

# COMBINE TEST SYSTEM FOR DETERMINING HARVEST LOSS IN RICE

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## ABSTRACT

A test system for determining combine performance was designed and evaluated in field tests. The test system allowed for the collection of material from the clean grain auger, shoe discharge, and rotor discharge separately and simultaneously. The collection devices were activated by a single switch, and the entire system was contained on the combine. The test system allowed for as many as 30 test runs to be conducted within a 4-h period. Operational experiences and recommendations for conducting combine tests in rice are described.

**KEYWORDS.** Combines, Harvest loss, Rice.

## INTRODUCTION

There have been many combine tests conducted in most crops. Test systems have ranged from very simple to elaborate designs. When testing combines in rice, it is essential that the test system be designed to operate in unfavorable field conditions such as mud and water. Thus, it is desirable that the test system be completely contained on the combine. Also, it is essential that the test system meet the requirements of pertinent ASAE standards and at the same time be an automated system that can simultaneously collect material from all normal combine discharge points.

One of the discrepancies among combine test systems is the method used to collect material when determining grain loss rates. The ASAE Standards (1990a) state that "the apparatus for catching crop material discharged from the combine shall be built and operated so that the whole of the effluent from the combine is caught during the catch period". However, there are many different ways of meeting this requirement. Mailander (1983) conducted combine tests in corn to determine the processing characteristics of the IH 1460 combine. The method of collecting the threshing system discharge was to place a tarp on the ground behind the combine. This method may be adequate in a dry field for corn, but it would be impractical under many rice field conditions. Dilday (1989)

collected rice stalks after the combine had passed to represent the material discharged. This method is not acceptable if the data are to be used to accurately determine feedrates or loss rates.

The Prairie Agricultural Machinery Institute (PAMI) used an elaborate test system to collect material from the grain tank, shoe, and separator discharges simultaneously (PAMI, n.d.). The separator discharge material was conveyed sideways from the back of the combine into a collection bag. The conveying system was attached to the rear of the combine and pulled through the field. This system worked well in dry fields. However, pulling and maneuvering extra equipment behind a combine under some rice field conditions is virtually impossible. PAMI also used a divider that allowed grain delivered to the grain tank during a test to be monitored.

Case IH (1990) used a system that allowed collection from either the rotor discharge or the shoe discharge, but not simultaneously. The system consisted of a single collection bag that opened and closed hydraulically and attached directly to the combine.

The objective of this article is to describe a combine test system designed and constructed for measuring loss rates and quality reduction in rice. The system allowed collection of material discharged from all normal discharge points of the combine without interrupting normal operation of the combine. System performance under field conditions is described, and recommendations for testing combines in rice are made.

## TEST SYSTEM DESIGN

A study was conducted to determine optimum settings for combine operating parameters when harvesting rice. A Case IH, model 1680, axial flow combine was used for evaluating the effects of operating parameters including forward speed, rotor speed, and concave setting on harvesting losses and damage imparted to the grain over a range of rice moisture contents. To evaluate the effects of these parameters, loss rates and grain quality had to be quantified for each test run. Due to the rapid changes in rice moisture content from day to day, it was important to complete all test runs within an experimental block in a single day. To test each combination of all the variables in the proposed experimental designs, as many as 30 test runs per day were required.

A schematic of the overall test system and placement on the combine is illustrated in figure 1. The collection system consisted of two rear collection bags, one for the shoe discharge and one for the rotor discharge. The two bags were supported by separate frames, and moved

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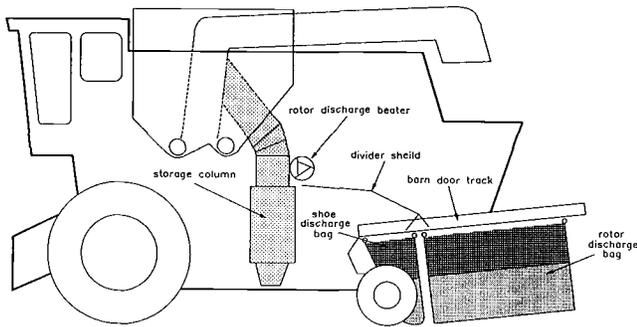


