tilted to the required angle by means of adjustable arms When in operation the chute should be so aligned that the discharge end clears the top of the spreader hopper by about 1 inch and extends over the forward edge about 2 inches The sacks of cement are stored on the bed of the towing truck ahead of the cutting table

The device is operated by placing the sacks singly on the cutting table and drawing them across the saw edge by hand This splits the sacks, allowing the cement to fall through the chute into the spreader hopper

This method of feeding the cement is somewhat slower than that using the convoy, however, four men can handle the cement at a rate of 25 sacks per minute for short durations of time A slower and more continuous run can be had by blocking off some of the spreader conveyor screws (figure 8-D), giving a narrower width of application, and requiring less frequent stopping of the truck for loading cement

CALIBRATION OF THE CEMENT SPREADER

The calibration tests of cement spreader number 3 were made following a procedure similar to that used in testing model number 2 The machine was jacked up from the ground and power was applied to both wheels simultaneously by means of chain drives from a motor During the tests the hopper was kept filled with cement and the r p m of the wheels and the quantity of discharged cement were carefully measured. Knowing the forward travel of the wheels per revolution, and the width and depth of the proposed treatment, it was possible to calibrate the machine in terms of dial setting against output of cement (figure 17 and 18) These calibration curves (larger scale copies of which are included as part of the equipment of each machine) enable the operator to set the transmission control dial at the position necessary to deliver a predetermined amount of cement This quantity may be expressed in either (1) percentage of cement per volume of compacted depth, (2) cubic feet of cement per square yard, or (3) pounds of cement per square yard. In either case the desired dial setting can be read from the calibration curves either directly or after a simple preliminary calculation.

For example, if the quantity of cement required is given in percent volume for a 4-, 6-, or 8-inch depth of treatment, the required dial setting can be read directly from the curves of figure 17. Values for other thicknesses can be computed by proportion, since the required dial setting is a function of the depth of treatment as shown in the explanation of column 13 of the data sheet.

If the quantity is given in cubic feet or pounds per square yard, the dial setting is read from the curves of figure 18. If expressed in cubic feet, the value is read directly, but if expressed in pounds per square yard the value must be converted to cubic feet by dividing by 94 (the weight of cement per cubic foot) before using the curve.

The calibration tests were run through the complete range of dial settings for various rates of forward speed. Results showed that the machine would deliver 0.25 to 1.00 cubic feet of cement per square yard and, further, that within normal operating limits the quantity of cement delivered was practically independent of the forward speed of the spreader (figure 18).

The observed and calculated results of typical check runs on the spreader are shown in the data sheet. For these tests three positions of the dial were chosen, namely, 2.3, 5.1, and 7.2, corresponding to percentages of 8, 12, and 16, respectively, all based on a 6-inch depth of treatment.

The following is a brief discussion of the methods of calculating these results. The numbers (1) to (17) designate the column numbers referred to in the data sheet.

Column (1) - The run number is the number designated to each spread.
Column (2) - Dial setting is the reading of the dial position.
Column (3) - The number of conveyor screws delivering cement from the spreader.
Column (4) - The time in seconds elapsed during each spread.
Column (5) - The number of revolutions of the spreader wheels during the time in Column (4).
Column (6) - The number of revolutions of the conveyor screws during the time shown in Column (4).
Column (7) - The net weight of cement spread in each run.
Column (8) - The r.p.m. of the spreader wheels is obtained by dividing Column (5) by Column (4) and multiplying by 60.
Column (9) - The r.p.m. of the screws equals Column (6) divided by Column (4) x 60.
Column (10) - The distance traveled by one complete revolution of the spreader wheel was measured accurately to be 9.2083 ft.

$$\frac{\text{No. wheel rev. x 9.2083 ft.}}{\text{3 ft.}} = \text{Linear Yds. Spread}$$

Reducing this equation to its simplest form, then,
Linear Yds. Spread = Column (5) x 3.0694.

Column (11) - Square Yds. Spread = Linear Yds. Spread x Width

$$\text{Spread (6 ft.)} = \frac{\text{Column (10) x 6 ft.}}{\text{3 ft.}} = \text{Column (10) x 2}$$

Column (12) - $\text{Lbs. Cement per Sq. Yd.} = \frac{\text{Net Wt. Cement Spread}}{\text{No. Sq. Yds. Spread}} = \frac{\text{Column (7)}}{\text{Column (11)}}$

Column (13) - Each square yard of soil-cement stabilized section 6 in. thick contains 3 x 3 x 0.5 or 4.5 cu. ft.
1 percent by volume, then = 4.5 x 0.01 = 0.045 cu. ft.
The weight of 1 percent by volume = 0.045 x 94 lbs., or 4.23 lbs.

$$\text{Percent by volume} = \frac{\text{Lbs per sq. yd}}{4\ 23\ \text{lbs}} \text{ or, } \frac{\text{Column (12)}}{4.23\ \text{lbs}}$$

Column (14) - Sacks per sq. yd $= \frac{\text{Lbs cement per sq. yd}}{94\ \text{lbs. per sack}}$ or, $\frac{\text{Column (12)}}{94}$

Column (15) - Lbs cement per rev of 8 screws =

$$\frac{\text{Net wt. of cement spread}}{\text{No of rev of screws}} \text{ which} = \frac{\text{Column (7)}}{\text{Column (6)}}$$

Column (16) - Lbs. of cement per rev. of 1 screw $= \frac{\text{Column (15)}}{8}$

Column (17) - The ratio of the number of revolutions of the screws to the number of revolutions of the wheel $= \frac{\text{Column (6)}}{\text{Column (5)}}$

M P H. $= 9\ 2083\ \text{ft} \times \frac{\text{No. wheel rev.}}{\text{Time in Seconds}}$ = Ft per sec traveled

Then, $\frac{9\ 2083 \times \text{No. wheel revolutions} \times 60 \times 60}{\text{Time in Seconds} \times 5{,}280}$ = M P.H.

Reducing this to its simplest form,

$$\text{M.P H} = \frac{\text{Column (5)} \times 6.278}{\text{Column (4)}}$$

TYPICAL CALIBRATION TESTS OF THE CEMENT SPREADER

(1) Run No.	(2) Dial Set.	(3) No. Screws	(4) Time in Sec	(5) Rev. of Wheel	(6) Rev. of Screw	(7) Weight Cement Spread	(8) R p m of Wheels	(9) R p m. of Screw
1	2.3	8	20	3.867	19.653	793 0	11.60	58 96
2	2 3	8	20	3 858	19.603	796.5	11.57	58 81
3	2.3	8	20	3.867	19 711	789 0	11 60	59 13
4	5.1	8	20	3.800	28.347	1130.5	11 40	85.04
5	5.1	8	20	3.808	28 578	1149.0	11 42	85 73
6	7.2	8	15	2 733	26 903	1094 5	10 93	107 61
7	7.2	8	15	3 800	37.606	1582 0	15.20	150 42

(10) Lin. Yds. Spread	(11) Sq. Yds Spread	(12) Lb Cem. Sq. Yd.	(13) Percent by Volume	(14) Sks. Per Sq Yd.	(15) Lb. Cem. Per Rev 8 Screws	(16) Lbs. Cem Per Rev 1 Screw	(17) Ratio Rev. Screw Rev. Wheel
11.87	23 74	33 40	7.90	0.355	40.35	5.04	5.082
11.84	23 68	33.63	7 95	0 358	40 63	5.08	5 081
11.87	23.74	33.24	7 86	0.354	40 03	5 00	5 092
11 66	23.33	48.46	11 46	0.516	39 88	4 99	7 460
11.69	23 38	49.15	11 62	0 523	40 21	5.03	7 505
8.39	16.78	65 24	15 42	0.694	40.68	5 09	9 844
11.66	23.33	67 82	16 03	0 721	42 07	5.26	9 896

Run No.:	1	2	3	4	5	6	7
M.P.H	1 21	1 21	1.21	1 19	1.19	1 14	1 59

FIELD TESTS OF THE SPREADER AND ACCESSORY EQUIPMENT

Road Tests

In order to determine the behavior of the spreader and convoy during transportation to and from construction jobs, road tests under full load and while empty were conducted at speeds ranging from 15 to 42 miles per hour During these tests no leakage of cement or other defects were noticeable

Because of vibration and impact loads during transportation there was a tendency for the cement to pack at the bottom of the convoy around the conveyor screws In order to determine whether this packing had any effect on the discharge screws, additional tests were made by towing the loaded convoy over rough roads at various rates of speed At the end of these runs the convoy motor was started, the discharge screw clutches meshed, and the motor control gear engaged There was no difficulty in thus starting the screws under full load, and the discharge of cement appeared to be normal During these tests it was found that the discharge of the conveyor screws decreased slightly as the pressure head of cement decreased However, even when the convoy was nearly empty the discharge was more than ample to keep the spreader hopper filled

Acceptance Tests

The final acceptance tests of the equipment were made during the construction of a soil cement section of Oklahoma State Highway Number 17 near the town of Sterling For this job 12 percent of cement by volume, based on a 6-inch depth of treatment, was required This amount corresponded to a dial setting of 5 1 on the spreader output control

During the job a total of 3,200 cubic feed (300,800 pounds) of cement was spread over an area of 6,118 square yards, using both the convoy and cutting table methods for storing and feeding the material to the spreader A 10-ton Army truck from Fort Sill, Oklahoma, was used to tow the spreader and carry the convoy and cutting table

Throughout the tests all parts of the equipment worked very well together The delivery rate of cement from the convoy to the spreader hopper was checked several times during the tests and the average found to be 29 15 cubic feet per minute The over-all variation between the required amount of cement and the actual measured amounts delivered by the spreader was less than 0 4 percent, based on the volume of compacted soil This figure is well within the limits set forth in the specifications

Figures 19 through 22 illustrate the operations during these tests, the over-all results of which were as follows

Total amount of cement spread .	3,200 cubic feet
Total area spread .	6,118 square yards
Average percentage of cement delivered with a 12 percent dial setting	. 11 56 percent
Average delivery rate from convoy to spreader	29 15 sacks per minute

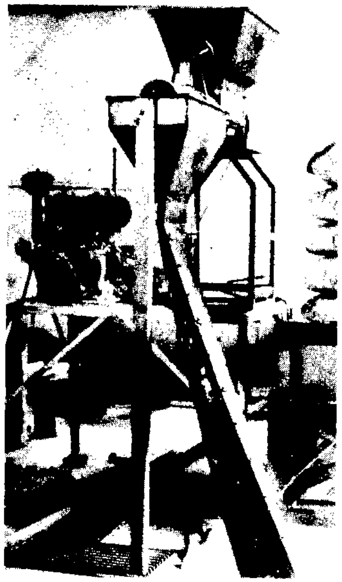
CONCLUSIONS

The results of tests and studies in connection with this development indicate that the use of the mechanical cement spreader and its accessory equipment will improve and simplify the usual procedures for applying portland cement, or similar material, to suitable soil that has been prepared for stabilization Use of this equipment offers a rapid and economical method of distributing bulk and sacked cement evenly and in accurately controllable amounts

The equipment is simple in design, easy to operate and maintain, and throughout all testing operations has proven to be rugged in construction and constantly accurate in performance

The ease with which the units can be broken down into individual parts and reassembled makes this equipment particularly suitable for use in combat zones or other areas where transportation by air is desirable

FIGURE INDEX

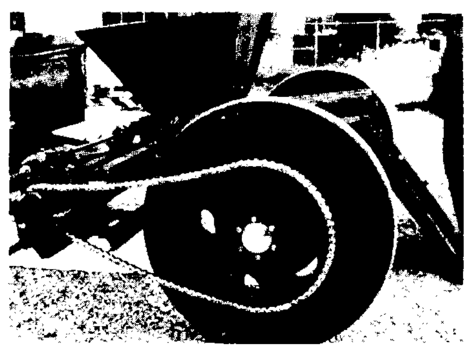


(A)

(B)

(C)

