AN ANALYSIS OF SYSTEMS AND EQUIPMENT FOR HANDLING MATERIALS ON MICHIGAN LIVESTOCK FARMS

By

Robert William Kleis

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

1957

Approved ______________________

ROBERT WILLIAM KLEIS ABSTRACT

As much as 80 percent of the total labor load on livestock farms is associated with work in and around the farm buildings. Almost all this work around the farmstead is involved in materials handling. Considering the fact that many materials are handled several times, a rather modest livestock farm operation could easily involve handling 2,000 tons or 4,000,000 pounds of materials annually.

Agricultural experiment stations, industry and other agencies are devoting much attention to the general problem of materials handling through programs of research and education. However, these activities are suffering from a lack of specific and applicable data on the requirements for and effects of performing various operations by different methods. Most existing information is based upon case studies and examples. As such, this information can be appropriately applied only to other situations with similar conditions, if such exist.

This study was not concerned with theoretical effects or conditions but with the actual materials handling situation on livestock farms in general. The project included a sufficiently large number of farms to permit valid statistical analyses of the data; 320 farms were studied.

Thirty different materials handling operations were analyzed in this study. The methods of performing each operation were classified as eliminated, manual, semi-mechanized, mechanized or automatic. Data obtained from each of the 320 farms for each of the thirty operations included annual tonnage, method of handling and man-hours per ton. The analyses of these data provided tabulated information on the performance of each operation by various degrees of mechanization. As an example, the total man-hours per ton for handling baled hay is 2.05 for completely manual operations and .38 on farms with the greatest mechanization and efficiency. These data do not represent individual farms but means of varied numbers of farms.

Additional data were obtained, analyzed and tabulated, relating to the first costs, operating costs, repair costs, age, expected life and annual usage of twenty different items of materials handling equipment. The greatest total cost per hour used is associated with the barn cleaner; $1.63 per hour used. When work capacities are considered, a man's time is worth $.41 per hour in competition with the barn cleaner. Similar data were obtained for other mechanical units.

The data have been processed statistically and summarized to serve as reference data for education and promotion activities. They also serve to demonstrate readily those operations which are most in need of engineering attention. Farmers' comments were noted and also serve to emphasize the most critical needs. Hay and grain handling are, in general, the most critical from the standpoint of quantity and nature of effort required. Silage and manure handling, on the other hand, are more highly mechanized and the component operations are more commonly integrated into complete systems.

A rather detailed analysis was conducted on the correlation of investments in materials handling equipment to over-all relative labor requirements. The resulting correlation coefficient of .193 with 310 degrees of freedom is highly significant.

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INTRODUCTION

Farming is frequently referred to as a 'way of life'. This is not generally contested but its importance is decreasing with respect to serving as a primary basis for choosing to enter or continue farming as a career. The uniqueness of farming and farm living is lessening with advances in such things as transportation and communications. Other factors have come to the forefront for consideration by those who are comparing farming to other vocations for purposes of making a decision.

Modern agriculture is a highly technical field and farming is a business. A successful farm is a paying farm. An unsuccessful farm soon looses its appeal as a 'way of life'.

The farm provides the farmer with a job, work for his family and perhaps some work for hired labor. The largest single cost in farming is the cost of labor. It is the principle thing the farmer has to sell. The efficiency associated with the use of labor is then, often the determining factor of the success or failure of a farm business.

Many production processes and practices have their bases in tradition. In a changing technical field and competitive business, however, historical precedent is hardly a sound operating guide. One of the general traditional notions among farm people has been that long hours of 'hard work' is an indication of a thrifty and good farmer. While this is a wholesome and refreshing attitude to encounter, it is suggested that, as a criterion of successful farm operation, it might be modified to 'effective work'. Accomplishment, and in turn productivity, does not result necessarily from hard work but from effective application of effort. There is a trend toward the use of energy applied through mechanical units for greater effectiveness of human effort. This trend is not particularly recent in origin but yet has much need for continuation.

Investments in machinery on farms today are seldom below $5,000 per farm and frequently reach levels of $20,000 or more on larger farms. The average undepreciated investment in machinery (42) on farms in central Michigan in 1955 was $7,937. In comparison with these investments in field machinery the common investments in equipment for reducing labor about the farmstead are quite insignificant. This, coupled with the fact that on livestock farms as much as 80 percent of the work load is around the farmstead, indicates a lack of balance in investments for labor reduction. There are perhaps several logical reasons for this unbalance.

1. The high percentage of effort expended in and around farm buildings on livestock farms is

caused to a large extent by the rather advanced stage of mechanization of field operation.

2. Electric service on many farms is relatively new and the availability of application equipment even newer. With the exceptions of water systems and milking machines most of the major items of labor reducing equipment have been developed to a state of satisfactory operation since the termination of World War II.

3. There is a lack of uniformity of procedure in performing farmstead operations which makes it difficult to develop one unit which will fit the circumstances of every farm. This situation did not exist to such an extent in the case of field machinery.

4. Because of the situation mentioned in item three and because much of the farmstead equipment must be installed as part of a system within a farm structure, the merchandising of such equipment is more difficult. Because of this and the fact that volumes of sales are rather low, merchandising programs have not been developed to the satisfaction of the farmer.

5. Farmers, in general, have not developed an appreciation of the amount of time they devote to materials handling about the farmstead, and

continue to underestimate the value of that time.

6. There is a serious lack of specific information concerning the effects of the use of mechanical farmstead equipment on labor efficiency and in turn on over-all production efficiency.

The study and analysis reported in this thesis were designed and conducted to provide some of the material mentioned in item six. It is expected that this material will be useful in planning and executing educational programs directed toward the problems indicated in items three through five, especially number five.

OBJECTIVES

The general objective of this study is to evaluate the effects of the use of mechanical equipment for materials handling in livestock farm operations in Michigan. More specific objectives are:

1. To obtain data on labor requirements for performing various materials handling operations with different degrees of mechanization under actual operating conditions.
2. To evaluate the effect of materials handling mechanization on over-all production efficiency.
3. To assemble information on costs of owning and operating various specific items of materials handling equipment.
4. To determine what is actually being done with whatever, if any, time is saved by the use of mechanical equipment.
5. To determine the critical needs for improvement of existing or development of new equipment for livestock farms.

REVIEW OF LITERATURE

Much work has been done and a great deal has been written on problems and topics related directly and indirectly to materials handling on farms. Whether it be classified as materials handling, farm work simplification, chore mechanization, farmstead mechanization, feed handling, chore labor efficiency, or farmstead automation, it is directed toward the common objectives of reduction of labor and drudgery and/or improving production efficiency. The references cited here represent only a small portion of what is available and only a part of what was reviewed in connection with this study.

Some general observations resulting from a review of past and current work and published material in this area are:

1. A large part of the published material is a popular style; either extension publications or popular magazine articles.
2. Much of the material is supported only by the judgment of the author rather than research findings. This is not to say that it is not serving a worthy purpose, but it must be evaluated according to what it represents.

3. Considerable duplication of effort exists in this general area of research.
4. Nearly all of the work has been and is applied research.
5. Most of the activities and reports deal with the development or performance of a unit for a specific operation with little consideration being given to it as part of a system.
6. Current concern is shifting toward the analysis and development of systems for handling materials on farms. This appears logical. The development of a solution to a materials handling problem must be reduced to working on the specific operations involved. The solution with respect to method and equipment for a particular operation should, however, be considered in relation to other operations and equipment in the over-all system for that farm.

Significance of Materials Handling on the Farm

The farmstead of a livestock farm is a processing plant where the raw materials such as hay, grain, silage, water and concentrates are converted into milk, eggs or meat. When considered in this respect, the importance of materials handling procedures as a principle factor in production efficiency is apparent. As in industrial processing plants, materials handling on the livestock farm is essentially a matter of movement from one processing unit to the next or from one location to another without involving a process. Also, as in industry, materials handling on the farm involves storage, physical processing, continuous metering, bulk quantity control, chemical processing and blending. The similarity extends further to the disposal of waste products such as corn cobs and manure and the handling of plant materials such as bedding.

The tonnage of materials handled on a livestock farm, while small compared to industrial plants, is substantial in terms of effort involved. In a modest livestock enterprise, such as a twenty cow dairy herd, the annual tonnage of materials involved would be about 500 tons (28). Much of this material would be handled five or six times or more so that the tonnage handled annually could well be in the range of 2,000 tons or 4,000,000 pounds. On larger farms these quantities would be proportionally greater.

The importance of the materials handling problem is not, however, essentially a function of its magnitude (21). It is rather a function of the proportion of total effort which materials handling represents. Materials handling on livestock farms represents a large portion of the effort required in such enterprises.

Mechanization of field operations has shifted the peak labor loads to the farm buildings. About one third of all farm work, including cash crop enterprises, is done there (41). The percentages for livestock enterprises (2) are considerably higher as illustrated in Figure 1. As shown, eighty percent of the total work in milk and poultry enterprises is performed in and around farm buildings. This work is nearly all expended in materials handling operations, especially on poultry production.

The percentages are somewhat lower but still substantial in enterprises involving hogs, cattle and sheep; the figures being about 40, 30 and 25 percent respectively. As with poultry, this work is practically all connected with materials handling.

Furthermore (41), when the size of these various enterprises is considered and the actual hours are recorded, the production of milk and eggs accounts for over half of the hours of work performed in and around farm buildings in the United States. In the light of the importance of dairy and poultry enterprises in Michigan, materials handling is surely a primary factor in agricultural production efficiency.

Relationship of Farmstead Mechanization to Farm Operation

The degree and nature of mechanization and other labor saving procedures of materials handling operations which can be effectively applied is directly related to the nature of the livestock program. Self-feeding of grain is

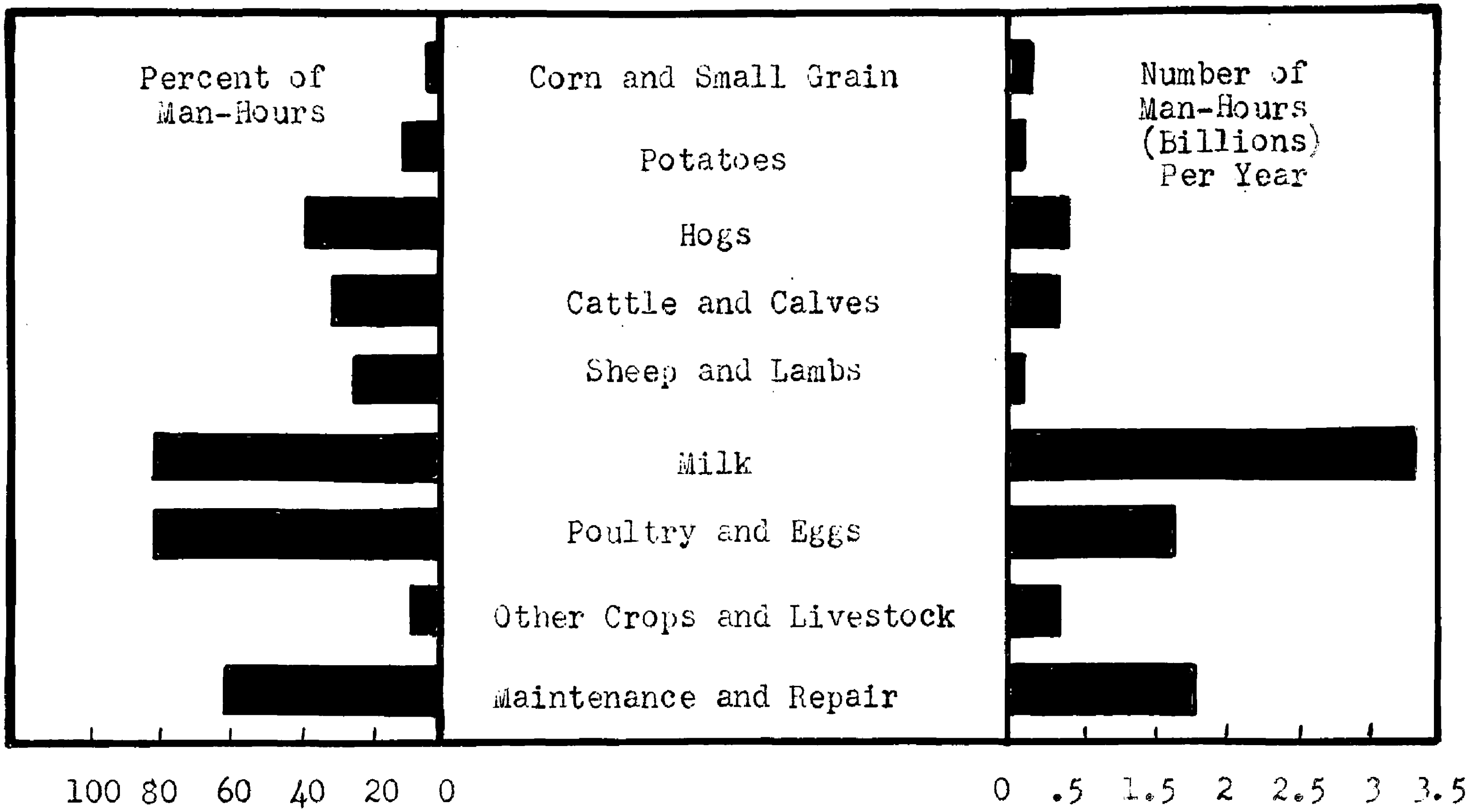

Figure 1. Work done in and around farm buildings in the United States.

accepted as a sound production practice for hogs, while it is not for beef cattle or dairy cattle. Shelled corn is commonly fed to hogs while ground ear corn is the more commonly used for feeding beef cattle. The requirements of handling equipment and procedures are therefore different.

General production practices for a given type of livestock also influence the materials handling problems. For example, the materials handling requirements are considerably different for a stanchion system dairy operation as compared to a loose housing system. Self-feeding of hay and silage from ground level storage is well suited to loose housing operations, while in stanchion barns roughages must be moved and distributed to the cows. Whether or not roughages are self fed in turn affects the possible field harvesting procedures. Likewise the most efficient method of feeding hogs depends upon whether they are being pastured or fed in a dry lot; whether sows are farrowed in portable houses or in a central house. Also involved in these alternatives is the problem of manure removal.

A third relationship is that between suitable handling methods and type of materials involved for a given type of enterprise. Geographical location has a primary effect in this respect. Different areas are adapted to different types of roughage, different grains, different commercial supplements and different storage requirements. Horizontal silos are more suited to drier and better drained areas. A farmer near Detroit may have access to economical brewers grain, while one near a New York Central terminal may find it desirable to buy soy bean meal in large bulk lots. Their handling requirements are different from those of an operator who buys 32 percent protein supplement in bags. The form, as well as the physical characteristics of the material, including the flow and bridging properties, differ. Many mechanical units which work well for handling soy bean meal are not at all suitable for brewers grain or bulk bran.

Fourthly, farmstead materials handling operations are often directly associated with field operations. Whether corn is harvested with a picker or with a picker-sheller, has much effect on methods and equipment for handling it. Harvesting method may affect methods of unloading, elevating, distribution in storage; removal, metering, blending, grinding and perhaps even feeding if grinding is not included.

It is obvious then, that materials handling problems and requirements are highly dependent on nearly all harvesting and livestock management practices. Sometimes production practices can be modified to accommodate certain desired material handling methods. More often, however, it is more sound to establish production practices on other bases and the problem is then one of fitting and reconciling materials handling methods to them.

Mechanization Versus Labor Inputs

Resources involved in agricultural production can be either technical complements or technical substitutes (20). They are considered technical complements when they must be provided in somewhat fixed proportions. For example, if the size of a dairy herd is increased, the physical facilities and feed quantities must be increased nearly proportionally.

Technical substitutes on the other hand are resources which can be interchanged or reshuffled while production remains constant. Labor input and investment in feed handling machinery are then technical substitutes. When one is increased the other may be decreased for a given production level.

While there are many other types of resources involved in planning an over-all farm program, this study is concerned primarily with the relationship between mechanization and labor. When these two resources are considered further, a complicating difference is discovered. Labor input may be considered a theoretically continuous factor while mechanization is largely accomplished in discrete steps. Machines are manufactured in certain discrete sizes with fixed capacities and thus represent a category of indivisible factors. The indivisibility of these units can be overcome if the services rendered instead of the units themselves are considered. This, however, leads to hiring machinery or custom work which introduces serious and often costly management problems.

Labor also in some areas may be essentially a discrete factor in the balance against machinery. There are several reasons why seasonal or temporary help may not be practical in certain situations. When this is the case, labor too becomes an indivisible factor where the smallest unit is the full time worker.

The effect of indivisibility is illustrated in Figure 2 (20). In this illustration, labor is considered a continuous variable.

> The presence of corners such as a, b, c, d, e and f on a product contour, give rise to important implications. Any one of the corner combinations causes factor combinations at these points to be highly stable. Price ratios have to change outside of wide ranges before substitution is profitable. The ratio of machine price to labor price must vary by more than the difference in the slopes cb and bh if an original machine-labor combination at b is to be discarded as unprofitable. This is the reason why farmers often cling to given techniques as factor prices and farm costs vary.

This reasoning appears sound and significant in any consideration of farmstead mechanization as well as in field operations upon which it is based. In considering its application to the area of this study there are several observations which seem pertinent.

1. The discrete nature of mechanization units is less severe with field machinery because the investments are smaller and more variable due to varying degrees of mechanization of a particular operation.
2. Few farms are operating at a 'corner' combination point.

