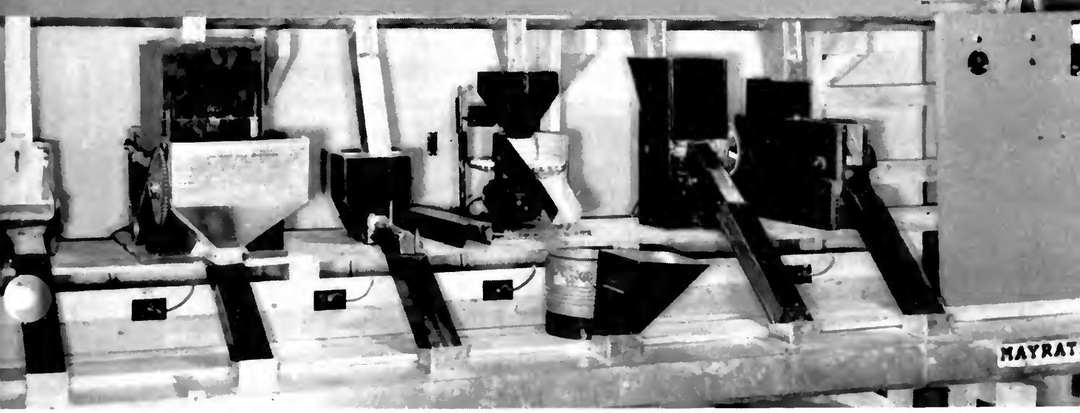
VOLUMETRIC FEED METERS

Their Performance for Automatic Feeding Systems

By H. B. Puckett and Robert M. Peart



Bulletin 618

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FEED METERS are essential to any system of automatic feed preparation and distribution. In addition to their use in blenders, feed meters are in increasing demand for other farm jobs. A feed meter is necessary for applying ground feed uniformly to silage as the silage and ground feed are distributed in a bunk by a mechanical feeder. It is needed to apply ground corn uniformly to legume silage at the silo filler. A feed meter is useful wherever a uniform rate of application of a granular material is required.

A feed meter is one of five parts of an automatic feed-grinding system. Such a system consists of: (1) storage bins for grain and supplements from which the feed will flow to a central point[3]; (2) a blender, consisting of two or more feed meters to deliver a continuously proportioned ration; (3) a grinder suitable for electric operation and automatic control[4, 9]; (4) conveyors to move feed to point of use[7]; and (5) distributors to place the feed before the livestock.

Until the present time, two general types of meters, volumetric meters and weight-type blenders, have been used in automatic feed-grinding systems. L. S. Foote and others have done considerable work on feed metering devices in developing the Illinois automatic feeding system. Foote worked with several types of volumetric meters and installed them with automatic feed-grinding systems on farms of co-operators. All automatic feed-grinding systems on Illinois farms use volumetric meters. Foote also worked with a weight-type blender similar to that developed by H. D. White [14] at the University of Georgia. The weight-type blender and meter, although considered more accurate, is necessarily large and complicated compared with volumetric meters. For this reason, the more recent work on feed metering and blending has been done with volumetric meters.

Since the installation by farm cooperators of 10 pilot automatic feeding systems in Illinois, over 100 other automatic feeding systems, using at least six different types of meters, have been installed in the state. Results of tests of the various types of meters will greatly aid agricultural engineers and farmers in selecting feed meters for various applications. These results should also help guide manufacturers in selecting a type of feed meter for development of the rapidly growing market for automatic feeding equipment.

Aim of the Study

The object of the study was to determine the most desirable type of feed meter. A testing program was initiated to establish the accuracy of various types of meters under operating conditions. With the results of these tests, a type or types that would best meet the requirements of accuracy and simplicity required by an automatic feeding system could be selected for future development.

Standards for the accuracy required were established. Several animal nutritionists were consulted to establish the permissible variability of feed ingredients in a ration. In these discussions, it was determined that plus or minus 10 percent of the indicated protein content of a ration would be acceptable for livestock feeding. For instance, if the ration called for 10 percent protein, 9 to 11 percent would be acceptable. They were of the opinion that this variability could be larger from day to day if within the period of a week the protein content averaged within 10 percent of that desired. On the basis of 10-percent variability in nutrient content, a level of 5-percent error with 95-percent confidence was selected as acceptable meter performance. Tests were then designed to provide information supporting selection of the simplest meter that would meet this requirement for accuracy.

Some volumetric meters should fall within the 5-percent variability limit, and because they are simpler than weight-type meters, it was decided to test only volumetric meters. The volumetric meter is simpler to construct, operate, and maintain than a weight-type meter.

Six principles of volumetric metering were selected for testing. They are pictured and described on pages 4-9.

