TITLE UTILIZATION OF THE PRINCIPLE OF EXTIRPATION IN THE HARVESTING OF SUGAR BEETS

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UTILIZATION OF THE PRINCIPLE OF EXTIRPATION
IN THE HARVESTING OF SUGAR BEETS

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A THESIS

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A. Early Developments

The problem of providing better machinery for sugar beet production has been recognized as meritorious since the early stages of the development of the sugar beet industry, due to the vital concern of both the producer and the processor of this farm crop. Progress, however, was almost stagnant during the period prior to 1930, in spite of numerous attempts made by inventors, sugar companies, and experiment stations to mechanize the planting, blocking, and harvesting of sugar beets.

The harvesting problem which is the only concern of this investigation has received the most attention and has proved to be extremely difficult to conquer.

Evidence of the objectionable factors encountered during the first and most elementary step in the mechanization of the harvesting process was given by L. S. Ware (12) who wrote in 1880 the following: "The extraction of sugar beets may be accomplished by hands or by machines; the latter being done by ploughs of various descriptions. The machine frequently adopted in Germany consists of several coupled curved prongs, penetrating the soil much beneath the maximum depth attained by the roots; the whole is drawn by horses or cattle. The objection to this or any other similar method is the traction made use of, the feet of the animals greatly bruising the roots. -- But some device different from anything up to the present adopted, such as steam plowing, etc., could alone be used in the U.S.A."

One of the earliest attempts to improve on the hand handling of sugar beets was made by Gratton (2) of Lincolnshire, England. A topping device was constructed by him which consisted of a semicircular foot which was placed on the root at the place where it was desired to cut off the tops, a knife which was pressed down by a handle at the side of a light piece of wood to which the elements were attached, and a spring which pulled the knife back.

Although the main concern of inventors up to 1925 was with the design of lifters alone, as is indicated by the numerous variations of this type of implement which were at this time on the American and European markets, designs, with the aim of total mechanization, appeared as early as during the turn of the century.

Plate I shows a machine which was already in operation in 1907. Myrick (7) described the performance of it as follows: "This invention of the Johnson Harvester Company, Batavia, New York has now been so perfected as to do its work most satisfactorily. It digs and lifts the beets, cuts off the tops and delivers the topped beets at the side of the row ready for factory or silo."

Plate I. -- Sugar Beet Harvester Built by the Johnson Harvester Company, Batavia, New York, U.S.A. (In operation in 1907.)

No further information on the principle of operation was given.

An invention which was received with a considerable amount of enthusiasm appeared during the early twenties.

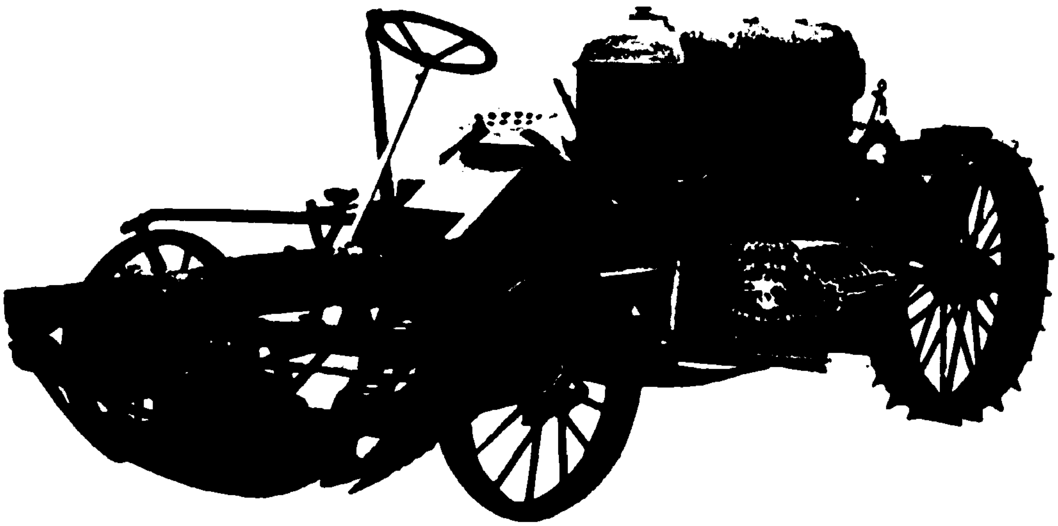
This machine (Plate II) was known as the "Greyhound" sugar beet harvester and was developed by The Banting Manufacturing Company, Toledo, Ohio.

The main features of this machine consisted of two elements. The one was the topper which consisted of a power driven tread belt and a power driven revolving bell disk cutting unit. This unit severed the crown from the beets while the roots remained in the ground. The other was the lifter which raised the beets after they had been topped, cleaned them of dirt and carried them to a conveyor belt at the rear, whence they were dumped on the ground in heaps.

Contemporaries of the "Greyhound" harvester were the "L'Aevenir" and the "Friris le Hant."

The "L'Aevenir" (Plate III) was developed in France by Monsieur Jean Moreau and operated as follows. The topping mechanism consisted of a drum which rode vertically on a horizontal cutting disk, the height of the latter being adjustable in relation to the working position of the drum.

The topper was brought in position for cutting by



<u>Plate II.</u> -- The Greyhound Sugar Beet Harvester. (U.S.A. 1925).

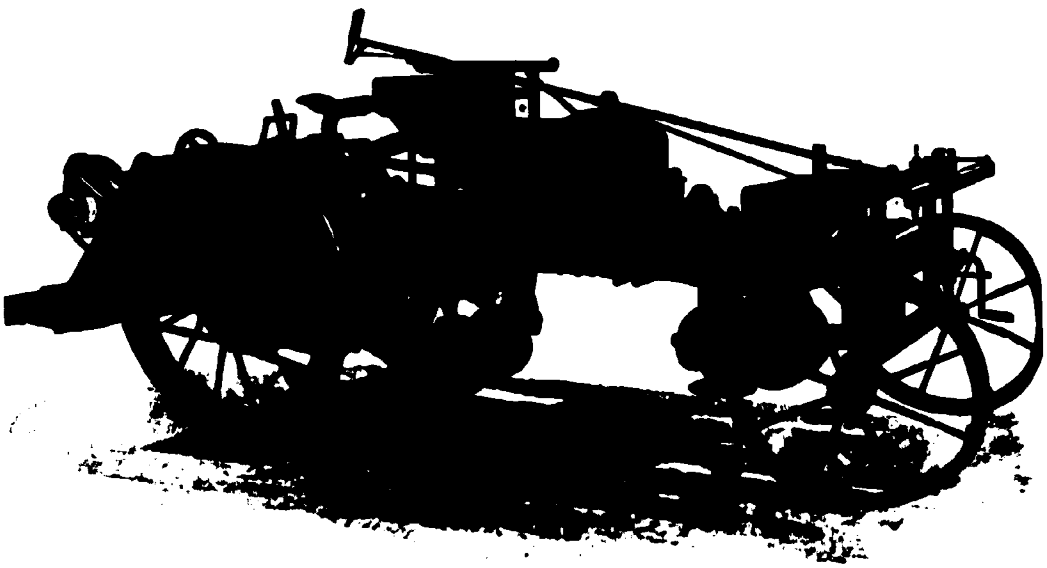


Plate III. -- The L'Aevenir Sugar Beet Harvester. (France 1926.)

the drum which rode over the root. An adjustment was available for changing the relative height between drum and topper. The leaves subsequent to cut were received by two endless metal bands and deposited at the side. The lifting of the roots was accomplished by the wedge pressure from the prongs placed behind the bands.

Landrian Frires and Fexhe le Hant of Clocher, Belgium were the inventors of the other machine (Plate IV.) They accomplished the topping in a rather unusual fashion. A sheet of metal shield or foot was held by springs and weights at a predetermined tension. As the machine was drawn along the row, the leaves were pressed down due to the tension mentioned above, and were then severed by a following knife. The knife was set obliquely to the axis of the machine.

The "Greyhound" was introduced in England in 1926 and took part in the annual sugar beet machinery demonstration contest of that year. Wilding (13) wrote the following about its performance: "Of all the combined machines which we have seen for dealing with the topping and lifting of sugar beets, this is by far the most effective one."

However, the performances of the harvesting machines of that time did not justify a commercial production of any of them, especially from an economical viewpoint.

Plate IV. -- The Frires and le Hant Sugar Beet Harvester. (Belgium 1926.)

With the exception of Germany and Holland the harvesting problem seems to have received less attention in the U.S.A. than in the European countries during the following ten years. Mechanization was less urgent in these three countries because of the relatively cheap and abundant hand labor that was available.

Among the more popular machines which appeared in Europe were: the "Premier" (1929 - English), the "Marliere" (1930 - French), the "Siedersleben" (1930 - German), the "Holland" (1931 - Dutch), the "Desbonnet" (1934 - French), the "Rosenstand Thacht" (1935 - Danish), while others like the "Greyhound" and "L'Aevenir" were improved.

The vast majority of the new models showed no radical deviation, in principle, from one general method composed of the following parts.

1. The ground topper which consisted of a finder for the purpose of locating the crown of the beet for proper topping, and the knife which was actuated for the correct cutting position by the finder.

2. The lifter which was similar to the conventional lifters of that time.

3. The elevator for the loading of the beet on trucks.

Finders that showed the most promise were of two types -- one a track-type and the other a serrated wheel.

Knives were either power driven or stationary and were still experimented with for better performance.

The separation of beets from dirt was by far the most difficult problem. Many devices for mechanical separation such as shaking or bumping of conveyors, piercing pickup wheels, and conveyors with a rubbing or rolling action were experimented with, but they offered no satisfactory solution. This resulted in the anticipation of other methods of harvesting which was basically different.

One system which received more attention in Europe consisted of lifting the beets with the conventional lifter plows, loading them on a wagon by hand, and driving them to a conveyor table where the topping was done by a mechanical stationary topper. A topper of this kind was developed by Morton and Standen (England).

Another and more radically different method of operation was proposed in 1932. It suggested a machine with which the beets would be pulled out by the tops, thus reducing the amount of dirt to be handled by the machine.

An early experimental machine that was constructed on this principle is shown in Plate V. This method did not gain much popularity during the first few years of

Plate V. -- Early Invention on the Scott-Urschel Principle (United States 1932.)

experimentation. Irregularity in height of the roots above the ground contributed much to its ineffective performance.

Thompson (U.S.A. 1934) invented a machine that related to the new principle. The roots together with their immediately surrounding soil were first lifted as one body, and then, as the implement moved forward, travelled rearwardly through the machine still as a body and with the roots upward. The roots were then subjected to an adjusting action whereby the tops were caused to take a common level. After this adjustment a cutter bar removed the tops, which were finally discarded.

An invention (Plate VI) by Borley (England 1937) had the following new feature. Following the lifter was a pair of disks so inclined that the foremost points on their peripheries were wider apart than the rearmost points. A plurality of fingers composed of spring steel rods extended in a radial-like manner from these disks. The free ends of these rods bore idly upon the ground and consequently the two disks with their rods were brought almost into contact with each other. The beets after being lifted were engaged by the rotating radial rods, picked up and gripped firmly between the resilient rods while they were conveyed backwards.

Plate VI. -- The Borley Sugar Beet Harvester. (England 1937).

<u>Plate VII.</u> -- The Catchpole Sugar Beet Harvester. (England 1938).

The most promising European invention of that time was the "Catchpole" (1938) which was developed by W. M. Catchpole of Stanon, England (Plate VII.)

A pair of vertical disks cleaned away soil and rubbish from the path of the topping mechanism which followed immediately behind. A pair of disks was automatically guided into position for cutting by a chain or spiked track unit which rode on top of the crowns of the beets. Spider spinners thrust the severed tops out of the way and shallow shares set at an angle lifted the beets onto a slatted conveyor.

Studies conducted in 1938 at the California Agricultural Experiment Station on American machines such as the Davis Thompson, Great Western, and Scott Viner, showed that the performances of these machines were still far from effective. The machines delivered too much trash and dirt with the beets and the topping quality was unsatisfactory. None of the machines was capable of combatting the irregularities in height above the ground and the varying thicknesses of the beets.

B. The Commercializing Era

(1) Research at the University of California.

The year 1938 marked the beginning of a new phase in the evolution of the mechanization of sugar beet production.

Research of a more basic and scientific nature, and with special concern toward the development of a new type of sugar beet harvester, was commenced at the University of California during this year. A joint project was established between the U.S.D.A. and the University of California for the purpose of investigating the possible fields of mechanization in beet growing and of encouraging and assisting implement manufacturers in the design of sugar beet machinery.

A compendium of this work (8) can best be made under the following four more or less independent sections: topping, plowing, root elevation, and root disposal.

Topping: The common practice up to the beginning of the project was to divide the beets into two size groups -- those less than three and three-quarters inches in greatest diameter, and those of greater diameter. The smallest beets were then trimmed by hand to the level of the lowest leaf scar, and the larger ones three-quarters of an inch higher.

It was then reasoned by the California investigators that, because of this importance of the location of the lowest leaf scar, it was necessary that, for the purpose of mechanization, some dimension of a beet be indicative of the location of the lowest scar leaf.

Data accumulated at harvest time in California, Colorado, Idaho, and Utah indicated approximate linear relationships between beet height above the ground, greatest diameter, and crown thickness (distance from the top of a beet to its lower scar leaf.)

From these relationships arose two obvious angles of approach for the design of experimental machines: the height-crown thickness relation and the diameter-crown thickness relation. Difficulties in connection with the utilization of these relations are: (1) Machines which top beets in their growing position are restricted to the height-crown relationship because the greatest diameters occur often below ground level, and (2) Machines that top after lifting are limited to the diameter-crown thickness since the height-crown thickness relationship is usually sacrificed during the plowing operation.

The investigation was henceforth concerned only with the topping before lifting method which was believed to be showing greater promise for precise work.

Several kinematic, kinetic, and mechanical features involved in the operation of a topping mechanism were investigated. A modified curve was derived for the finder-knife relationship by which the spacing between finder and knife was kept constant when the finder falls below a certain value. This modification resulted in an appreciable reduction of the top tare on small beets while the topping loss remained low.

Special attention was given to the knife design and position in an attempt to correct the slant topping of large beets. Other kinetic requirements considered were the horizontal force and weight of the topping mechanism.

A non-oscillating knife and a finder equipped with a cleated chain was found to be more effective in minimizing breakage of the roots than other methods used.

The frame of the topper was carried on shoes which slid along the ground adjacent to the beet row. Two rotating drums equipped with flexible fingers gathered and windrowed the tops.

Plowing: An effort was made to improve on the traditional type of plow for mechanical harvesting which proved to be unsuitable in many ways.

The form which was finally evolved consisted of two pieces of strip steel twisted about their outer edges as axes, to form a right hand and left hand helicoid. A final selection of the helical pitch, size, angles, etc. was made after various tests on different soils.

It was found that the plow was less sensitive to off-row operation than older types but the layer of soil which lay above the plow points seriously interfered with beet recovery.

Root elevation: The versatility of commercial harvesters in operation under different soil conditions was found to be an inverse function of the soil contacted by the root grasping mechanism. With this in mind an attempt was made to devise a machine which would grasp the roots at points removed from the soil mass. This was accomplished by the utilization of two pairs of gathering chains. One pair was mounted slightly below the plow surface extending backwards in a slanted direction. The other pair of chains was similarly mounted slightly above the ground surface. The beets were trapped between each pair of chains around the taproot and crown respectively, and carried to an elevator at the rear of the machine.

