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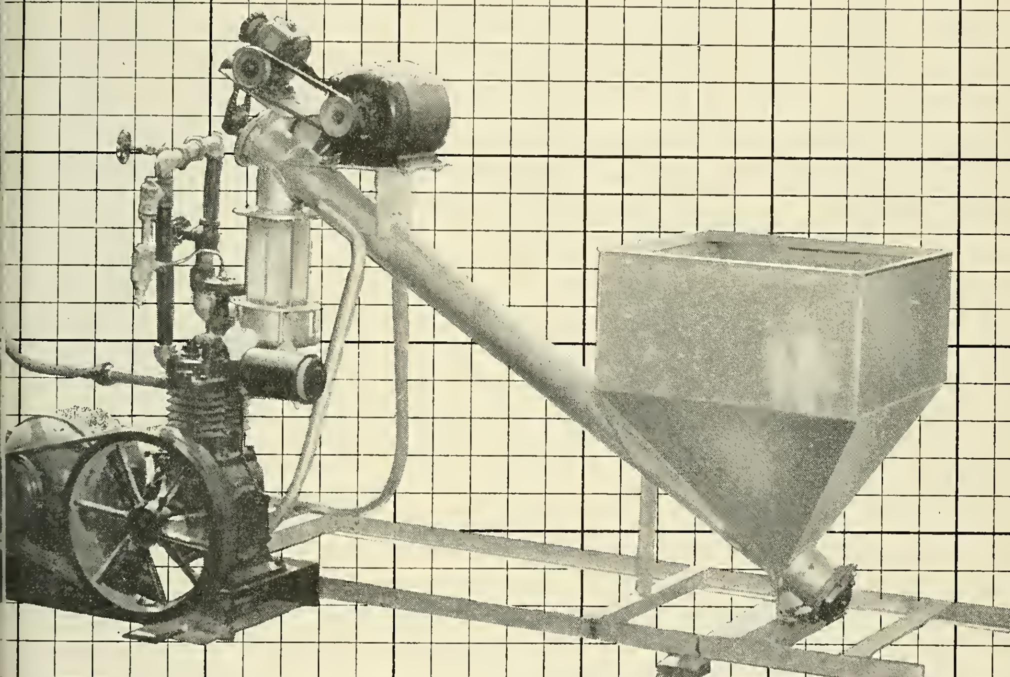

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The Fluidized-Grain Conveyor*

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Introduction

CONVEYING grain and feed from bin to bin in storage, in the processing plant, or on the farm requires considerable time and money. It is hoped that the conveyor described herein will be adaptable to many conveying chores that lie within the limits of its capacity.

The grain conveyor depends for its operation upon the principle of fluidization. This consists of mixing air with a solid in such a manner that each solid particle is surrounded by a film or cushion of air. Such an air-solid mixture can be made to flow through pipes or tubes in much the same manner as a liquid. This principle is not to be confused with the older pneumatic method which imparts momentum to the solid particles by means of a high velocity air stream. In fluidization, much lower pressures and velocities are normally used and much higher solid-air ratios are realized. However, in the fluidization of larger or heavier particles, such as grain, it may be necessary to employ air pressures which approach or even exceed those usually associated with pneumatic conveying.

Although the fluidization principle has been used for some time by the petroleum industry, it was first utilized in the conveying of pulverized coal by a batch-type feeder developed jointly by the Morgantown Station, U.S. Bureau of Mines, and the Engineering Experiment Station of West Virginia University. When pulverized coal was used (90 per cent of which could pass through a 200-mesh screen) this fluidizer could move approximately 250 lbs of coal per pound of air, using a conveying air pressure only sufficient to overcome the pressure drop through the conduit. From the results obtained with this unit, the idea of applying the fluidization principle to the conveying of grain was conceived.

To move grain and feed by this process seemed feasible, but not practical with the batch-type unit. To be of value in agriculture, a continuously fed unit would have to be developed. Before attempting

*This project is being conducted jointly by the West Virginia University Agricultural Experiment Station and the West Virginia University Engineering Experiment Station.

to build this unit, preliminary tests using whole wheat were made with the batch unit. The fluidizing chamber was 10-inch vertical steel (Fig. 1) pipe, 10 feet high, charged from the top through a gate valve. The discharge line was the equivalent of about 75 feet of one-inch rigid conduit