Figure 1—Placement of test system components on the combine.

independently on separate barn door tracks, as is depicted in figure 2. The tracks were positioned on the combine so that the bags could be opened and closed under the rear discharge points in a manner similar to the system used by Case IH. The bag frames were constructed of 2.54 cm (1 in.) steel tubing. The design described herein expanded the Case IH single-bag system into a two-bag system. The frames of each bag were moved simultaneously with individual hydraulic cylinders that were controlled by a single solenoid.

The bags were designed with a capacity to enable collection of discharged material for approximately 9 m (30 ft) of forward travel using a combine equipped with a header 6.1 m (20 ft) in width. This constraint was based on ASAE Standards (1990a), which recommends that a catch period be at least 9 m (30 ft) in length.

A primary concern was to design both bags in such a way that the air flow from the combine cleaning system would not be affected. A collection bag that does not allow air to flow through the bag creates a positive air pressure inside the bag, and discharged material is sometimes blown out the top opening of the bag. Another design concern was the adverse field conditions to which the bags would be exposed, including mud and water in the field. Finally, the bag material would be required to have sufficient strength to support the material discharged during a test run.

With regard to these criteria, the bags were made from a combination of 18 oz vinyl and nylon screen (fig. 3). The bottom half of the rotor discharge bag was made of vinyl to repel water, and the top half was made of nylon screen so that the air flow would not be restricted. Material from the rotor was discharged almost vertically into the center of the rotor discharge bag. However, discharged material from the shoe fell over the edge of the shoe and into the shoe discharge bag. Therefore, the front side of the shoe discharge bag was made of vinyl to allow the discharged material to more readily slide down the inside front of the bag. The other three sides were made of a combination of vinyl and nylon screen as illustrated in figure 3.

A divider shield was designed to keep the rotor discharge material separate from the shoe discharge material. The initial design for the shield was similar to that used by Case IH. The shield consisted of two pieces of flat aluminum hinged together to form one solid shield as illustrated in figure 4a. The shield was placed in the combine immediately behind the discharge beater (fig. 1).

When testing in rice, it is not only important to measure the amount of grain collected during a test run, but also to determine the quality of the grain. The quality of rice is determined chiefly by head rice yield and the presence of fines and foreign material (dockage). For head rice yield and dockage determinations to be performed, a representative sample was taken from each test run. This was accomplished by modifications made in the grain tank as illustrated in figure 5. A "Y" valve or flow director was placed in the grain tank at the discharge point of the clean grain auger. The Y-valve was operated by a hydraulic cylinder that was controlled by the same solenoid that controlled the two cylinders for the rotor and shoe discharge bags. During the initialization of the combine to a steady-state harvesting condition, grain was allowed to flow into the grain tank. During each test run, the Y-valve was actuated to direct the flow of the grain into a tube that passed through the bottom of the grain tank and down the side of the combine. The tube was used to store grain collected during a test run. At the end of each test run, a