This system did not seem to have been successful in reducing to an appreciable extent the amount of soil lifted along with the beets. A further ineffectiveness of the principle was its inability to trap small beets when the chains were spread by adjacent large beets.

Root disposal: The three popular systems of root disposal then were: (1) Harvested beets from several rows placed in a single row to be picked up later by a separate machine, (2) The lifted beets disposed of directly on a truck which followed the machine, (3) A topper towed behind the harvester in which the beets were deposited. The beets were later transferred to trucks along side the field.

A combination of hopper and loader which was mounted on the tractor, was used during the California investigation. This resulted in an increase of traction available to operate the harvester unlike the situation with a trailed hopper.

The overall performance of the machine seemed to have been promising in spite of some problems incident to the chain performance.

Due to the work done under Powers, by the University of California through subsidized research, inventors, and a few commercial companies, became interested and developed, among others, such units as the Braden, Alvos and Dewey Publo, the Walz machine of Avondale, Colorado, which eventually became the John Deere, and the Oliver.

Rimple at the California Station developed a finger pickup unit with a special plow. Tramoti at the same station worked on a vibrating lifter and Armer made preliminary studies on beet pickups by spikes. Armer also devised a variable cut disk topper based on beet size relationships determined by Powers.

These investigations resulted in much progress in the topping problems but the clod problem remained unsolved. The pressure for some kind of labor saving equipment brought loaders, cross conveyor harvester units, and disk toppers into the picture. Among those were the Alvos, Rapetti, Hansen, and Hunt Brothers. All of these units proved to be cumbersome and relatively expensive to operate, even though some labor was saved.

(2) Progress on a Commercial Basis.

Industry started to show great interest by 1942. The John Deere Company placed approximately 15 of its new experimental machines in the field during this year and programmed 100 for the following year. The variable disk-type topper as developed earlier by Armer, was adopted by the International Harvester Company, while the Blackwelder Company constructed a harvester after the design by Schmidt, Jongeneel and Associates. Experimentation was also done by the Allis-Chalmers Manufacturing Company and the Sawtooth Company.

In September 1944 Walker (11) described the status of mechanical harvesting units as follows: "The work on harvesting machinery has continued with varying success ... Machines now commercially available are operating in the field with sufficient success to keep them going; but these are also sufficiently faulty to create a desire for improvements. Topping, top recovery, and removal of roots without excessive dirt and breakage, appear to be the bottlenecks for a more satisfactory product at the dumps (factory). The problems of these commercial units have caused us (California Station) to direct our studies toward obtaining a better harvested product."

Progress made by Powers during the 1945-1947 seasons seems to have been of considerable significance. His single row tractor mounted harvester unit, consisting of a variable cut topper, helical plow, chain lift conveyor, cleaning elevator and overhead bin, enabled him in 1947 to obtain 96% recovery of well topped beets, with relatively low dirt tare, in soils ranging from hard dry to moist and sticky. In the meantime the implement industry has provided new types of harvesters, and it was estimated (9) that nearly 4000 harvester units were in operation in the U.S.A. in 1947 to harvest 30% of the nation's sugar beet crop.

In the same year, according to Cannon (1), approximately 3000 mechanical beet harvesters operated in the sugar beet growing sections of Washington, Oregon, South Dakota, North Dakota, Minnesota, Iowa, Nebraska, Colorado, Wyoming, Montana, Idaho, and Utah. An analysis of these machines showed that approximately 55% were John Deere, 31% International, 3% Scott Urschel, and 3% Keist. The remaining 8% was an assortment of various makes. About 21% of the sugar beet growing areas in these states was harvested mechanically.

The output per machine varied greatly in different areas and with different makes of machines. The use of various types of machines has been dependent on soil conditions and other variables, with one machine finding greater favor under one type of condition and another fitting in better somewhere else.

It was found (1) that the John Deere performed more satisfactorily in the lighter soil types while the International topper, which was introduced for large scale use in the fall of 1946, operated favorably in areas where the John Deere was not suitable. The Scott Urschel was more successful in the inter-mountain area, especially on heavy soil, and was noted for its high capacity.

The Roto-Beater developed by the Olson Manufacturing Company of Boise was introduced for commercial distribution in the Western area in 1947. It was equipped with the beater topping unit which was developed during the previous year. For the most part the harvesting systems, involving beater topping were confined to the lighter soil type areas and to areas where beet tops have not been fully utilized for livestock feed.

The Keist harvester which was introduced in the inter-mountain area had a great deal of mechanical trouble (8) during its operations.

Commercial sugar beet harvesters were introduced in the Eastern sugar beet growing area in the fall of 1943, and have experienced increased acceptance during the following years.

In 1946, 130 mechanical harvesters operated in the sugar beet producing parts of Michigan, Ohio, Wisconsin, Illinois, and Ontario, Canada, and harvested about 3.4 per cent of the 240,000 acres. The most popular machine in these areas was the Scott Urschel which harvested about 3.3 per cent of the total area.

Harvesting data, accumulated during the 1946 season in these areas by Michigan State College and the U. S. Department of Agriculture in a combined project, showed that the average percentage of tare figures for mechanical harvesting was about 2.28 per cent greater than for hand harvesting and that the dirt per ton of clean beets was about 48 pounds less in the case of hand harvesting.

Mechanization of the harvesting operation across the country expanded more rapidly during the 1947-1948 period than during previous years. Surveys made by the Sugar Beet Development Foundation, as given by McBirney (6), indicated that the percentage of sugar beet acreage which was machine harvested increased from 27 per cent to 53 per cent in 1948. However, less favorable weather and soil conditions in 1949 had as a result an increase of less than one per cent in total area during this season.

A total of about 9000 sugar beet harvesters were in operation during the 1949 season. Adequate supplies of hand labor were available in many sections.

(3) Classification of Machines.

The following is a list of some of the numerous American inventions classified according to their principles of operation.

I. Topping before lifting (Combined operation)

Name	Manufacturer or Inventor
Diethelm Sugar Beet Harvester	Mahl Equipment Company Minneapolis, Minnesota
Grandsen Sugar Beet Harvester	--- Edinville, Michigan
Great Western	Great Western Sugar Company
Grew Experimental Sugar Beet Harvester	--- Bay City, Michigan
International Sugar Beet Harvester	International Harvester Company

II. Topping before lifting (Separate units)

Name	Manufacturer or Inventor
Ashley Sugar Beet Harvester	U.S. Farm Equipment Company, San Francisco, California
Carl Oppel Harvester	---Fort Collins, Colorado
Ford-Ferguson Two-Row Topper	Ford-Ferguson Company
Harry Ferguson Sugar Beet Harvester	Harry Ferguson, Inc.

John Deere Two-Row Topper	John Deere Company
John Deere Two-Row Digger and Lifter	———
John Deere Beater Topper	———
Kiest Two-Row Topper	Olsen Mfg. Company
Kiest Two-Row Digger	———
King Wyse Two-Row Harvester	--- Saginaw, Michigan
Miller Harvester	--- Waterville, Ohio
Olsen Rotobeater	Olsen Mfg. Company Boise, Idaho
John Deere Two-Row (1943)	John Deere Company
Persons Sugar Beet Harvester	--- Merril, Michigan
Ropke Harvester	--- Elmore, Ohio
Sam Spencer Harvester	--- Fort Collins, Colorado
Sichs Sugar Beet Harvester	Julius Sichs & Company Torrington, Wyoming
Two-Row Kiest Harvester	Kiest Beet Harvester Co.
University of California Sugar Beet Harvester	University of California
Yuel Harvester	Swartz Creek, Michigan

III. <u>Topping after lifting</u>

Flintjer Sugar Beet Harvester	H. Flintjer, Cheyenne, Wyoming
Flora Engineering Co. Sugar Beet Harvester	Flora Engineering Company Cheyenne, Wyoming

Flo-Walk Harvester	E. J. Florrette Saginaw, Michigan
Harval Sugar Beet Harvester	Sterling Machine Co. Minneapolis, Minnesota
Marbeet Harvester	Schmidt Brothers Rio Vista, California
Marbeet Midget	———
Scott-Urschel	Scott Viner Company Columbus, Ohio
Scott-Urschel Stub Bar	———

Mechanization progressed at a relatively much slower pace in Europe during the period after 1938, and the continental developments tended in the direction of machines that lift and clean the beets after they have already been topped by hand or by separate machines.

Demonstrations held in England in the fall of 1946 revealed only a few contributions in the line of new harvesting machinery. The Catchpole was at that time still the only British machine in commercial production.

In 1947 only about 1.4 percent of Briton's sugar beet crop was harvested mechanically. A British Mission appointed by the British Minister of Agriculture was sent to the U.S.A. to investigate the harvesting developments in this country at that time.

The nature of their findings was summarized by Wilding (5) as follows: "But the inescapable impression created by the report is that it is a case of "making do" with what is available. 'Although at the present time' it was concluded in the report, 'the machines are far from perfect and may not be capable of doing the work as efficiently as average casual labor, they are being used on a rapidly-increasing scale in an endeavour, firstly, to overcome the acute labor shortage and secondly, to decrease the cost of beet harvesting'."

Soviet Russia also showed interest in the American machines and imported a few John Deere harvesters and tried them out in 1945. However, Kerenkov and Yeremeyev (4) stated that the performance of the John Deere was inferior to that of the U.S.S.R. under Russian conditions.

Very little information on the early developments in Russia could be found. Russia did not participate in any of the International Demonstration shows which were regularly held on the continent and in England.

Kerenkov and Yeremeyev (4) stated that mechanization of the crop started in 1930 and that, after experimentation with conventional types, they developed a method much of the same order of operation as are followed when the beets are harvested by hand.

The machine that operated on this principle was known as the S.K.T.S.K.. Kerenkov and Yeremeyev (4) describe its operation as follows: "A chain puller 'clutches' the leaves of the beet just as the worker's hand grasps hold of them, the root is dug out by a one-sided digger and the heads of the plants are evened up according to length. The tops are cut off by a revolving disk knife and the roots are cleaned and thrown into a hopper."

The chief defect of the topping apparatus according to Kerenkov and Yeremeyev was the slanting characteristic of the cuts due to the weak clutch of the root at the moment of topping.

Later on another machine, the S.K. 3, was designed by Pvlov and Gerasimov on the same principle as the S.K.T.S.K. but of lighter construction and with a simplified pulling unit.

The Russians also investigated the possibility of multiple row harvesters and claimed (11) that they were the first to build a multiple row harvester. When this was achieved was not indicated.

Trends in the direction of increased capacity in the United States appeared as early as 1940 when a 12-ton lifter topper was developed (3). This machine was self-propelled by a 90 H.P. diesel engine which drove the machine through chains to 16 pneumatic tired rear wheels. The lifting was accomplished by five "sticker" or "picker" wheels, one for each row of beets. The beets were removed from the wheels by metal bars which passed between the sharp spikes on the wheels. The economical applicability of this type of machine was extremely limited and restricted to large size farms.

A more recent machine of this nature was developed in France. It was designed by Ruhlmann to handle three rows simultaneously. The machine participated for the first time in demonstrations held in France in 1947. A description of this invention is given later on.

The trend in England remained toward small units of simple construction. An analysis concerning this trend indicated that mechanization seemed to have been more completely carried out by the small growers during recent years, which was largely to be accounted for by the advent of the lower priced unit machines.

A survey (10) of the Northern European beet producing area, which was carried out during September and October 1948, revealed that about 30 different types of machines participated in demonstrations in England, France, Belgium, and The Netherlands.

The names of those machines appear in the following list:

English: Name	Manufacturer
Birtley-Sick	Birtley Co., Durham, England
Catchpole	Catchpole Engineering Co., Suffolk, England
Minns Model S-SL	Minns Manufacturing Co., Oxford, England
Minns Model HW	Minns Manufacturing Co., Oxford, England
Murray	Elstree Engineering Co., London, England

Name	Manufacturer
Robot-Hilleshog	Transplanters, Ltd. Herts, England
Salmon	John Salmon Engineering Company, Essex, England
N.A.I.E. Prototype	National Institute of Agricultural Engineering, Bedfordshire, England
French:	
Caby	J. Caby, Nord, France
G.S.	Ateliers de Construction, G.S., Seine, France
LaGerbe	M. de Guillebon, Nord, France
Moreau	S.E.M.A.M., Nord, France
Ruhlmann	A. Ruhlmann, Paris, France
Ferte	A. Ferte, Soissons, France
Verbyst	(France)
Loiseau	(France)
Cappelle	(France)
Tuscher	(France)
Munch	(France)
Danish:	
Hesse Lager	Flemstofte Maskinfabrik, Fuglebjerg, Denmark
Mern -2	Dameco, Aalborg, Denmark
Roerslev	Rasm Holbeck & Son, Odense, Denmark
Madsamby	Madsamby, Aalborg, Denmark
Belgian:	
Vandemeir	G. Vandemeir, Battice, Belgium
Vassart	Fonderies et Ateliers de Construction, Max Vassart, Ligny
Simples-de Saint Haubert	Etablissements Industriels et Commerciaux, Orp-Le-Grand, Belgium
Dutch:	
Zeeland	Firma W. Schipper & Soon Goes, Holland

Name	Manufacturer
Swedish:	
Hilleshog	Curt Howeller, Landskrona, Sweden

Several American machines were also exhibited, including the International, John Deere, Scott-Urschel, and Marbeet.

The John Deere gave the best performance, under French conditions, of any of the machines, while the International harvester was favoured under soil conditions in Holland. None of the American machines did a presentable job due to local conditions of the demonstration farm during the demonstration in England.

Machines of 24 different types were operated in England during 1949 among which were 12 British, two American, three French, five Danish, and two Dutch makes.

These machines totaled 1922 as compared to 118 in 1946 and harvested 10.8 percent of the total acreage as compared to .98 percent in 1946.

A large variation of machines took part in the 1950 demonstration contest, most of which were in the field for quite a number of years. There were no machines with entirely new principles, but various attempts, most of which were of little significance, were made to improve on the older models. A new entry in the lifter section that performed very favorably was the Rational combined potato and sugar beet lifters. A discussion of these implements is given under the next section.

II. Principles of Operation of Some Principal Present-Day Machines

The following is a selection of sugar beet harvesting machines that represent the popular principles of operation during recent years in the United States and Europe. A brief description of the general principle of operation of each machine accompanies the photo. Most of the machines are in experimental stage and are subject to frequent changes. They were selected in accordance with the various areas under which conditions they give favorable performances.

A. American Machines

The International Harvester. Topping and lifting by this machine are accomplished in the following manner. A fully-floated or balanced topping unit has a drag type "finder" or "feeler" to slide over the beet and gauge the amount of crown for removal, and, in this manner register the cutting for the immediately following rotating disk which does the topping. At this instant a transversely revolving finger device sweeps the tops from the dished topping disk and places them in a row at the side.

Following the topping unit are two notched rolling coulters that cut the trash and reduce the sizes of the clods. The beets, after being lifted in the regular manner, are then passed to a cleaning trough with kicker wheels. This unit is supplemented by what are known as canvas retarders placed transversely to the travel of the beet so that they slow up the rearward travel of the beets.