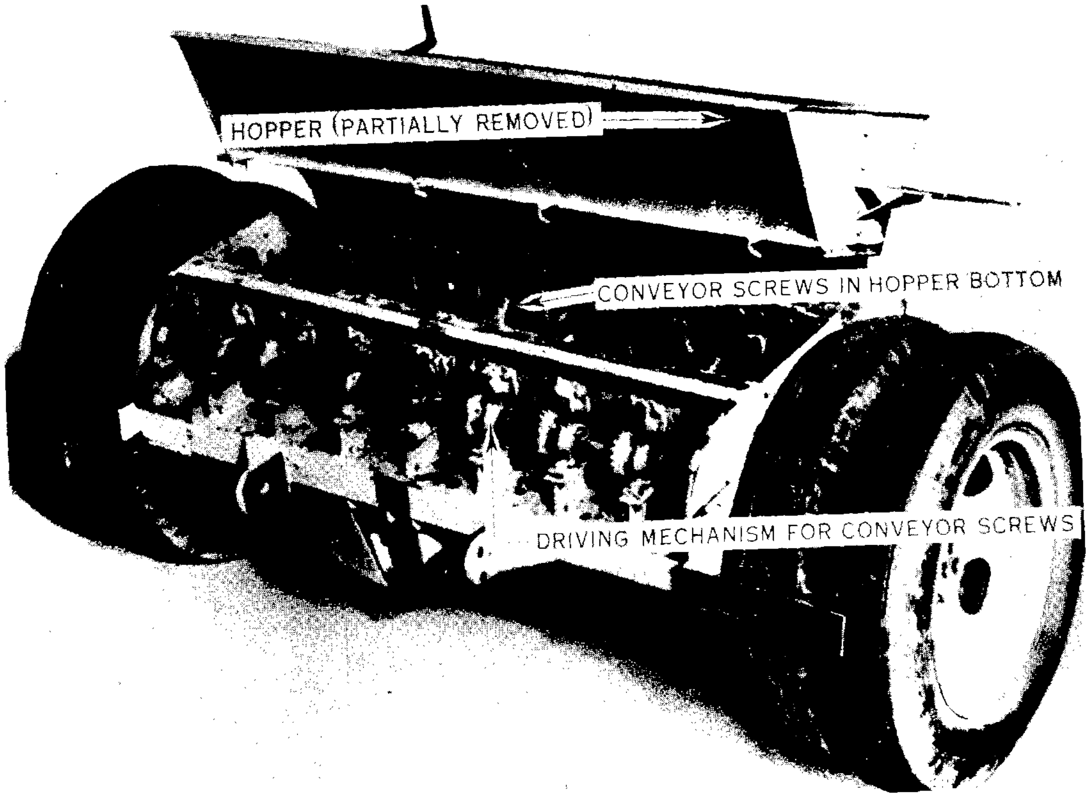
(D)



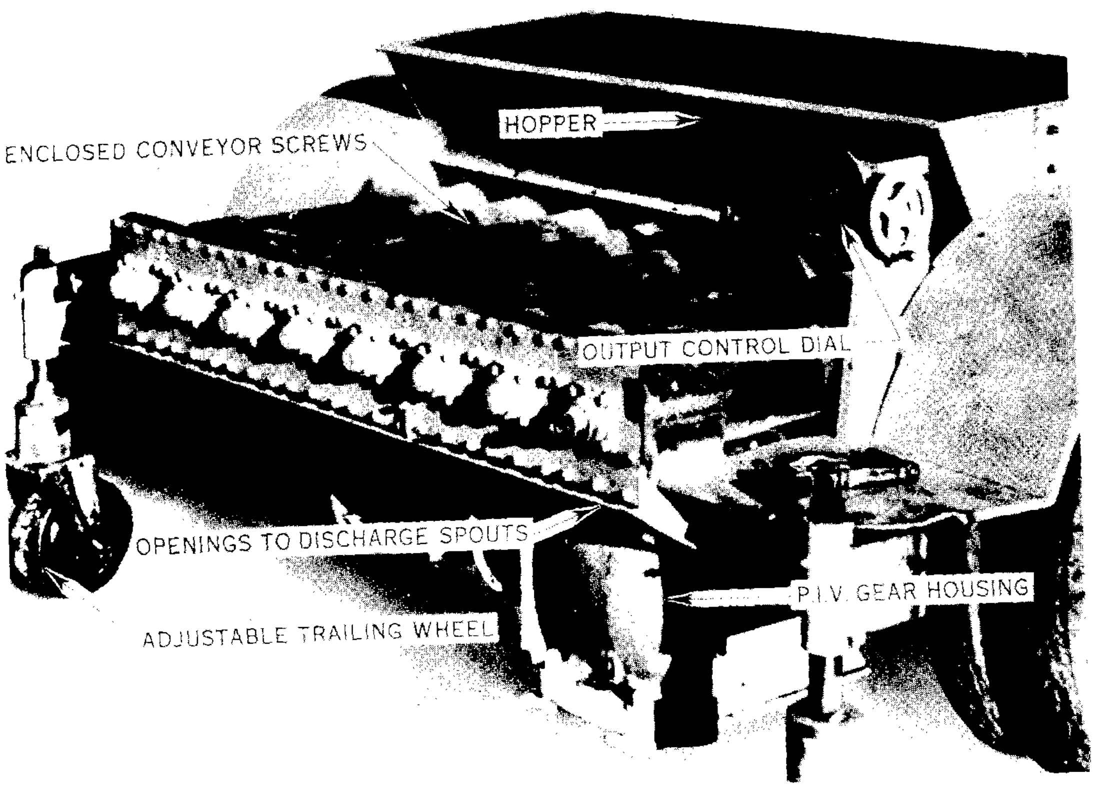
(E)

(F)

Figure 1. Initial Stages in the Development of the Cement Spreader.

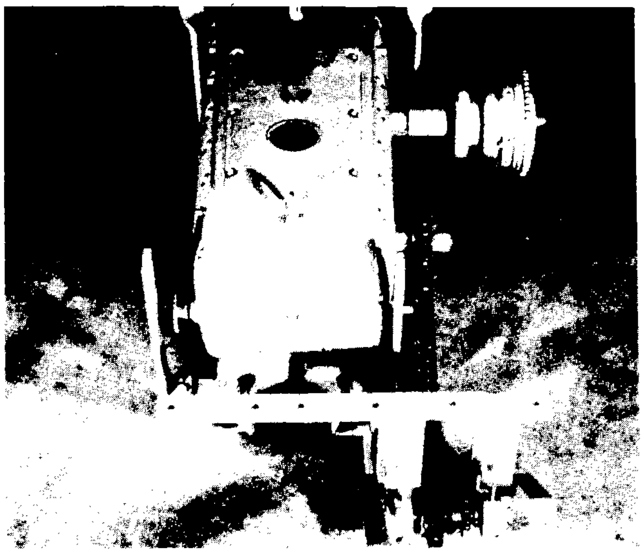


FRONT VIEW

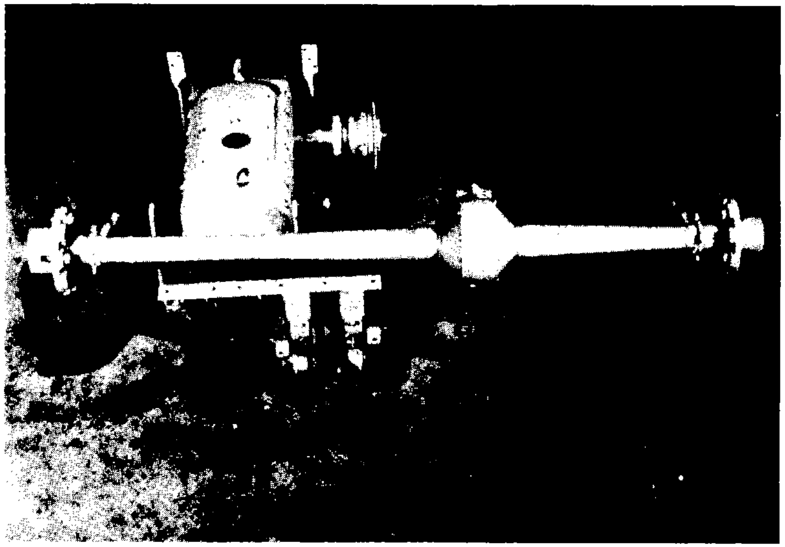


REAR VIEW

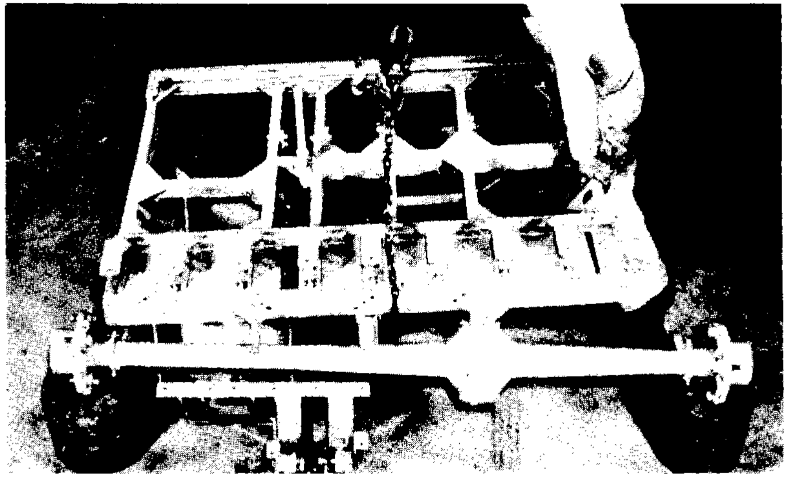
Figure 2. Partial Assembly of the Cement Spreader.



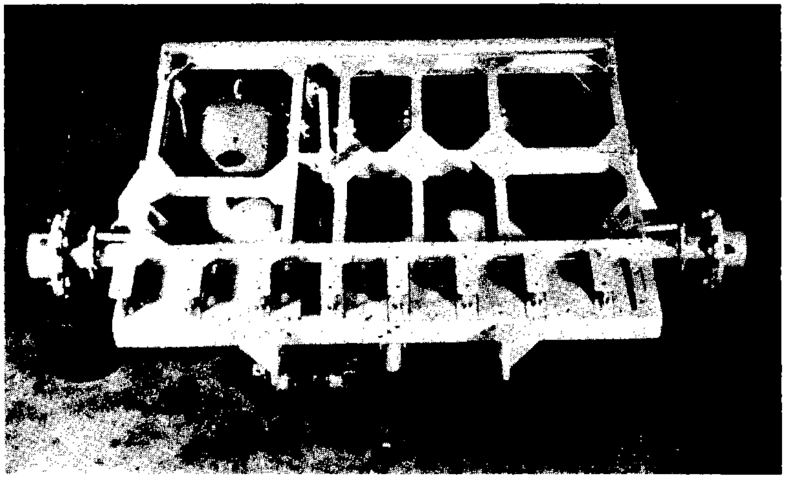
A — P.I.V. GEAR AND SUB FRAME



B — AXLE



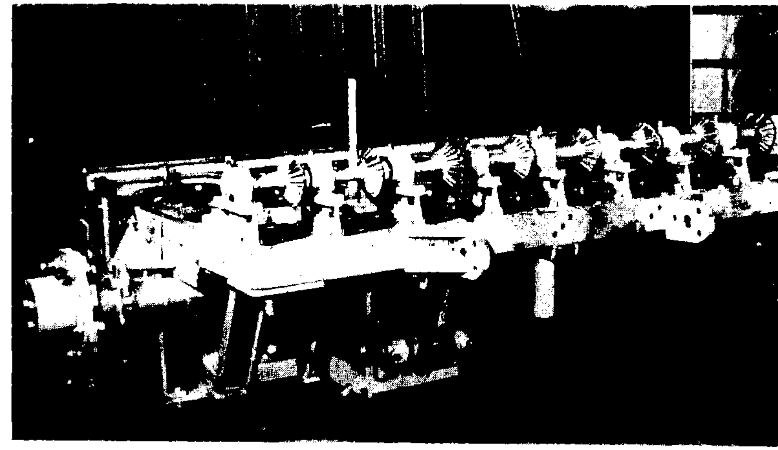
C — MOUNTING MAIN FRAME



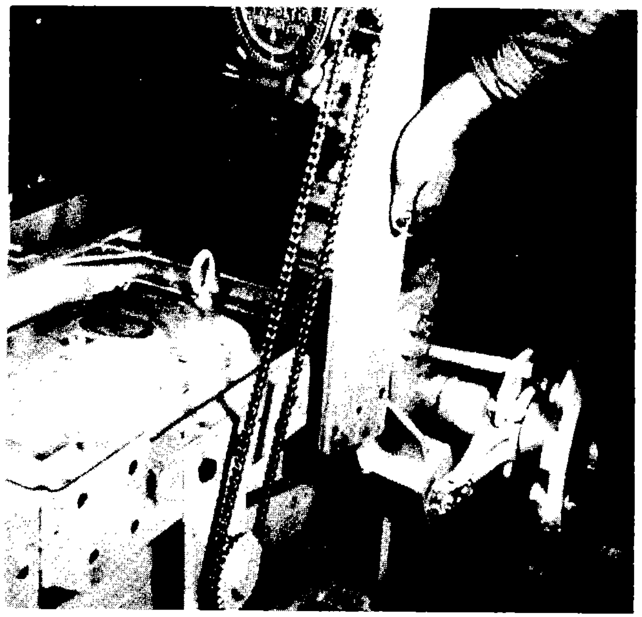
D — MAIN FRAME IN PLACE

Figure 3. Progressive Assembly of the Cement Spreader.