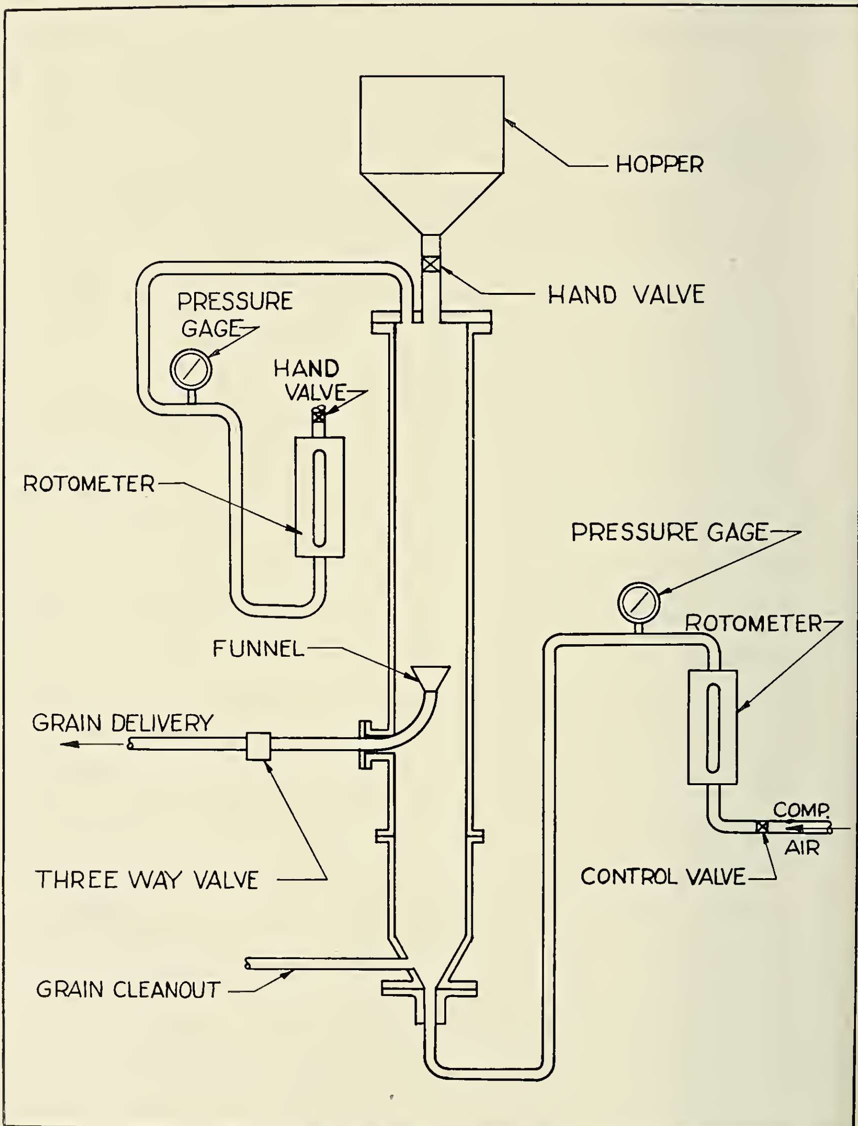


FIGURE 1. EXPERIMENTAL fluidizing equipment.

with long-radius elbows. Tests made with this equipment showed that whole grain such as wheat could be moved at the rate of one ton per hour through one-inch pipe over a distance of 50 feet, half of which was vertical. The air-solids ratio for these trials was 1 to 25 (Table 1). Increased pressures in the fluidizing chamber resulted in increased grain flow, but the air-solids ratio decreased with an accompanying increase in power consumption.

Table 1. Summary of Data on Wheat Using 1-Inch Delivery Pipe 75 Feet Long

Pressure psig	Air Flow cfm	Lb. Air Per Min.	Lb. Grain Per Lb. Air	Ton/Hr.	hp-hr Per Ton
5	14.00	1.54	22.88	1.040	.350
8	21.50	2.46	19.58	1.450	.660
10	23.50	3.14	16.77	1.590	.870

Soon after the foregoing tests were analyzed, an attempt was made to build a continuously fed unit. The first unit, or model, had a 4-inch horizontal screw feeder from the hopper to the base of the fluidizing chamber (Fig. 2) just above the discharge outlet. Although it moved grain fairly well it did not perform with complete satisfaction, primarily because grain from the screw feeder had to push other grain ahead of it up into the fluidizing chamber. Any air lost through the screw feeder to the hopper was wasted. This caused lower over-all efficiency of the conveyor. These two disadvantages were overcome by inclining the screw feeder to a 30° angle from the base of the hopper to the top end of the fluidizing chamber. This design was incorporated into a new model (Fig. 3). In this model the grain drops into the fluidizing chamber and mixes with the incoming air. Also, any air escaping through the screw feeder, which acts as an air lock for the fluidizing chamber, is not necessarily wasted since when transporting finely ground material such as laying mash, it is necessary to allow a small portion of the incoming air to bubble up through the mash or grain to completely fluidize it, and to pass out through the screw feeder or through a valve at the top of the fluidizing column. This model proved the most satisfactory of all units constructed and will be described in detail.

Other models were tried but they did not operate as effectively. For instance, instead of using a screw feeder, a rotary valve was placed at the top of the fluidizing chamber to meter the grain as well as to serve as an air lock (Fig. 4). It proved ineffective because of excessive air leakage.

Each time a new model was constructed and tested it was possible to reduce the size of the fluidizing chamber until in the final model it was only 10 inches high and 5 inches in diameter.

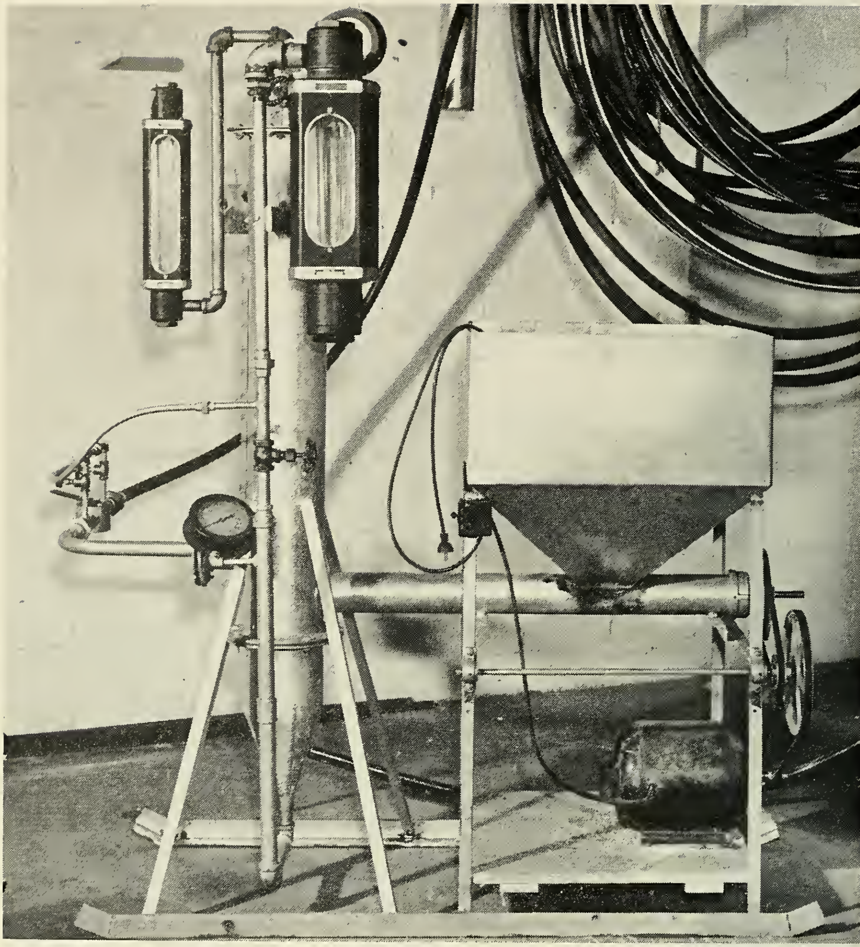


FIGURE 2. ORIGINAL model with horizontal conveyor showing plastic discharge pipe and air flow measuring equipment.

