METHODS FOR EVALUATING IMPORTANT FACTORS AFFECTING SELECTION AND TOTAL OPERATING COSTS OF FARM MACHINERY

Thesis for the Degree of Ph. D.

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George Herbert Larson

1955

This is to certify that the

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METHODS FOR EVALUATING IMPORTANT FACTORS AFFECTING SELECTION AND TOTAL OPERATING COSTS OF FARM MACHINERY

By

George Herbert Larson

AN ABSTRACT

Submitted to the School for Advanced Graduate Studies of
Michigan State University of Agriculture and Applied Science
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Agricultural Engineering

Year 1955

Approved by H. F. McColly

Mechanization of agriculture is requiring a relatively large capital investment in equipment. For 1953, records of 501 farms in the state of Michigan showed that the total capital investment per farm not including house averaged $33,385, with the investment in machinery and equipment amounting to $7461 per farm, or 22.4 percent of the total farm capital. Moreover, machinery investment has increased approximately 62 percent from 1949 to 1954.

With the rapid development of new farm machines the farm manager is faced with the problem of making adjustments which require cost prediction. One of the problems that needs further study is the development of some simple method for estimating costs of operating machinery that could be used by a person of non-technical background, say a farm equipment dealer, farm operator, or perhaps extension workers.

A set of alignment charts or nomographs has been developed for making machinery operating cost estimates; and tables have been prepared which are an aid to using the alignment charts.

Another problem which is in need of investigation is a method for determining when a machine is no longer economical to operate and should be replaced by a new machine. One of the important factors affecting the point beyond which a machine is no longer economical to operate is cost of repairs. Review of literature indicated that there is a very limited amount of data on how repair costs vary with use. This factor alone limited the amount of work that could be done to develop a feasible method for determining when a machine is no longer economical to operate.

The research work reported in the thesis was approached first by a review of existing literature and by obtaining published material in the form of bulletins, circulars, mimeographed material and personal correspondence relative to farm equipment costs. This information was needed as background material for developing mathematical relationships and preparing alignment charts for estimating operating costs of farm equipment.

The above program was partially accomplished by writing to the heads of departments of agricultural engineering at colleges and universities in the United States and by consulting commercial agencies associated with farm equipment.

A survey in person was made of the cost records for tractors operated at Seabrook Farms, Bridgeton, New Jersey. Machinery cost records obtained from J. I. Case Company and Green Giant Company were examined. Also cost records, received from Professor Bateman, agricultural engineering department at the University of Illinois, were analyzed.

The investigation confirms that one of the major factors affecting total operating cost of farm machinery is depreciation which is considered to be a fixed or ownership cost.

It appears that the declining-balance method of depreciation as suggested by tax legislation for income tax purposes might also be used for estimating cost of depreciation for farm machinery when the exact amount is not known since it tends to give a more realistic value than the straight-line method.

Some of the simple nomographs or alignment charts constructed were tried out in a farm machinery class. The results indicate that the charts will perhaps have some practical application by farm equipment personnel, extension workers and farm operators. Enthusiasm expressed by a representative of one of the major farm equipment companies indicates that the charts have some merit.

Results of a study of repair cost data on seven tractors for a period of ten years indicate annual repair costs increase at an increasing rate according to the relationship, $Y = 0.314X^{1.61}$ where Y is repair cost in percent of new cost and X is the year in question. This relationship is based on an average annual use of 550 hours per year.

For the group of tractors analyzed it appears that they should be replaced at the ninth or tenth year based on the proposed method for determining when a tractor is no longer economical to operate.

For the same group of tractors studied, it was observed that a three year old tractor would provide the lowest average annual operating cost due to the high rate of depreciation during the first two years of use.

It is believed that more detailed information is needed on the relationship between repair cost and use to adequately evaluate the factors influencing operating costs of various farm machines. Past performance data of certain farm machines is probably the best source of information for predicting behavior of future machines.

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Special credit is due to Professor H. P. Bateman, Agricultural Engineering Department, University of Illinois, for his assistance in supplying unpublished data relative to repair costs of tractors.

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VITA

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candidate for the degree of

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Final Examination, July 28, 1955, 9:00 A.M., A. E. Room 120

Dissertation: Methods for Evaluating Important Factors Affecting Selection and Total Operating Costs of Farm Machinery

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TABLE OF CONTENTS

LIST OF TABLES

TABLE | Page

LIST OF FIGURES

FIGURE PAGE

INTRODUCTION

The factors which influence the operating costs of farm power and machinery, and which are closely related to the selection and management of power and machinery for the farm have been of great concern among agricultural economists and agricultural engineers for many years. It will continue to be so due to the continual development of modern machines for complete mechanization of agriculture.

Mechanization of agriculture is requiring an investment with a relatively large amount of capital in equipment. In 1953, records of 501 farms* in the state of Michigan showed an average capital investment per farm to be $33,385 not including the house, while the investment in machinery and equipment amounted to $7461 per farm, or 22.4 percent of the farm capital was invested in machinery and equipment. Also, it is to be noted that machinery investment has increased approximately 62 percent from 1949 to 1954.

The trend toward complete mechanization tends to require a much larger area of land on which to operate as well as to reduce the number of people engaged in farming.

Further, rapid developments of new sizes and types of farm machines in recent years require adjustments in farm

*Doneth, John C. (1954). Michigan Farm Business Report, Michigan Quarterly Bulletin, Vol. 37, no. 2, pp. 264-272.

operations and production methods. Advantageous adjustments, however, require cost prediction. The actual operating cost of farm machinery is therefore one of the important factors that needs to be considered in keeping the total costs of production for a farming enterprise at a minimum.

One of the problems is the development of some simple method for estimating costs of operating machinery that could be used by a person with non-technical background, by a farm equipment dealer, farm operator, etc.

The possibility of using alignment charts for cost estimating purposes has been suggested and have been developed for this program.

Another problem which is in need of investigation is developing a method for determining when a machine is no longer economical to operate. A concept has been developed in this thesis which may have some merit in determining when a machine is no longer economical to operate.

OBJECTIVES

1. To study the cost factors that are involved in estimating operating costs of farm equipment.
2. To develop nomographs or alignment charts which farm equipment personnel and farm operators can use to determine quickly from equipment specifications, the cost of a certain operation or combination of operations.
3. To determine the relationship between repair and maintenance costs and use for various farm machines.
4. To develop a method for estimating when a farm machine is no longer economical to operate.

METHOD OF PROCEDURE

The research work reported in this thesis was approached first by a review of existing literature and obtaining published material in the form of bulletins, circulars, mimeographed material and personal correspondence relative to farm equipment costs, needed in the way of background material for development of mathematical relationships and preparation of alignment charts for estimating operating costs of farm equipment.

The above program was partially accomplished by writing to the heads of departments of agricultural engineering at colleges and universities in the United States and by consulting with commercial agencies working with farm equipment.

A personal survey was made of the cost records for tractors operated at the Seabrook Farms, Bridgeton, New Jersey.

Cost records of tractors from various states as reported by the owner to the J. I. Case Company, which were obtained through correspondence with the company representative, were examined.

Cost records of tractors, sweet corn harvesters and corn planters were obtained through correspondence with a representative of Green Giant Company.

Cost records of seven tractors for a ten-year period obtained from the Agricultural Engineering Department at the University of Illinois were analyzed.

REVIEW OF LITERATURE

Some of the factors which influence cost of production are as follows:

1. Crops or products produced.
2. Operations involved in their production.
3. Season or period of time available for the various operations.
4. Acreage to be covered for each crop.
5. Capacity and performance of machine.
6. Adaptability of machine to soil conditions.
7. Power available.
8. Whether or not custom work is to be done with a combination of machines and power.
9. Relationship between labor and machinery costs.
10. Actual cost of the operation.

Davidson (1931) points out the fact that machinery cost is recognized as an important item in the total cost of agricultural production and that, therefore, in efficient and economical farm practice the investment in machinery should be confined to an amount which will insure adequate returns.

Bradford and Johnson (1953) state that when considering the quantity of equipment for the farm as a whole the capital available for desirable machinery purchases will be a limiting factor. For example, one short of capital may be forced to forego otherwise desirable machinery purchases since land improvements, production of livestock and soil improvement may also be needed.

Thus, when considering the farm as a whole, the problem is one of allocating capital so as to get equal marginal returns from the last dollar spent on each part of the whole farming enterprise.

A. Cost Functions

There are several kinds of costs involved in most production processes. They are generally divided into two categories, (a) fixed or ownership costs, and (b) variable costs. In the case of farm machinery the total cost is made up of the cost of the machinery, power and labor.

The fixed or ownership costs generally include only those costs which do not depend on amount of use or output. They include such costs as depreciation, interest on investment, insurance, taxes and housing.

The variable costs include those costs which are a function of the amount of use or output resulting in production process. Variable costs for farm equipment include such items as repairs, maintenance, lubrication, fuel and oil consumption of the auxiliary power unit, tractor or truck and labor.

B. Fixed or Ownership Costs

Depreciation is one of the most important fixed costs. According to Barger, Carleton, McKibben and Bainer (1954) depreciation refers to the loss in value and service capacity of the machine resulting from natural wear, deterioration due to action of the elements such as rusting, corrosion and weathering, accidental damage, and obsolescence.

It is obvious that a machine naturally wears out with use; however, the rate of wear depends upon such factors as skill of operator, lubrication, the conditions under which the machine operates and the design of the machine.

Obsolescence is considered to be an important factor in depreciation and is a difficult one to evaluate because new machines superior to the old ones are continually becoming available. Some investigators have noted that some of the new tractor mounted implements are apt to have their obsolescence determined by the life of the tractor upon which they are mounted. Depreciation is therefore caused by two factors, time and use. Time depreciation which is generally referred to as obsolescence takes place regardless of the amount of use. Use depreciation* is related to number of days or hours machine is used per year.

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*Contradicts the definition of fixed or ownership costs; however the life expectancy of the machine is also dependent upon the care and maintenance it receives. So depreciation is not an operating cost and is included as a fixed cost.

Review of literature indicates that depreciation is considered to be by far the largest cost of the fixed costs group.

Hertel and Williamson (1941) in a study at Cornell University show that depreciation represents in general about 44 percent of the total machinery costs; whereas repairs, interest and housing represent 22.19 and 13 percent of the total costs respectively.

Fenton and Fairbanks (1955) in a study at Kansas State College show that depreciation represents 60.1 percent of the ownership costs and 14.8 percent of the total costs for the plowing operation.

It is quite evident that depreciation costs must be determined in calculating cost of using machinery. It is needed for such items as resale value, trade-in value, appraisal value, or for income tax purposes.

The most common methods used for calculating depreciation are (a) the straight-line method, and (b) the constant percentage method or reduced balance method. The straight-line method of depreciation reduces the value of a machine by an equal amount each year during its useful life. This method has been most widely used for farm machinery since it is the simplest method for calculating depreciation.

For the constant percentage method, a constant percentage is deducted each year from the value remaining from the previous year. This method appears to be more realistic since it permits higher rates of depreciation in the early years of use of the machine and a decreasing amount of depreciation in its later life. This method has often been used where value of machine is desired for resale purposes or making appraisals.

The straight-line method has been considered legitimate for estimating depreciation costs when the machine was not purchased for resale purposes but was purchased to perform service for its entire life.

It should be noted according to the North Central Farm Management Extension Committee (1955) a new method for figuring depreciation has been brought on by the new tax legislation. The new method is known as the declining balance method and has been designed to permit a higher rate of depreciation for income tax purposes for farm equipment and all farm buildings except the dwelling that is owned and occupied by the tax payer. This method has been studied for cost estimating purposes and has been reported later in the thesis.

Interest on investment is considered to be one of the costs of ownership of a farm machine since money used to buy a machine can not be used for other purposes such as purchase of land, livestock, and other productive enterprises. Interest is a return over and above the principal expected for its use and risks taken when money is lent or invested. In the case of farm equipment, the interest rate to use for cost estimating purposes will depend on local conditions and investment value of money; however, if the exact rate is not known a rate of 5 to 6 percent is generally used.

The average annual amount to charge off during the life of the machine is generally based on one-half the initial cost plus estimated salvage value of the machine. This, of course, implies that the straight-line method of depreciation is used.

<u>Taxes</u> for farm machinery are based generally on the same rate as other farm equipment. The tax rate applied to the assessed valuation will vary widely in different counties and school districts. Fenton and Fairbanks (1955) report that tractors, combines, and trucks are usually evaluated for tax purposes as follows:

> ...70 percent of first cost for the first year, 55 percent for the second, 45 percent for the third, 35 percent for the fourth, 25 percent for the fifth, 20 percent for the sixth, and 15 percent for the seventh. Other farm machines are assessed on an estimated value. Over the full life of a machine the amount of the property taxes will be slightly less than 1.0 percent of the original cost of the machine per year.

A person survey of several states indicated that the method used for determining the assessed valuation varied from state to state. These results are shown in Table I. Table II shows the assessment schedule suggested by Michigan State Tax Commission.

According to Fenton and Fairbanks (1955) <u>insurance</u> of farm machinery for loss of fire, windstorm, etc. is not a universal practice; however, a charge for insurance is

TABLE I

ASSESSMENT SCHEDULE USED BY SEVERAL STATES

State	Assessment Schedule	Tax Average Rate - Percent %	Year
Illinois	Based on average finance value as reported in National Tractor and Farm Implement Blue Book which is approximately 2/3 of average cash value.	2.83	1953
Kansas	Based on Farm Implement Blue Book. Approximately 50% of "as is" value.	3.93	1952
Michigan	Based on percentage of current or last published list price. See Table II for rates suggested by Michigan State Tax Commission. Suggested rates used when not listed in tractor trade-in manual.	3.26	1951
Iowa	Based on approximately 60% of actual value of machine.	-	-
Indiana	Based on "average finance" value as listed in National Tractor and Farm Implement Blue Book. If not listed in blue book, 30% depreciation for first year, 10% additional for second and third year each, and 5% additional for each following year down to 30% of cost value	-	-

TABLE II

ASSESSMENT SCHEDULE SUGGESTED BY MICHIGAN STATE TAX COMMISSION

Method 1		Method 2		Method 3	
Age	% Good	Age	% Good	Age	% Good
1	75	1	75	1	75
2	65	2	65	2	65
3	55	3	55	3	55
4	50	4	51	4	52
5	45	5	47	5	49
6	40	6	43	6	46
7	35	7	39	7	43
8	30	8	35	8	40
9	25	9	31	9	37
10	20	10	27	10	34
		11	23	11	31
		12	19	12	28
		13	15	13	25
				14	22
				15	19
				16	16
				17	13
				18	10

Method 1

Cultivator - tractor	Tractor Buck Rake	Combine
Mower - tractor	Pick-up Baler	Corn picker
		Tractor

Method 2

Tractor Plow	Potato Planter	Forage Harvester
Disc Plow	Rotary Hoe	Grain Binder
Disc Harrow - Tractor	Mower - Horse	Thresher
Endgate Seeder	Side Delivery Rake	Corn Binder
Grain Drill	Hay Loader	Stationary Silage Cutter
Corn Planter	Stationary Baler	Husker - Shredder
		Manure Spreader

Method 3

Walking Plow	Springtooth Harrow	Soil Pulverizer
Riding Plow	Spiketooth Harrow	Riding Cultivator
Disc Harrow - Horse	Roller	Dump Rake
	Hay Rack	Wagon-Gear and Box

TABLE II (Cont.)

Instructions

1. Use depreciation tables only when the desired information is not listed in the tractor trade-in manual.

2. Base value for any equipment to be depreciated will be either the current or last published list price.

3. The depreciation tables are based upon the average life (or hours to wear out) for any piece of equipment listed. The appraiser may vary from the schedule if any machinery has had maintenance which is better or worse than average.

Source: Michigan State Tax Commission.

considered justifiable. If insurance is not considered, this means that the owner carries the risk himself. The rate to charge will vary with locality. However if the exact rate is not known, an average annual charge of 0.25 percent of the initial cost is suggested to cover farm machinery insurance.

Housing is an expense and ought to be included as a charge when calculating costs of farm equipment. There appears to be some doubt among investigators whether or not housing has any great influence on operating costs.

Davidson and Henderson (1942) have stated:

> It may be clear that housing has some beneficial influences in reducing the cost of repairs, but since the cost of repairs is affected so greatly by other causes, the influence of housing is more or less indeterminate.

According to Barger, Carleton, McKibben and Bainer (1954) a fair charge for housing is two percent of the initial investment. Day (1951) reported a charge for housing based on the cost per square foot of storage space required for housing the machine. This method would probably be more exact from a housing cost standpoint but requires the cost of housing to be known or estimated. The most common practice seems to be to estimate housing costs based on some constant percentage of the initial cost of the equipment.

C. Operating or Variable Costs

The operating costs generally include such items as fuel, oil, lubrication or daily service, repairs and labor of operation.

Fuel and oil consumption costs for tractors have been estimated in a number of ways when the exact amount is not known. Barger, Carleton, McKibben and Bainer (1954) suggest average values as shown in Table III for fuel consumption to use for different sizes of tractors and also suggests estimating oil consumption rate of 0.5 gallon per day when exact amount is not known.

TABLE III

AVERAGE GALLONS PER HOUR TRACTOR FUEL CONSUMPTION

Tractor Size	Gallons per Hour
One-plow	1.00
Two-plow, light	1.50
Two-plow, heavy	1.75
Three-plow	2.25
Four-plow	3.00

Another method for estimating fuel consumption that is sometimes used consists of taking the fuel data for three-fourths load of the variable load tests as reported in the summary of results for the Nebraska tractor tests. The average of all variable load tests is also considered satisfactory. The reason that the above method will give reasonable results is that it has been found that the average yearly load on a farm tractor is about 75 percent of the rated load.

A survey carried on at South Dakota State College resulted in a method for estimating tractor fuel and oil consumption costs when no accurate figures are known by means of the following formula:

$$\text{Fuel and oil cost per day} = \text{Belt Horsepower} \times 0.8 \times \text{Fuel Price per Gallon}$$

It is claimed that this formula makes enough allowance to include cost for grease.

Kitchen and Larsen (1952) constructed an alignment chart with which one can estimate what the fuel cost will be for different fuel burning tractors over a year's time. To use this chart one needs to know the rated drawbar horsepower, the fuel consumption in horsepower hours per gallon and the operating hours per year for the tractor being considered. The rated drawbar horsepower and fuel consumption are obtained from the Nebraska Tractor Test Summary Sheet.

A chart of the type just discussed is especially useful for comparing fuel consumption cost of different fuel burning tractors of comparable size.

The question of how to estimate the fuel, oil and grease costs for power units on combines, balers, etc. is of interest. McKee (1953) reported using a constant percentage of retail price of machine for estimating the fuel, oil and grease costs. He reported these costs to be as follows:

Combines	Annual Charge Percent of Retail Price
6' motor mounted	1.7
7' motor mounted	1.7
8' self-propelled	2.4
10' " "	2.4
12' " "	
Balers	
Motor mounted	4.3

Repair costs are probably the most difficult to estimate since they are influenced by the amount of care, maintenance and use given the machine. Repair costs generally include material and labor costs. Although they are not generally the largest of the total operating costs they are an important item of expense to consider.

Hertel and Williamson (1941) consider repairs as second in order of relative importance.

Black, Clawson, Sayre and Wilcox (1951) suggest that the best method of handling these costs is to distribute the total cost of all renewals over the whole life of the machine.

> This requires estimating the total renewals in advance at the time the machine first goes into use. The same analysis applies to repairs, which are essentially no different from renewals.

At the present time the repair costs are based on some constant percentage of the original cost of the machine during its useful estimated life by many cost estimators.

There seem to be two schools of thought as to what percentage to use for estimating repair costs. Many investigators use an annual charge for repairs based on a constant percentage of original investment. For example, tractor repairs are often assumed to be approximately 3 to 4 percent of original investment. The other method seems to be to base the repair cost as a total percentage of new cost for an estimated number of hours of life for the machine in question. Richey (1950) reported total repair costs during life of machine in percent of new cost instead of an annual charge in percent of new cost.

Thompson and Wenhardt (1952) in their study of records suggest the following percentages to charge for repair costs where replacement cost is the price prevailing locally for a new and comparable machine.

Tractor ----------------	10,000 hours, 80 percent of present replacement cost.
Tillage machinery-------	3,000 hours, 100 percent of present replacement cost.
Seeding machinery-------	2,000 hours, 150 percent of present replacement cost.
Harvesting machinery----	2,000 hours, 150 percent of present replacement cost.

The above values include actual repair parts, time required to obtain repair parts, shop equipment, and labor required for doing the actual repair work, and also lost time in the field while repairing machine.

Worthington (1951) claims, since need for maintenance results largely from natural wear, that maintenance costs for tractors are in the order of 3 percent of the delivered cost per 1000 hours of use. He stated that this figure is based on the experience of many farmers.

In actual practice it is known that repair costs increase with use, and therefore the assumption of charging off a constant percentage per year or hour during the life of the machine would be justified only when the owner expects to keep the machine for its entire service life and then only for limited use. If one does not expect to keep the machine its entire life then the question arises as to when the machine is no longer economical to operate. Two important factors that will have a great influence on the above question are the rate of depreciation and how repair costs vary with use. Surprising as it may seem, little information of this nature is available. Apparently this kind of information has been in the past of little concern to most investigators in the field of agriculture.

In order to estimate maintenance costs for any particular year it is of primary importance that something is known about the behavior of repair costs during the serviceable life of the machine. There appears to be an extremely limited amount of information of this kind available.

Williams (1936) reported his experience concerning annual repairs and maintenance for two tractors on his farms for a period of 10 years. A plot of the data for one tractor is shown in Figure 1. The results in Figure 1 indicate that the relationship between repair costs and use is linear for the first few years and levels off for the rest of the period of study.

D. Determination of Break-Even Point When to Hire and When to Own the Equipment

The question of when to hire and when to own the equipment is of great concern to the operator who has a small acreage or few hours of annual use for the equipment in question.

Some of the factors that ought to be considered before one makes a decision are as follows:

1. Is there enough annual use to justify ownership?
2. Is the service available at the time desired?
3. Will the delay of an operation result in losses greater than the savings afforded by custom service?
4. Pride of ownership or personal desire.
5. Independence associated with owning the equipment.
6. Availability of capital required for owning the equipment.