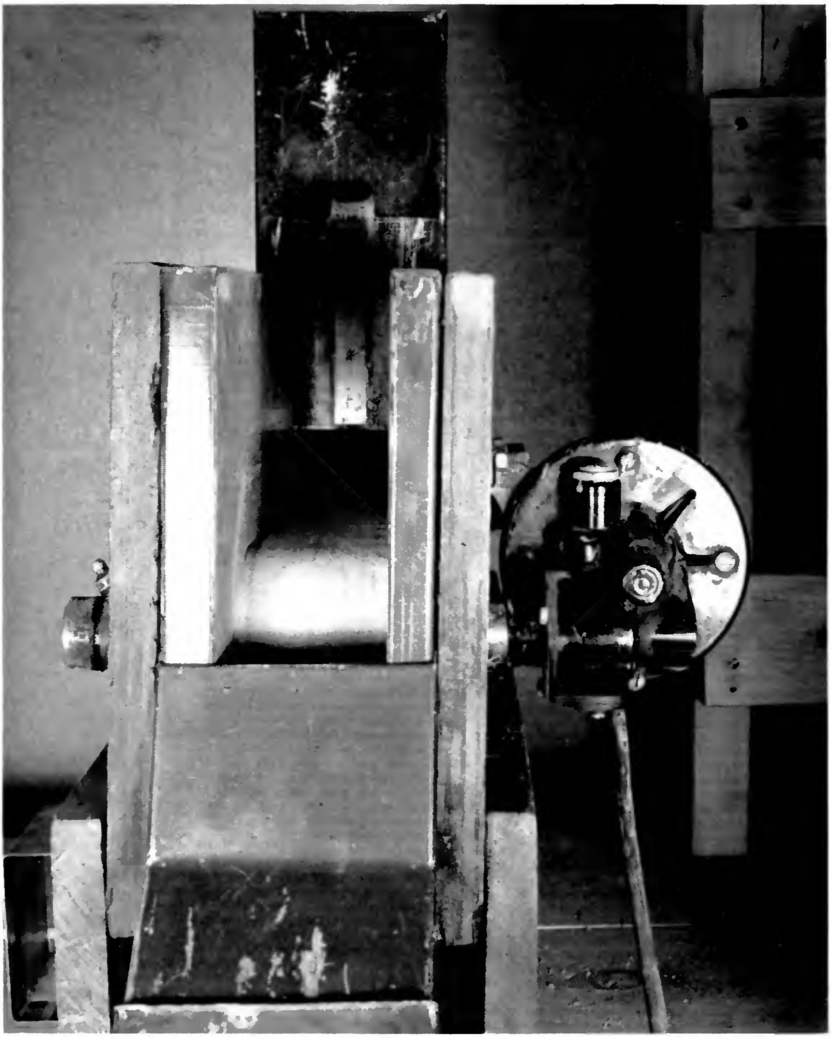
Methods of Testing

The six types of volumetric meters were tested for: accuracy at various rates of output and for different feed materials; and for accuracy when operated continuously and when operated intermittently. Results aided in selecting the best meter.

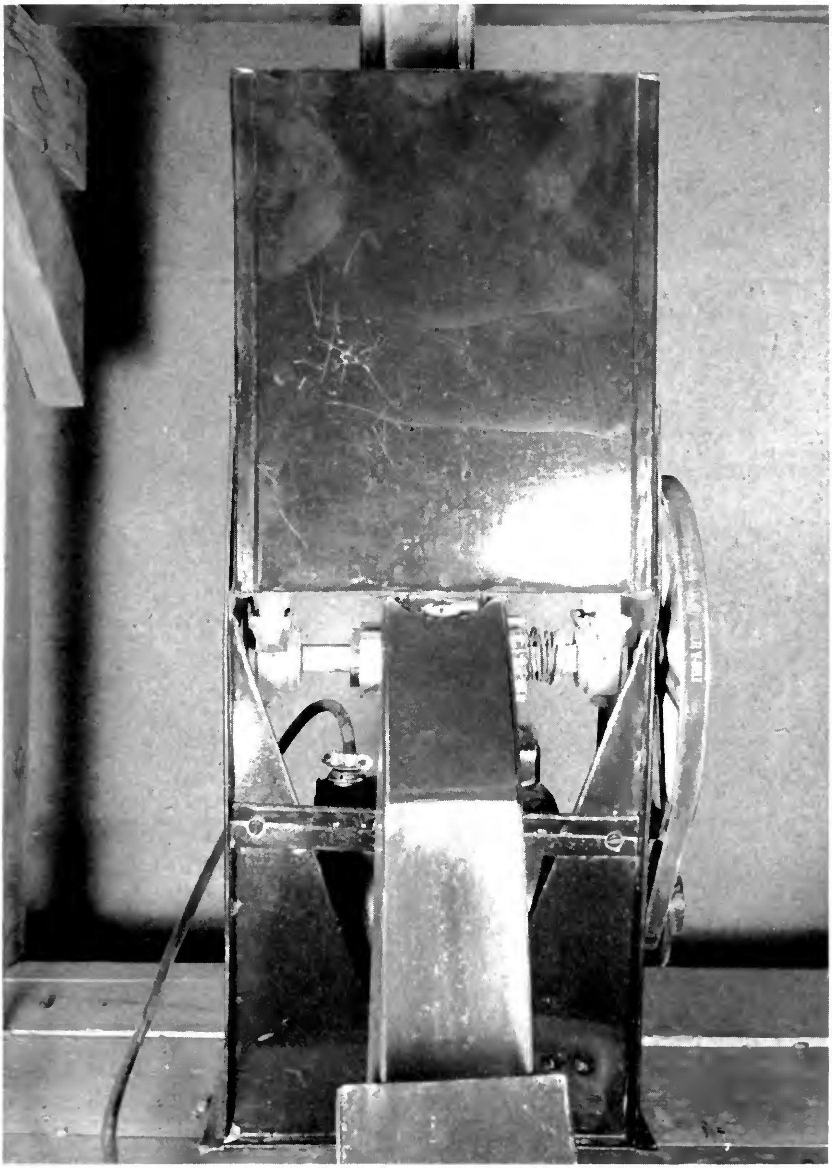
Statistical methods were used to evaluate the data. The method of collecting the data was adjusted to minimize possible sources of error. To minimize error further and to assist in collecting the data, a special testing apparatus was built (see cover picture). The apparatus stored and continuously delivered feed to all meters under test. The hopper of each meter was kept full. Any excess feed was returned to the storage hopper with feed material run through the meters. Each meter was built so that a sample of feed for a measured interval of time could be easily collected. The same timer was used to time each meter and was automatic, once initiated by the operator. The apparatus permitted each meter on test to run continuously when its output was not being collected during a timed run.

To simulate intermittent operation, each meter was turned off for 3 seconds and on for 3 seconds by an automatic recycling timer, the