Construction Details

The conveyor consists of a hopper, helicoid screw including power drive, fluidizing chamber, air distribution ring, and discharge pipe.

The 24 by 24-inch hopper made of 1/16-inch black iron will hold several bushels of grain (Fig. 5). It is made as low as possible to facilitate unloading from wagons and trucks. The rim is reinforced with 1 by 1 by 1/16-inch angle iron. Details for construction of the hopper are shown in Figure 6. Extreme care should be taken when laying out and cutting the base of the hopper so that it will fit up against

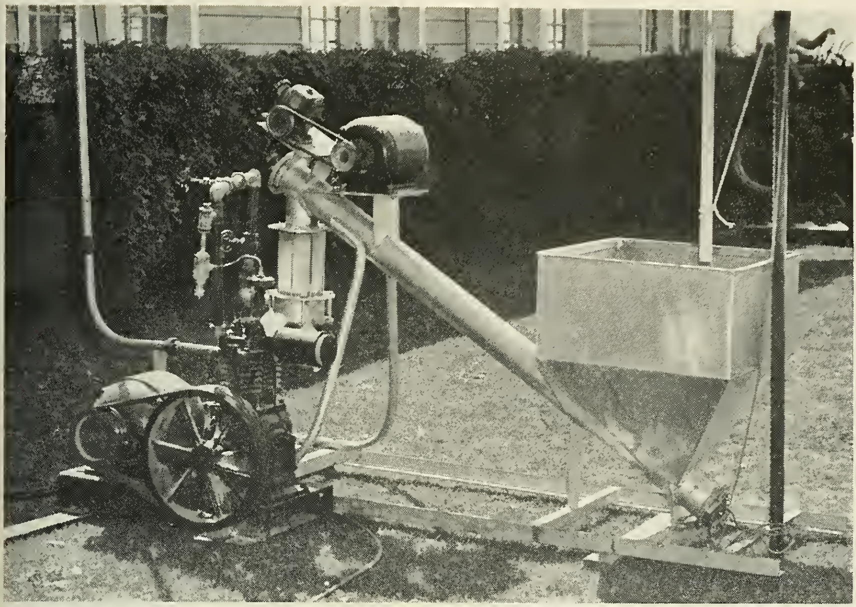


FIGURE 3. COMPLETE conveyor with 5 hp. air compressor but without tank.

the conveyor screw casing. The hopper is then welded to the casing. The welding should proceed slowly, avoiding excessive heat, which would warp the casing. Another method of fastening the hopper to the casing is by the use of gaskets and screws. If this is done, the base of the hopper that comes in contact with the casing must be ¾ inches longer so as to extend around and fit the casing. Either arc or acetylene welding may be used to join the edges of the hopper (Fig. 5).

The 4-inch helicoid screw carries the grain from the hopper through a 4-inch iron pipe or casing to the top of the fluidizing chamber. The pipe must be straight since there is but little tolerance allowable between screw and casing. This is necessary because too much clearance between the screw and casing allows the grain to be pushed back into the hopper by air pressure built up in the fluidizing chamber. The column of grain moving through the screw feeder to the fluidizing chamber must serve as an air lock in order to build up sufficient pressure in the fluidizing chamber; without it the conveyor will not function.

The 4-inch pipe serves as the "backbone" of the conveyor. It is mounted on two 2 by 2 by ¼-inch angle iron runners 25 inches apart (Fig. 7).

The lower saddle is welded to the pipe and bolted to the cross brace on the runner. Two pieces of 1½-inch iron pipe or rigid conduit are

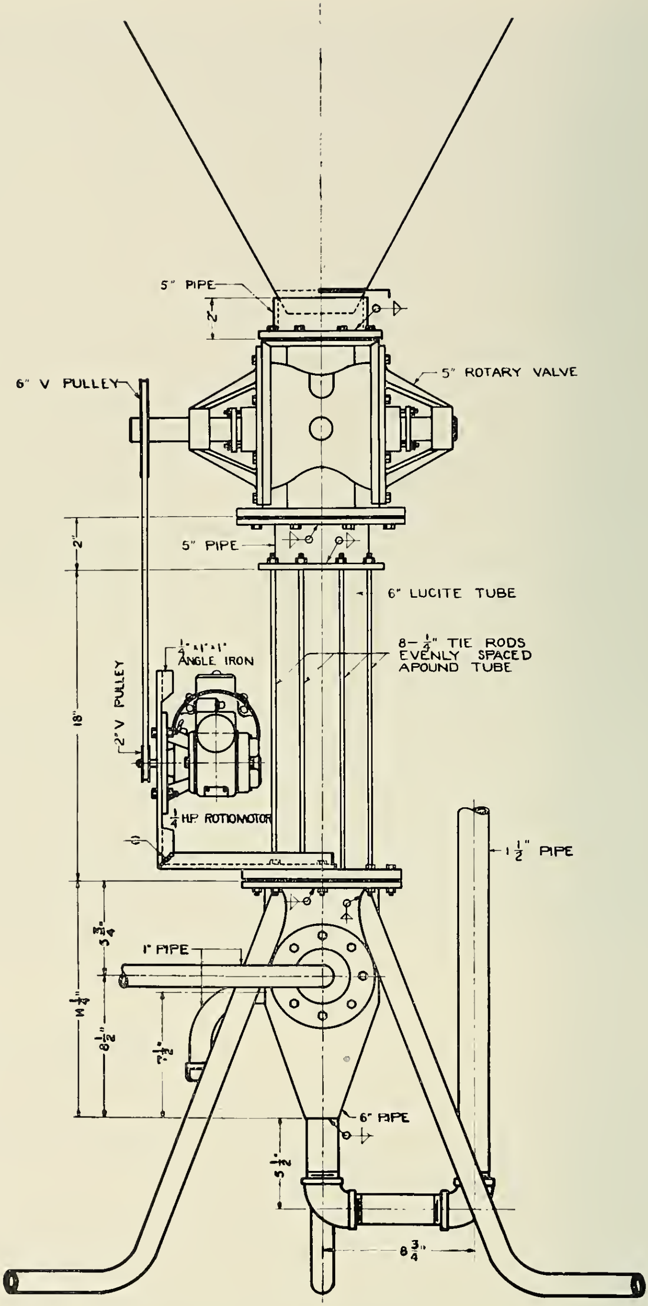


FIGURE 4. **ROTARY VALVE** above fluidizing chamber.