Frick and Weeks (1951) state that, in general, a farmer can afford to hire when total cost of custom work for a single piece of equipment is equal in value to the annual ownership,

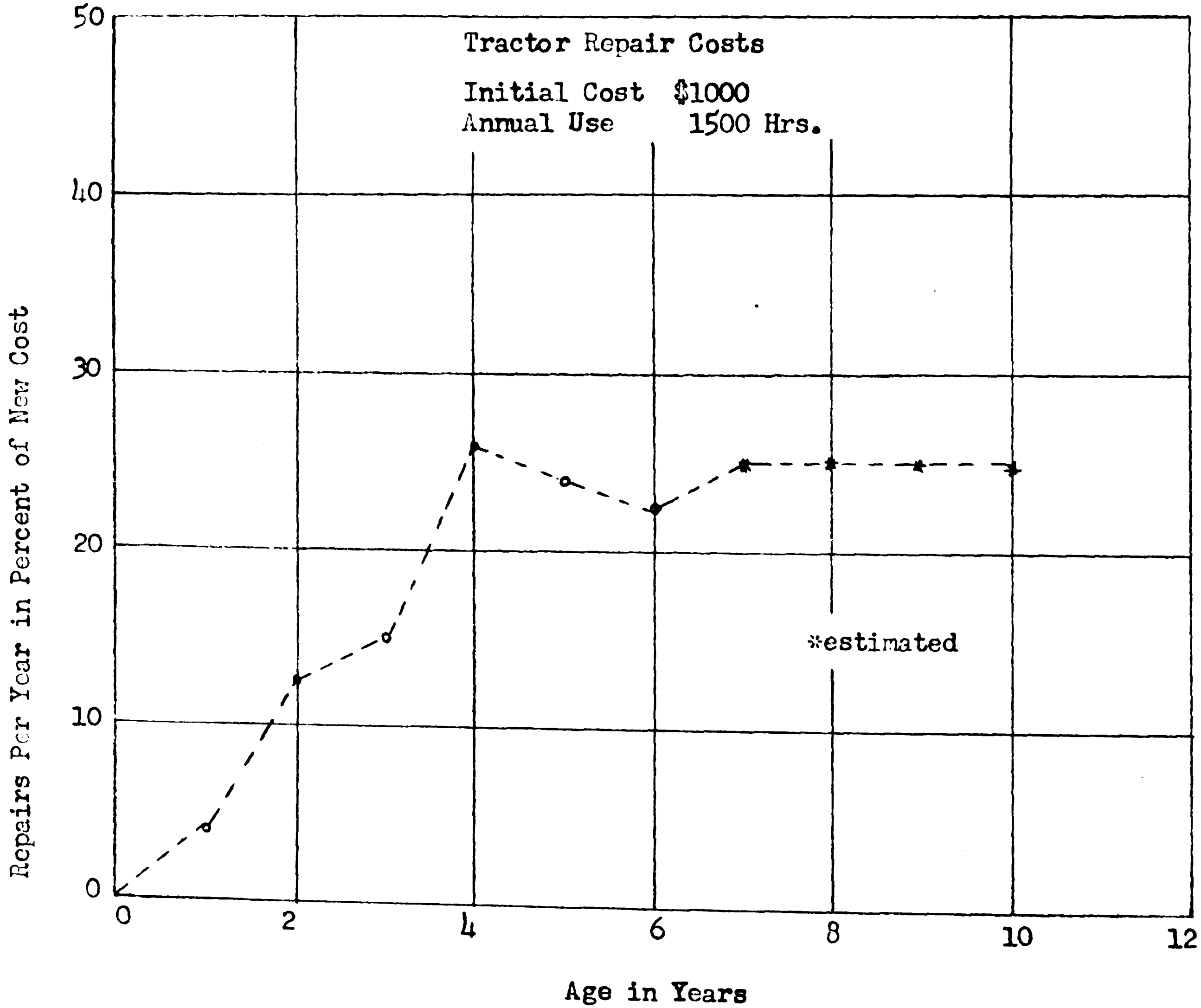

Fig. 1. Relationship Between Tractor Repair Costs and Use.

direct operating and labor costs for using equipment. Based on the above reasoning one can use the following formula as a means for determining the break-even point.

$$\text{Cost per hour custom work} - \text{operating cost per hour} = \text{net cost per hour}$$

$$\frac{\text{Fixed costs per year}}{\text{Net costs per hour}} = \text{Break-even point, hours per year}$$

According to the above formula if one uses the machine fewer hours per year than the calculated value, then he would not be justified in owning the equipment from an economic point of view.

If one needs to know how many acres per year the machine should cover, the following formula would be appropriate:

$$\frac{\text{Break-even point, hours per year}}{\text{Performance rate of machine, hours per acre}} = \text{Break-even point, acres per year}$$

Custom operation appears to be on the increase in some areas of the United States since the small operator is faced with the problem of getting enough use of his equipment to justify ownership.

Large commercial farming operations generally own their equipment and in a few instances contract certain operations during peak periods. This scheme tends to reduce over-machining for the production process and keeps operating costs at a minimum.

It is of interest to note that one large vegetable shipper in this country is operating 2500 acres without owning a single piece of agricultural equipment. All his work is contracted and he sticks to administration only since he believes this is the farmer manager's real function.

Table IV indicates approximate annual use required to justify ownership of selected machines in Pennsylvania.

TABLE IV

ANNUAL USE TO JUSTIFY PURCHASE OF SELECTED MACHINES[1]

Machine	Annual Cost to Own*	Annual Use to Justify
Combine, 6' power take-off	$180	50 acres
Combine, 6' auxiliary engine	237	70 acres
Combine, 12' self-propelled	548	180 acres
Corn picker, 1 row, pull type	124	36 acres
Corn picker, 2 row, mounted	202	50 acres
Forage harvester, power take-off	185	50 acres
Baler, twine tie, power take-off	193	84 tons
Baler, twine tie, auxiliary engine	329	142 tons
Diesel tractor	---	1500 hours

*Includes depreciation, housing, taxes, insurance, and interest.

[1]Anonymous (1952). Pennsylvania Farm Economics, Pennsylvania State College Agricultural Extension Service, Number 46. P. 3.

INVESTIGATION

Part I

Development of Alignment Charts for Estimating Duty Requirements of a Given Machine

The greatest single factor affecting the unit cost of operation of a machine is the amount of use. It is well known that any increase in annual use will tend to reduce the unit operating cost since the fixed costs remain essentially constant. As annual use increases, however, a point will eventually be reached beyond which untimeliness of the operation will result. Any untimeliness of operation will tend to induce losses which will more than offset the apparent decrease in unit operating cost. Thus it is one of the important factors to consider in selection and management of a power and machinery plant.

The amount of annual use for a particular machine is influenced by the following factors:

1. Crops or products produced.
2. Operations involved in their production.
3. Season or period of time available for the various operations.
4. Time actually available for field work in some localities may be only a small part of the total season due to inclement weather.
5. Size of fields - acreage of each crop produced.

6. Whether or not custom work is to be done with a combination of power and machines.
7. Effective capacity of machine.

To estimate the amount of annual use required of a machine for a given set of conditions presents a problem. Therefore, a set of alignment charts has been prepared for this purpose. The use of alignment charts eliminates the need of making mathematical calculations.

If the effective capacity of a machine is not known the first step is to use the alignment chart in Figure 2 which takes into account the variables (a) width of machine in feet, (b) speed of travel in miles per hour, and (c) lost time in performing the operation, in percent.

The percentage of time lost may be due to factors such as (a) lubrication, (b) adding fuel, (c) machine adjustment, (d) loading seed, fertilizer, etc., (e) unloading harvested products, (f) idle travel such as traveling to field, turning at ends, etc., (g) clogging, and (h) breakdowns.

The percentage of time lost is difficult to evaluate. Results of three seasons' records on a typical Illinois grain farm reported by Bateman (1943) indicate the following values to be reasonable for estimating purposes.

Machine	Percentage of Lost Time *
2-bottom, 16-in. tractor plow	16-22
8' tandem disk	9-23
18' spiketooth harrow	24-30

*Does not include time for turning at ends.

EFFECTIVE CAPACITY OF FARM MACHINES

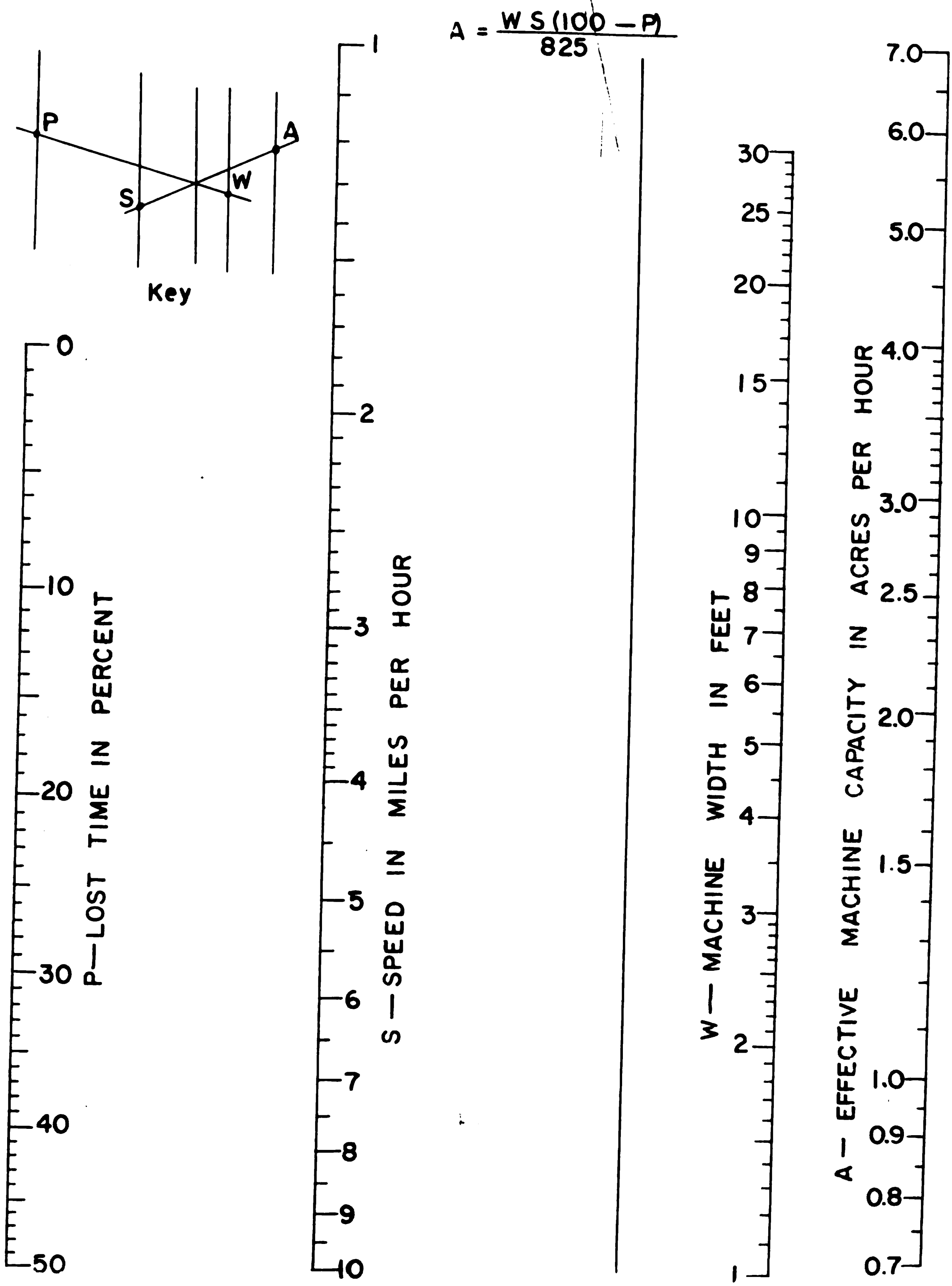

Fig. 2

8' grain drill	22-30
4 row corn planter (checkrowing)	41
2 row tractor cultivator	
1st cultivation	20
2nd "	15
3rd "	12
7' tractor mower	31
12' combine	37-43
2 row pull-type corn picker	35

If the amount of lost time for any particular machine is not known a figure of 17.5 percent is generally used.

By knowing the percent lost time and width of machine in feet line PW can be established as shown in the key of Figure 2. Then by knowing the approximate speed of travel in miles per hour the second line SA can be located by means of point on S scale and where line PW intersects the dummy or blank scale. The effective capacity of machine is then determined by the intersection of the line with the A scale.

Once the effective capacity of the machine has been determined either by the alignment chart in Figure 2 or from actual experience, then Figure 3 can be used to determine the number of acres to be covered per year. The number of acres a machine can cover in a year is a function of hours available per day for the operation, the days available to perform the operation per year and the effective capacity of the machine in acres per hour.

REQUIRED RATE OF PERFORMANCE FOR FARM MACHINE

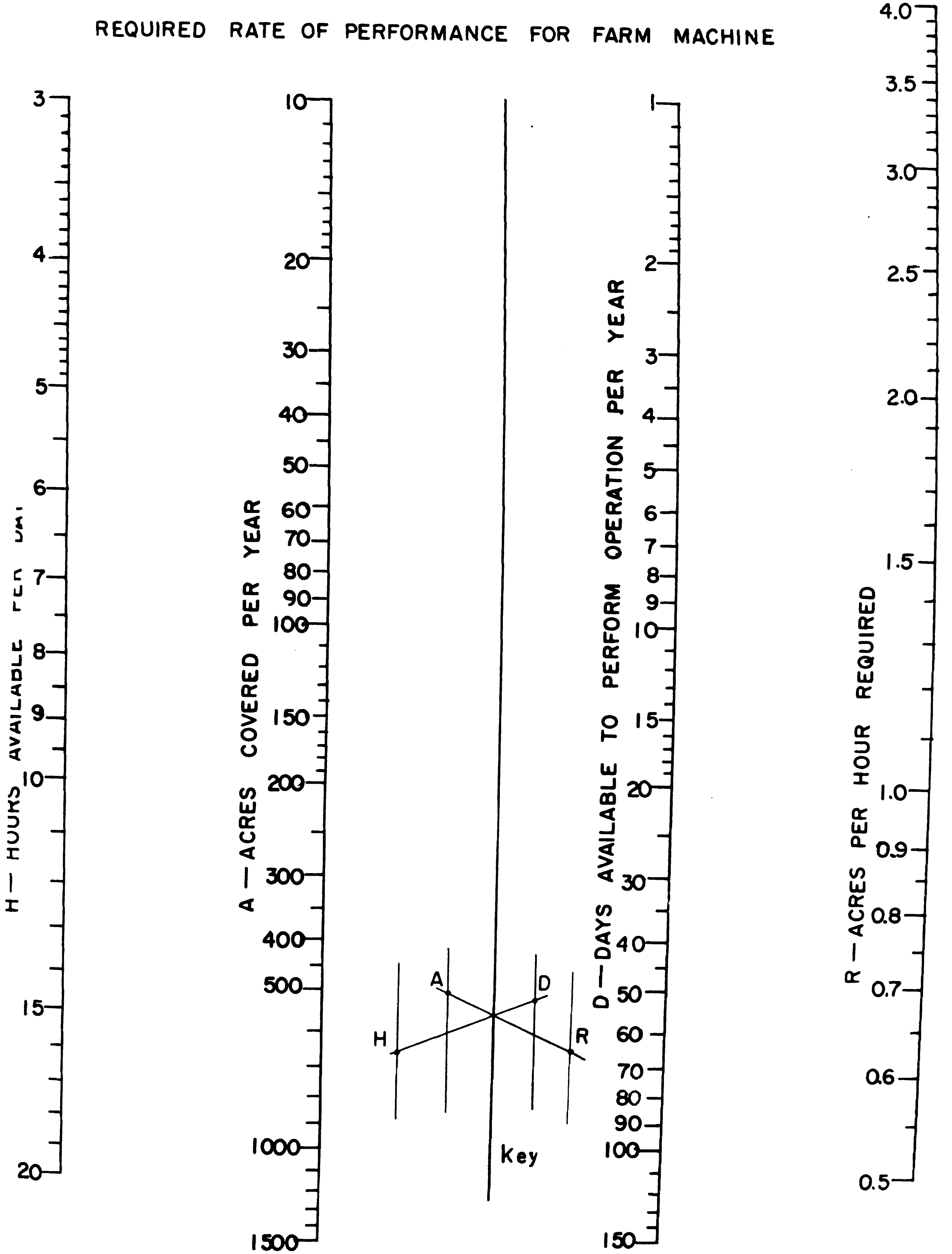

Fig. 3

Very little data exists on how many hours per day are available for the various operations of farm equipment. The number of hours available per day to perform a certain operation obviously differs with geographical locations as well as with the time of year and perhaps type of operation. For example, for harvesting wheat in Michigan fewer hours per day are available than for harvesting wheat in Kansas owing to the difference in atmospheric conditions.

Table V shows estimates of the number of work hours per day and the number of days suitable for field work for the state of Georgia. Information of this kind is needed for different geographical locations; however, this was the only published data discovered by the writer.

The days available to perform the operation per year are dependent upon the length of season for each operation for the particular crop in question and the actual days available for field work allowable by the weather. Some work was done on this phase to determine the approximate periods for common crops for the area around Lansing. Table VI shows the results of this study. The data was obtained by personal consultation with Leyton Nelson of the Farm Crops Department and from information sheet prepared by Professor McColly of the Agricultural Engineering Department. This information does not consider the days that would not be available due to the weather. This kind of information is difficult to obtain as conditions will change from season to season and from locality to locality.

TABLE V

ESTIMATES OF THE NUMBER OF WORK HOURS PER DAY AND THE NUMBER OF DAYS SUITABLE FOR FIELD WORK

STATE	GEORGIA* Bullock County		
Month	Number of Work Hours in Day	Days Suitable for Field Work	
		In First Half of Month	In Second Half of Month
January	8	7	7
February	9	7	7
March	10	8	9
April	11	9	9
May	12	9	9
June	12 1/2	9	9
July	12	9	9
August	11	9	9
September	10	9	9
October	9 1/2	9	9
November	8 1/2	9	8
December	8	8	8

*Hendrix, W. E. and W. T. Fullilove (1942). Labor and Power Needs on Crops in Bullock County, Georgia. Georgia Experiment Station. Circular 139, 15 pp.

TABLE VI

AVAILABLE OPERATING PERIODS FOR SEVERAL FARM MACHINES*

Operation	Grain Crops in Michigan						
	Corn	Oats	Barley	Rye	Wheat	Flax	Buckwheat
Seedbed Preparation Plow Disk Harrow	** April 25 to June 10	** March 25 to April 1	** Same as Oats	** Aug. 4 to Sept. 15			
Seeding Time	May 15 to June 15	April 1 to May 1	"	Aug. 25 to Oct. 1	Sept. 15 to Oct. 15	May 15 to June 1	Up to July 10
Cultivating	3 weeks after planting 2 or 3 times						
Harvesting Combine Corn Picker Field Chopped	Oct. 10 to Nov. 10 Silage Sept. 20 to Oct. 5	July 15 to Aug. 7	"	Harvested by Cattle	July 4 to Aug. 4		

*Information sheet - Professor McColly, 11/16/54.

**For Lansing area. Personal consultation with Leyton Nelson, Farm Crops Department, Michigan State University.

TABLE VI (Cont.)

Operation	Special Crops in Michigan					
	Field Beans	Sugar Beets	Soy Beans	Potatoes	Mint	Alfalfa and Clover
Seedbed Preparation						
Plow Disk Harrow		Fall plow	** April 25 to June 10			
Seeding Time	June 1 to June 15	April 15 to May 15	Little** later than corn, May 15 to June 15	May 15 to June 1	April 15 to May 1	Seeding in wheat Mar. 15 to May 7
Harvesting						
Combine	Sept 1 to Sept. 30		** Sept. 25 to Oct. 25			
Harvester		Oct. 25 to Nov. 15		July 1-15 Sept. 15-30	Aug. 1 to Sept. 30	
Harvesting Method:						
A. Wilted 1. Mow 2. Chop and haul 3. Blow into silo						** Grass silage 1st cutting June 10-15
B. Direct Cut 1. Chop and haul 2. Blow into silo						"
C. Long Hay - Field Cured - Baled 1. Mow 2. Rake 3. Load and haul 4. Store						** 1st and/or 2nd cutting Aug. 10-25
D. Chopped Hay - Field Cured 1. Mow 2. Rake 3. Chop						June 10-25

With the foregoing information, however, it is possible at least to approximate the days available to perform the particular operation so that line HD as shown in the key of Figure 3 can be established. Then by knowing the performance rate of the machine in acres per hour, the acres to be covered per year can be determined by locating line AR as shown in the key.

It should be pointed out that the alignment chart in Figure 3 can be used to determine the required rate of performance in acres per hour needed for a known number of acres to be covered, days available to perform the operation per year, and hours available per day. Once the required rate of performance has been determined then Figure 2 can be used to determine what size machine is needed to do the job in the time available.

Part II

A Study of Depreciation Rates

New tax legislation has instigated a new method for depreciating equipment at a higher rate. This method should be examined for possible use in estimating operating costs of farm equipment.

The new method, known as the declining balance method, uses a rate not to exceed twice the straight-line rate. It will permit depreciation of approximately two-thirds of the cost of the depreciable item during the first half of its life. An explanation of how the double-declining balance method works is in order. If, for example, certain equipment has a 10-year life, 10 percent a year is taken on a straight-line basis. For the accelerated method the maximum depreciation allowed is 20 percent for the first year. In subsequent years, 20 percent depreciation is taken on the remaining unrecovered cost.

The following equation was developed for the purpose of calculating the value at the end of year in question for any desired estimated life and rate of depreciation:

$$V = C(1 - \frac{R}{L})^X$$

where C = initial investment

L = estimated service life

X = year in question

R = rate of depreciation claimed

V = value at end of year in question

According to the new tax legislation, R must not exceed two. When two is used this scheme is called the double-declining balance method. Tables have been prepared for several different years of estimated service life and are based on $100 initial investment. The dollar value shown in the table might also be interpreted in percent of initial investment since it is based on 100 units.

Table VII indicates the value remaining after depreciation at the end of year in question. Table VIII indicates the amount of depreciation to be charged off for year in question. Table IX indicates the amount of depreciation to be charged off for current year on the double-declining balance method up to the year when it is more advantageous to change over to the straight-line method on the remaining balance. Beyond the broken line, the table indicates the amount of depreciation to be charged off for the current year on the straight-line method.

The optional method is permitted in order that one can recover through depreciation allowance the full cost of item when it is advantageous for income tax purposes. Figure 4 shows the comparison of depreciation rates for the double-declining balance method and the combination of double-declining balance and straight-line method.

