The harvesting efficiency of a combine depends on how well and how quickly the following operations can be performed —

1. Cut the growing crop or if swathed pick up the windrow.
2. Feed the material into the threshing mechanism.
3. Thresh thoroughly without grain damage.
4. Separate the grain from the straw and chaff.
5. Discharge the straw in one of the following ways — placed in a windrow, spread, chopped and spread or baled.
6. Transport large quantities of grain without excessive ground pressure and unload quickly.
7. Remove weed seeds and foreign material.

These operations must be performed under a variety of conditions with reliability, minimum routine maintenance, ease and convenience of operation, ease of adjustment or change for varying crops and conditions, and with an ample reserve of power.

A few conditions encountered during harvesting are noted below.

Crops ranging in size from small grass seeds to beans and corn must be handled with the further complication that in many cases different varieties of the same crop have different characteristics.

Climatic conditions affect the moisture content of the material being harvested and also the ground conditions. Cereal crops ranging in moisture content from 8-25% and corn crops with a moisture content as high as 35%, are commonly harvested. Combines operate in temperatures from below 0°F to well over 100°F with a resultant change in crop conditions.

The combines must operate on flat and rolling topography, irrigated and dry land, smooth and rough fields and wet and dry soil.

Crops containing heavy weed growth as well as clean crops must be cut.

Lodged and tangled crops, short and tall straw, light and heavy yields, as well as mixtures of these conditions must be handled.

To develop a combine to operate efficiently under the various conditions three main phases of test work are conducted. These are —

1. Life and performance testing of component parts prior to assembly.
2. Structural testing of complete machine.
3. Functional testing in the field and laboratory to assess the overall performance of the machine including capacity and general operating characteristics.

Certain phases of the third aspect of test work will be covered in this paper.

**ASSESSMENT OF GRAIN LOSS AS AFFECTING CAPACITY AND EFFICIENCY**

The measurement of machine performance at various rates of work under a range of conditions, is determined by efficiency or commonly called loss tests. These tests when complete, give a picture of machine capacity and efficiency.

Grain losses must be analyzed at the following points in a combine.

1. Table, including cutter bar and reel or pickup.
2. Cylinder.
3. Walker or rack.

Due to the many variations encountered which affect operation, it is only possible to obtain comparative figures. To do this a “standard” combine is used as a yardstick against which other machines are compared.

The standard machine will be a machine which has proven to give good reliable performance under a wide range of conditions.

When conducting tests an effort must be made to locate uniform crops. It is also important to conduct the tests as rapidly as possible to minimize the influence of changing humidity and temperature. The machines being compared should be operated side by side with each machine taking its full width cut to minimize the effect of uneven crop.

**DETAILS OF EFFICIENCY TESTS**

1. **Table Loss**

To determine the loss caused by the reel and cutter bar or pickup, the material loss caused by shelling and wild life must be first determined. This is done by hand sampling and grain collection over several random areas and free grain or heads obtained is known as the natural loss. The machine can then be operated in the field and immediately after the passage of the table the ground is covered for sampling to protect it from contamination by other losses. The total grain loss in the covered area can then be determined. This loss includes both natural and table losses. The table loss can then be obtained by subtracting the natural loss from the total loss from the covered area.

2. **Separating Losses**

Separating losses are determined simultaneously by making separate catches of walker and shoe affluent. Various methods have been used to collect walker and shoe material. In some cases rolls of canvas are carried on the back of the machines and are deposited on the ground as the machine moves to catch the material. Another method is to use canvas bags which are attached to the machines by various means. In windy areas it is impossible to use the canvas strip method due to the loss of material from the open canvasses in the field.
The material from each catch is separated in a special machine and the total weight of straw and chaff and the weight of free grain in each of the catches is determined.

The weight of threshed grain delivered to the grain tank is also determined during the collection of walker and shoe material. To obtain a picture of the capabilities of a machine a complete performance curve has to be obtained starting with operation at the minimum speed and reaching the limiting factor. Thus a series of tests each at a different ground speed are made on the machine being tested and on the standard machine.

To interpret results in graph form, several points are required to produce a line. The larger the number of points used the better is the line defined. For example, four or five points can indicate a curve but a larger number of points would not only indicate the curve but also give information on the spread of results or the band within which all the points lie. A spread in results can be caused by a variety of reasons such as, blockages of short duration, slippage of drives or some great change in crop conditions. The scatter of the curve will indicate whether a comparison between various machines can safely be made on the results of any one series of tests.

A minimum of nine catches over a distance of 50 to 100 feet has proven to be quite satisfactory for rating machines.

