FIELD CAPACITIVE PERFORMANCE OF COTTON PICKING MACHINES IN ARIZONA

by

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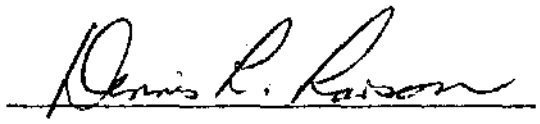
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ABSTRACT

Information on the time study of mechanical cotton picking is useful to farm managers, researchers, and cotton harvesting machinery designers. Using operational analysis, time study information can be used to improve the field performance of cotton picking machines, and yield clues for machine design changes.

This report presents a time study of mechanical cotton picking made during the 1974 harvest season. The time study information was used to compute the machine field capacitive performance. Factors affecting the performance are discussed. A method for mechanizing the collection of the time study information was designed for installation and testing.

CHAPTER 1

INTRODUCTION

Background

The invention of machines for harvesting cotton started over a hundred years ago. The two types of machines developed for cotton harvesting are commonly known as pickers and strippers. A cotton picker was patented in 1850, but it was not until 1946 that these machines were manufactured in any appreciable quantity. A cotton stripper was patented in 1871, but it was not until 75 years later that the stripper came into extensive use.

Mechanical cotton pickers are selective in that the seed cotton is removed from the open bolls and green unopened bolls are left on the plant to mature for later picking. Mechanical pickers are best adapted to situations where yields are ordinarily high, the fibers are long, the bolls are of the open type, and vegetative growth is rank.

Strippers, on the other hand, are once-over machines. All cotton bolls, whether open or closed, are removed from the cotton plant in a single pass. Strippers are most successful with plants having storm-resistant bolls and in areas with dry weather during the harvest season (7). Pickers are generally found to be more versatile than strippers, tolerating a wider range of plant characteristics and conditions, and being less affected by grass and weeds (7).

In 1968, over 90% of the cotton produced in the United States was harvested by machines (3). It is now believed that nearly 100% is harvested by machines. Mechanical cotton pickers are the machines used to harvest most cotton in Arizona.

Mechanical Cotton Pickers

A mechanical picker must be capable of gathering mature seed cotton with a minimum of waste and without causing damage to the fiber, plant, or unopened bolls. Kepner et al. (7) reported that a mechanical picker consists essentially of the following functional units:

1. An arrangement for guiding the cotton plants into the picking zone and providing necessary support while the seed cotton is being removed.
2. Devices to remove the cotton from the open bolls.
3. A conveying system for the picked cotton.
4. A storage basket or container in which the picked cotton can be accumulated.

Most pickers in Arizona are self-propelled, two-row machines. A typical two-row mechanical picker in operation is shown in Figure 1.

Mechanical Picker Field Performance

Mechanical picker field performance can be expressed in terms of its field capacity and field efficiency. The rate of picking cotton in terms of area per unit time is the picker field capacity. McKibben (8) derived the equation for the theoretical hourly capacity of a field machine as follows:



Figure 1. A Typical Two-Row Cotton Picker in Operation.

$$C_t = \frac{(S)(W)}{8.25}, \quad (1)$$

where C_t is the uninterrupted capacity in acres per hour, S is the speed in miles per hour, and W is the width of the implement or machine in feet. He further derived the relationship for effective capacity

$$C_e = \frac{C_t(100-P)}{100}, \quad (2)$$

where C_e is the effective capacity in acres per hour and P is the percentage of time lost because of support functions. Effective capacity, as distinguished from theoretical capacity, takes into account time used for nonpicking activities. Picker field efficiency is the ratio of effective field capacity to theoretical field capacity, expressed as a percent. Field efficiency includes the effects of time lost in the field and of failure to utilize the full width of a machine. The equation for field efficiency can be written as follows

$$E_{ff} = \frac{C_e(100)}{C_t}, \quad (3)$$

where E_{ff} is the field efficiency in percent.

Review of Literature

Studies of mechanical picker performance to determine field capacities and efficiencies and to provide information for operational analysis have been made by many, but only published by a few investigators. Detailed time studies, involving the observation of the various

activities required in cotton picking, are essential to an evaluation of picker field performance.

Renoll (9), in discussing the effects of management on capacity and efficiency of farm machines, gave an example of a detailed time study of a cotton harvesting operation using a one-row cotton picker. His observed times, reduced to a per-acre basis, are shown in Table 1. Barnes (2) did a time study of mechanical cotton picking in Arizona involving one-row and two-row pickers. The data obtained from this study were later used to predict the effective field capacity of a four-row picker (6). Barnes' analysis yielded effective field capacities of 0.57 to 0.61 acre per hour for one-row pickers, 0.97 to 1.33 acres per hour for two-row pickers and a predicted 2.08 acres per hour for four-row pickers.

Corley (3) studied the basic factors affecting performance of mechanical cotton pickers. In his study, he conducted laboratory tests to determine the effect of spindle speed, spacing, exposure time with cotton boll location, and crop conditions on picker performance. In association with Stokes, Corley (4) studied mechanical cotton harvester performance as influenced by plant spacing and varietal characteristics. The results of their study showed that cotton plant spacing and variety affected performance of both picker and stripper harvesters. Renoll (10) used time study data of one-row and two-row cotton pickers to illustrate the value and use of operational analysis in improving row-crop machinery efficiency. The results of field studies by many investigators have been summarized in the Agricultural Engineers Yearbook (5).

Table 1. Activity and Time Required in Harvesting One Acre of Cotton by a One-Row Picker, Renoll (9).

Activity	Minutes per acre
Turn at row ends	2.6
Dump basket	4.6
Clean machine	2.3
Idle travel	1.1
Travel to and from wagon	3.6
Pack basket	2.1
Other down time	0.7
Actual picking	36.0
Total time per acre	53.0

Objectives

The objectives of this study were to:

1. Study mechanical cotton harvesting operations in Arizona and collect field data on the operating performance of cotton pickers.
2. Analyze these data to determine picker field capacity and efficiency and to compare these performance measures with results reported by other researchers.
3. Study factors affecting picker field capacity and efficiency and determine possible improvements through operational analysis.
4. Design a system for automating the data gathering process.