Figure 5 was prepared to show the relationship between value and age of a Farmall "M" tractor with different methods

DOUBLE DECLINING BALANCE METHOD OF DEPRECIATION

VALUE AT END OF YEAR BASED ON $100 INITIAL INVESTMENT

End of Year	Estimated Service Life - Years																			End of Year
	5	6	7	8	9	10	12	14	15	16	18	20	22	24	25	30	35	40	50	
0	$100.00	$100.00	$100.00	$100.00	$100.00	$100.00	$100.00	$100.00	$100.00	$100.00	$100.00	$100.00	$100.00	$100.00	$100.00	$100.00	$100.00	$100.00	$100.00	0
1	60.00	66.67	71.43	75.00	77.78	80.00	83.33	85.71	86.67	87.50	88.88	90.00	90.90	91.66	92.00	93.33	94.29	95.00	96.00	1
2	36.00	44.45	51.02	56.25	60.50	64.00	69.44	73.46	75.12	76.56	79.00	81.00	82.63	84.02	84.64	87.10	88.90	90.25	92.16	2
3	21.60	29.63	36.44	42.18	47.06	51.20	57.86	62.96	65.11	66.99	70.22	72.90	75.11	77.01	77.87	81.29	83.82	85.74	88.47	3
4	12.96	19.75	26.29	31.64	36.60	40.96	48.21	53.96	56.43	58.62	62.41	65.61	68.27	70.59	71.64	75.87	79.03	81.45	84.93	4
5	7.78	13.17	18.78	23.73	28.47	32.77	40.17	46.25	48.91	51.29	55.47	58.95	62.06	64.70	65.91	70.81	74.51	77.38	81.53	5
6	....	8.78	13.41	17.80	22.14	26.22	33.47	39.64	42.39	44.88	49.30	53.06	56.41	59.30	60.64	66.09	70.25	73.51	78.27	6
7	....	....	9.58	13.35	17.22	20.98	27.89	33.98	36.74	39.27	43.82	47.75	51.28	54.35	55.79	61.68	66.24	69.83	75.14	7
8	....	....	....	10.01	13.39	16.78	23.24	29.12	31.84	34.36	38.95	42.98	46.61	49.82	51.33	57.57	62.46	66.34	72.13	8
9	....	....	....	....	10.41	13.42	19.36	24.96	27.60	30.07	34.62	38.68	42.37	45.67	47.22	53.73	58.90	63.02	69.24	9
10	....	....	....	....	....	10.74	16.13	21.39	23.92	26.31	30.77	34.81	38.51	41.86	43.44	50.15	55.53	59.87	66.47	10
11	....	....	....	....	....	....	13.44	18.33	20.73	23.02	27.35	31.33	35.01	38.37	39.96	46.80	52.36	56.89	63.81	11
12	....	....	....	....	....	....	11.20	15.71	17.97	20.14	24.31	28.20	31.82	35.17	36.76	43.68	49.37	54.05	61.26	12
13	....	....	....	....	....	....	....	13.47	15.57	17.62	21.61	25.38	28.92	32.24	33.82	40.77	46.55	51.35	58.81	13
14	....	....	....	....	....	....	....	11.55	13.49	15.42	19.21	22.84	26.29	29.55	31.11	38.05	43.89	48.78	56.46	14
15	....	....	....	....	....	....	....	....	11.69	13.49	17.07	20.56	23.90	27.09	28.62	35.51	41.38	46.34	54.20	15
16	....	....	....	....	....	....	....	....	....	11.80	15.17	18.50	21.73	24.83	26.33	33.14	39.02	44.02	52.03	16
17	....	....	....	....	....	....	....	....	....	....	13.48	16.65	19.75	22.76	24.22	30.93	36.79	41.82	49.95	17
18	....	....	....	....	....	....	....	....	....	....	11.98	14.99	17.95	20.86	22.28	28.87	34.69	39.73	47.95	18
19	....	....	....	....	....	....	....	....	....	....	....	13.49	16.32	19.12	20.51	26.94	32.71	37.74	46.03	19
20	....	....	....	....	....	....	....	....	....	....	....	12.14	14.83	17.53	18.87	25.14	30.84	35.85	44.19	20
21	....	....	....	....	....	....	....	....	....	....	....	....	13.48	16.07	17.36	23.46	29.08	34.06	42.42	21
22	....	....	....	....	....	....	....	....	....	....	....	....	12.25	14.73	15.97	21.90	27.42	32.36	40.72	22
23	....	....	....	....	....	....	....	....	....	....	....	....	....	13.50	14.69	20.44	25.85	30.74	39.09	23
24	....	....	....	....	....	....	....	....	....	....	....	....	....	12.37	13.51	19.08	24.37	29.20	37.53	24
25	....	....	....	....	....	....	....	....	....	....	....	....	....	....	12.43	17.81	22.98	27.74	36.03	25
26	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	16.62	21.67	26.35	34.59	26
27	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	15.51	20.43	25.03	33.21	27
28	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	14.46	19.26	23.78	31.88	28
29	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	13.51	18.16	22.59	30.60	29
30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	12.61	17.12	21.46	29.38	30
31	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	16.14	20.39	28.20	31
32	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	15.22	19.37	27.07	32
33	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	14.35	18.40	25.99	33
34	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	13.53	17.48	24.95	34
35	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	12.76	16.61	23.95	35
36	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	15.78	22.99	36
37	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	14.99	22.07	37
38	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	14.24	21.19	38
39	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	13.53	20.34	39
40	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	12.85	19.53	40
41	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	18.75	41
42	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	18.00	42
43	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	17.28	43
44	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	16.59	44
45	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	15.93	45
46	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	15.29	46
47	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	14.68	47
48	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	14.09	48
49	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	13.53	49
50	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	12.99	50

TABLE VIII

DOUBLE DECLINING BALANCE METHOD OF DEPRECIATION

DEPRECIATION FOR CURRENT YEAR BASED ON $100 INITIAL INVESTMENT

Year	Estimated Service Life - Years																			Year
	5	6	7	8	9	10	12	14	15	16	18	20	22	24	25	30	35	40	50	
0																				0
1	$40.00	$33.33	$28.57	$25.00	$22.22	$20.00	$16.67	$14.29	$13.33	$12.50	$11.12	$10.00	$ 9.10	$ 8.34	$ 8.00	$ 6.67	$ 5.71	$ 5.00	$ 4.00	1
2	24.00	22.22	20.41	18.75	17.28	16.00	13.89	12.25	11.55	10.94	9.88	9.00	8.27	7.64	7.36	6.23	5.39	4.75	3.84	2
3	14.40	14.82	14.58	14.07	13.44	12.80	11.58	10.50	10.01	9.57	8.78	8.10	7.52	7.01	6.77	5.81	5.18	4.51	3.69	3
4	8.64	9.88	10.15	10.54	10.46	10.24	9.65	9.00	8.68	8.37	7.81	7.29	6.84	6.42	6.23	5.42	4.79	4.29	3.54	4
5	5.18	6.58	7.51	7.91	8.13	8.19	8.04	7.71	7.52	7.33	6.94	6.66	6.21	5.89	5.73	5.06	4.52	4.07	3.40	5
6	....	4.39	5.37	5.93	6.33	6.55	6.70	6.61	6.52	6.41	6.17	5.89	5.65	5.40	5.27	4.72	4.26	3.87	3.26	6
7	....	....	3.83	4.45	4.92	5.24	5.58	5.66	5.65	5.61	5.48	5.31	5.13	4.95	4.85	4.41	4.01	3.68	3.13	7
8	....	....	....	3.34	3.83	4.20	4.65	4.86	4.90	4.91	4.87	4.77	4.67	4.53	4.46	4.11	3.78	3.49	3.01	8
9	....	....	....	....	2.98	3.36	3.88	4.16	4.24	4.29	4.33	4.30	4.24	4.15	4.11	3.84	3.56	3.32	2.89	9
10	....	....	....	....	....	2.68	3.23	3.57	3.68	3.76	3.85	3.87	3.86	3.81	3.78	3.58	3.37	3.15	2.77	10
11	....	....	....	....	....	.....	2.69	3.06	3.19	3.29	3.42	3.48	3.50	3.49	3.48	3.35	3.17	2.98	2.66	11
12	....	....	....	....	....	....	2.24	2.62	2.76	2.88	3.04	3.13	3.19	3.20	3.20	3.12	2.99	2.84	2.55	12
13	....	....	....	....	....	....	....	2.24	2.40	2.52	2.70	2.82	2.90	2.93	2.94	2.91	2.82	2.70	2.45	13
14	....	....	....	....	....	....	....	1.92	2.08	2.20	2.40	2.54	2.63	2.69	2.71	2.72	2.66	2.57	2.35	14
15	....	....	....	....	....	....	....	....	1.80	1.93	2.14	2.28	2.39	2.46	2.49	2.54	2.51	2.44	2.26	15
16	....	....	....	....	....	....	....	....	....	1.69	1.90	2.06	2.17	2.26	2.29	2.37	2.36	2.32	2.17	16
17	....	....	....	....	....	....	....	....	....	....	1.69	1.85	1.98	2.07	2.11	2.21	2.23	2.20	2.08	17
18	....	....	....	....	....	....	....	....	....	....	1.50	1.66	1.80	1.90	1.94	2.06	2.10	2.09	2.00	18
19	....	....	....	....	....	....	....	....	....	....	....	1.50	1.63	1.74	1.77	1.93	1.98	1.99	1.92	19
20	....	....	....	....	....	....	....	....	....	....	....	1.35	1.49	1.59	1.64	1.80	1.87	1.89	1.84	20
21	....	....	....	....	....	....	....	....	....	....	....	....	1.35	1.46	1.51	1.68	1.76	1.79	1.77	21
22	....	....	....	....	....	....	....	....	....	....	....	....	1.23	1.34	1.39	1.56	1.66	1.70	1.70	22
23	....	....	....	....	....	....	....	....	....	....	....	....	....	1.23	1.28	1.46	1.57	1.62	1.63	23
24	....	....	....	....	....	....	....	....	....	....	....	....	....	1.13	1.18	1.36	1.48	1.54	1.56	24
25	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.08	1.27	1.39	1.46	1.50	25
26	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.19	1.31	1.39	1.44	26
27	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.11	1.24	1.32	1.38	27
28	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.03	1.17	1.25	1.33	28
29	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0.97	1.10	1.19	1.28	29
30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.04	1.13	1.22	30
31	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0.98	1.07	1.18	31
32	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0.92	1.02	1.13	32
33	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0.87	0.97	1.08	33
34	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0.82	0.92	1.04	34
35	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0.77	0.87	1.00	35
36	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0.83	0.96	36
37	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0.79	0.92	37
38	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0.75	0.88	38
39	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0.71	0.85	39
40	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0.68	0.81	40
41	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0.78	41
42	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0.75	42
43	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0.72	43
44	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0.69	44
45	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0.66	45
46	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0.64	46
47	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0.61	47
48	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0.59	48
49	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0.56	49
50	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0.54	50

TABLE 1A COMBINATION DOUBLE DECLINING BALANCE METHOD AND STRAIGHT LINE METHOD OF DEPRECIATION

. Line(------------) indicates point beyond which straight line method is advantageous over the double declining balance method.

DEPRECIATION FOR CURRENT YEAR BASED ON $100 INITIAL INVESTMENT

Year	Estimated Service Life - Years																			Year
	5	6	7	8	9	10	12	14	15	16	18	20	22	24	25	30	35	40	50	
0																				0
1	$40.00	$33.33	$28.57	$25.00	$22.22	$20.00	$16.67	$14.29	$13.33	$12.50	$11.12	$10.00	$ 9.10	$ 8.34	$ 8.00	$ 6.67	$ 5.71	$ 5.00	$ 4.00	1
2	24.00	22.22	20.41	18.75	17.28	16.00	13.89	12.25	11.55	10.94	9.88	9.00	8.27	7.64	7.36	6.23	5.39	4.75	3.84	2
3	14.40	14.82	14.58	14.07	13.44	12.80	11.58	10.50	10.01	9.57	8.78	8.10	7.52	7.01	6.77	5.81	5.18	4.51	3.69	3
4	10.80	9.88	10.15	10.54	10.46	10.24	9.65	9.00	8.68	8.37	7.81	7.29	6.84	6.42	6.23	5.42	4.79	4.29	3.54	4
5	10.80	9.88	8.76	7.91	8.13	8.19	8.04	7.71	7.52	7.33	6.94	6.66	6.21	5.89	5.73	5.06	4.52	4.07	3.40	5
6	....	9.88	8.76	7.91	7.13	6.56	6.70	6.61	6.52	6.41	6.17	5.89	5.65	5.40	5.27	4.72	4.26	3.87	3.26	6
7	....	....	8.76	7.91	7.12	6.56	5.58	5.66	5.65	5.61	5.48	5.31	5.13	4.95	4.85	4.41	4.01	3.68	3.13	7
8	....	....	....	7.90	7.12	6.55	5.58	4.86	4.90	4.91	4.87	4.77	4.67	4.53	4.46	4.11	3.78	3.49	3.01	8
9	....	....	....		7.12	6.55	5.58	4.69	4.41	4.31	4.33	4.30	4.24	4.15	4.11	3.84	3.56	3.32	2.89	9
10	....	....	....	....	....	6.55	5.58	4.69	4.41	4.31	3.95	3.87	3.86	3.81	3.78	3.58	3.37	3.15	2.77	10
11	....	....	....	....	....	....	5.58	4.69	4.41	4.31	3.94	3.49	3.50	3.49	3.48	3.35	3.17	2.98	2.66	11
12	....	....	....	....	....	....	5.57	4.69	4.41	4.31	3.94	3.48	3.19	3.20	3.20	3.12	2.99	2.84	2.55	12
13	....	....	....	....	....	....	....	4.68	4.40	4.31	3.94	3.48	3.18	2.93	2.94	2.91	2.82	2.70	2.45	13
14	....	....	....	....	....	....	....	4.68	4.40	4.31	3.94	3.48	3.18	2.84	2.82	2.72	2.66	2.57	2.35	14
15	....	....	....	....	....	....	....	....	4.40	4.30	3.94	3.48	3.18	2.84	2.82	2.54	2.51	2.44	2.26	15
16	....	....	....	....	....	....	....	....	....	4.30	3.94	3.48	3.18	2.84	2.82	2.37	2.36	2.32	2.17	16
17	....	....	....	....	....	....	....	....	....	....	3.94	3.48	3.18	2.84	2.82	2.37	2.23	2.20	2.08	17
18	....	....	....	....	....	....	....	....	....	....	3.94	3.48	3.18	2.84	2.82	2.37	2.10	2.09	2.00	18
19	....	....	....	....	....	....	....	....	....	....	....	3.48	3.18	2.84	2.82	2.37	2.04	1.99	1.92	19
20	....	....	....	....	....	....	....	....	....	....	....	3.48	3.18	2.84	2.82	2.37	2.04	1.89	1.84	20
21	....	....	....	....	....	....	....	....	....	....	....	....	3.18	2.84	2.82	2.37	2.04	1.80	1.77	21
22	....	....	....	....	....	....	....	....	....	....	....	....	3.18	2.84	2.82	2.37	2.04	1.80	1.70	22
23	....	....	....	....	....	....	....	....	....	....	....	....	....	2.84	2.82	2.37	2.04	1.80	1.63	23
24	....	....	....	....	....	....	....	....	....	....	....	....	....	2.84	2.82	2.37	2.04	1.80	1.56	24
25	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.82	2.37	2.04	1.80	1.50	25
26	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.37	2.04	1.79	1.45	26
27	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.36	2.03	1.79	1.45	27
28	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.36	2.03	1.79	1.45	28
29	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.36	2.03	1.79	1.44	29
30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.36	2.03	1.79	1.44	30
31	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.03	1.79	1.44	31
32	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.03	1.79	1.44	32
33	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.03	1.79	1.44	33
34	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.03	1.79	1.44	34
35	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.03	1.79	1.44	35
36	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.79	1.44	36
37	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.79	1.44	37
38	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.79	1.44	38
39	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.79	1.44	39
40	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.79	1.44	40
41	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.44	41
42	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.44	42
43	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.44	43
44	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.44	44
45	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.44	45
46	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.44	46
47	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.44	47
48	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.44	48
49	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.44	49
50	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.44	50

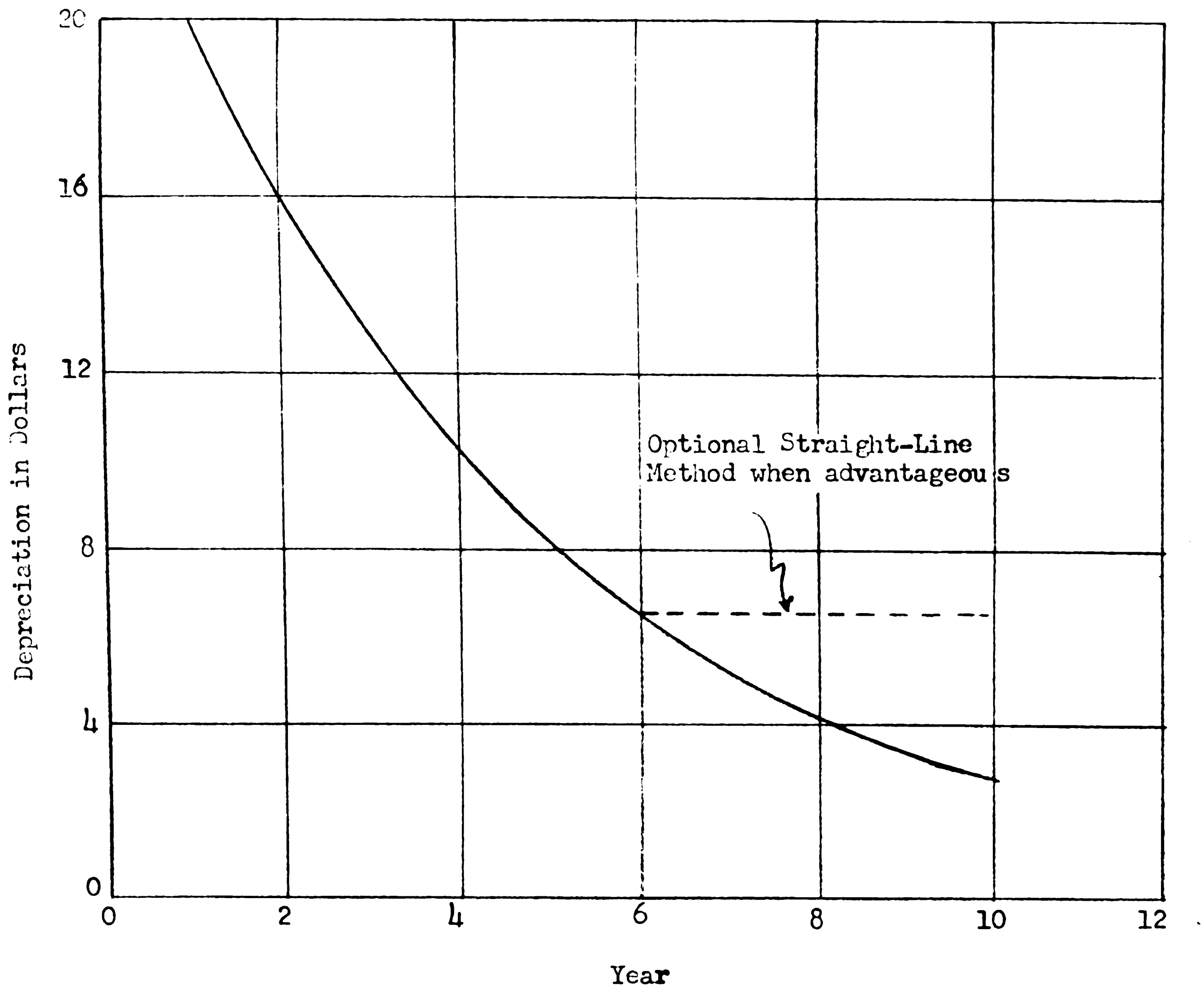

Fig. 4. Comparison of Depreciation Rates for Double Declining Balance Method and the Combination of Double Declining Balance and Straight Line Method of Depreciation.

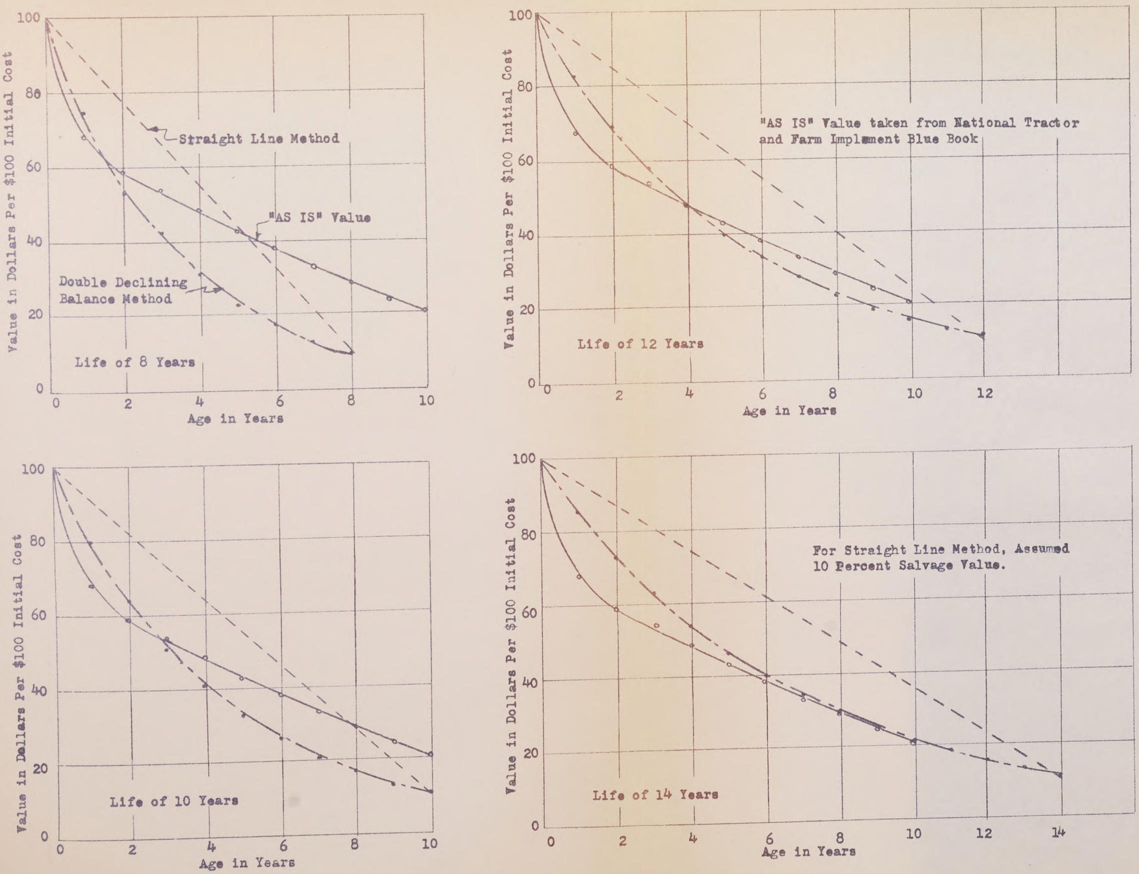

Fig. 5 Relationship Between Value and Age of Farmall "M" Tractor with Different Methods of Depreciation

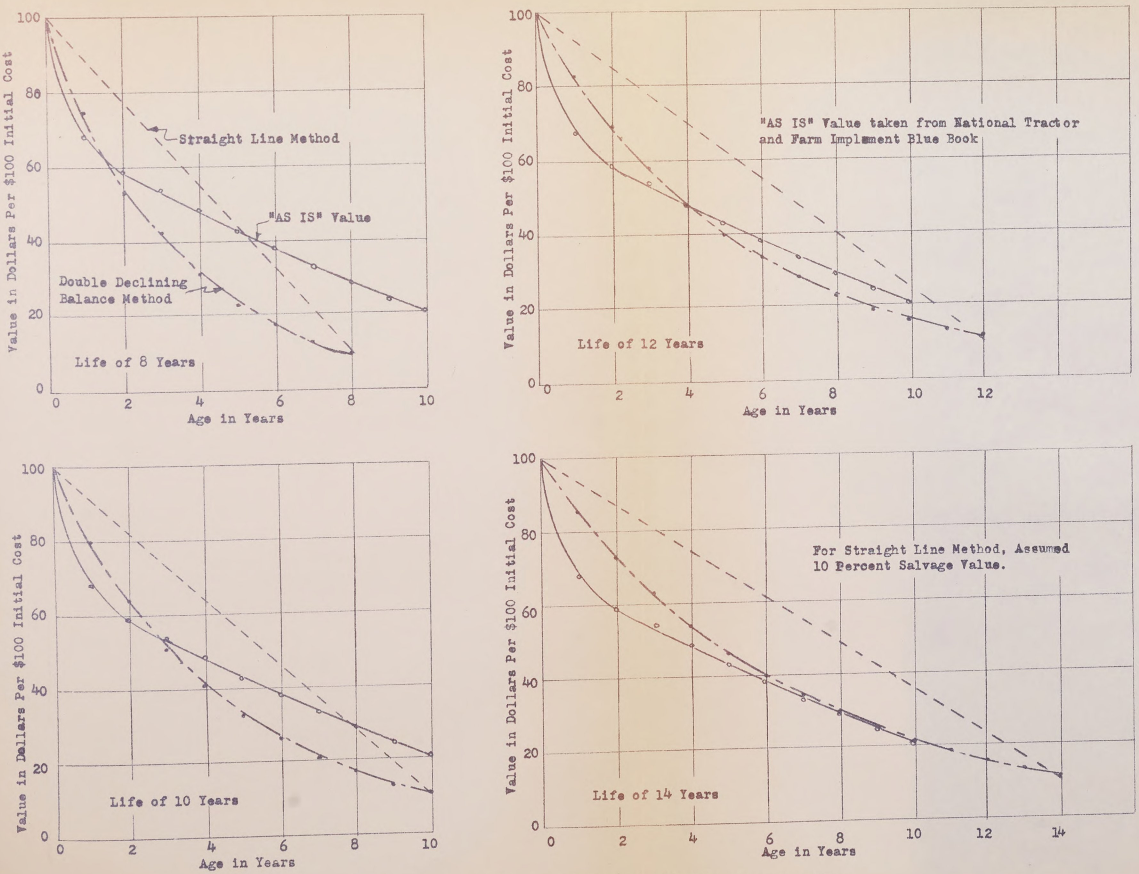

Fig. 5 Relationship Between Value and Age of Farmall "M" Tractor with Different Methods of Depreciation

of depreciation. The straight-line method, double-declining balance method and "as is" value are compared for estimated lives of 8, 10, 12 and 14 years. For the straight-line method it was assumed that the tractor at the end of its life had a 10 percent salvage value. The "as is" value is the appraised value given in the National Tractor and Farm Implement Blue Book published by National Market Reports, Inc.