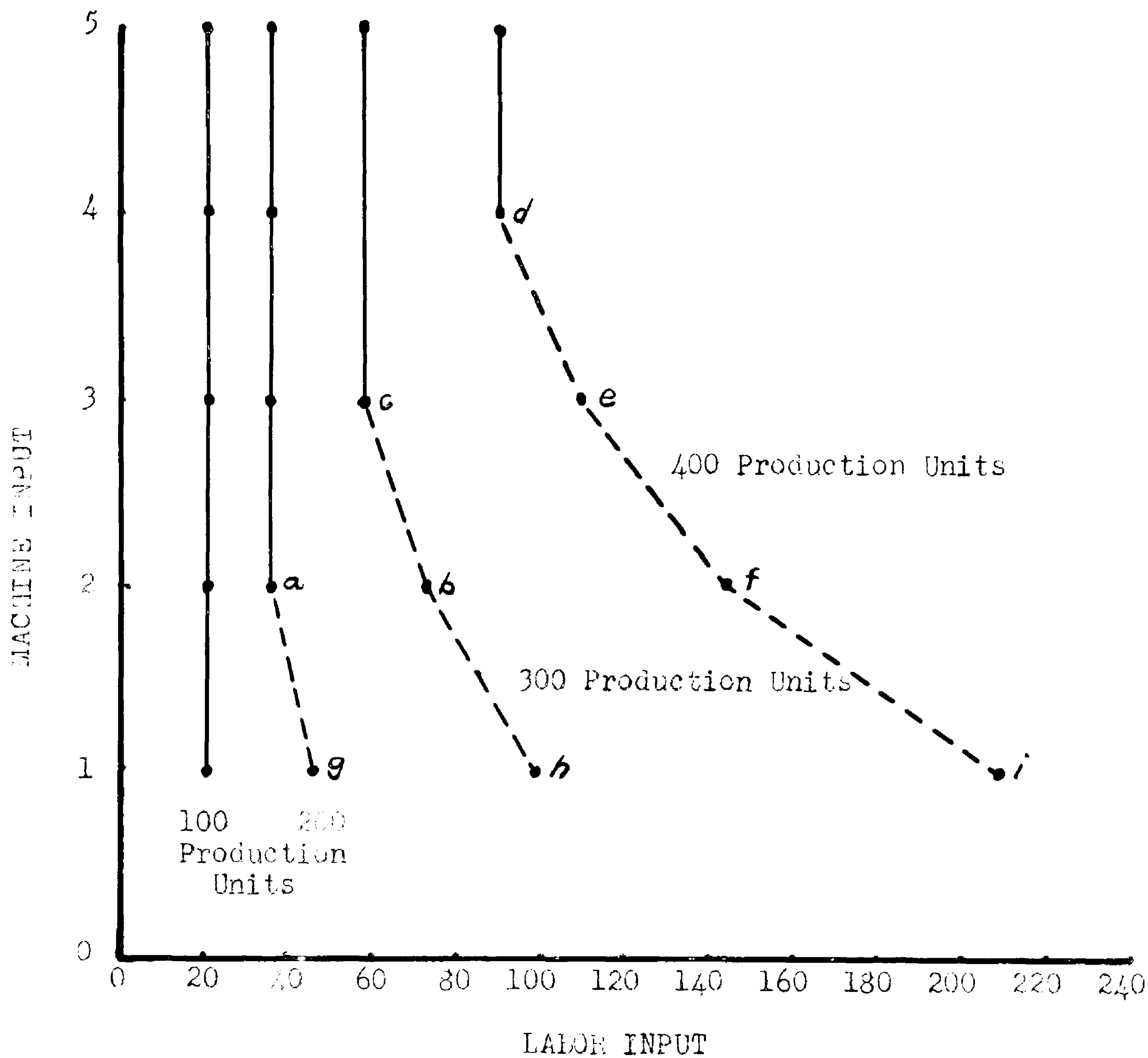

Figure 2. Product contours and resource substitution with one indivisible factor.

3. It is doubtful that many farmers are adhering to their current or past procedures because of the relative slopes of the production contours on either side of their location.
4. It might well be desirable for an operator to modify his machine-labor combination, even though price relationships have changed little or none since its inception; if it were not originally the most satisfactory.
5. The observation that is most significant with respect to this study is that there exists practically no data from which to determine the production contours, determine slopes and locate the desirable corner points. It is intended that material assembled in this field study will be applicable to such programming procedures.

Intangible Factors

There are several factors which influence the planning of materials handling which can not be evaluated in engineering or economic terms. Indeed, these factors can be evaluated only in the abstract manner and then only by the individuals directly concerned. Their value whether positive or negative with respect to any particular alternative will depend on such things as local sociological conditions and the attitude, physical condition, philosophy and personal objectives of the individual operator.

The author recalls a comment often made by Professor E. W. Lehmann, outstanding pioneer of agricultural engineering, "Thank goodness farmers do not operate by economics alone". Few would challenge the factuality of this statement and not many would contest the philosophy involved. On the other hand, it must be remembered that failures in farm operations are, in the final analysis, based on economics alone. Other factors must, however, be recognized and considered in connection with planning procedures and systems for performing materials handling operations.

The human factor. - Efficiency in the performance of any particular operation depends much upon the characteristics of the individual involved (41).

> Certain human characteristics such as skill in using a method, the effort exerted and working conditions greatly influence the workers rate of activity. The dexterity of some people in the use of their hands may make them more productive than others in spite of methods used. On the other hand the attitude of a person toward his work may completely offset the advantage of a good method. Farm work simplification must direct attention to both the job and the worker.

This same source (41) discusses the physical strength of a worker as a factor in determining operating methods. Age, physical stature and general health are all involved here, but they do not permit general evaluation nor pre-evaluation.

Another characteristic of primary importance in connection with mechanization is mechanical aptitude. Even the best engineered unit may fail to function satisfactorily under the influence of an incompetent operator. In mechanization this factor is eliminated only with complete automation. The automatic water system, now commonly used, is an example of independence from operator ability.

Family labor. - Much of the work on farms is done by women and children (41). Their energy is adapted to more jobs and greater effectiveness by mechanization and other forms of work simplification. Indeed, young people and their objective appraisal of work methods have been and are responsible for much mechanization and work simplification.

The term 'farm family' can not be directly and conversely associated with the term 'family farm'. With a high percentage of all farms can be associated a 'farm family'. The proportion of 'family farms' is, however, considerably smaller and is reported, often with alarm, to be decreasing (20). From 1950 to 1955 approximately 20,000 farms in Illinois went out of existence as separate units (27). All the aspects of the desirability of this shift to larger operating units are not directly relevant to this discussion. Suffice it to point out that the larger scale operations involve more non-family labor and thus less family scale enterprises. From the standpoint of mechanization and production efficiency, this is essentially sound (42).

On the increasing number of farms where hired labor is involved the question of mechanization, or substitution of capital for labor, can be evaluated in physical and economic terms. To do this, however, the effect of mechanization on labor required for various operations must be known.

The evaluation in specific terms of capital investment in machinery as a substitute for labor become difficult when the labor in question is or becomes family labor. Few, if any, would attempt to put a dollar value on the educational, disciplinary and emotional effect of family youth participation in the responsibilities of managing and operating a farm business. Absolute evaluation becomes a reality, however, when it becomes economically impossible to continue operation on a small, however long established, scale.

The intangible 'fringe benefits' mentioned above are not exclusive characteristics of the 'family farm', but rather of the 'farm family'. The enjoyment of these benefits does not preclude the recognition and adoption of technological developments. Indeed, they may be considered complementary. Acceptance of this theory makes the evaluation of these intangibles immaterial.

Availability and reliability of labor. - The nature of the labor supply in a given area is a highly significant factor in determining operating methods. In many industrial areas the cost of hired labor may be prohibitive. In other areas and for irrelevant reasons labor may not be available for hire. In such situations the substitution of capital through physical equipment for labor may not be a question but a necessity. Manual handling of materials may not be, in reality, an alternative.

Quality and reliability of hired labor is another factor to be considered. Incompetence or failure of the hired man to report for work may prove extremely costly for a farm operator in certain seasons and disturbing and inconvenient, to say the least, in all seasons. This may be illustrated (not proven) by an example. Edward Vitko of Gardner, Illinois, operated 160 acres with 36 dairy cows with one full time hired man from 1946 to 1951. Paying $3,000 per year plus house and other benefits, he became 'fed up' with trying to obtain and retain a good man. In 1951 he invested approximately $8,000 in an automatic feed grinding system, automatic conveying equipment, a barn cleaner, a silo unloader and a pipe line milking system (26). Since 1951 he has operated on the same scale without a hired man but with more participation by his wife and young daughter. This increased family participation was made possible by mechanization. This is also an example of a 'farm family' enterprise being converted to a 'family farm' by mechanization.

Principles of Work Simplication

The factors and operations involved in farm work simplification have been summarized into five items (41).

1. Eliminate all unnecessary work.
2. Simplify the hand and body motions used in doing the work.
3. Provide more convenient arrangement of work and location of materials for doing the work.
4. Increase the adequacy, suitability and use of equipment needed for the work.
5. Organize the work routine for full and effective use of men and machines.

These five items of consideration in work simplification may be further summarized as a critical examination of the following:

1. Operations required.
2. Operator efficiency.
3. Farmstead arrangement.
4. Physical equipment.
5. Work pattern.

Principles of work simplification more specifically directed toward materials handling on livestock farms are listed (28) as:

1. Do away with unnecessary work.
2. Use gravity wherever possible.
3. Let livestock do the work whenever practical.

4. Reduce distances.
5. Handle feed in bulk form rather than in small batches.
6. Mechanize hand operations.
7. Select versatile equipment.

It is significant to note that 'mechanization' appears near the end of each list of principles. This is logical in that capital investment in machinery should not be considered if the operation can be eliminated or performed as efficiently by other means. It is important that any particular operation be considered as one component of the over-all system rather than an independent entity; it is not uncommon for an apparent solution to one operation to be completely incompatible with other operations or desirable management practices.

The objectives of this study are related directly to evaluation of procedures and equipment involved in items 1, 2, 3, 5 and 6.

The design and development of systems for handling materials is an engineering problem. The justifications of, and needs for, improved systems are, however, essentially economic. The inseparability of engineering and economic considerations is evident in each of the fore mentioned lists of principles. These lists are essentially the same; one being compiled by an Agricultural Economist and the second by an Agricultural Engineer.

Mr. B. A. Moski, an industrial engineer and a plant manager (30), considers materials handling principles from a slightly different standpoint. As an engineer preparing material for other engineers, he finds it necessary to discuss materials handling principles in terms of economic effects as well as engineering methods. With slight modification of terms for agricultural applications these principles are:

1. As materials handling does not increase the value of a product, the entire cost of handling is an economic waste.

2. The objective of all materials handling analyses is the elimination of all handling.

3. If materials handling cannot be eliminated, it is necessary to minimize the frequency and distance of all handling as well as the use of all manual effort.

4. The cost of actual travel is generally small in comparison with the cost of unloading, loading, lifting, lowering and storing materials.

5. Maximum use should be made of gravity and power to replace manual effort, because of the resultant decreased costs.

6. An uninterrupted flow of materials to processing and production centers serves to increase labor productivity by minimizing delays in processing operations.

7. An ideal system consists of each productive operation being performed while the material is progressing to the next operation.

While these principles were prepared for application to industrial engineering they also apply to agricultural engineering. One important factor which brings in another principle is the fact that some of the processing units on farms are animals and, therefore, have mobility and limited judgment. This makes it possible to consider letting livestock do some of the work.

Another factor for consideration, especially with respect to continuous flow and use of equipment, is that most materials handling operations on the farm are seasonal in nature. This makes it desirable to consider versatility of equipment for more than one use to increase its annual use.

In this list (30) also, mechanization is not particularly prominent in the order of presentation. It is brought into consideration only after other methods of eliminating manual effort have been found inapplicable.

As with all general principles, these cannot be applied alone for the solution of a specific problem or the design of a particular system. The development of a solution or recommendation must be based upon principles applied through and by means of specific data on requirements, conditions and effect of alternatives. Such data is lacking for the application of engineering to material handling on farms. Hence, the need for this and other studies.

Trends in Mechanization and Production on Farms in the United States

Mention has already been made of increasing investments in machinery on farms and the shift toward fewer but larger operating farm units. There is much evidence of this in various references and particularly in United States Census reports. It might well be suspected from the numerous abandoned farmsteads observed in passing through farming areas, that the land is being farmed but has been combined with an adjoining or near-by farm for a larger enterprise.

Figure 3 illustrates the trends in machinery investments, production and hired labor on farms in the United States since 1870. These curves up to 1945 (20) indicate a 450 percent increase in machinery and equipment and a 350 percent increase in production. A substantial portion of the increased production must be attributed to clearing new land and bringing it into production. This would also account for much of the increase in mechanization.

The data plotted for 1950 are from a different source (40) but adjusted to be consistent with the earlier figures. They indicate a continued rapid upward trend both in production and mechanization.

The amount of hired labor increased during the period 1870 to 1910 but at a relatively low rate. Since 1910 hired labor has declined steadily even though production has more than doubled. Mechanization, primarily of field operations, must be largely credited with this.

Hired labor is, however, only part of the over-all farm labor supply. The number of farm units has been, and is, dropping as shown in Table I. As a result of this the number of operators and amount of family labor has decreased also.

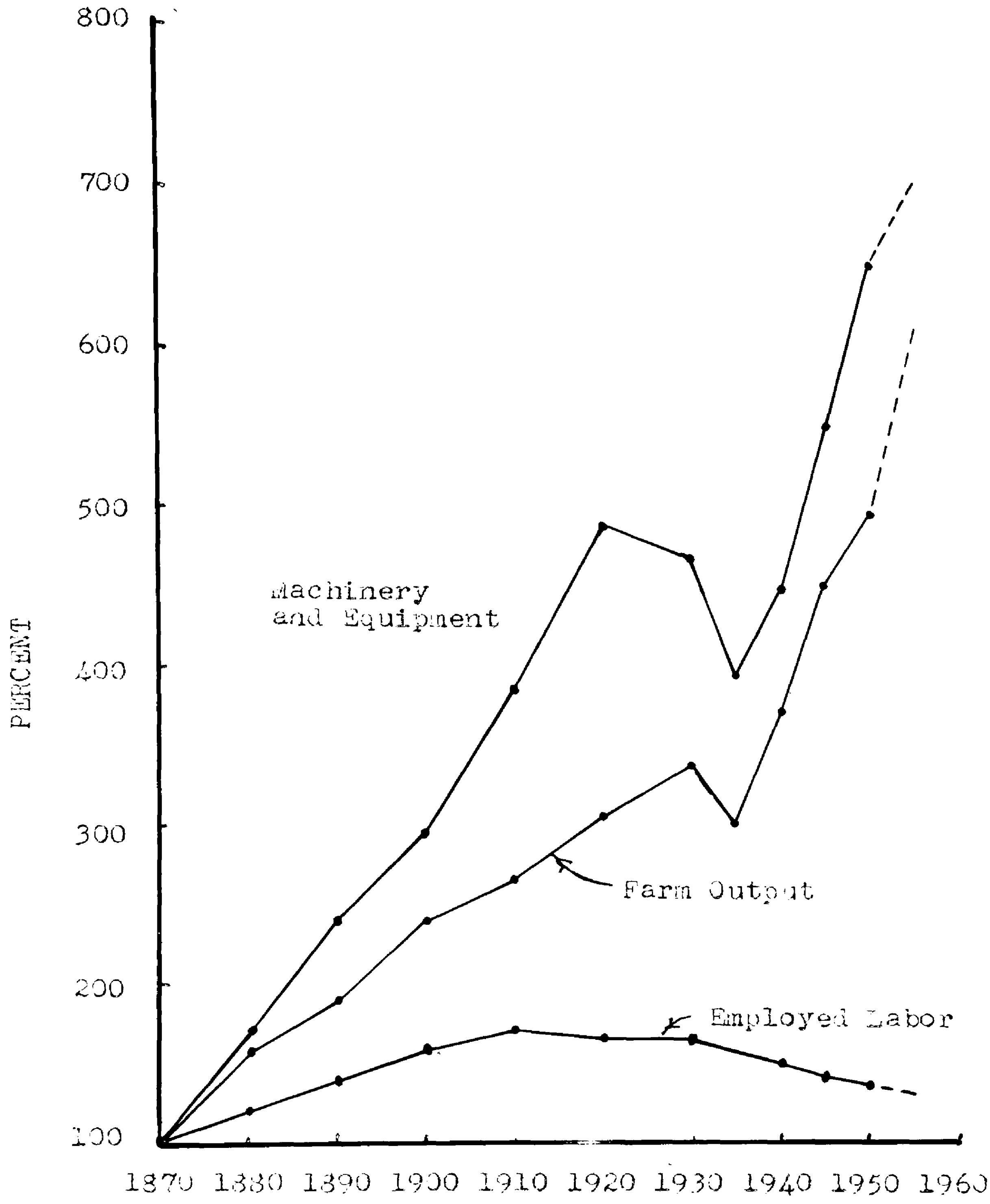

Figure 3. Total volume of farm machinery and equipment, output and employment in the United States. Volume in terms of 1935-39 dollars. Index numbers, 1870=100. (References 20 and 40)

TABLE I

NUMBER OF FARMS AND ACRES FARMED IN MICHIGAN (FROM U.S. CENSUS REPORTS)

	Number of Farms	Acreage in Farms
1900	203,261	....
1910	206,960	18,941,000
1920	196,447	19,033,000
1930	169,372	17,119,000
1940	187,589	18,038,000
1950	155,589	17,270,000

Combining the effects of increased production and trends in hired and operator labor the production per worker approximately doubled in the half century preceding 1920; then again almost tripled in the following thirty years with the introduction of the internal combustion tractor with power machinery. The latter statement is further demonstrated in the Farm Output column of Table II. The total farm production indices went from 47 to 137 in the period 1920 to 1955; slightly less than tripled.

A comparison of the data for crops and livestock in Table II also reveals some differences in efficiency trends. Crop production per man hour has increased to nearly 400 percent since 1919 while livestock production efficiency has less than doubled. This adds support to the contention that farmstead mechanization has not kept pace with mechanization of field operations.

TABLE II

INDEX NUMBERS - FARM PRODUCTION PER MAN-HOUR[a]
EAST NORTH CENTRAL DIVISION
(1947 - 49 = 100)

Year	Farm Output	Livestock and Products				Crops			
		Total	Meat Animals[b]	Milk Cows	Poultry[c]	Total	Feed Grains[d]	Forage[e]	Food Grains[f]
1919	46	71	84	60	71	42	36	51	30
1920	47	69	86	59	72	43	38	52	24
1925	51	72	88	67	75	46	41	54	30
1930	50	74	90	68	78	43	35	55	37
1935	58	70	89	66	81	53	47	57	38
1940	66	82	95	73	82	60	56	64	50
1945	84	92	98	90	94	80	77	81	75
1950	112	109	102	109	106	118	122	126	125
1955	137	120	104	119	118	155	179	142	192

[a] *Changes in Farm Production and Efficiency*, U.S.D.A., ARS 43-33, 1955.
[b] Cattle, calves, sheep, lambs and hogs.
[c] Chickens and turkeys.
[d] Corn, oats, barley and sorghum grain.
[e] Hay, sorghum forage and silage.
[f] Wheat, rye and buckwheat.

INVESTIGATIONAL PROCEDURE

Because it was desired to obtain information relative to mechanization of materials handling on Michigan livestock farms[1] in general, it was necessary to study a rather large number of farms selected in a manner to provide a representative sample. A limited number of examples or case study farms could not provide the desired material.

It was recognized that the farm operations to be studied were subject to extreme variations due to varying local conditions, economic levels, operator aptitudes and attitudes, family size, condition of farm, arrangement of buildings, etc. In order to minimize the influence of variations caused by indirectly related factors it was doubly important that the number of farms studied be large.

It was decided that the study should include at least 320 farms. The number of farms studied and the amount of information obtained from each farm made it impractical for one person to make the study. The Consumers Power Company made the services of its twenty-two Farm Service Advisors available for securing field data. These data were collected during October and November 1956 after a

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[1]The term 'livestock farms' is used here in its broad sense to include dairy and poultry farms rather than the Census Bureau definition which includes only hogs, beef cattle and sheep.

series of four regional orientation and kick-off meetings with the Farm Service Advisors. Each Advisor worked with approximately fifteen farmers.

Information Desired

For purposes of clarity, in explaining the type and various classifications of material obtained from each farm, copies of the original data sheets are included on the following four pages in essentially the same form as they were used.