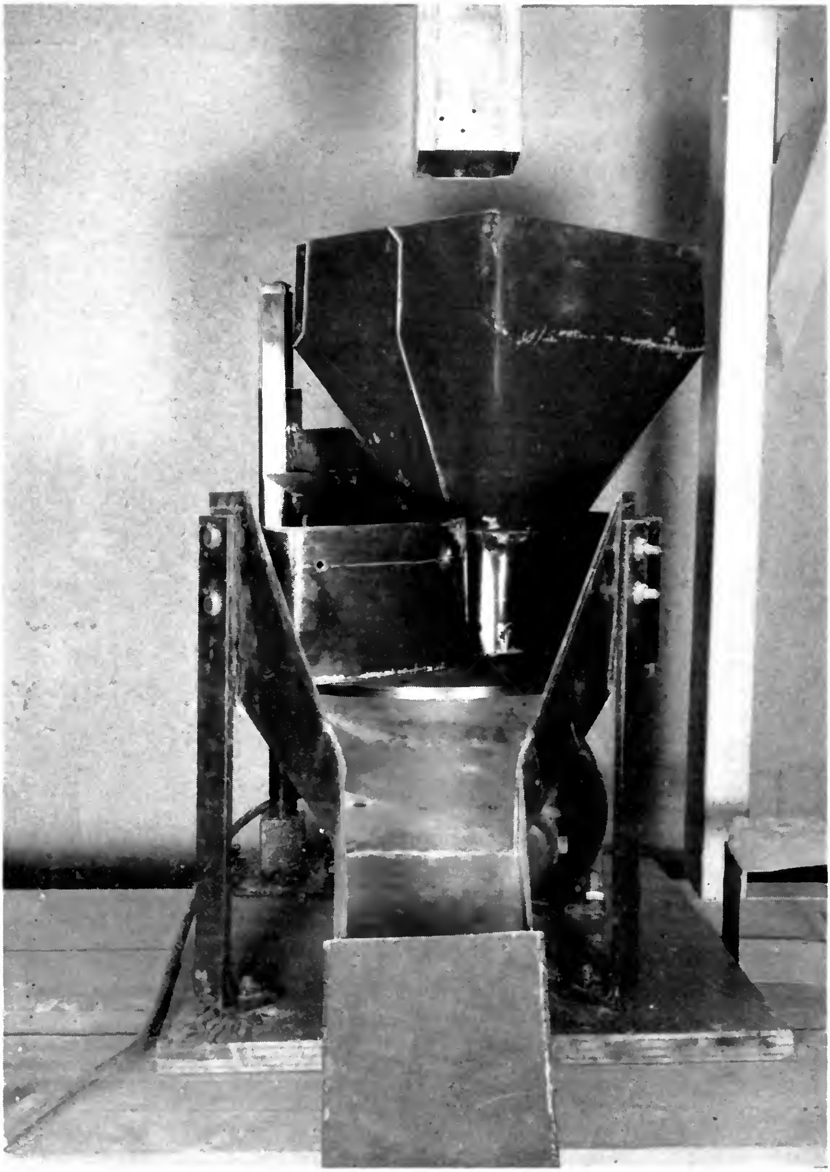
(Continued on page 10)



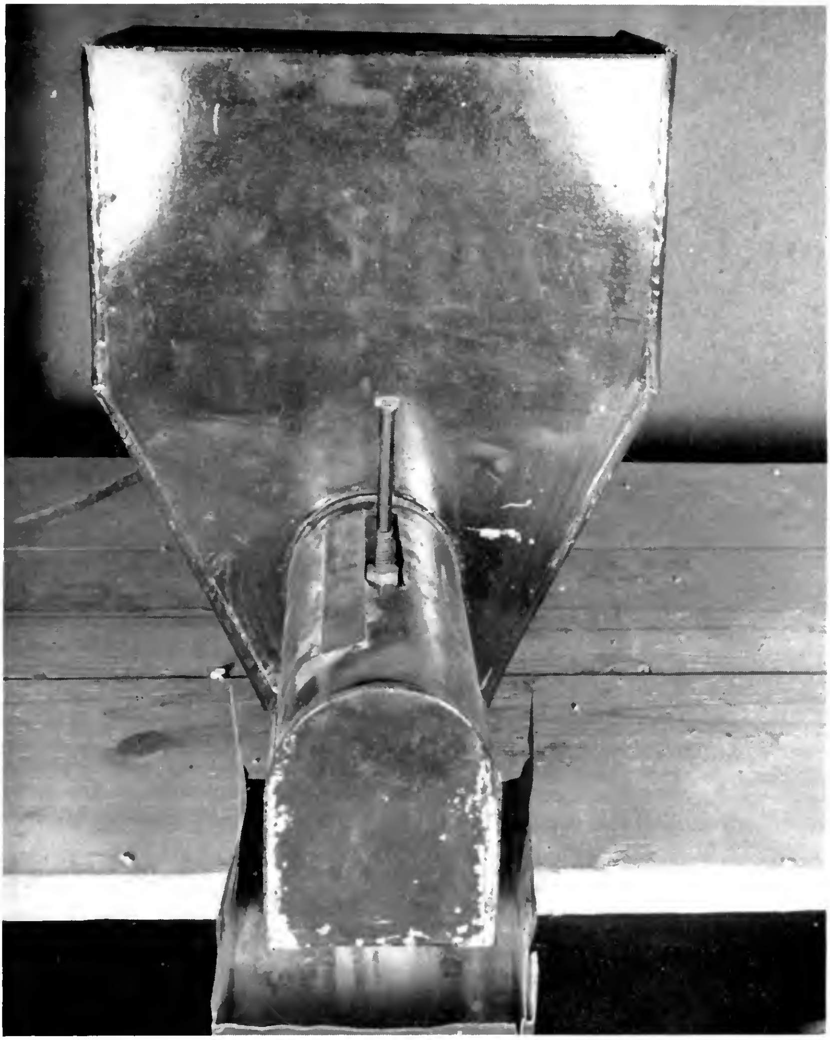
This flat fabric-belt meter consisted of a 4-inch cotton belt over which a gate was arranged to regulate the amount of material pulled out of the holding bin by the belt. This type of meter must be gravity fed. It cannot remove feed from a large storage bin directly, because it does not transmit enough force. The belt travelled 19 feet per minute. The feed occupied the center 2½ inches of the belt. The gate adjusted from 0 to 4-inch maximum opening. (Fig. 1)