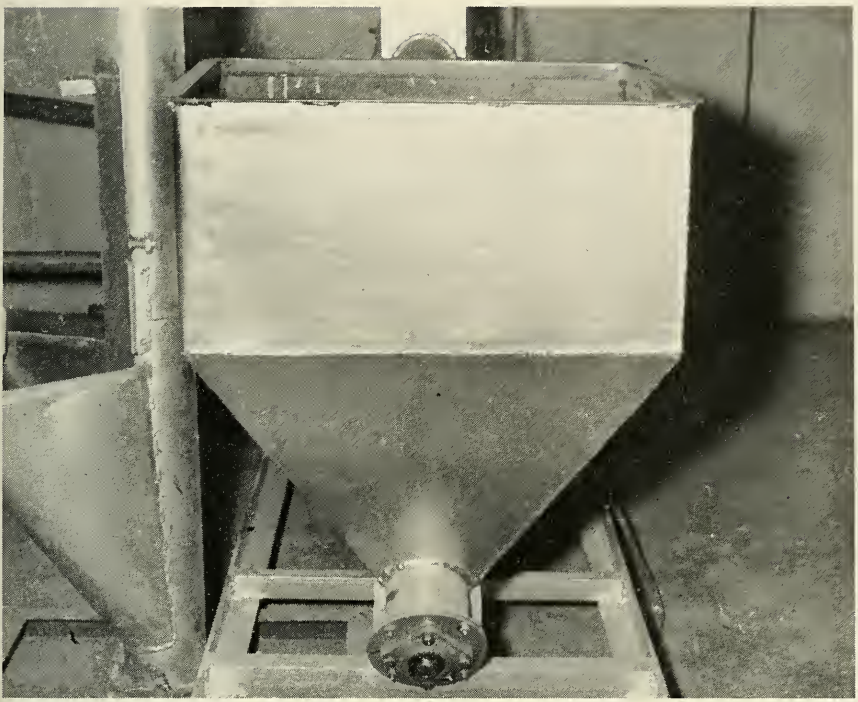


FIGURE 5. COMPLETE HOPPER showing location and method of attaching to casing.

bent as shown in Figure 7 and welded to the upper end of the pipe and bolted to the base.

Collars of 3/8-inch steel plate are welded flush with each end of the pipe for fastening the bearing plates. These also are 3/8 inch thick (Fig. 8). A one-inch self-aligning ball bearing is mounted on these plates to support the shaft of the helicoid screw. Thin gaskets are used, if necessary, to make the ends airtight.

The screw is driven through a 10-1 speed reduction unit by means of a 1 hp. electric motor (Fig. 9). Belting requirements and screw speed will vary with each installation. The screw must turn approximately 60 rpm to move one ton of wheat per hour, 120 rpm for two tons, and 180 rpm for three tons.

The brackets (Figs. 9, 10, and 11) for the motor mount and speed reducer are of 3/8-inch steel welded to the screw casing. Slots for anchor bolts are cut in the base to allow for adjusting belt tensions.

The fluidizing chamber (Fig. 12) is a transparent lucite cylinder 8¾ inches long with a 5-inch inside diameter. Steel flanges on each end are