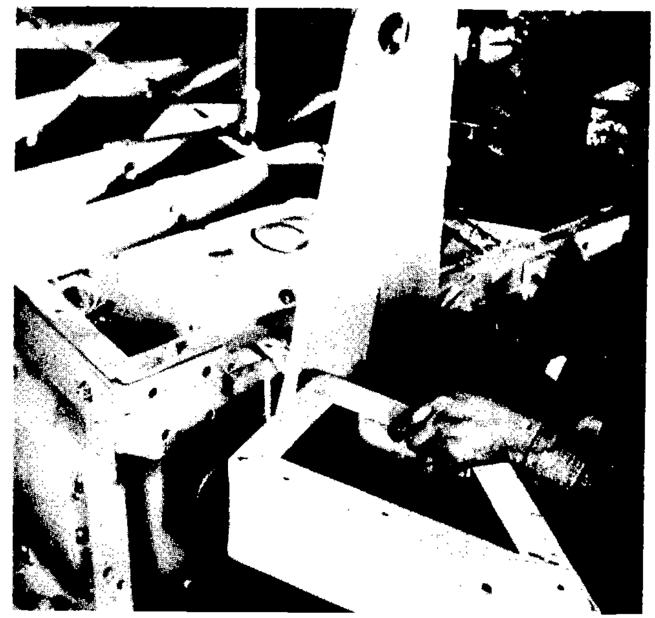
A — MOUNTING DRIVE SHAFT



B — DRIVE SHAFT IN PLACE

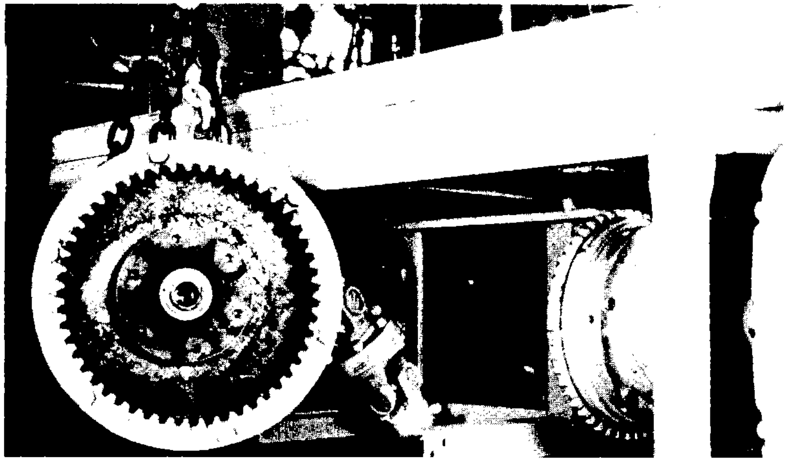


C — P.I.V. REMOTE CONTROL AND BRACKET

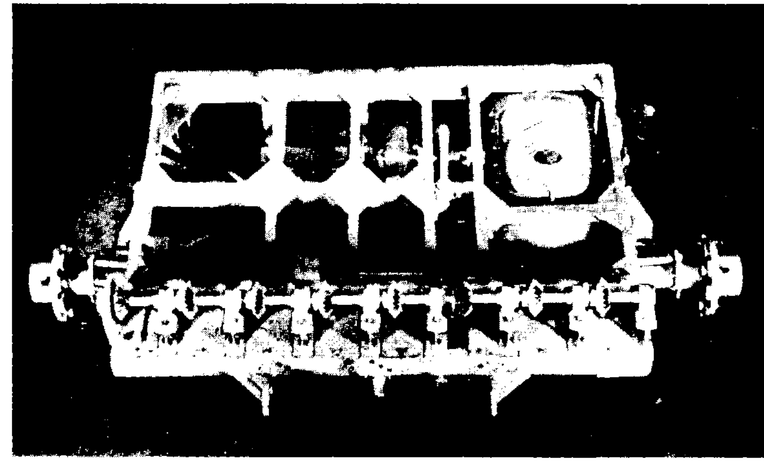


D — TRAILING WHEEL SUPPORT

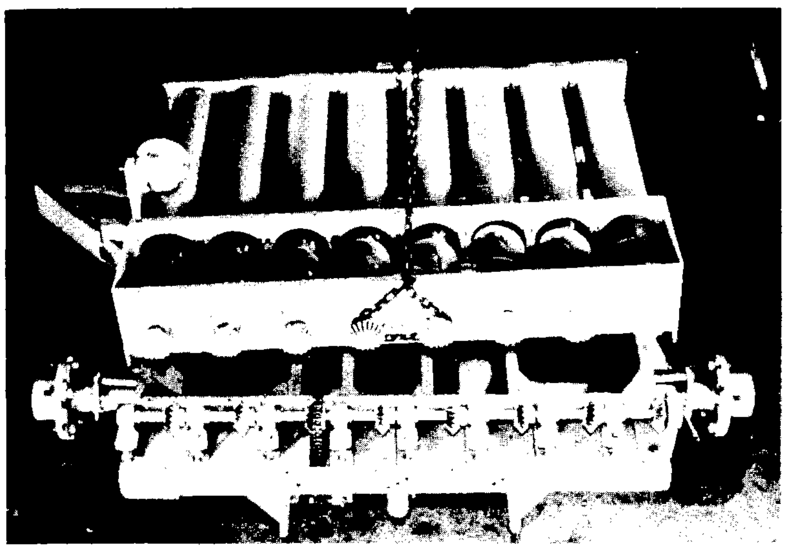
Figure 4. Progressive Assembly of the Cement Spreader. (Continued).



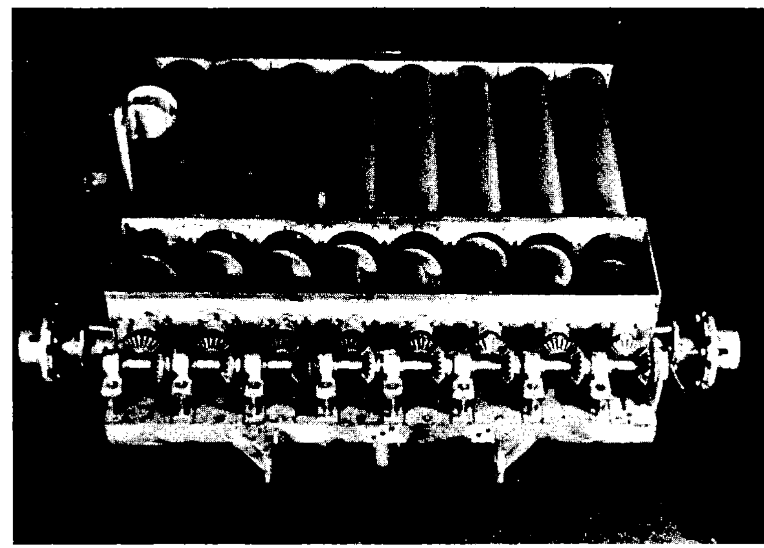
A — MOUNTING CLUTCH



B — CLUTCH AND SHIFTER MECHANISM

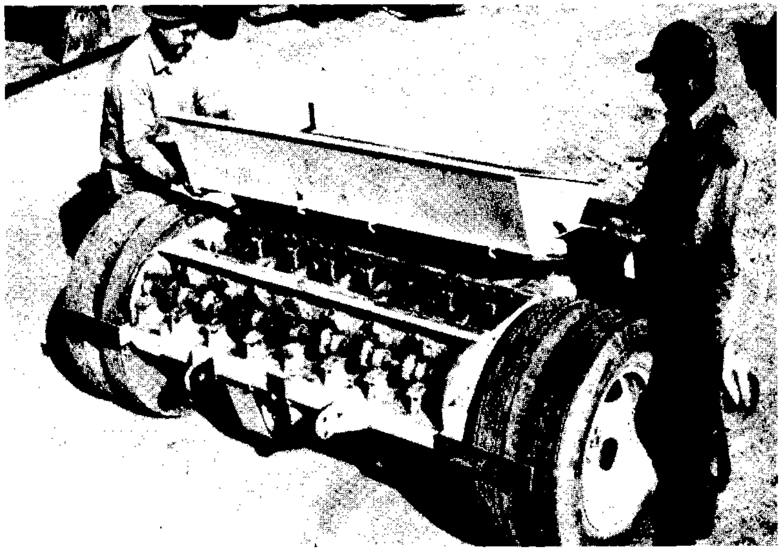


C — MOUNTING TUBES AND HOPPER BOX



D — TUBES AND HOPPER BOX IN PLACE

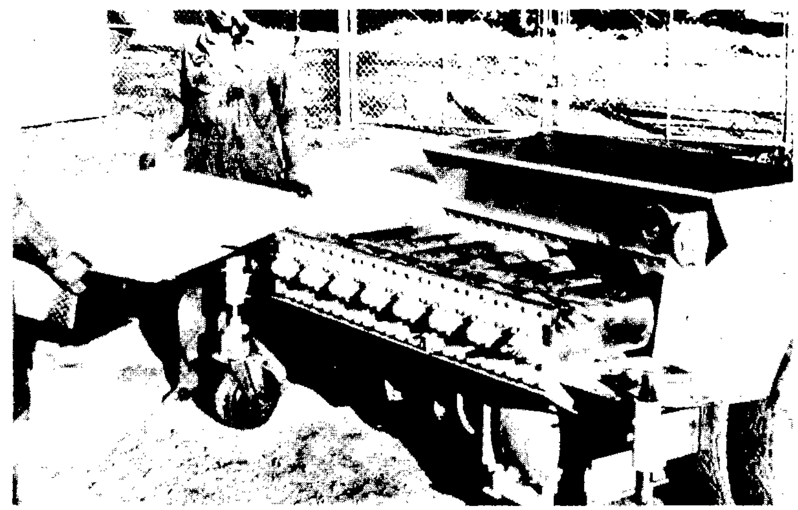
Figure 5. Progressive Assembly of the Cement Spreader. (Continued).