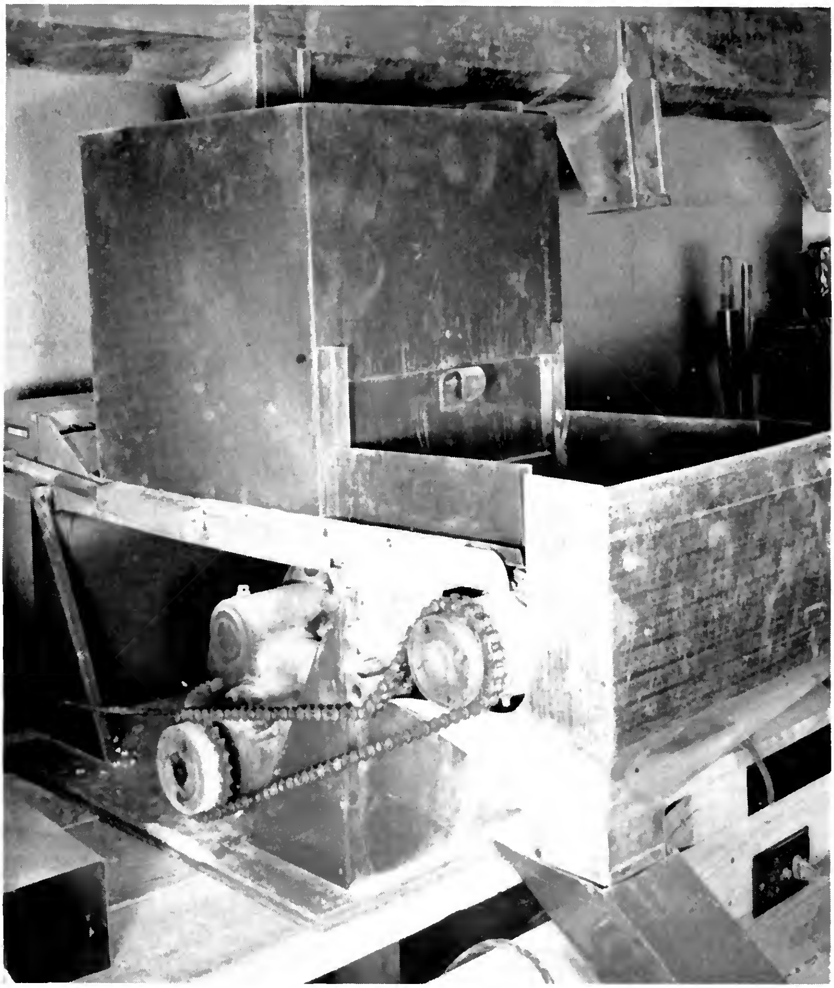
This fluted wheel meter consisted of a small fluted wheel unit taken from a small-grain drill. It was driven at 450 r.p.m. to achieve the desired volume. Its capacity was regulated by sliding the fluted wheel in and out of the well at the bottom of the feed hopper. (Fig. 2)



This rotating table meter consisted of a 12-inch flat disk powered by a 36 r.p.m. gear motor. The capacity was regulated by adjusting the height of the grainspout above the disk top. The spout was centered on the disk. (Fig. 3)



In this auger meter, a small auger, 1½ inches in diameter with a 3-inch tube, was driven directly by an 1150 r.p.m. 1/30 horsepower motor. The auger was driven at this speed to avoid speed reduction. Speed reduction would increase the cost and complexity of the meter. The capacity of the meter was regulated by adjusting an inner sleeve that varied the exposure of the auger to the feed. (Fig. 4)



In this metal-belt meter, a metal belt 14 inches wide, driven by a gear motor, pulled feed out of the bottom of a 14″ x 16″ bin. Capacity was regulated by adjusting the speed of the belt through gear changes (1.5 feet and 4.4 feet per minute) and by adjusting the striking gate over the belt to regulate the amount of the material pulled from the bin. This belt is strong enough and its drive positive enough to permit it to be installed in a large storage bin as the bin floor. (Fig. 5)

This vibrator meter consisted of a metal box with a 120-volt, 60-cycle AC vibrator attached to the bottom. Previous tests[10] indicated that this particular type of vibrator unit would satisfactorily operate at line voltage and that the capacity could be regulated by adjustment of a gate in the discharge trough. For these tests, line voltage was used on the vibrator and all capacity adjustments were made with the gate. (Fig. 6) operation of which was also controlled by the interval timer used to time all tests. Timed runs of ½ minute were made to collect samples for steady operation. Timed runs of 1 minute, during which the meter was operated half the time, were made for intermittent operation. These timing intervals made comparing the output of a meter at steady and at intermittent operation easier. Each meter was checked, insofar as its range would permit, at six different rates, ranging from 2 to 32 pounds per minute. Thirty-two pounds per minute corresponds to approximately 1 ton of feed per hour. A farm meter would probably not be required to deliver a greater amount.

Soybean meal, oats, and shelled corn were the feed materials tested. They are representative of feeds the meters would be expected to handle.

Two operators were used in the test. The first determined, through a series of trials, the calibration for each meter at each capacity to be tested. He then used this calibration to adjust the meters. The second operator used the same calibration. In no event during a test was the calibration adjusted to keep the meter output more nearly in line with that desired. Each operator collected 3 weight samples from each meter

Table 1.—Performance of Vibrator Meter With Soybean Meal for Steady and Intermittent Runs[a]; Two Operators, A and B

Replication No.	Output in pounds at capacities of—											
	1 lb.		2 lb.		4 lb.		8 lb.		12 lb.		16 lb.	
	Op. A	Op. B	Op. A	Op. B	Op. A	Op. B	Op. A	Op. B	Op. A	Op. B	Op. A	Op. B
	Steady run for 30 seconds											
	.85	.81	2.23	1.75	3.65	3.17	7.98	9.98	11.90	11.87	15.20	18.29
1	.75	.79	2.05	1.72	3.77	3.23	7.99	9.53	11.75	11.68	15.28	18.17
	.79	.71	2.09	1.57	3.75	3.27	7.98	9.31	11.45	11.54	15.15	18.06
	.67	.57	1.80	1.29	3.23	2.63	9.27	8.94	10.66	10.63	17.25	17.25
2	.77	.60	1.74	1.32	3.27	2.69	9.04	8.64	10.66	10.64	17.31	17.58
	.78	.58	1.70	1.31	3.26	2.69	9.22	7.84	10.94	10.58	16.65	17.30
	.89	.84	1.49	1.94	3.37	3.79	8.40	8.62	11.07	10.66	18.19	17.32
3	.92	.82	1.47	1.95	3.37	3.72	8.12	8.48	10.88	10.69	17.63	17.34
	.89	.79	1.49	1.84	3.41	3.75	8.15	8.37	10.93	10.56	17.69	16.51
Sum.....	7.31	6.51	16.06	14.69	31.08	28.94	76.15	79.71	100.24	98.85	150.35	157.82
Aver.....	.81	.72	1.78	1.63	3.45	3.22	8.46	8.86	11.14	10.98	16.71	17.54
	Intermittent run, 3 seconds on and 3 seconds off for 1 minute											
	.81	.79	2.07	1.66	3.68	3.21	10.13	9.87	10.64	11.81	16.00	18.81
1	.78	.85	1.84	1.64	3.78	3.18	9.80	9.71	10.86	11.46	17.30	17.60
	.82	.80	1.92	1.63	3.71	3.24	9.72	9.75	10.76	11.46	15.90	17.45
	.45	.59	1.76	1.32	3.09	2.66	10.50	8.36	11.09	11.06	16.29	17.60
2	.42	.61	1.87	1.10	3.16	2.79	10.04	8.26	11.19	11.49	16.50	16.75
	.41	.59	1.80	1.12	3.24	2.60	10.01	8.79	11.41	10.87	16.93	16.59
	.83	.97	1.60	1.97	3.48	4.13	8.30	8.01	10.83	10.80	16.32	18.44
3	.82	.89	1.48	1.96	3.54	3.96	8.14	8.27	10.78	10.57	16.49	17.11
	.79	.85	1.60	1.93	3.51	3.68	8.42	8.09	10.83	10.65	16.32	17.08
Sum.....	6.13	6.94	15.94	14.33	31.19	29.45	85.06	69.11	98.39	100.17	148.05	157.43
Aver.....	.68	.77	1.77	1.59	3.47	3.27	9.45	8.79	10.93	11.13	16.45	17.49

[a] Complete data available upon request.

for each adjustment at each mode of operation. This sampling process was repeated 3 times on subsequent days.