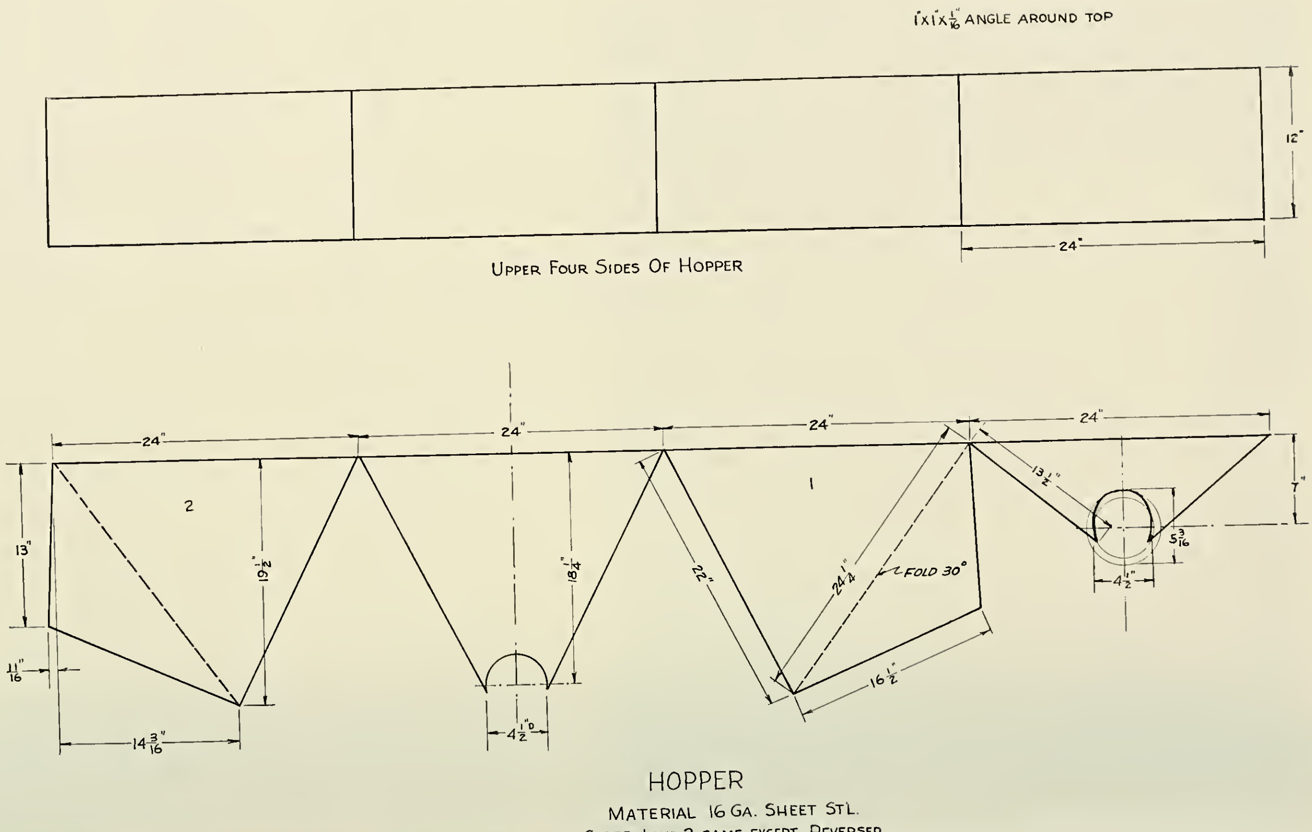


FIGURE 6. GRAIN HOPPER construction details.

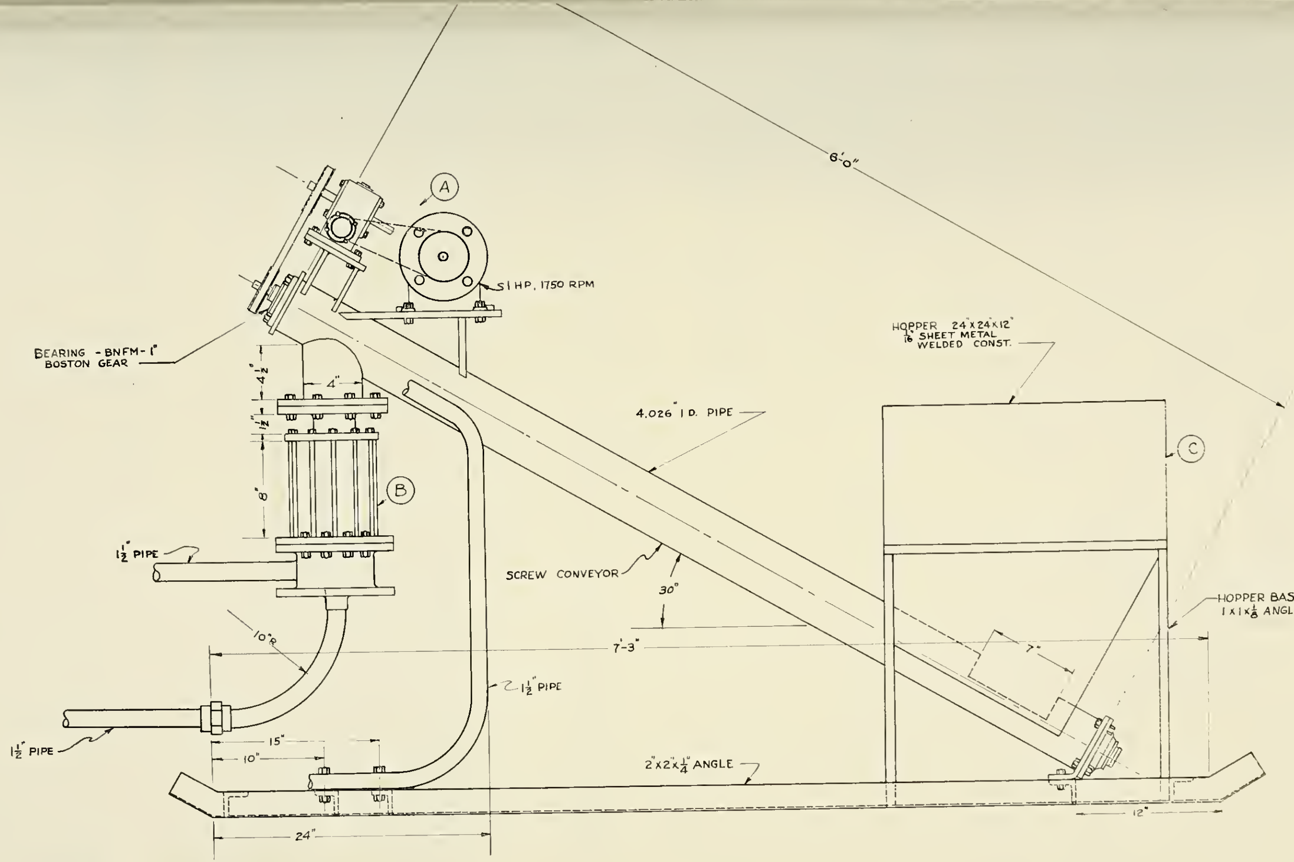
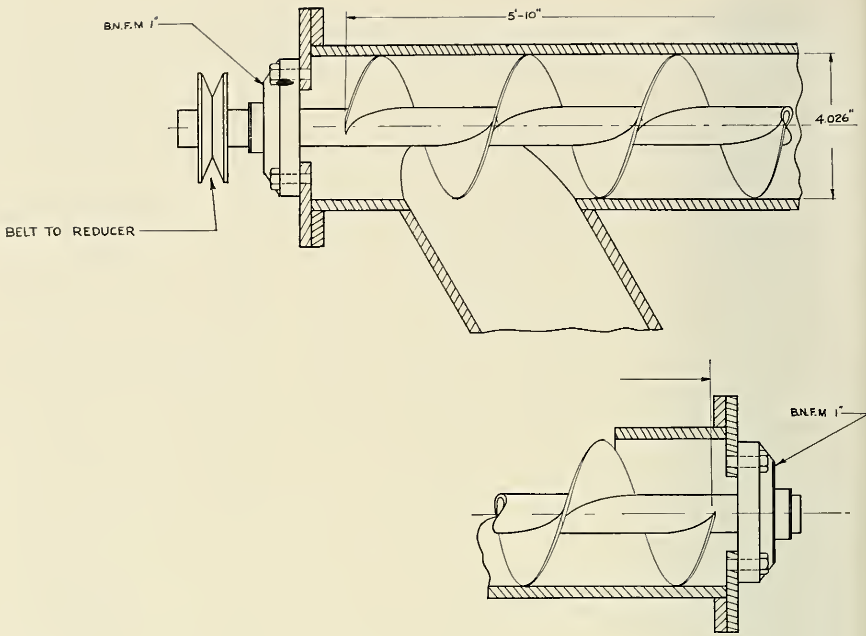


FIGURE 7. SIDE VIEW of conveyor.



