NEW CONCEPTS IN POTATO HARVESTING

by
L. F. Johnson, E. M. Bailey and C. L. Peterson *

Potato growers in Washington and Idaho lose millions of dollars each year as a result of the potato bruises inflicted during the harvesting operation. Both states have for several years conducted research to find ways of reducing the bruise. During the 1973 Washington Potato Conference it was suggested that the Agricultural Engineers working on the bruise problem should pool their efforts and develop a "Low Damage Potato Harvester." A harvester incorporating ideas generated during the past several years of study which had potential for reducing harvester caused potato damage could jointly be designed and constructed.

As a result of this initial discussion contact was made with Thiokol Hall-way who expressed an interest in supporting the project financially and ultimately pledged $28,500 in materials, and other support for carrying on the work. Encouraged by industry support, a joint proposal for cooperative action was written which involved the University of Idaho, Washington State University, The Idaho Potato Commission, The Washington Potato Commission, and Thiokol Hall-way. The proposal was entitled, "Development of a Low Damage and High Efficiency Potato Harvester."

The automatic position control for the potato harvester boom, which is discussed in this paper as a part of the low damage harvester was developed as a separate project by the Department of Agricultural and Electrical Engineering at the University of Idaho.

OBJECTIVES

The objectives set up in the initial proposal were as follows:

1. To design a minimum damage potato harvester which incorporates the latest harvester improvements developed by University of Idaho and Washington State University potato harvester researchers.

2. To test and evaluate the harvester under field conditions in both Idaho and Washington.

DEVELOPMENT AND DESIGN

Personnel from each cooperating agency met together in an initial planning meeting to discuss concepts to be incorporated into the harvester. It was generally agreed that while new concepts were important they must be practical for use by the industry under today's management practices.

Two harvesters were designed and built at the University of Idaho Aberdeen Experiment Station. One machine was designed for use under Idaho conditions to be tested in Idaho. A second machine was designed for testing in Washington.

---

* Lynn F. Johnson is Research Professor, Department of Agricultural Engineering, University of Idaho Branch Experiment Station, Aberdeen, Idaho.
Everett M. Bailey is Associate Professor and Acting Chairman, Department of Electrical Engineering, University of Idaho, Moscow, Idaho.
Charles L. Peterson is Associate Professor, Department of Agricultural Engineering, University of Idaho, Moscow, Idaho.

DESIGN CONCEPTS FOR BRUISE REDUCTION

Twelve concepts with potential bruise reduction capability were selected for incorporation into the harvester design. These were chosen because of the way they fit together in developing a harvester with a smooth flow path and allowed use of results from prior research and existing technology so that the machine would have maximum opportunity for success.

1. Vibrating Digger Blade.

A vibrating digger blade has been designed and tested by Johnson (1973). A side view of the blade is shown in Figure 1 and a front view of the blade in Figure 2. Two blades are used, one for each row; one moves forward while the other moves back which effectively dampens out much of the vibration as far as the remainder of the machine is concerned. The blades are hydraulically driven providing a vibrating speed of from 0 - 750 strokes per minute.

Previous tests have shown the vibrating blade reduces injury to potatoes by about 50 percent of that caused by the standard-blade-equipped harvester. However, the vibrating blade did cut more potatoes.

The vibrating blade harvester was also found to have lower draft than the standard blade harvester. No net saving in power is realized because of the power expended in driving the hydraulic motor which powers the blade. In soil conditions where traction is a problem, this trade-off from drawbar to PTO horsepower may have a real advantage.

2. Infinitely variable speed control on chain drives.

The machine is powered by a PTO shaft to a gear box which drives three hydraulic pumps. One to supply power to the vibrating blade, a second to provide power for the digger chain and deviner chain and a third for all other functions of the harvester. Thus, by utilizing hydrostatic drives for all chains complete speed control is possible.

Independent speed control was included on these prototype harvesters to allow for further research on the effect of chain speeds on harvester damage to go along with that work already conducted in Washington by Peterson et al. (1973). It is very likely that this provision for individual speed control on each chain would not be necessary on production machines once the proper speed relationships were established on the prototype. The production machine would likely use one speed control for the rear cross, side elevator, and boom chains which would adjust all of their speeds simultaneously.