This method of sampling gave a total of 216 individual readings for each meter for each type of feed tested, or a grand total of 3,888 readings. The organization of the data and the system of collecting it permitted the inspection of error from the following sources: meter, output rate, feed material, meter resetting, operator, and intermittent and continuous operation. The analysis of the data permitted the construction of curves which depict the accuracy of the various meters for feed type, mode of operation, and output rate. A sample of the data is given in Table 1. The table represents $\frac{1}{18}$th of the data.

Results

The flat fabric-belt meter gave very accurate results (Figs. 7 and 8). There was some difference in performance due to material, but the error was in no case large. The percent of error climbed very rapidly in the lower range and went down to a minimum in the upper middle ranges of meter capacity. The meter was below 5-percent error for both soybean meal and oats at capacities of 2 to 32 pounds per minute, and below 5-percent error for shelled corn at capacities of 4½ to 32 pounds per minute. The percent of error increased with intermittent operation but was still not outside acceptable limitations.

The table meter gave very good results for steady operation (Figs. 9 and 10). For both soybean meal and oats, the error at capacities of 2 to 32 pounds per minute was below 3½ percent. The greater error existed at the high capacities. For shelled corn, the error was quite high at the 2 pounds per minute rate, but dropped steadily until the rate reached 32 pounds per minute. The difference in performance was undoubtedly caused by the difference in the size of the particles being metered.

The table meter performed quite satisfactorily within the range anticipated for an automatic feed-grinding system. As was expected, the error increased for all feeds with intermittent operation because of the inertia of the motor. The disadvantage of this meter is that it is subject to clogging and will not clear itself easily. It also requires a slow speed drive which increases its cost.

The fluted wheel meter on soybean meal and oats had very low error at capacities of 2 to 20 pounds per minute (Fig. 11). The percent of error for soybean meal increased rapidly, while that for oats increased less rapidly. For shelled corn at capacities of 4 to 32 pounds per minute the error was below 5 percent.

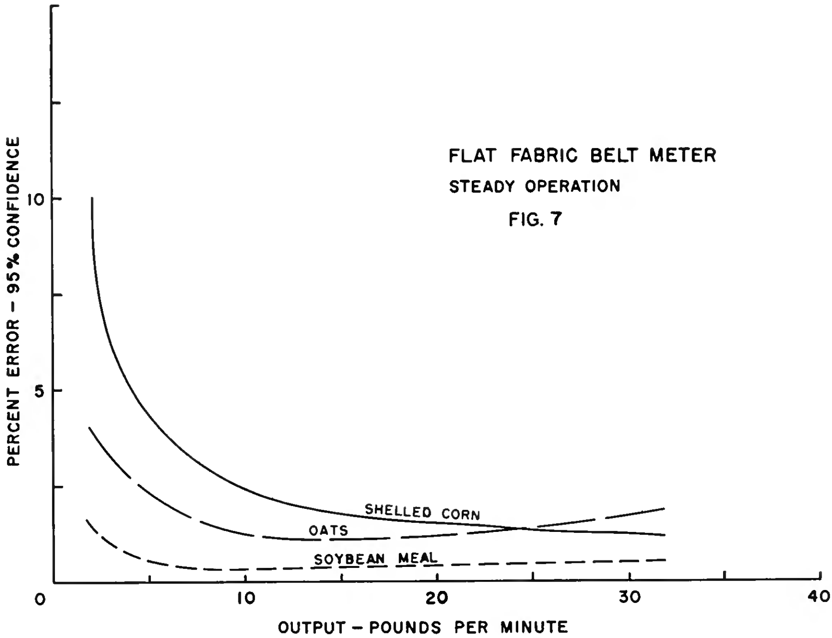

FLAT FABRIC BELT METER
STEADY OPERATION
PERCENT ERROR - 95% CONFIDENCE
10
5
0
10
20
30
40
SHELLED CORN
OATS
SOYBEAN MEAL
OUTPUT - POUNDS PER MINUTE