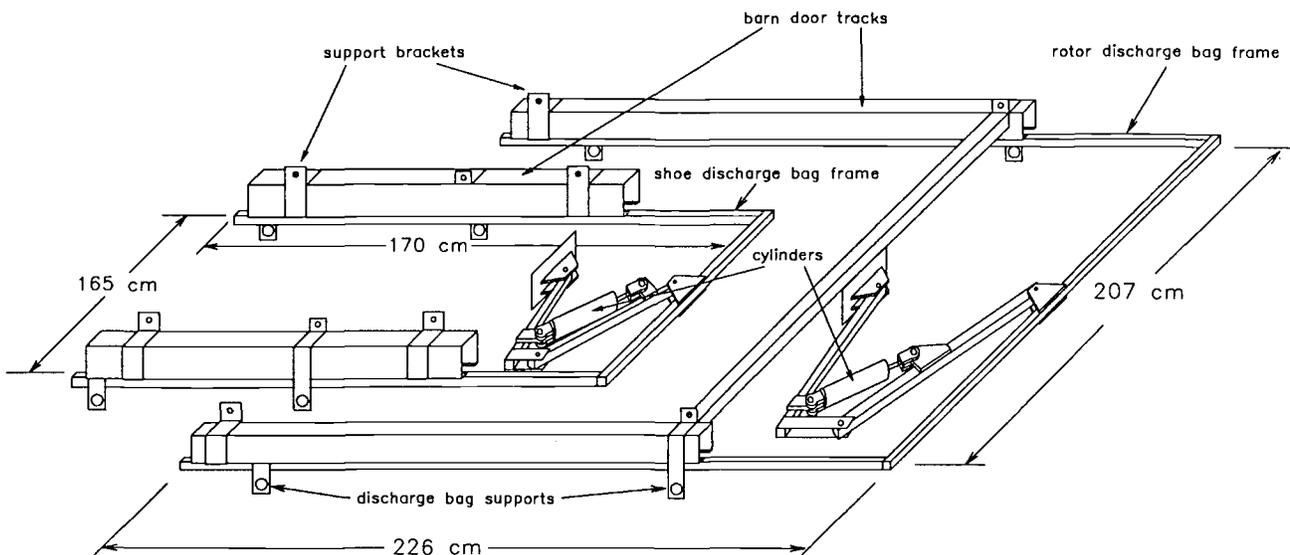


Figure 2—Shoe and rotor discharge bag frames and tracks for the combine test system.

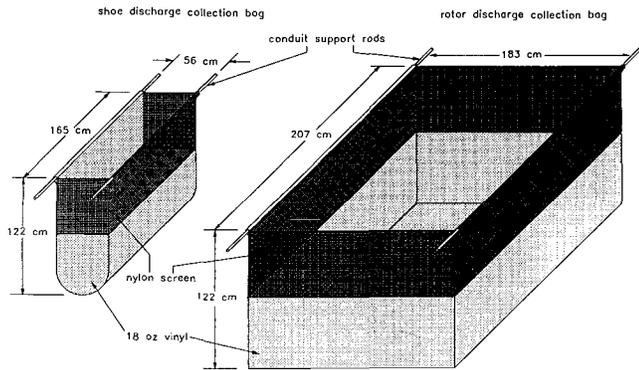


Figure 3—Discharge collection bags for the combine test system.

sliding gate at the bottom of the tube was opened to collect grain for weighing and sampling.

The hydraulic supply for the test system was provided by the auxiliary hydraulic supply of the combine. The combine used an auxiliary hydraulic pump to operate

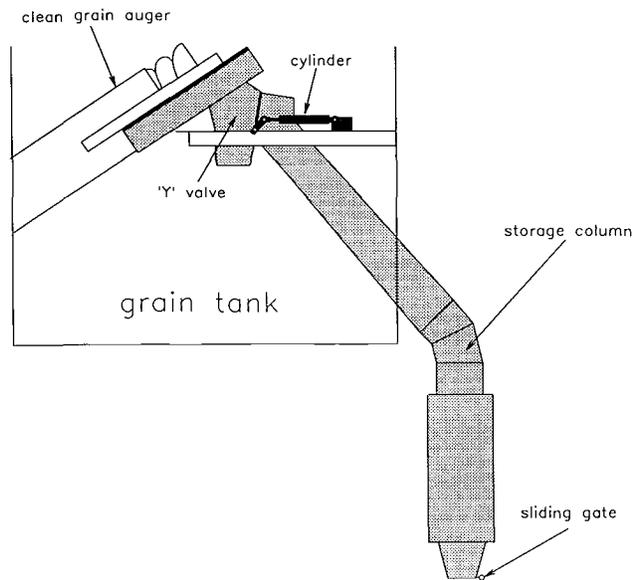


Figure 5—Storage column and Y-valve for grain collected during a test period.