CHAPTER 2

DATA GATHERING AND ANALYSIS PROCEDURES

Data Gathering Procedure

Data were gathered by a time study of the various activities involved in cotton harvesting operations. The observer followed the pickers through the field and timed each step in the sequence of events or activities involved in machine harvesting of cotton. A time study board and stop watches were used in timing the operations. The labor elements or activities timed during the harvesting operation were:

1. Travel down the row picking cotton.
2. Turning time.
3. Travel to and from the dumping area.
4. Dumping picker baskets into trailers or module builders.
5. Time taken for cleaning, minor servicing, adjusting the machine during picking, and for personal operator tasks. These activities were combined because an arbitrary separation of times was frequently required.

A field data sheet, as attached in Appendix A, was used to record detailed information for each observation. Normal field observations were of 4 to 8 hours duration.

Data Analysis Procedure

Sixteen different observations of mechanical harvesting of cotton were made at various locations in Arizona during the 1974 harvest

season. Time study data on the harvesting operations were collected and analyzed.

Each observation was analyzed and summarized to obtain information such as total time taken for each event during harvesting, acreage harvested and picker field capacity and efficiency. An observation was analyzed and summarized using the following steps:

1. The recorded time for each separate activity was totaled. Machine preparation time and travel to and from the field were considered nonpicking activities and were not included in the study. Any field adjustment or servicing of over thirty minutes duration was considered a breakdown and was, also, not included in the study.
2. Total area harvested was determined from the row length, row spacing, and number of rows picked.
3. Effective field capacity was determined by dividing the area harvested in acres by the total time spent harvesting the acreage.
4. Theoretical field capacity was determined by dividing the area harvested in acres by the time in hours the machine was actually picking.
5. Field efficiency was determined by dividing actual picking time by the total time taken to harvest the area. An equation to determine field efficiency is

$$E_{ff} = \frac{t_{pick} \times 100}{t_{pick} + t_{lost}}, \qquad (4)$$

where E_{ff} is the field efficiency in percentage and t_{lost} is the time lost in turning, dumping, travel not associated with picking, and in doing miscellaneous tasks.

An example of an observation data sheet and the analysis of the data are included in Appendix A.

CHAPTER 3

RESULTS AND DISCUSSION

The quantitative results of the analysis of all observations are summarized and presented in Table 2. Details of the individual harvesting operations which were observed are attached as Appendix B.

The summarized results show that for two-row cotton pickers using trailer dumping, 67.4% and 70.2% of the total field time was spent actually picking during the first and second picking operations, respectively. Based on four observations of the module dumping system, two-row cotton pickers spent 77.9% and 82.1% of the total field time actually picking during the first and second picking operations, respectively.

Effective field capacities for the systems ranged from 1.00 to 1.30 acres per hour for first picking and 1.00 to 1.70 acres per hour for second picking operations. Effective field capacity and field efficiency averages and their standard deviations are shown in Table 3. Only the average effective field capacity for first picking operations using the trailer dumping system showed a high standard deviation. This was due to substantial differences in picker speeds and dumping, travel and miscellaneous times recorded between observations (Table 2).

When trailers were used, dumping, turning, and travel associated with dumping the basket combined required 20.2% of the total field time during the first and 11.1% of the time during the second picking

Table 2. Summary of Harvest Time Study of Cotton Pickers.

Obs. No.	Operation	Speed, mph	Ave. row length, ft.	Operating (picking), min/Ac	Turning, min/Ac	Dumping, min/Ac	Travel to and from dump, min/Ac	Misc., min/Ac	Total, min/Ac	Eff. field cap., Ac/hr	Field eff., %
1	1st picking	2.5	936	29.20	2.97	4.10	4.66	6.36	47.29	1.30	61.8
2	"	2.6	936	28.32	0.89	5.78	5.60	11.83	52.42	1.10	54.0
3	"	2.1	1276	35.26	1.96	6.91	3.34	5.58	53.10	1.13	66.5
4	"	1.7	1168	43.21	2.54	7.25	3.44	3.20	59.64	1.00	72.5
5 md	"	2.0	1100	37.44	1.25	0.98	4.00	3.36	47.03	1.30	79.6
6 md	"	2.0	1100	37.27	2.50	0.67	2.50	5.89	48.83	1.20	76.1
7 md	2nd picking	2.5	800	29.57	1.37	0.59	0.96	5.61	38.10	1.60	77.6
8 md	"	2.4	800	30.70	1.53	1.48	0.84	0.75	35.31	1.70	87.0
9	"	2.5	1500	30.29	1.73	3.84	0.63	1.48	37.97	1.60	79.8
10	"	2.1	1500	36.10	1.17	6.76	2.10	12.66	58.79	1.00	61.4
11	1st picking	1.6	1500	45.86	0.67	3.80	3.60	6.47	60.40	1.00	76.0
12	2nd picking	2.4	1500	31.54	1.66	0.41	0.63	1.75	35.99	1.70	87.5
13	"	2.1	1500	35.20	1.48	1.00	0.66	13.20	51.54	1.20	68.3
14	"	2.3	1500	32.24	1.47	1.56	1.30	13.48	50.10	1.20	64.4
15	1st picking	2.3	1500	32.68	1.70	2.00	3.23	6.10	45.71	1.31	71.5
16	2nd picking	2.9	1300	25.62	3.10	0.18	0.42	8.30	37.62	1.60	68.2
1st pick ave (trailer)				35.76	1.79	4.97	3.98	6.59	53.10	1.13	67.4
1st pick ave (module builder)				37.27	1.88	0.83	3.25	4.63	47.86	1.25	77.9
2nd pick ave (trailer)				31.83	1.77	2.29	0.96	8.48	45.33	1.32	70.2
2nd pick ave (module builder)				30.14	1.45	1.04	0.90	3.18	36.71	1.63	82.1

Note: Miscellaneous time includes adjusting, minor servicing, cleaning, and personal times recorded during picking operations.

md = module dumping; others were trailer dumping.