Screw Conveyor

FIGURE 8. BEARINGS supporting screw are mounted on each end of casing.

held together by eight ¼-inch rods, 10 inches long. The upper flange is welded to a short nipple of 4-inch steel pipe, which in turn is welded to the upper end of the screw feeder casing. The lower flange supports the air distribution ring (Fig. 13).

The air distribution ring is made of two 8-inch diameter steel flanges and two pieces of pipe. The outer ring is a 6-inch pipe, 3½ inches long (Fig. 13). The air line from the compressor is fastened to this ring. The inner ring made from 4-inch pipe, 3¼ inches long is welded to the bottom plate, or flange. It contains eight ½-inch holes evenly spaced to admit the air into the fluidizing chamber.

The distribution pipe is welded to the lower flange so that its upper end is 3¼ inches above the flange, or flush with the top of the distribution ring. This pipe should preferably be a long-radius elbow. The assembly (including flange, 4-inch distribution ring, and pipe) may be made for either 1-inch, 1¼- and 1½-inch pipe for quick interchange if different capacities are needed (Fig. 14).

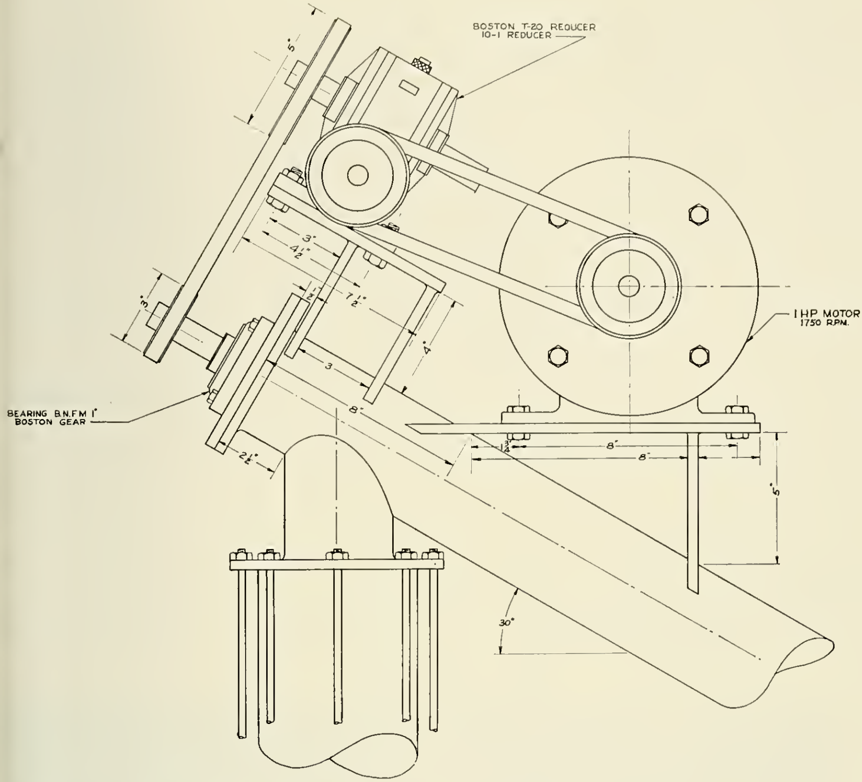


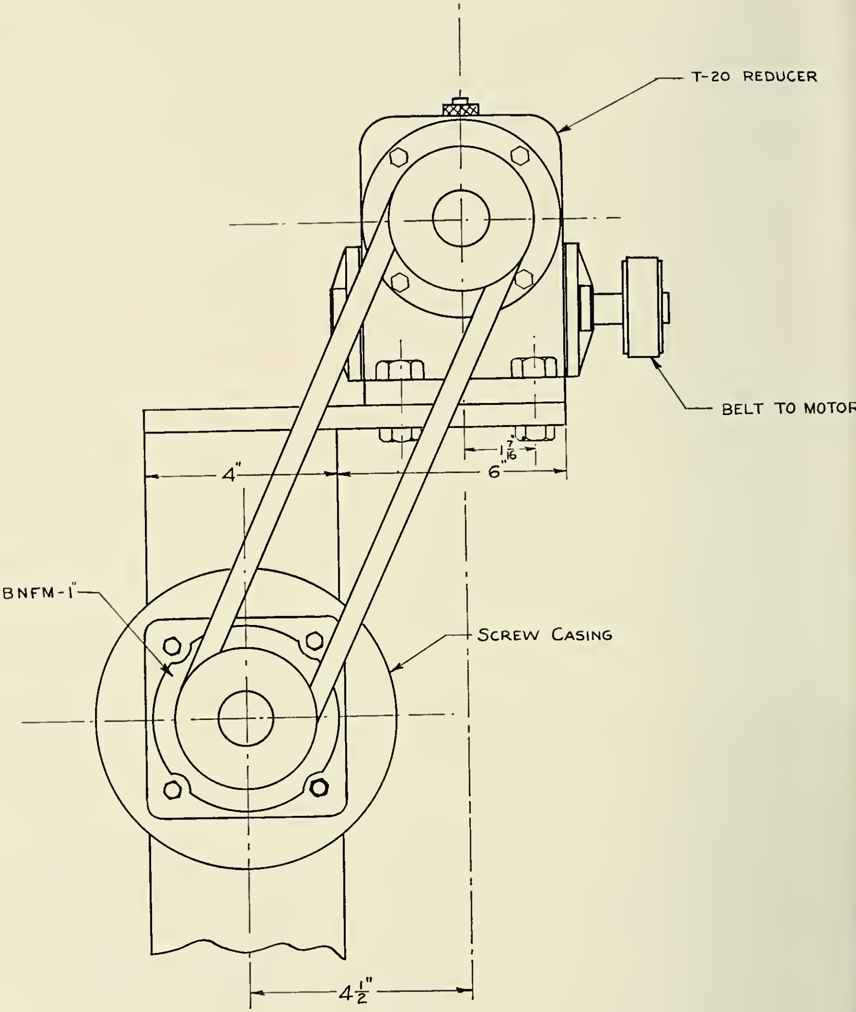
FIGURE 9. SPEED REDUCER and motor mounts.