Plate VIII. The International Harvester Sugar Beet Harvesting Machine. (Midwestern Area, United States.)

The beets then travel up the steeply angled elevator for either direct discharge into the trailer cart or onto a special endless rubberized canvas belt, from which the beets are removed by hand while the unwanted material is discarded by the belt.

The John Deere. There are several types of machines in the field, most of which are still in experimental stage. The general principles of operation are, however, more or less the same.

A two-unit outfit is shown on Plate IX. The topping and lifting in this system are done in separate operations.

The topper (upper picture) is mounted on a tractor and has in addition a rubber spiked rotor mounted at the rear of the tractor to clean the portion of the beets above the ground. A curved knife, gauged by driven finder wheels, tops the beets in the ground. The tops are picked up by fingers mounted on a drum immediately behind the knife. They are disposed of in windrows of three or four rows each, by means of a conveyor.

The lifter (lower picture) is pulled behind the tractor and is driven from the power take-off. The beets are lifted by two spiral bars, pitched into an elevator by a pair of kicker wheels. The elevator delivers them on a conveyor belt for dirt removal. Another elevator delivers the beets onto a truck driven alongside the machine.

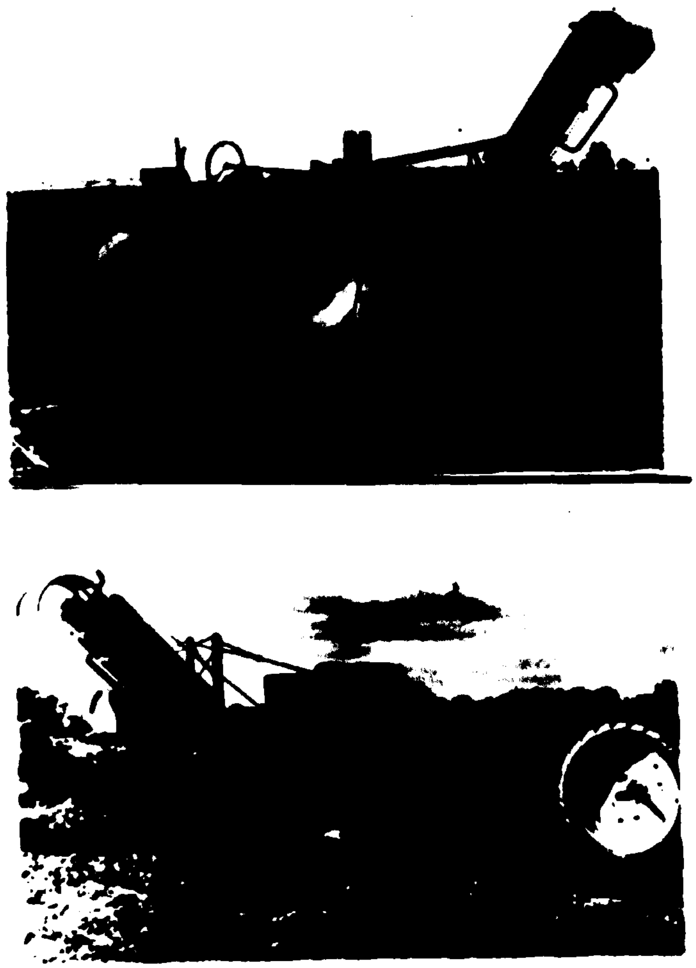


Plate IX. The John Deere Sugar Beet Harvester. (Midwestern Area.)

The Marbeet. This machine consists of a large wheel with a wide rim containing five rows of curved spikes, spaced at two inches from center to center, mounted on a swing frame. This frame supports the lifting plows which cut the top root off and then engage the beets on the spikes. The topping knives, mounted between the rows of spikes at the top of the wheel, sever the roots from the tops as the wheel is turned. The roots then tumble over a series of filter rolls, slightly retarded by spring loaded belt curtains, and then fall into a hopper from which they are carried by a potato chain-type elevator into a vehicle running alongside. The tops are cleaned from the wheel by a series of strippers mounted below the topping knives, allowing them to fall on a cross conveyor, which discharges them into a windrow.

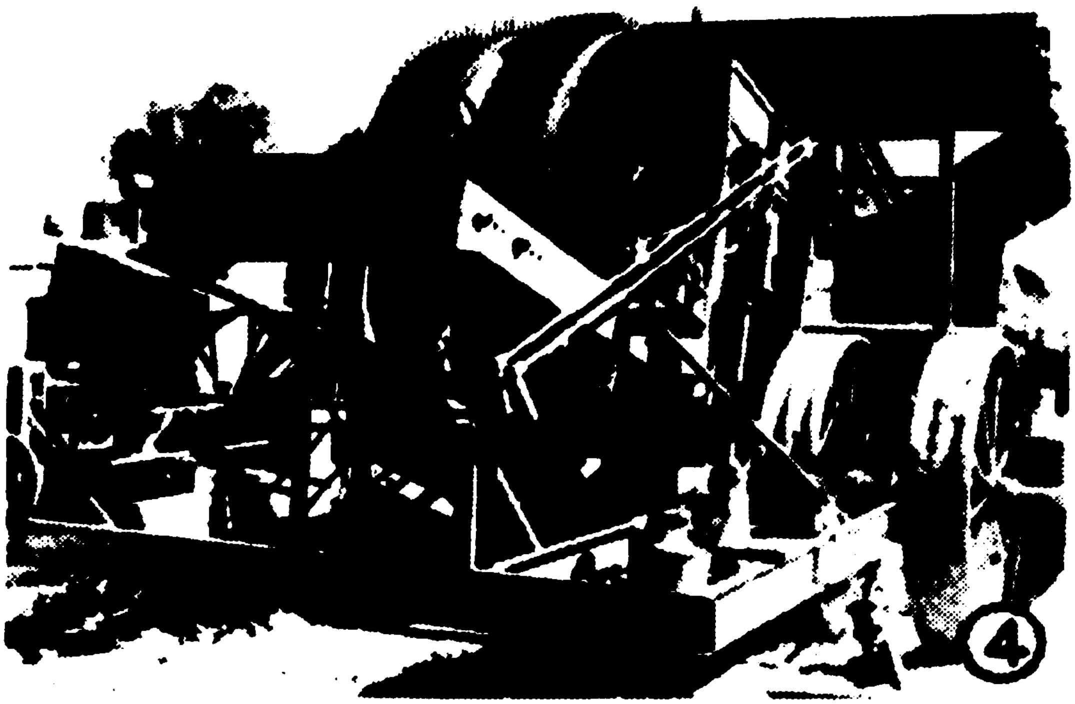


Plate X. The Marbeet Sugar Beet Harvester. (Western Area, United States.)

The Marbeet Midget is a tractor mounted machine. A 30-inch diameter wheel with four rows of spikes is mounted on a spring loaded swing frame mounted on the right hand side of the tractor. Two overlapping power-driven disks are used for topping. The roots are loosened and carried back along the side of the tractor to an elevator, which loads them into a truck behind the tractor. The tops are placed on a cross conveyor and windrowed.

Plate XI. The Marbeet Midget Sugar Beet Harvester. (Western Area, United States.)

<u>The Scott-Urschel</u> is a trailed power-driven machine and operates on the principle of topping the beets when they are out of the ground. A pair of conventional gathering points which straddles along down the row lifts the leaves. Just behind these points, a pair of chain elevators (in the later models replaced by V-belts) grasps the beet tops at the same time that the roots are loosened by small shares running beneath the row. The beets are elevated by their tops to a set of horizontal roller bars which position them for topping. The height of topping can be adjusted to suit the operator's desire.

The tops are removed by power-driven circular discs and are then discharged at the rear of the machine. The beets can either be loaded directly into a truck, or, with the aid of a special windrowing attachment, they can be placed in windrows.

Considerable changes and additions had been made in the models that followed the one shown on Plate XII, the most recent of which is the replacement of the roller bars by a pair of spring cushioned rods.

Plate XII. The Scott-Urschel Sugar Beet Harvester. (Eastern Area, United States.)

B. European Machines.

The Catchpole is an independently-steered one-row machine, power take-off driven by a medium-sized tractor.

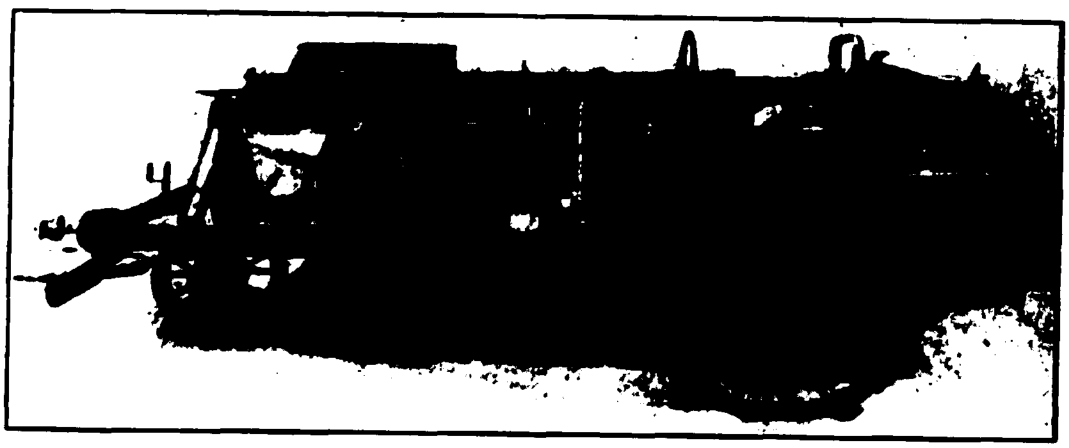
Plate XIII. The Catchpole Sugar Beet Harvester. (England).

The main characteristic is its topping mechanism. This includes a small tracklaying type of "feeler" or height finding unit to bring the topping elements to the position for uniform action. It receives its power from the tractor through gears and chain drives. The discs are horizontally carried on spring-mounted brackets. The topping unit is suspended in the frame by means of a parallel linkage.

After topping the severed crowns and leaves are swept to one side by a spinner unit having flexible rubber beaters and the beets are raised by shares and conveyed to knocking rolls via a rod link conveyor. The beets travel up the knockers which have spring tines, and after the loose soil has been removed they arrive at a wooden-slatted conveyor to be disposed of.

The latest new feature of the machine is the device for collecting the tops immediately after cutting in order to minimize the soiling thereof. Harvesting and topping are accomplished by a combined performance.

The "Moreau" is a combined topper and lifter. A chain or track-type feeler unit brings the rotary cutting disc to the roots. The tops and crowns are swept aside, two following discs pare off more rubbish after which lifting is done by plowing type fittings. The beets are urged on a rotating grid, jolted upwardly to remove adhering soil and ultimately pass by a traverse delivery belt into a single line that can accommodate six to ten rows in a windrow. This machine is available in single as well as multiple row patterns which are all tractor power take-off driven units.



Moreau's Latest Combined Machine

Plate XIV. The Moreau Sugar Beet Harvester. (France.)

<u>The Peter Stanton</u> consists of a front and rear assembly. The front assembly is mounted on a tractor and is composed of a feeler device comprising a multiple series of wheels which have serrated gripping edges. These wheels are spaced and flexibly mounted with a strong spring in the assembly. They are free to ride up and down the tops so as to bring the single fixed cutting blade into correct relation for topping. The serrated edges are to prevent the beets from being pushed over.

Passing between the feeler wheels as they rotate are a corresponding series of rods which register with the feeler wheel interstices in such a manner that they clear away trash and rubbish in order to keep the feeler device clean.

The rear assembly is carried by two pneumatic-tired wheels and is a more or less conventional type of lifter.

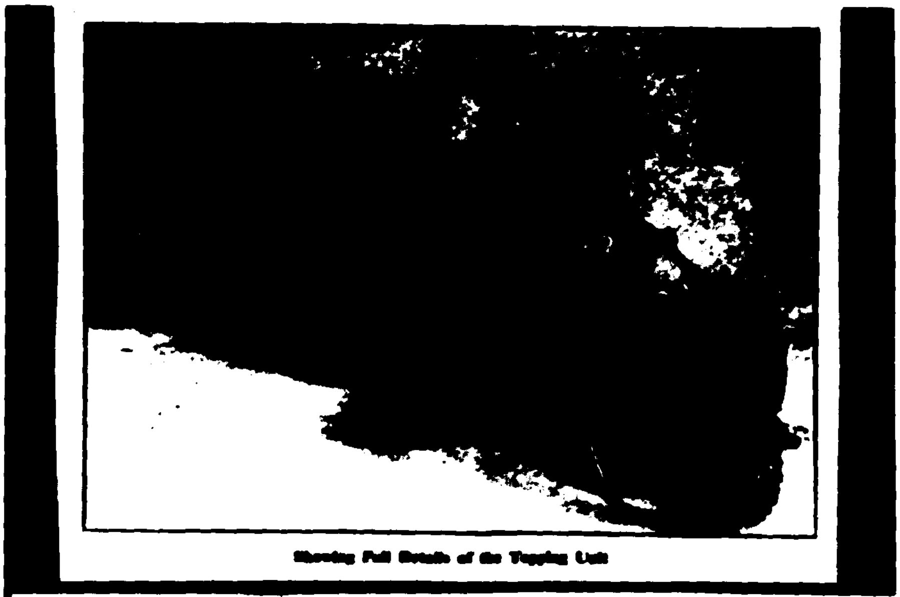


Plate XV. The Peter Stanton Sugar Beet Harvester. (England.)

The Rational is available in three different models operating on the same principle. Topping has to be done previously by a special machine. The special feature of this machine is the lifter which consists of a power driven spinner with spiral steel bars. The spinner rotates just above ground level, and the beets are engaged and pulled out by the rods. They are discarded at the rear of the spinner, where guide screens windrow the beets. A soil scraper levels the ground where the beets are to be laid. The beets are loosened by two specially shaped shares, one for each row, and front guide runners are used to direct the beets to the shares.

These machines can be changed to potato diggers by supplying them with special double digging shares.