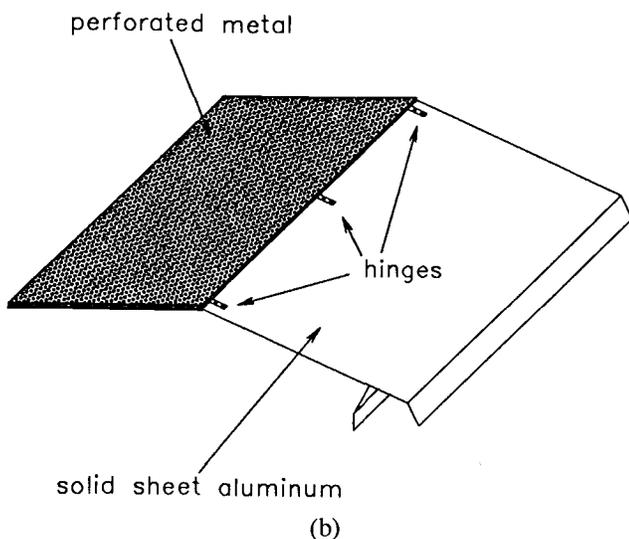
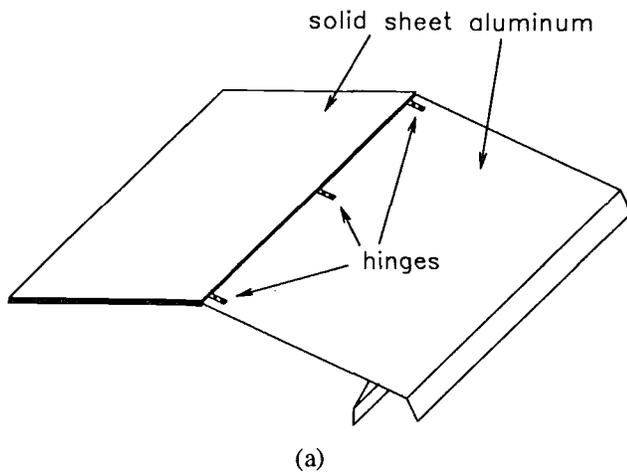


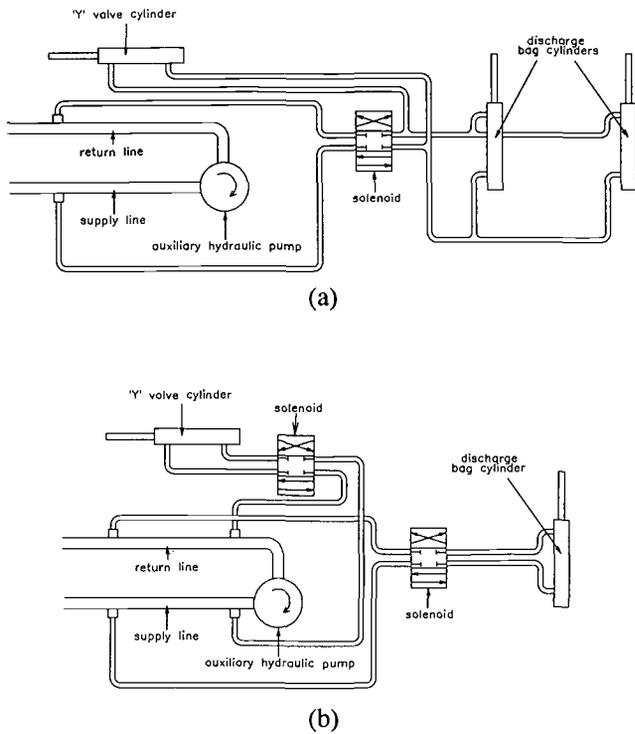
Figure 4—(a) Initial design of the divider shield for the combine test system. (b) Final design of the divider shield for the combine test system.

hydraulic components including the header lift and unloading auger. The auxiliary hydraulic system operated at approximately 16.5 MPa (2,400 psi). The return line from the test system was spliced into the return of the auxiliary hydraulic system. A schematic of the hydraulic system used for the initial test system is shown in figure 6a.