General

Operator's name ________________ Farm No. ________________

Interviewer's name ______________ County ________________

Owner operated ________________ Tenant ________________

Total acreage ________________ Operator's age __________
(both owned and rented)

Man months/year ____________ (family) ____________ (hired)
(consider children over 12 and under 16 as half-man for time they work) (include custom work as hired labor)

Livestock

Dairy cattle: _________ (cows) _________ (young cattle)

Beef cattle: __________ (cows) _________ (feeders per year)

Hogs: ________________ (sows) _________ (marketed per year)

Sheep: ________________ (ewes) _________ (marketed per year)

Poultry (per year) ____ (layers) ______ (broilers or fryers)

____ (turkeys)

Use of Time Saved by Use of Feed Handling Equipment

Check one (or more if applicable)

1. _____ Expanded production
2. _____ Reduction of labor supply
3. _____ More leisure time
4. _____ Care and maintenance of machinery
5. _____ More time and care devoted to other production activities
6. _____ More time for community and service activities (Farm Bureau, political, church, 4-H, etc)

Needs: What feed handling operations need new or improved equipment most critically?

Feed Handling Operations

Material	Operation	tons/yr	Method* 1, 2, 3, 4 or 5	Man hrs/ ton **
Hay	Unloading (from field)			
	Distributing in mow			
	Removal from mow			
	Moving to feeding point (including loading and unloading)			
Baled / Chopped / Loose	Feeding			
Silage	Unloading (from field)			
	Distributing in silo			
	Removal from silo			
	Moving to feeding point (including loading and unloading)			
Vertical silo / Horizontal silo	Feeding			
Bedding	Unloading (from field)			
	Distribution in storage			
	Removal from storage			
	Moving to area of use (including loading and unloading)			
Baled / Chopped / Long / Other	Distribution in area of use			

* (1) Eliminated - operation not included in farmers program.
(2) Manual - shoveling, pitching, pushing, carrying, etc.
(3) Semi mechanized - such as lifting or shoveling feed on to an elevator.
(4) Mechanized - requires an operator but no hand labor.
(5) Automatic - such as barn cleaners, silo unloaders, self feeders, etc.

** Include time of setting up, changing loads, starting machinery, etc.

Feed Handling Operations

Material	Operation	tons/yr	Method * 1, 2, 3, 4 or 5	Man hrs/ ton **
Manure	Removal from stable			
	Transporting to pile			
	Loading into spreader			
Small grain (including soy beans and shelled corn)	Unloading			
	Moving into storage			
	Removal from storage			
Concentrates	Unloading			
	Moving into storage			
	Removal from storage			
Ear Corn	Unloading			
	Removal into storage			
	Removal from storage			
Ground feed	Grinding and blending			
	Moving to feeding point (including loading and unloading)			
	Feeding			

* (1) Eliminated - operation not included in farmers program.
(2) Manual - shoveling, pitching, pushing, carrying, etc.
(3) Semi mechanized - such as lifting or shoveling feed on to an elevator.
(4) Mechanized - requires an operator but no hand labor.
(5) Automatic - such as barn cleaners, silo unloaders, self feeders, etc.

** Include time of setting up, changing loads, starting machinery, etc.

Feed Handling Equipment

Item (If a farmer is using more than one of a particular item give totals for costs and hours used and averages for age and life)	Number: (e.g. - 3 self feeders or 2 carts	Cost when new (including motors)	Cost of repairs and maintenance per year. (repair parts, belts, pulleys, chain, paint, etc.)	Wattage if electric (consider 1 HP as 1000 watts)	Age in years since new	Total years of expected life (including age)	Hours used per year for all uses
Auger elevator							
Chain or belt elevators							
Blowers							
Grain bin unloaders or meters							
Unloading wagons							
Barn cleaner							
Mechanical feeder							
Grain dispensers							
Self feeders							
Tractor manure loaders							
Silage distributors							
Feed carts							
Track type litter carrier							
Hay hoist							
Hammer mill							
Burr mill							
Other type feed grinder							
Corn sheller							
Feed mixer							

Statistical Design

The farms to be studied were selected on the following basis by the men doing the field work.

1. Livestock farms only.
2. Avoid farms which might be considered 'show farms' on which the economic status is supplemented by industrial money or outside income of any type.
3. Farms to be distributed geographically about the service area of the man doing the field work.
4. Each farm studied should make use of at least one of the items of equipment listed on page four of the field data form.
5. The farms should be selected randomly as far as possible within the restrictions mentioned above.

It was recognized that the selection procedure would likely result in a somewhat biased sample of livestock farms. Item four, in particular, would be expected to cause a bias toward the more highly mechanized farms. Inasmuch as this is a study of the effects of mechanization, this possible bias was considered necessary and, indeed, desirable.

The breakdown of classifications of data for statistical analysis is:

1. Types of materials - 8
2. Operations involved - 30
3. Methods per operation - 5

4. Replication per method - variable.

Other classification criteria for further breakdown of data in analysis are:

1. Owner or tenant operated.

2. Type of livestock enterprise.

3. Form of hay and bedding (baled, chopped or loose).

4. Vertical or horizontal silos.

Many of the data obtained from each farm were needed for classification purposes and for secondary analyses. The data considered of primary and direct interest were the man-hours per ton figure for performing various operation by one of five methods under different conditions. The study was designed for the use of analyses of variance procedures (10, 11, 37) in the analysis of these primary data. It was also anticipated that tests of correlation of certain data would be run.

Data Processing and Analysis

The facilities and mechanical procedures of the computer laboratory were used because of the large amount of data to be processed, analyzed and tabulated. The raw data were transferred from the original data forms to punched cards. In many cases the data required some intermediate processing before they could be put on cards. Eight data cards were required for each farm studied.

The arrangement of the data on the cards is not directly relevant. Suffice it to say that some of the data had to be coded for entry into the cards while the numerical data could be entered directly.

Much of the tabulating and classification was done on the IBM 604 electronic computer. The interpreting unit was also used for removing intermediate and final data from the cards.

The analysis of variance procedures which were planned to be used were shown early in the analysis work to be inappropriate. One of the basic assumptions upon which analysis of variance procedures are based is that the various classifications of data being compared have the same underlying distribution (10). That the means are equal is the hypothesis being tested. That they all have the same normal distributions and homogeneous variances are, however, assumptions which must hold true for the test of means to be valid. The data obtained in this study failed to satisfy the Bartlett test of homogeneity of variance (37). Thus the analysis of variance procedure could not be used.

A form of Student's T test of differences was then used in place of analysis of variance. Because the numbers of items, in various classifications to be compared were not equal, the conventional Student T test could not be used. Rather it was necessary to use the modified test (11) developed by Cochran and Cox where the applicable T value for a given level of significance had to be calculated and weighted according to the two numbers of items involved. This procedure was valid and actually was advantageous as compared to analysis of variance because the specific differences were automatically located.

ANALYSIS OF DATA AND DISCUSSION OF RESULTS

Nature of Farms Studied

The 320 Michigan farms included in this study were selected so as to represent an unbiased sample of livestock farms using some degree of mechanization in materials handling. There is no information available for use in determining to what degree this was accomplished. If such data were available the need for this study would have been considerably less. This sample is not considered to be representative of all Michigan farms nor even of all Michigan livestock farms. It is, however, considered to be representative of the universe defined above.

Geographical distribution. - All of the farms studied are in the lower peninsula of Michigan. This is not considered a significant source of bias because of the relatively small amount of livestock in the upper peninsula. Also the upper peninsula conditions are similar to the conditions in the lower peninsula north of Clare county and the sample is weighted slightly above this line considering the amount of livestock there. This may reasonably be considered to compensate for the limited amount of livestock in the upper peninsula.

Figure 4 shows the distribution of farms studied by counties. The only significant void area is in the Thumb

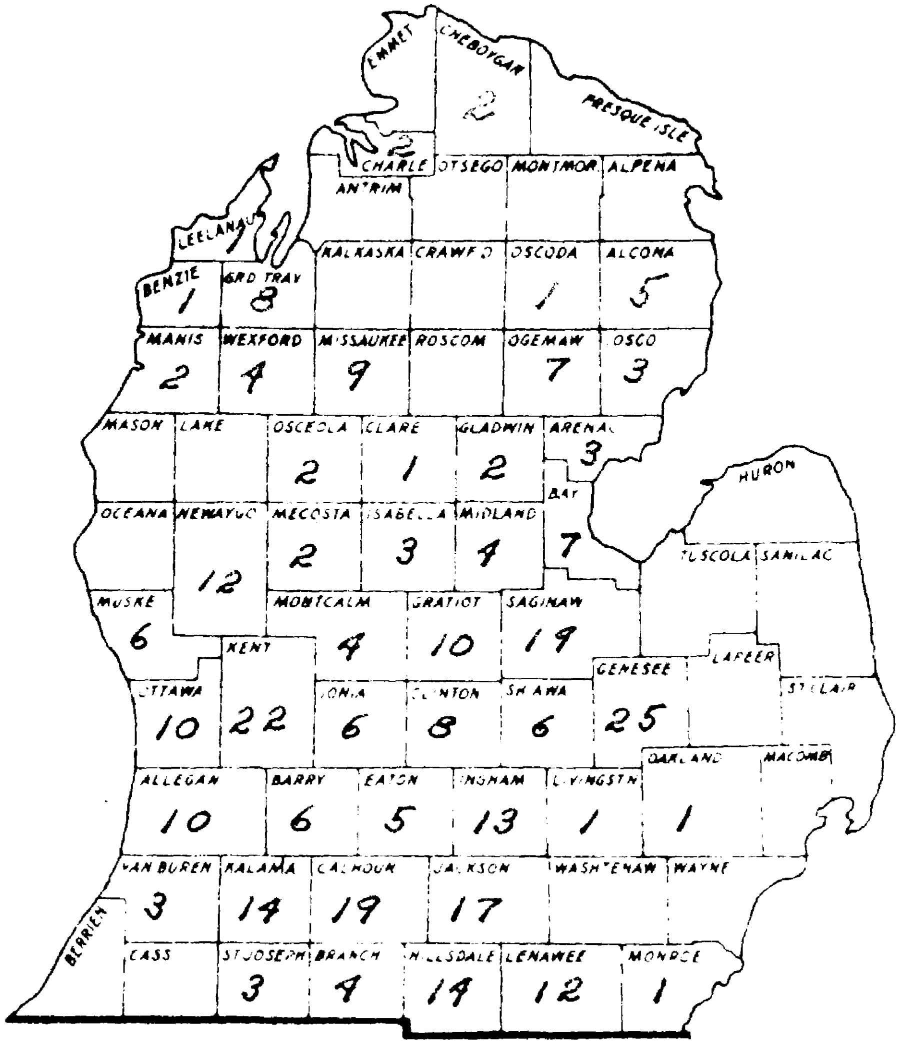

Figure 4. Geographical distribution by counties of farms included in this study.

region. This is compensated for to some extent by the large number of farms studied in Genesee and Saginaw counties. In other areas the numbers are about proportional to the amount and nature of livestock farms. The relatively heavy concentrations around Ingham, Kalamazoo and Kent counties are caused by the major cities and the related markets for milk and other livestock products.

Types of livestock enterprises. - Table III shows the breakdown of types of livestock enterprises on the farms involved. It will be noted that the average number of livestock enterprises per farm is more than two. This includes many farms which were specialized in one type of livestock. There were also many farms which had three to five classes of livestock.

Also included in Table III is the breakdown of farm classifications by type of livestock. If a given type of livestock on a particular farm accounted for over 75 percent of the total livestock enterprise, that farm was so classified. (See APPENDIX IV for conversion factors). If no one type of livestock accounted for as much as 75 percent of the total livestock enterprise, that farm was classified as 'general livestock'.

Dairy farms are the dominant classification and this is in line with its importance in Michigan. Five percent beef cattle farms and 4.4 percent poultry farms appear at first glance to be rather low. It should be remembered, however, that these figures represent only those farms where those respective enterprises are almost exclusive. Twenty-nine percent of the farms had some beef cattle and sixty-one percent had some poultry. Perhaps these figures are more indicative of the importance of their enterprises but they also must be considered with an understanding of what they represent.

TABLE III

TYPES OF LIVESTOCK ENTERPRISES
ON 320 FARMS STUDIED

	Farms Having		Farm Classification	
	No.	Pct.	No.	Pct.
Dairy cattle	271	85.0	183	57.2
Beef cattle	93	29.0	16	5.0
Hogs	119	36.2	0	0.0
Sheep	26	8.1	2	0.6
Poultry	195	61.0	14	4.4
Layers	153	47.8	...	....
Broilers	36	11.3	...	....
Turkeys	6	1.9	...	....
General	...	....	105	32.8
Total	704	219.3	320	100.0

<u>Size of farms studied</u>. - Table IV gives the distribution of acreage of farms studied in fifty acre intervals. Approximately two-thirds of the farms are between 100 and 300 acres in size and four-fifths between 100 and 400 acreas. The over-all average is 258 acres. Figure 5 illustrates the size distribution graphically.

TABLE IV

ACREAGE OF 320 FARMS STUDIED

Acreage Interval	No. Farms	Pct. Farms
0 - 49	3	0.9
50 - 99	19	5.9
100 - 149	47	14.7
150 - 199	59	18.5
200 - 249	67	21.0
250 - 299	34	10.6
300 - 349	26	8.1
350 - 399	20	6.3
400 - 449	15	4.7
450 - 549	5	1.6
500 - 549	6	1.9
550 - 599	2	0.6
600 - 649	5	1.6
650 - 699	1	0.3
700 - 749	4	1.2
750 - 799	1	0.3
800 - 849	2	0.6
850 - 899	1	0.3
900 - 949	2	0.6
950 - 999	1	0.3
Total	320	100.0

Average - Over-all = 258
Owner Operated = 254
Tenant Operated = 277

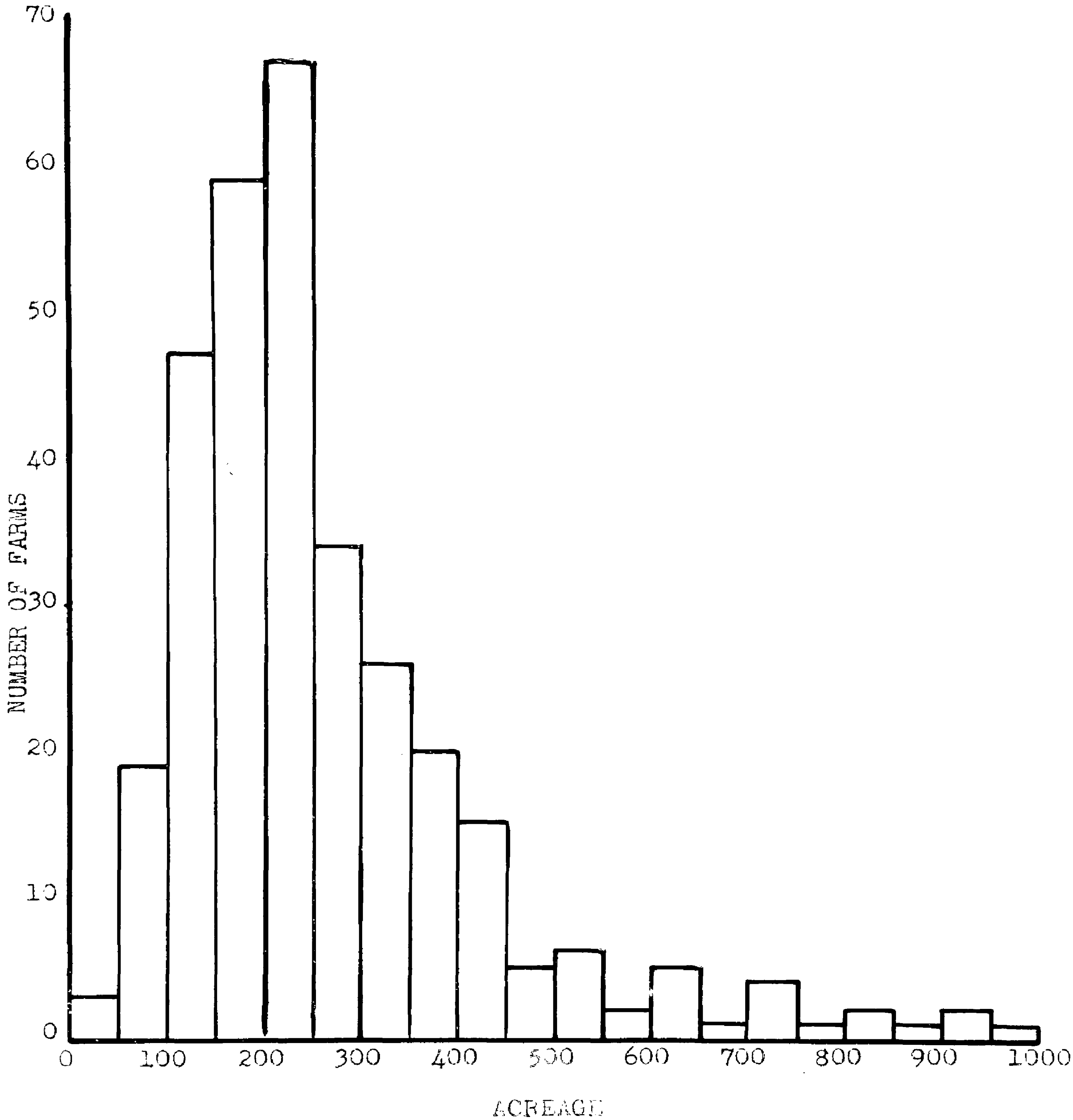

Figure 5. Distribution of acreage of 320 farms studied

The average acreage of the farms studied is somewhat higher than the general average for livestock farms and considerably higher than for all Michigan farms. Here again, however, there is no reason to believe that the size of farms studied is not representative of livestock farms which are turning to mechanization of labor consuming materials handling operations.

It should be noted that the size of tenant operated farms is greater than owner operated farms. This might perhaps have been expected from the standpoint that tenant operations are often the source of livelihood for both the tenant and the owner. Also, often the owner participates to a limited extent in the maintenance of physical facilities.

Age of operators. - The age distribution of operators in ten year intervals is given in Table V. This distribution is rather typical and might well have resulted from a random sampling of all farms. The principle fact to note here is the low percentage of operators below 30 years of age. This is believed to reflect the effect of large capital investments to enter farming, even on a tenant basis.

The declining relative numbers of operators beyond 50 years of age does, as would be expected, show the effects of retirements.

Age versus acreage and investment in materials handling machinery (Table V). - The only significant trend with respect to effect of age on scale of operation is in the decline in acreage operated by operators over 60. This may be the result of either cutting down from their original scale or of size of farms 20 or 30 years ago.

TABLE V

DISTRIBUTION OF AGES OF FARM OPERATORS AND RELATIONSHIP TO FARM SIZE AND MECHANIZATION (AVE. AGE = 430)

Age Interval	Number of Operators Tenants	Owners	Both	Ave. Acreage	Ave. Investment in Materials Hand. Mach.
Under 20	1	0	1	...	....
20 - 29	5	16	21	252	1741
30 - 39	10	90	100	256	2138
40 - 49	6	109	115	268	1971
50 - 59	6	51	57	268	2166
60 - 69	2	21	23	212	1704
70 - 79		3	3	203	2547

It will be observed that investments in materials handling equipment are lower at both ends of the age range. In the younger age bracket this is explained by limited capital. In the 60 to 69 year age interval the cause is not apparent but the decrease is significant. The greater investment which is indicated for the 70 to 79 year age interval is of questionable significance because it is based on only three farms.