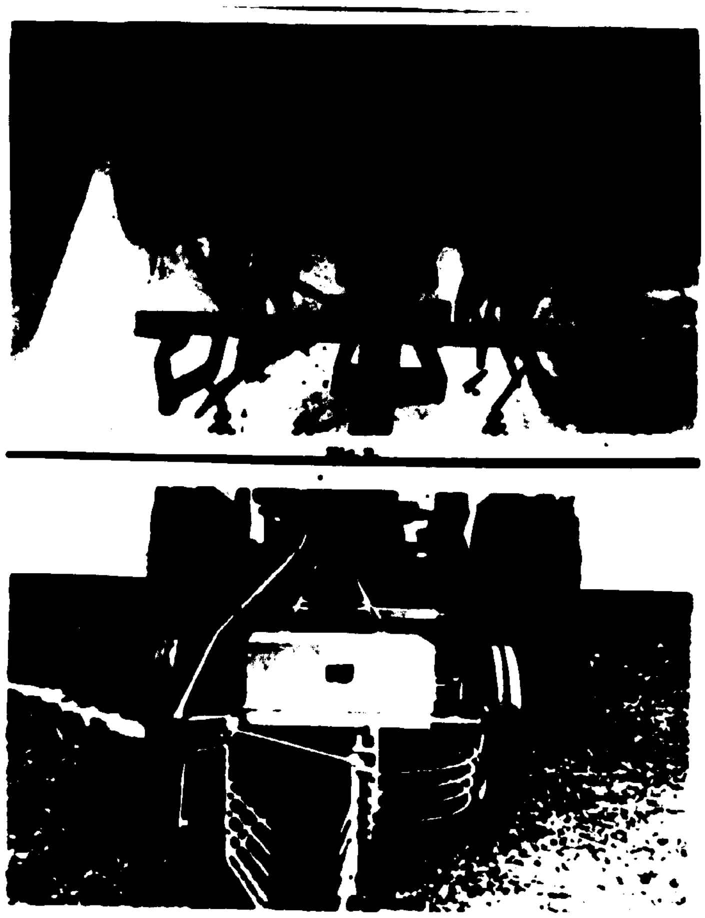
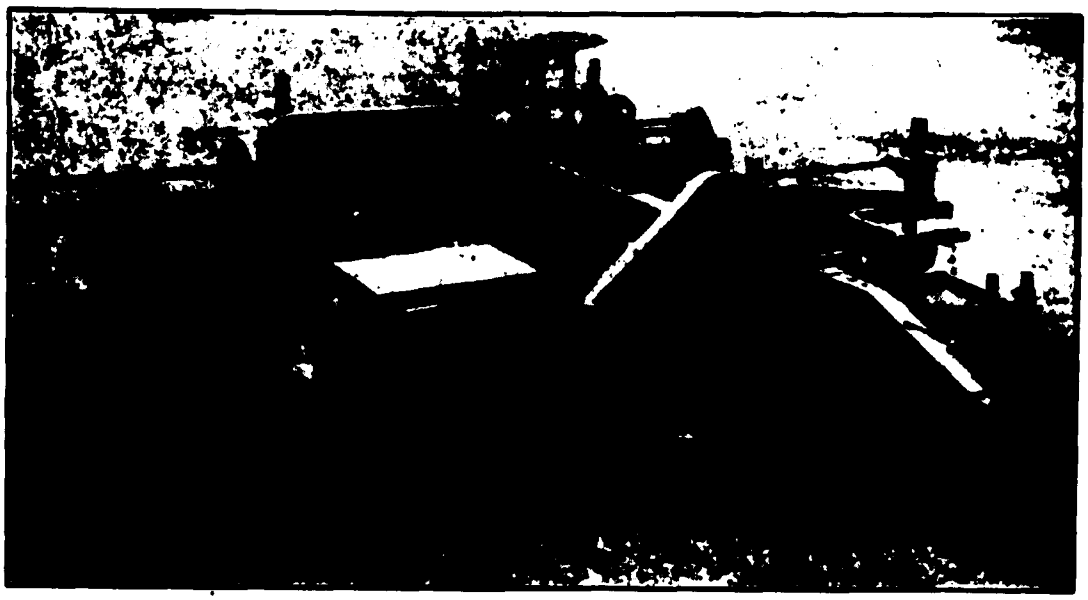


Plate XVI. The Rational Sugar Beet Lifter. (Denmark.)

The Ruhlmann is a three row topping unit which consists of a stem or standard affixed to the frame of the machine. This carries on its lower part two small bars or connecting rods running horizontally backwards in the form of a parallelogram. At the other extreme they are connected by an arched or curved member, which also carries the topper itself and the feeler. The topper is a diagonal or slanting horizontal knife. The feeler unit is in the form of an open adjustable pan so as to bring the knife in correct relationship with the beet.

After topping, the leaves and crowns are formed into a single row. The beets are lifted by a pair of plow-type lifting units, after which they are caught by what are variously described as articulated forks and fork wheels in pairs for a row. These direct the beets onto a shaking device to which a jerking motion is imparted. The beets are then discarded in collective rows.



The Multiple-Row "Loiseau" Topper and Lifter

Plate XVII. The Ruhlmann Sugar Beet Harvester. (France.)

III. Purpose of Investigation

A critical review of the status of the more successful sugar beet harvesting machines of today reveals the following:

1. Sugar beet harvesting machinery has made considerable progress during the last eight years in comparison with the period prior to 1942.

2. The development and performances of the various machines have been strongly influenced by the local climatic and soil conditions of the various sugar beet growing areas.

3. The availability of hand labor in the various areas during the harvesting season has been a predominate control in the expansion toward total mechanization in the respective areas.

4. The economical justification of mechanical harvesting has been largely restricted to large growers, especially in the case of complete harvesting units.

5. Most of the machines are of relatively heavy construction, and the majority of them utilize separate units for the topping, lifting, cleaning, and loading operations.

6. Considerable amounts of dirt are handled by the various machines during the plowing and lifting operations. The effective separation of the dirt from the

beets is still a major problem.

7. The majority of machines do not make use of the tops as a medium of lifting the beets out of the ground.

8. The effective saving and loading of the tops for use as forage, which is of vital importance in many areas, is not provided for in most of the machines.

It was mainly in view of the preceding factors concerning the status of sugar beet harvesters that this work was commenced.

The purpose was to investigate the possibilities of a new principle for the harvesting of sugar beets, with regard to its capability of improving on the conventional machines in the following respects:

1. Reducing and simplifying the units required to accomplish the removal of the tops from the beets, and the lifting and loading of both the tops and the beets at the same time.

2. Reducing the drawbar requirements by diminishing the amount of soil handled, and the depth of plowing during the lifting operation, and by utilizing the tops to assist in the lifting of the beets.

3. More effective proportional removal of the crown by utilizing the diameter-crown thickness relation, revealed by Powers in the results of an investigation (8).

The basic principle of this invention is based on the utilization of two large wheels to lift the beets while they are loosened by a plowing unit, and to convey them to the cutting unit where the tops are removed. The wheels have flexible rims and, when in position, are pressed against one another in such a way that they are compressed along the rear half of their circumferences and are separated along the front half of their circumferences.

The tops are gripped at the lowest point on the circumferences, and are released at the highest point after being sliced off from the beets.

IV. Procedure

A. Preliminary Design. The design of the experimental machine, which was started during the beginning of the winter term of 1950, was continued and completed during the following spring term. An isometric drawing of the component parts of the experimental machine and several detail drawings were made to be used as guidance during the construction of the machine.

Fig. 1 (a) shows the framework which was to carry the topping unit and the beet and tops receiver chutes. This framework mounts on the main framework and over the principal wheels shown in Fig. 1 (b).

Fig. 2 (a) and (b) show ideas envisioned for the construction of the principal wheels and Fig. 2 (c), (d), and (e) some of the details.

In Fig. 3 (a) are shown ideas envisioned for the plowing as well as the topping units. Fig. 3 (b) is a plan view of the main framework and Fig. 3 (c) is the section XY through this framework. Fig. 3 (d) shows a section X'Y' indicated on Fig. 3 (a).

These drawings are not described in detail here because many changes and additions were made during the actual construction of the machine.

A more complete description of the principle of operation and of the various elements is given later.

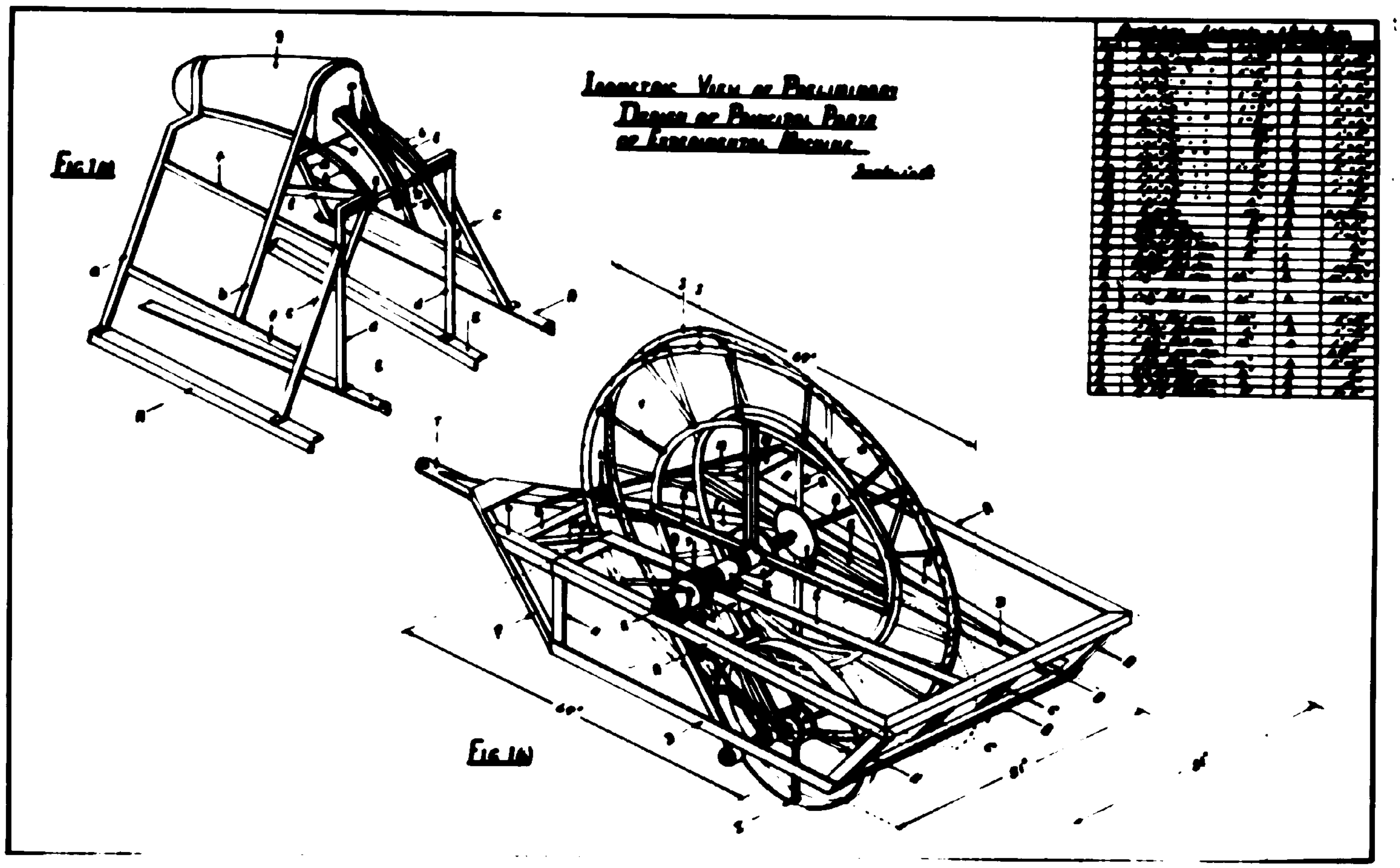


Figure 1.

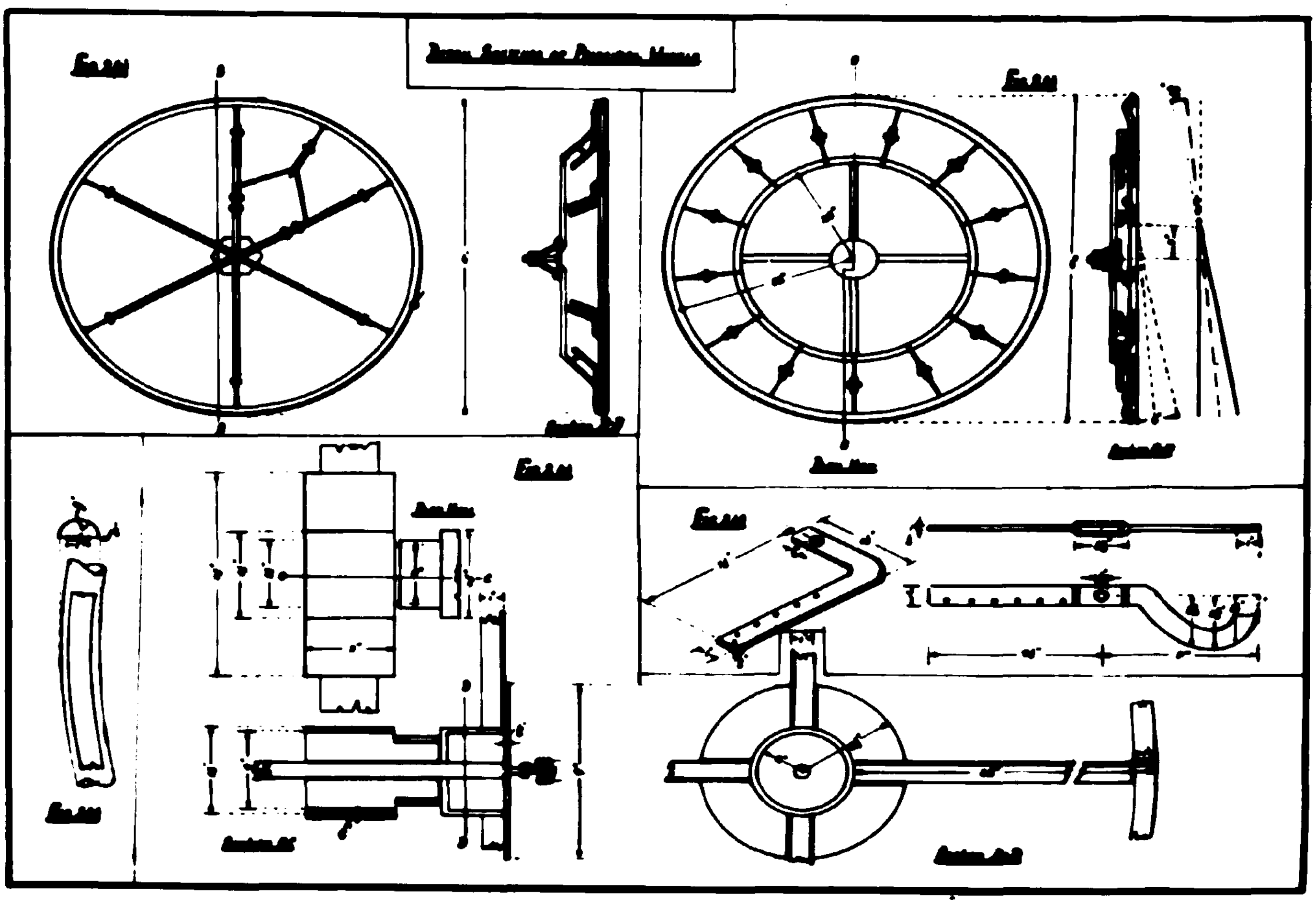


Figure 2.