Table 3. Standard Deviations of Effective Field Capacities and Field Efficiencies.

Performance	Average	Standard Deviation	Percent Deviation from Average
Effective Field Capacity	Ac/Hr		
1st pick (trailer)	1.13	0.70	62
2nd pick (trailer)	1.32	0.32	24
1st pick (module)	1.25	0.23	18
2nd pick (module)	1.63	0.10	6
Field Efficiency	%		
1st pick (trailer)	67.4	8.3	12
2nd pick (trailer)	70.2	10.1	14
1st pick (module)	77.9	2.5	3
2nd pick (module)	82.1	6.7	8

operations. Minor machine adjustments, servicing, and cleaning plus personal time occupied 12.4% of the total field time during the first and 18.7% of the time during the second picking operations.

Based on four observations of the module dumping system, turning, dumping, and travel associated with dumping together required 12.4% of the total field time during the first and 9.2% of the time during the second picking operations. Minor machine adjustments, servicing and cleaning plus personal time occupied 9.7% of the total field time during the first and 8.7% of the time during the second picking operations.

Turning times for the observations ranged from 0.67 to 3.10 minutes per acre. Surface condition and amount of field turning space and picking pattern accounted for the differences in recorded turning times between observations.

Travel time to and from the dump wagon ranged from 0.42 to 4.66 minutes per acre. Frequency of dumping and distance from harvesting area to dump wagon accounted for the differences in recorded travel times.

Four evaluations were made using summarized data. These were: 1) an evaluation of the relationship between picker harvesting speed field capacity and field efficiency; 2) an evaluation of the relationship between picker field efficiency and time spent on miscellaneous activities. Miscellaneous activity times are those spent on cleaning, minor field adjusting and servicing of the picker, and for personal operator tasks; 3) an evaluation of module builder and trailer dumping times; and 4) a comparison of field capacities and field efficiencies with values obtained during a similar study by Barnes (2) in 1959.

Picker ground speeds for the observations ranged from 1.6 to 2.6 miles per hour during first pick and from 2.0 to 2.9 miles per hour during the second picking operation. Harvesting speeds and correspondingly attained effective field capacities and field efficiencies are compared in Table 4. From this comparison it can be seen that field efficiency is not directly related to effective field capacity or harvest speed. Effective field capacity is plotted against harvest speed in Figure 2. A regression line through the plotted points indicates that higher harvesting speeds generally yield higher effective field capacities.

The time spent on miscellaneous activities is the most variable of the activity times recorded. It ranged from 0.75 to 13.48 minutes per acre. The time spent on miscellaneous activities is compared to correspondingly attained field efficiencies in Table 5. The data, plotted in Figure 3, indicate that field efficiency is directly affected by the amount of time devoted to miscellaneous activities during the picking operations.

Module-builder dumping times are compared with trailer dumping times in Table 6. An average dumping time of 4.97 minutes per acre or 3.15 minutes per dump was required when using trailers as compared to only 0.83 minutes per acre or 0.47 minutes per dump using module builders during first picking. During second picking, an average dumping time of 2.29 minutes per acre or 4.59 minutes per dump was required when using trailers as compared to 1.04 minutes per acre or 1.5 minutes per dump using module builders. The comparison shows that module

Table 4. Harvest Speed in Ascending Order versus Effective Field Capacity and Field Efficiency.

Obs. No.	Harvest speed mph	Effective Field Capacity Ac/Hr	Field Efficiency %
11	1.6	1.00	76.0
4	1.7	1.00	72.5
5	2.0	1.30	79.6
6	2.0	1.20	76.1
3	2.1	1.13	66.5
13	2.1	1.20	68.3
10	2.1	1.00	61.4
15	2.3	1.31	71.5
14	2.3	1.20	64.4
12	2.4	1.70	87.5
8	2.4	1.70	87.0
9	2.5	1.60	79.8
1	2.5	1.30	61.8
7	2.5	1.60	77.6
2	2.6	1.10	54.0
16	2.9	1.60	68.2