Factors Involved in Analysis of Specific Operations

A large and important portion of the information obtained in this study is presented in table form in Tables VI through XXVII. These summarized data are related to specific methods of performing specific materials handling operations. The column of particular importance in each table is the man-hours per ton column. These figures serve for direct comparison of methods which might be used for handling as well as methods of harvesting and types of storage for some materials.

Definitions of the various classifications of methods have been given previously in this thesis but they will be repeated here because they are important in understanding the analyses which follow.

1. Eliminated - operation is not included in the farm program.
2. Manual - operations are performed completely by hand, e.g. shoveling, pushing, and carrying.
3. Semi-mechanized - operations include both manual and machine handling, e.g. lifting bales or shoveling feed onto an elevator.
4. Mechanized - operations involve manual effort only for operating machinery, e.g. bunk feeding of cattle with an unloading wagon.
5. Automatic - requires neither manual handling nor a machine operator, e.g. silo unloaders or self feeders.

Students' T test with T values modified as discussed in the Procedure section was used to test the significance of differences in 'man-hours per ton' for the various methods of performing a specific operation. Significant differences are indicated by an asterisk adjacent to a bracket between the figures involved. It should be pointed out here and remembered when reviewing or using these data that the lack of an indication of significant differences does not imply that apparent differences are not actual. It implies rather that they can only be considered actual with something less than 95 percent confidence; some of them with 90 percent and perhaps some with as low as 50 percent confidence. The magnitude of the difference, the number of farms involved and the sample variances all have an effect on this confidence level.

Figure 6 illustrates what these 'average man-hours per ton' represent with respect to three methods of performing a particular operation. Both significant and non-significant differences are illustrated.

A typical distribution of the man-hours per ton for performing a particular operation is shown by the histogram in Figure 7. It will be noted that this distribution does not assume the shape of a normal distribution. It is somewhat skewed to the left. This is, however, not particularly significant in the application of Students' T test to means but would in theory have a slight effect on the distribution of the statistic T.

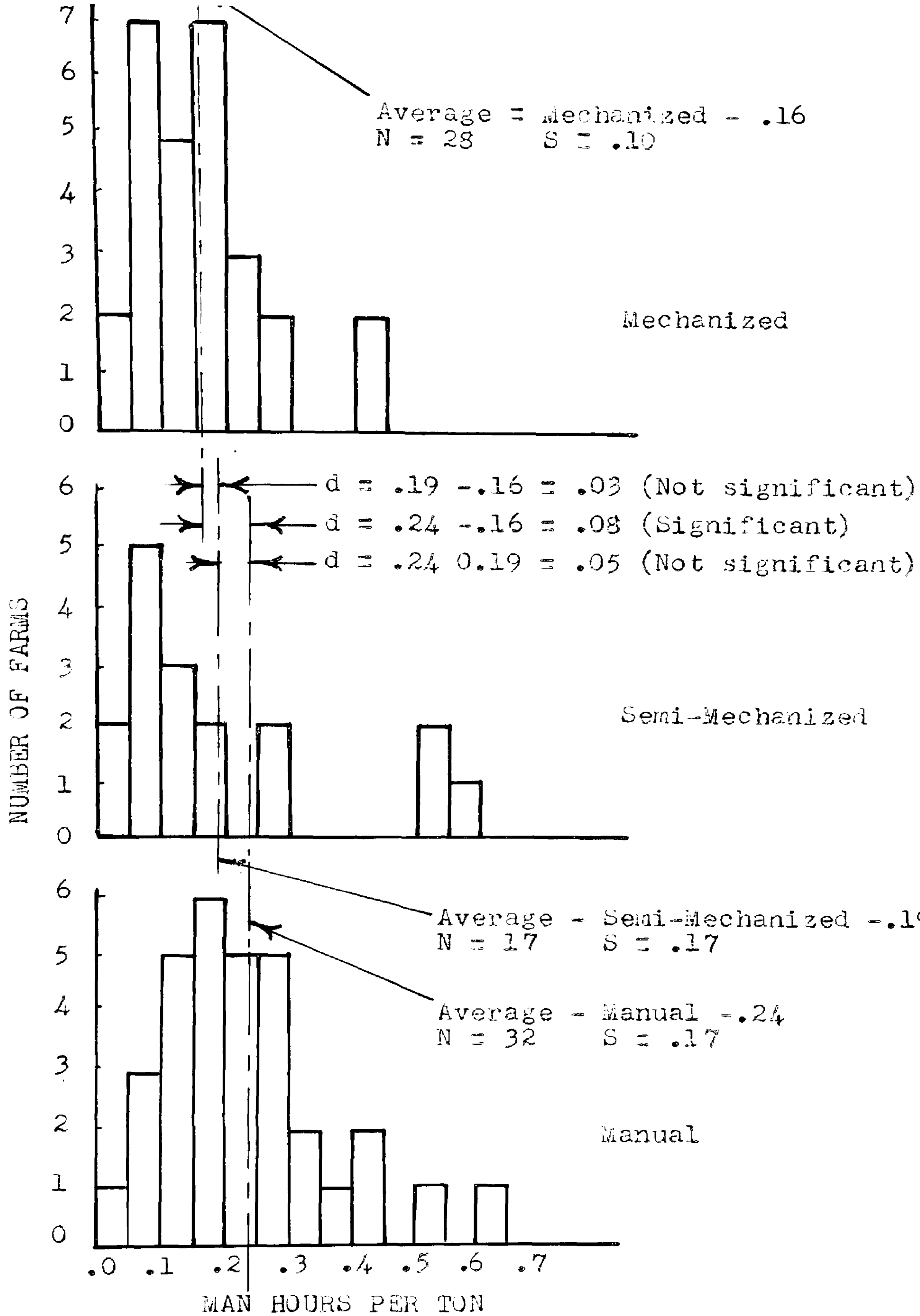

Figure 6. Distributions of man hours per ton for placing Ear Corn in storage by three different methods. This is a typical pattern.

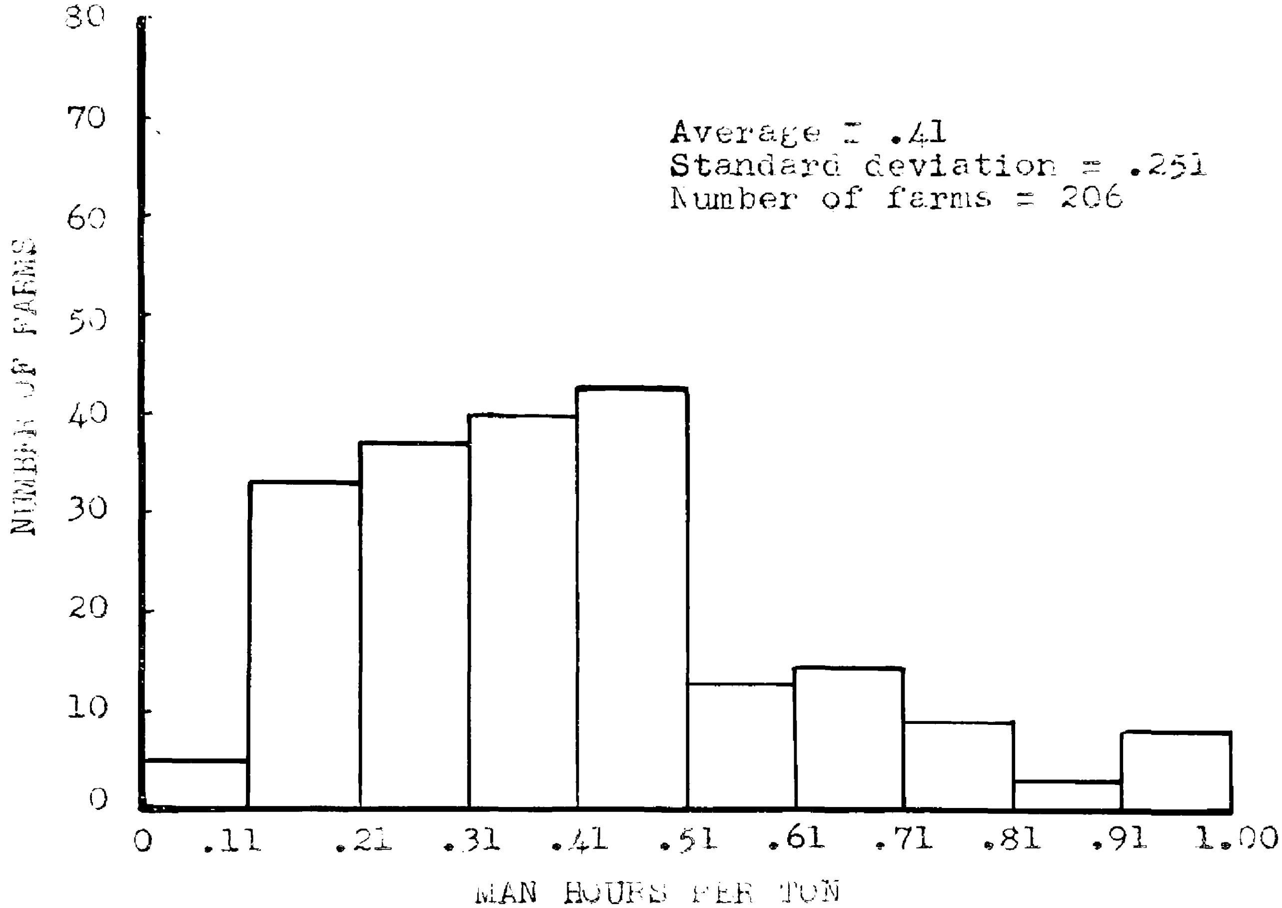

Figure 7. Distribution of man hours per ton for removal of baled hay from the mow.

The other data included in Tables VI through XXVII might be considered secondary or supplementary. The number and percentage of farms employing a given method is first an indication of the extent to which that method is used. Secondly, it can be used as an indication of the reliability of the labor data. When four or less farms are involved the 'average man-hours per ton' figure is of questionable validity.

The annual tonnage data are included only to indicate the magnitude of the operation. When considered together with the relative number of farms involved, an indication of the relationship between scale of operation and method adopted is obtained. It is also used to obtain data for annual labor requirements as discussed in a later section.

The data listed under the heading '95 percent limit' represent the man-hours per ton figures which would not be expected to be exceeded by 95 percent of such operations using that method. These figures were calculated statistically but are based on field data.

Because the data (Tables VI through XXVII) are largely self explanatory when the system and terms of presentation are understood, it is considered unnecessary and, indeed, undesirable to discuss them in full detail in the following sections. Only the more significant and perhaps less obvious points will be discussed.

Hay Handling Operations
(Tables VI, VII and VIII)

It will be noted that the greatest labor requirement per ton, in terms of man-hours, is, as might be expected, with long-loose hay followed by baled hay and chopped hay in that order; the figures being 2.77, 1.57 and 1.37 man-hours per ton, respectively. In spite of this, baled hay is the most commonly used form by a wide margin. Long-loose hay is still used to only a very limited extent and the primary reason is indicated by these data on time requirements.

Further justification for this is apparent when it is realized that these data indicate only labor time and do not evaluate the intensity of effort involved. Handling long-loose hay is hard and disagreeable work. It has, perhaps, contributed more than any other single operation to young mens' decisions to leave the farm. This form of hay is currently used to a rather insignificant extent and the comparison of common forms is then essentially between baled and chopped.

Baled hay requires more handling time than chopped hay for all operations except removal from the mow. Also chopped hay handling is more highly mechanized so that much of the time required is used to operate equipment rather than handling hay directly. Baled hay handling on the other hand involves several manual operations for each and every pound even when maximum mechanization is employed. These operations not only represent time consumed but very hard

TABLE VI

METHODS AND MAN HOURS PER TON FOR HANDLING BALED HAY

Operation and Method	No. of Farms	Pct. of Farms	Ave. Tons Per Yr.	Man Hrs. Per Ton Ave.	Man Hrs. Per Ton 95 Pct. Limit
Unloading from Vehicle	...	....	...	0.23	....
Manual...............	20	9.6	79	0.42)*	0.94
Semi-Mechanized.....	185	88.5	127	0.21)	0.45
Mechanized..........	4	1.9	40	0.31	....
Distribution in Mow	...	....	...	0.25	....
Eliminated..........	19	19.9	137	0.00	0.00
Manual..............	171	81.8	115	0.28	0.67
Semi-Mechanized.....	18	8.6	143	0.25	0.48
Mechanized..........	1	0.5	100	0.10	....
Removal from Mow	...	....	...	0.41	....
Eliminated..........	2	1.0	185	0.00	0.00
Manual..............	206	98.5	120	0.41	0.82
Semi-Mechanized.....	1	0.5	45	0.17	....
Moving to Feeding Area	...	....	...	0.17	....
Eliminated..........	110	52.6	124	0.00	0.00
Manual..............	92	44.1	111	0.36	0.76
Semi-Mechanized.....	4	1.9	276	0.27	....
Mechanized..........	3	1.4	72	0.32	....
Feeding	...	....	...	0.51	....
Manual..............	182	87.1	111	0.58	1.22
Semi-Mechanized.....	1	0.5	170	0.83	....
Automatic...........	26	12.4	148	0.00	0.00
Total.......	209	....	120	1.57	....

*Statistically significant difference at 95 percent level.

TABLE VII

METHODS AND MAN HOURS PER TON HANDLING
CHOPPED HAY

Operation and Method	No. of Farms	Pct. of Farms	Ave. Tons Per Yr.	Man Hrs. Per Ton Ave.	Man Hrs. Per Ton 95 Pct. Limit
Unloading from Vehicle	..	....	...	0.20	....
Semi-Mechanized......	37	42.5	120	0.24)*	0.44
Mechanized...........	50	57.5	124	0.17)*	0.33
Distribution in Mow	..	....	...	0.08	....
Eliminated...........	42	48.3	111	0.00	0.00
Manual...............	18	20.7	121	0.21	0.41
Semi-Mechanized......	4	4.6	159	0.21	....
Mechanized...........	14	16.0	148	0.18	0.42
Automatic............	9	10.4	121	0.00	0.00
Removal from Mow	..	....	...	0.50	....
Eliminated...........	8	9.2	158	0.00	0.00
Manual...............	76	87.3	111	0.55	1.15
Semi-Mechanized......	3	3.5	127	0.59	....
Moving to Feeding Area	..	....	...	0.13	....
Eliminated...........	57	65.5	111	0.00	0.00
Manual...............	25	28.8	141	0.41)*	0.92
Semi-Mechanized......	2	2.3	222	0.23)*	....
Mechanized...........	2	2.3	125	0.17	....
Automatic............	1	1.1	78	0.00	0.00
Feeding	..	....	...	0.46	....
Manual...............	63	72.4	119	0.62	1.42
Semi-Mechanized......	1	1.1	105	1.00	....
Automatic............	23	26.5	122	0.00	....
Total.........	87	....	122	1.37	....

*Statistically significant difference at 95 percent level.

TABLE VIII

METHODS AND MAN HOURS PER TON FOR HANDLING
LOOSE HAY (LONG)

Operation and Method	No. of Farms	Pct. of Farms	Ave. Tons Per Yr.	Man Hrs. Per Ton Ave.	Man Hrs. Per Ton 95 Pct. Limit
Unloading from Vehicle	..	.....	..	0.78	....
Manual...............	1	7.7	30	0.45	....
Semi-Mechanized.....	11	84.6	63	0.83	1.69
Mechanized..........	1	7.7	35	0.50	....
Distribution in Mow	..	.....	..	0.56	....
Manual..............	13	100.0	58	0.56	1.19
Removal from Mow	..	.....	..	0.71	....
Manual..............	13	100.0	58	0.71	1.10
Moving to Feeding Area	..	.....	..	0.19	....
Eliminated..........	7	53.8	70	0.00	0.00
Manual..............	6	46.2	44	0.41	0.74
Feeding	..	.....	..	0.53	....
Manual..............	13	100.0	58	0.53	1.05
Total.......	13	.....	58	2.77	....

work.

Why then is hay baled on more than two-thirds of the farms? It is not a matter of equipment cost even though chopped hay requires, by nature of its form, a higher degree of mechanization. A large portion of the operators who bale hay also have chopping equipment which they use for silage. The baler then represents an added investment. The following statements are commonly offered in defense of baling hay.

1. Chopped hay must be drier for safe storage than baled hay.
2. Chopping hay pulverizes the leaves and creates a severe dust problem in the storage and feeding areas.
3. Field losses due to shattering and pulverizing are greater for chopped hay.
4. Chopped stems are harsh and cause sore mouths in livestock.
5. Baled hay can be stored in rather open shelters or even stacked outside without extensive spoilage.
6. Baled hay may be more easily transported if the hay is to be sold or fed at a location other than near its storage point.

Some of these statements are valid and some are questionable. They are, in either case, real to the operators expressing them, and present design and educational challenges to agricultural engineers. The big advantage of chopping over baling hay is, as shown, that it can be more easily and more completely mechanized. If self feeding is used, all manual handling can be eliminated from chopped hay operations. This is not possible with existing equipment for handling baled hay.

Observation of the data for specific handling operations of both baled and chopped hay, reveals that the operations of removal from mow and feeding are in critical need of engineering attention. They are almost completely manual operations. Mechanical equipment for their performance is non-existent. The only current alternative to manual handling is self-feeding from the mow and this is not possible with many types of enterprises and existing storage structures. The importance of hay in beef and dairy enterprises, the importance of these enterprises in the mid-west and the tonnages of hay involved should lend high priority to work in this area.

Hay pelleting is receiving attention. It is an example of imagination applied to the problem rather than trying to develop smoother fork handles or more convenient bale hooks. Pelleting shows promise of being an answer to many handling problems through elimination of some and adaptability of others to mechanization.

Silage Handling Operations
(Tables IX and X)

Horizontal silos, while used to a lesser extent than vertical silos, appear to be gaining rapidly in popularity. There are two reasons expressed for this apparent trend. They can be built with a low investment for temporary or emergency use and can be constructed at a greater but still relatively moderate cost for permanent use. Secondly, horizontal silos are well suited to self-feeding and other procedures for minimizing handling labor. This is shown by the data in the tables on the following pages. Another observation made while assembling field data for this study is that the lower investment in horizontal silos is perhaps of secondary importance to the users because several of them had vertical silos standing empty.

Spoilage and wastage is one of the disadvantages of horizontal silos. It has been demonstrated, however, that excessive spoilage is not necessary. With proper construction and good management it may be confined to as little as five percent which is comparable to that of vertical silos. In other cases, however, spoilage may be as great as twenty-five percent or even greater.

Silage handling is similar to hay handling in that on farms where it is used, considerable tonnages are normally involved. It is different, on the other hand, in that equipment is available for complete mechanization of essential operations with either type of silo. Feeding silage in a stanchion type dairy barn might be considered an exception to this but it too can be mechanized with existing mechanical feeders.

The average over-all man-hours per ton of silage are 0.60 and 1.47 for horizontal and vertical silos, respectively.