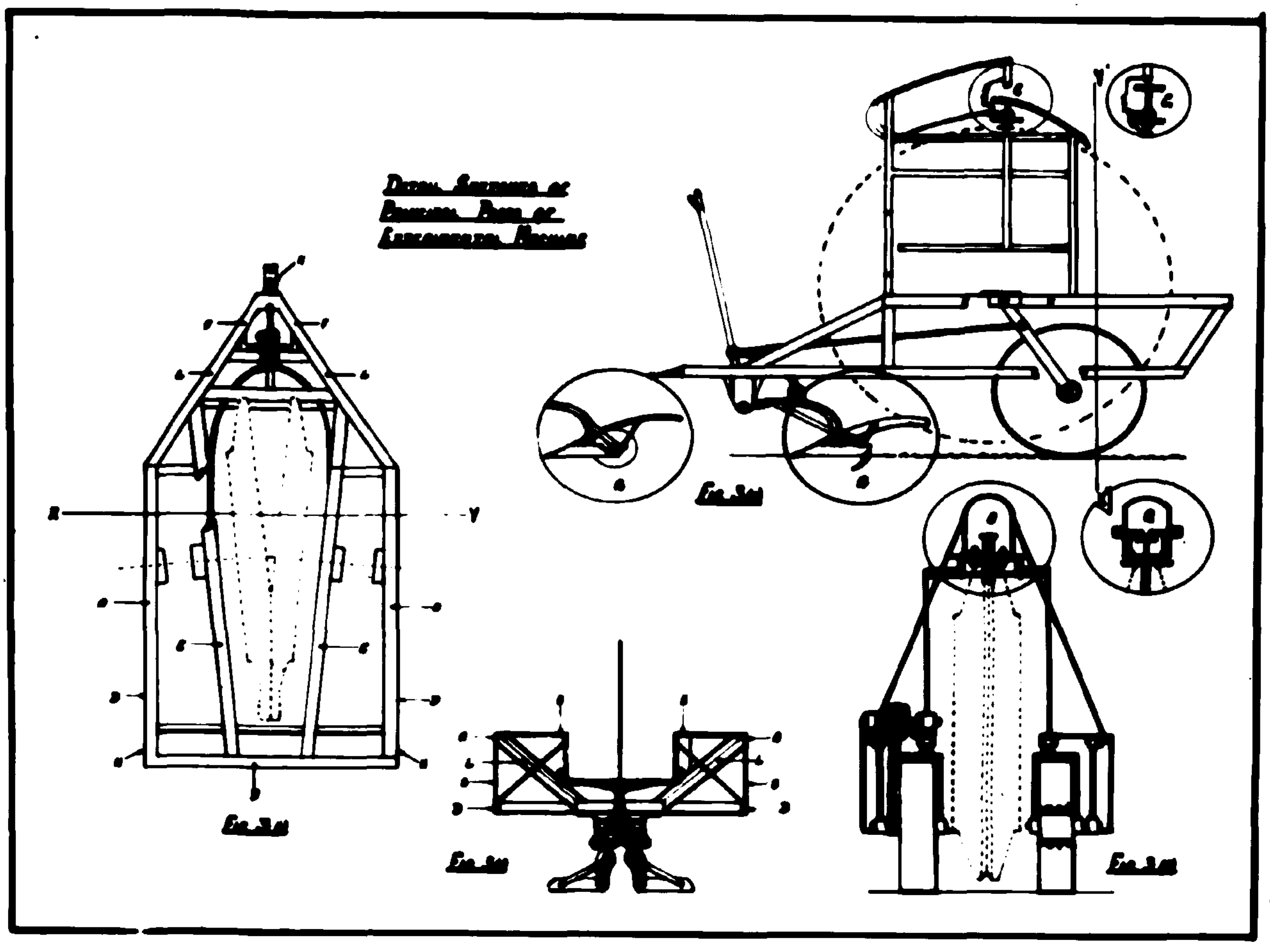


Figure 3.

B. Mathematical Aspects. A mathematical analysis of the kinematical features of the principal wheels was made before the actual construction was started, in order to facilitate the selection of the speed relation between the forward movement of the machine and the rotation of the principal wheels.

The equation of the locus of each point on the perimeter of the principal wheels relative to the ground can be derived as follows.

Consider motion in the plane XOY and with OX and OY as reference axes as shown in Fig. 4 (a).

Let the machine travel with uniform linear velocity v parallel to OX while the circle with radius AB rotates with uniform angular velocity w, and let O be the initial point of B. Let A' be the position of point A and B' the position of point B after a time "t" has elapsed.

Then from Fig. 4 (a):

$$x_1 = vt \qquad (1)$$

$$x = r + vt + r \cos \theta \qquad (2)$$

$$x = r + vt + r \cos (180^\circ - wt) \qquad (2a)$$

$$y = r \sin wt. \qquad (3)$$

$$t = \frac{1}{w} \sin^{-1} \frac{y}{r} \qquad (4)$$

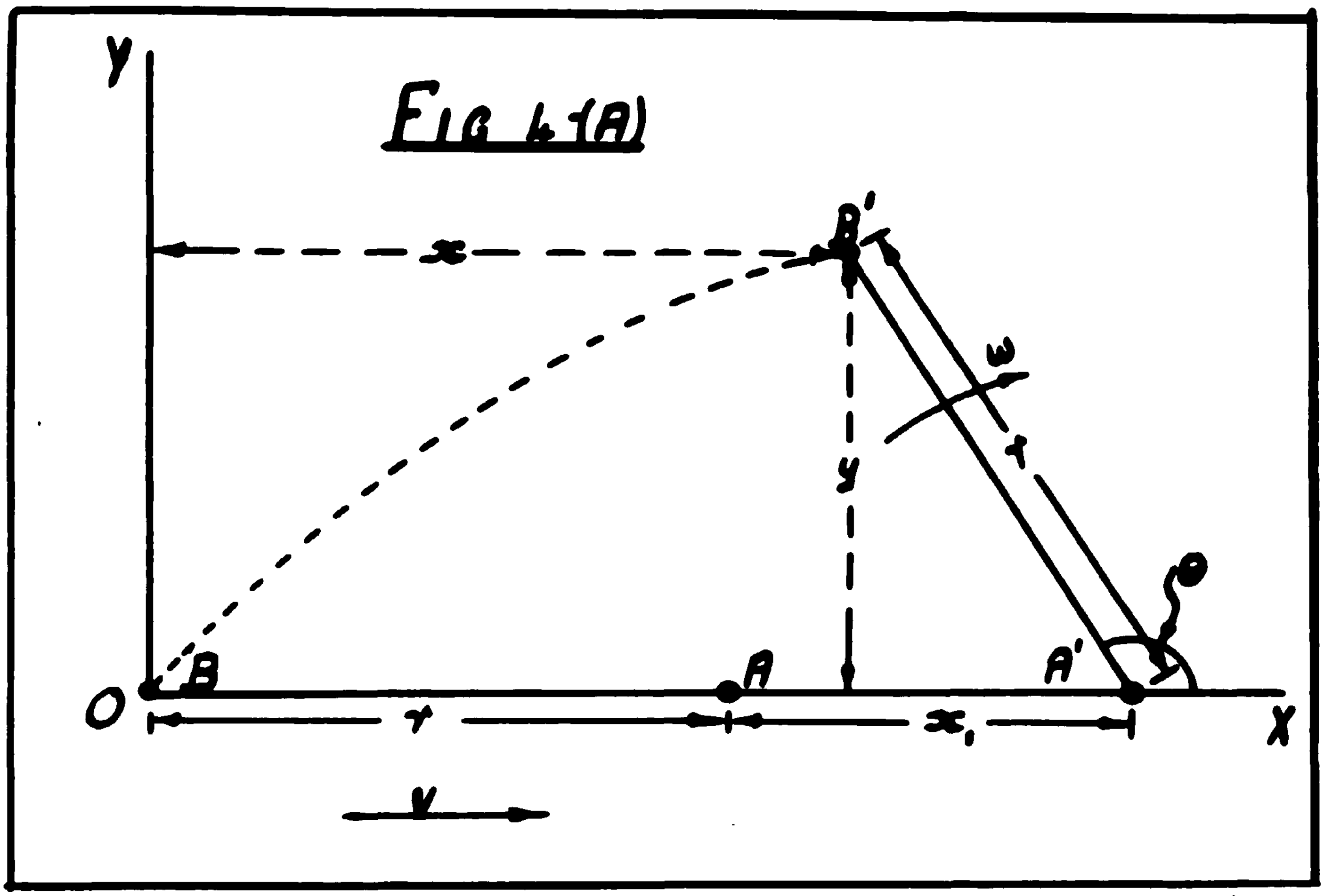


Figure 4 (a).

From equations (1) and (2a) and (4):

$$x = r + \frac{v}{w} \sin^{-1} \frac{y}{r} - r \cos\left(w \frac{1}{w} \sin^{-1} \frac{y}{r}\right)$$

$$x = r + \frac{v}{w} \sin^{-1} \frac{y}{r} - r \frac{\sqrt{r^2 - y^2}}{r}$$

$$x = r + \frac{v}{w} \sin^{-1} \frac{y}{r} - \sqrt{r^2 - y^2} \qquad (5)$$

which is the equation for the locus of point B in terms of the coordinates x and y.

The relation between x and y is dependent only of the variables v and w.

It can further be deduced from equation 3 that point B performs a periodic motion around the x-axis, with period $T = \frac{2\pi}{w}$ and amplitude $L = 2a$.

The linear distance through which point B travels along the x-axis per revolution is obtained by substituting $\theta = 2\pi$ and $t = \frac{2\pi}{w}$ into equation (2).

$$x = r + v \frac{2\pi}{w} + r \cos 2\pi.$$

$$= 2\left(r + \pi \frac{v}{w}\right) \qquad (6)$$

On Fig. 4 (b) is shown the effect on the locus of point B when the relation between v and w is varied. The change in the form of the loop, which is formed below the x-axis, is of great importance, because it reveals the fundamental principle on which the idea of this invention is based.

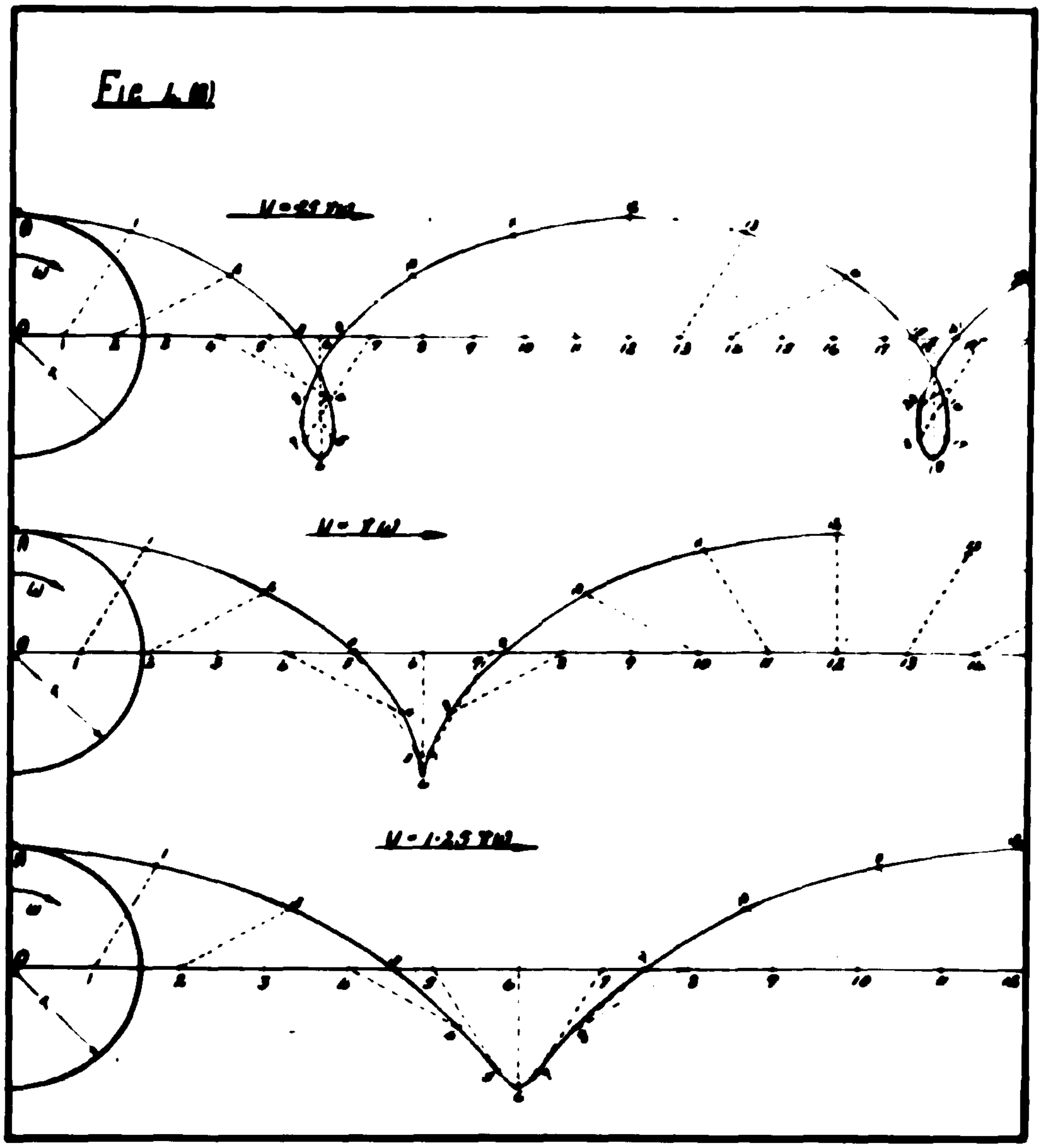


Figure 4 (b).

The ratio of $v = .9rw$ was finally selected to be used in the transmission of the machine. The locus of B according to this relation is shown on Fig. 4 (c). This ratio enables an element (of small dimension) on the perimeter of the wheel, to perform the lifting operation in an approximate vertical direction, while the machine travels through a distance from point 4 to point 8, which is 1/3 of the distance travelled during one revolution of the lifting wheels. This consequently results in a vertical lift of the beets out of the ground with only a slight to-and-fro motion parallel to the line of travel.

The width of the loop between points 5 and 7 on the curve, for constant linear speed and constant angular motion, can be determined by calculation of the respective x components for B_5 and B_7.

From equation (2)

$$x = r + vt + r \cos \theta$$

$$\theta_5 = -\frac{5}{6} \pi$$

$$t_5 = \frac{5}{6} \frac{\pi}{w}$$

$$\therefore \quad x_5 = r + v \times \frac{5}{6} \frac{\pi}{w} + r \cos\left(-\frac{\pi}{3}\right) \qquad (7)$$

$$\theta_7 = \pi + \frac{\pi}{6} = \frac{7}{6} \pi$$

$$t_7 = \frac{7}{6}\frac{\pi}{w}$$

$$\therefore \quad x_7 = r + v \times \frac{7}{6}\frac{\pi}{w} + r\cos(-2\frac{\pi}{3}) \qquad (8)$$

From equat. (7) and (8)

$$x_5 - x_7 = \frac{v}{w}(\frac{5}{6}\pi - \frac{7}{6}\pi) + r(\cos 2\frac{\pi}{3} - \cos\frac{\pi}{3})$$

$$x_5 - x_7 = -\frac{1}{3}\frac{v}{w}\pi + r(\frac{\sqrt{3}}{2} - \frac{1}{2})$$

$$\therefore \quad x_5 - x_7 = \frac{.73r}{2} - \frac{1}{3}\frac{v}{w}\pi \qquad (9)$$

The ratio of w and v for a desired value of $(x_5 - x_7)$ can therefore be calculated.

From equat. (9)

$$\frac{v}{w} = \frac{3}{\pi}\left(.36r - \overline{x_5 - x_7}\right)$$

A minimum value of $(x_5 - x_7)$, for a maximum amount of approximate vertical lift during that interval, guided the selection of the relation between n, w, and r.