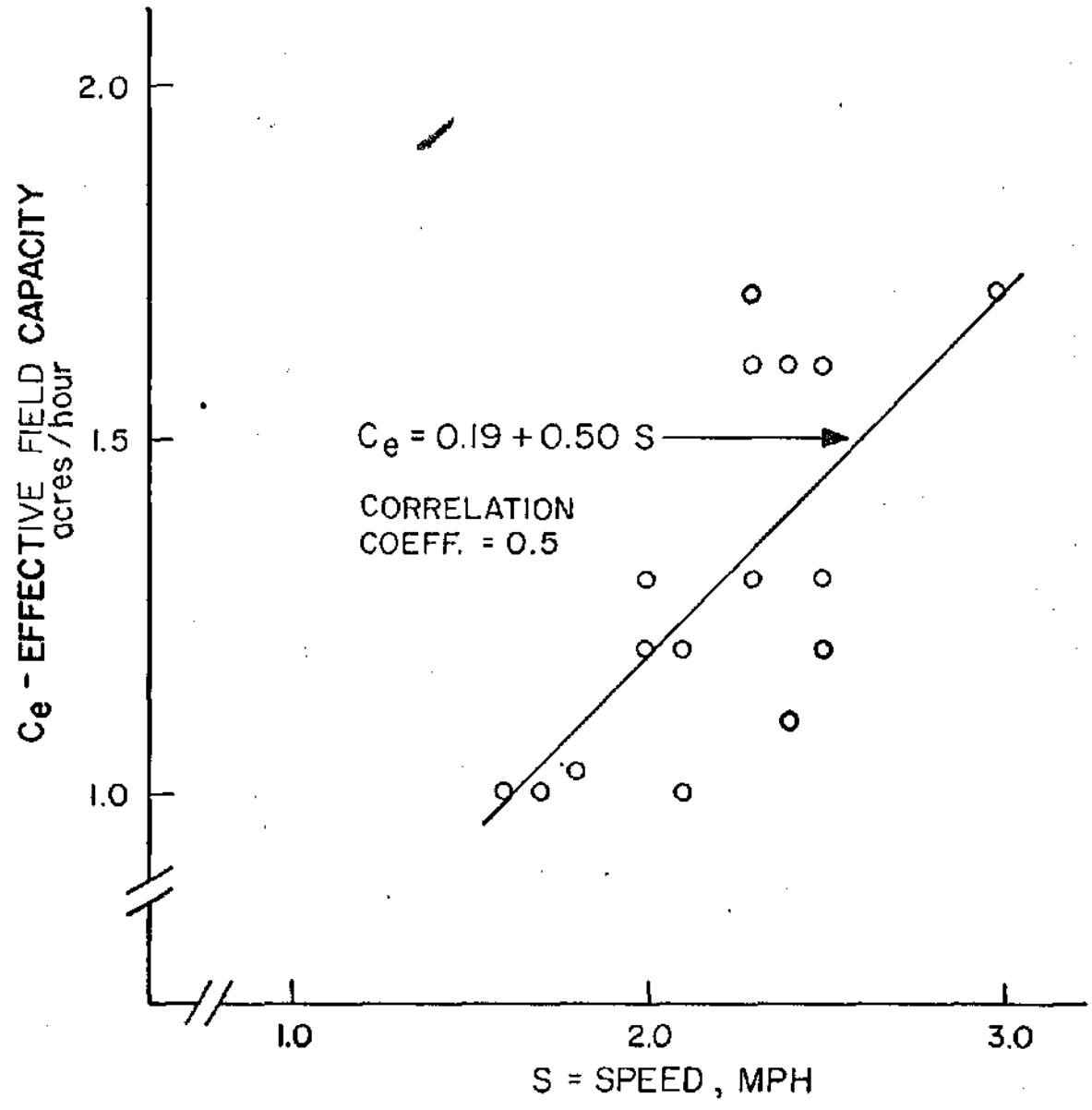


Figure 2. Effective Field Capacity versus Harvest Speed.

Table 5. Time Spent on Miscellaneous Activities versus Field Efficiency.

Obs. No.	Miscellaneous Time Min/Ac	Field Efficiency %
8	0.75	87.0
9	1.48	79.8
12	1.75	87.5
4	3.20	72.5
5	3.36	79.6
3	5.58	66.5
7	5.61	77.6
6	5.89	76.1
15	6.10	71.5
1	6.36	61.8
11	6.47	76.0
16	8.30	68.2
2	11.83	54.0
10	12.66	61.4
13	13.20	68.3
14	13.48	64.4

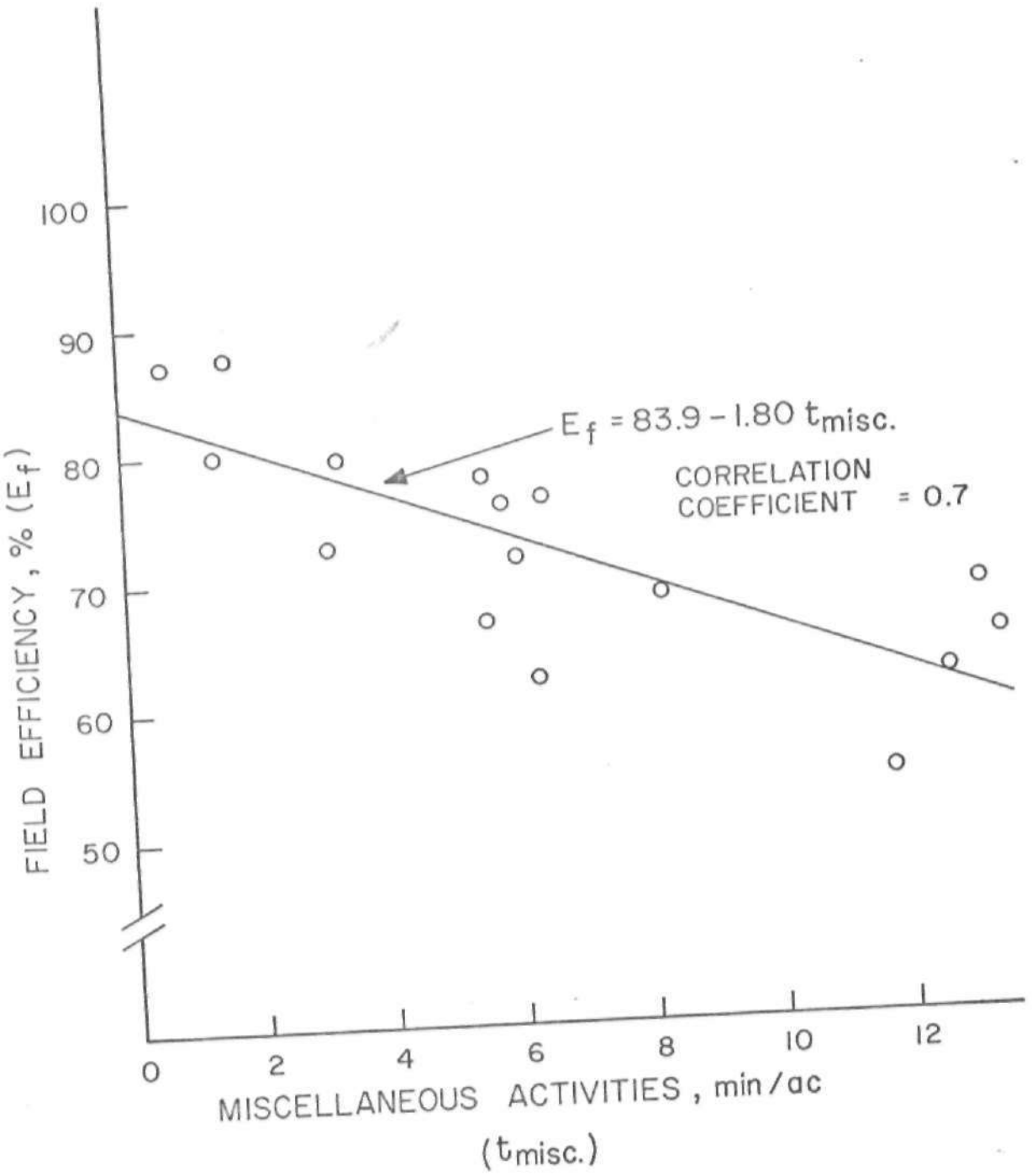


Figure 3. Field Efficiency versus Miscellaneous Activity Time.