TABLE IX

METHODS AND MAN HOURS PER TON FOR HANDLING
SILAGE - VERTICAL SILOS

Operation and Method	No. of Farms	Pct. of Farms	Ave. Tons Per Yr.	Man Hrs. Per Ton Ave.	Man Hrs. Per Ton 95 Pct. Limit
Unloading from Vehicle	...	....	...	0.13	....
Manual	9	4.1	91	0.21)*)*	0.42
Semi-Mechanized	102	46.4	197	0.13	0.35
Mechanized	109	49.5	215	0.13	0.38
Distribution in Silo	...	....	...	0.04	....
Eliminated	142	64.6	208	0.00	0.00
Manual	62	28.2	178	0.12	0.27
Semi-Mechanized	8	3.6	178	0.11	0.24
Mechanized	6	2.7	278	0.11	0.22
Automatic	2	0.9	285	0.00	0.00
Removal from Silo	...	....	...	0.51	....
Manual	196	89.1	178	0.57	1.14
Automatic	24	10.9	364	0.00	0.00
Moving to Feeding Area	...	....	...	0.25	....
Eliminated	102	46.4	213	0.00	0.00
Manual	91	41.4	196	0.50)*)*	1.24
Semi-Mechanized	21	9.5	163	0.35)*	0.76
Mechanized	5	2.2	172	0.18	0.36
Automatic	1	0.5	400	0.00	0.00
Feeding	...	....	...	0.54	....
Manual	197	89.6	177	0.59)*	1.85
Semi-Mechanized	9	4.1	216	0.36	0.78
Automatic	14	6.3	528	0.00	0.00
Total	220	....	201	1.47	....

*Statistically significant difference at 95 percent level.

TABLE X

METHODS AND MAN HOURS PER TON FOR HANDLING SILAGE - HORIZONAL SILOS

Operation and Method	No. of Farms	Pct. of Farms	Ave. Tons Per Yr.	Man Hrs. Per Ton Ave.	Man Hrs. Per Ton 95 Pct. Limit
Unloading from Vehicle	..	....	...	0.14	....
Semi-Mechanized......	6	25.0	220	0.10	0.17
Mechanized..........	18	75.0	330	0.16	0.53
Distribution in Silo	..	....	...	0.10	....
Eliminated..........	2	8.3	375	0.00	0.00
Manual..............	4	16.7	135	0.19	....
Semi-Mechanized......	3	12.5	100	0.25	....
Mechanized..........	11	45.8	395	0.12	0.30
Automatic...........	4	16.7	330	0.00	0.00
Removal from Silo	..	....	...	0.16	....
Eliminated..........	13	54.1	380	0.00	0.00
Manual..............	7	29.9	196	0.35	0.62
Moving to Feeding Area	..	....	...	0.09	....
Eliminated..........	14	58.3	363	0.00	0.00
Manual..............	3	12.5	300	0.33)*	....
Mechanized..........	7	29.2	181	0.11)	0.18
Feeding	..	....	...	0.11	....
Manual..............	7	29.2	736	0.35)*	0.54
Mechanized..........	2	8.3	315	0.11)	....
Automatic...........	15	62.5	98	0.00	0.00
Total.......	24	....	302	0.60	....

*Statistically significant difference at 95 percent level.

By selecting the optimum method used for each operation, however, these totals can be as low as 0.22 and .13 man-hours per ton for horizontal and vertical silos. This assumes the use of a silo unloader and mechanical feeder in connection with the vertical silo. At the other extreme, considering that each operation is performed in the least desirable manner shown, these figures could be as great as 1.44 and 1.99. Individual cases could be cited which would fall considerably outside these limits which are based on means of various sized samples.

The principle labor consuming silage handling operations are removal from vertical silos and feeding. Only a relatively small percentage of farms have silo unloaders and mechanical feeders. This is partially due to normal lag between development and adoption of equipment. This is the case particularly with respect to mechanical feeders. They have been developed to an acceptable stage only recently. Silo unloaders on the other hand have been available for about ten years.

Farmers have not been satisfied with the performance of silo unloaders. There have been many mechanical problems and many farmers who installed the early models shortly after World War II gave up and discarded them after a season or two. Current models are much improved, but farmers are still skeptical.

A common comment of farmers in this study was that the capacity of silo unloaders is too low. This indicates a need for education in their use. Silo unloaders are essentially automatic and operate without the presence of an operator and capacity is therefore unimportant. The only practical requirement is that they be able to deliver a day's feeding in 24-hours. From the standpoint of engineering design and materials handling principles, current unit capacities of 50 to 250 lbs per minute are too great. It is suggested that instead of a three horsepower unit operating 20 minutes a day, perhaps a silo unloader should be designed for one-fourth horsepower operation for 4-hours per day.

It can be noted in the tables that the most efficient handling methods, from the standpoint of man-hour requirements, are associated with the larger scale operations. This is as would be expected and is generally true of other materials also.

Bedding Handling Operations
(Tables XI, XII, XIII and XIV)

The labor requirement for handling a ton of any form of bedding is very high; 2.69, 2.10, 3.08 and 2.31 man-hours, respectively, for baled, chopped, long-loose and other forms. Mechanization has not been applied to handling bedding to a significant extent except in connection with placement in storage.

Long-loose straw is used on only a small number of

TABLE XI

METHODS AND MAN HOURS PER TON FOR HANDLING BALED BEDDING

Operation and Method	No. of Farms	Pct. of Farms	Ave. Tons Per Yr.	Man Hrs. Per Ton Ave.	Man Hrs. Per Ton 95 Pct. Limit
Unloading from Vehicle	...	.....	..	0.28	....
Manual	29	12.9	20	0.43)*	1.18
Semi-Mechanized	185	82.6	35	0.26)*	0.53
Mechanized	10	4.5	28	0.23	0.31
Distribution in Storage	...	.....	..	0.25	....
Eliminated	16	7.2	31	0.00	0.00
Manual	190	84.8	33	0.28	0.56
Semi-Mechanized	18	8.0	33	0.24	0.47
Removal from Storage	...	.....	..	0.46	....
Manual	224	100.0	33	0.46	1.10
Moving to Stable Area	...	.....	..	0.30	....
Eliminated	101	45.1	32	0.00	0.00
Manual	117	52.2	34	0.53	1.33
Semi-Mechanized	4	1.8	20	0.79	....
Mechanized	2	0.9	30	0.63	....
Distribution in Stable	...	.....	..	1.40	....
Manual	224	100.0	33	1.40	3.35
Total	224	.....	33	2.69	....

*Statistically significant difference at 95 percent level.

TABLE XII

METHODS AND MAN HOURS PER TON FOR HANDLING CHOPPED BEDDING

Operation and Method	No. of Farms	Pct. of Farms	Ave. Tons Per Yr.	Man Hrs. Per Ton Ave.	Man Hrs. Per Ton 95 Pct. Limit
Unloading from Vehicle	..	.....	...	0.26	....
Manual	3	4.5	13	0.75	....
Semi-Mechanized	31	46.3	36	0.28)*	1.13
Mechanized	33	49.2	58	0.19)*	0.57
Distribution in Storage	..	.....	...	0.10	....
Eliminated	43	64.2	40	0.00	0.00
Manual	19	28.3	35	0.31	1.10
Mechanized	5	7.5	139	0.21	0.57
Removal from Storage	..	.....	...	0.61	....
Manual	65	97.0	46	0.62	1.35
Semi-Mechanized	2	3.0	40	0.46	....
Moving to Stable Area	..	.....	...	0.21	....
Eliminated	38	56.7	52	0.00	0.00
Manual	26	38.8	33	0.49	1.20
Semi-Mechanized	1	1.5	30	0.33	....
Mechanized	2	3.0	92	0.37	....
Distribution in Stable	..	.....	...	0.92	....
Manual	67	100.0	46	0.92	2.32
Total	67	.....	46	2.10	....

*Statistically significant difference at 95 percent level.

TABLE XIII

METHODS AND MAN HOURS PER TON FOR HANDLING
LOOSE BEDDING (LONG)

Operation and Method	No. of Farms	Pct. of Farms	Ave. Tons Per Yr.	Man Hrs. Per Ton Ave.	Man Hrs. Per Ton 95 Pct. Limit
Unloading from Vehicle	..	.....	..	0.37	....
Manual................	6	60.0	28	0.41	0.95
Semi-Mechanized......	3	30.0	38	0.33	....
Mechanized...........	1	10.0	30	0.25	....
Distribution in Storage	..	.....	..	0.12	....
Eliminated...........	3	30.0	27	0.00	0.00
Manual...............	3	30.0	28	0.38	0.00
Automatic............	4	40.0	29	0.00	0.00
Removal from Storage	..	.....	..	0.91	....
Manual...............	10	100.0	31	0.91	1.90
Moving to Stable Area	..	.....	..	0.18	....
Eliminated...........	7	70.0	32	0.00	0.00
Manual...............	3	30.0	28	0.58	....
Distribution in Stable	..	.....	..	1.50	....
Manual...............	10	100.0	31	1.50	2.94
Total........	10	.....	31	3.08	....

TABLE XIV

METHODS AND MAN HOURS PER TON FOR HANDLING OTHER BEDDING (SAWDUST, SHAVINGS, CORN-COBS, ETC.)

Operation and Method	No. of Farms	Pct. of Farms	Ave. Tons Per Yr.	Man Hrs. Per Ton Ave.	Man Hrs. Per Ton 95 Pct. Limit
Unloading from Vehicle	..	....	...	0.53	....
Manual................	5	41.7	65	0.58	1.11
Semi-Mechanized......	3	25.0	45	0.69	....
Mechanized...........	4	33.3	87	0.34	....
Distribution in Storage	..	....	...	0.08	....
Eliminated...........	8	66.7	89	0.00	0.00
Manual...............	4	33.3	24	0.25	....
Removal from Storage	..	....	...	0.45	....
Eliminated...........	2	16.7	140	0.00	0.00
Manual...............	10	83.3	53	0.54	1.15
Moving to Stable Area	..	....	...	0.50	....
Eliminated...........	5	41.7	16	0.00	0.00
Manual...............	4	33.3	51	0.63	....
Semi-Mechanized......	3	25.0	174	1.17	....
Distribution in Stable	..	....	...	0.75	....
Manual...............	11	91.7	69	0.81	1.84
Mechanized...........	1	8.3	50	0.15	....
Total........	12	....	67	2.31	....

farms. It is shown by tonnages involved that these are relatively small scale operations and it was observed that nearly all of them were located in the less productive areas of the state. It also was noted that on four of these farms stationary threshing machines were used and the straw was delivered to and distributed in storage automatically.

Special forms of bedding other than straw were all grouped together and summarized as such. Each of the twelve farms involved has some particular arrangement for securing this material which is particularly desirable because of location, type of enterprise or other special feature. The value of this data for projection to general use is therefore doubtful.

The principle forms of bedding used are baled and chopped straw. While the tonnages involved are relatively low compared to hay and silage, the man-hours per ton are enough greater to make bedding handling an operation of similar scale. Here again the time requirement is higher for baled than chopped bedding but baling is the most common procedure.

With both baled and chopped bedding the items of time required for removal from storage and moving to stable area are substantial. The method of performing these operations is largely manual. The difference between baled and chopped bedding in this respect is little.

The greatest single item of labor is associated with the operation of distribution of the bedding in the stable area. This is a major item with 0.92 and 1.40 man-hours per ton for chopped and baled, respectively. In both cases it is 100 percent manual. The farm operator has no alternative of method; only of form. Baled bedding requires time in breaking up the bales and shaking up the slices. This operation is obviously a logical subject of future mechanization research. There is also a need for improved methods of handling bedding into and out of storage.

Manure Handling Operations
(Tables XV and XVI)

Manure handling on livestock farms is the most highly mechanized of all the materials considered in this study. Not only has it become mechanized more generally but also the management practices and building facilities have been modified to minimize labor in manure handling. On over half of the farms there is no manual handling except a little in scraping aprons, walks, ramps, corners, etc. On a majority of the remaining farms the manure is handled only once; either manually or by semi-mechanized methods.

The practice of piling manure outside the stable area during winter months has been abandoned on approximately 85 percent of all livestock farms studied. This was practically standard procedure less than twenty years ago. The 15 percent who have not eliminated this practice are mainly in the northern area of the state. These farmers pile manure primarily because deep snow prevents immediate hauling to the field.

With the trend away from piling, the separate operation of loading manure into a spreader has nearly been eliminated. Loading the spreader is accomplished directly and simultaneously with removal from the stable area. Even if this is done manually as it is on many farms, one handling does the entire operation except spreading in the field which is, of course, mechanized.

The extent of mechanization and elimination of manure handling operations may be attributed to such things as:

1. The extremely hard work involved in manually removing packed manure from stable area and piles.

2. The development of effective tractor manure loaders which are moderate in cost.

3. The improvement of tractors and spreaders with respect to use in winter conditions.

4. The increased use of the loose housing practice for dairy herds.

5. The development of effective mechanical cleaners for stanchion type dairy barns.

The need for education concerning efficient practices of manure handling is slight compared to other areas. The failure of some farmers to develop efficient systems is not based on a lack of understanding of what could be done. With such a high percentage of farms with good systems the trend becomes self perpetuating. This is not to say that engineering and perhaps specific education problems do not exist. There is always a need for education on care, maintenance, safety, etc. There are engineering challenges

TABLE XV

METHODS AND MAN HOURS PER TON FOR HANDLING MANURE FOR DAIRY AND BEEF CATTLE

Operation and Method	No. of Farms	Pct. of Farms	Ave. Tons Per Yr.	Man Hrs. Per Ton Ave.	Man Hrs. Per Ton 95 Pct. Limit
Dairy					
Removal from Stable	...	....	...	0.31	....
Manual.............	79	43.2	487	0.57	1.14
Semi-Mechanized....	9	4.9	455	0.48)*)*	0.98
Mechanized.........	56	30.6	610	0.14)	0.38
Automatic..........	39	21.3	541	0.00)	0.00
Transporting to Pile	...	....	...	0.04	....
Eliminated.........	154	84.2	565	0.00	0.00
Manual.............	17	9.3	299	0.34)*	0.70
Semi-Mechanized....	8	4.3	517	0.19)	0.43
Automatic..........	4	2.2	392	0.00	0.00
Loading into Spreader	...	....	...	0.06	....
Manual.............	15	8.2	322	0.47)*)	1.00
Semi-Mechanized....	4	2.2	434	0.24))*	....
Mechanized.........	14	7.7	392	0.15)	0.33
Automatic..........	150	81.9	572	0.00	0.00
Total......	183	....	535	0.41	....
Beef					
Removal from Stable	...	....	...	0.18	....
Manual............	1	6.3	80	1.00	....
Mechanized........	15	93.7	767	0.13	0.32
Transporting to Pile	...	....	...	0.02	....
Eliminated........	15	93.7	767	0.00	0.00
Semi-Mechanized...	1	6.3	80	0.25	....
Loading into Spreader	...	....	...	0.02	....
Mechanized.........	1	6.3	80	0.25	....
Automatic..........	15	93.7	767	0.00	0.00
Total......	16	....	724	0.22	....

*Statistically significant difference at 95 percent level.

TABLE XVI

METHODS AND MAN HOURS PER TON FOR HANDLING MANURE ON POULTRY AND GENERAL LIVESTOCK FARMS

Operation and Method	No. of Farms	Pct. of Farms	Ave. Tons Per Yr.	Man Hrs. Per Ton Ave.	Man Hrs. Per Ton 95 Pct. Limit
Poultry					
Removal from House	..	....	...	0.74	....
Manual.............	10	71.4	127	0.97) *	1.17
Mechanized.........	4	28.6	188	0.17) *	....
Transporting to Pile	..	....	...	0.01	....
Eliminated.........	13	92.9	151	0.00	0.00
Manual.............	1	7.1	50	0.10	....
Loading into Spreader	..	....	...	0.01	....
Manual.............	1	7.1	50	0.20	....
Automatic..........	13	92.9	151	0.00	0.00
Total......	14	....	144	0.76	....
General Livestock					
Removal from Stable	..	....	...	0.31	....
Manual.............	45	42.8	429	0.52) *) *	1.15
Semi-Mechanized....	4	3.8	784	0.33) *	....
Mechanized.........	46	43.8	682	0.16) *	0.35
Automatic..........	10	9.6	640	0.00	0.00
Transporting to Pile	..	....	...	0.05	....
Eliminated.........	87	82.9	621	0.00	0.00
Manual.............	12	11.4	321	0.30	0.75
Semi-Mechanized....	6	5.7	390	0.25	0.40
Loading into Spreader	..	....	...	0.06	....
Manual.............	13	12.4	375	0.35) *	0.76
Mechanized.........	13	12.4	495	0.12) *	0.26
Automatic..........	79	75.2	619	0.00	0.00
Total......	105	....	574	0.42	....

*Statistically significant difference at 95 percent level.

involved also. Comments of farmers interviewed for this study, point up such needs as:

1. Improved chain design for more durable barn cleaners.
2. More versatile barn cleaner units which can be used in oddly arranged barns.
3. Mechanical cleaners for poultry houses.

Ear Corn Handling Operations
(Table XVII)

Handling ear corn is a relatively moderate operation with respect to labor requirements. Unloading from the transporting vehicle is largely mechanized. Of the 273 farms involving ear corn 218 of them have elevators for taking it from the vehicle to the crib. Most of them use some manual effort to get it into the elevator. The other 79 have mechanically unloading vehicles - unloading wagons or dump boxes. Only 55 operators actually shovel the corn from the vehicle into the crib and they are smaller scale operators handling less than average tonnage.

Distribution in the crib is not a separate operation on most farms. Most of this is done by timely moving and appropriate positioning of the elevator. This procedure is classified in Table XVII as automatic. While, to be sure, the maneuvering of the elevator would require some time and effort, it is not in this analysis associated with distribution. It is rather, included in the time indicated for unloading.

TABLE XVII

METHODS AND MAN HOURS PER TON FOR HANDLING
EAR CORN

Operation and Method	No. of Farms	Pct. of Farms	Ave. Tons Per Yr.	Man Hrs. Per Ton Ave.	Man Hrs. Per Ton 95 Pct. Limit
Unloading from Vehicle	...	....	...	0.24	....
Manual...............	55	20.3	53	0.36 } * } *	0.75
Semi-Mechanized.....	139	50.8	72	0.24 } *	0.52
Mechanized..........	79	28.9	111	0.17	0.41
Distribution in Crib	...	....	...	0.06	....
Manual...............	32	11.6	72	0.24 } *	0.54
Semi-Mechanized.....	17	6.2	68	0.19	0.49
Mechanized..........	28	10.5	107	0.16	0.33
Automatic...........	196	71.7	81	0.00	0.00
Removal from Crib	...	....	...	0.49	....
Manual	209	76.5	73	0.54 } * } *	1.12
Semi-Mechanized.....	54	19.8	93	0.38 } *	0.88
Mechanized..........	10	3.7	147	0.18	0.38
Total.......	273	....	80	0.79	....

*Statistically significant difference at 95 percent level.