3. Tractor Seat Control of the Primary Chain and Deviner Chain Speeds.

Since the speed of these two chains is dependent on soil and field conditions, control from the tractor seat is essential for the operator to properly maintain the flow of material across these chains. Speed control provisions were provided by utilizing a variable delivery manually controlled hydraulic pump and a fixed displacement motor.

4. Elimination of drop between primary and secondary.

To eliminate the two part digger chain it was necessary to carry the deviner chain down and around the nose cone with the digger chain. Thus it was possible to retain the deviner chain together with a one piece digger chain.

Initiallv the deviner chain and primary chain utilized only one nose cone with the deviner riding on the primary chain, however, one cone was found to be unsatisfactory. Two nose cones were then installed as shown in Figure 3. This concept allows a very gradual transfer of product through the deviner chain onto the digger chain and is assisted by the vibrating blade elevating the tubers (through the vibrating action of the blade) up the extension rods to a point above the chains as shown in Figure 4. Figure 5 shows the two chains on the return side, deviner chain below and digger chain above.

Figure 1. The vibrating blade in operation.

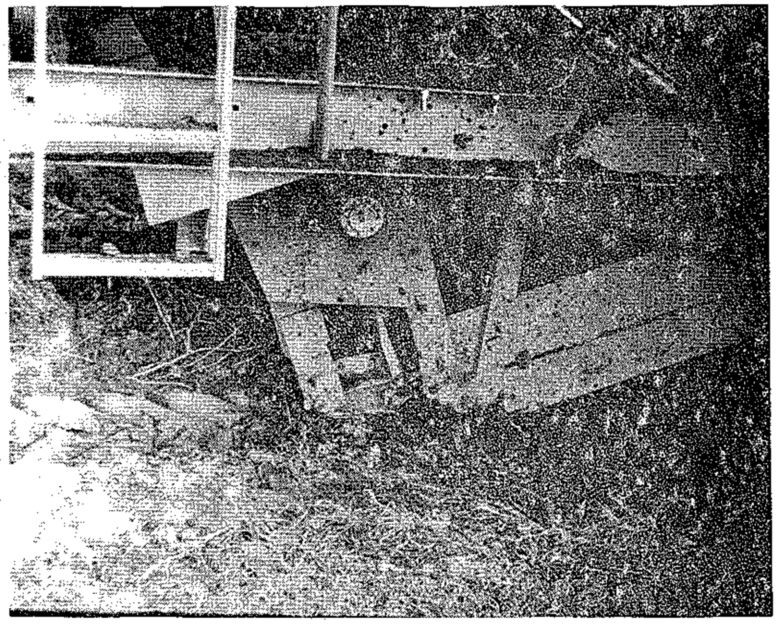


Figure 2. Front view of the vibrating blade showing the individual oscillating blades for each row.

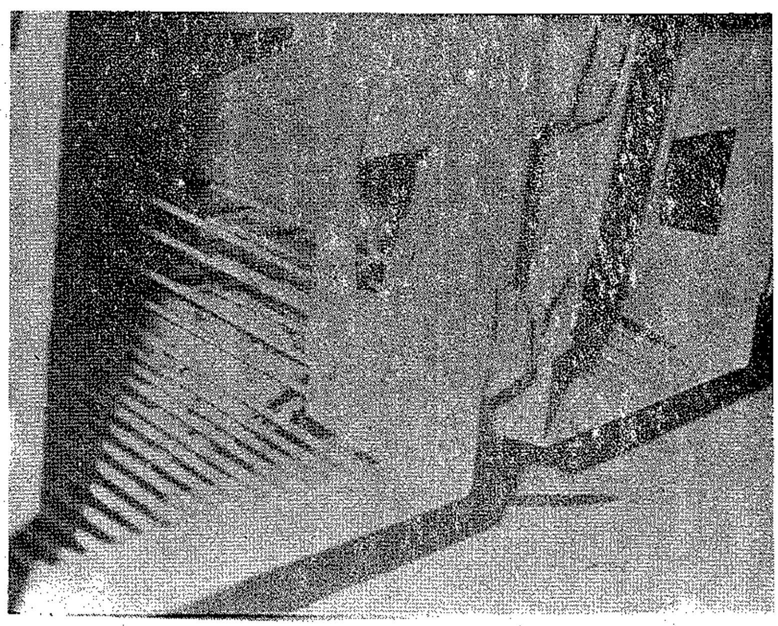


Figure 3. Double nose cones for the digger and deviner chains.