Table 6. Average Dumping Time Required for Module and Trailer Systems on Various Arizona Farms.

Trailer Dumping						Module Builder Dumping					
First Pick			Second Pick			First Pick			Second Pick		
Obs. No.	Min/ Ac	Min/ Dump	Obs. No.	Min/ Ac	Min/ Dump	Obs. No.	Min/ Ac	Min/ Dump	Obs. No.	Min/ Ac	Min/ Dump
1	4.10	2.58	9	3.84	8.80	5	0.98	0.49	7	0.59	0.73
2	5.78	1.99	10	6.76	4.67	6	0.67	0.45	8	1.48	2.26
3	6.91	5.40	12	0.41	1.04	Avg	0.83	0.47	Avg	1.04	1.50
4	7.25	5.84	13	1.00	3.66						
11	3.80	1.75	14	1.56	2.78						
15	2.00	1.69	16	0.18	0.60						
Avg	4.97	3.15	Avg	2.29	4.59						

dumping times were lower than trailer dumping times. The low dumping times recorded during second picking operations were primarily due to low yields. Other factors accounting for the differences in dumping times between observations were the number of dumps per unit area, which is related to the yield, amount of cotton already in dump wagon and operator procedures used in dumping. Interestingly, the average module builder dumping time during the second picking operation was higher than that for the first picking operation (Table 6). This was because the operator in observation 8 used more time per dump.

A similar time study of cotton picking machines in Arizona was reported by Barnes (2) in 1959. The actual effective field capacities observed in that study ranged from 0.97 to 1.33 acres per hour, harvesting speeds ranged from 1.90 to 2.37 mph and the average field efficiency was 70.4% for two-row pickers during the first picking. In the 1974 study, from Table 2, effective field capacities ranged from 1.00 to 1.31 acres per hour, harvesting speeds from 1.6 to 2.6 mph and the average field efficiency was 67.4% for two-row pickers during first picking. Two-row picker field capacities, harvesting speeds, and average field efficiency during first picking operation did not change appreciably between these studies.

CHAPTER 4

DISCUSSION OF FACTORS AFFECTING FIELD CAPACITY AND FIELD EFFICIENCY

The differences between the observed field capacities and field efficiencies are primarily due to three factors. These are machine or system factors, field and crop conditions, and management.

The machine or system factors found to influence performance measures were the picker harvesting speed, basket size, and cotton field storage system used. Faster harvesting speeds resulted in increased field capacity. The basket size affected the duration and frequency of dumps and consequently the total time devoted to dumping. Field efficiency could be improved if dumping times were reduced. The reduction could be realized by using a field storage unit such as a module builder (Figure 4). Time per dump was reduced when the module builder was used since cotton compaction provides dumping space (Figures 4, 5, 6).

The time devoted to some miscellaneous activities such as minor field adjustment, servicing, and cleaning of the harvester was due to crop and picker mechanical conditions. Reliability, as measured in terms of amount of time spent on these activities, thus affected field efficiency.

A number of harvesters, cotton field storage units, and transport trucks were observed to make up a harvesting system. There is a relationship between individual harvester performance and the performance of the



Figure 4. Module and Trailer Dumping.



Figure 5. Trailer Dumping with Helper.



Figure 6. Packing Apparatus of the Module Builder.

whole system. Age did not appreciably affect the attained harvesting speeds or field capacities for the harvesters observed (Table 7).

Table 7. Machine Age and Representative Values of Harvesting Speed, and Effective Field Capacity During First Pick.

Obs. No.	Year Purchased	Speed mph	Effective Field Capacity Ac/Hr
2	1964	2.6	1.10
6	1968	2.0	1.20
3	1971	2.1	1.13
4	1971	1.7	1.00
1	1972	2.5	1.30
11	1974	1.6	1.00
15	1974	2.3	1.30

The field factors not measured but observed to affect turning time and idle travel time were amount and condition of turning space and field harvesting patterns. Turning times were high where the turn area was not smooth or wide enough to allow an easy turn. Harvesting pattern and dump wagon locations influenced idle travel time. An efficient harvesting pattern and location of dump wagon would reduce time spent on turning and idle travel within a given field. The harvesting pattern commonly practiced, an overlapping, alternating system (Figure 7) has been found to be efficient in minimizing nonproductive time (1).