The delivery or discharge pipe may be rigid conduit, thin-wall conduit, or galvanized or black iron pipe. Joints must be smooth to prevent clogging, and all bends or turns in the line should have a radius not less than six times the inside diameter of the pipe. The pipe and equipment must be grounded to discharge static electricity.

Plastic pipe has been used to convey wheat but the static electricity charge was so great, that it tended to restrict flow and it constituted a fire hazard. Moreover, it cannot be grounded since it is not a good conductor of electricity.

Operation--Capacity and Limitations

Quantity of material handled per hour was dependent upon size of the discharge pipe and capacity of the air compressor. The conveyor operated most efficiently when the velocity of the air in the discharge pipe was just adequate to maintain fluidization. This was about 60 feet



AXIAL VIEW - SCREW CONVEYOR

FIGURE 10. SPEED REDUCER off set to allow for belt tightening and better alignment with motor. (Pulleys not drawn to scale.)

per second for whole wheat. Any reduction in this velocity allows the conveyed material to fall out of the air stream and causes plugging. Uneven flow or "slugging" of the material indicated insufficient air velocity and actual stoppage would occur. On the other hand, excessive velocities gained but little increase in solids flow, but there was increased

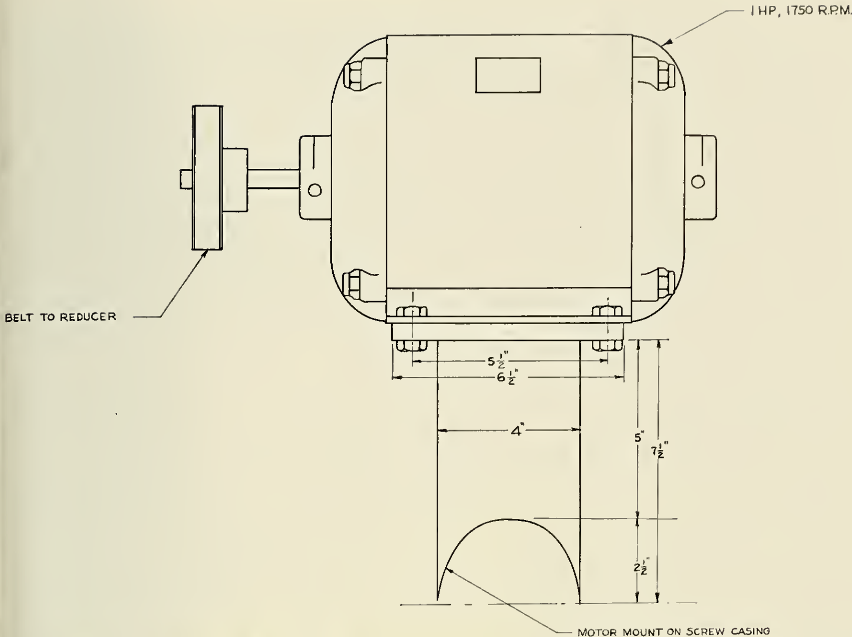


FIGURE 11. REAR VIEW of motor and mounting.

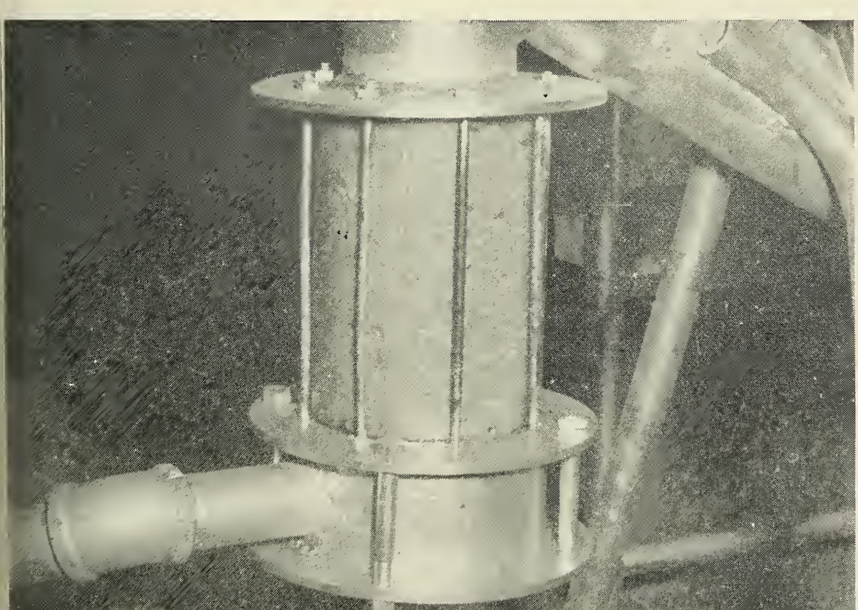


FIGURE 12. FLUIDIZING CHAMBER containing wheat.