A — HOPPER

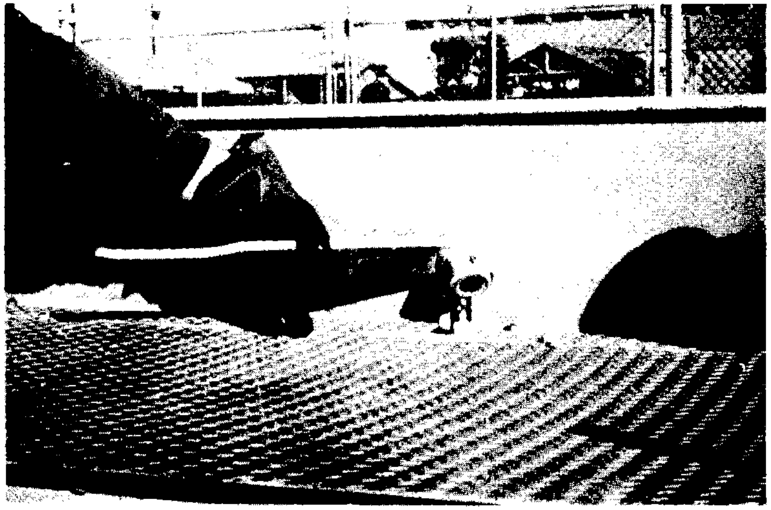
B — TRAILING WHEEL

C — FENDER

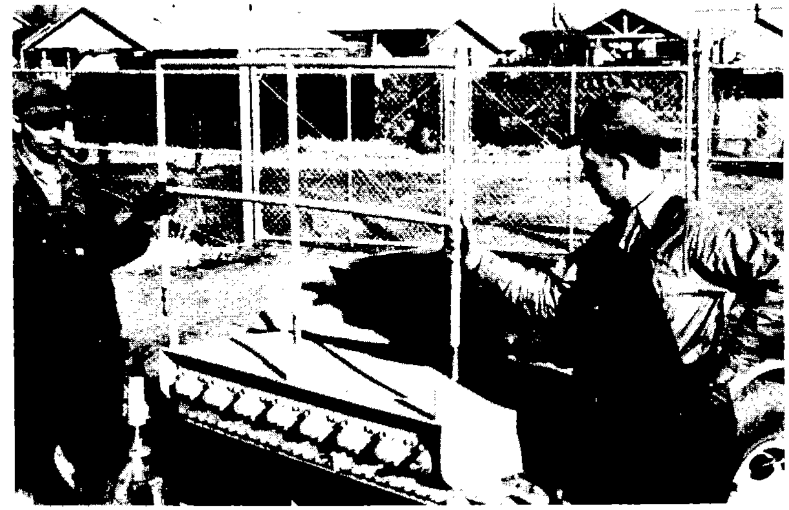


D — FLOOR PLATE

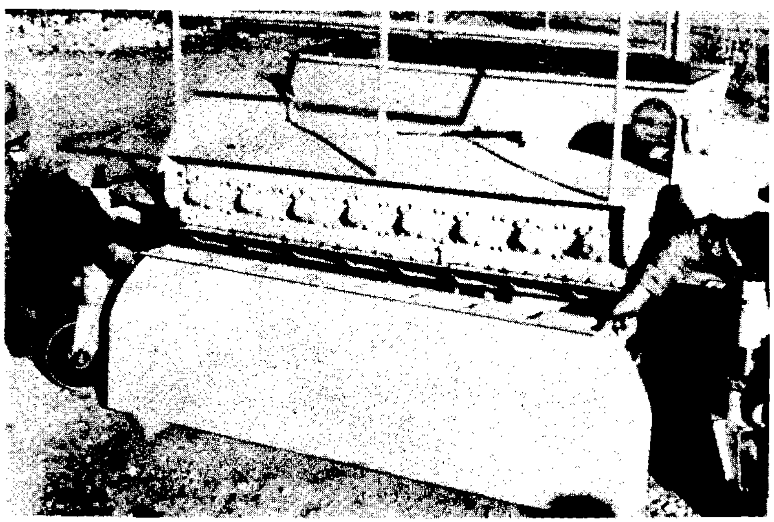
Figure 6. Progressive Assembly of the Cement Spreader. (Continued).



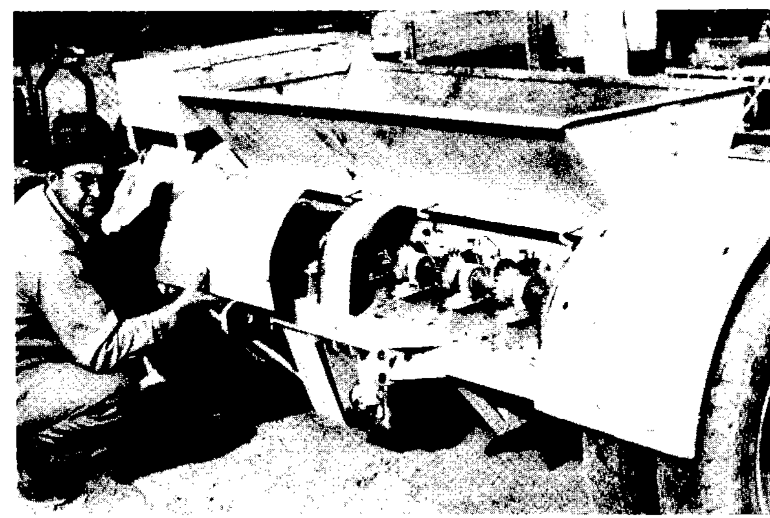
A — SHIFTER LEVER



B — GUARD RAIL

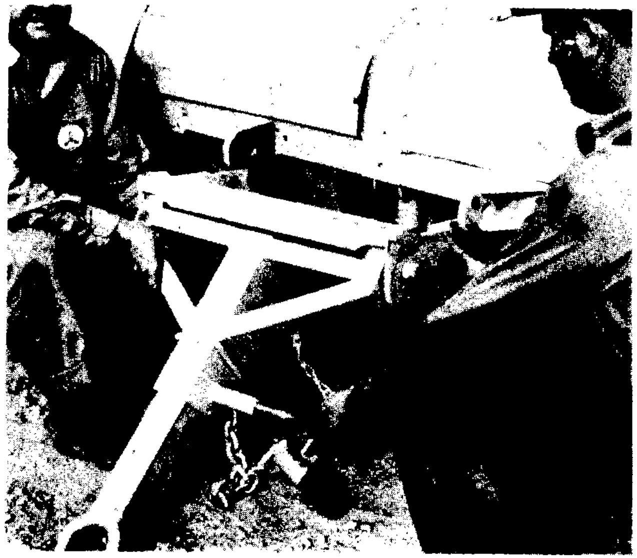


C — OUTLET SPOUTS

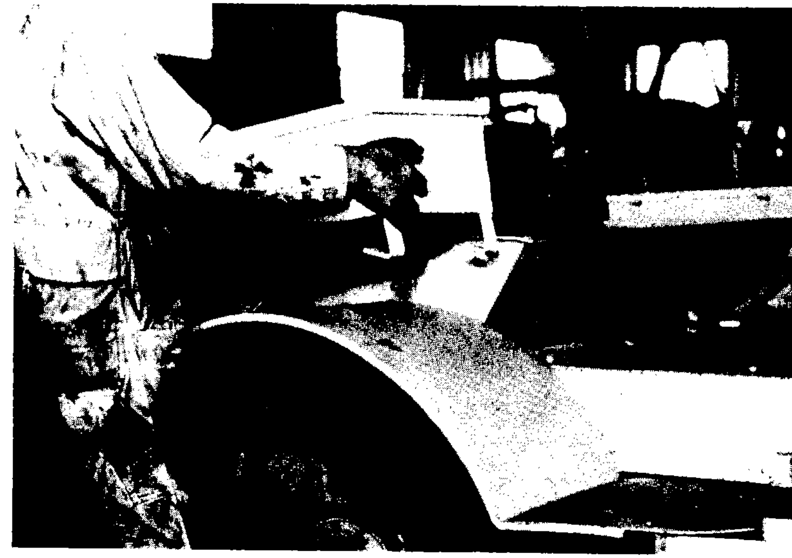


D — FRONT GEAR COVER

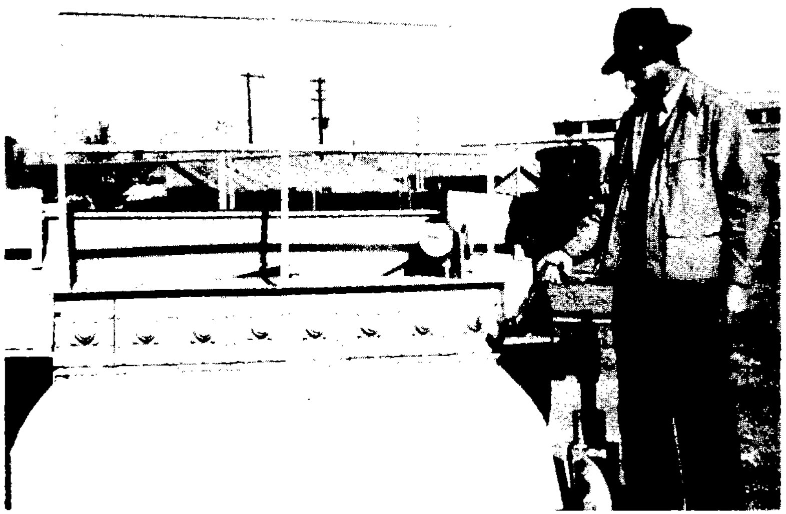
Figure 7. Progressive Assembly of the Cement Spreader. (Continued).



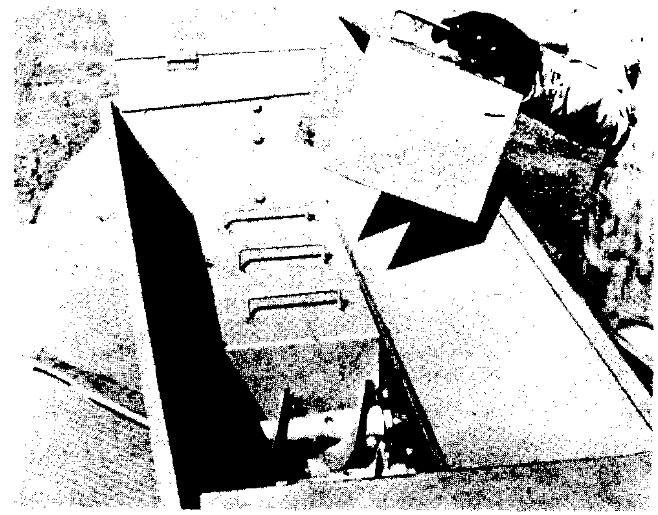
A — TONGUE ASSEMBLY



B — TOOL BOX



C — HAND CRANK



D — BLOCKING FEEDER SCREWS

Figure 8. Progressive Assembly of the Cement Spreader. (Continued).