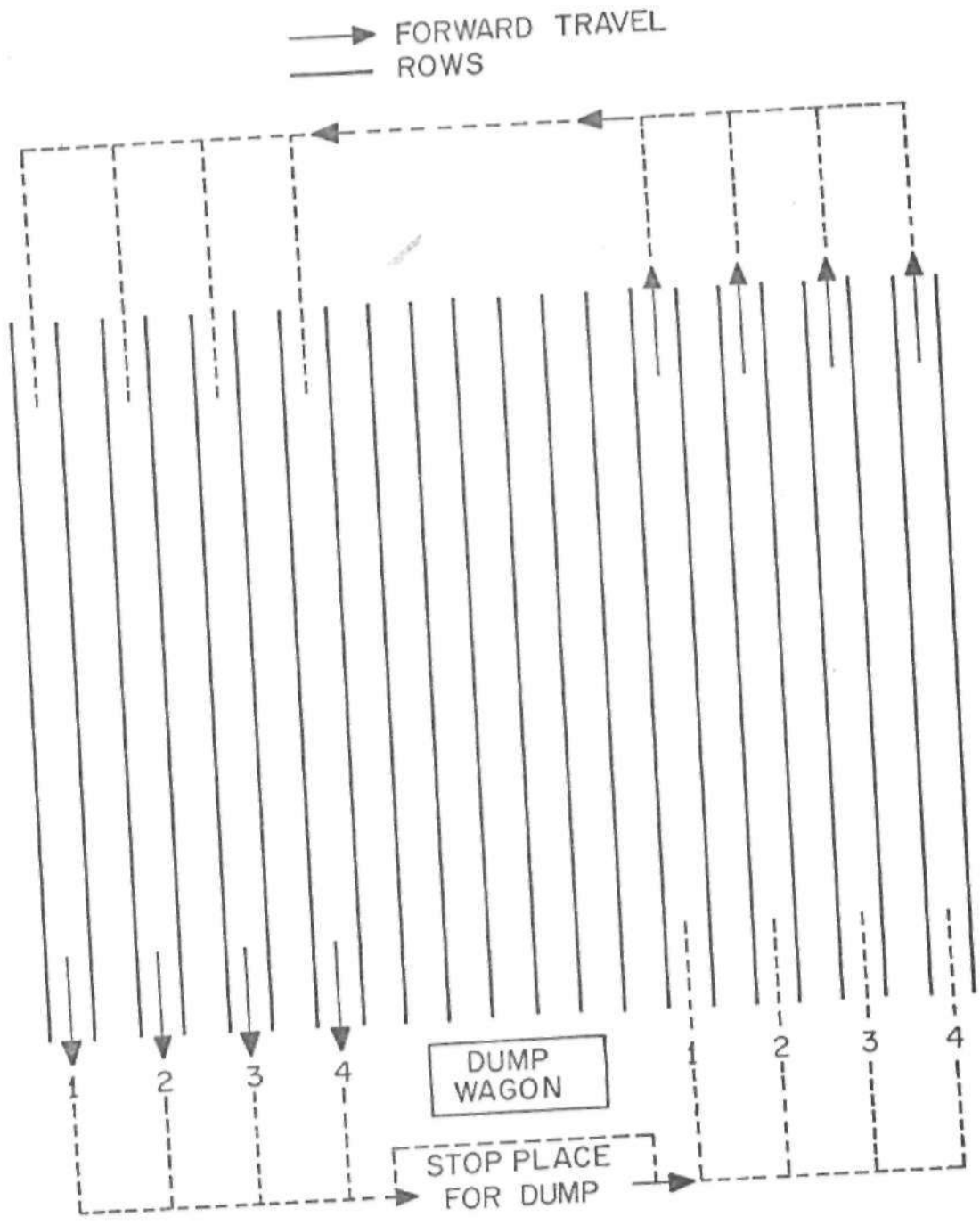


Figure 7. Harvesting Pattern for Two-Row Pickers.

A reduction in picker harvesting speed was observed in situations where the cotton yields were high. Machine cleaning was more frequent in fields with high weeds or in fields not well defoliated. All these field and crop factors had cumulative effects on attained picker field capacity and field efficiency.

Management factors did influence the field capacity and efficiency, because not only does management have control of field layout, but it also affects preventive care and maintenance of pickers, operator performance, harvesting schedules, and supervision of defoliation. By proper decisions management has the key to improving the field capacity and efficiency of cotton pickers.

Time studies can help the manager of a cotton harvesting operation improve harvester field capacity and efficiency by locating potential areas for improvement. Table 8 illustrates the information gained from the 1974 time study. The third picker (below average) in Table 8 spent a large amount of time in cleaning and adjusting the picker and for personal tasks. Management could locate this with a time study and change the machine preventive maintenance program, improve operator supervision, or alter other conditions judged to be causing the situation. Less time spent by this picker on traveling to and from the wagon and for dumping would also improve field capacity and efficiency. Management could investigate the adjustment of harvesting patterns and dump wagon locations to reduce idle travel and provide easy access for dumping. The use of module builders could also reduce dumping times. The first picker (above average) was comparatively more

efficient as more of the total field time was spent actually picking. Similarly, time studies could be used by management to study other operations and obtain more efficient use of harvesting time.

Table 8. Distribution of Time in Minutes per Acre to Harvest Cotton in Three Separate Harvesting Operations by Machines Using Trailer Dumping During First Pick.

Activity	Picker 1 Obs. 15 (above ave.)	Picker 2 Obs. 1 (average)	Picker 3 Obs. 2 (below ave.)
Actual picking	32.68	29.20	28.32
Turning	1.70	2.97	0.89
Dumping	2.00	4.10	5.78
Travel to and from dump wagon	3.23	4.66	5.60
Misc. activities (cleaning, adjusting, servicing, and personal)	6.10	6.36	11.83
Total time	45.71	47.29	52.40
Effective field capacity (Ac/Hr)	1.31	1.30	1.10
Field efficiency (%)	71.50	61.80	54.00
Speed (mph)	2.30	2.50	2.60

CHAPTER 5

CONCLUSIONS

The following conclusions were drawn from this study:

1. Even though technological advances have been made on cotton picking machines, such as larger picker baskets and improved operator comfort and control of machine, no appreciable increases in field capacities and field efficiencies were demonstrated by this study as compared with a similar study carried out in 1959.
2. Generally, higher speeds were found to yield higher field capacities. Data ranged from 1.00 acre per hour at 1.6 mph to 1.70 acres per hour at 2.9 mph.
3. Dumping time can be reduced by using a module builder. The field studies showed dumping cotton into a module required an average of 0.83 minutes per acre during first pick and 1.04 minutes per acre during second pick, while trailer dumping required an average of 4.97 minutes per acre during first pick and 2.29 minutes per acre during the second picking operation.
4. Field efficiency cannot be readily related to effective field capacity. Field efficiency was primarily affected by field and crop conditions and machine and operator

performances, whereas effective field capacity was primarily affected by speed.