The "as is" value is based on the premise that the tractor is in average "as is" condition. This value is used generally in arriving at a fair trade-in allowance valuation. Many dealers use it as their absolute maximum allowance figure. From Figure 5 and from the definition it is to be noted that in all cases the straight-line method gives a higher value than the double-declining balance. Also, it may be noted that value at the end of the estimated life for declining balance method is within a few dollars of the 10 percent salvage value assumed for the straight-line method. It appears that the double-declining balance method will approach the more realistic "as is" value for estimated lives of 12 and 14 years. It is believed that the double-declining balance method would have more merit than the straight-line method now being used by most cost estimators. This would be particularly true for one who does not intend to keep his tractor or machine its entire life.

Since accelerated rate of depreciation is equivalent to a more rapid return of investment to the farmer he may make use of it sooner. Larger farm operators who actually set aside reserves, based on depreciation write-offs, will be in a better position to buy replacements sooner.

In cost estimating work it appears that one might be interested in knowing the average annual depreciation to date based on the double-declining balance method of depreciation. With this in mind, Table X was prepared to give the average annual depreciation to date for several estimated service-life years.

TABLE X

DOUBLE DECLINING BALANCE METHOD OF DEPRECIATION: AVERAGE ANNUAL DEPRECIATION TO DATE BASED ON $100 OF INITIAL INVESTMENT

Year	Estimated Service Life - Years														
	5	6	7	8	9	10	12	14	15	16	18	20	22	24	25
1	40.00	33.33	28.57	25.00	22.22	20.00	16.67	14.29	13.33	12.50	11.12	10.00	9.10	8.34	8.00
2	32.00	27.78	24.49	21.88	19.75	18.00	15.28	13.27	12.44	11.72	10.50	9.50	8.69	7.99	7.68
3	26.13	23.46	21.19	19.27	17.65	16.27	14.05	12.35	11.63	11.00	9.93	9.03	8.30	7.66	7.38
4	21.76	20.06	18.43	17.09	15.85	14.76	12.95	11.51	10.89	10.35	9.40	8.60	7.93	7.35	7.09
5	18.45	17.36	16.24	15.25	14.31	13.45	11.97	10.75	10.22	9.74	8.91	8.21	7.59	7.06	6.82
6		15.20	14.43	13.70	12.98	12.30	11.09	10.06	9.60	9.19	8.45	7.82	7.27	6.78	6.56
7			12.92	12.38	11.83	11.29	10.30	9.43	9.04	8.68	8.03	7.46	6.96	6.52	6.32
8				11.25	10.83	10.40	9.60	8.86	8.52	8.21	7.63	7.13	6.67	6.27	6.08
9					9.95	9.62	8.96	8.34	8.04	7.77	7.26	6.81	6.40	6.04	5.86
10						8.93	8.39	7.86	7.61	7.37	6.92	6.52	6.15	5.81	5.66
11							7.87	7.42	7.21	7.00	6.60	6.24	5.91	5.60	5.46
12							7.40	7.02	6.84	6.66	6.31	5.98	5.68	5.40	5.27
13								6.66	6.49	6.34	6.03	5.74	5.47	5.21	5.09
14								6.32	6.18	6.04	5.77	5.51	5.27	5.03	4.92
15									5.89	5.77	5.53	5.30	5.07	4.86	4.76
16										5.51	5.30	5.09	4.89	4.70	4.60
17											5.09	4.90	4.72	4.54	4.46
18											4.89	4.72	4.56	4.40	4.32
19												4.55	4.40	4.26	4.18
20												4.39	4.26	4.12	4.06
21													4.12	4.00	3.94
22													3.99	3.88	3.82
23														3.76	3.71
24														3.65	3.60
25															3.50

TABLE 1A

COMBINATION DOUBLE DECLINING BALANCE METHOD AND STRAIGHT LINE METHOD OF DEPRECIATION

Line(------------) indicates point beyond which straight line method is advantageous over the double declining balance method.

DEPRECIATION FOR CURRENT YEAR BASED ON $100 INITIAL INVESTMENT

Year	Estimated Service Life - Years																			Year
	5	6	7	8	9	10	12	14	15	16	18	20	22	24	25	30	35	40	50	
0																				0
1	$40.00	$33.33	$28.57	$25.00	$22.22	$20.00	$16.67	$14.29	$13.33	$12.50	$11.12	$10.00	$ 9.10	$ 8.34	$ 8.00	$ 6.67	$ 5.71	$ 5.00	$ 4.00	1
2	24.00	22.22	20.41	18.75	17.28	16.00	13.89	12.25	11.55	10.94	9.88	9.00	8.27	7.64	7.36	6.23	5.39	4.75	3.84	2
3	14.40	14.82	14.58	14.07	13.44	12.80	11.58	10.50	10.01	9.57	8.78	8.10	7.52	7.01	6.77	5.81	5.18	4.51	3.69	3
4	10.80	9.88	10.15	10.54	10.46	10.24	9.65	9.00	8.68	8.37	7.81	7.29	6.84	6.42	6.23	5.42	4.79	4.29	3.54	4
5	10.80	9.88	8.76	7.91	8.13	8.19	8.04	7.71	7.52	7.33	6.94	6.06	6.21	5.89	5.73	5.06	4.52	4.07	3.40	5
6	....	9.88	8.76	7.91	7.13	6.56	6.70	6.61	6.52	6.41	6.17	5.89	5.65	5.40	5.27	4.72	4.26	3.87	3.26	6
7	....	....	8.76	7.91	7.12	6.56	5.58	5.66	5.65	5.61	5.48	5.31	5.13	4.95	4.85	4.41	4.01	3.68	3.13	7
8	....	....	....	7.90	7.12	6.55	5.58	4.86	4.90	4.91	4.87	4.77	4.67	4.53	4.46	4.11	3.78	3.49	3.01	8
9	....	....	....		7.12	6.55	5.58	4.69	4.41	4.31	4.33	4.30	4.24	4.15	4.11	3.84	3.56	3.32	2.89	9
10	....	....	....	....	....	6.55	5.58	4.69	4.41	4.31	3.95	3.87	3.86	3.81	3.78	3.58	3.37	3.15	2.77	10
11	....	....	....	....	....	....	5.58	4.69	4.41	4.31	3.94	3.49	3.50	3.49	3.48	3.35	3.17	2.98	2.66	11
12	....	....	....	....	....	....	5.57	4.69	4.41	4.31	3.94	3.48	3.19	3.20	3.20	3.12	2.99	2.84	2.55	12
13	....	....	....	....	....	....	....	4.68	4.40	4.31	3.94	3.48	3.18	2.93	2.94	2.91	2.82	2.70	2.45	13
14	....	....	....	....	....	....	....	4.68	4.40	4.31	3.94	3.48	3.18	2.84	2.82	2.72	2.66	2.57	2.35	14
15	....	....	....	....	....	....	....	....	4.40	4.30	3.94	3.48	3.18	2.84	2.82	2.54	2.51	2.44	2.26	15
16	....	....	....	....	....	....	....	....	....	4.30	3.94	3.48	3.18	2.84	2.82	2.37	2.36	2.32	2.17	16
17	....	....	....	....	....	....	....	....	....	....	3.94	3.48	3.18	2.84	2.82	2.37	2.23	2.20	2.08	17
18	....	....	....	....	....	....	....	....	....	....	3.94	3.48	3.18	2.84	2.82	2.37	2.10	2.09	2.00	18
19	....	....	....	....	....	....	....	....	....	....	....	3.48	3.18	2.84	2.82	2.37	2.04	1.99	1.92	19
20	....	....	....	....	....	....	....	....	....	....	....	3.48	3.18	2.84	2.82	2.37	2.04	1.89	1.84	20
21	....	....	....	....	....	....	....	....	....	....	....	....	3.18	2.84	2.82	2.37	2.04	1.80	1.77	21
22	....	....	....	....	....	....	....	....	....	....	....	....	3.18	2.84	2.82	2.37	2.04	1.80	1.70	22
23	....	....	....	....	....	....	....	....	....	....	....	....	....	2.84	2.82	2.37	2.04	1.80	1.63	23
24	....	....	....	....	....	....	....	....	....	....	....	....	....	2.84	2.82	2.37	2.04	1.80	1.56	24
25	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.82	2.37	2.04	1.80	1.50	25
26	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.37	2.04	1.79	1.45	26
27	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.36	2.03	1.79	1.45	27
28	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.36	2.03	1.79	1.45	28
29	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.36	2.03	1.79	1.44	29
30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.36	2.03	1.79	1.44	30
31	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.03	1.79	1.44	31
32	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.03	1.79	1.44	32
33	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.03	1.79	1.44	33
34	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.03	1.79	1.44	34
35	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2.03	1.79	1.44	35
36	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.79	1.44	36
37	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.79	1.44	37
38	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.79	1.44	38
39	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.79	1.44	39
40	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.79	1.44	40
41	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.44	41
42	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.44	42
43	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.44	43
44	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.44	44
45	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.44	45
46	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.44	46
47	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.44	47
48	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.44	48
49	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.44	49
50	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1.44	50

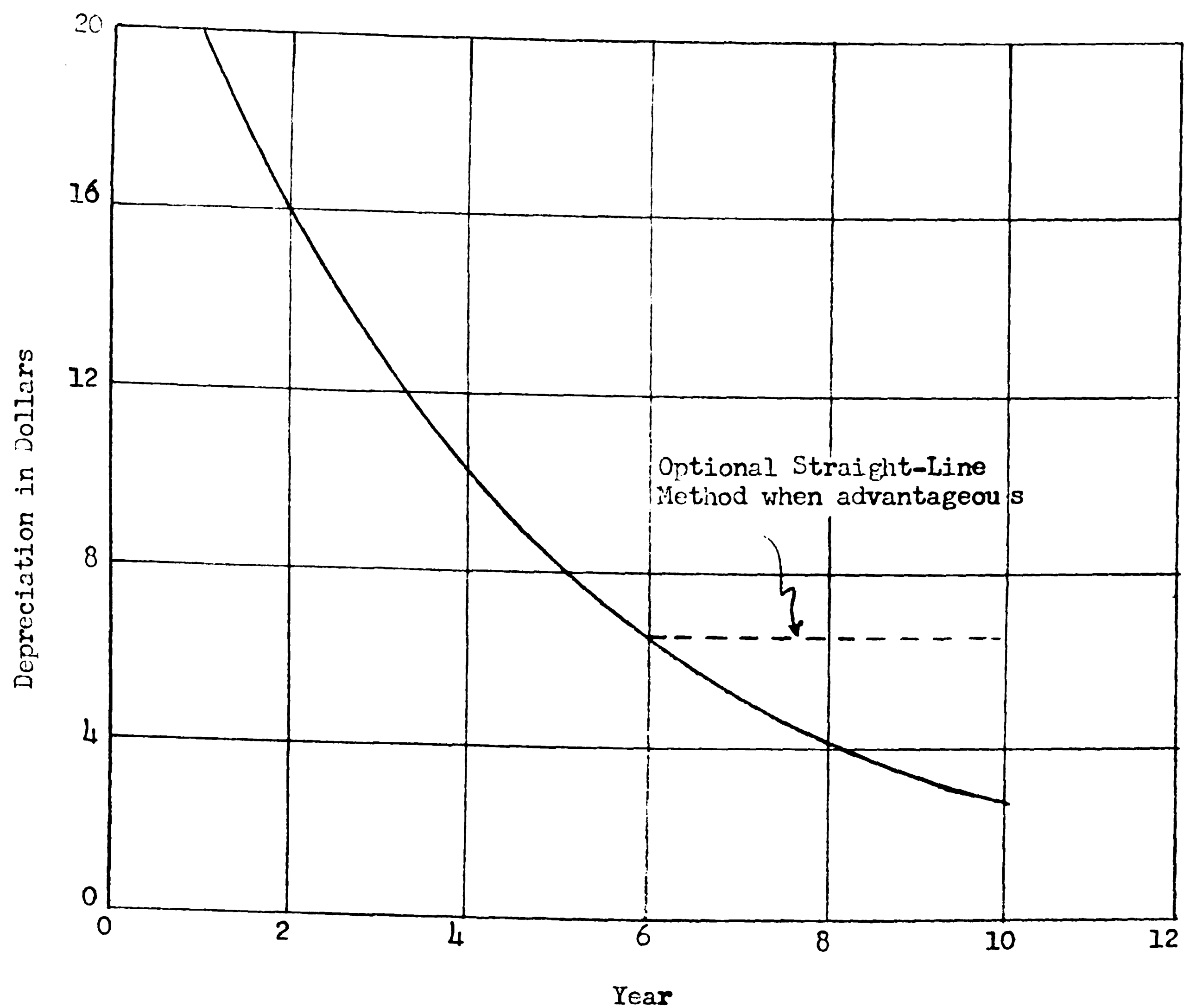

Fig. 4. Comparison of Depreciation Rates for Double Declining Balance Method and the Combination of Double Declining Balance and Straight Line Method of Depreciation.

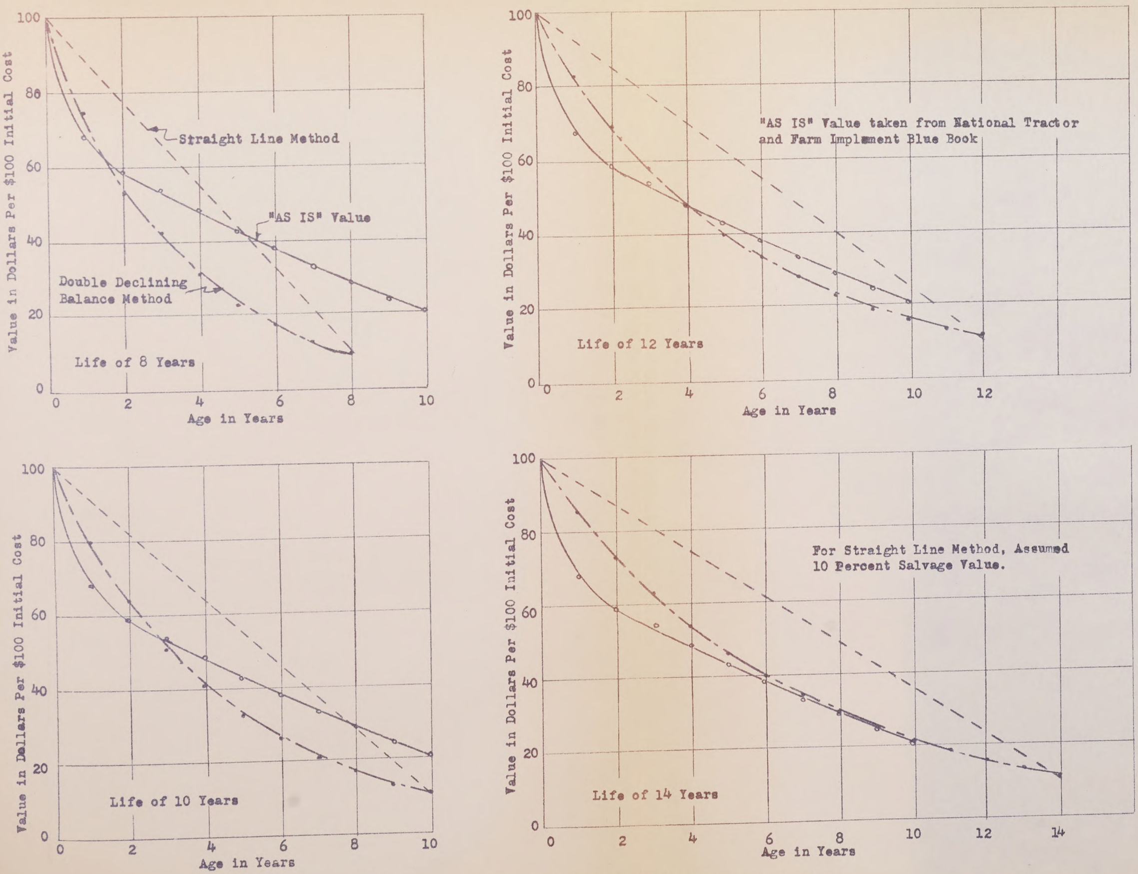

Fig. 5 Relationship Between Value and Age of Farmall "M" Tractor with Different Methods of Depreciation

of depreciation. The straight-line method, double-declining balance method and "as is" value are compared for estimated lives of 8, 10, 12 and 14 years. For the straight-line method it was assumed that the tractor at the end of its life had a 10 percent salvage value. The "as is" value is the appraised value given in the National Tractor and Farm Implement Blue Book published by National Market Reports, Inc.

The "as is" value is based on the premise that the tractor is in average "as is" condition. This value is used generally in arriving at a fair trade-in allowance valuation. Many dealers use it as their absolute maximum allowance figure. From Figure 5 and from the definition it is to be noted that in all cases the straight-line method gives a higher value than the double-declining balance. Also, it may be noted that value at the end of the estimated life for declining balance method is within a few dollars of the 10 percent salvage value assumed for the straight-line method. It appears that the double-declining balance method will approach the more realistic "as is" value for estimated lives of 12 and 14 years. It is believed that the double-declining balance method would have more merit than the straight-line method now being used by most cost estimators. This would be particularly true for one who does not intend to keep his tractor or machine its entire life.

Since accelerated rate of depreciation is equivalent to a more rapid return of investment to the farmer he may make use of it sooner. Larger farm operators who actually set aside reserves, based on depreciation write-offs, will be in a better position to buy replacements sooner.

In cost estimating work it appears that one might be interested in knowing the average annual depreciation to date based on the double-declining balance method of depreciation. With this in mind, Table X was prepared to give the average annual depreciation to date for several estimated service-life years.

TABLE X

DOUBLE DECLINING BALANCE METHOD OF DEPRECIATION: AVERAGE ANNUAL DEPRECIATION TO DATE BASED ON $100 OF INITIAL INVESTMENT

Year	Estimated Service Life - Years														
	5	6	7	8	9	10	12	14	15	16	18	20	22	24	25
1	40.00	33.33	28.57	25.00	22.22	20.00	16.67	14.29	13.33	12.50	11.12	10.00	9.10	8.34	8.00
2	32.00	27.78	24.49	21.88	19.75	18.00	15.28	13.27	12.44	11.72	10.50	9.50	8.69	7.99	7.68
3	26.13	23.46	21.19	19.27	17.65	16.27	14.05	12.35	11.63	11.00	9.93	9.03	8.30	7.66	7.38
4	21.76	20.06	18.43	17.09	15.85	14.76	12.95	11.51	10.89	10.35	9.40	8.60	7.93	7.35	7.09
5	18.45	17.36	16.24	15.25	14.31	13.45	11.97	10.75	10.22	9.74	8.91	8.21	7.59	7.06	6.82
6		15.20	14.43	13.70	12.98	12.30	11.09	10.06	9.60	9.19	8.45	7.82	7.27	6.78	6.56
7			12.92	12.38	11.83	11.29	10.30	9.43	9.04	8.68	8.03	7.46	6.96	6.52	6.32
8				11.25	10.83	10.40	9.60	8.86	8.52	8.21	7.63	7.13	6.67	6.27	6.08
9					9.95	9.62	8.96	8.34	8.04	7.77	7.26	6.81	6.40	6.04	5.86
10						8.93	8.39	7.86	7.61	7.37	6.92	6.52	6.15	5.81	5.66
11							7.87	7.42	7.21	7.00	6.60	6.24	5.91	5.60	5.46
12							7.40	7.02	6.84	6.66	6.31	5.98	5.68	5.40	5.27
13								6.66	6.49	6.34	6.03	5.74	5.47	5.21	5.09
14								6.32	6.18	6.04	5.77	5.51	5.27	5.03	4.92
15									5.89	5.77	5.53	5.30	5.07	4.86	4.76
16										5.51	5.30	5.09	4.89	4.70	4.60
17											5.09	4.90	4.72	4.54	4.46
18											4.89	4.72	4.56	4.40	4.32
19												4.55	4.40	4.26	4.18
20												4.39	4.26	4.12	4.06
21													4.12	4.00	3.94
22													3.99	3.88	3.82
23														3.76	3.71
24														3.65	3.60
25															3.50

Part III

Use of Alignment Charts as a Method for Estimating Total Operating Costs of Farm Equipment

Some work has already been done to present cost estimates graphically. Richey (1950) has presented a few logarithmic charts which one can use for making cost estimates. It is believed that the construction of simple three-line alignment charts which provide the solution for making operating cost analysis would be quite useful for persons such as operators of farm equipment, equipment dealers and possibly extension workers.