The most labor consuming operation in connection with ear corn handling is removing it from the crib. On most farms this is still a manual operation. Those which are classified as semi-mechanized are essentially all using one of two procedures. (1) They discharge the corn out of an opening in the side manually and by gravity into an elevator which discharges into a grinder or transporting vehicle. (2) The corn is discharged manually and by gravity onto the ground or crib floor from which it is picked up with a tractor loader. These methods are much better than manual handling but the flow rate is difficult to control for grinding or other processing.

The few mechanized removal operations are mostly mechanical drag systems used for bulk and perhaps custom shelling. They are not adaptable to operations where ear corn is not shelled out. There is need, therefore, for improvement in ear corn removal methods if ear corn is to continue as a principal material on farms. Before devoting much time and money to this problem, however, serious consideration should be given to the future of ear corn in view of the new but rapidly increasing practice of field shelling. If corn is to be shelled in the field in the future the whole system of storage and handling must be modified accordingly.

Many operators, especially dairy farmers and beef feeders, indicate that they are going to continue to want to feed corn-cob meal rather than ground or whole shelled corn. If this is to hold, then ear corn is still a materials handling problem. It is suggested that it might be well to recall the attitudes of farmers to other new items and procedures shortly before they were generally adopted. The author recalls comments of neighbor farmers in western Michigan in 1939 and 1940 to the effect that they would not go to combining grain because of excessive field losses and the straw handling problem. By 1944 all custom threshing units, which they depended upon and which depended upon them, were out of business. Perhaps the war labor situation had some effect but at most it was only an expediting influence.

There are many who predict that corn pickers and cribs are going the way of threshers and straw stacks. Storage costs and handling problems will support this trend which has already started in the corn belt states.

Small Grains and Concentrates Handling Operations (Table XVIII)

The term 'small grains' is used here to include shelled corn and beans. Methods used in handling small grains are similar to those used for ear corn. Most of the unloading operations may be classified as semi-mechanized or mechanized. Only a rather small percentage of farm operators perform this operation manually. Also most of the unloading operations are managed so that the distribution in storage is accomplished simultaneously or automatically.

The most substantial portion of the labor involved in handling small grains is associated with removal from storage. Most farmers remove the grain manually with a labor output of nearly two-thirds of a man-hour per ton for this operation alone. This labor represents not only time but hard work. In spite of the fact that this material is granular and more adaptable to gravity flow and mechanization these methods have not been generally adopted. Perhaps the principle reasons are:

1. Rather low tonnages are involved, especially in the less mechanized system.

2. Limitations of older existing storage structures prevent the use of gravity flow. It should be added, however, that newer types of grain storage structures do not generally permit this method either.

3. Machinery which is reasonably priced and effective is not available for complete mechanization.

Factors two and three present problems needing engineering attention. These problems need to be considered in connection with ear corn practices, grinding, blending and feeding programs. All need to be integrated into an overall system. Some work has been and is being done on this (12).

Concentrate handling is also largely a manual operation in all phases. This is not as serious as with other materials because of the smaller quantities involved. Here again suitable equipment is not generally available. The metering and blending of concentrates into the prepared grain ration is an important part of the system development suggested above.

TABLE XVIII

METHODS AND MAN HOURS PER TON FOR HANDLING SMALL GRAINS AND CONCENTRATES

Operation and Method	No. of Farms	Pct. of Farms	Ave. Tons Per Yr.	Man Hrs. Per Ton Ave.	Man Hrs. Per Ton 95 Pct. Limit
Small Grains					
Unloading from Vehicle ...	...	....	..	0.27	....
Manual..............	54	18.9	32	0.41)*)*	0.91
Semi-Mechanized.....	133	46.7	33	0.27)*)	0.65
Mechanized..........	98	34.4	56	0.19))	0.49
Distribution in Storage...		....	..	0.08	....
Manual..............	38	13.3	36	0.25	0.62
Semi-Mechanized.....	42	14.7	33	0.21	0.52
Mechanized..........	29	10.2	37	0.18	0.43
Automatic...........	176	61.8	44	0.00	0.00
Removal from Storage	...	....	..	0.50	....
Manual..............	170	59.7	34	0.64)*)*	1.56
Semi-Mechanized.....	72	25.2	43	0.37)*)	0.72
Mechanized..........	31	10.9	51	0.26))	0.66
Automatic...........	12	4.2	99	0.00	0.00
Total.......	285	....	47	0.85	....
Concentrates					
Unloading from Vehicle ...	...	....	..	0.34	....
Manual..............	98	88.3	13	0.35)*	0.75
Semi-Mechanized.....	5	4.5	17	0.20)	0.32
Mechanized..........	8	7.2	24	0.26	0.89
Distribution in Storage...		....	..	0.16	....
Manual..............	46	41.4	11	0.36	0.77
Semi-Mechanized.....	4	3.6	11	0.21	....
Automatic...........	61	55.0	16	0.00	0.00
Removal from Storage	...	....	..	0.62	....
Eliminated..........	7	6.3	6	0.00	0.00
Manual..............	96	86.5	11	0.71)*	1.33
Semi-Mechanized.....	3	2.7	45	0.16)	....
Automatic...........	5	4.5	45	0.00	0.00
Total.......	111	....	14	1.12	0.00

*Statistically significant difference at 95 percent level.

Ground Feed Handling Operations
(Tables XIX and XX)

It is significant that on a high percentage of farms grinding and blending is not done by the farm operator. Most of those classified as 'eliminated' employ the services of custom grinders, either at local elevators or by mobile units. It was not practical to attempt to evaluate the time involved in such operations for comparison purposes in this study. These farmers' comments indicated that they spend considerable time loading up grain, taking it to town and getting it ground. The only cost that is commonly considered in connection with this procedure is the actual charge for grinding. The main advantage and principle reason for this practice is the thorough and accurate blending of ingredients including supplements purchased at the elevator.

Semi-mechanized grinding operations involve manual feeding of the grinding unit while mechanized systems include gravity or mechanical feeding to the grinder. There were no automatic grinding systems included in the farms studied although such systems have been developed and are being used to a limited extent.

It has been stated (25) that with an ideally arranged farmstead there would be no problem of moving feed from the storage area to the feeding area. These areas would be located either vertically or laterally adjacent to each other. The fact remains, as is illustrated by these data, that farmsteads are not commonly so arranged, and consider-

TABLE XIX

METHODS AND MAN HOURS PER TON FOR HANDLING
GROUND FEED FOR DAIRY AND BEEF CATTLE

Operation and Method	No. of Farms	Pct. of Farms	Ave. Tons Per Yr.	Man Hrs. Per Ton Ave.	Man Hrs. Per Ton 95 Pct. Limit
Dairy					
Grinding and Blending	...	.....	...	0.36	....
Eliminated...........	88	53.3	59	0.00	0.00
Semi-Mechanized......	65	39.4	69	0.78	1.55
Mechanized...........	12	7.3	85	0.65	1.59
Moving to Feeding Area	...	.....	...	0.49	....
Manual...............	105	63.7	53	0.62)*)*	1.43
Semi-Mechanized......	19	11.5	116	0.39	0.66
Mechanized...........	22	13.3	71	0.34	1.06
Automatic............	19	11.5	71	0.00	0.00
Feeding	...	.....	...	1.25	....
Manual...............	153	92.8	57	1.30)*	3.88
Mechanized...........	7	4.2	100	0.34	0.81
Automatic............	5	3.0	234	0.00	0.00
Total........	165	.....	65	2.10	....
Beef					
Grinding and Blending	...	.....	...	0.40	....
Eliminated..........	5	41.7	170	0.00	0.00
Semi-Mechanized.....	4	33.3	241	0.97	....
Mechanized..........	3	25.0	130	0.29	....
Moving to Feeding Area	...	.....	...	0.49	....
Manual..............	4	33.3	134	0.85	....
Semi-Mechanized.....	3	25.0	88	0.72	....
Mechanized..........	2	16.7	330	0.14	....
Automatic...........	3	25.0	273	0.00	0.00
Feeding	...	.....	...	0.60	....
Manual..............	12	100.0	184	0.60	1.86
Total.......	12	.....	184	1.49	....

*Statistically significant difference at 95 percent level.

TABLE XX

METHODS AND MAN HOURS PER TON FOR HANDLING GROUND FEED ON POULTRY AND GENERAL LIVESTOCK FARMS

Operation and Method	No. of Farms	Pct. of Farms	Ave. Tons Per Yr.	Man Hrs. Per Ton Ave.	Man Hrs. Per Ton 95 Pct. Limit
Poultry					
Grinding and blending	..	....	...	0.30	....
Eliminated..........	9	69.2	136	0.00	0.00
Semi-Mechanized.....	3	23.1	54	1.00	....
Mechanized..........	1	7.7	372	0.92	....
Moving to Feeding Area	..	....	...	0.91	....
Manual..............	10	76.9	125	0.96	2.42
Semi-Mechanized.....	2	15.4	192	1.08	....
Automatic...........	1	7.7	125	0.00	0.00
Feeding	..	....	...	1.12	....
Manual..............	8	61.5	86	1.79	4.33
Mechanized..........	1	7.7	110	0.25	....
Automatic...........	4	30.8	239	0.00	0.00
Total.......	13	....	135	2.33	....
General Livestock					
Grinding and Blending	..	....	...	0.32	....
Eliminated..........	47	48.0	70	0.00	0.00
Semi-Mechanized....	47	48.0	105	0.64)*	1.53
Mechanized..........	4	4.0	215	0.26)*	0.68
Moving to Feeding Area	..	....	...	0.48	....
Manual..............	63	64.3	79	0.60)*	1.60
Semi-Mechanized.....	12	12.3	82	0.40)*)*	0.75
Mechanized..........	14	14.3	145	0.33)*	1.04
Automatic...........	9	9.1	117	0.00	0.00
Feeding	..	....	...	1.04	....
Manual..............	92	93.9	89	1.11	2.38
Mechanized..........	1	1.0	73	0.20	....
Automatic...........	5	5.1	169	0.00	0.00
Total.......	98	....	94	1.84	....

*Statistically significant difference at 95 percent level.

able time and effort is expended in transporting between these areas. A practical solution to this problem, and one which can be easily intergrated with an automatic grinding and automatic feeding system, is the low pressure pneumatic conveyor (25 and 26). This, however, is only a substitute for well arranged facilities.

With all types of livestock enterprises the labor output for feeding grain is extremely high. This is especially true for dairy cattle in stanchion barns where grain feeding is entirely a manual operation. There is no satisfactory alternative now available for stanchion barn enterprises. Loose housing relieves this situation as well as many other materials handling problems.

There are available means of feeding other types of livestock mechanically and even automatically. Self-feeding may be used for beef cattle, hogs or poultry. Very satisfactory mechanical feeders are available for beef cattle, poultry or even for dairy cattle if loose housing is practiced. A substantial percentage of poultry farms studied used automatic mechanical feeders.

Reference has been made to a need for a complete system for handling and processing grains and concentrates. This need is substantiated by these data. Such a system would necessarily be made up of complementary individual units designed for various specific operations. According to the principles of work simplification the system should provide for continuous flow through the various units in series.

The specific operations involved could include removal from storage, metering, blending, grinding, moving to feeding area and feeding. Such an intergrated system for handling grains and concentrates 'from storage bin to feed bunk' would span the major labor consuming operations currently existing. The University of Illinois has for several years been working toward this type of system (12, 13, 22 and 28). As a result of this work, systems and component units are commercially available and being used on about 100 Illinois farms. Available systems for including ear corn are rather expensive.

Agricultural Experiment Stations in Georgia, Kansas, Pennsylvania and Wisconsin have also done work on feed grinding systems. They have all worked with batch process units rather than continuous flow and to date this work has not resulted in units available to the farmer.

Summary of Labor Requirements for Materials Handling (Tables XXI and XXII)

Many of the most labor consuming operations discussed previously in connection with the more detailed data, are more obvious in tables XXI and XXII. Some of the most prominent time consuming operations from Table XXI in order of magnitude per ton are:

1. Distribution of bedding in the stable area, especially baled bedding.

TABLE XXI

SUMMARY OF MAN HOURS PER TON FOR HANDLING FEEDS ON 320 LIVESTOCK FARMS

Material and Farm Type	Man Hours Per Ton				
	Unloading *	Distributing	Removal **	Moving	Feeding or Dist.
Hay:					
Baled	0.23	0.25	0.41	0.17	0.51
Chopped	0.20	0.08	0.50	0.13	0.46
Loose	0.78	0.56	0.71	0.19	0.53
Silage:					
Vert. Silo	0.13	0.04	0.51	0.25	0.54
Horiz. Silo	0.14	0.10	0.16	0.09	0.11
Bedding:					
Baled	0.28	0.25	0.46	0.30	1.40
Chopped	0.26	0.10	0.61	0.21	0.92
Loose	0.37	0.12	0.91	0.18	1.50
Other	0.53	0.08	0.45	0.50	0.75
Manure:					
Dairy	0.31	0.04	0.06	....	....
Beef	0.18	0.02	0.02	....	....
Poultry	0.74	0.01	0.01	....	....
General	0.31	0.05	0.06	....	....
Small Grain	0.27	0.08	0.50	....	....
Concentrate	0.34	0.16	0.62	....	....
Ear Corn	0.24	0.06	0.49	....	....
Ground Feed:					
Dairy	....	....	0.36	0.49	1.25
Beef	....	....	0.40	0.49	0.60
Poultry	....	....	0.30	0.91	1.12
General	....	....	0.32	0.48	1.04

*Removal from stable for manure.
**Grinding and blending for ground feed.

TABLE XXII

SUMMARY OF TOTAL LABOR USED IN HANDLING
VARIOUS MATERIALS ON FARMS STUDIED

Material and Farm Type	No. of Farms	Man Hours Per Ton	Average Tonnage	Ave. Man Hrs. Per Farm Per Year
Hay:				
Baled	209	1.57	120	188
Chopped	87	1.37	122	167
Loose	13,	2.77	58	167
Silage:				
Vert. Silo	220	1.47	201	296
Horiz. Silo	24	0.60	302	181
Bedding:				
Baled	224	2.69	33	89
Chopped	67	2.10	46	97
Loose	10	3.08	31	96
Other	12	2.31	67	155
Manure:				
Dairy	183	0.41	535	219
Beef	16	0.22	724	160
Poultry	14	0.76	144	109
General	105	0.42	574	241
Small Grain	285	0.85	47	26
Concentrates	111	1.12	14	16
Ear Corn	273	0.79	80	63
Ground Feed:				
Dairy	165	2.10	65	136
Beef	12	1.49	184	274
Poultry	13	2.33	135	314
General	98	1.84	94	173

2. Feeding ground feed; especially to dairy cows in stanchion barns.

3. Moving ground feed from storage area to feeding area.

4. Removal of hay from storage.

5. Removal of silage from vertical silos.

6. Removal of all types and forms of grain from storage.

7. Feeding hay and silage.

There currently exists no generally satisfactory substitute for manual effort in items 1, 2, 4 and 6. Mechanical equipment and labor saving procedures have, however, been developed for items 3, 5 and 7. This should not imply that further research and development is not needed in these areas. The more efficient methods, however, have not been generally adopted. Perhaps this, in turn, indicates the need for improvement or modification.

One of the most conspicuous items in Table XXII is the annual time associated with ground feed. It should be pointed out again that these data do not include the grinding and blending operation on the large portion of farms where this is done in town or by mobile custom grinders. The integrated automatic system discussed earlier, would eliminate nearly all of the man-hours per year associated with small grain, concentrate, ear corn and ground feed. It would also eliminate the custom grinding cost and inconvenience.

By virtue of large tonnages, manure handling is still a major activity in terms of man-hours per year. It will be recalled that time of hauling to and spreading in the field is not included. As has been pointed out, however, manure handled is generally performed quite efficiently through elimination and mechanization of operations.

In spite of the manual effort required for distributing bedding, the annual requirement is not major because of relatively small quantities handled.

Costs and Other Factors Involved in Owning and Operating Feed Handling Equipment (Tables XXIII and XXIV)

Tractor and engine operated power equipment is more commonly used than electrically operated units. Elevators, blowers, unloading wagons, manure loaders and feed grinders are examples of common engine powered equipment. Some items such as silo unloaders, barn cleaners and mechanical feeders are entirely electrically operated. In all cases only the units which are electrically operated are used in determining the average wattage.

In considering the first costs of the various items of equipment, it is significant to remember that the data represent the purchase prices at the particular times when the purchases were made. With items which are rather uniform in style, size and capacity there were surprisingly small variations in purchase prices. With items such as elevators, bin unloaders and feed grinders, however, there were considerable ranges of first cost.

The 'hours used per year' and 'cost per hour used'

TABLE XXIII

WATTAGE, AGE, EXPECTED LIFE AND EXTENT OF USE OF FEED HANDLING EQUIPMENT

Item	No. of Farms	No. Elec. Drive	Ave. Wattage	Age (Yrs.)	Total Expected Life
Auger Elevators	71	70	513	3.7	13.3
Chain or Belt Elevators	258	196	1130	4.2	14.2
Blowers	173	7	3800	5.1	13.3
Grain Bin Unloaders	12	5	960	2.5	18.4
Unloading Wagons	207	99	487	5.0	13.8
Barn Cleaners	69	69	2915	3.6	13.5
Silo Unloaders	25	25	....	...	....
Mechanical Feeders	24	23	1650	2.6	13.3
Grain Dispensers	10	000	....	2.8	18.5
Tractor Manure Loaders	186	000	....	5.1	13.7
Silage Dist. (in silo)	7	1	100	2.1	13.6
Self-feeders	76	000	....	4.1	12.7
Feed Carts	103	000	....	7.5	17.1
Monorail Carriers	32	1	800	13.5	20.7
Hay Hoists	17	5	2100	14.4	22.2
Hammer Mills	96	7	3630	8.0	15.8
Burr Mills	14	000	....	5.9	12.3
Other type Mills	2	2	5950	1.5	15.0
Corn Shellers	17	3	4170	6.7	15.5
Feed Mixers	18	15	2250	6.7	16.8

TABLE XXIV

COSTS OF OWNING AND OPERATING
FEED HANDLING EQUIPMENT

Item	No. of Units	Ave. First Cost	Annual Repair Cost	Hrs. Used Per Yr.	Ave. Over-Head * Annual	Ave. Over-Head * Per Hr. Used
Auger Elevators	76	$115	$ 2.65	31	$14.10	$0.46
Chain or Belt Elevators	294	401	11.45	81	49.65	0.61
Blowers	175	516	11.70	74	63.30	0.86
Grain Bin Unloaders	17	109	0.70	35	9.30	0.27
Unloading Wagons	395	388	18.50	77	56.30	0.73
Barn Cleaners	69	$1390	$40.30	116	$178.10	$1.54
Silo Unloaders	33	....	.....	170	......	....
Mechanical Feeders	24	992	29.40	411	128.80	0.31
Grain Dispensers	36	56	1.15	80	5.60	0.40
Manure Loaders	189	352	11.20	115	45.60	0.40
Silage Dist. (in silo)	7	$103	$ 3.60	85	$13.80	$0.16
Self Feeders	161	75	2.00	...	9.80	....
Feed Carts	149	50	1.30	122	5.50	0.05
Monorail Carriers	32	217	0.95	154	16.85	0.11
Hay Hoists	17	134	7125	41	16.85	0.41
Hammer Mills	96	$222	$13.00	67	$32.50	$0.49
Burr Mills	14	385	19.40	90	60.30	0.67
Other Type Mills	2	675	20.30	65	82.30	1.26
Corn Shellers	17	439	12.90	41	52.20	1.27
Feed Mixers	18	394	10.55	100	43.85	0.44

*Includes depreciation, repairs and 5 percent simple interest.

columns in Table XXIV are of particular interest and significance. As an example, consider the highest cost per hour used which is associated with the barn cleaner. In a typical installation fifteen minutes of operation could easily replace an hour of hard disagreeable manual work. The overhead cost of $1.54 for a barn cleaner plus about $.09 for operating power would make a man's manual effort worth about $.41 an hour. It is impossible to evaluate units such as feed grinders and corn shellers entirely in terms of cost of labor saved because they modify the material and presumably increase its worth for the use intended.