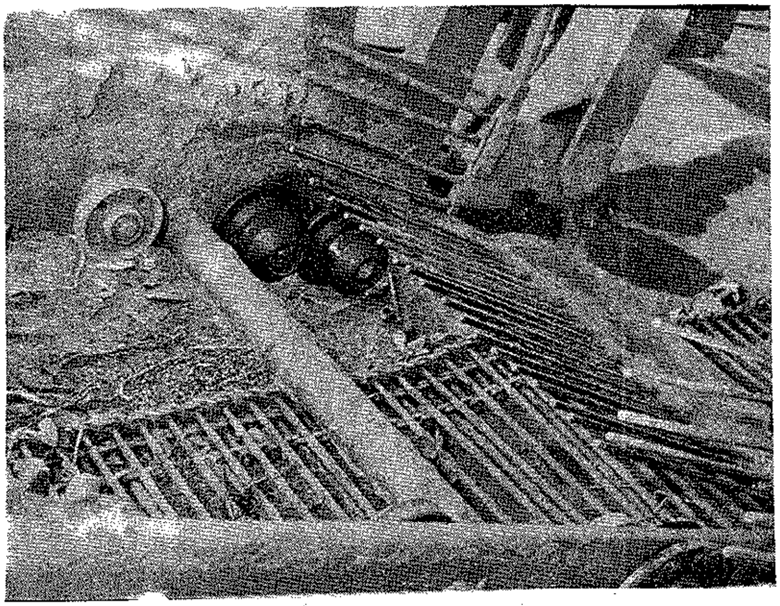


Figure 4. Discharge of the vibrating blade directly above digger chain and deviner chains.

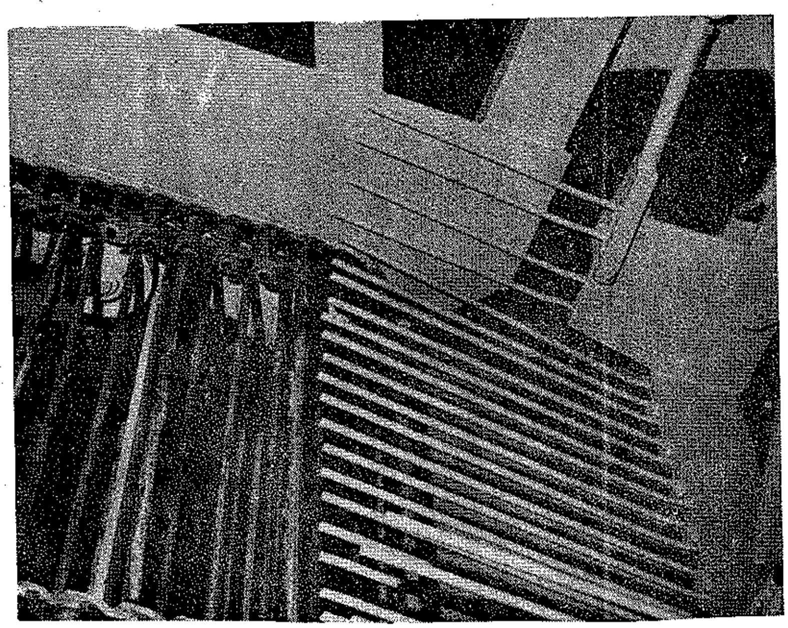


Figure 5. Return side of digger and deviner chains. Digger chain is above the deviner chain.