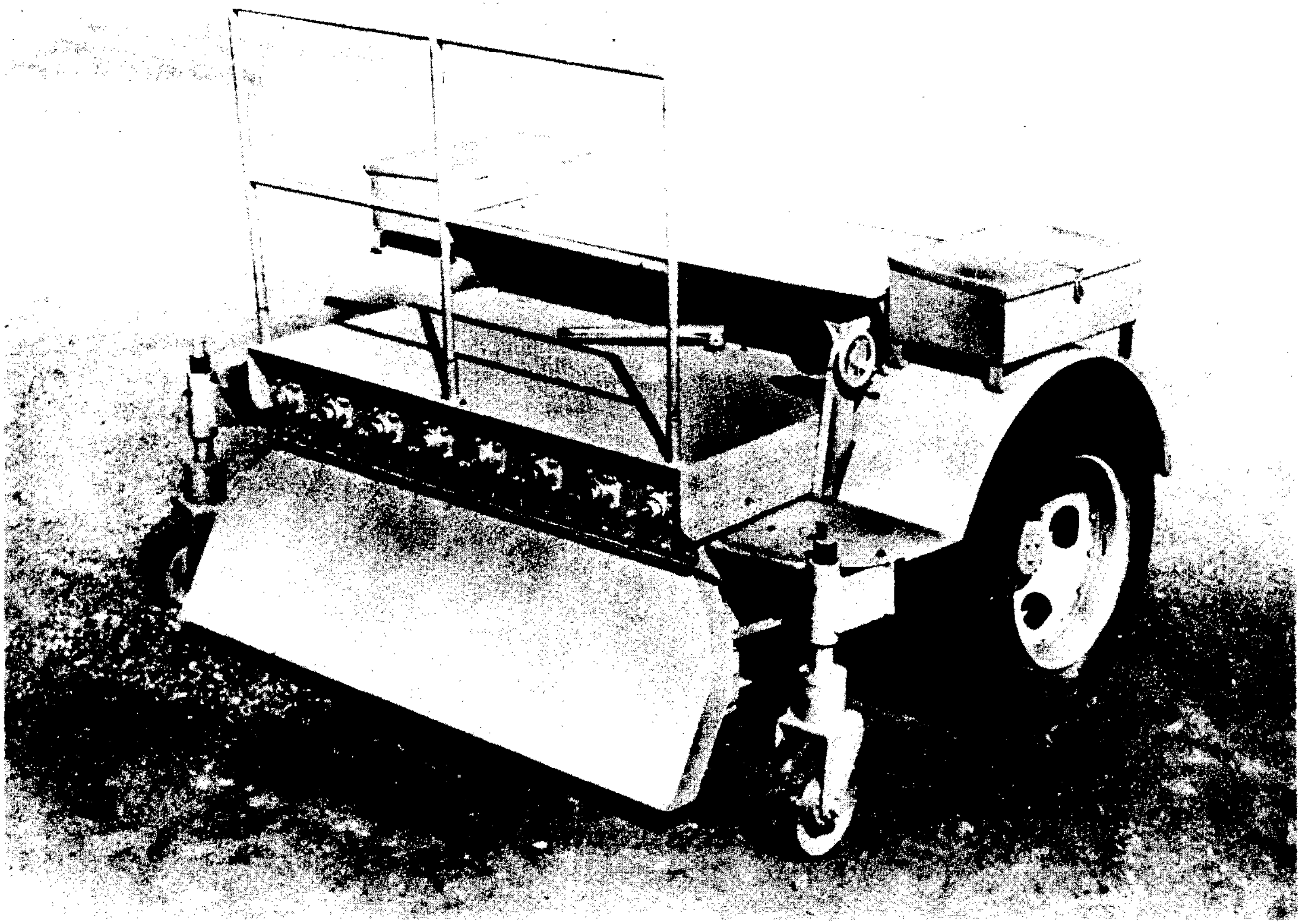
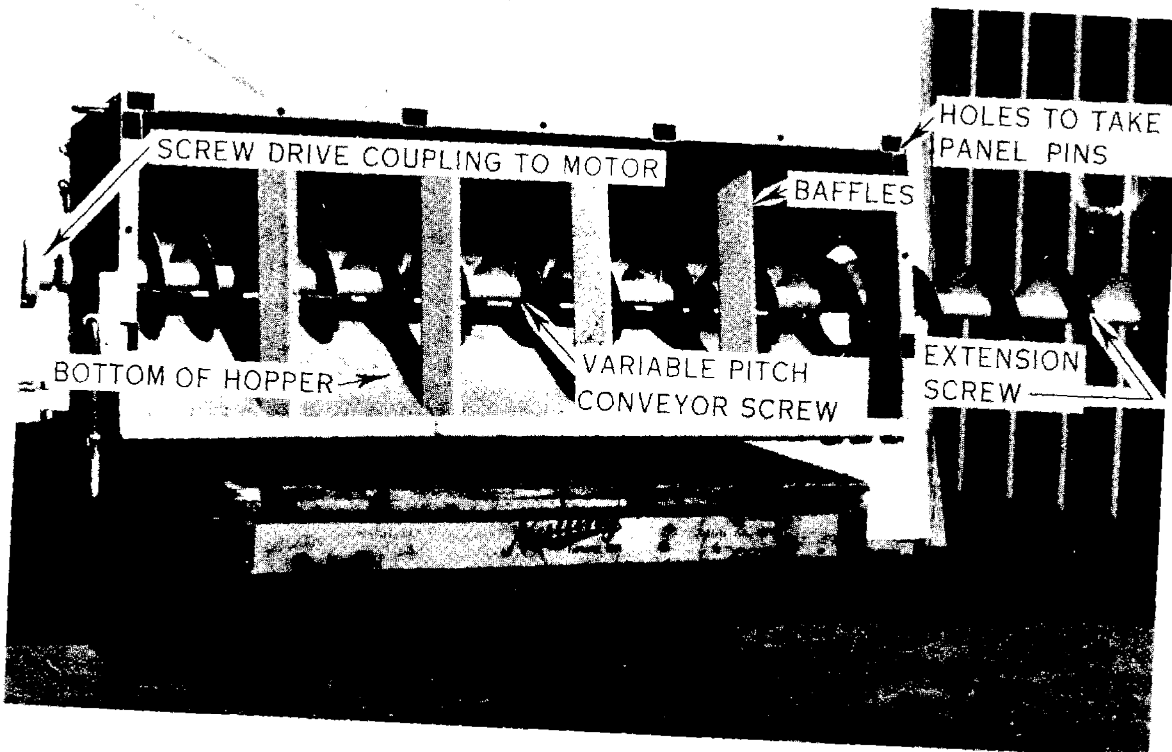
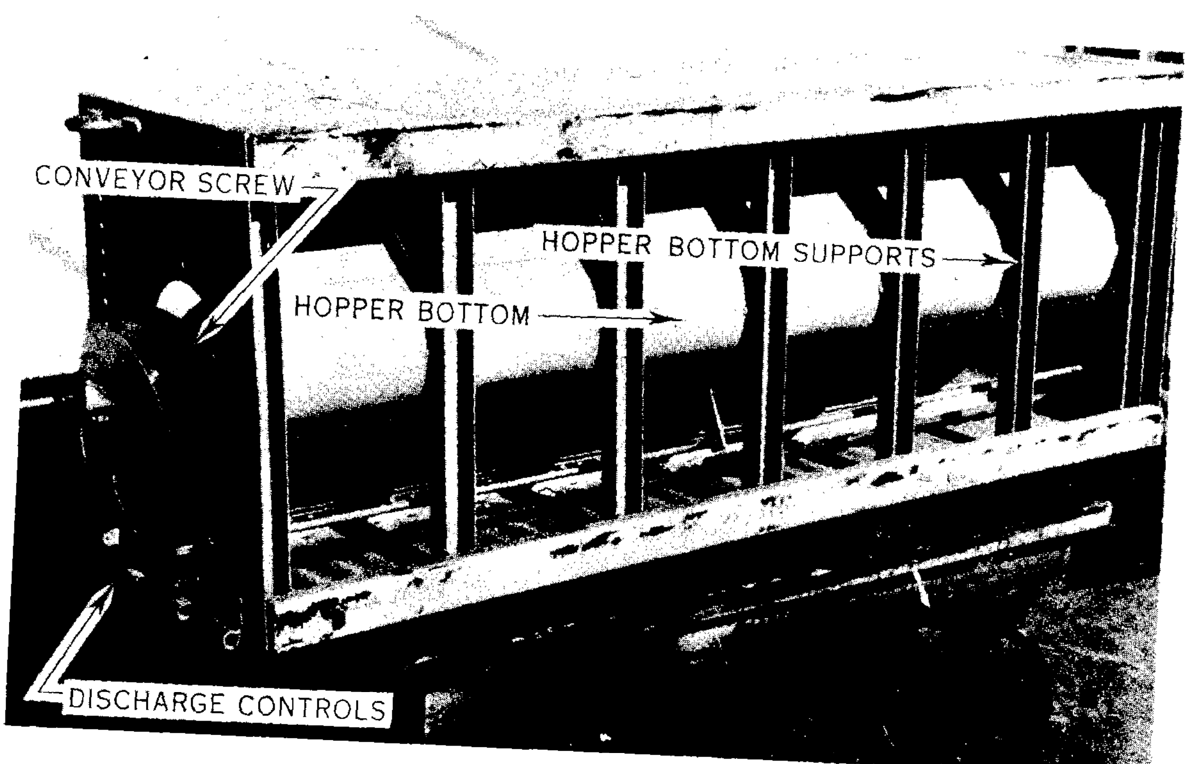


Figure 9. Assembled Cement Spreader.

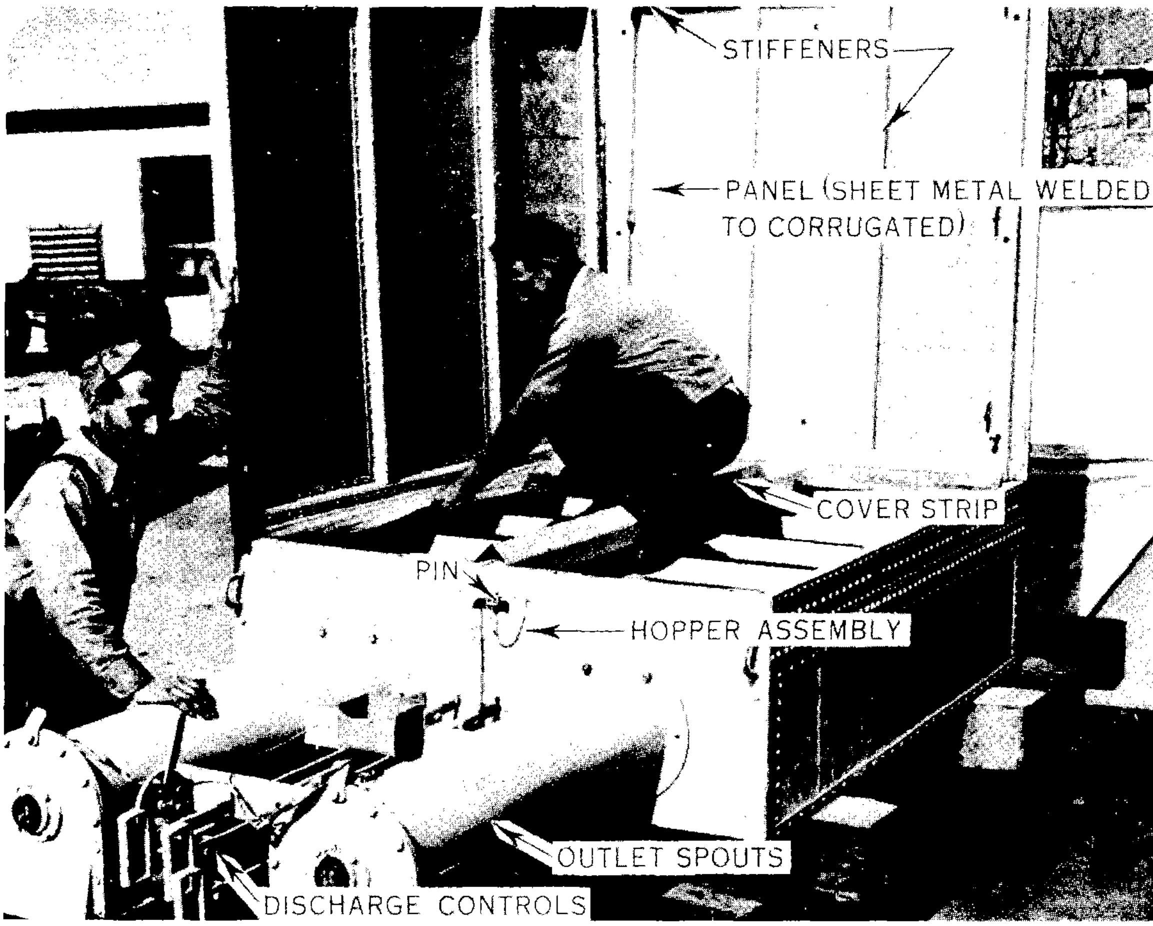


TOP VIEW

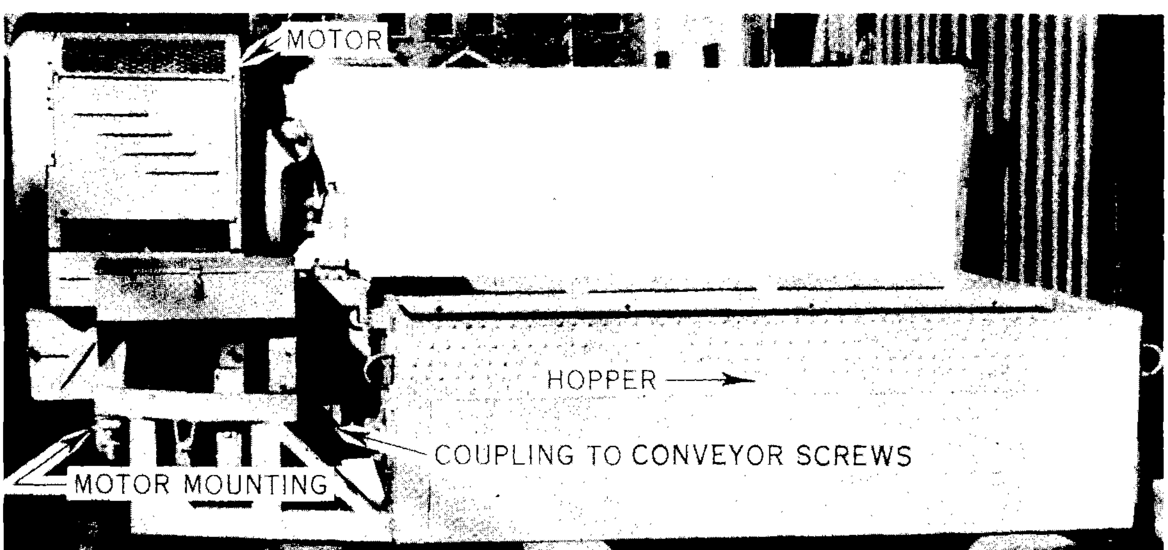


BOTTOM VIEW

Figure 10. Details of Convoy Hopper.