FIG. 7

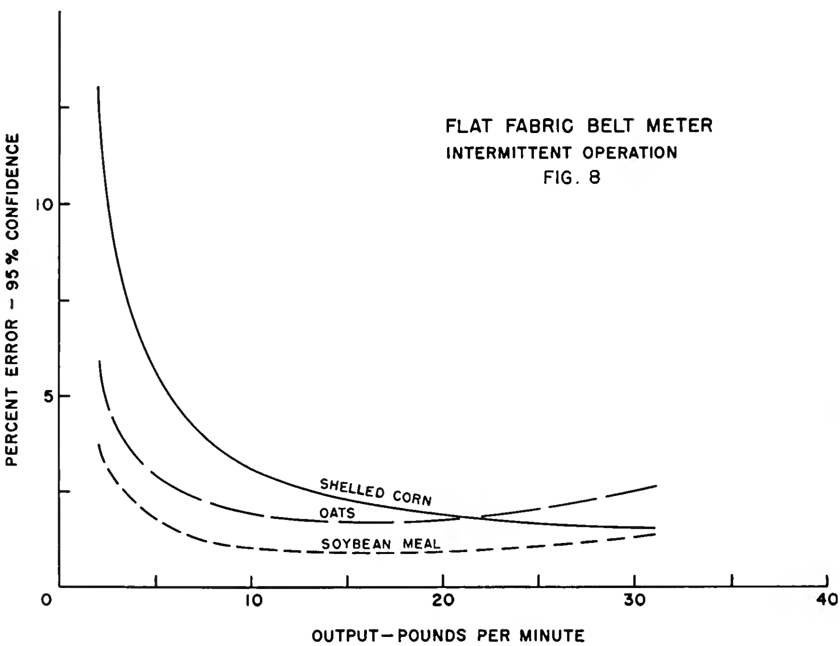
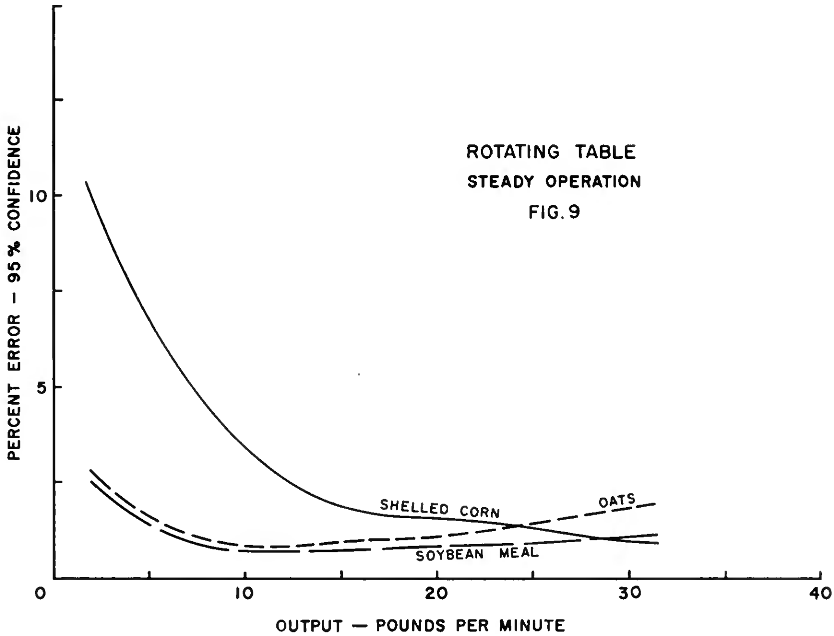
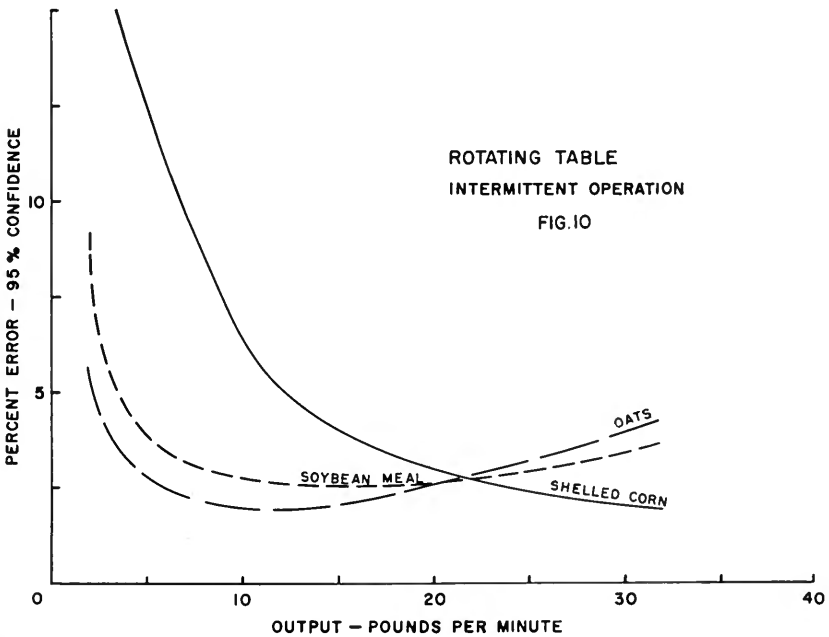

FLAT FABRIC BELT METER
INTERMITTENT OPERATION
PERCENT ERROR - 95% CONFIDENCE
10
5
0
10
20
30
40
SHELLED CORN
OATS
SOYBEAN MEAL
OUTPUT-POUNDS PER MINUTE

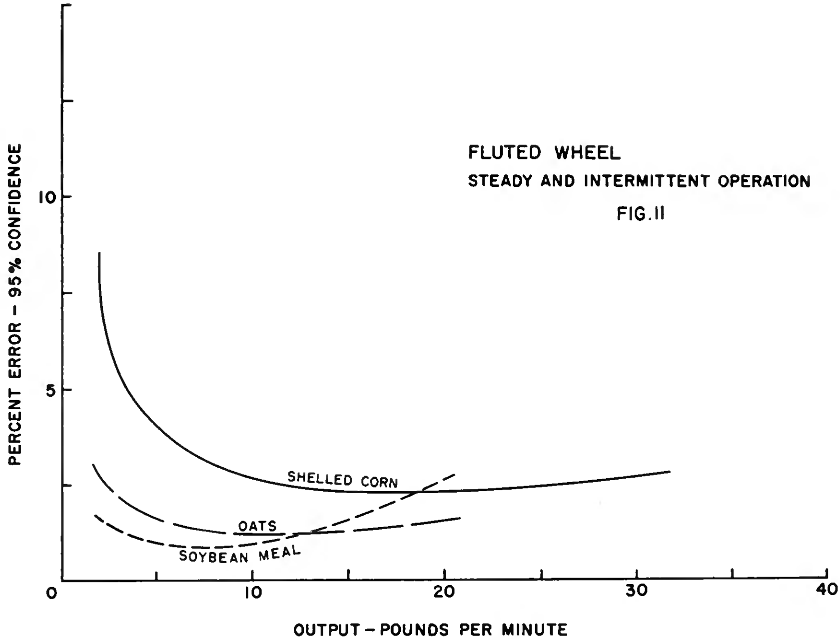
FIG. 8



ROTATING TABLE
STEADY OPERATION
FIG. 9
PERCENT ERROR - 95 % CONFIDENCE
10
5
0
10
20
30
40
OUTPUT — POUNDS PER MINUTE
SHELLED CORN
OATS
SOYBEAN MEAL