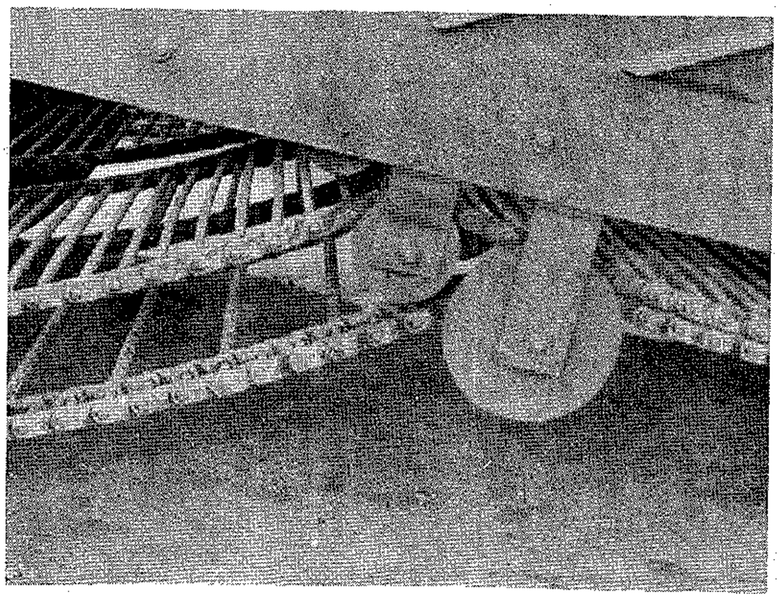
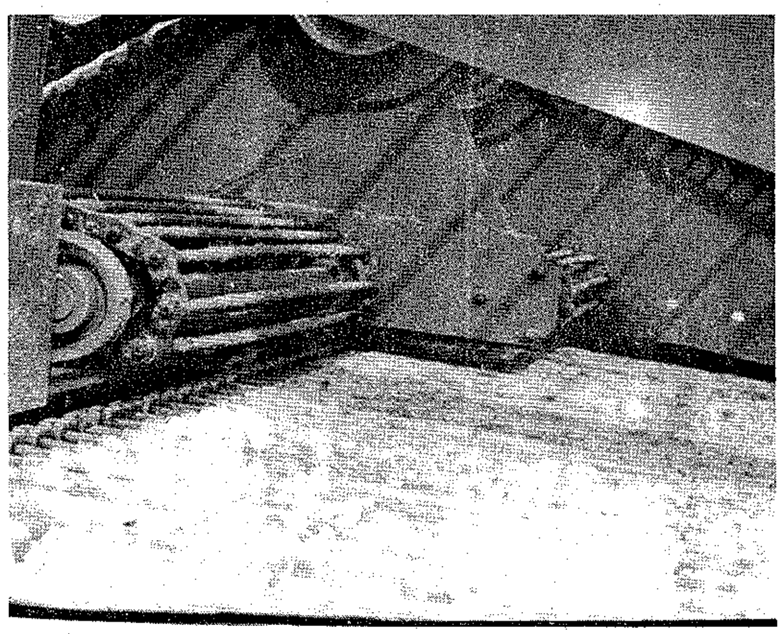


Figure 6. Auxiliary roller which gives downward discharge and staggered head shafts on digger chains can both be seen in this picture.



5. Extra long digger section to minimize lift angle and roll back.

To cut down on the angle at which the tubers are elevated the moveable digger section is extended 15" in length over that of the standard machine so the lift angle at normal digging depth is 21°. A reduced angle results in reducing tuber roll back and tuber motion on the primary chain.

6. Drop heights limited to 5 inches or less.

One goal of the low damage harvester was to limit drop heights to the minimum possible amount. Since it has been said that a potato dropped 6 inches will bruise, a height of 5 inches was selected as the maximum allowable drop.

7. Auxiliary roller prior to the head shaft of primary chain and side elevator to provide a downward rather than an upward tuber trajectory at discharge.

As the tubers are being elevated by the primary and side elevator chains near the discharge point, the chain direction is changed by passing over an idler roller. The chain is then angled slightly downward so that tubers are discharged toward the receiving chain rather than up and away from it. A shorter drop and a lower impact velocity results. (Figure 6).

8. Return side drive on primary to minimize drop.

Drop height from the primary chain to the rear cross was further reduced by providing a return side drive.

Driving the return side keeps the primary chain in tension as it goes around the head shaft and allows the rear cross to be moved within about 1-1/4 inches of the primary without the problem of chain entanglement which can occur if the chain goes slack as it comes off the head shaft.

9. Staggered loading of rear cross.

To provide for utilization of the full capacity of the rear cross the primary chain discharges were staggered as is also seen in Figure 6. The row furthest from the side elevator discharges into the back half of the rear cross and the near row discharges into the front half of the rear cross. Maximum utilization of the full width of the rear cross allows a lower chain speed and more uniform loading without a rearward slope on the chain (Figure 7).