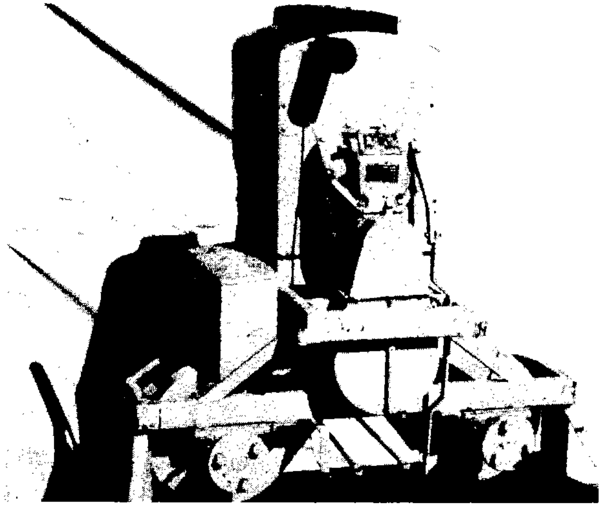


REAR VIEW OF PARTIALLY ASSEMBLED CONVOY

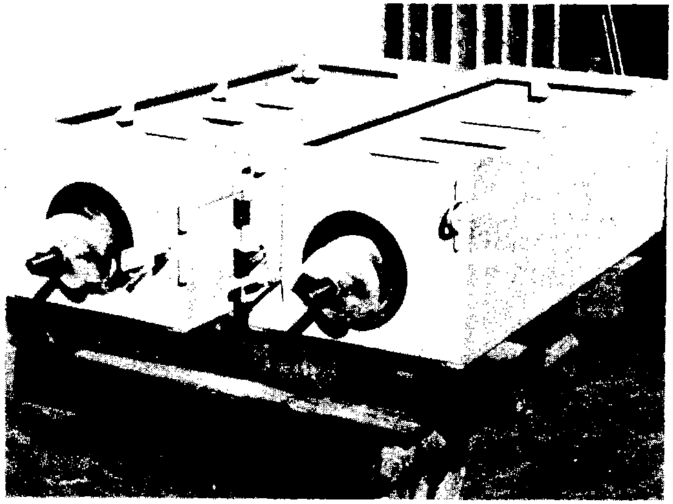


MOTOR ASSEMBLY

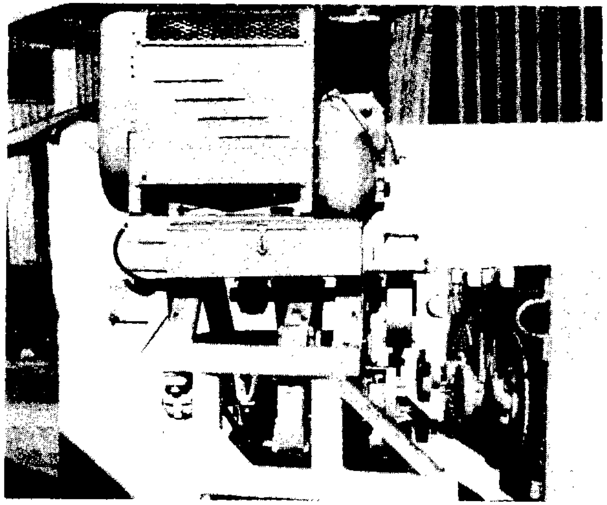
Figure 11. Unit Parts of the Convoy.



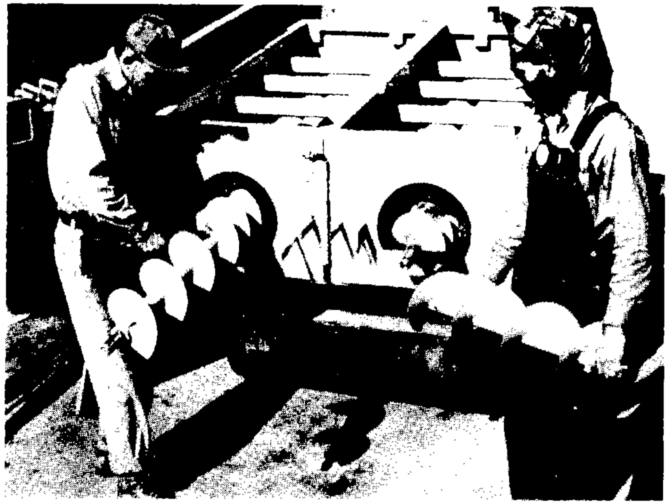
A — MOTOR AND MOUNTING



B — SECTIONS OF HOPPER

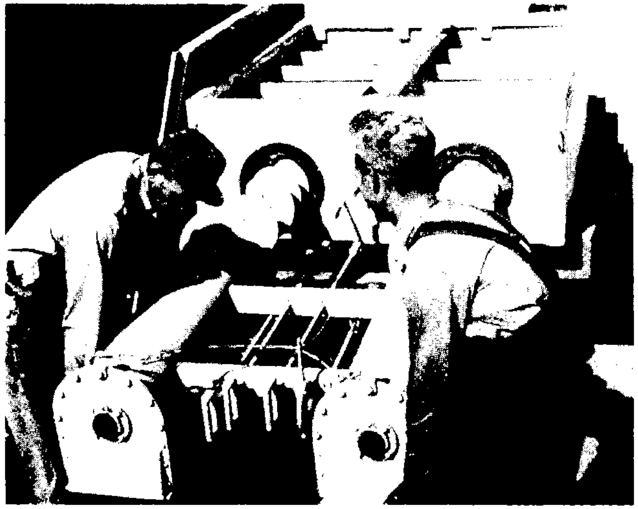


C — MOTOR CONNECTION
TO CONVEYOR SCREWS

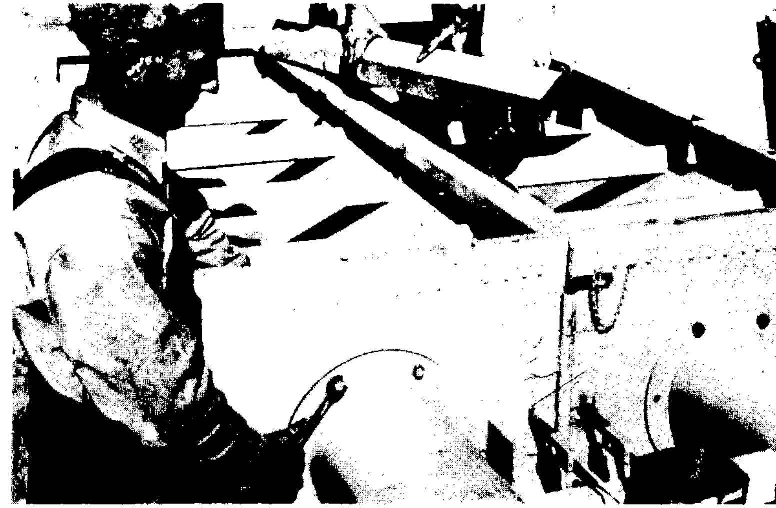


D — EXTENSION SCREWS

Figure 12. Progressive Assembly of the Collapsible Convoy



A — EXTENSION SPOUTS

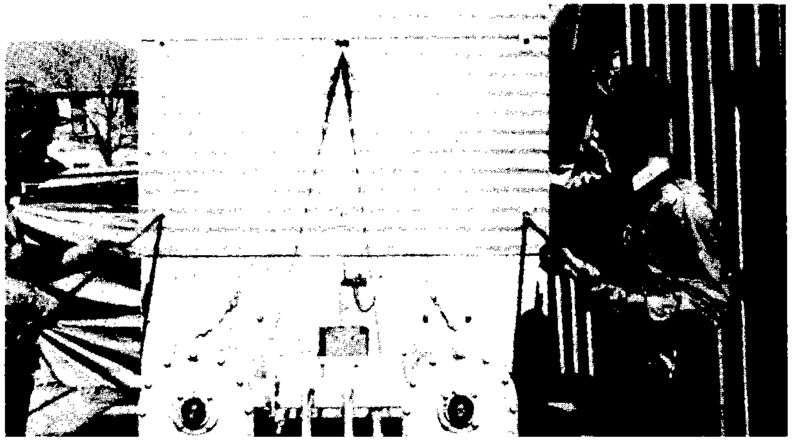


B — ATTACHING SPOUTS AND COVER STRIP

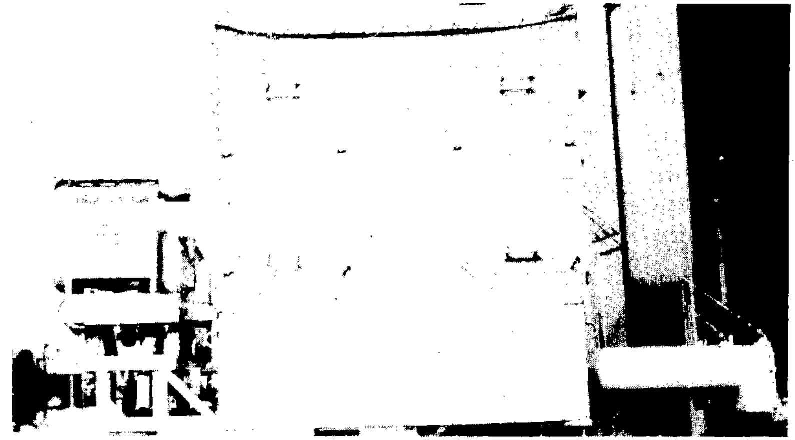
C — ERECTING SIDES

D — SIDE AND END SECTIONS

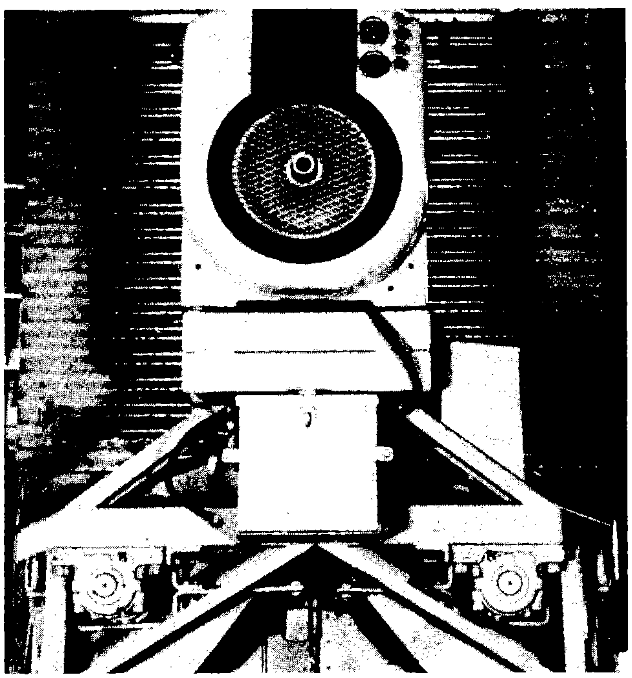
Figure 13. Progressive Assembly of the Collapsible Convoy (Continued).