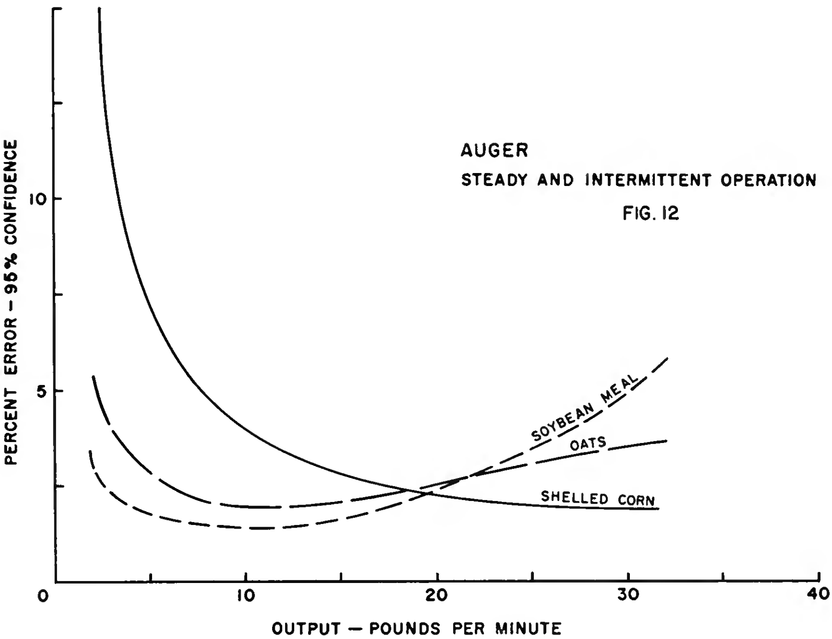


ROTATING TABLE
INTERMITTENT OPERATION
FIG. 10
PERCENT ERROR - 95 % CONFIDENCE
10
5
0
10
20
30
40
OUTPUT — POUNDS PER MINUTE
OATS
SOYBEAN MEAL
SHELLED CORN



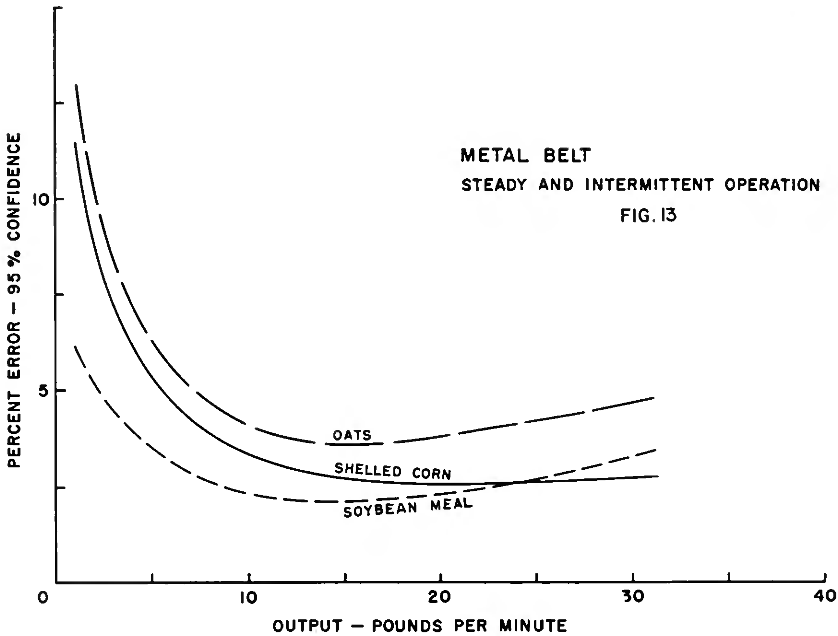
Two changes would improve the performance of this meter: (1) slowing the speed of the flutes; and (2) increasing their size to obtain sufficient capacity at slower speed. Slow speeds could be provided economically if this type of meter were incorporated as an integral part of an automatic feed-grinding mill. The meter becomes more of a problem and expense if it is built as a separate piece of equipment with its own power unit. The over-run or the coasting time of the meter when the power was off during intermittent operation contributed to the error for intermittent operation and caused doubt as to the desirability of using this meter with another one which would immediately stop the flow of feed if the power were disconnected. This type of meter is best suited for a unit of two or more metering devices with all feed ingredients metered by the same unit.

The auger meter performed well considering the high speed at which the auger operated and the method of controlling its capacity (Fig. 12). The type of auger meter tested was as inexpensive an auger meter as it was possible to build. The error was below 5 percent for soybean meal and oats at rates between 2½ and 30 pounds per minute. At 32 pounds the error was 2 percent. For the very low rates, a smaller auger and delivery tube were used in the meter, but the control and



the operating speed were the same. From the beginning of the testing, it was felt that this auger meter had distinct possibilities as an economical and simple feed meter. While it is not one of the best meters tested, it is acceptable in the range of 8 to 30 pounds of feed per minute. Lowering the auger speed would increase the efficiency of the meter but would also increase the cost unless a simple and low-cost method for driving the auger were provided. A commercial slow-speed auger-type blender had a probable error of only 1 percent.[2]

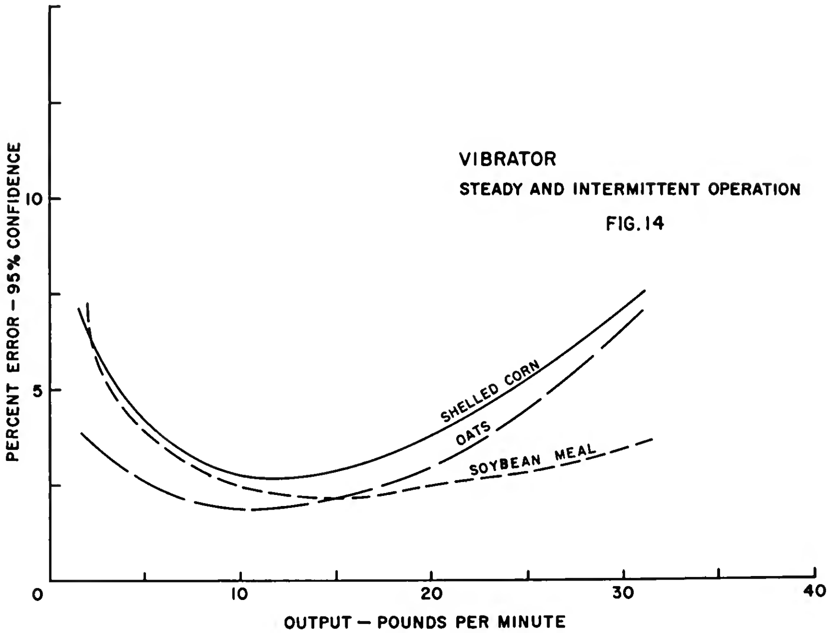
The metal-belt meter had a high percent of error in the low ranges; the error decreased to a minimum, then increased as the capacity increased (Fig. 13). With this particular meter, an effort was made to drive the mat slow enough so that most of the capacities desired could be had by increasing the gate setting from 0 to 4 inches. Because it proved impossible to control capacities by this method, two belt speeds were used, 1½ and 4½ feet per minute. The increase in error with the increase in capacity was accounted for by the short period (30 seconds) which the meter was operated for each reading and by the depth of material on the belt. The greater the depth of the ribbon of material from the bin, the more material could slide off the end of the belt at the end of the testing period. This loss would show as an error.