10. Removal of the flights from side elevator.

In order to minimize the drop from the rear cross to the side elevator and from the side elevator to the boom chain it was necessary to remove the flights. The transfer onto the side elevator was then directly onto the chain with no flights for the tubers to impact in the transfer.

11. Anti-Roll belt on the side elevator.

Since the flights were removed from the side elevator it was necessary to provide a means for elevating the tubers without roll-back. An anti-roll belt was added as shown in Figure 8. It is an endless belt with no tail pulley. The belt lays between the uprights on the side elevator and is driven by a head shaft and two friction wheels (Figure 9). The belt holds the tubers, prevents roll back, and tuber movement on the chain. It also gives an unexpected feature of aiding in eliminating dirt and breaking up clods.

The anti-roll belt was a trial to give preliminary data looking ahead to the possibility of a steeper side elevator using a similar system. A steeper side elevator might allow for a very low angled primary chain with nearly all of the elevation of tubers being obtained with the anti-roll belt.

Figure 7. Even loading of rear cross with no rolling to rear gives maximum utilization of rear cross.

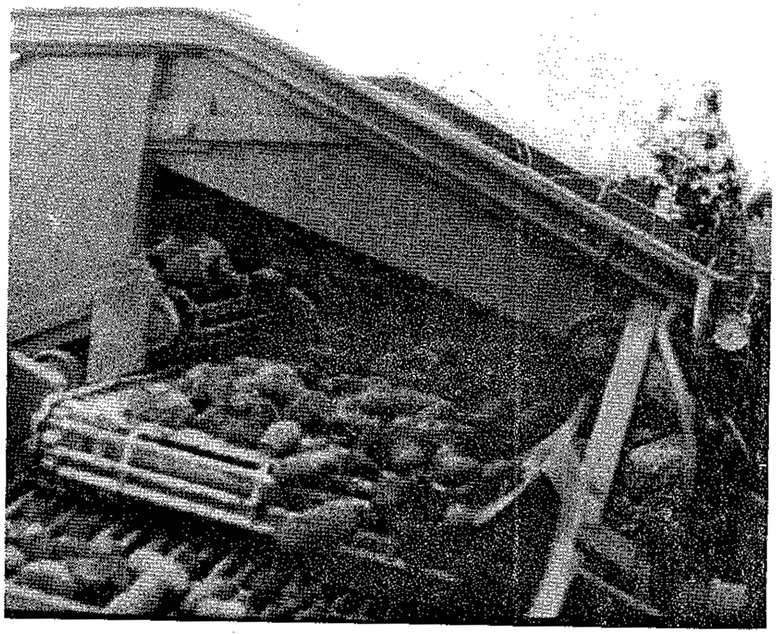
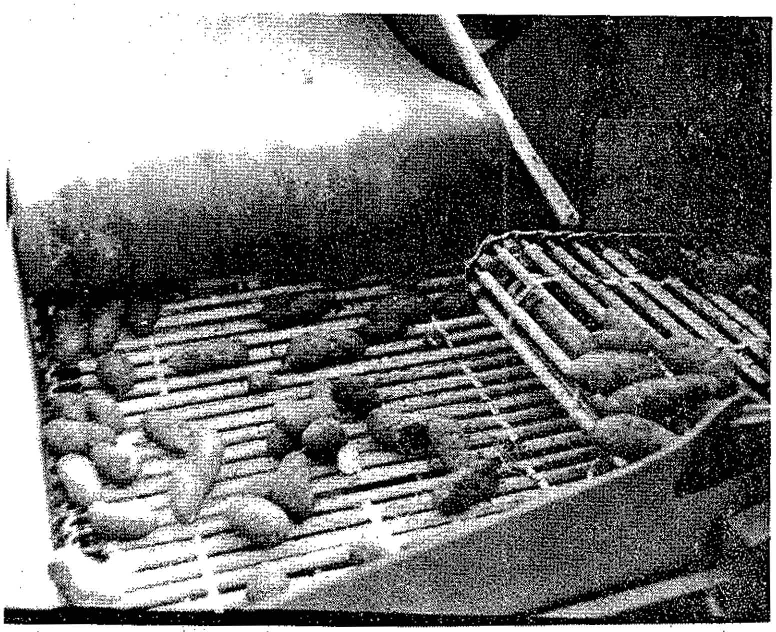


Figure 8. Shortened drop height from the rear cross to the side elevator is made possible by removing flights from side elevator. Tuber roll back on side elevator is prevented by addition of anti-roll belt shown. Note that no tail pulley is used.