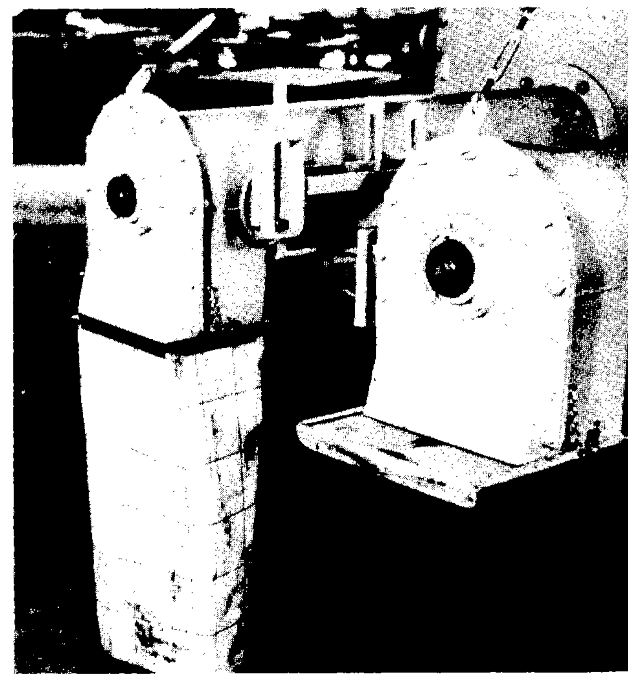
A — REAR VIEW SHOWING TIE RODS



B — SIDE VIEW SHOWING CANVAS TOP



C — FRONT VIEW



D — DISCHARGE SPOUTS

Figure 14. Progressive Assembly of the Collapsible Convoy (Continued).

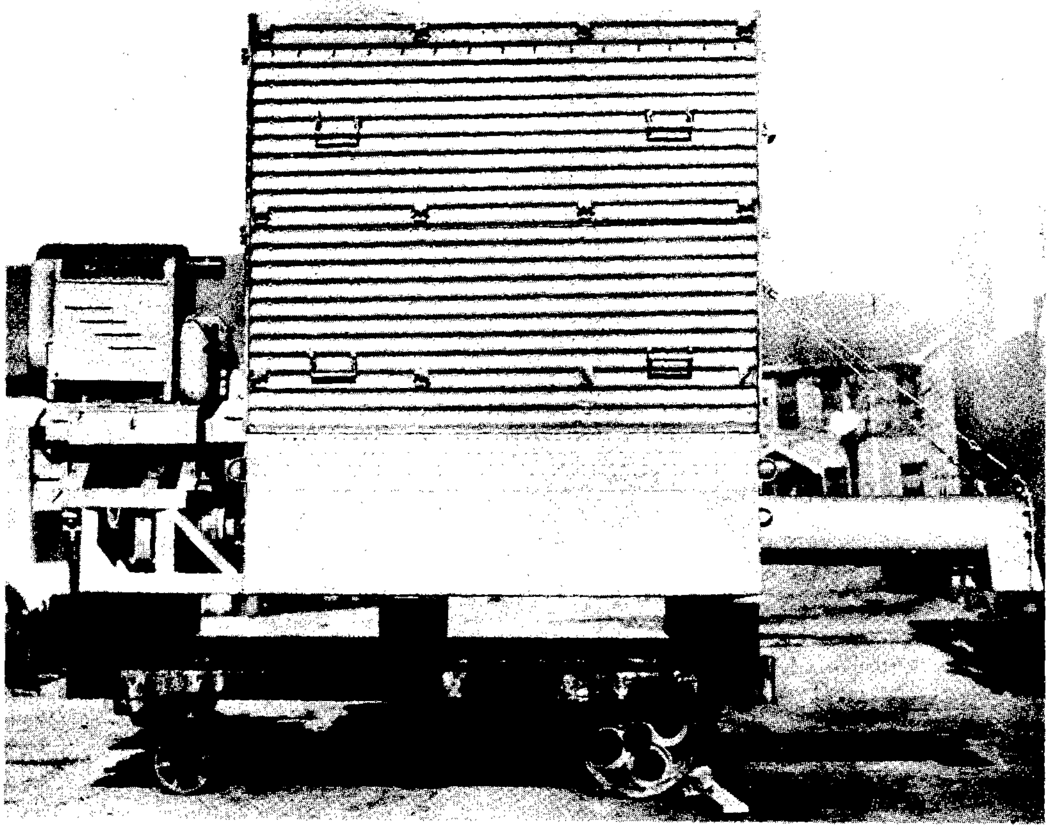


Figure 15. Assembled Convoy.

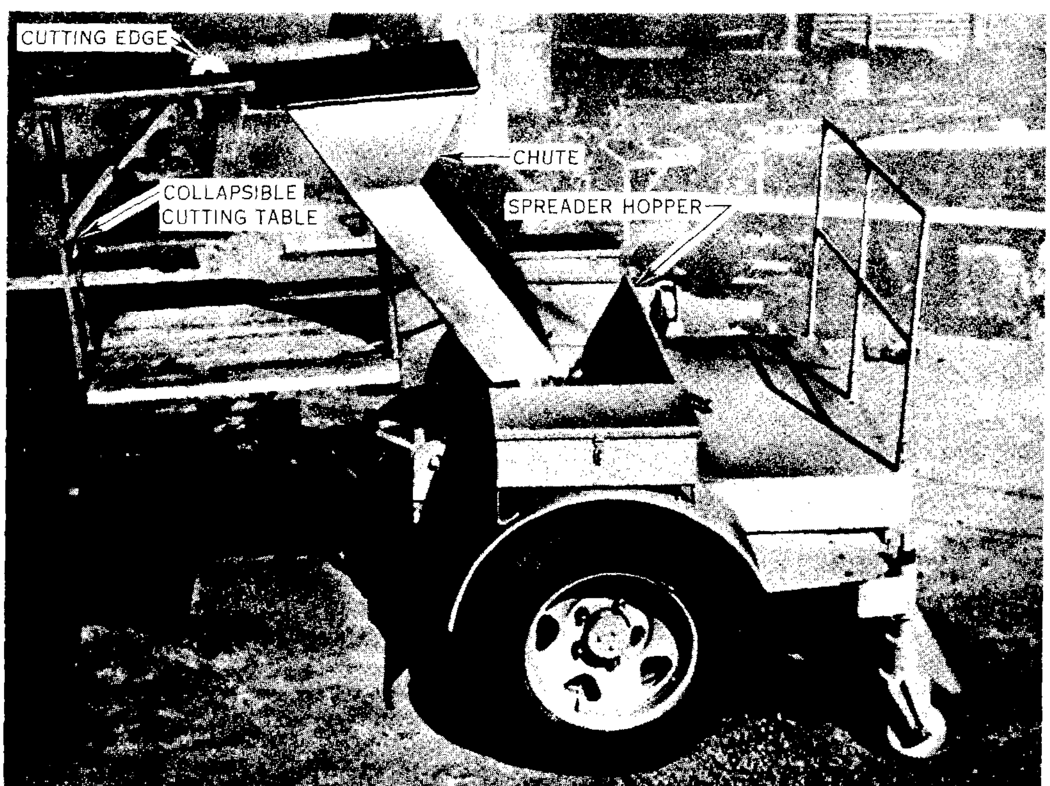


Figure 16. Collapsible Cutting Table and Discharge Chute.

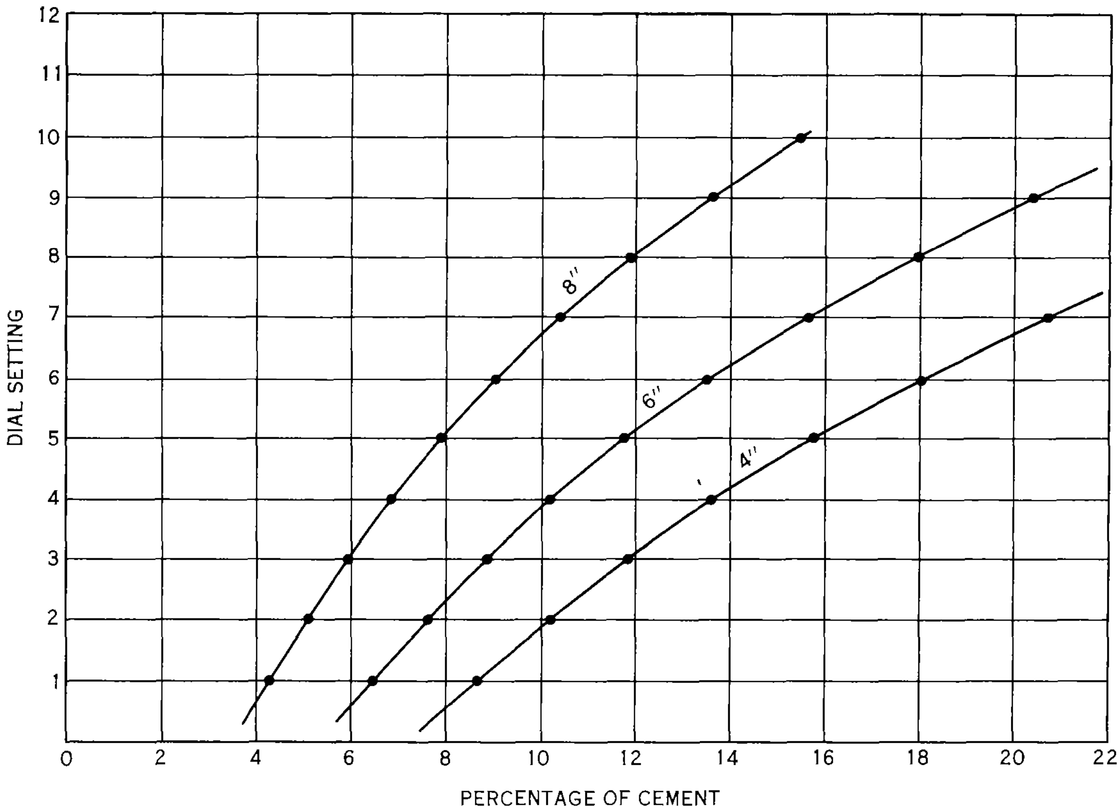


Figure 17. Calibration Curves of the Spreader Dial Setting vs. Percentage of Cement Per Volume of Compacted Base-Various Thicknesses of Treatment.

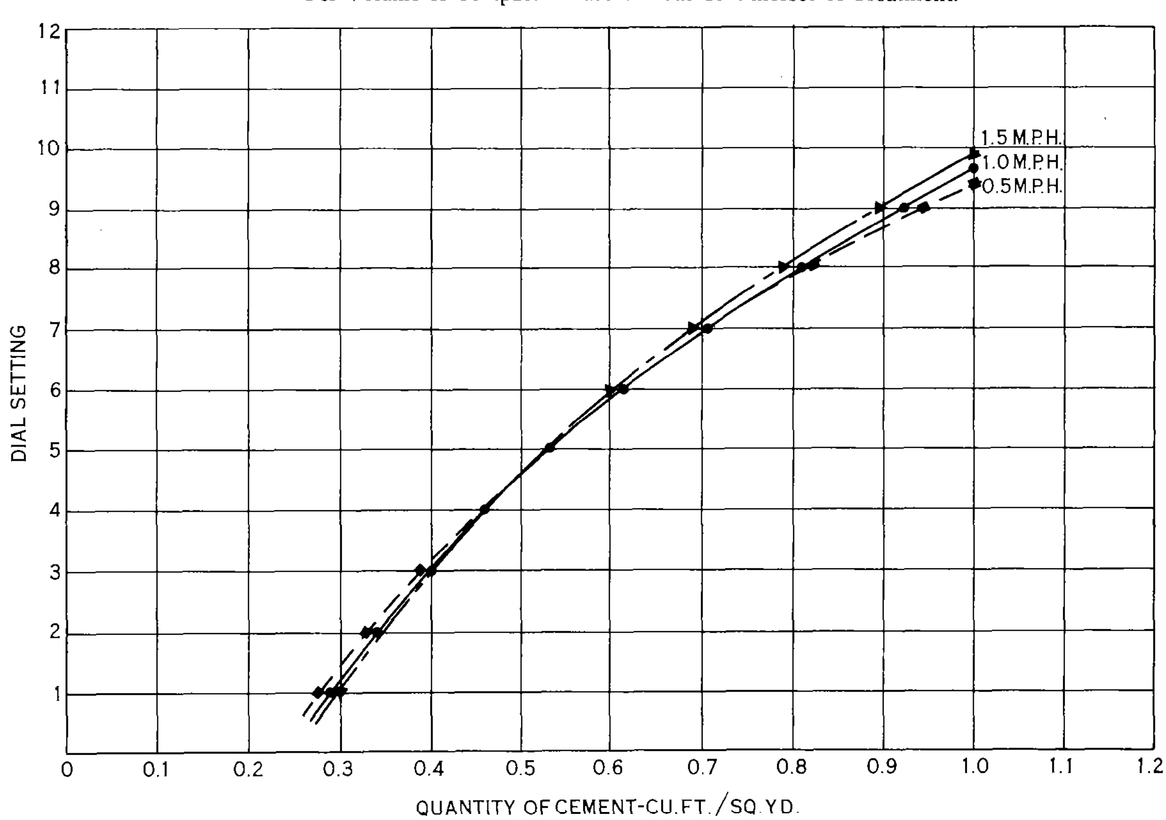


Figure 18. Calibration Curves of the Spreader Dial Setting vs. Cubic Feet of Cement per Square Yard-Various Forward Speeds.