3. Cylinder Losses

The cylinder loses occur in two forms —

1. Cracked grain.
2. Unthreshed material.

The percentage of cracked grain is determined by examination of samples taken from the grain tank during the test run. The unthreshed grain loss is obtained from the walker and shoe catches by rethreshing all the material after the free grain has been removed.

4. Limiting Factors

As part of the above tests the limiting factors preventing faster work such as cutting, lack of power or blockages are obtained.

5. Additional Information Recorded

As a part of each test the following additional information is recorded to be used partly for calculation of results and partly for reference — type of crop and variety, general crop conditions, width of cut, length of cut, duration of test, length of straw cut and all machine settings.

EFFICIENCY AND CAPACITY GRAPHS

When loss tests are conducted over a range of operating speeds performance curves can be plotted for each machine, using the through-put in pounds of straw and chaff per minute as one axis and grain loss from each portion of the machine as well as the total loss as a percentage of the total grain intake as the other axis. These curves also show the limit of capacity and the cause.

Loss test graphs as well as showing overall capacity and efficiency of a machine also show the efficiency of individual parts of the unit. If a sufficient number of tests are conducted and all details of the test conditions are recorded, it is possible to present the relative capacity of a number of combines provided the same "standard" machine is used throughout. This is done by expressing the capacity of any combine at various grain losses such as 1, 3 or 5% as a percentage of the capacity of the "standard" machine at the same grain losses.

Figure 1 will illustrate how the test results are compiled and used to compare combines. This graph shows the total loss of a standard machine and a comparison machine under one set of field conditions.

When comparing the efficiency of machines, the loss at any particular feed rate can be found from the chart. For example, at 300 pound feed rate of straw and chaff per minute, the standard machine had a loss of 2.3% while the comparison machine showed a loss of 1.35%, thus at this feed rate the comparison machine is more efficient.

To compare capacities the feed rate at any percentage grain loss can be determined; as an example, at 3% loss the standard machine had a capacity of 320 pounds of straw and chaff per minute while the comparison machine had a feed rate of 350 pounds per minute indicating a greater capacity.

OTHER FACTORS AFFECTING CAPACITY AND EFFICIENCY

As mentioned earlier there are many other items which influence overall combine capacity.

A reduction in routine maintenance time allows the machine to be operated more hours.

A large grain tank capacity and faster unloading mechanism means less time for unloading.

Correctly placed and easily operated controls and comfortable seats prevent operator fatigue and aid in obtaining increased capacity through better operating practices.

Lack of mechanical failures is one of the most important factors affecting overall combine capacity or ability to do work.
Different operating conditions place different demands on combines and thus a machine that is flexible to meet varying conditions and operate as efficiently as possible is desired. Labor and fuel costs, the value of the grain being harvested and weather conditions influence the selection of the rate of work on a combine. A combination of low labor costs, high crop price and lack of risk of unfavourable weather will usually result in operation at a capacity giving highest efficiency. A low price for a crop of the factors which affect the very or the risk of unfavourable weather being harvested and weather meet varying conditions and operate as efficiently as possible is desired. A low price for a crop or the risk of unfavourable weather will usually result in operation at a higher capacity with a slight reduction in efficiency.

The above remarks illustrate some of the factors which affect the very complex question of combine capacity and efficiency and why it is necessary to consider all these factors when rating a machine for comparative purposes. In the final analysis however, it is the responsibility of the user to obtain maximum output at minimum cost under the conditions encountered.

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A second characteristic of such a system as that illustrated in figure 8, is the decision to be made by the system as to whether or not an error signal is a true indication of an error or whether it is a random impulse or “noise”. This aspect of control involves the theory of statistical quality control and communications theory, both of which generally fall outside of standard undergraduate curricula.

These are brief, the technical areas in which solutions to problems of farmstead mechanization and control circuitry wherever found, are to be located. Much of this is unfamiliar ground to Agricultural Engineers. Nevertheless, if Agricultural Engineers are to make a high level contribution to advanced mechanization then some understanding of these fields is necessary. It is hoped that educators will keep these needs in mind, particularly in developing graduate programs of study and research, and that all keep in mind that technical libraries contain all of the technical material that has been referred to. The responsibility to make use of this information rests with individual Agricultural Engineers.

REFERENCE

SELECTED REFERENCES FOR STUDY

General Industrial Management:

Control Engineering:

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It should be mentioned that as the same general differential equations appear in many other engineering areas, including electrical circuits containing inductance, capacity and resistance, that a great deal of useful simulation of control circuitry can be carried out by means of an analog computer. This important tool with its natural ability to directly simulate physical phenomena is often overlooked in favor of digital computers. Digital machines have caught the public fancy, but are only capable of handling differential problems that lend themselves to numerical approximations. Analog machines on the other hand can even include human elements in system simulation.

REFERENCES