12. Boom height monitoring control.

It is estimated that the operator of the present harvesters spends from 50 to 75 percent of his time monitoring the boom while he is digging. This often leaves too little time to attend to the operation of the rest of the machine. As a result, more potatoes are bruised than necessary because of improper machine operation. The boom is often set high above the potatoes in the truck so that less operator time is required to monitor the boom. This height is too great to load the potatoes with little damage.

In the spring of 1972, a joint effort between the Agricultural Engineering Department and the Electrical Engineering Department of the University of Idaho was initiated to develop an automatic height control for the potato harvester boom. The initial efforts reported last year pointed to the modifications required. The first year's unit was modified and two units were built for the 1973 harvest. These units were mounted on the low damage harvesters. Operation was satisfactory with only minor modifications necessary for it to be ready for commercial use.

The unit uses high frequency sound to sense the distance from the potatoes. The sensor is located about 30 inches from the potatoes and no part of the device need ever touch the potatoes. When the sensor senses the distance to be greater or less than desired, an electrical signal is generated. This signal is fed to the proper solenoid of the hydraulic valve. The valve is activated until the boom is returned to the proper height. The height maintained above the potato pile can be adjusted. The end section of the boom is controlled in both directions. If the end section reaches its upper limit and is still not high enough, the inner section is raised automatically by the controller. In order to obtain the maximum advantage from the controller, the truck bed should have a full length drop side. The truck should also be loaded evenly the whole length instead of making a pile, then loading onto it.

An attempt was made to have an emergency circuit that would raise both boom sections if a collision with an obstacle became apparent but we were unsuccessful in securing a reliable signal and that feature was discarded for the present.

A control panel (Figure 10) is located near the operator station on the tractor. The operator has full manual control of the boom by merely pressing the up or down switches for the main boom section or the end boom section as seen in the figure. To place the unit in automatic the operator pushes the button labeled "automatic" and the electronic unit takes over control of the boom, it remains on automatic control until the operator pushes any one of the four manual control buttons. A grower may also decide to keep his present hydraulic control valve, although it is not thought to be necessary, doing so poses no problems for installation of the automatic unit on a machine. The present hydraulic control system may be left intact and operable. Figure 11 shows the automatic unit mounted on the outer boom section of a harvester. Figure 12 is a schematic diagram of the control logic.

VINE HANDLING

The vines have presented one of the most difficult problems associated with the harvest. When they are green, they hang up on the machine. When they are wet and tough, they hairpin on all obstructions, wrap around shafts, and collect around the side of the digger nose. Coulters and discs have been added to the digger to help alleviate the problem but the tough vines resist cutting. The override devining chain is almost universally used now and it works better if the vines are left intact. However, this leaves the problem of vines catching on the sides of the digger nose when the vines are wet.

During the development of the vibrating blade, the problem of the vines catching on the digger nose was more serious because the vibrating blade requires arms between the rows. At the suggestion of a grower, special hilling discs designed to clear the vines and wheels from between the rows were used. This device works very well and removes all material from between the rows. Very few vine problems were encountered when preceeding the harvester with the hilling discs. A small tractor equipped with a set of discs can keep up with several harvesters. (Figure 13).

Figure 9. Head end of anti-roll belt. Note wheels to give friction necessary for driving the belt and large throat area to prevent clogging the discharge.