When testing the combine, the speed and distance traveled during a test run had to be monitored. A radar system was installed on the combine to facilitate this need. However, the results yielded by the radar system were not precise and gave an inaccurate indication of the distance traveled. As a substitute for the radar system, the combine was equipped with a pair of electromagnets mounted to the rear axle of the combine. When the collection devices were activated to initiate a catch period, a weight with a spike extending from it was dropped from one of the electromagnets. When the collection devices were deactivated at the end of a catch period, a second weight was dropped. The distance from the first weight to the second was measured and recorded as the distance traveled during the catch period. The time elapsed during the collection of material for each test run was also monitored with a stop watch. Thus, the speed of the combine could be calculated regardless of tire slippage. Cylinder stops were placed on the header lift cylinders to maintain a constant header height.

#### OPERATIONAL EXPERIENCES

Preliminary tests of the system were conducted in a long-grain variety of rice, 'L202', near West Helena, Arkansas, in August 1990. The discharge collection bags and associated controls and linkages worked well. Actuation time and the size of the bags were adequate. Although the divider shield worked well in tests conducted by Case IH in crops other than rice, problems were encountered when used in rice. Due to the high density and moisture content of the rice straw, the discharge beater alone was not capable of conveying the rice straw over the



**Figure 6—(a) Initial design for the hydraulic system used on the combine test system. (b) Final design for the hydraulic system used on the combine test system.**

shield and into the discharge bag, and the rice straw tended to build up on top of the solid shield. After observing the flow of the rice straw without the divider shield in place, it appeared that the air flow from the cleaning shoe fan aided in conveying the rice straw from the discharge beater to the rear of the combine. In an attempt to utilize the air flow from the cleaning shoe fan, the solid shield was replaced with a perforated shield as shown in figure 4b. The perforated shield consisted of 2.8 mm (7/64 in.) diameter holes that yielded 34% open area, which reduced air flow resistance yet prevented the shoe discharge material from being mixed with the rotor discharge material. After the modification to the divider shield, the rotor discharge material was successfully conveyed to the rear of the combine and into the rotor discharge bag. Thus, the shield and collection bags worked properly and the rotor and shoe discharge material could be collected separately and simultaneously.

In September of 1990, the combine was transported to Keiser, Arkansas, where combine performance tests were conducted in 'Newbonnet' rice, a short-statured, long-grain variety. This particular rice was an exceptionally high density crop both in terms of grain and straw yield. A problem was encountered in this rice in collecting the rotor discharge material acquired over a 9-m (30-ft) catch period. Although the rotor discharge bag capacity was large enough, the angle of repose for the rice straw was such that the discharge material tended to build up in the front of the bag and up into the combine. Also, the amount of material collected over a 9-m (30-ft) catch period was such that practical weight limitations of the amount of material to be subsequently threshed and cleaned was exceeded. Rotor discharge amounts, when using a 9-m

(30-ft) catch period and at a grain moisture content above 22% w.b., were approximately 75 kg (165 lb) and the grain discharge amounts were approximately 70 kg (155 lb). A decision was made to conduct catch periods over approximately 6 m (20 ft), based on practical considerations of the amount of material that could be handled for rethreshing and cleaning procedures and not on the capacity of the test system.

In addition to the 'Newbonnet' rice, tests were also conducted in 'Lemont' rice, which is a semi-dwarf variety. In the 'Lemont' rice, the rotor discharge material tended to build up on the perforated metal shield. Due to the semi-dwarf nature of the 'Lemont' variety and the low crop density of this particular field, the mass flow rate of the rotor discharge material was less than that of the 'Newbonnet' variety. It was speculated that the momentum of the rotor discharge material in the 'Lemont' variety was not great enough to convey all the material over the shield and into the discharge bag. It is recommended that in order to keep the rotor and shoe discharge material separated under all rice conditions, a conveying system should replace the divider shield.