The use of alignment charts as a method of approach to solving engineering problems is receiving more attention as an aid in all fields of engineering and agriculture. With this in mind the following method is presented as a means for making cost estimates graphically by simple alignment charts. It should be mentioned at the outset that a straight edge is the only tool required in addition to the charts.

All cost estimates used in the charts are based on $100 of initial investment in those cases where initial cost is one of the factors involved in the solution. The total unit cost of item in question is equal to the chart value times initial cost divided by $100, which means essentially marking off two decimal places on the initial cost.

Figure 6 is an alignment chart for estimating depreciation cost of a farm machine. It is based on the straight-line method of depreciation and is so constructed that charges for depreciation can be determined either on the basis of hours of total life built into the machine, or on the basis of hours of use per year and number years until obsolete.

If hours of life is the determining factor then it is only a matter of reading directly across on the conversion scale to get the cost of depreciation in cents per hour. If years until obsolete is the determining factor then the three scales are used as indicated by the key in the figure. It must be noted that if the salvage value is known then this value should be subtracted from the new cost in order to get the true value upon which depreciation cost is to be estimated.

Figure 7 is an alignment chart for estimating combined charge for interest on investment, taxes, insurance, and housing. It is necessary to point out that the rate of interest to use in Figure 7 will be one-half the actual rate of interest estimated since the annual charge for interest is to be an average rate during the life of machine. The amount to charge for insurance, taxes, and housing is also one-half the estimated rate. The sum of the average percentages for the items (I, T, I, and H) is to be used as the total average percentage to charge per year for machine in question. By knowing the hours of annual use, a straight edge laid across the points will indicate the cost in cents per $100 initial cost on the center scale.

DEPRECIATION COST OF FARM MACHINERY

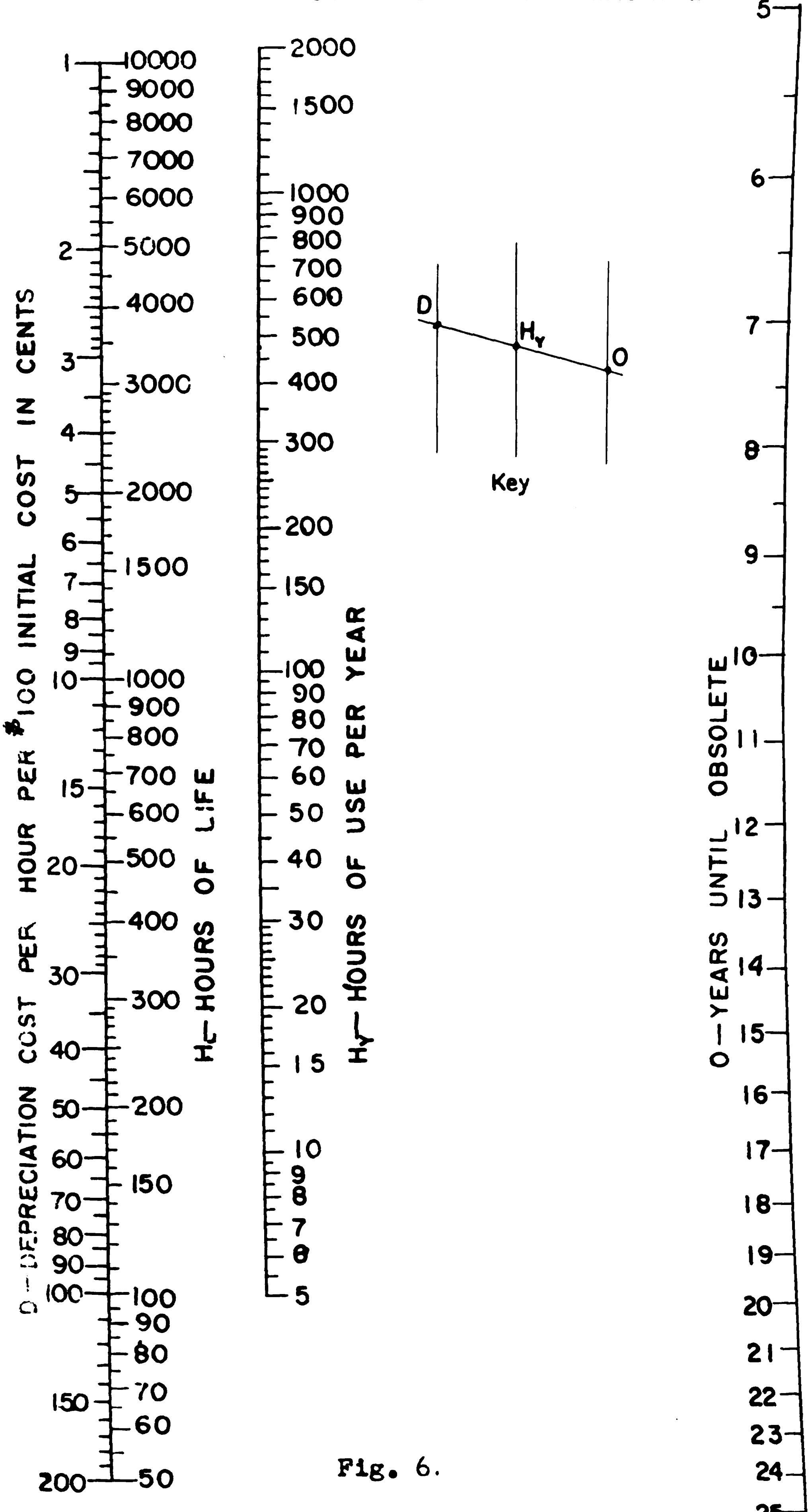

Fig. 6.

FARM MACHINERY COSTS
INTEREST, HOUSING, TAXES, INSURANCE

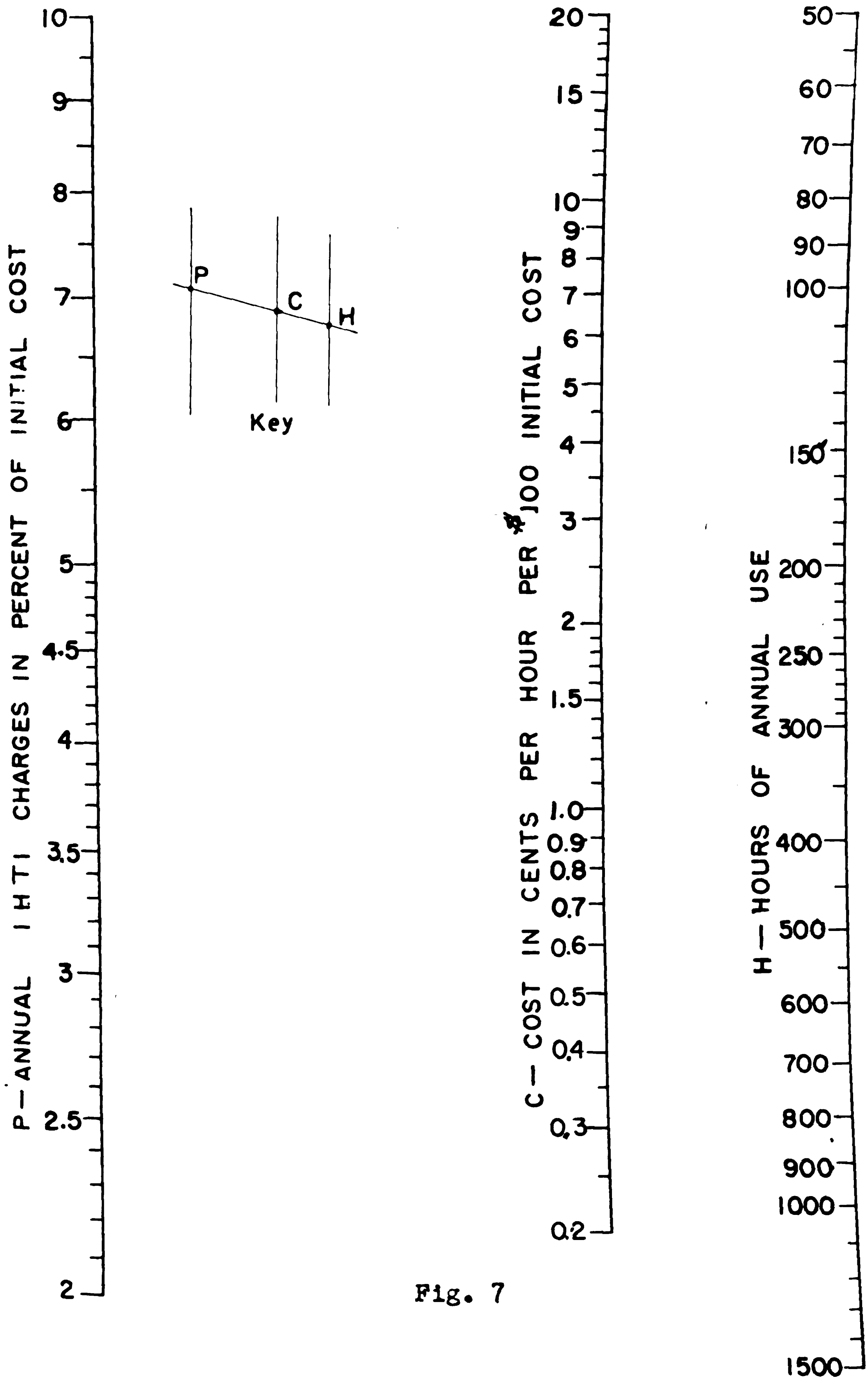

Fig. 7

Figure 8 is an alignment chart for estimating repair cost per hour. Repair cost for this chart was based on total percentage for repairs during the machine life. By knowing the hours of life built into the machine and total percentage to charge for repairs, one can determine repair cost in cents per hour by laying a straight edge across points on chart and noting cost per hour on center scale.

Figure 9 is an alignment chart for estimating tractor fuel and oil consumption costs. The equation used for developing this chart is based on work done at South Dakota State College. If more appropriate values are known it is recommended that they be used in place of this chart.

To get the total estimated cost for operating a machine, one adds the cost per hour obtained from each alignment chart - Figures 6, 7, 8, and 9. This sum will give the total estimated cost per hour for operating a particular machine or tractor based on the items considered. It should be emphasized that since Figures 6, 7, and 8 were based on $100 initial cost, the results of these three charts must be adjusted to true initial cost before adding unit cost of fuel and oil consumption.

Tables XI and XII have been prepared as an aid for using the alignment charts.

A. Simplified Method of Cost Prediction

Often one may wish to make cost estimates by figuring the total annual charges for the machine in terms of percent of

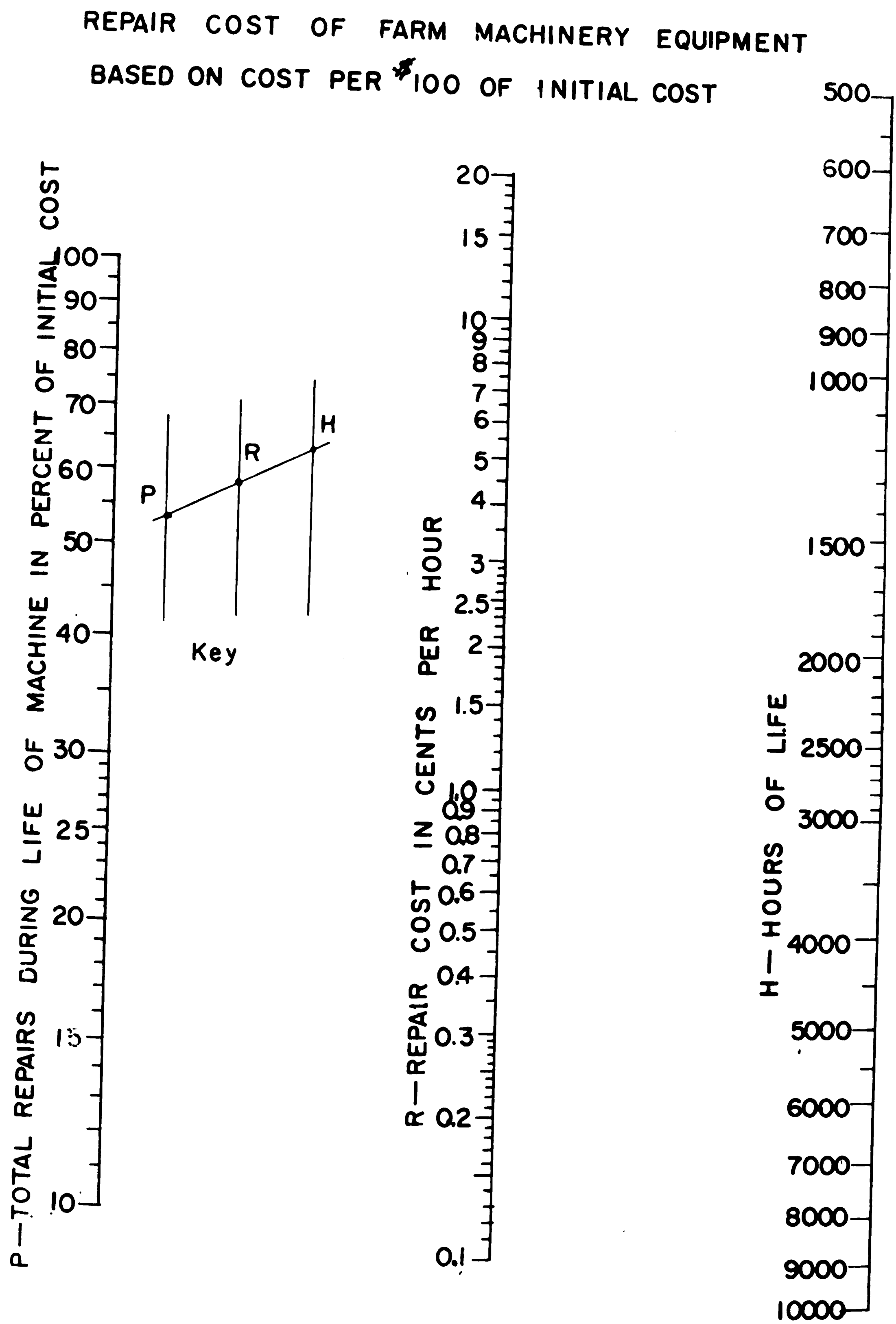
REPAIR COST OF FARM MACHINERY EQUIPMENT
BASED ON COST PER $100 OF INITIAL COST
P—TOTAL REPAIRS DURING LIFE OF MACHINE IN PERCENT OF INITIAL COST
100
90
80
70
60
50
40
30
25
20
15
10
P
R
H
Key
R—REPAIR COST IN CENTS PER HOUR
20
15
10
9
8
7
6
5
4
3
2.5
2
1.5
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
H—HOURS OF LIFE
500
600
700
800
900
1000
1500
2000
2500
3000
4000
5000
6000
7000
8000
9000
10000

Fig. 8

TRACTOR FUEL AND OIL CONSUMPTION COSTS

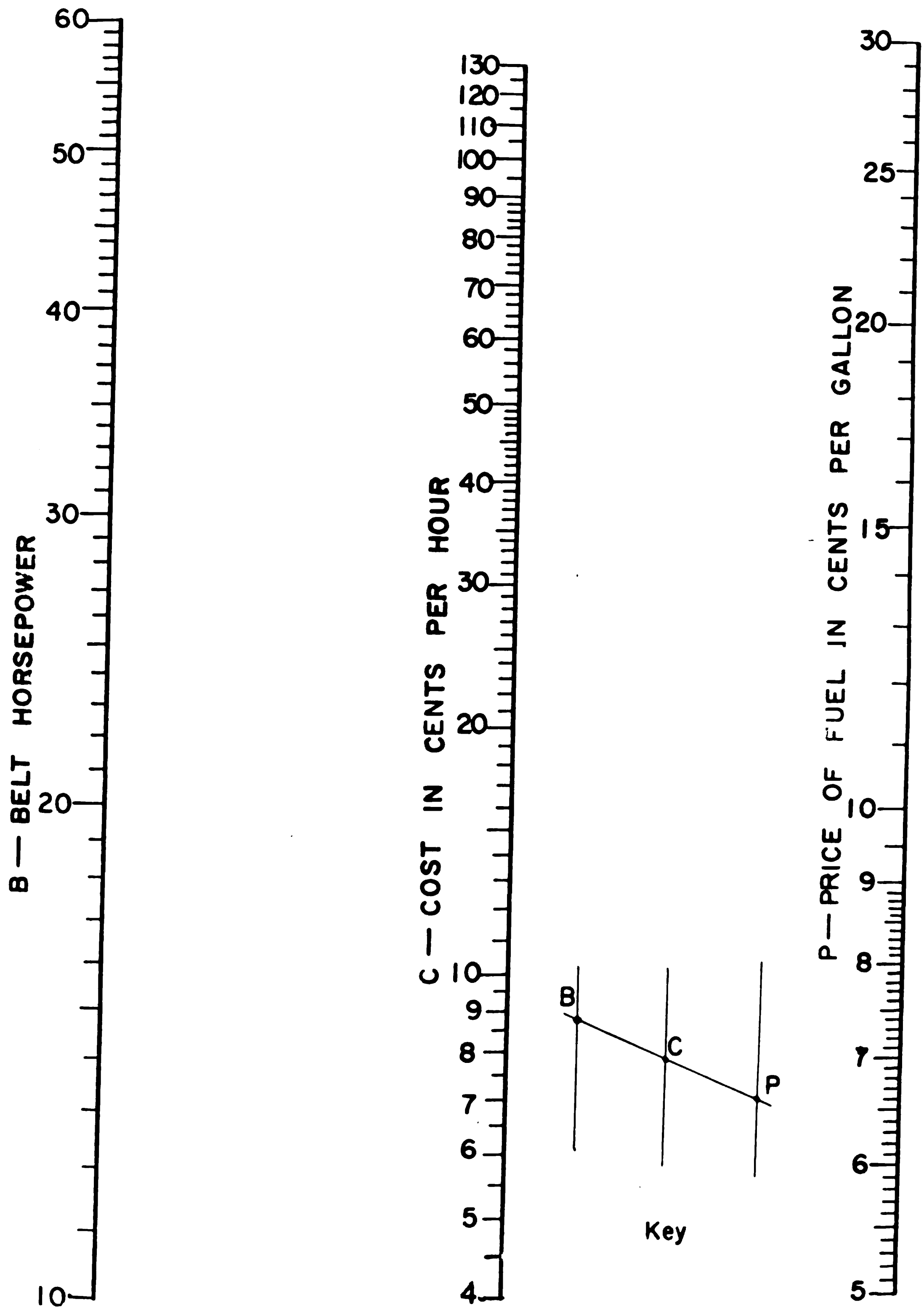

Fig. 9

TABLE XI

SUGGESTED VALUES TO USE FOR TOTAL REPAIR COST IN PERCENT OF NEW COST FOR VARIOUS FARM MACHINES*

Machine	Years Until Obsolete	Hours of Life	Total Repair Cost in Percent of New Cost
Tillage			
Tractor plow	15	2000	80
Disc harrow (tractor)	15	2000	30
Springtooth harrow	20	2000	40
Spiketooth harrow	20	2500	30
Roller	25	1500	10
Soil pulverizer	20	2000	15
Planting			
Endgate seeder	20	800	30
Grain drill	20	1200	25
Corn planter	20	1200	30
Cultivating			
Rotary hoe	15	1500	20
Tractor cultivator	12	2500	40
Hay Harvesting			
Mower (tractor)	12	2000	75
Side-delivery rake	20	1200	25
Tractor buck rake	12	1500	25
Hay loader	20	1800	25
Pickup baler	15	3000	40
Forage harvester and blower	10	1200	30
Grain Harvesting			
Grain binder	20	1000	45
Thresher	20	2500	25
Combine	10	2000	40
Corn Harvesting			
Corn picker	10	1500	30
Miscellaneous			
Manure spreader	15	4000	25
Wagon gear and box	25	15,000	50
Tractor	15	7500	35

*Richey, C. B. (1950). Crop Machinery Use Data. Agri. Engineering Data 2, American Society of Agricultural Engineers, St. Joseph, Michigan. P. 4.

TABLE XII

SUGGESTED VALUES TO USE IN CALCULATING ANNUAL REPAIR COSTS FOR VARIOUS FARM MACHINES*

Machine	Annual Repairs in Percent of New Cost of Machine	Machine	Annual Repairs in Percent of New Cost of Machine
Baler, with engine	3.0	Loader, hay	1.5
Binder, grain	2.5	Mower	3.5
Binder, row	2.5	Picker, corn	3.0
Combine, engine driven	3.0	Planter, corn	2.0
Combine, self-propelled	3.0	Plow, one-way	5.0
Combine, power take-off	3.0	Plow, pull type	7.0
Cultivator, duckfoot	3.5	Plow, tractor-mounted	7.0
Cultivator, listed corn	3.5	Sprayer, field	5.0
Cultivator, shovel	3.5	Spreader, manure	1.5
Cutter, ensilage	3.0	Rake, side-delivery	2.0
Drill, grain	1.5	Rake, sweep	4.0
Field forage harvester	4.0	Thresher, grain	3.0
Grinder, feed, burr	3.0	Tractor	3.5
Grinder, feed, hammer	2.0	Truck	5.0
Harrow, disk	3.0	Wagon	1.5
Harrow, drag	1.0	Weeder, rod	2.0
Lister	5.0		

*Fenton and Fairbanks (1954). The Cost of Using Farm Machinery, Kansas State College Engineering Experiment Station, Bulletin 74, p. 24.

initial cost. Vary (1954), and Bradford and Johnson (1953) have specified what percent should be charged off the initial investment in making cost estimates. The alignment chart in Figure 10 was constructed for this purpose and Table XIII is an aid in making use of the one alignment chart which will essentially replace the charts in Figures 6, 7 and 8.

TABLE XIII

TOTAL CHARGES IN PERCENT OF INITIAL COST FOR DEPRECIATION, INTEREST, TAXES, HOUSING AND REPAIRS*

Machine	Percent
Hayloader	13.0
Buckrake	18.5
Baler	17.0
Hay Crusher	15.5
Small Field Chopper	15.5
Large Field Chopper	15.5

*Vary, Karl A. (1954). Hay harvesting methods and costs. Mich. Expt. Sta. Spec. Bul. 392, p. 10

According to Bradford and Johnson (1953)

> A good rule-of-thumb measure of the total annual cost for using a piece of machinery is to take 15 percent of the original cost (when new) for the complicated machines and 10 percent for the less complicated ones.