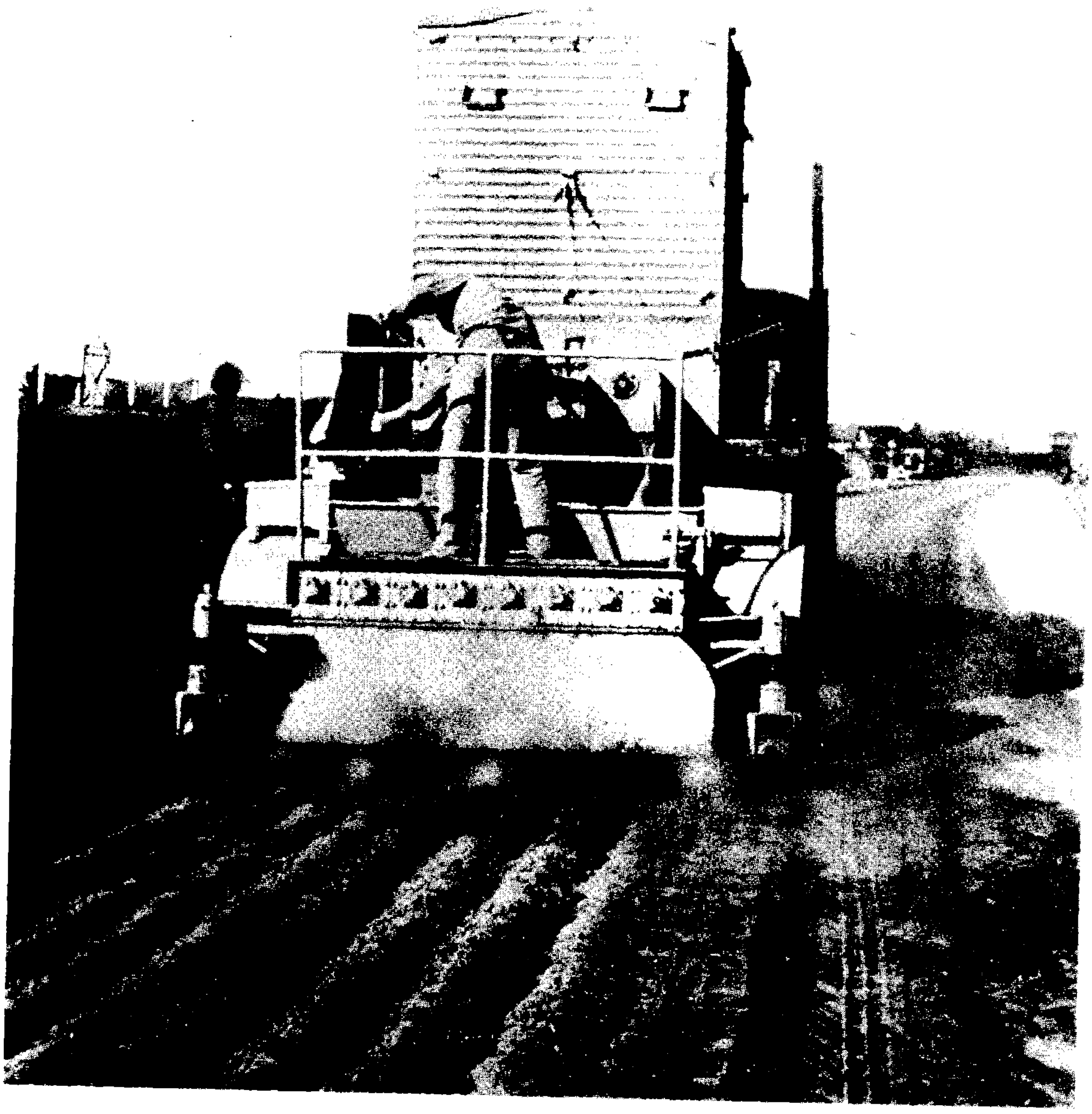


Figure 19. Operation of Spreader and Convoy During Field Tests

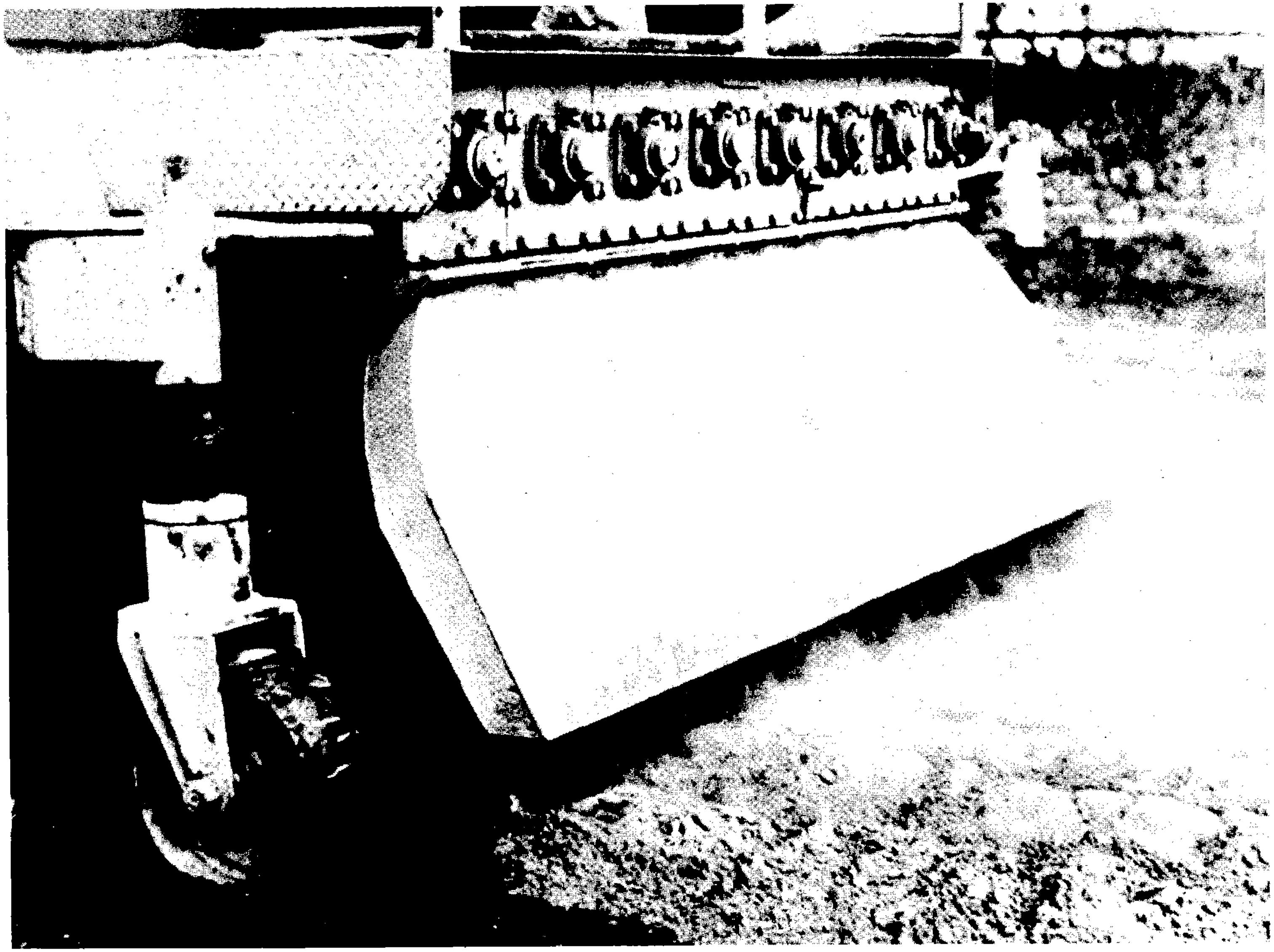


Figure 20. Cement Leaving Discharge Spouts of the Spreader

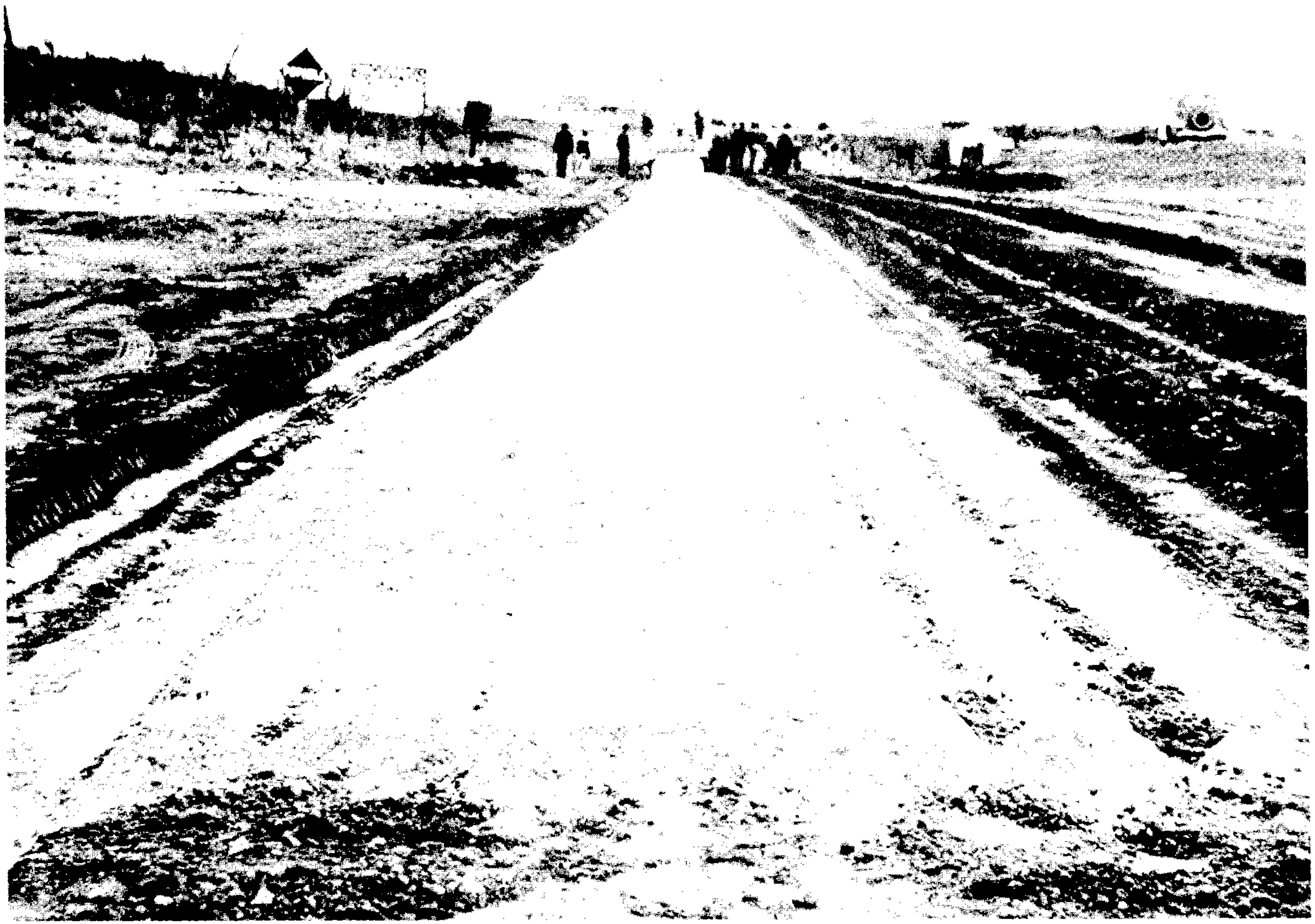


Figure 21. Area of Cement as Applied by the Spreader.

Figure 22. Operation of the Spreader When Using Sacked Cement.