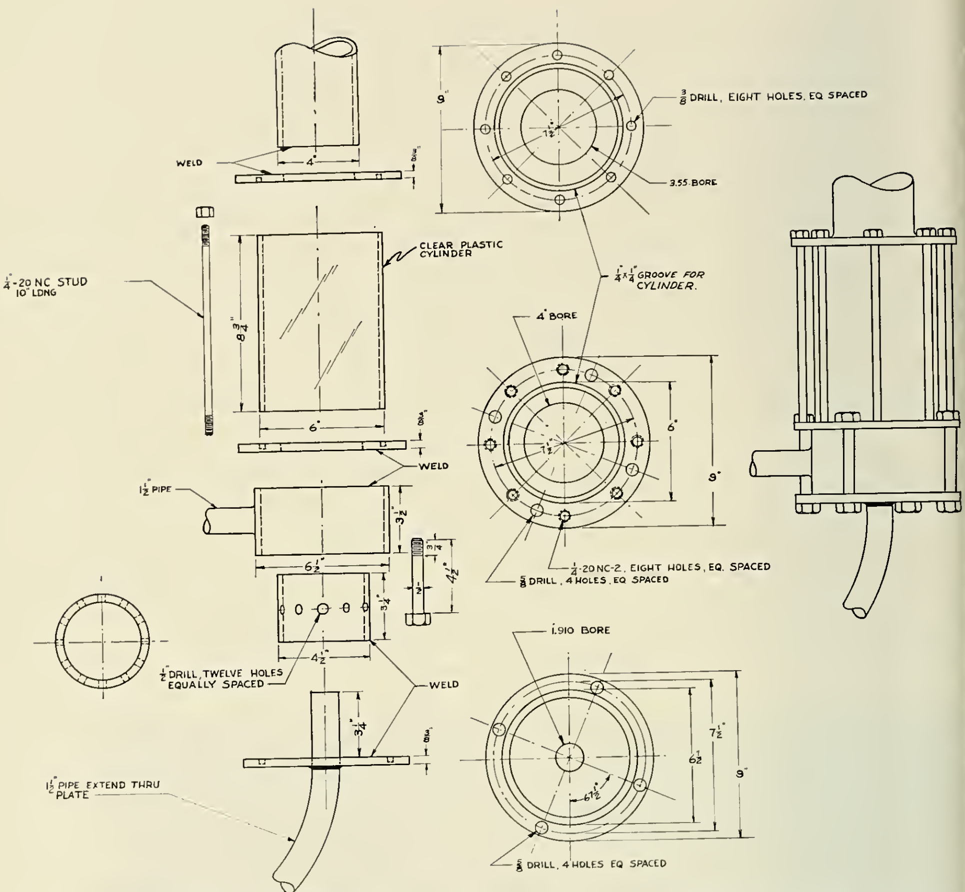


FIGURE 13. CONSTRUCTION details of the fluidizing chamber and air distribution ring.

air flow which reduced the air-solids ratio, thus increasing cost. Increased velocity of the grain also caused considerable shelling and breaking of the seed. This was not desirable.

A one-inch discharge pipe handled up to one ton of whole wheat per hour when a 5 hp. reciprocating air compressor was used. A 1½-inch discharge pipe carried two tons of wheat per hour with a 10 hp. compressor. It was possible to convey three tons per hour through the 1½-inch pipe but some seed injury occurred.

The distance over which grain was conveyed depended on the number of turns in the discharge line. These should be kept to a minimum to reduce friction and turbulence at the elbows. It was found

FIGURE 14. A ONE-INCH discharge pipe with lower flange and distribution ring attached.

that whole wheat could be elevated 50 feet vertically at 4.5 psig in the fluidizing chamber when using four long-radius elbows, permitting the collection of the grain in a container on the roof of the Agricultural Engineering Laboratory. Under favorable conditions, using fewer turns, or elbows, it was possible to elevate wheat more than 50 feet.

For the average farm, where only single-phase electric power is available, conveyor operations will be limited to the capacity of a 5-7½ hp. air compressor, and under such conditions it should be possible to use 1¼-inch discharge pipe which would convey approximately 1½ tons of whole wheat per hour. When planning the conveyor system it should be kept in mind that the compressor can be used for many other farm operations, and making it a portable unit would increase its usefulness.

Application and Uses

It is impossible to describe all of the possible applications and uses of this conveyor. Potentially, the fields of use, either agricultural or otherwise, are enormous. The two limiting factors to its use are size and weight of particles conveyed and the volume of air available. Wheat was used almost exclusively during the development of the conveyor because it is the heaviest of all grains, was most readily available, and it was felt that most grains and seeds could be conveyed if wheat could be handled satisfactorily. Some possible uses of the conveyor are:

1. It should find ready acceptance in seed houses where exisiting, conventional conveyor systems constantly contaminate pure strain seeds.

2. Feed mills that handle both whole grain and ground feed from bins, mixers, and grinders may find many uses for the new conveyor.

3. Large dairy farmers and others who move large quantities of grain and feed may be able to adapt this conveyor to their farm chores to lessen hand labor requirements.

4. Grain storage firms can load elevators and aerate fresh grain by unloading it from the bottom and blowing it back in at the top. This could be a 24-hour process using less expensive equipment. At the same time, insecticides may be introduced in the air stream for effective insect control.

5. Many non-agricultural uses undoubtedly exist but will not be discussed here.

Power Requirements

Air volume and pressure requirements for this conveyor operating on wheat demanded a reciprocating air compressor. Other types of compressors including the rotary failed to provide sufficient air volume at operating pressures but would probably be adequate with ground feed or small seeds. It was found that to move a ton of wheat per hour required 5 hp. of compressor capacity.

The screw feeder is powered with a 1 hp. electric motor, although ¾ hp. motor may be used if operating pressures in the fluidizing chamber do not exceed 2 or 3 psig. Normally pressures will not exceed 4.5 psig when elevating 50 feet or less. Elevating grain more than 50 feet above the conveyor is possible, but there is insufficient information to permit such procedure to be unconditionally recommended at this time.

Further Developments Needed

Automatic control of conveyor operations is possible but has not been tried. Pressures in the fluidizing chamber are rather stable during normal operation. Should the line plug there is an immediate rise in pressure. If for any reason grain stops flowing into the fluidizing chamber, the pressure drops slightly. A diaphragm activated by pressure in the fluidizing chamber connected to a micro switch or relay will control the compressor and feeder motors.

Research on and development of the fluidized-grain conveyor is by no means completed. Tests on wheat indicate it will have considerable application. How well it will handle materials other than wheat will only be known after trials are made, and how well it will perform with automatic controls is a matter of conjecture at this time. The cost of the conveyor, exclusive of the compressor, is not great. Any person skilled with welding equipment and the usual complement of farm shop tools can build the conveyor.

Blueprints are available at a nominal fee. They may be obtained by writing to the Department of Agricultural Engineering, West Virginia University, Morgantown, W.Va.