FARM MACHINERY COSTS PER HOUR PER $100 INITIAL COST

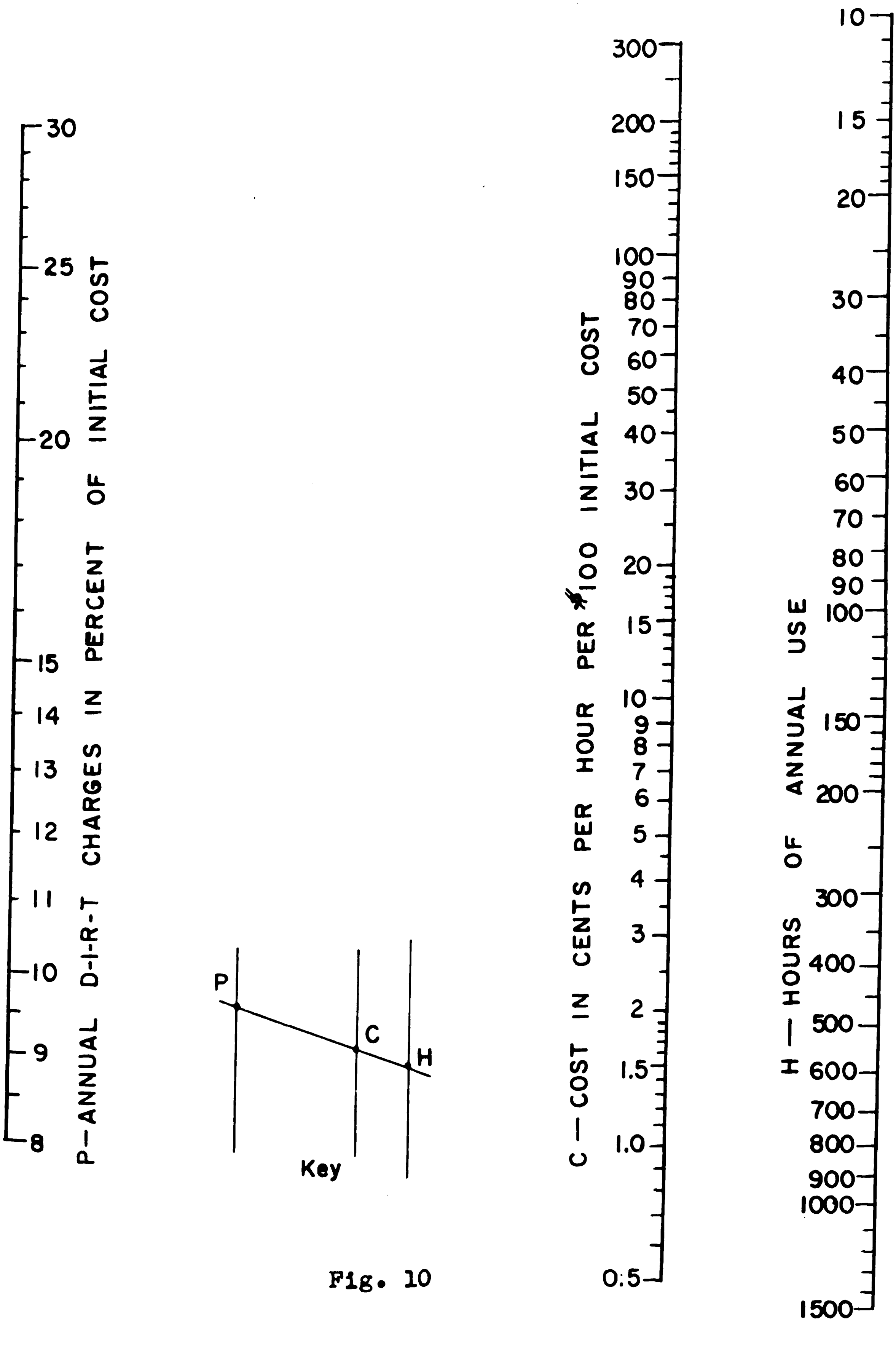

Fig. 10

Part IV

A Study of Fuel and Oil Consumption Costs

The work at South Dakota State College showed that fuel and oil consumption costs can be estimated by the following formula in the absence of precise figures.

Fuel and Oil Cost per Day = Belt H.P. x 0.8 x Fuel Price per Gallon

The writer had the privilege of reviewing data from the 1952 tractor record book summaries supplied by Samsel (1954). Pertinent data was tabulated in Table XIV. The table indicates that average fuel consumption for twenty-two Case "V" Series tractors with fifteen rated drawbar horsepower was 61.2 percent of the fuel consumption as reported in test H of the Nebraska Tractor Test Results, 52.1 percent for sixteen "S" Series tractors with 22.41 rated drawbar horsepower and 68.5 percent for twenty "D" Series tractors with 25.74 rated drawbar horsepower. It was also determined from Table XIV that for the total group of fifty-eight tractors the oil cost averaged 7.20 percent of the total fuel cost.

Based on the above data, the following formula was developed for estimating fuel and oil costs per hour operation.

Cost per Hour = Gallons/Hour @ RDHP x 0.70 x Price of Fuel/Gallon + 0.08 x Gallon/Hour x Price of Fuel/Gallon where RDHP = Rated Drawbar Horsepower

Cost per Hour = Gal./Hr. @ RDHP x Price/Gal. (0.70 + 0.08)

Cost per Hour = Gal./Hr. @ RDHP x Price/Gal x 0.78

The final equation gives cost per hour for fuel and oil which is about the same as in the studies described. The factor of 0.7 was used in the above formula as an "over" estimate since it was determined that one group of tractors used 68.5 percent of fuel consumption at rated drawbar horsepower from the Nebraska Tractor Test Results. The factor 0.08 was used as a slight "over" estimate for oil costs.

By determining the approximate fuel consumption per rated drawbar horsepower, the fuel and oil cost could be estimated by knowing only the rated drawbar horsepower of the tractor and price of fuel per gallon. For the three groups of tractors studied it was determined that the average fuel consumption per rated drawbar horsepower was 0.11 gallons per hour. Therefore, the final equation becomes

Cost/Hour = RDHP x Price of fuel/Gallon x 0.086

where cost per hour is in cents per hour

RDHP = rated drawbar horsepower

price of fuel per gallon is in cents per gallon

The data studied concerned only gasoline operated tractors and so the equation is valid only for gasoline operated tractors. This equation tends to give a cost figure slightly lower than the South Dakota equation gives if the latter were put on a belt horsepower basis. The difference is probably due in part to the fact that cost of lubrication is not included in the data for the Case tractors, however, there is reasonably close agreement between the two equations.

TABLE XIV

SUMMARY OF DATA TAKEN FROM THE 1952 TRACTOR RECORD BOOK SUMMARIES OF THE J. I. CASE COMPANY

Code No.	Age in Yrs.	Location State	Size Farm Acres	Avg. Use Hours Per Year	Fuel Cost Per Year	Oil Cost Per Year	Oil Cost Percent of Fuel Cost	Fuel Consumption Gal./Hr.
				Case V Series Tractors				
1	4	Nebraska	160	245	$ 212.95	$ 14.24	6.68	1.00
2	3	Texas	160	747	416.49	18.90	4.54	1.13
3	4	New York	50	350	206.39	8.90	4.31	0.98
4	2	Missouri	420	373	157.13	6.65	4.23	1.18
5	4	Wisconsin	158	815	501.28	53.00	10.57	0.82
6	4	Washington	46	267	201.15	27.34	13.59	1.05
7	3	Virginia	104	257	147.02	15.30	10.41	0.69
8	3	S. Dakota	160	595	232.90	22.00	9.45	1.10
9	1	S. Dakota	-	473	124.44	4.12	3.31	1.03
10	5	S. Carolina	-	333	340.99	56.92	16.69	1.34
11	2	Missouri	245	355	120.77	6.20	5.13	0.89
12	1	Pennsylvania	245	803	194.81	6.50	3.34	1.05
13	1	Canada	320	641	237.25	21.39	9.02	1.42
14	1	Pennsylvania	165	370	67.40	4.75	7.05	0.91
15	1	Iowa	134	567	124.76	5.56	4.46	1.11
16	3	Canada	228	894	744.25	44.74	6.01	0.93
17	7	Indiana	160	266	353.87	21.82	6.17	1.20
18	4	Illinois	236	440	385.42	25.93	6.73	1.29
19	1	Maryland	197	441	-	-	-	0.78
20	1	Canada	400	466	-	-	-	1.03
21	1	S. Carolina	15	291	-	-	-	0.64
22	1	Missouri	245	278	51.87	-	-	0.80

Av. Gal./Hr. = ...1.02

(Continued)

TABLE XIV (Cont.)

Code No.	Age in Yrs.	Location State	Size Farm Acres	Avg. Use Hours Per Year	Fuel Cost Per Year	Oil Cost Per Year	Oil Cost Percent of Fuel Cost	Fuel Consumption Gal./Hr.
				Case S Series Tractors				
23	1	Wisconsin	120	126	$ 15.66	2.73	17.43	0.69
24	1	Canada	100	556	275.00	23.60	8.58	1.98
25	1	Kentucky	130	451	261.56	12.00	4.59	2.23
26	4	Kentucky	150	297	279.43	30.65	10.96	0.71
27	2	Michigan	210	316	176.06	21.90	12.44	1.26
28	3	Pennsylvania	100	880	330.69	24.46	7.40	0.84
29	3	Canada	150	262	264.33	20.32	7.69	1.23
30	7	Pennsylvania	65	509	500.93	65.17	13.00	0.89
31	1	"	65	307	85.45	5.78	6.76	1.28
32	3	"	-	795	514.67	19.58	3.80	1.04
33	1	Kentucky	150	449	159.44	14.50	9.09	1.42
34	3	Virginia	300	207	186.05	8.97	4.82	1.03
35	4	Missouri	200	248	53.75	2.75	5.12	1.19
36	1	Wisconsin	82	427	138.34	11.00	7.95	1.50
37	1	Canada	400	805	--	-	-	1.10
38	8	Oregon	-	136	--	-	-	1.14

Avg. Gal/Hr. 1.22

TABLE XIV (Cont.)

Code No.	Age in Yrs.	Location State	Size Farm Acres	Avg. Use Hours Per Year	Fuel Cost Per Year	Oil Cost Per Year	Oil Cost Percent of Fuel Cost	Fuel Consumption Gal./Hr.
				Case D Series Tractors				
39	2	Illinois	200	387	$ 370.05	$ 18.62	5.03	2.07
40	3	Indiana	160	419	507.27	27.30	5.38	1.69
41	2	Iowa	300	362	168.30	8.80	5.23	2.46
42	1	Canada	-	402	165.66	6.40	3.86	1.87
43	4	Canada	150	263	266.95	33.78	12.65	1.52
44	1	Canada	107	593	241.56	24.00	9.94	1.70
45	1	Missouri	-	808	242.40	13.92	5.74	1.88
46	1	Indiana	215	202	50.00	4.50	9.00	1.24
47	2	Wisconsin	258	269	233.06	7.02	3.01	2.32
48	1	Kansas	-	318	102.14	3.75	3.67	1.79
49	2	Minnesota	400	843	752.71	51.78	6.88	2.29
50	2	Canada	430	780	550.30	34.50	6.27	1.55
51	2	Canada	316	416	309.80	28.60	9.23	1.78
52	1	Pennsylvania	-	524	168.97	6.00	3.55	1.37
53	1	Minnesota	160	508	170.90	12.42	7.27	1.68
54	1	New York	76	508	230.85	4.95	2.14	2.02
55	4	Ohio	160	862	968.31	51.65	5.33	1.28
56	1	Kansas	298	440	176.09	8.55	4.86	1.86
57	1	Pennsylvania	165	536	201.80	14.72	7.29	1.88
58	1	Iowa	145	495	-	-	-	1.45

Avg. Gal./Hr. 1.77

Avg. Annual Use for all tractors -- 479 Hrs.
Avg. Oil Cost for all tractors -- 7.20% of fuel cost.

Part V

Investigation of How Repair Costs Vary With Use

It was pointed out earlier that practically no detailed information exists on the relationship between repair costs and use for farm equipment. Although various farm account records do contain information on machinery expenses, no complete record is available regarding the history of a particular machine. It appears now that this area is in need of study since repair cost is an important factor for determining when need for replacement of a machine is evident.

Through the cooperation of Bateman (1954), yearly repair cost figures were obtained on seven tractors for a period of 10 years (1936-1946). Since the annual hourly use of these tractors was practically the same, the age of tractor was used for comparison in place of hourly use. The repair cost figures were converted to percent of new cost of tractor and plotted as shown in Figure 11 and Figure 12. These data indicate that the relationship between repair costs and use is <u>not</u> necessarily proportional. The equation determined by the least squares method for these data is the following:

$$Y = 0.314X^{1.61}$$

where Y = Repair cost in percent of new cost

X = Age of tractor in years

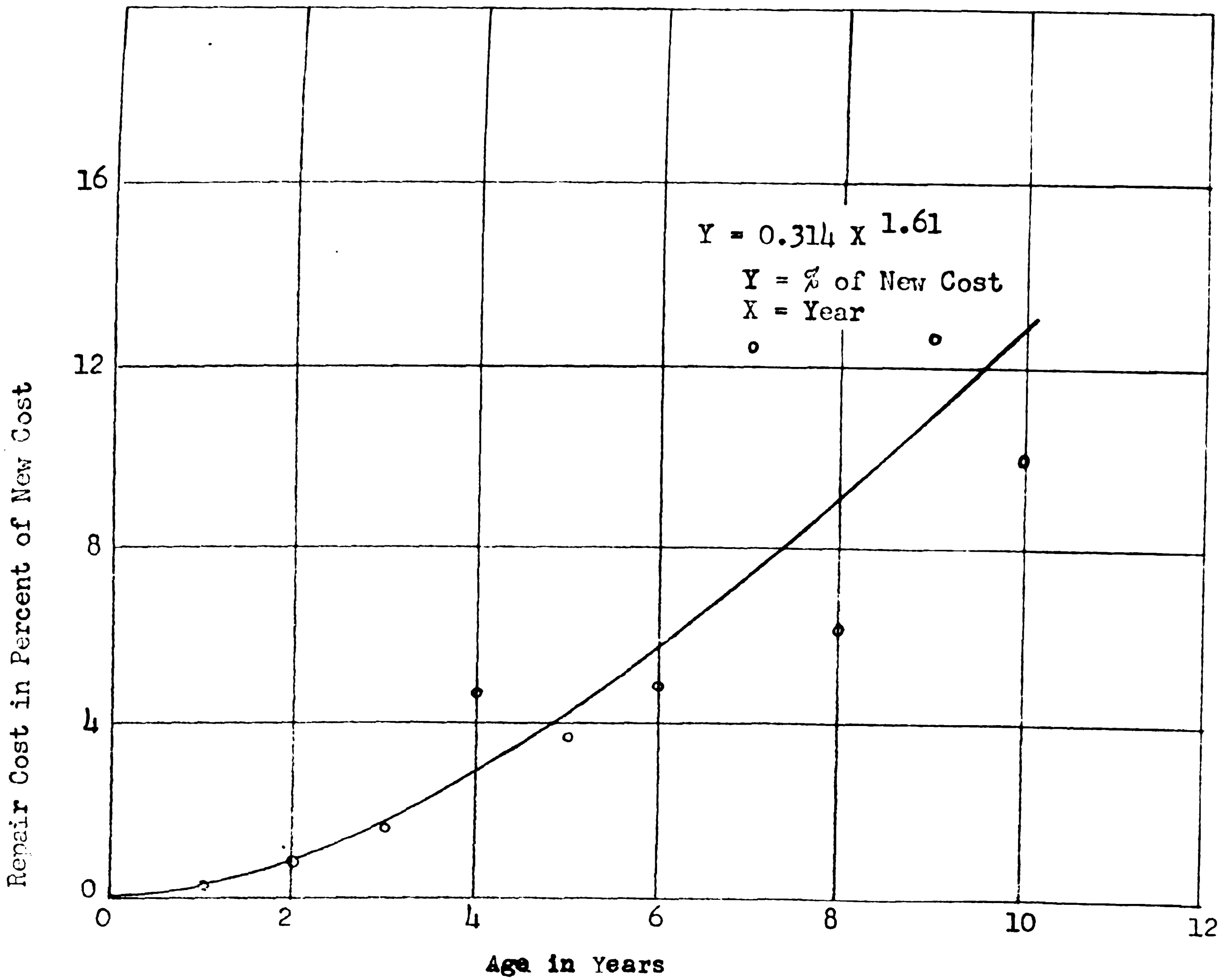

Fig. 11. Relationship Between Tractor Repair Costs and Use for Group of Seven Tractors for the Period 1936 to 1946. Average Annual Use 550 Hours.

Source of Data: H. P. Bateman, Agric. Eng. Dept., University of Illinois

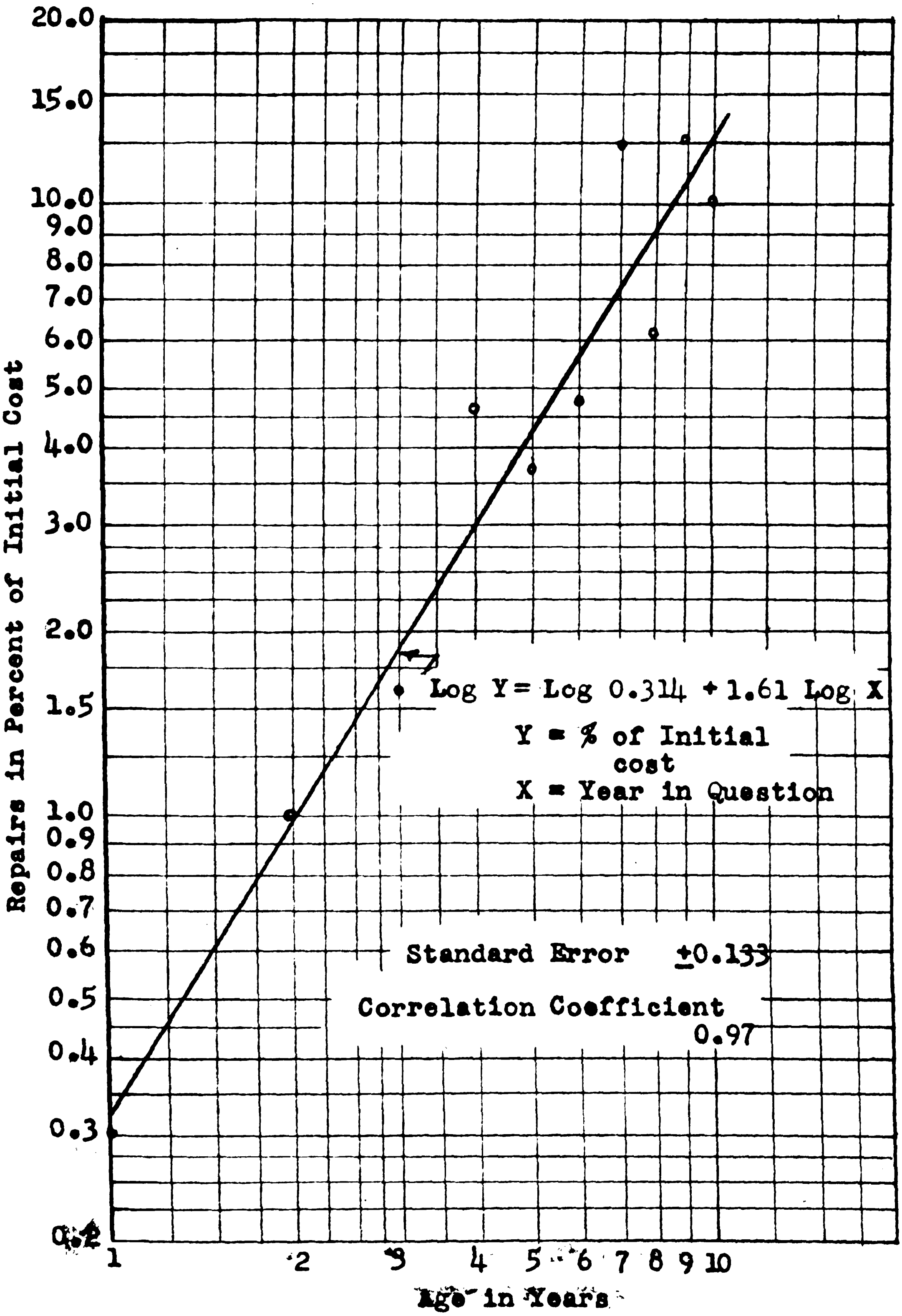

Fig. 12. Relationship Between Tractor Repair Costs and Use for Group of Seven Tractors for the Period 1936 to 1946. Average Annual Use 550 Hours.

The standard error of estimate was calculated to be $\pm$ 0.133 percent and the correlation coefficient was calculated to be 0.97.

Although the average repair costs were larger for the 4th and 7th year, Bateman reported that there is no definite pattern as to the year of first large repair cost for individual tractors. Consequently it is believed that the analytical relationship as indicated is valid. The data for the seven tractors is based on continuous records kept on grain farms in Champaign County, Illinois, and that practically all the engine repairs were made at a machinery dealer by a skilled mechanic.

Additional information regarding repair costs were received from Pfost (1955). The data is summarized in Table XV for different groups of machines and tractors. It was determined that maintenance labor costs range from 5.88 percent to as high as 33.20 percent of the total maintenance costs for the harvesters and corn planters for the years indicated. Maintenance labor costs for the diesel tractors varied from 22.87 percent to 71.51 percent of the total maintenance costs. Maintenance labor costs for the gasoline tractors varied from 25.87 percent to 36.03 percent of the total maintenance costs.

Figures 13 and 14 which show the dependence of maintenance costs on use for sweet corn harvesters indicate that the relationship is approximately linear. Since all 33

TABLE XV

SUMMARY OF MAINTENANCE COSTS AND USE DATA

Source of Data: Green Giant Company, LeSueur, Minnesota

Year	Material	Labor	Maintenance Costs Total	Avg. Cost Per Acre	Labor Percent of Total
SWEET CORN HARVESTERS					
Plant B*					
1951	$ 123	$ 12	$ 135	$ 0.45	8.89
1952	382	95	477	1.59	19.92
1953	354	176	530	1.77	33.20
1954	458	130	588	1.96	22.10
Plant H**					
1951	107	38	145	0.48	26.21
1952	269	70	339	1.13	20.65
1953	227	95	332	1.11	28.61
1954	444	103	547	1.82	18.83
I.H.C. CORN PLANTER - 4-Row***					
1952	16	1	17	0.034	5.88
1953	31	12	43	0.086	27.90
1954	72	29	101	0.202	28.71
FARMALL MD TRACTORS					
Plant H****				Avg. Cost Per Acre	
1952	23	57.75	80.75	0.083	71.51
1953	242	71.75	313.75	0.322	22.87
1954	201	127.75	328.75	0.337	38.85
MINNEAPOLIS-MOLINE MODEL UTU TRACTORS					
Plant F*****					
1950	76	35.00	111.00	0.094	31.53
1951	205	108.50	313.50	0.265	34.60
1952	174	98.00	272.00	0.229	36.03
1953	295	117.25	412.25	0.348	28.44
1954	351	122.50	473.50	0.400	25.87

*Average costs for 12 units and harvested approximately 300 acres per year per unit. Assumed labor at $1.00 per hour. Purchased 1951.