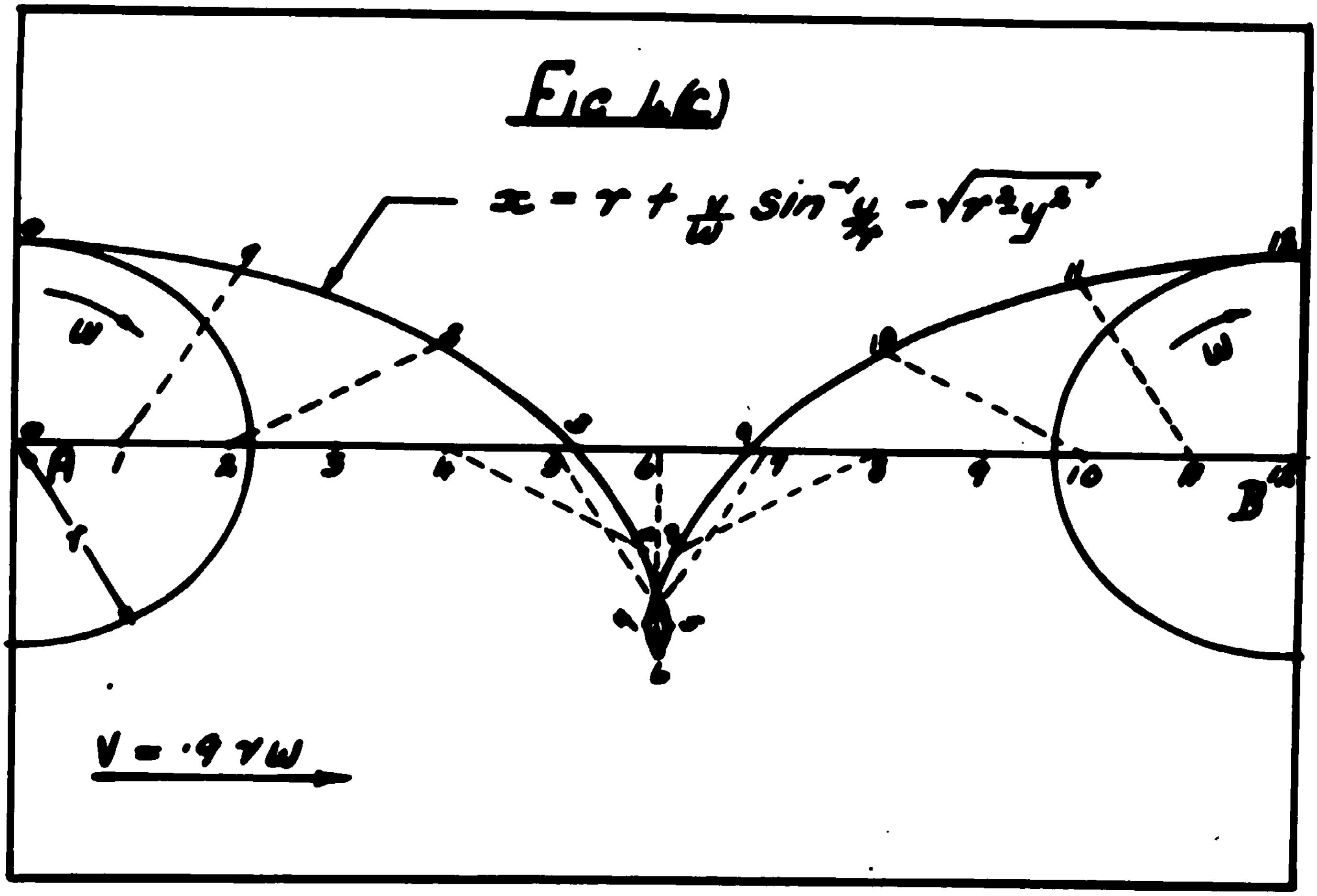


Figure 4 (c).

C. Construction.

A decision was finally made to build a one-third scale model instead of a full size machine, and to investigate the performance of this model on the various types of vegetables which resemble sugar beets on an approximate one-third scale.

The main reasons for the above decision were the following:

1. It was doubtful whether the time available until the coming sugar beet harvesting season would be sufficient for the completion of a full size machine. Only one season was available for this investigation.

2. It was anticipated that more tests could be performed on different kinds of vegetables at convenient intervals, due to their variation in growing seasons.

3. A consideration of the economical aspects of the project indicated an appreciable diminution in the total expenditures in favor of a one-third scale model.

4. It was expected that the performance of the model would provide worthwhile information, and a reliable indication, of the practicability of the essential features of the new principle, and that the adaptability thereof on a full size machine, would be sufficiently exposed.

5. An anticipated idea, to simplify the construction of the principal wheels by utilizing rubber for the creation

of flexibility, lacked information on the required characteristics of such a rubber material. The manufacturing cost of the proposed rubber construction would have been relatively high and uneconomical, especially where the rubber was still to be experimented with. It was with this in mind that the finger system was designed as a temporary substitute, by which a variation in the peripheral pressure of the principal wheels could be accomplished. The decision on a smaller scale had another advantage here, in that it would make the construction of the finger system more easily feasible, by allowing the use of readily procurable material and equipment.

6. More direct information on the applicability of the principle in the harvesting of sugar beets could be obtained from a specially designed hydraulic pulling mechanism. This design provides the registration of: (1) the maximum amount of pull that can be exerted on the tops of individual sugar beets; (2) the required pull to lift the beets for various depths of plowing or loosening of the soil; (3) the required side thrust on the leaves in each of the above cases.

7. It was, however, duly realized that some of the features of the performance of a full size machine would be forfeited; but it was improbable that these would cause any significant defective influence on the performance of

the model as a reliable source of information on the principle under investigation.

The final product of the model is shown on Plates 1 and 2.

The machine consists of the five principal units indicated by the letters A, B, C, D, and E. Each unit will be described separately.

The plowing unit (A) was designed to provide a system which would allow for the adjustment of the soil loosening mechanisms, over a range of depths and forward and rearward positions, below, and to the rear of the principal wheels. The linkage system also enables more clearance of the machine above ground level when the machine is not operating. It was furthermore endeavored to cause the breaking up of the soil with this system, in such a manner, that the loose soil would follow the curvature of the principal wheels for a brief distance, during which time little or no relative motion between the gripped vegetables and the rubber rims would occur.

Some of the elements of this unit that were used during the tests, are shown on Plate 3.

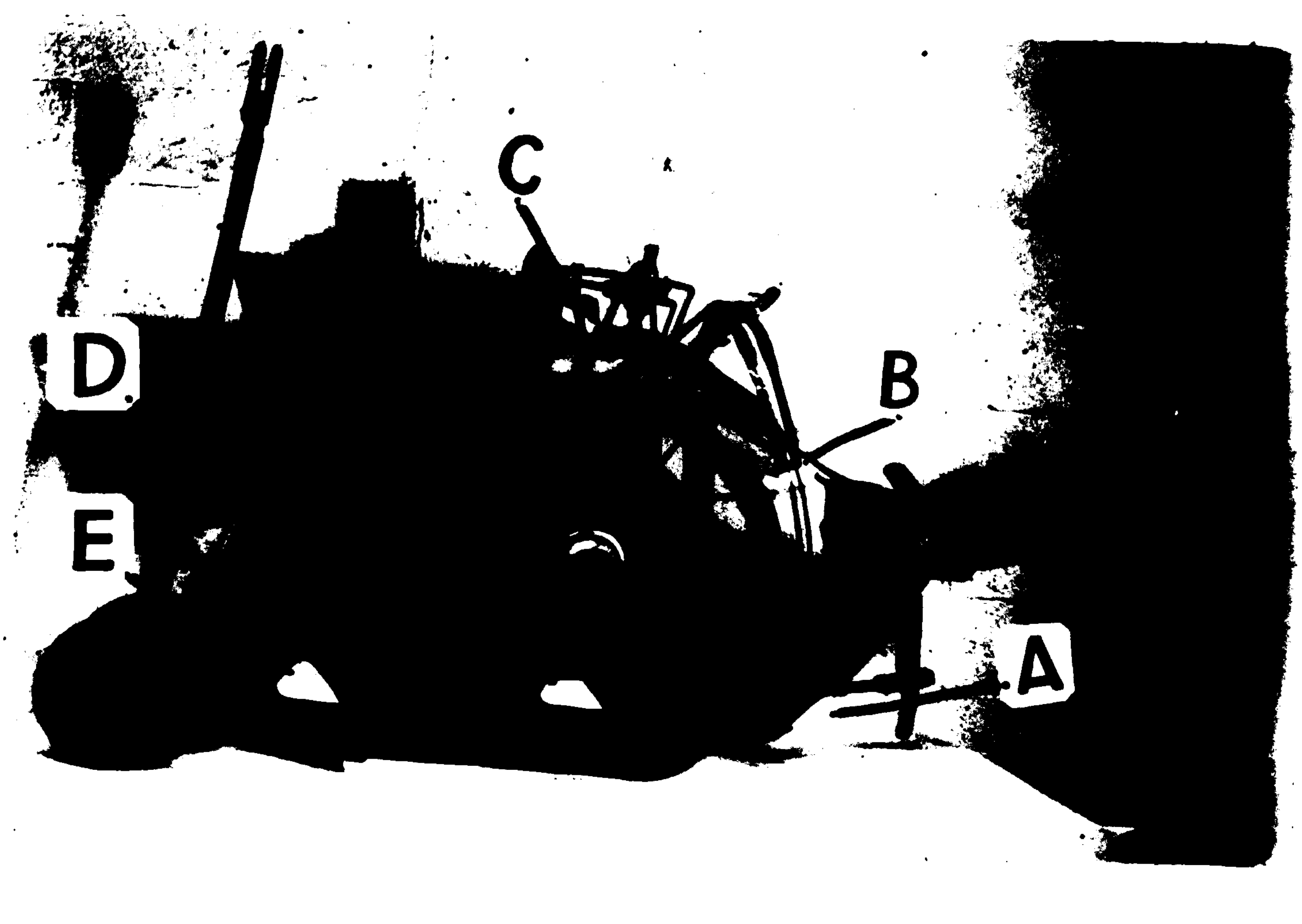


Plate 1. (Left-side View)

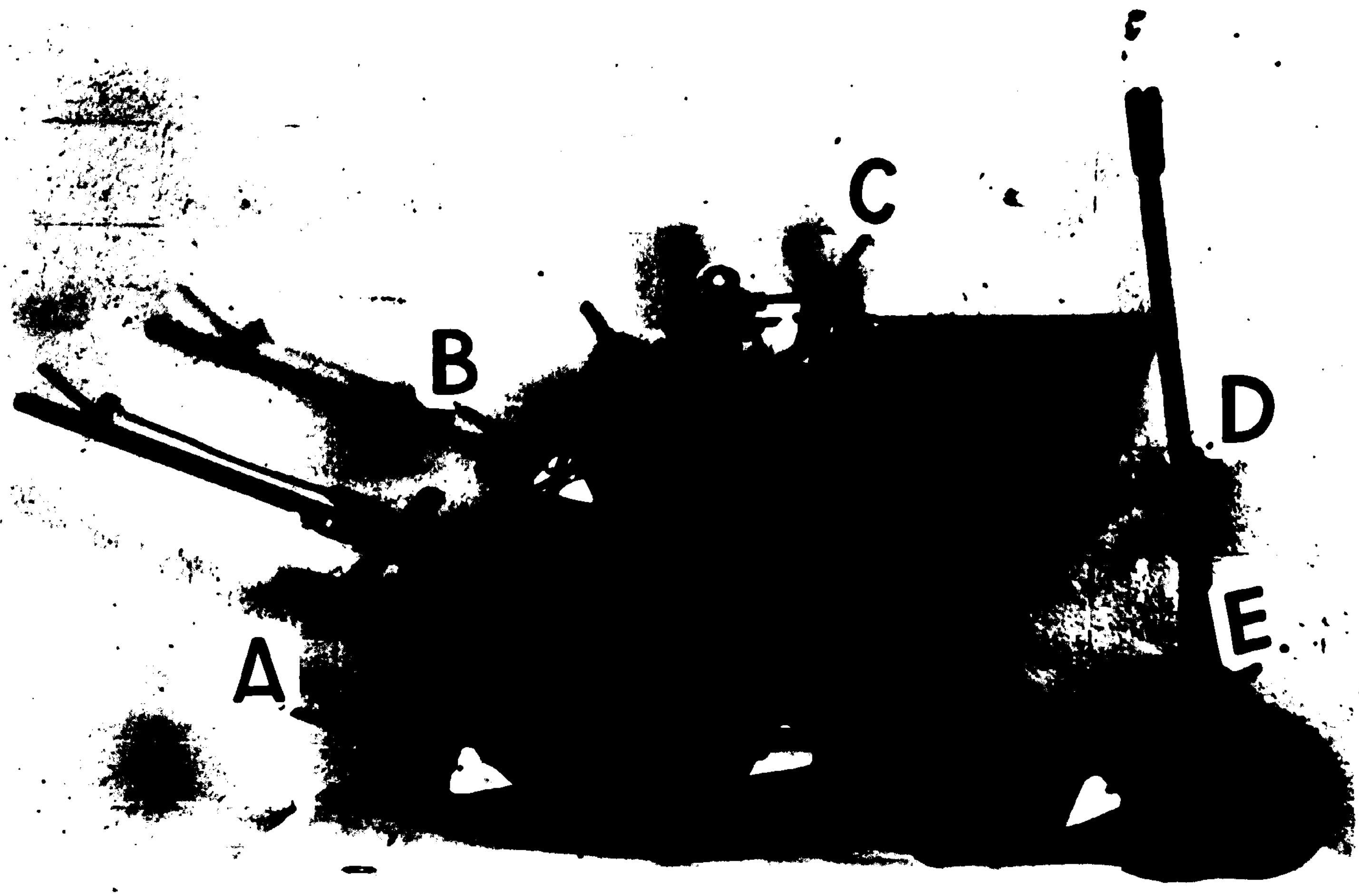


Plate 2. (Right-side View).