It was difficult to readjust the gate to the exact setting indicated from the calibration data. The error of resetting was also included in the error term. The length of the gate and the significance of minute differences in the height of the gate made readjustment difficult. It seems that the accuracy of this meter should follow a straight line, and its error should decrease to a minimum as the capacity is increased. The minimum error should be near the variability of the density of the material being tested. The metal-belt meter is more expensive than others tested. The gear motor or other low-speed power source is a major factor in its cost. It is extremely effective in moving hard-to-flow materials from the storage bin and metering them into a feed-grinding system.

The vibrator meter tests indicate that, at rates between 3½ and 25 pounds per minute, variability is less than 5 percent and that intermittent operation does not affect the accuracy of the output (Fig. 14). Its mode of operation fits in very well with the on-off feed-rate control of automatic grinding systems using an electric control. It requires no upkeep as it has no moving parts, such as shafts, pulleys, or motors, and therefore needs no lubrication.

After these tests, the vibrator meter was developed further and plans for constructing it are available.[14]



The vibrator meter may be used as an add-a-meter where a farmer has a grinding system and wishes to add more meters, or may be used with a system where it is not feasible to convey the feed for a long distance from storage bins to a gravity-fed meter at the mill. In the latter situation, these vibrator meters would be installed near the bin where they could easily be fed by gravity and the output of the meter would be taken to the feed grinder by a conveyor. Such an installation is illustrated in Fig. 16.

Summary and Recommendations

The series of tests reported in this bulletin was designed to establish a basis for selecting a particular type of feed meter that could best meet the requirements for dependability and accuracy needed in a farm-type automatic feed-grinding system. A large number of tests were made, their results were statistically analyzed, and conclusions were drawn.

From the standpoint of cost and accuracy, the auger or the fluted wheel meter will best meet the requirements for a feed meter that is to be integrally mounted on a feed-grinding system. Slow speed drive shafts would be, or could be, made available at low cost to drive either of these units. One manufacturer has developed a very satisfactory speed control for the auger-type meter. If the metering units are to be separate or individually mounted away from the grinding mill and controlled electrically, the vibrator meter is the most promising. Its accuracy is acceptable within the ranges required for the automatic feed-grinding system, and its simplicity of operation and construction would contribute to long life and trouble-free operation. It would perhaps be the lowest priced of the three types.

One exception should be made to the above recommendations. If extremely difficult feeds that tend to bridge in the feed bin and will not flow out by gravity through a 4- or 6-inch pipe have to be handled, the metal-belt meter is recommended. While it is the most costly of the meters tested, it gives a positive drive to the feed material and would have acceptable accuracy under the most difficult conditions. In any event, the meter that would have acceptable accuracy for the particular application and that, from the standpoint of purchase price and life expectancy, would be the most economical should be chosen. To strive for extremely high levels of accuracy, levels beyond those required, would contribute to expense without improving the product.

Any attempt to meter extremely small percentages of feedstuffs is not recommended. This is particularly true when the deviation of the meter output is a significant proportion of the ingredient to be metered. Instead of attempting to meter these materials on the farm, premixed supplements should be used in which trace materials have previously been added by weight and thoroughly mixed. The most accurate method of blending, of course, is the batch system where specific quantities of material are weighed in and thoroughly mixed. A farmer should use a premixed supplement if he wishes to feed antibiotics or growth regulators to his livestock.

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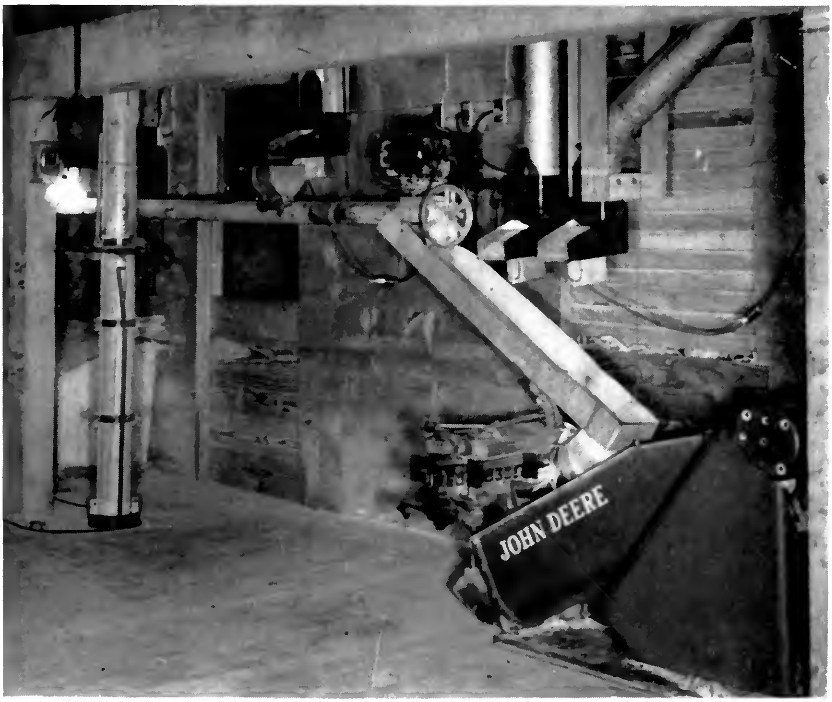

In this vibrator-meter installation, the meters are installed under each ingredient bin. (Fig. 16)

The need for accurate evaluation of the performance of metering devices for automatic feed-grinding systems led to the tests reported in this bulletin. The work was part of a cooperative research program between the Agricultural Engineering Department of the University of Illinois Agricultural Experiment Station and the Agricultural Research Service, U. S. Department of Agriculture.

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This bulletin reports research conducted by H. B. Puckett, Agricultural Engineer, Agricultural Engineering Research Division, Agricultural Research Service, U. S. Department of Agriculture, and Robert M. Peart, Assistant Professor, Agricultural Engineering Department, University of Illinois.

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