CHAPTER 6

SUGGESTIONS FOR IMPROVING THE DATA COLLECTING METHOD

Mechanizing the cotton harvesting time data gathering process should result in an increased quantity of unbiased data with a savings in observer and data reduction time. One method could use an event recorder on the machine that prints the time of harvesting activity initiation after receiving input commands from the various machine elements. The design of this method is presented and discussed in Appendix C. An improvement in this method could involve use of magnetic tape for recording the data for computer separation and analysis.

APPENDIX A

FIELD DATA SHEET

Time Study: Machine Harvesting of Cotton

Date: October 17, 1974 Field Location: West of Phoenix

Owner: J. Jones Operator: H. Smith

Weather: Sunny and clear Machine Make: International 2-Row Picker

Model: 622 Speed: 2.5 mph Row Spacing: 40 in.

Cotton variety: Delta pine 61 Row Length: 936 ft.

1st Pick: 95% open

Condition: Well defoliated, good, plants on row and upright

Time: Minutes;

Pick	To wagon	Dump	From wagon	Turn	Clean	Adj.	Personal	Misc.
4.60				0.26	....	....	....	....
4.60				0.46				
4.45				0.55				
4.62	2.30	3.60	2.05					
4.48				0.44				
4.49				0.65				
4.45				0.44				
4.53	1.35	2.25	1.05					
4.45				0.37				
4.50				0.37				
4.30				0.20				

Pick	To wagon	Dump	From wagon	Turn	Clean	Adj.	Personal	Misc.
4.43	1.37	3.33	2.60					
4.30				0.50				
4.30				0.80				
4.36				0.52				
4.40				0.73				
4.28				0.62				
4.35	1.70	1.77	1.80			1.30		
4.25				0.40				
4.24				0.40				
4.10				0.40				
4.20				1.05				
4.07				0.74				
4.17	1.12	2.10	1.80					
4.13				0.55				
4.10				0.53				
4.07								
4.03				0.44				
4.10	0.90	3.40						16.24[a]
3.99				0.63				
4.00				0.61				
3.92				0.63				
3.83	0.76	3.24	3.57					
4.20				0.61				
4.00				0.98				
3.95				0.77				
3.93	1.23	1.70			1.60	20.15[b]		
3.94				0.48				
3.85				0.60				
3.89				0.47				
3.80	1.44	3.80	1.90					

Pick	To wagon	Dump	From wagon	Turn	Clean	Adj.	Personal	Misc.
3.87				0.25				
3.80				0.46				
3.75				0.79		0.75[c]		
3.80	1.44	0.60	END					

[a]Filling water tank

[b]Engine hot, adjust, rest

[c]Row mistake

Example of Summary Analysis of Field Data Sheet

Observation No. 1

Location: West Phoenix

Date: October 17, 1974

Actual Picking	183.9	mins.
Turning	18.7	"
Dumping	25.79	"
Travel to and from trailer	29.38	"
Adj., service, cleaning and personal (misc.)	40.04	"
Total	297.81	mins.

Ave. row length 936 ft.

row spacing 3.33 ft.

No. of rows picked 88

Area picked $\frac{936(88)\ (3.33)}{43560}$ acres = 6.3 acres

Average speed 2.5 mph

Theoretical capacity $6.3\ Ac \times \frac{60\ mins}{Hr} \times \frac{1}{183.9\ mins} = 2.1\ Ac/Hr$

Effective Field Capacity $6.3\ Ac \times \frac{60\ mins}{Hr} \times \frac{1}{297.81\ mins} = 1.3\ Ac/Hr$

Field Efficiency $\frac{182.9}{297.81} \times 100 = 61.8\%$

APPENDIX B

DESCRIPTION OF FIELD OPERATIONS OBSERVED

Obs. No. 1. West of Phoenix. Two-row International model 622. Bed planting. First picking Delta pine 61, 95% open. Average row length 936 ft. Trailers located at one end of field. Area observed 6.3 acres.

Obs. No. 2. West of Phoenix. Two-row International model 422. Bed planting. First picking Delta pine 62, 75% open. Average row length 936 ft. Trailers located at one end of field. Area observed 1.72 acres.

Obs. No. 3. Marana. Two-row International model 622. Bed planting. First picking Stoneville 7A. Row length 1276 ft. Trailers located at one end of field. Area observed 4.7 acres.

Obs. No. 4. Marana. Two-row International model 611. Bed planting. First picking Pima S-4, 90% open. Average row length 1168 ft. Trailers located at one end of field. Area observed 3.22 acres.

Obs. No. 5. Coolidge. Two-row International model 422. Bed planting. First picking Pima, 90% open. Average row length 1100 ft. Module builder located at one end of field. Area observed 1.00 acre.

Obs. No. 6. Coolidge. Two-row International model 422. Bed planting. First picking Pima, 95% open. Average row length 1100 ft. Module builder located at one end of field. Area observed 4.04 acres.

Obs. No. 7. Coolidge. Two-row International model 422. Bed planting. Second and final picking Pima. Average row length 800 ft. Module builder located at one end of field. Area observed 2.45 acres.

Obs. No. 8. Coolidge. Two-row International model 422. Bed planting. Second and final picking Delta pine. Row length 800 ft. Module builder located at one end of field. Area observed 3.05 acres.

Obs. No. 9. Avra Valley. Two-row John Deere model 699. Bed planting. Second and final picking DPL 16. Row length 1500 ft. Trailers located at one end of field. Area observed 2.29 acres.

Obs. No. 10. Avra Valley. Two-row International model 422 Bed planting. Second and final picking DPL 16. Row length 1500 ft. Trailers located at one end of field. Area observed 1.38 acres.

Obs. No. 11. Avra Valley. Two-row International model 422. Bed planting. First picking Pima, 99% open. Row length 1500 ft. Trailers located at one end of field. Area observed 0.92 acres.