**Average costs for 21 units and harvested approximately 300 acres per year per unit. Purchased 1951.

(table continued next page)

***Average of two 4-row corn planters, model 440, purchased 1952, average per unit per year 500 acres.

****Average of 3 Diesel tractors. Annual use 975 hours. Purchased 1952.

*****Average costs for three gasoline tractors. Average annual use 1185 hours. Purchased 1950.

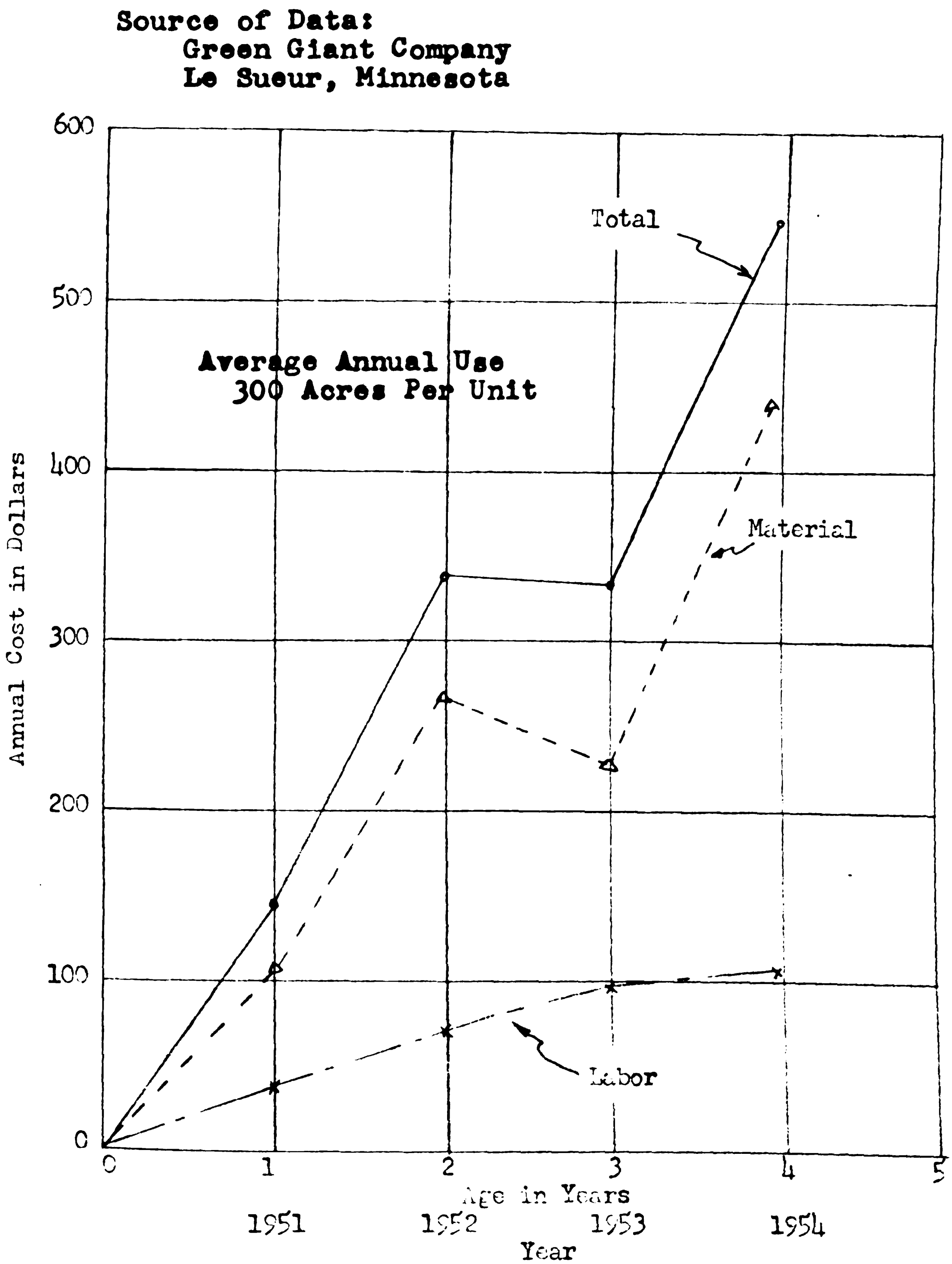

Fig. 13. Relationship Between Total Maintenance Costs and Use for Twenty-one Sweet Corn Harvesters at Plant H.

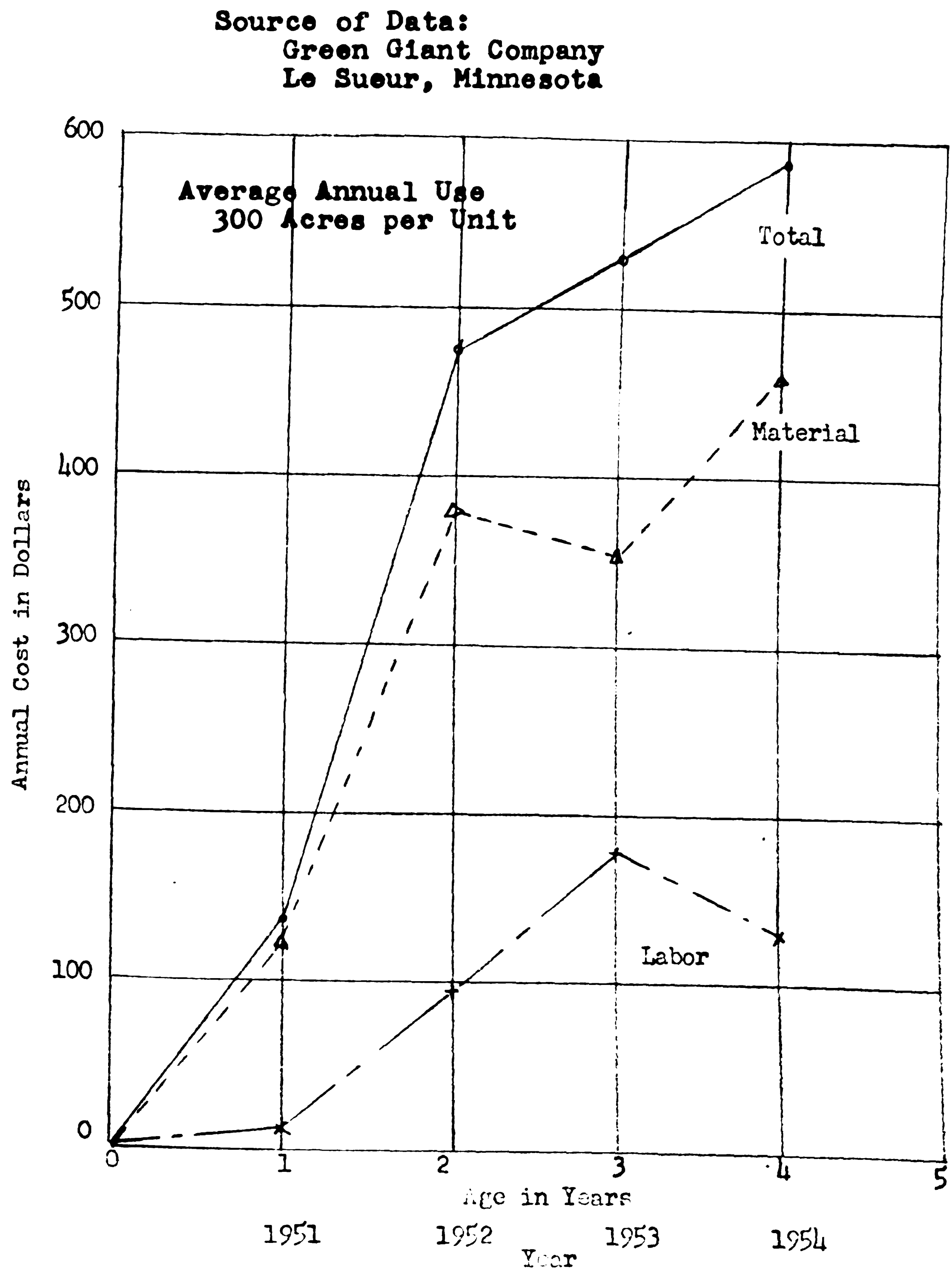

Fig. 14. Relationship Between Maintenance Costs and Use for Twelve Sweet Corn Harvesters at Plant B.

harvesters were the same model, size, and had the same amount of duty except that 12 were operated at one plant and 21 were operated at another plant, the sets of data were combined and plotted as shown in Figure 15. Analysis of the data resulted in a regression line,

$$Y = 0.182 + 0.426X$$

where Y = cost per acre in dollars

and X = the year in question.

The standard error of estimate was calculated to be ± 0.254 dollars, and the correlation coefficient to be 0.88. For more conclusive evidence data for more years of service is needed.

Figure 16 which shows the relationship between maintenance costs and use of corn planters for the three years reported tends to indicate that maintenance costs increase at an increasing rate. The regression line for corn planters was not calculated due to insufficient data.

Pfost (1955) stated that assuming labor cost for the harvesters and corn planters at $1.00 per hour is considered realistic. The labor cost for tractor maintenance was, however, running approximately $1.75 per hour.

An investigation made in person on the maintenance costs of different groups of tractors from the files of the Seabrook Farms located at Bridgeton, New Jersey, revealed the following cost data for material and labor as summarized in Table XVI. These data indicate that labor costs represent from 11.71 percent up to 76.47 percent of the total maintenance costs.

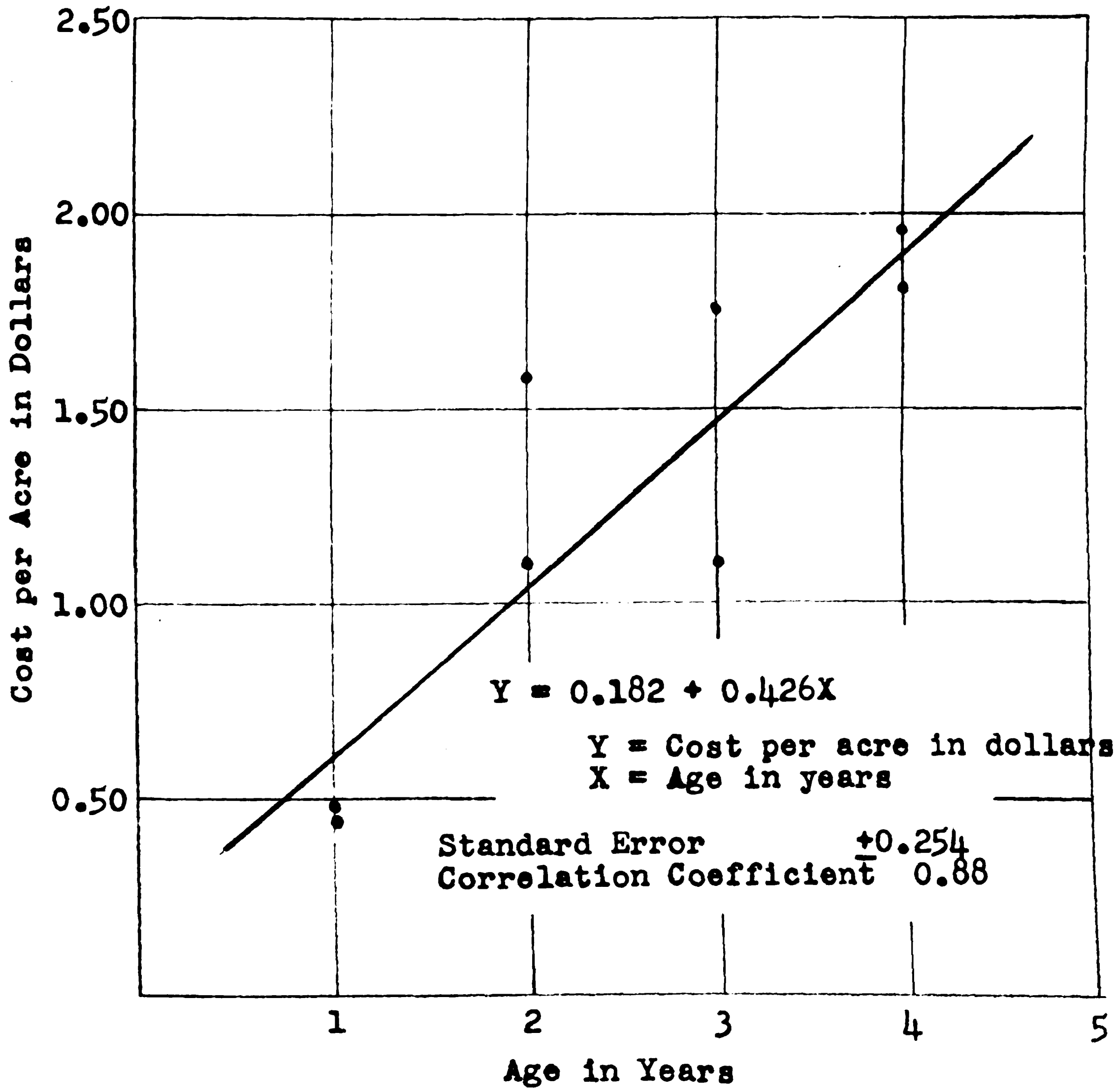

Fig. 15. Relationship Between Maintenance Costs and Use for 33 Sweet Corn Harvesters at Green Giant Company, Le Sueur, Minnesota.

Source of Data:
Green Giant Company
Le Sueur, Minnesota

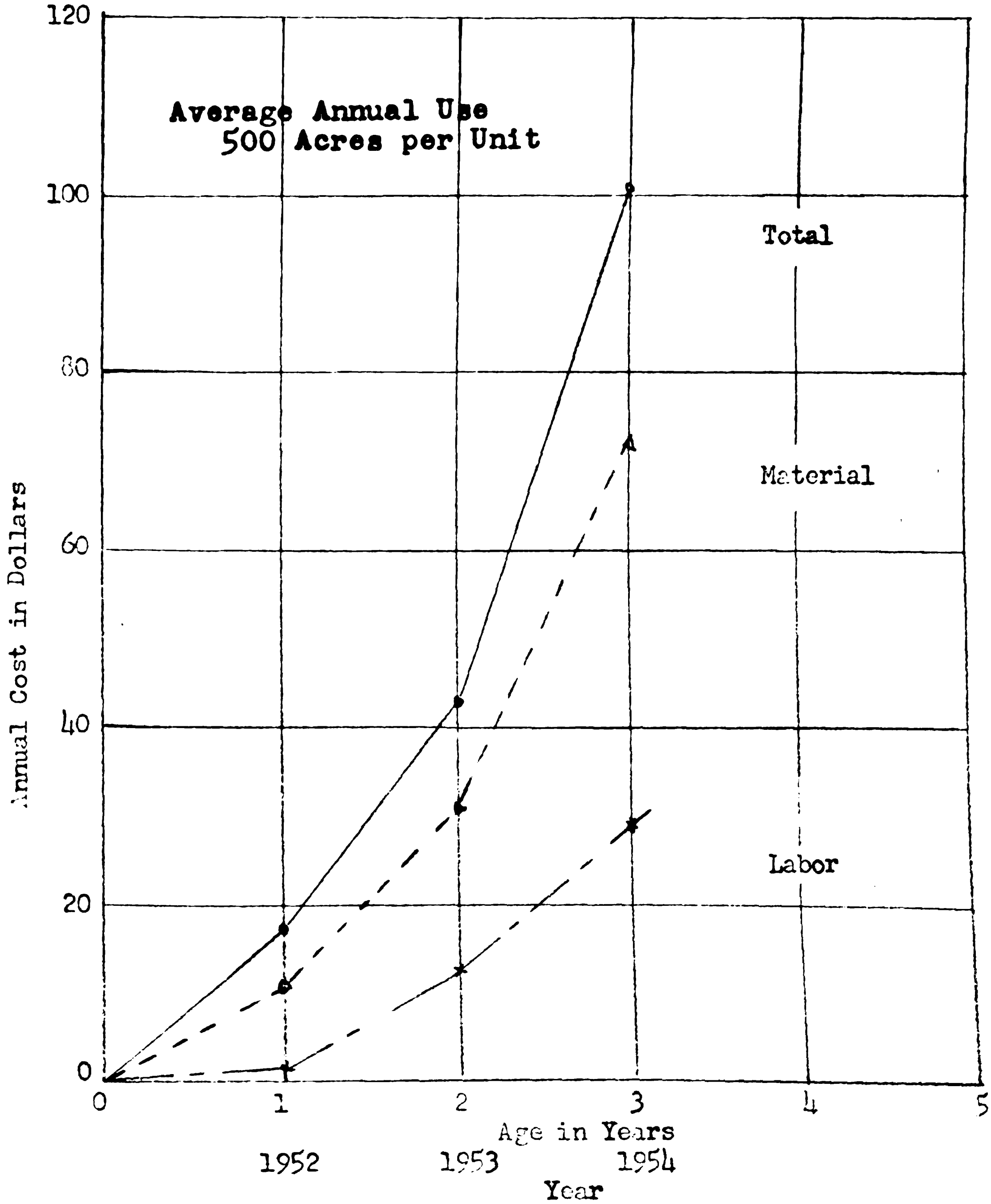

Fig. 16. Relationship Between Average Maintenance Costs and Use for Four IHC Four-Row Corn Planters.

TABLE XVI

SUMMARY OF TRACTOR MAINTENANCE COSTS AND USE DATA

Source: Seabrook Farms, Bridgeton, New Jersey

	Year	Maintenance Costs Material	Maintenance Costs Labor	Maintenance Costs Total	Avg. Cost Per Hour	Labor Cost Percent of Total
*	1950	$ 39.86	$ 10.37	$ 50.23	$ 0.091	20.65
	1951	115.57	32.32	147.89	0.268	21.85
	1952	164.05	44.65	208.70	0.359	21.39
	1953	191.83	25.44	217.27	0.520	11.71
	1954	255.05	42.99	298.04	0.567	14.42
**	1950	17.60	-	17.90	0.023	-
	1951	145.31	49.83	195.14	0.238	25.54
	1952	459.85	144.62	604.47	0.776	23.93
	1953	8.91	28.96	37.87	0.046	76.47
	1954	107.58	147.19	254.77	0.631	57.77
***	1951	79.32	50.03	129.35	0.139	38.68
	1952	85.89	108.53	194.42	0.205	55.82
	1953	163.02	97.64	260.66	0.281	37.46
	1954	187.86	121.41	309.26	0.341	39.26
****	1951	16.44	8.75	25.19	0.035	34.74
	1952	70.05	40.59	110.64	0.152	36.69
	1953	85.02	46.27	131.29	0.211	35.24
	1954	86.52	65.87	152.39	0.363	43.22

*Average costs for 6 Farmall M tractors operated on gasoline purchased in 1950. Average annual use was 525.5 hours.

**Average costs for one Caterpillar D-4 Diesel tractor purchased 1950. Average annual use 713.8 hours.

***Average costs for 12 Oliver "88" Diesel tractors purchased in 1951. Average annual use was 908 hours.

****Average costs for 3 Oliver "77" Diesel tractors purchased 1951. Average annual use was 622 hours.

Examination of Figures 17 and 18 indicate that the relationship between maintenance cost and use for the groups of tractors studied might be approximated as linear; however, more years of use are needed for reliable conclusions.

From the results obtained thus far one suspects that the cost figures from the Green Giant Company and Seabrook Farms are more realistic in that all labor costs including those needed for servicing the equipment are included, whereas the Illinois data includes only labor cost for repairs and does not include all service costs associated with the tractor.

Since the Illinois data covers a greater span of years and more hours of use, it would probably be more reliable for cost estimating purposes until more data is accumulated on the commercial farms.

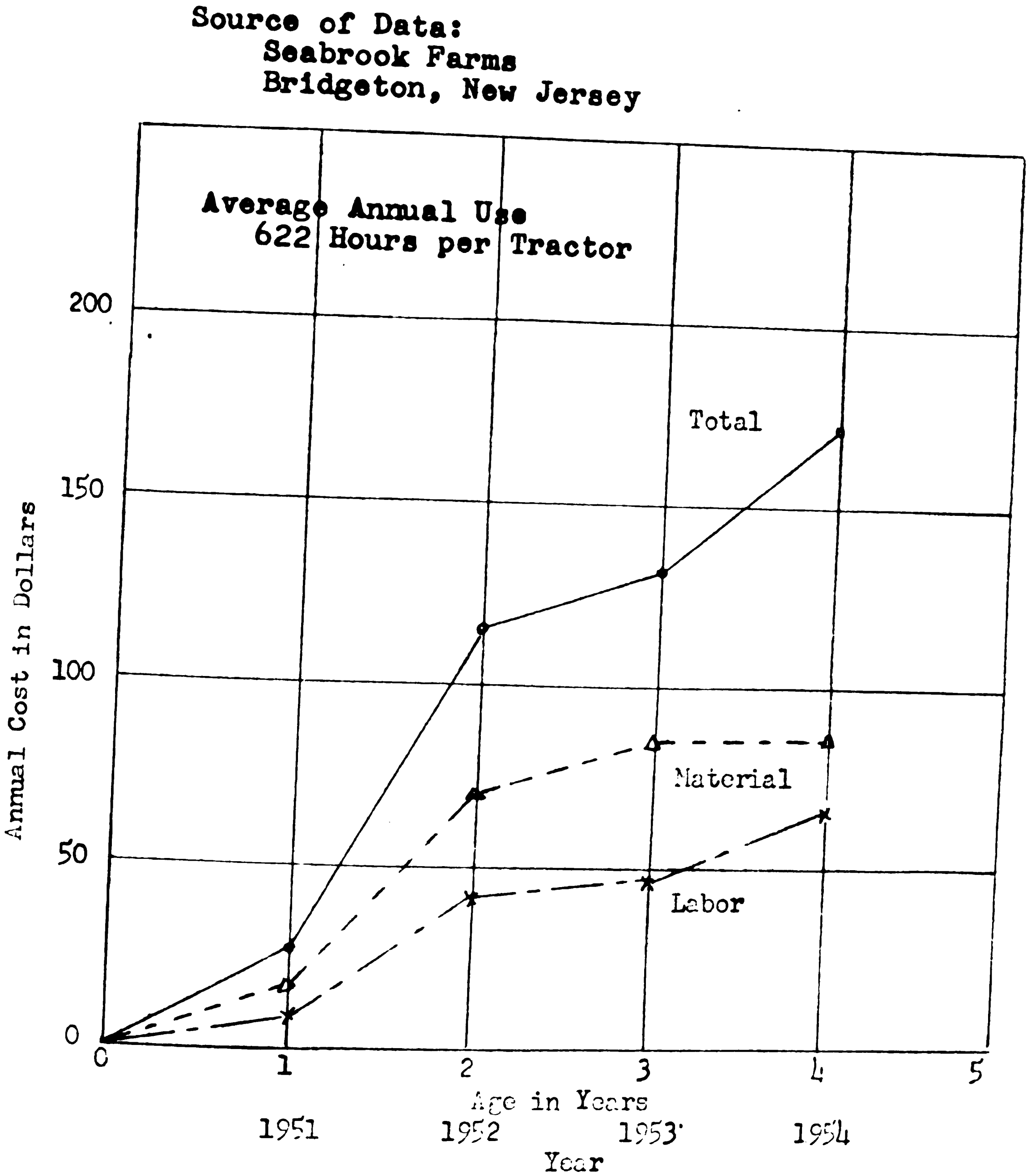

Fig. 17. Relationship Between Average Maintenance Costs and Use of Three Oliver "77" Diesel Tractors.