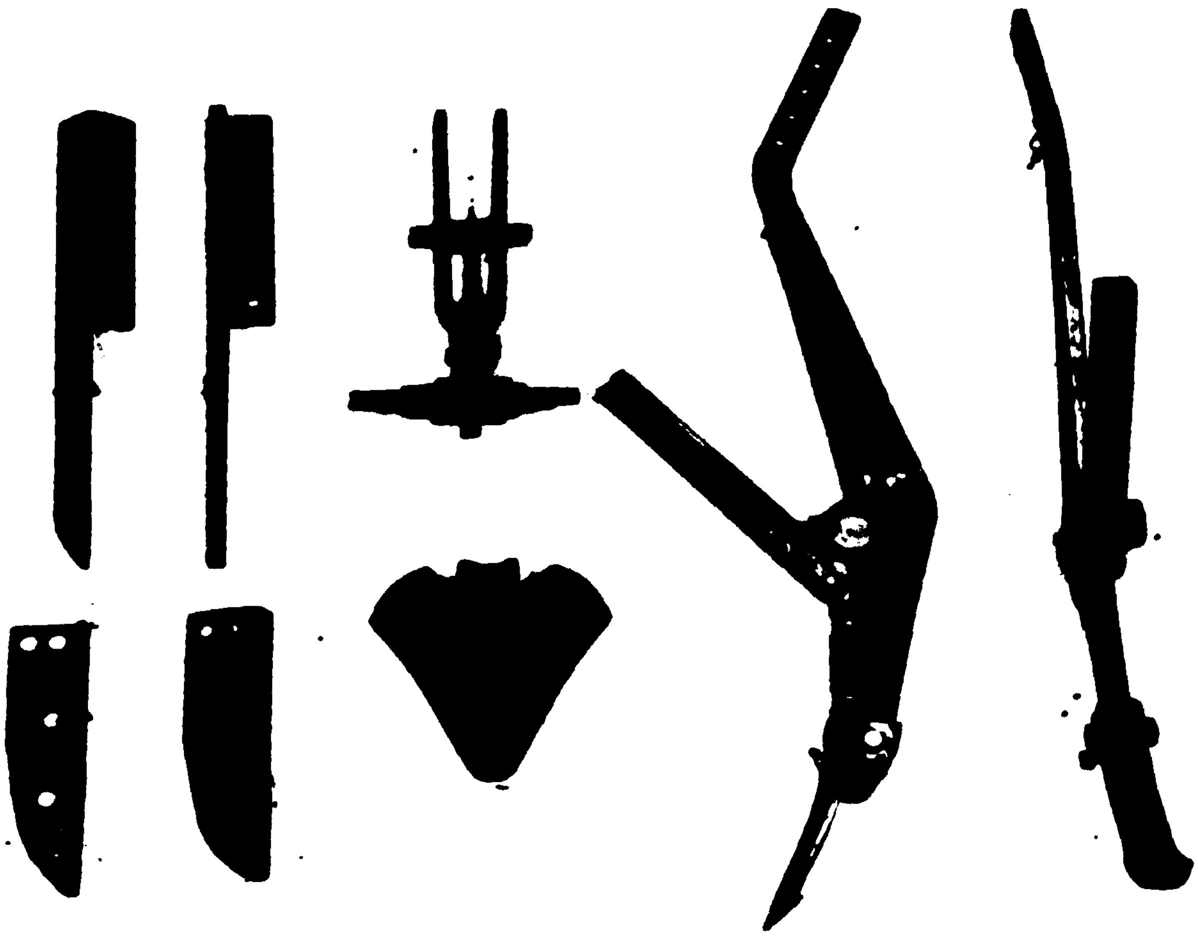


Plate 3. (Plowing Unit.)

The pulling and lifting unit (B) consists of a pair of principal wheels by which the pulling and elevation of the vegetables are accomplished. Each of these wheels consists of a hub to which six spokes of angle iron are welded, two circular bands of flat steel reinforcement, a flexible perimeter of rubber tubing with a steel core, and a finger system which combines the perimeter and the internal framework. The wheels are mounted in such a way that they are pressed against one another along the rear half of their circumferences and are separated in front. The bearings of the axles of these wheels are provided with set screws by which the shafts can be tilted. This enables a variation in the relative initial points of contact of the wheels.

A variation of the position of the rubber bands on the fingers, relative to the pivoting points, causes a change in the peripheral stiffness of the rubber rims. This consequently provides a control on the pressure existing between the two rims when the wheels are mounted in their proper position. This variation enables a study of the optimum pressure required for the effective lifting of the vegetables.

Two types of rims, the descriptions of which follow, were finally selected after some experimentation with various rubber tubes and steel cores.

Plate 4. (Pulling and Lifting Unit.)

1. A spring steel wire core consisting of two five-sixteenths inch rods is pushed through a rubber tube of one inch O.D. and a quarter of an inch I.D. The rods are fixed to the steel fingertips with "thimbles", which, at the same time, keep one of the rods on the inside circle of the other rod. This construction provides a flat thrust surface between the two rims, and permits the steel rods to slide through the holes in the "thimbles", in order to compensate for the variation in the circumference when the wheels are pressed into position.

2. It was realized that some difficulty might be experienced with the rotating of the rubber around the wire core in construction No. 1. A thin flat bar would probably have been more effective, but would require special manufacturing if spring steel were to be used. It was therefore decided to substitute cold rolled steel for the spring steel, and to find out whether it would provide the required flexibility in the specific construction.

The latter construction was finally used in the machine as is shown on Plate 4.

The cutting mechanism (C) is carried on a separate framework which is mounted over the principal wheels and is bolted onto the main frame. It consists of: (1) a pair of spring cushioned steel bars with pivoting units at one end close to the circumferences of the principal wheels; (2) two circular floating discs mounted on the free ends of the bars; (3) a pair of rubber disc feeders, one of which is power-driven from a ground wheel.

These units are shown on Plate 5. The steel bar system is held at an angle above the perimeters of the principal wheels by two springs extending from the upper frame, and which are balanced by a piece of flat rubber. The other end of the tube is fixed to the chute.

The object of the slanted position of the bars is to compensate for the variation in distance of the crowns of the beets to the rubber rims and to guide the crown of each beet to the cutter discs, irrespective of this variation. Beets that are high out of the ground are likely to be gripped close to the crown. Such beets would press the cutter mechanism guides downward to conform with the rubber rims. The amount of downward pressing depends on the distance of the crown of the beet from the rubber rims. The variation in this distance is directly related to the irregularity of beet heights above the ground. The experimental unit was designed to cope with a range of two inches in crown height.

The handling of the roots and tops after separation is accomplished by two chutes, which, in the full size machine, would deliver the products onto side-drawn trailers or trucks. The chutes on the model are provided only to prevent the material from interfering with the

Plate 5. (Cutting Mechanism.)

operation of the machine, because the loading operation was considered as of minor importance in the present investigation. Details of the cutter units are shown on Plate 6 (A & B).

The power wheels (D) are shown on Plates 1 and 2. The wheels are ten inches in diameter and have solid rubber rims. The belt pulleys are fixed to the hubs of the wheels and rotate with the wheels on stationary shafts. The wheel shown on Plate 1 drives the principal wheels which are connected by means of a universal joint. The other power wheel (Plate 2) drives one of the disc feeders of the cutting unit.

This specific design of the power unit was decided upon to secure the power wheels as close as possible to the principal wheels so that:

1. The principal wheels, guided by the power wheels, would follow the profile of the soil down the row, with a minimum amount of deviation from it.

2. Transmission would be possible for various positions of the power wheels when adjusted to bring about different heights of the principal wheels relative to the ground.

3. The effect of the front wheels on the relative height of the principal wheels would be minimized.

The front guides (E) are the ones that were finally constructed as a result of experimentation with guides

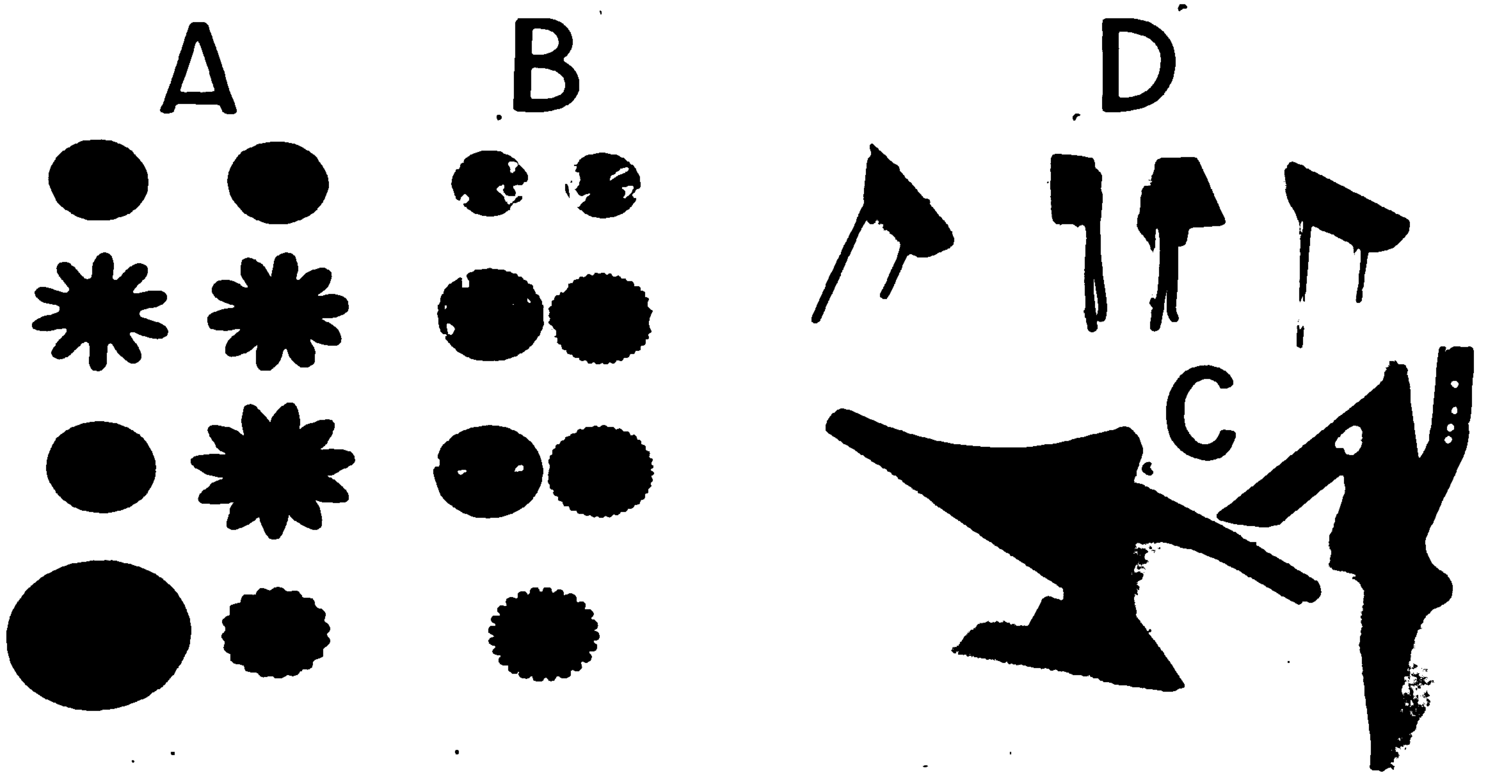


Plate 6. Details of Cutting Units (A & B) and of Front Guides (C & D).

Plate 7. (Front Guides.)

shown on Plate 6 (D).

The latter consist of conventional duck-foot shovels, with one of the wings removed, and spring steel rods. These rods, when the guides are mounted, extend to the inside of the flexible rims. Specially-shaped sheet iron members, (Plate 6 (C) and Plate 7), which cover the rubber rims along the entering passage of the leaves, replaced . the rods in the final construction.

D. Preparation of Test Crops.

An area of land was prepared while the machine was under construction and carrots, red beets, and turnips were planted at intervals. The soil varied from a clay loam to a sandy clay and was heavily disked in order to break down the clods to a fine seedbed structure.

The vegetables were planted in rows, 28 inches apart, with a hand-push garden seeder. The total crop consisted of 30 rows of carrots, 30 rows of beets, and 20 rows of turnips, each 80 feet long. An alternative sequence of 10 rows of carrots and beets was used to compensate for the variation in soil structure. The turnips were planted later in the season.

Excessive rain caused heavy and rapid vegetable growth, and also of weeds which were present in an extensive assortment. The plot was cultivated two times, and stones and large clods were removed.

The construction of the model was completed toward the end of August, at which time the first section of carrots and beets were ready for harvesting. However, the wet condition of the soil delayed the first trial for a few weeks.

It also became apparent that a highly impervious sub-soil was present. This resulted in the drowning of the turnips which were planted in the lowest section of the area.

The growing of the beets was very irregular; the sizes varied from two inches in diameter to five inches in diameter at the time the first test was performed. The vegetables were thinned by hand to an approximate five-inch spacing in the row, and the largest ones were removed at intervals.

The first trial was finally run with the condition of the soil still relatively wet. The condition of the vegetables was the main factor against further postponement. A section of the land just before the tests were commenced is shown on Plate 8.

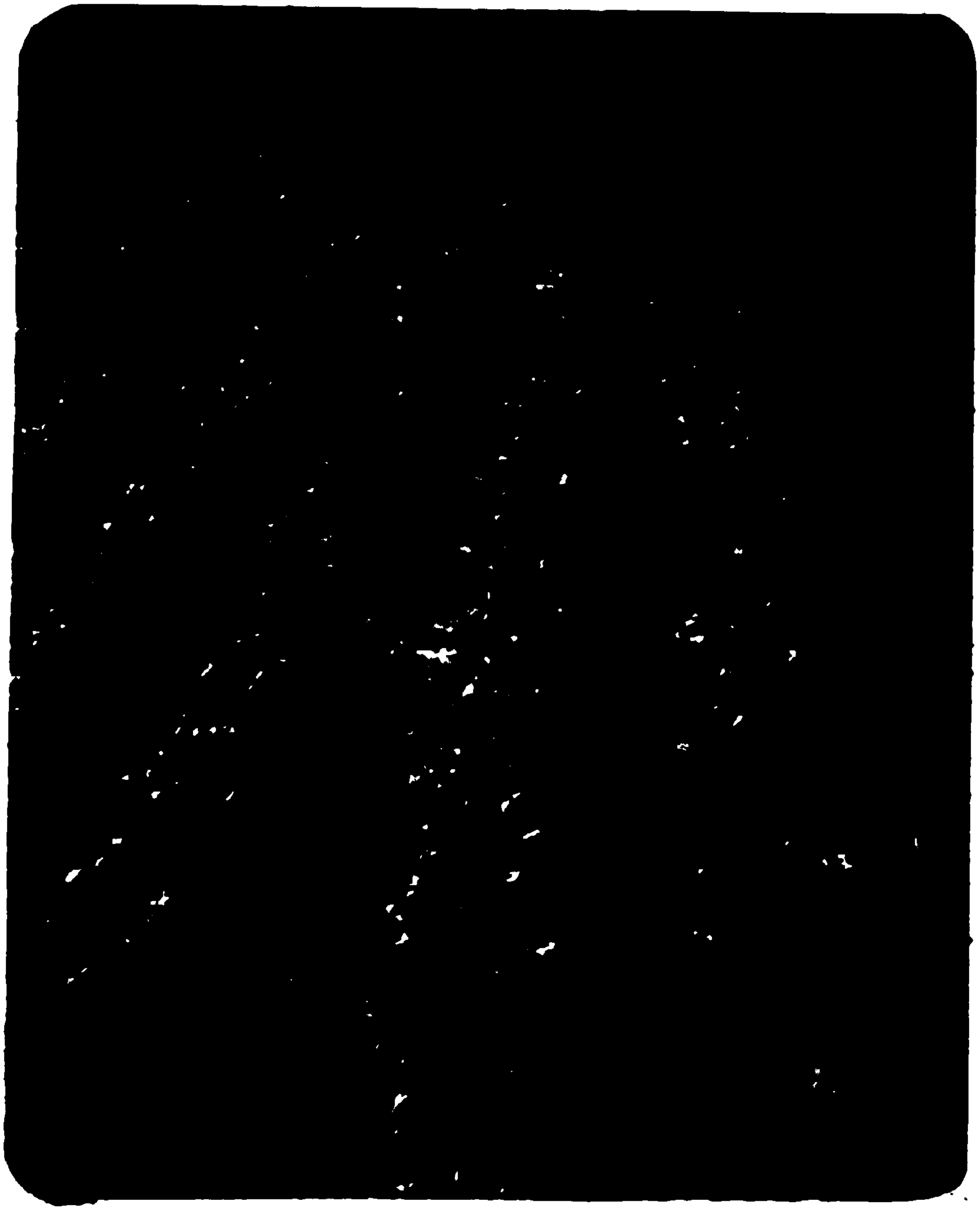


Plate 8. (Section of Vegetable Land.)