Obs. No. 12. Avra Valley. Two-row John Deere model 99. Bed planting. Second picking DPL 16. Row length 1500 ft. Trailers located at one end of field. Area observed 2.52 acres.

Obs. No. 13. Avra Valley. Two-row International model 422. Bed planting. Second and final picking DPL 16. Row length 1500 ft. Trailers located at one end of field. Area observed 7.34 acres.

Obs. No. 14. Avra Valley. Two-row John Deere model 99. Bed planting. Second and final picking DPL 16. Row length 1500 ft. Trailers located at one end of field. Area observed 7.12 acres.

Obs. No. 15. Avra Valley. Two-row International model 422. Bed planting. First picking Pima. Row length 1500 ft. Trailers located at one end of field. Area observed 5.06 acres.

Obs. No. 16. Marana. Two-row International model 611. Bed planting. Second and final picking Pima. Row length 1300 ft. Trailers located at one end of field. Area observed 3.58 acres.

APPENDIX C

DESIGN OF AN AUTOMATED SYSTEM FOR RECORDING

COTTON PICKER OPERATIONAL DATA USING AN EVENT RECORDER

Use of an event recorder would entail monitoring the activities of the picking machine elements during the harvesting operation and relaying this information to the event recorder. The event recorder could print the time at which an event changes and the state of each sensor signal at that time. Table 9 lists harvesting activities and the machine elements whose state can be sensed to determine each activity. For example, when the machine is picking, the picker header is down, spindles are rotating, basket is in the frame or not in tipping position, cotton is flowing in ducts, transmission is in travel, blower is on, and the engine is on. Similarly, the state of each machine element during each harvesting activity is determined. Further information on automating the data collecting method is shown in a flow chart of information to the event recorder (Figure 8). The picker machine elements to be sensed, a method for sensing the machine elements and relaying the information to the event recorder, and the best locations for mounting sensors on the picker are shown in Table 10.

Table 9. Harvesting Activities and the State of Picker Machine Elements.

Machine element	Harvesting activity				
	Picking	Turning	Travel to and from dump wagon	Dumping	Misc.[a]
A Header down = 1	1	0	0	0	1,0
B Spindles rotating = 1	1	0,1	0	0	0
C Basket tipped = 1	0	0	0	1	0,1
D Cotton in ducts, cotton blowing = 1	1	0	0	0	0
E Transmission traveling = 1	1	1	1	0	0
F Blower on = 1	1	1	1,0	0	1,0
G Engine on = 1	1	1	1	1	1,0

[a]Cleaning and adjusting machine + personal time.

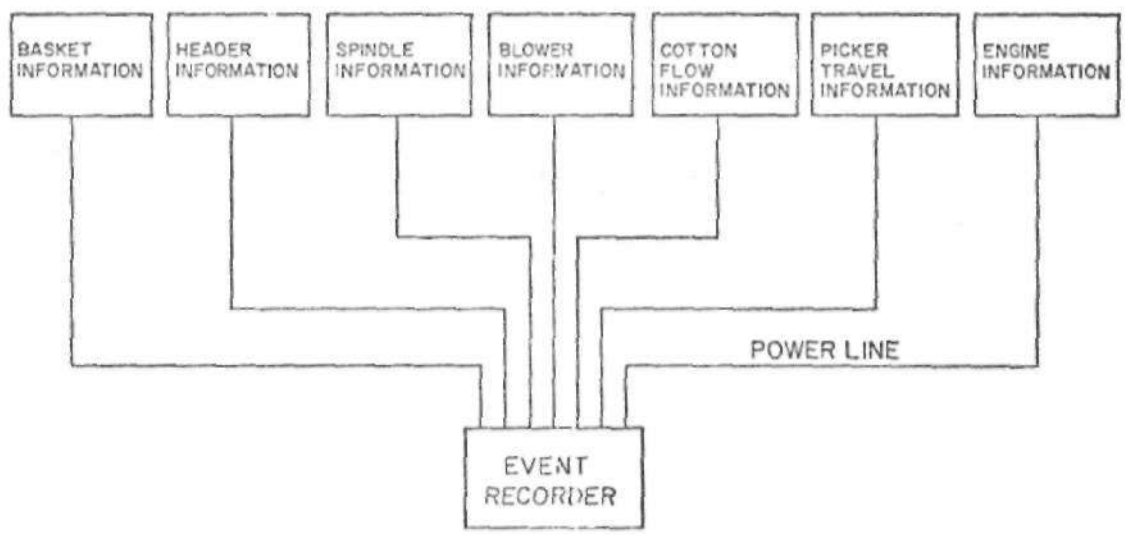


Fig. 8. Flow Chart of Information to Event Recorder.

Table 10. Possible Method of Sensing Picker Machine Elements and Location of Sensors.

Picker element to be sensed	Condition or state	Possible method of sensing	Suggested location of sensor on picker
Spindles	Rotating or still	Wire connection from spindle on-off switch through a relay to the event recorder	Picker control panel that contains the spindle on-off switch
Engine (power)	On or off	Wire connection from ignition switch through a relay to the event recorder	Picker control panel
Picker travel	In motion or stationary	By connecting a small generator to the picker axle drive shaft; the current generated can be sensed by a relay connected to the event recorder	Generator can be fixed by the side of the picker axle drive shaft
Cotton blower fan	On or off	Wire connection from fan switch on the control panel through a relay to the event recorder	Picker control panel
Basket	Tipped or in frame	Microswitch	Bracket and switch can be placed at top of basket pivot plate so that the switch makes contact with the basket pivot when basket is in dump position
Cotton flow into basket	Flowing or not	Microswitch fitted with a perforated light flat plate for registering cotton impact but still allowing air to pass through	The microswitch fitted with the plate could be mounted on a bracket and attached to the inside of one drum door where cotton is thrown from the doffers
Header	Up or down	Microswitch	Bracket and switch can be located on picker frame to sense when the header is in the up position

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