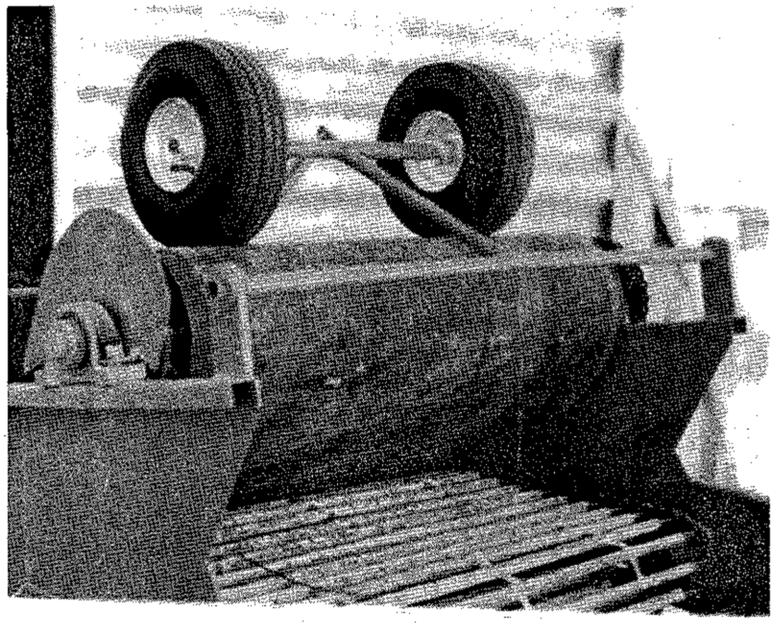


Figure 10. Schematic diagram of operator control panel for the automatic boom height control.

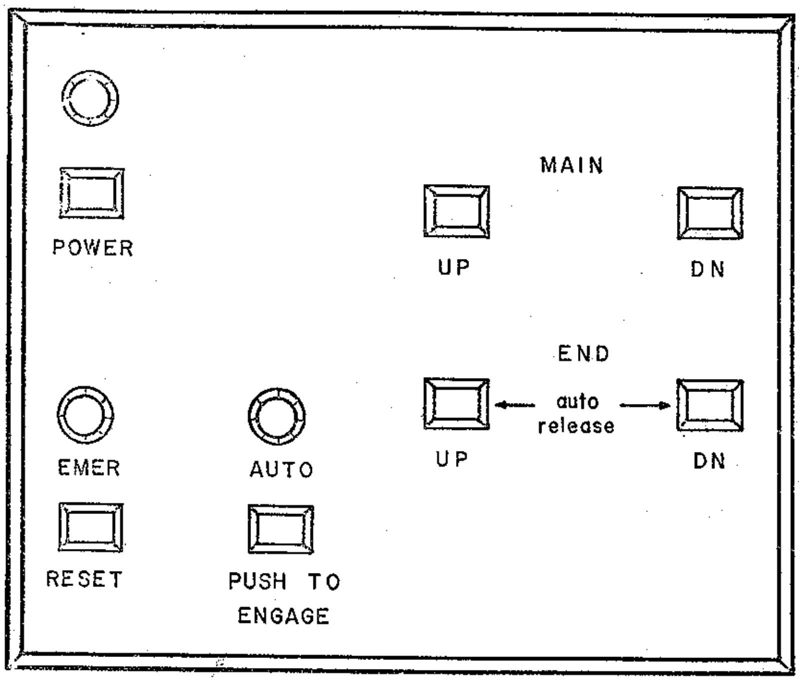


Figure 11. Sensor utilized in the automatic boom height control.

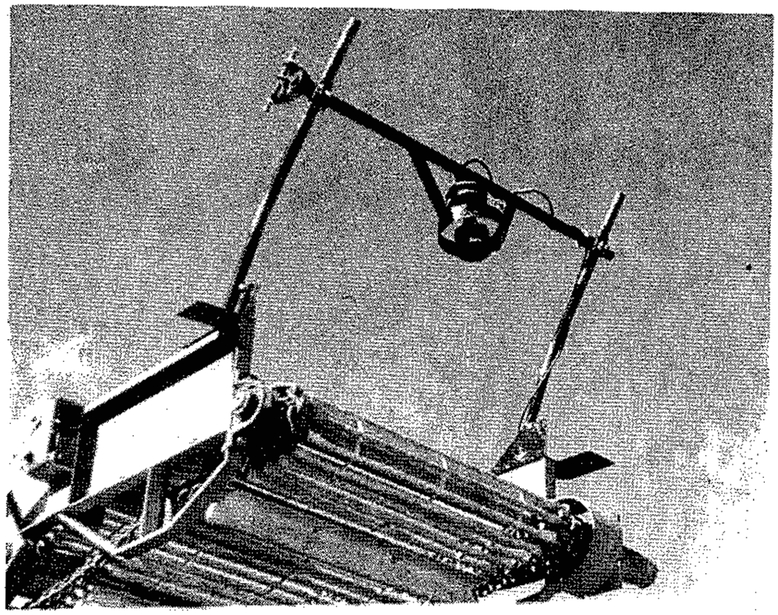


Figure 12. Schematic diagram of control logic for the automatic boom height control.