The cost of strictly materials handling units can in general be easily justified on the basis of labor saved if the labor can be disposed of or profitably applied elsewhere. This is related to a discussion of the uses made of time saved included later in this thesis.

Mechanization and Production Efficiency (Figure 8)

The distribution of relative labor requirements as plotted against investment in materials handling equipment is illustrated by Figure 8. Also shown is the regression line of the ordinate scale on the mantissa scale.

Investment here includes the non-depreciated first cost of items of equipment included in the study as listed previously. Relative labor requirement was calculated for each farm as follows:

$$\text{R.L.R.} = \frac{\text{Man months per year used}}{\text{Livestock equivalent man months}} \times 100$$

where man months per year used includes operator, family and hired labor. Livestock equivalent man months is the theoretical man month requirement based upon the amount of livestock involved. Various types of livestock were converted to a common base with appropriate factors. See APPENDIX IV. The actual R.L.R. value for a given farm has little significance except for comparison and correlation purposes. It is an index of labor efficiency.

Mathematical analysis. - The calculation of the regression and correlation coefficients will be described for clarification of their significance. The pertinent data involved are:

N (sample size) = 311

$\sum X_i$ (investment grand total) = \$631,700

$\sum X_i^2 = 1,921,432,400$

$\bar{X} = \frac{\sum X_i}{N} = \$2.030$

$\sum Y_i$ (R.L.R.) = 36,709 percent

$\sum Y_i^2 = 6,309,045$

$\bar{Y} = \frac{\sum Y_i}{N} = 118$ percent

$\sum X_i Y_i = 67,587,442$

The regression coefficient of Y on X is then

$$b = \frac{\sum X_i Y_i - \sum X_i \sum Y_i / N}{\sum X_i^2 - \frac{(\sum X_i)^2}{N}}$$

$$= \frac{67,587,442 - (631,700)(36,709)/311}{1,921,432,400 - (631,700)^2/311}$$

$$= -0.0107 \text{ (slope of line shown)}$$

The correlation coefficient, r, was obtained as follows:

$$r = (bb')^{.5}$$

where b = regression coefficient of Y on X

and b' = regression coefficient of X on Y

$$b' = \frac{\sum X_i Y_i - \sum X_i \sum Y_i / N}{Y_i^2 - (\sum Y_i)^2 / N}$$

$$= -3.50$$

then,

$$r = (3.50 \times .0107)^{.5} = \underline{0.193}$$

The correlation coefficient for 300 degrees of freedom and at a 99 percent confidence level is 0.148 (37). The correlation coefficient of 0.193 with 310 degrees of freedom is highly significant.

Interpretation of Figure 8. - The curve shown represents the expected average effect of investment in materials handling equipment on the relative labor requirement of a livestock farm. The equation of the curve shown is

$$R.L.R. = 141 - 0.0107\ I$$

where I is investment.

Whether or not this should be a first order curve may be questioned. The curve for any given farm would not form a line of uniform slope as more equipment is added. Rather it would be made up of straight segments, the slopes of which would depend upon the cost of the particular item and the labor saved by it. However, to attempt to form a generally applicable curve of other than first degree would be to assume an order of purchase of the various items. It

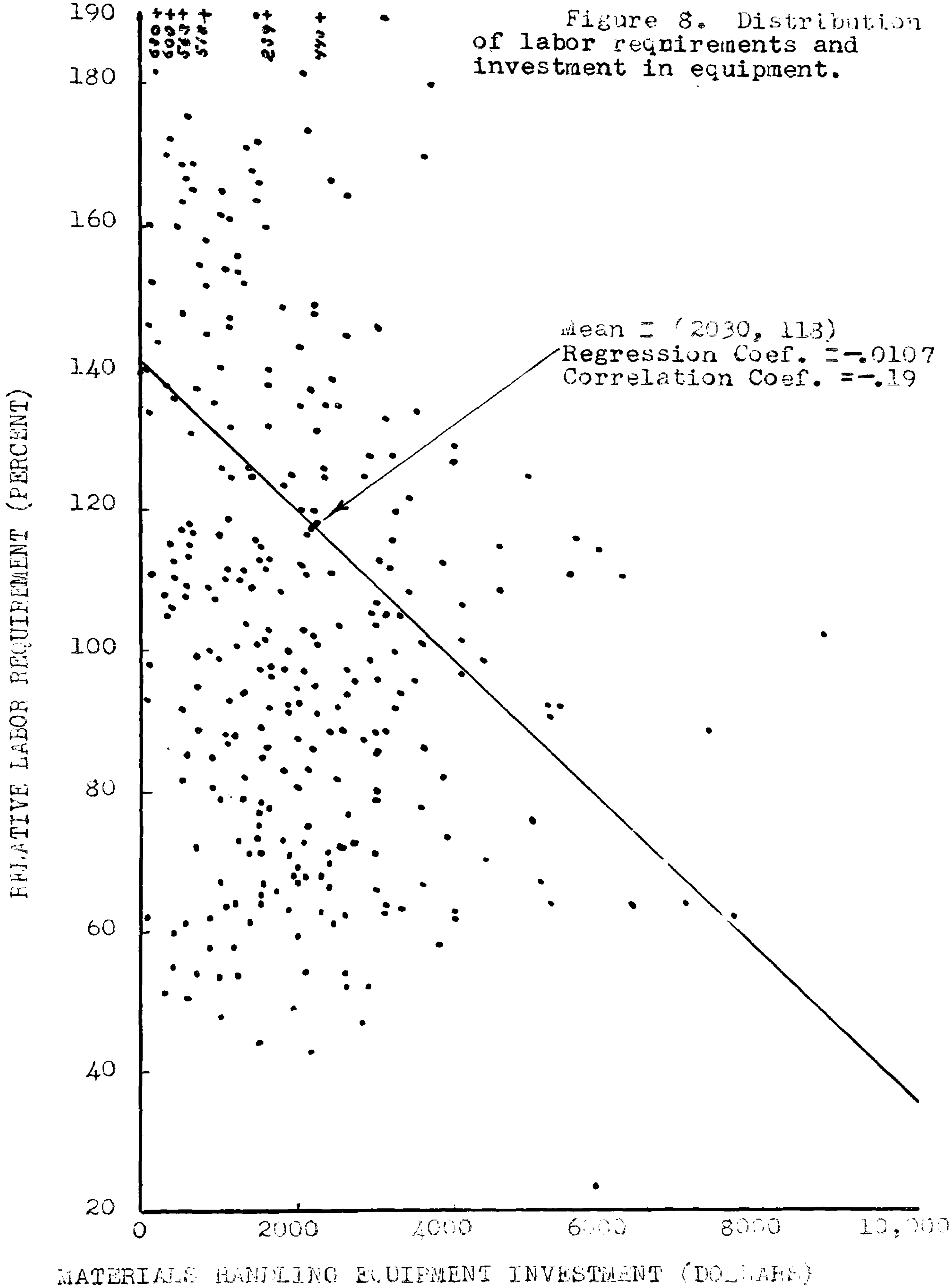

Figure 8. Distribution of labor requirements and investment in equipment.

is suggested that the data on units owned do not support such an assumption. There is, however, a point beyond which the curve shown cannot be projected. It is inconceivable that even an unlimited investment in equipment could completely eliminate human labor from farming.

On the other hand it is reasonable to assume that within the investment limits represented by Figure 8, each $1,000 logically invested in equipment could be expected to reduce the R.L.R. by 10.7 percent on the average.

The dispersion of points would indicate that other factors also greatly influence the labor required on livestock farms. These factors would include such things as building arrangement, mechanical aptitude of operator, physical stature, physical condition and management ability of the operator and other workers. It would, therefore, be hazardous to predict, on the basis of this curve, what exact effect any individual farmer might obtain from the purchase of a particular unit.

The primary significance of this curve is the demonstration of the high degree of correlation between mechanization of materials handling and over-all labor efficiency.

Substitution of Equipment for Hired Labor
(Tables XXV and XXVI and Figures 9 and 10)

With a fixed size enterprise, mechanization can relieve the labor requirement effectively only if the labor released is hired labor. On 146 of the 320 farms studied there was no hired labor involved. On these farms the justification

TABLE XXV

MAN MONTHS OF LABOR PER YEAR
ON 320 LIVESTOCK FARMS
(AVERAGE = 21.2)

Man Months Interval	No. Farms	Pct. Farms
0 - 3	0	0.0
4 - 6	1	0.3
7 - 9	1	0.3
10 - 12	31	9.7
13 - 15	70	21.7
16 - 18	56	17.6
19 - 21	31	9.7
22 - 24	45	14.1
25 - 27	24	7.5
28 - 30	26	8.1
31 - 33	7	2.2
34 - 36	15	4.7
37 - 39	3	0.9
40 - 42	3	0.9
43 - 45	2	0.6
46 - 48	2	0.6
over 48	3	0.9
Total	320	100.0

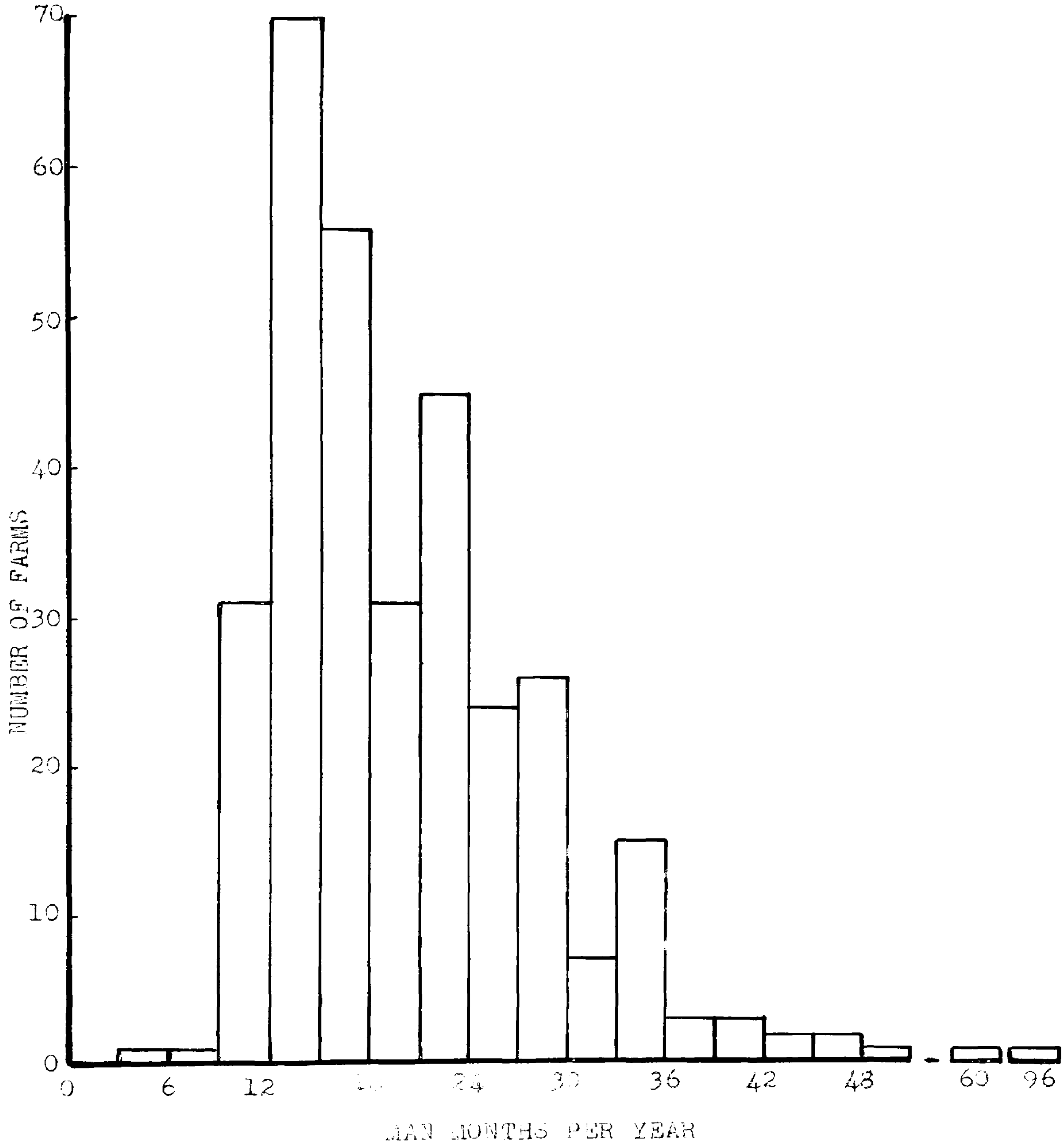

Figure 9. Distribution of total labor used on 320 farms studied.

TABLE XXVI

MAN MONTHS OF HIRED LABOR PER YEAR
ON 320 LIVESTOCK FARMS
(AVERAGE = 3.5)

Man Months Interval	No. Farms	Pct. Farms
1 - 3	91	28.4
4 - 6	32	10.0
7 - 9	7	2.2
10 - 12	25	7.8
13 - 15	5	1.6
16 - 18	4	1.3
19 - 21	1	0.3
22 - 24	5	1.6
25 - 27	0	0.0
28 - 30	1	0.3
31 - 33	1	0.3
34 - 36	1	0.3
37 - 39	0	0.0
40 - 42	0	0.0
over 42	1	0.3
Total	174	54.4

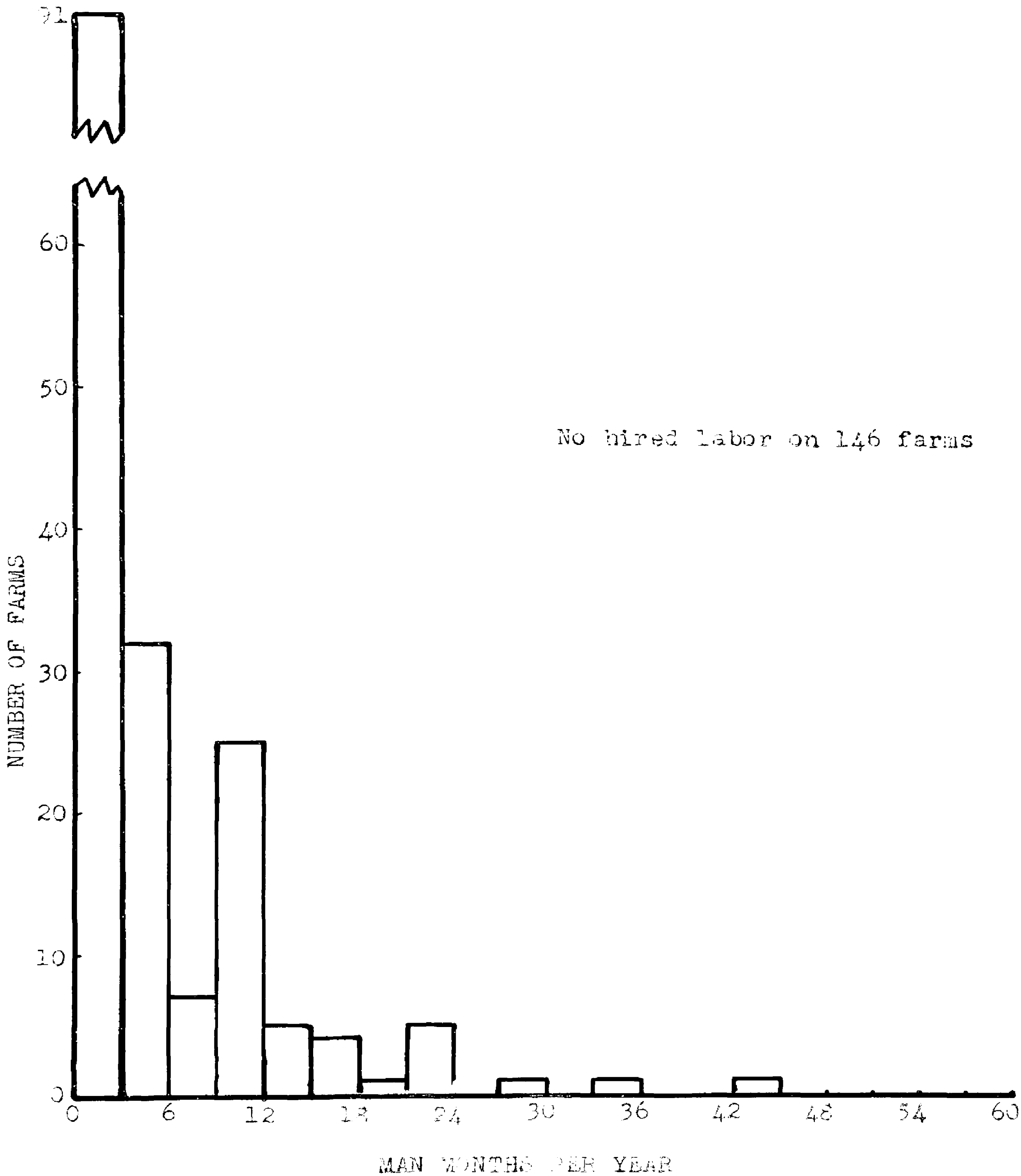

Figure 10. Distribution of hired labor used on 320 farms studied

of increased mechanization must be based upon:

1. Expanded scale of operation.

2. More intensive production within the existing limits.

3. Or relief from drudgery or disagreeable work.

In analyzing the labor used on the farms studied it appears that the most fertile area for application of machinery for increasing efficiency is on those farms using hired labor. Theoretically, hired labor can be reduced as it is released by mechanization. Practically, however, this may not be the case if all hired labor is represented by full-time workers. Unless a full-time worker can be completely released in such operations, mechanization may again need to be justified on the basis of a change in scale or intensity. Part-time help is not a desirable alternative in many areas.

It appears that the farms which should most logically consider increased mechanization are those which employ part-time seasonal help; more specifically those farms employing from one to three man months of labor over even full-time increments. Table XXVI shows 28.4 percent of all farms studied employ from one to three man months of help and 1.6 percent hire thirteen to fifteen man months. These represent a total of 30 percent of the farms which might well consider selective mechanization of the seasonal operations now requiring extra help. In many cases this would involve handling in connection with harvesting and placement in storage.

Use of Time Saved by Materials Handling Equipment

The operator of each farm studied was asked what was done with the time, if any, which was saved by use of feed handling equipment. For consistency and to facilitate summarizing their responses, six categories of possible uses were suggested. The categories and responses are tabulated and broken down by tenant and owner operators in Table XXVII.