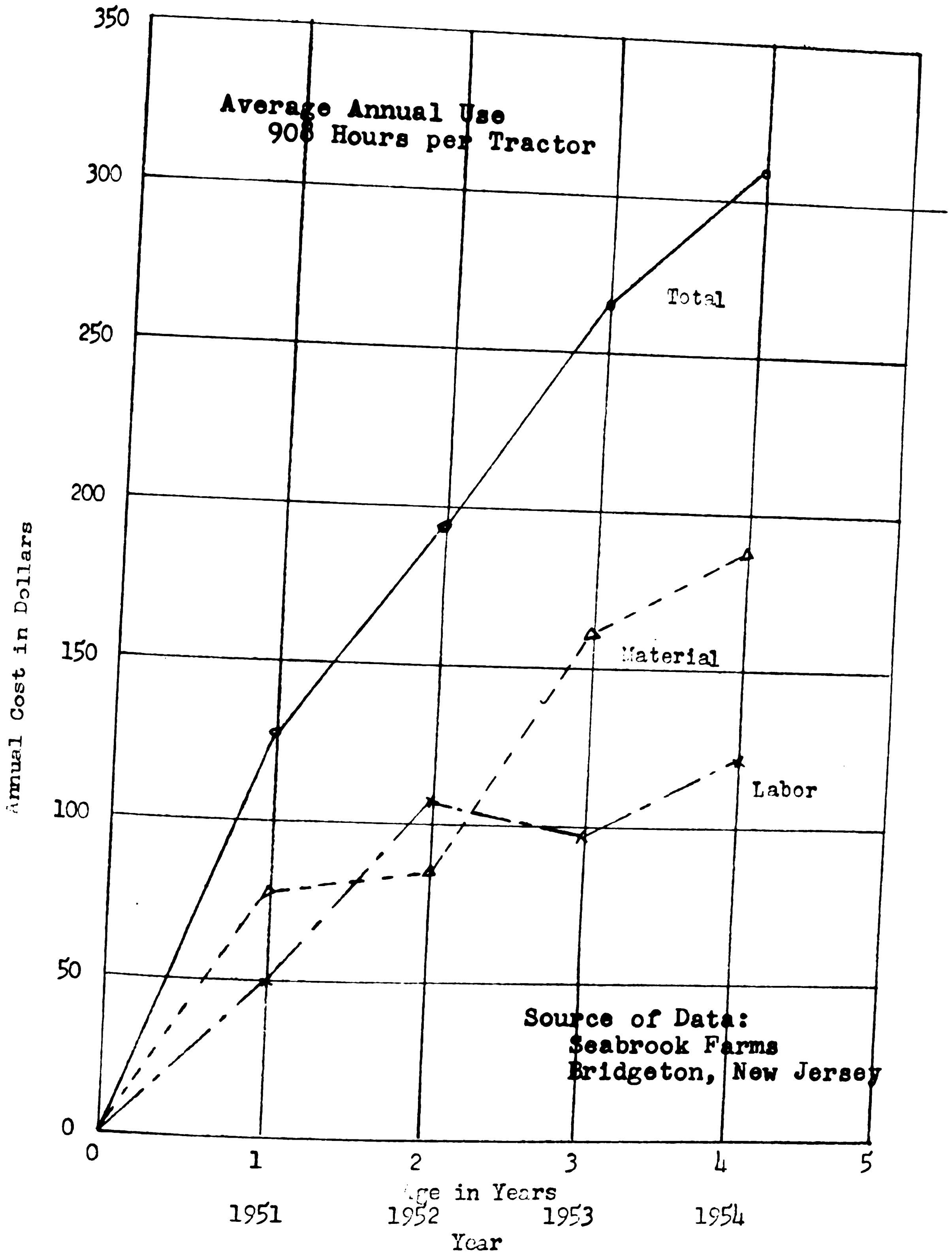

Fig. 18. Relationship Between Average Maintenance Costs and Use for Twelve Oliver "88" Diesel Tractors.

Part VI

Development of a Technique for Estimating When a Farm Machine is No Longer Economical to Operate

Once a farmer purchases a farm machine he will at some future date be faced with the problem of making a decision when to replace it with a new or more modern machine. When to justify replacement of a machine is a controversial question among farm operators and depends upon their judgment for determining when a machine is in need of replacement. Even large commercial farming operators depend only upon intuitive judgment for determining when a machine is in need of replacement. It is therefore of great concern that a more scientific means of approach be worked out whereby one can determine the time when a machine is no longer economical to operate.

There are two basic reasons for replacement: (a) when a machine ceases to function physically, or (b) when it does not provide service as economically as a replacement. The idea of replacement should occur when it is most economical rather than when an item of equipment is worn out, appears to be contrary to the fundamental concepts of thrift to many people. People tend to feel secure with familiar equipment and to be skeptical in regard to change, even though they may profess a progressive outlook.

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Replacement probably should be thought of as a method of conservation; that is, conservation of effort, energy, material and time resulting from replacement. Therefore, the causes for replacement might involve one or more of the following:

(a) Excessive maintenance

(b) Inadequacy - capacity not adequate, thus resulting in untimeliness of operation and loss of returns from crop due to reduced yield and quality.

(c) Obsolescence - owing to improved design of newer equipment.

(d) Reducing efficiency - resulting in loss of crop, higher fuel and oil consumption, etc.

(e) Ability of new machine to combine a number of distinct operations to be done by one machine.

(f) High resale value for old machine.

(g) Greater returns per dollar invested.

(h) Pride of ownership of new machine.

(i) New machine more dependable and easier to operate.

Some methods which have been advocated and used for making replacement determination in industry, as designated by their replacement criterion, are:

1. Replace every X years or Y hours. This method has the disadvantage that the costs involved in operating the machine are not solely a function of age or total hours of use, since operating conditions, skill of operator and kind

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of maintenance will influence the operating costs. It also ignores the price and productivity of the new machine.

2. Replace when the machine is fully depreciated. The disadvantage of this method is that the rate of depreciation used may not be the true value and does not take into consideration the increased maintenance cost due to excessive use and poor maintenance.

3. Replace when the maintenance cost of old machine exceeds the depreciation charge of the new machine. This method is based on the fact that direct operating costs such as fuel, lubricants, and other incidentals will be the same for the new machine and the old machine. This may not be true for a particular machine. It also assumes that the rate of depreciation is the same for the new machine as for the old machine, which may not be true.

4. Replace when the unit cost of the old machine is lowest. The chief disadvantage of this method according to Dean (1948) is that the point at which decline of depreciation cost is just canceled by the rise of maintenance and other costs, has no economic significance except when compared with an alternative course such as average life cost of new machine.

5. Replace when the machine is "worn out" beyond repair. This method does not appear to have any reasonable justification since with modern methods of maintenance a machine can be made to run almost indefinitely by merely replacing or rebuilding worn parts.

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6. Replace when expected machine costs (capital and operating) during the next year are higher than average annual costs (capital and operating) of a new machine sufficient to yield an adequate cost-savings return. Dean (1948) calls it the capital earnings method and highly recommends it. However, he says this method also has limitations and that it can have errors in projecting costs into the future. This method requires training in economic analysis and capital budgeting.

A Method for Determining When a Tractor is No Longer Economical to Operate

The method that will be proposed here might be called the minimum-cost method. The criterion for this method is the theory of maximum profit as used by production economists. When the marginal cost equals the average total cost, a point has been reached on the production function curve which is considered to be the maximum profit point. It should be noted that when this point is reached the average total cost curve will be at a minimum.

Bradford and Johnson (1953) make the following statement:

> The fundamental economic principle with respect to the profitable use of machines is the same as that with respect to other production factors. One must equate the marginal cost of using a machine with its marginal value product. Marginal returns include labor saved, value of marginal physical product, timeliness, and increased quality of product.

In applying the above criterion to tractor costs it is assumed that the marginal returns (output) from the tractor remain constant. This assumption is reasonably correct when the tractor is kept in good repair, used a constant amount each year and that the jobs it performs are timely. It is believed that when the average costs become equal to the marginal cost a point has been reached where one needs to make a decision regarding replacement.

Marginal cost is defined as the increment of cost added to total costs as a result of raising the level of output by one unit. Mathematically it is defined as the slope of the total cost curve. Arithmetically, marginal costs can be calculated by dividing the increase in either total or variable costs by the increase in output which results from the addition of inputs to production process. This method does not give exact marginal costs but is the average marginal unit cost for the range of the increase in output.

For determining exact marginal cost it is necessary to take the first derivative of the total cost curve.

It should be pointed out that the marginal cost curve will always intersect the average variable and average total cost curves at their minimum point.

In order to demonstrate the proposed method for estimating when a tractor is no longer economical to operate, the following assumptions were made:

<u>Depreciation</u> was based on the average "as is" appraisal values as given in National Tractor and Farm Implement Blue Book. To be more accurate one should take the current appraisal values in the area of use.

<u>Interest on investment</u> was assumed to be six percent and was charged off each year on the undepreciated balance. Interest is assessed at the end of the year, but the balance of the investment on which it is calculated is that which stood at the beginning of the same year.

<u>Insurance</u> was assumed to be one percent. Actually the rate for insurance might better be taken as some fraction of one percent.

<u>Taxes</u> were assumed to be two percent. The rate, of course, will vary with the locality. Taxes are based on some percentage of the actual value. The percent of value used in Table XVII is that suggested by the Michigan State Tax Commission for Tractors.

<u>Repairs</u> are based on the values suggested in Figure 11 for the seven Farmall "M" tractors. Table XVII shows the cost factors used for determining when the tractor is supposedly no longer economical to operate. The table was prepared in such a way that all cost figures are based on an initial investment of $100.

Table XVII does not include all costs involved when estimating total cost of operating tractors. The other costs are fuel, oil, lubrication and daily service, and housing.

TABLE XVII

RELATIONSHIP BETWEEN AVERAGE COST TO DATE AND MARGINAL COST BASED ON AVERAGE VALUES FOR SEVEN FARMALL "M" TRACTORS OPERATED AN AVERAGE OF 550 HOURS PER YEAR

End of Year	Value	Depreciation		Int on Investment 6%	Insurance 1%	Taxes 2%		Repairs	Average Cost to Date	Marginal Cost
		Percent	Dollars			% of new cost	Dollars			
0	$ 100.00	0.0	0.00	$ 6.00	$ 1.00	75	$ 1.50	$ 0.30	$ 40.80	$ 40.80
1	68.00	32.0	32.00	4.08	0.68	65	1.30	0.90	28.30	15.80
2	59.16	13.0	8.84	3.55	0.59	55	1.10	1.80	22.89	12.07
3	54.13	8.5	5.03	3.25	0.54	50	1.00	2.90	20.50	13.32
4	48.50	10.4	5.63	2.91	0.48	45	0.90	4.20	19.17	13.87
5	43.12	11.1	5.38	2.58	0,43	40	0.80	5.70	18.40	14.51
6	38.12	11.6	5.00	2.29	0.38	35	0.70	7.30	17.98	15.47
7	33.32	12.6	4.80	2.00	0.33	30	0.60	9.00	17.77	16.29
8	28.96	13.1	4.36	1.74	0.29	25	0.50	10.90	17.77	17.80
9	24.59	15.1	4.37	1.48	0.25	20	0.40	12.90	17.87	18.77
10	20.85	15.2	3.74							

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Williams (1936) indicated that for a tractor kept in good repair the fuel and oil consumption costs will increase only a few percent during its service life. Bateman (1955) states that based on their experience the increase in fuel consumption was less than ten percent for the total period of service life. The oil consumption was observed to be less than 15 percent for the total period. Since these costs are practically constant they would have ngeligible effect on the point where average cost curve crosses the marginal cost curve. Since the annual charge for housing is based on some constant percentage of initial cost it would therefore not affect the location of point desired on the cost curves.

Examination of Table XVII and Figure 19 indicates that the average cost to date and marginal cost will be equal at approximately the end of the ninth year. In other words, if the criterion for determining the point at which a tractor is no longer economical to operate is correct, it appears from the results that one might consider replacement at the end of the 9th or 10th year. At this time the average cost has reached a minimum point and the marginal cost is getting greater than the lowest average cost.

It should be noted in Table XVII that rate of depreciation and rate of repairs have the greatest influence on determining the year when the lowest operating costs will occur.

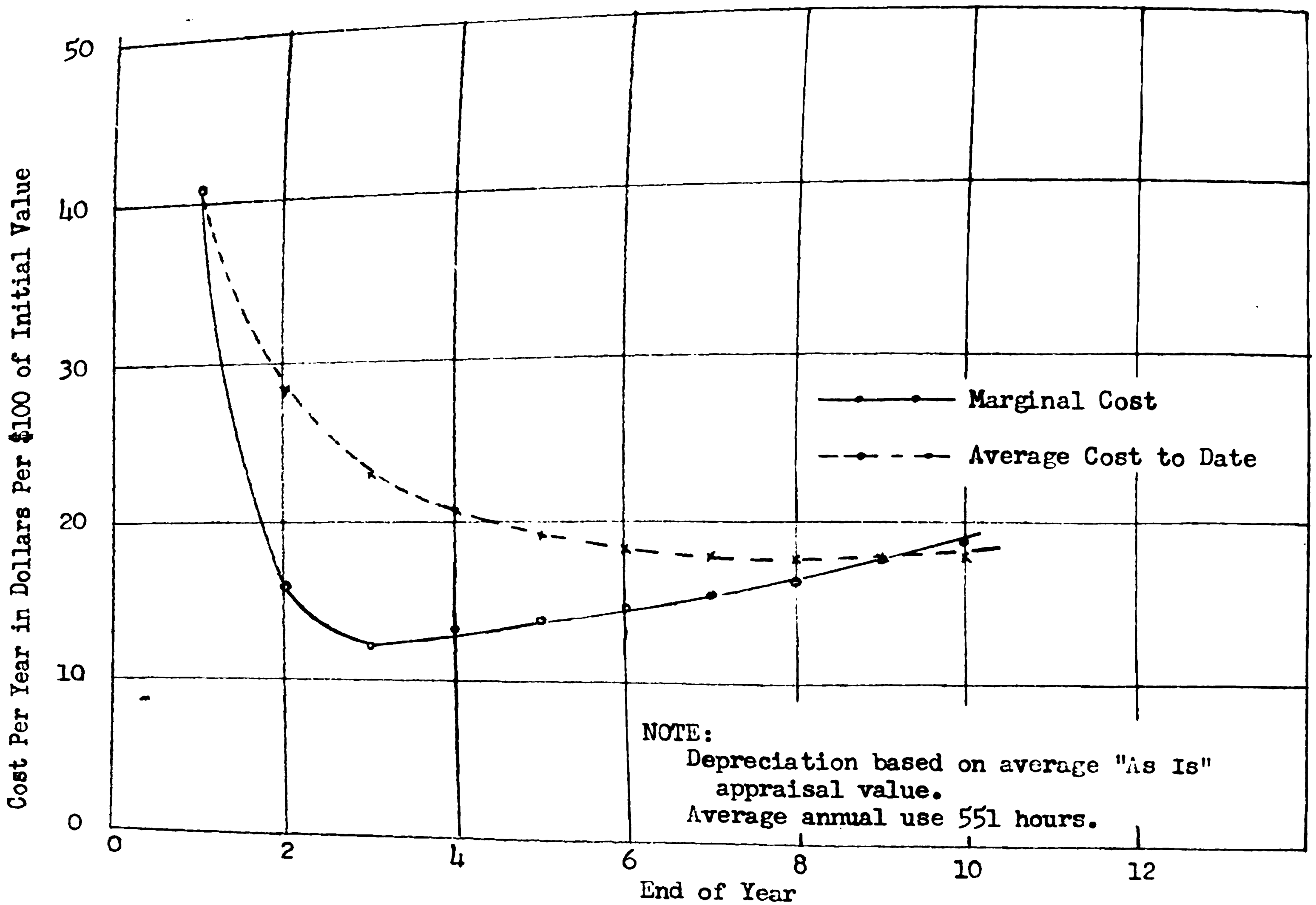

Fig. 19. Relationship Between Marginal Repair Cost and Average Repair Cost to Date for a Group of Seven Farmall "M" Tractors.

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The question often arises whether the purchase of a second-hand tractor would be cheaper to operate than a new one. Figure 20 shows the relationship of average cost to date and marginal costs for a tractor purchase new and a second-hand tractor purchased at different ages.

It is of interest to note that the second-hand tractor will operate at a lower average cost up to and including the six year old. The primary reason for this result lies in the fact that the higher depreciation rates in the early years have a greater influence on costs than do the maintenance or repair costs. It may also be noted that a three year old tractor will operate at the lowest average cost. The marginal cost curves for the second-hand tractors were assumed to follow the same trend as the new tractor for the years in question after the first year of use.

In general it might be stated based on the results in Figure 20, that from an economic point of view a three year old tractor would provide the lowest average operating cost but probably should be kept for a shorter period of time than a new tractor.

In actual practice, however, a farmer generally purchases a tractor to operate for several years of service and not for resale purposes.

From the foregoing analysis it appears that the method proposed for determining when a tractor is no longer economical to operate would consider primarily the factors

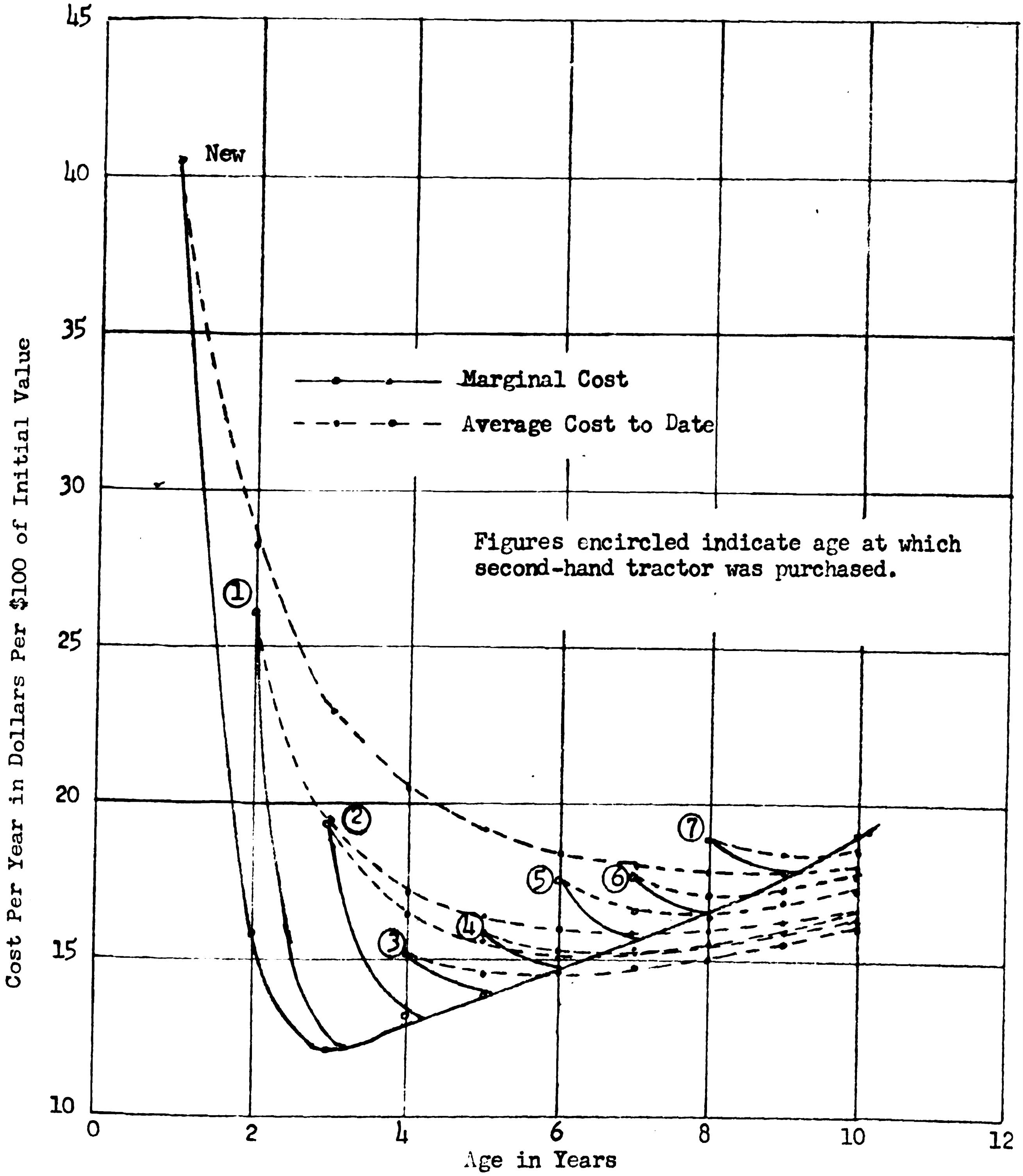

Fig. 20. Relationship Between Average and Marginal Repair Costs for a Tractor Purchased New and Second-Hand.

(a) obsolescence, and (b) excessive maintenance. This method will have limited use since it does not account for factors such as reliability, inadequacy due to size, improved efficiency resulting from better design of new machine, labor saved, personal desires such as better comfort and other possible hidden cost savings which one might realize with the replacement of a new tractor. We are also assuming that the new tractor will follow the same rate of depreciation and maintenance requirement, which is not necessarily true. It is believed, however, that past performance records for repair costs for various types of equipment are quite useful in predicting the maintenance costs of future machines.

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CONCLUSIONS

1. It appears that the declining balance method of depreciation as suggested by tax legislation for income tax purposes might also be used for estimating cost of depreciation for farm machinery when the exact amount is not known for estimating cost of operating machinery. This method tends to give a more realistic value than the straight-line method of depreciation which is commonly used.

2. The method used for determining assessment schedule for taxes of farm equipment is not consistent among the states studied.

3. Repair and maintenance cost data from the commercial farms, Seabrook Farms and Green Giant Company tend to indicate a linear relationship between total maintenance costs and use for the years studied thus far; however, more years of service or hours of use are needed in order to get more conclusive evidence.

4. Results of a study of repair cost data on seven tractors taken at the University of Illinois for a period of ten years indicate that repair costs increase at an increasing rate according to the relationship $Y = 0.314X^{1.61}$ where Y is repair cost in percent of new cost, and X is the year in question. This relationship is valid only for an average annual use of 550 hours per year.

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5. A method was worked out for estimating the approximate time when a tractor should be replaced or is no longer economical to use. Results for group of tractors purchased new and operated an average of 550 hours per year indicate that they should be replaced at the 9th or 10th year.

6. For second-hand tractors, it was observed that a three year old tractor would give the lowest average operating cost due to the high rate of depreciation during the first two years of use.

7. It is believed that more detailed information is needed on how repair costs vary with use for the various farm machines since it is one of the important factors which determine when a point is reached beyond which the machine ceases to be economical to operate. Past performance data of certain machines is probably the best known source of information for predicting behavior of future machines.

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