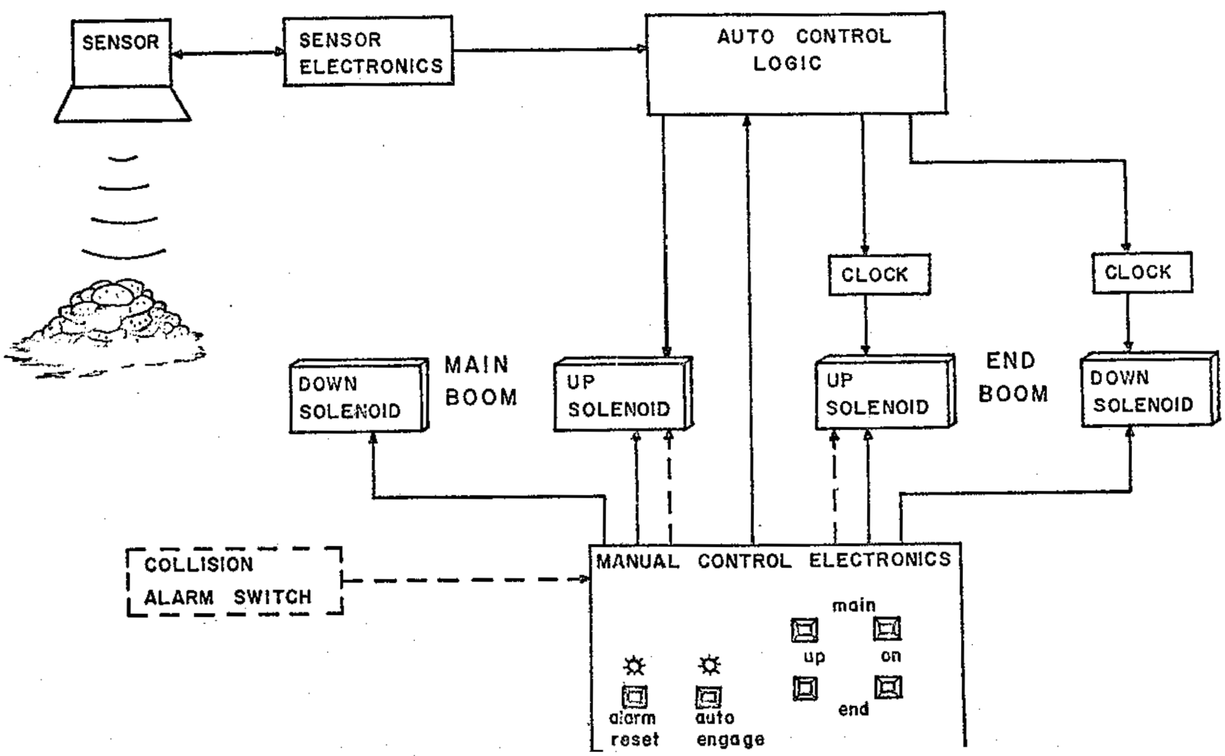


Figure 13. Hilling discs for cleaning vines and trash from furrows ahead of harvester.

FIELD TRIALS

Original projections were to have the harvesters in the field early in the 1973 harvest, however, delay in obtaining the hydraulic pumps held up field testing until October 8, 1973. By this time it was virtually impossible to move a harvester in time to do any testing so the Washington test was delayed one year. Effort was concentrated on the Idaho harvester and in the short time available about 10 acres were harvested. Only one set of samples were taken and these without adequately setting the harvester for the conditions. The results of the test as shown in Table 1 are encouraging. However, many more acres must be harvested and many additional samples taken before conclusive arguments can be made or before the harvester would be ready for commercial production.

Table 1. BRUISE EVALUATION DATA

	Sample Weight (lbs)	Tare (%)	% No Damage	% Slight	% Serious	% Cut	% Broken Knobs
Low Damage Harvester	283 3	5.4	84.1	14.3	0.3	0.5	0.7
Conventional Harvester	279.1	2 9	61.1	35.8	0.2	1.5	1.4