TABLE XXVII

USE OF TIME SAVED BY FEED HANDLING EQUIPMENT

Use of Time Saved	Tenants		Owner Operators		Total	
	No.	Pct.	No.	Pct.	No.	Pct.
Expanded Production	19	63	188	65	207	65
Reduction of Labor Supply	17	57	159	55	176	55
More Leisure Time	5	17	65	22	70	22
Care and Maint. of Mach.	9	30	75	26	84	26
More Effective Farming	12	40	118	41	130	41
Community Activities	6	20	87	30	93	29
Total	68	237	692	239	780	238

The largest response was in the category indicating expanded production. This is consistent with the general trend toward larger operating units cited before. These combined with those indicating reduction of labor supply make up over half of all responses. It will be noted that more than one category was checked for most farms.

It is interesting to note that the lowest response is associated with more leisure time.

SUMMARY

The 320 farms studied are considered to represent an unbiased sample of livestock farms using some degree of mechanization of materials handling. Farms were included from 46 of the 83 counties in Michigan and all principal livestock areas were represented. Because of the size and nature of the group of farms studied the use of statistical procedures in the analysis of the data was necessary and appropriate.

The size of the farms studied is somewhat larger than the average acreage of all livestock farms in Michigan. Tenant operated farms are slightly larger than owner operated farms. Both of these factors may be explained by effects of high investments in machinery, time of entry into the farming business and the economics of supporting both an owner and a tenant.

It was observed that over two-thirds of the farm operators are between 30 and 50 years of age. Only two percent were less than 30 years old, indicating again the effect of high initial investments required for farming. Investments in materials handling equipment are lower on farms with operators over 50 years old. This is consistent with the additional observation that scale of operation decreased with age of operators.

In analyzing various methods of performing materials handling operations, there were many cases where a certain degree of mechanization showed no significant saving in time over lesser degrees of mechanization. It must be remembered that the failure of a difference to demonstrate significance does not imply that the apparent differences are not actual. In addition to differences in time required to perform an operation by different methods, the differences in effort required and the nature of the operator's activity must be considered. Mechanization makes most jobs easier and more agreeable besides saving time. Indeed, mechanization often makes the difference between physical inability and ability of a particular individual to perform a certain operation. This, in turn, affects the use of family labor as related to hired labor and/or scale of operations.

Some of the more important specific findings of analyses of specific operations are as follows:

1. Baling of hay and bedding is considerably more common than chopping even though handling labor is greater and chopping equipment is often already owned for making silage.
2. The materials which consume the most handling time per ton in order of magnitude are:
    a) Ground feed
    b) Bedding
    c) Hay

3. The most highly mechanized handling is associated with:

   a) Manure

   b) Silage

   c) Small grains

4. General types of operations requiring greatest handling time are:

   a) Feeding or distributing

   b) Removal from storage

   c) Moving from storage to area of use

5. Consideration of average annual tonnages involved along with man-hours per ton reveals that the materials requiring the most total annual time in order of magnitude are:

   a) Ground feed

   b) Silage

   c) Manure

   d) Hay

6. Specific materials handling operations which are conspicuous for the time required by them and for their need of engineering attention are:

   a) Distribution of bedding in the area of use.

   b) Feeding ground feed; especially to dairy cattle.

   c) Moving ground feed from storage to feeding area.

   d) Removal of hay from storage.

e) Removal of silage from vertical silos.

f) Removal of ear corn and small grains from storage.

g) Feeding hay and silage.

7. Manure handling is by far the best developed and mechanized from the standpoint of complete systems which are designed to be compatible with production practices.

8. With most feeds certain handling operations are well mechanized and efficient, but, little consideration has been given to their effect on the other handling operations.

9. There is evidence of a need for system development which would make the methods of performing various operations not only compatible and complementary but coordinated and integrated for continuous flow and simultaneous performance.

10. Farm operators are interested in high power and high capacity. This is inconsistent with certain basic principles of work simplification and automation.

11. On equipment where it is possible, farmers use tractors and engines more commonly than electric motors.

12. Of all equipment studied, the barn cleaner has the highest combined operating and over-head cost per hour used. The cost of using this unit,

however, makes a man's time worth only 41 cents per hour for manual barn cleaning. Similar data were obtained for other equipment.

13. A highly significant correlation coefficient was demonstrated between amount of materials handling mechanization and over-all farm production efficiency.

14. As would be expected, there was evidence that other factors besides degree of mechanization also greatly influence production efficiency; such things as mechanical aptitude, physical stature, physical condition and managerial ability of the operator and other workers.

15. Thirty percent of all farms employ between one and three months of part-time help per year. These farms, especially, might well consider increased mechanization for elimination of this need for seasonal help.

16. Sixty-five percent of the farm operators indicated that they had expanded production as a result of time saved by materials handling equipment. Fifty-five percent had reduced their labor supply. Only twenty-two percent indicated that they had more leisure time.

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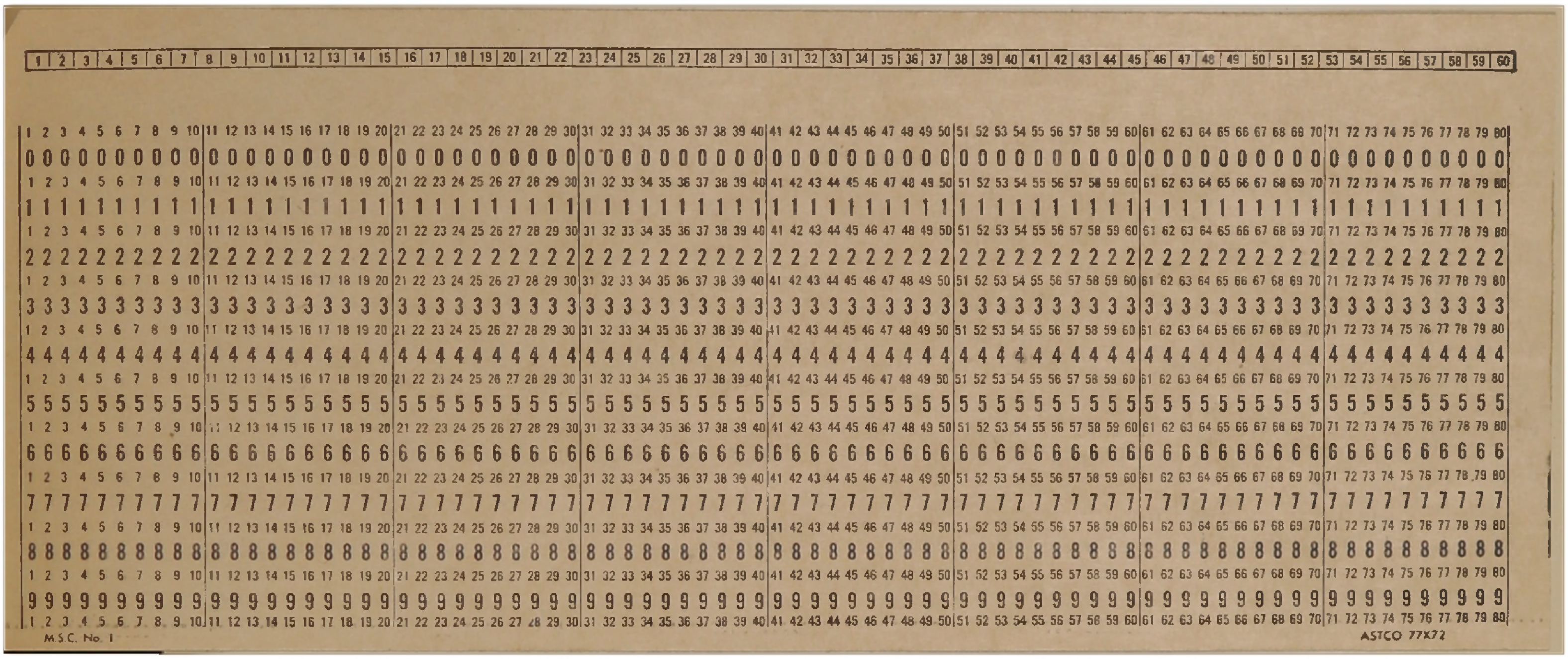
APPENDICES

APPENDIX I

IBM CARD PROGRAMMING CODE



CARD 1

Columns 1-2 : County number (See APPENDIX III)

3-4 : Farm number within county

5 : Owner (code no. 1) or tenant (code no. 2)

6-8 : Acreage of farm enterprise

9-10: Operator age

11-12: Family labor in man-months equivalent

13-14: Hired labor in man-months

15-17: Total labor in man-months

18-19: Dairy cows

20-21: Dairy young stock

22-23: Beef cows

Columns 24-25: Beef feeders per year

26-27: Sows farrowed

28-30: Hogs marketed per year

31-33: Ewes lambed

34-36: Sheep marketed per year

37-40: Laying hens

41-44: Broilers or fryers marketed per year

45-48: Turkeys marketed per year

49: Type of farm enterprise

Code No. 1 - Dairy

No. 2 - Beef

No. 3 - Swine

No. 5 - Poultry

No. 6 - General livestock

50-55: Total investment in materials handling equipment.

56-60: Total livestock labor months (See APPENDIX IV)

61-65: Relative labor requirement

$$= \frac{\text{Total labor (man-months)}}{\text{Total livestock labor months}} \times 100$$

74-79: Use of time saved (No. 1 is code)

74: Expanded production

75: Reduced labor supply

76: More leisure time

77: Care of machinery

78: More care to production activities

79: Community and service activities

80: Card number

CARD 2

Columns 1-2 : County number

3-4 : Farm number within county

5-28: Hay handling data

Column 5 : Baled (1), Chopped (2) or Long-loose (3)

6-8 : Annual tonnage

9 : Method of unloading
10-12: Man-hours per ton

13: Methods of distributing in storage
14-16: Man-hours per ton

17: Method of removal
18-20: Man-hours per ton

21: Method of moving to feeding area
22-24: Man-hours per ton

25: Method of feeding
26-28: Man-hours per ton

Columns 29-52: Silage handing data

Column 29: Vertical silo (1), Horizontal (2) or both (3)

30-32: Annual tonnage ÷ 10

33: Method of unloading
34-36: Man-hours per ton

37: Method of distributing
38-40: Man-hours per ton

41: Method of removing
42-44: Man-hours per ton

45: Method of moving to feeding area
46-48: Man-hours per ton

49: Method of feeding
50-52: Man-hours per ton

Columns 53-76: Bedding handling data

Column 53: Baled (1), Chopped (2), Long-loose (3) or other (4)

54-56: Annual tonnage

57: Method of unloading
58-60: Man-hours per ton

61: Method of distributing in storage
62-64: Man-hours per ton

65: Method of removing
66-68: Man-hours per ton

69: Method of moving to area of use
70-72: Man-hours per ton

73: Method of distributing for use
74-76: Man-hours per ton

Column 79: Type of livestock enterprise

80: Card number

CARD 3

Columns 1-2 : County number

3-4 : Farm number within county

5-20: Manure handling data

Columns 5-8: Annual tonnage

9: Method of removing from stable
10-12: Man-hours per ton

13: Method of transporting to pile
14-16: Man-hours per ton

17: Method of loading into spreader
18-20: Man-hours per ton

Columns 21-35: Small grain handling data

Columns 21-23: Annual tonnage

24: Method of unloading
25-27: Man-hours per ton

28: Method of moving into storage
29-31: Man-hours per ton

32: Method of removal from storage
33-35: Man-hours per ton

Columns 36-49: Concentrates handling data

Columns 36-37: Annual tonnage

38: Method of unloading
39-41: Man-hours per ton

42: Method of moving into storage
43-45: Man-hours per ton

46: Method of removal from storage
47-49: Man-hours per ton

Columns 50-64: Ear corn handling data

Columns 50-52: Annual tonnage

53: Method of unloading
54-56: Man-hours per ton

57: Method of moving into storage
58-60: Man-hours per ton

61: Method of removing from storage
62-64: Man-hours per ton

Columns 65-79: Ground feed handling data

Columns 65-67: Annual tonnage

68: Method of grinding and blending
69-71: Man-hours per ton

72: Method of moving to feeding area
73-75: Man-hours per ton

76: Method of feeding
77-79: Man-hours per ton

CARD 4

Columns 1-2 : County number

3-4 : Farm number within county

5-21: Auger elevator data

Column 5 : Number of units

6-9 : Initial cost

10-12: Annual repair cost

13-14: Wattage ÷ 100

15-16: Age

17-18: Expected life (including age)

19-21: Hours used per year

Columns 22-38: Chain or belt conveyor data*

42-58: Blower data*

62-68: Grain bin unloader or meter data*

79: Type of livestock enterprise

80: Card number

CARD 5

Columns 1-2 : County number

3-4 : Farm number within county

5-21: Unloading wagon data*

22-38: Barn cleaner data*

42-58: Mechanical feeder data*

62-78: Grain dispenser data*

79: Type of livestock enterprise

80: Card number

* Detailed within card field as outlined for auger elevators, Card 4.

CARD 6

Columns 1-2 :	County number
3-4 :	Farm number within county
5-21:	Self-feeder data*
22-38:	Tractor manure loader data*
42-58:	Silage distributor data*
62-78:	Feed cart data*
79:	Type of livestock enterprise
80:	Card number

CARD 7

Columns 1-2 :	County number
3-4 :	Farm number within county
5-21:	Track type letter carrier data*
22-38:	Hay hoist data*
42-58:	Hammer mill data*
62-78:	Burr mill data*
79:	Type of livestock enterprise
80:	Card number

CARD 8

Columns 1-2 :	County number
3-4 :	Farm number within county
5-21:	Other type grinder*
22-38:	Corn sheller data*

---

* Detailed within card field as outlined for auger elevators, Card 4.

Columns 42-58: Feed mixer data*

79 : Type of livestock enterprise

80 : Card number

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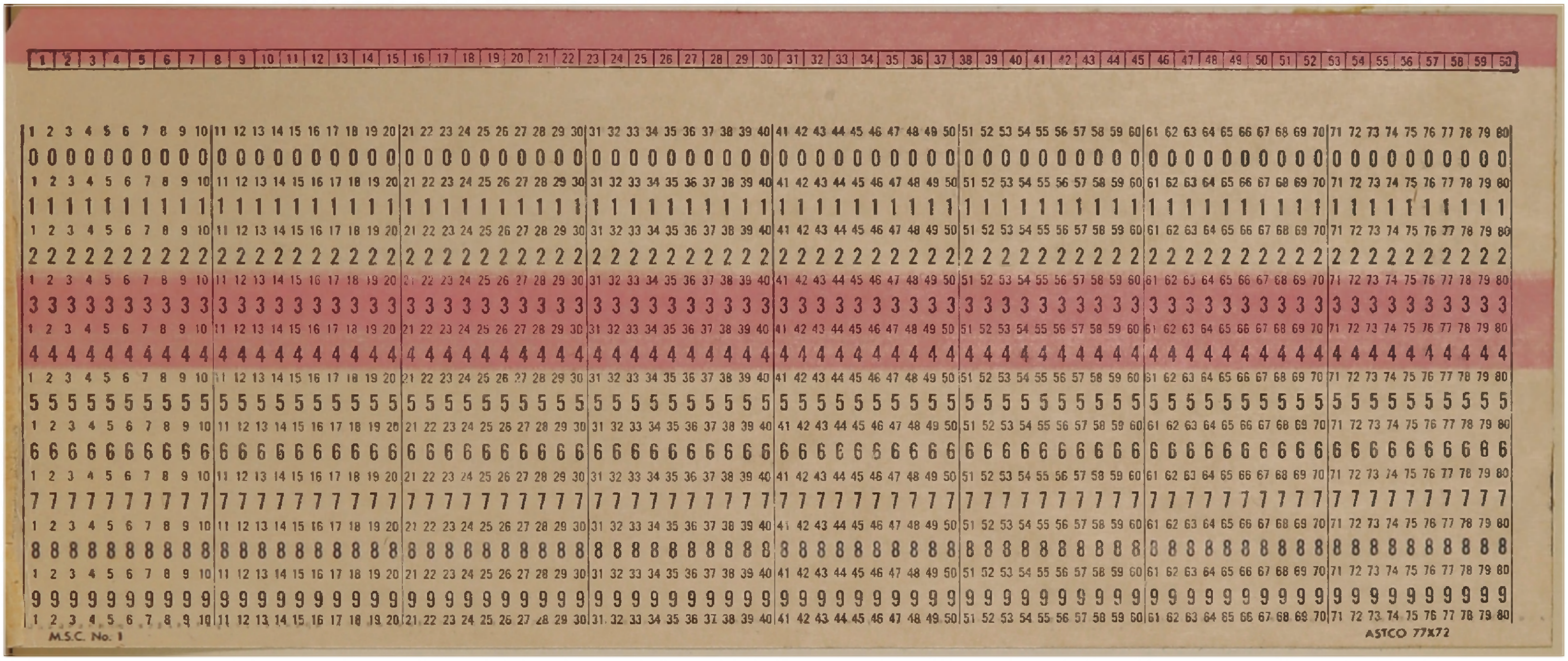
* Detailed within card field as outlined for auger elevators, Card 4.

APPENDIX II

IBM SUMMARY CARD PROGRAMMING CODE



Columns 1-8 : Sum of item indicated

11-18: Sum of squares of item indicated

22-25: Number of cards with item indicated included in sum and sum of squares

APPENDIX III

COUNTY CODE
(Columns 1 and 2 on all cards)

01	Alcona	31	Lake
02	Allegan	32	Leelanau
03	Alpena	33	Lenewee
04	Antrim	34	Livingston
05	Arena	35	Manistee
06	Barry	36	Mason
07	Bay	37	Mecosta
08	Benzie	38	Midland
09	Branch	39	Missaukee
10	Calhoun	40	Monroe
11	Charlevoix	41	Montcalm
12	Cheboygan	42	Montmorency
13	Clare	43	Muskegan
14	Clinton	44	Kewaygo
15	Crawford	45	Oakland
16	Eaton	46	Oceana
17	Emmel	47	Ogemaw
18	Genessee	48	Osceola
19	Gladwin	49	Oscoda
20	Grand Traverse	50	Otsego
21	Gratiot	51	Ottawa
22	Hillsdale	52	Roscommon
23	Ingham	53	Saginaw
24	Ionia	54	St. Joseph
25	Iosco	55	Schiawassee
26	Isabella	56	Van Buren
27	Jackson	57	Washtenaw
28	Kalamazoo	58	Wexford
29	Kalkaska		
30	Kent		

APPENDIX IV

CONVERSION FACTORS USED TO CONVERT LIVESTOCK NUMBERS INTO LIVESTOCK LABOR - MAN MONTHS (Source: Dr. K. T. Wright, Agricultural Economics Department, Michigan State University)

Type of Livestock	Man-Months Per Unit
Dairy cows	0.600
Young dairy stock	0.120
Beef cows	0.120
Beef feeder cattle	0.080
Sows farrowed	0.120
Hogs fattened	0.020
Ewes lambed	0.016
Sheep sold	0.004
Hens	0.008
Broilers or fryers	0.002
Turkeys raised	0.004