After the first day of actual testing, the amount of grain collected per unit area of ground varied dramatically with forward speeds. Further investigation showed that the hydraulic cylinder in the grain tank was not actuating at the same instant as the discharge bag cylinders. For the remainder of the tests in 1990, the cylinder was replaced with a manual lever. An individual controlled the lever and was signaled when to start and stop the collection of grain by a series of lights positioned in the grain tank. The lights were energized by the same switch used to activate the solenoid that controlled the discharge bag cylinders.

#### FINAL DESIGN

Analysis of data collected during the 1990 combine tests revealed that losses obtained from the cleaning shoe averaged 0.14%. Only in four cases, each at 6.4 km/h (4 mph), were losses from the shoe above 1.0%, and even then were not significant when compared to rotor loss and total loss. For tests conducted in 1991, shoe and rotor discharge material were collected together. This was accomplished by removing the frame and cylinder for the shoe discharge bag and sliding the tracks for the rotor discharge bag forward. Thus, the rotor discharge bag was used to collect all material discharged from the rear of the combine during a test period. In addition to changing the position of the collection bag, the divider shield was removed since the rotor and shoe discharge material was collected together.

The hydraulic system from the previous year was modified by using separate supply and return lines from the combine auxiliary hydraulic pump to operate the hydraulic cylinder in the grain tank (fig. 6b). Also, individual solenoids were used for the grain tank cylinder and discharge bag cylinder. The modifications to the hydraulic system provided a means of supplying both cylinders with a high flow rate and pressure. Thus, the actuation time for the discharge bag and grain tank cylinders was similar, and the problem with inconsistent amounts of grain collected per unit area was alleviated.

The final design of the test system provided for improved safety over other test systems which require

individuals to run with the combine or to collect grain samples directly out of the grain tank. By controlling the system from inside the cab of the combine and collecting the grain in the storage column located outside the grain tank, the need for any human intervention inside the grain tank was eliminated. Rear discharge catch mechanisms and distance measurement markers were also controlled from the cab, thus no human intervention from outside the cab was necessary while the combine was in operation.

## CONCLUSIONS

A test system was designed and tested for determining combine performance in rice. The test system was completely contained on the combine and enabled simultaneous collection of material from (1) the clean grain auger, (2) the shoe discharge, and (3) the rotor discharge. The test system allowed for as many as 30 test runs to be conducted within a 4-h period. Several conclusions were derived from the data and experiences with the test system.

1. When using a header of 6.1 m (20 ft) in width for testing in rice, a 6-m (20-ft) catch period is a practical limit based on the amount of material to be handled for threshing and cleaning.
2. When conducting tests in 'Newbonnet' rice, the shoe and rotor discharge material may be collected together since the loss from the shoe was minimal. However, if it is desired to collect shoe and rotor discharge material separately, the test system described could collect the discharges separately and simultaneously.

3. If shoe and rotor discharge material is to be collected separately, it is recommended to use a conveyor system instead of a divider shield to ensure that rotor discharge material is conveyed to the rear of the combine in all rice conditions that may be experienced.
4. When using hydraulic cylinders on the test system, it is important to maintain high flow rates and pressures at the cylinders. The use of separate control solenoids located close to each cylinder facilitates this, which in turn provides consistent, minimum actuation times and minimum differences in actuation times between cylinders.

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## REFERENCES

- ASAE *Standards*, 37th Ed. 1990a. S396.2. Combine capacity and performance test procedure. St. Joseph, MI: ASAE.
- . 1990b. S343.2. Terminology for combines and grain harvesting. St. Joseph, MI: ASAE.
- Case IH. 1990. Personal communications. Combine Test and Development, 7 South 600 County Line Road, Hinsdale, IL.
- Dilday, R. H. 1989. Milling quality of rice: Cylinder speed vs. grain-moisture content at harvest. *Crop Science* 29(6):1532-1535.
- Mailander, M. P., J. D. Schueller and G. W. Krutz. 1983. Processing characteristics of the IH 1460 combine. ASAE Paper No. 83-1586. St. Joseph, MI: ASAE.
- PAMI. n. d. Gleanings report 80 04. Prairie Agricultural Machinery Institute. Humboldt, Saskatchewan, Canada SOK 2A0.