E. Testing and Results.

The following is a description of each of the tests that were performed.

Test No. 1.

<u>Object:</u> To investigate the performance of the front guides and the single and double system shovels.

<u>Equipment:</u>

1. Bolens' Huskey Road Master tractor (used in all tests.)
2. Experimental machine with only the front guides, plowing mechanism, and pulling supports assembled.

<u>Procedure:</u>

1. The single shovel system was first tried out on soil with no vegetation. A conventional goose-foot type of cultivator shovel was set at two inches depth and the front guides were spaced three inches at the points.
2. The pulling supports were removed and the shovels were adjusted to a plowing depth of three inches.
3. The single shovel system was replaced by the double shovel system. Goose-foot type shovels with the wings removed were set to plow at a depth of five inches.
4. The first trial on carrots was finally run after the shovels were readjusted to a depth of three inches and shifted to a more rearward position.
5. The front guides were adjusted to a four inch spacing for the trial on the red beets which followed the test

on the carrots.

<u>Results:</u> The hard crust of the soil caused the formation of clods which started to accumulate against the pulling supports and the shovel beams. This was slightly improved by the removal of the pulling supports. Wet soil was brought to the surface with the shovel setting at three inches depth.

The double shovel system brought a large slice of wet clay to the surface when plowing at a depth of five inches and the machine travelled only a few feet before the wheels of the tractor started to spin. This indicated that the frame construction was strong enough to stand maximum pull without the aid of the pulling supports.

The trial on the carrots showed the following: The combined action of the front guides and the leaves facilitated the steering of the machine considerably. The machine was kept on the row with almost no difficulty. The performance of the front guides as far as gathering, lifting, and guiding of the tops were concerned showed great promise. The tops were released by the guides in a narrow strip, bent slightly forward.

The soil was well broken up on each side of the carrot row by the shovels. Some carrots were lifted along with the soil and were removed by hand. The others that remained in the ground were loose enough to be pulled out by two fingers. Difficulty with the blocking up of the soil was again encountered even though the plowing was done at a depth of three inches.

The trial on the red beets again showed a satisfactory performance of the front guides but blocking up occurred more rapidly.

Remarks:

1. It was easily perceptible during this test that the effect of the soil characteristics on the performance of a machine of this nature, makes the use of a one-third scale model undesirable for actual tests. This was true also in regard to the variation in size of the vegetables which was not of a one-third dimension.

2. The rotational action of the power wheels promoted the accumulation of the soil. This could be improved by providing the wheels with guards.

3. The width of the shovels could be reduced considerably.

4. The double shovels system appeared to be more suitable for the lifting of carrots.

5. No soil looseners are required for the lifting of the beets.

6. The shovel beam system should be changed to enable more rearward adjustment.

Test No. 2.

Object: To investigate the performance of the pulling wheels, cutting mechanism, and guides on red beets.

Equipment: Complete machine except for the soil loosening mechanism.

Procedure:

1. Guides were set for maximum front clearance.
2. Operating height of pulling wheels was adjusted to two inches above ground level.
3. Speed ratio v = .9rw (Approximately).
4. Half-an-inch clearance between knife guides, and the shafts in the third hole from the rear.
5. Knife feeders set at half-an-inch to the rear and half-an-inch above the knives when in their upper position. Feeding speed of driver was the same as the circumference speed of the large wheels.
6. Knives, later in the test, were readjusted to the most rearward position.
7. Tests were run at various speeds of the tractor.
8. A test was performed on the carrots with no changes made on the model.

Observations:

1. The condition of the soil was such that the power wheels of the machine caused a subsidence of the ground of approximately one inch. Wet clay stuck to the carrots when pulled out by hand. Age of vegetables at

the time this test was made was 98 days.

2. The machine appeared to be slightly top-heavy in the absence of the plowing mechanism.

3. The power wheels had no difficulty in driving the pulling wheels as long as the machine was not rocking sideways.

4. The front shovels appeared to be set too wide apart and the narrowing of the guides was too rapid.

5. The downward action of the perimeters of the large wheels, with no horizontal movement, forced some of the leaves down as soon as they made contact with each other. The guides did not offer enough protection.

6. Most of the tops were dragged forward by the guides, slipped through them, and were pressed down by the pulling wheels.

7. Some beets were properly gripped by the wheels and no difficulty was encountered with the extirpation of same.

8. The beets kept their position perpendicular to the perimeters of the wheels while elevated but all but two stopped at the entrance of the knife guides. The two that passed through were well handled, the tops being sliced off very effectively.

9. The presence of the tops between the perimeters of the pulling wheels advanced the separation of these

wheels two to three inches. This had the result that the wheels lost their grip on the tops before the beets were fed through the knives. The initial grip of the wheels was effective and could occur at a later moment.

10. No time was available for adjustments for the test on the carrots. The guides performed better in this test and most of the tops were pulled off while the roots remained in the ground.

Test No. 3.

The following changes were made due to observations during the second run:

1. The shaft bearings of the large wheels were furnished with set screws so that the inclination of the shafts to the horizontal plane could be varied.
2. The set screws were adjusted, after the main wheels were mounted, so that these wheels separated approximately two inches later at the top and made contact two inches later at the bottom.
3. The central link of the universal joint was also shortened to accomplish the above required departure and contact points of the outer rims.
4. A good idea of the required angle of the shovels was conceived, so that the adjustable brackets were eliminated. The shovels were solidly mounted onto the beams

and were changed in form in order to provide minimum obstruction to the loosened soil.

5. The height of the main wheels relative to the ground was decreased due to the tilting of their shafts. It seemed advisable during the previous test to have the main wheels operating approximately half-an-inch higher than was the case at that time, Wooden stops for the power shafts were installed to obtain this height.

6. The position of the flat piece of rubber tubing that counteracted the spring tension on the cutting mechanism was changed which resulted in a freer action of the knife guides.

7. The rubber bands on the main wheel construction were replaced by heavier ones.

8. The front guides for the gathering of the tops were replaced by solid metal strips to prevent tops from sliding through, as was experienced with the rod construction, and to eliminate early contact between the leaves and the perimeters of the main wheels.

9. The two-beam system of soil loosening mechanism was mounted onto the machine. The shovels were set at a three-inch depth and the ◘ section members were fixed behind the ◘ frame pieces to provide two inches of extra clearance between the shovels and the main

wheels.

10. The chute for the cut-off leaves was replaced by a shorter one without a leaf catcher in an effort to eliminate choking up of cut-off leaves.

Results: (Trial on carrots).

1. The water content of the soil was higher than during the previous trials due to rain during the week when the adjustments were made.
2. This resulted in an approximately similar amount of clodding as was experienced during the second test. The extra clearance provided seemed to have no effect on this problem.
3. A few carrots were lifted before the blocking of the soil developed and most of them were handled satisfactorily by the guides and the knives. The leaves, however, blocked up against a sharp point member below the cutting disks. The leaves and the blocked-up soil were removed and again the first few carrots were pulled out, lifted and the tops cut off. But blocking-up started eventually again at both places.
4. The clodding up of the soil was partly overcome by the removal of one of the plow beams. But the remaining shovel, operating alongside the row, did not sufficiently break up the soil in the row. Consequently most of the leaves were now pulled off by the

wheels while the roots remained in the ground. A few carrots were pulled out, but most of them obtained a backward position with respect to the perimeter. It was not possible for the feeding disks to grasp these carrots and they blocked up when they made contact with the knives.

5. The new rubber bands developed enough pressure in the perimeters of the main wheels for a firm grip on the leaves.

Conclusions:

1. A three-inch clearance between shovels is not sufficient to prevent clodding up of a soil of this condition or to permit free passing by of the soil.
2. The pulling action of the wheels on the carrots assists the upward movement of the whole slice of soil, which eventually results in blocking up.
3. The backward adjustment of two inches of the beams did not make any appreciable difference in the blocking up of the soil.
4. The feeding disks of the cutting mechanism should be advanced away from the knives to make an earlier grip possible.
5. The performance of the altered chute was satisfactory.
6. It appeared as if longer fingers on the disks would improve the cutting process.

7. The performance of the front leaf guides was very satisfactory on carrots. A trial on red beets showed, however, that these guides were still not capable of elevating the leaves close to the ground high enough to enable the wheels to grip them. Another observation during this trial was that the wheels had no difficulty in lifting beets, properly gripped, without the aid of a soil loosener.
8. It was decided that it might be worthwhile to replace the two-beam plowing system by a single-beam system in the center of the row and to move it still further to the rear.
9. The lengths of some carrots were over seven inches and caused trouble at the cross-bar of the feeding disks. It would be advisable to change the bar in order to cope with these extremities in length.

Test No. 4.

The following changes and adjustments were made for this test.

1. The concerned member of the cutting mechanism was changed to allow more clearance for the leaves after being cut off.
2. A single, center plowing system was mounted onto the frame.
3. A new set of rubber disks with longer fingers was

mounted.

4. The wooden stops were removed to investigate the performance of the wheels at a still lower level.
5. The rubber disks were advanced three-eighths of an inch away from the knives.

Results:

1. The moisture condition of the soil did not seem to have improved appreciably.
2. The performance of the single-beam plowing system proved to be less favorable than the two-beam system in spite of the increased clearance. Rapid blocking-up occurred.
3. The first few carrots were pulled out and elevated, but some of them were grabbed so close to the roots that they could not enter the opening between the knife guides.
4. A few went through between the disks and the leaves were cut off, but the carrots fell back against the disks.

Conclusions:

1. It was more obvious during this trial that the rapid blocking-up of the soil against the suspended beam members was mainly due to the combined action of the wheels and the shovel. The soil was loosened by the shovel more or less instantaneously with the commence-

ment of the upward movement of the carrot, caused by the pull on the leaves. This resulted in a higher lift of the soil before it started to break up and fall down, with the result that most of the soil was carried along up against the beam until it hit against the suspended brackets. The wet condition of the soil encouraged this action. This indicates that the loosening of the soil should be applied in such a way that it will allow a minimum amount of lifting action. The type of loosener should therefore be reduced in width to perform a mere cutting action through the soil. The two-beam system ought to be used and more clearance should be allowed.

2. No trouble was experienced in guiding the tops to the main wheels as long as the tops were standing up, but some of the leaves on the ground could not be picked up. It might be advisable to use two extra rods in front of the guides to take care of the fallen down leaves.
3. The height of the main wheels should not be lower than two inches above the ground level.
4. The disks used in trial No. 2 did a better job and were closer to the right position than the type used in trial No. 4.

Test No. 5.

Object:

1. To investigate the relative position of the soil-loosening mechanism to the main wheels and frame that would eliminate clogging and blocking up of the soil under the prevailing conditions.
2. To observe the performance of other types of disk feeders at the cutting mechanism.

Procedure: The cutting mechanism was taken apart and the crossmember behind the knives was changed to allow for maximum clearance for the leaves.

The side springs were shortened to decrease the side stiffness of the guides.

Two rubber disks of camel-back rubber were inserted.

Four soil looseners were made from flat iron bars of different thickness and were supplied with spacers that would permit the looseners to be mounted up to ten inches behind the main wheels.

The first run was started with the looseners in the above position. The rubber bands appeared to have lost some of their tension and were shifted to the position of maximum pressure between the perimeters. The soil was broken up fairly well although a few of the carrots which remained in the ground, required some pulling in order to be lifted. Only a few carrots, however, were lifted by the wheels. It was evident that the soil was broken up too late to be of any help to the lifting by the wheels. The wheels were performing very well and most of the leaves were pulled off while the carrots remained in the ground. Some slipping occurred, in cases where the leaves were strong enough, before the carrots were pulled out. These carrots were hanging down and could not be grasped by the feeders.

The soil looseners were then adjusted to an eight-inch clearance but this position had the same results on the lifting. No blocking up of the soil was experienced so far. More adjustments of closer and narrower positions were tried out, from which it was found that the best performance for the present construction of the machine, when equipped with the looseners that were tried out during this trial, was with a six-inch clearance between the main wheels and looseners and three inches between looseners. Blocking-up just started to occur in this position. Some carrots were still left behind by the wheels but not so many as in the previous runs.

Heavy clogging against the framework occurred when the looseners were moved closer to the wheels. It was clear that the problem was mainly due to the limited height of the small-scale machine above the ground. This test was performed under severe cold conditions.

Conclusions:

1. It was clear from the observations that a re-design of the rear part of the framework, that supports the loosening mechanism, is essential. This design should allow for the shovel beams to go down along each side of the pair of main wheels in such a position, and they should be of such a form, that the looseners attached to them, would start to break up the soil almost vertically under the center of the pair of main wheels and at an approximate depth of four inches. The shape of the looseners should also be of such a form that it will tend to make the broken-up soil follow the curvature of the main wheels for a few inches.

2. This will require a wider spacing of the power wheels which should have no appreciable influence on the overall performance of the machine. This statement is based on observations made on the influence of the variation in height of the main wheels on the performance of same.

   The main idea for the present design was to have the main wheels follow the profile of the ground as closely as possible.

   The relative position of the wheels along the length of the machine should be maintained.

3. The slipping of the power wheels that occurred now and then when the machine tilted over to one side or other, due to the unevenness of the soil, will be eliminated by the wider spacing of these wheels and the increase in weight of a larger size machine.
4. It seems to be necessary, as far as the performance of the cutting mechanism is concerned, that the roots should be grasped a few inches before they reach the knives and be carried along until the tops are sliced off. It may be possible to accomplish this by the use of two small V-belts or larger and cone-shaped rubber disks. It seems also advisable that both sides should be power-driven.
5. It was observed before the last test was commenced that the carrot leaves had flattened out much more, due to their age. This handicapped the performance of the front guides to a certain extent, and indicated that it would not be worthwhile to perform any later tests. The carrots were already over 90 days old.

The limitations of the small-scale machine was another factor that supported the decision that it would be of very little benefit to spend any more time on trials and changes.

Although unfavorable weather conditions were a great handicap to the experiment as a whole, it was nevertheless felt that valuable information about the principle of the machine was obtained, and that the small-scale model served its purpose satisfactorily especially from an economic viewpoint.

The experience gained during the construction and trials will be of great value in the design and construction of a full-size machine.

V. Suggestions for Future Investigations

The Cutting Mechanism:

The crown-diameter relation, which was found to exist by Powers (8), between the diameter of sugar beets and the thickness of the crown was not made use of in the experimental model. This experimental machine was tried on carrots and red beets so that the above information was not applicable.

A method by which this relation can be utilized is shown in Fig. 5 (A) and Fig. 5 (B). The basic principle of this cutter unit is the same as that used in the experimental machine.

The guides, B, which prevent the crown of the beet from sliding through, and which guide the beet to the knife

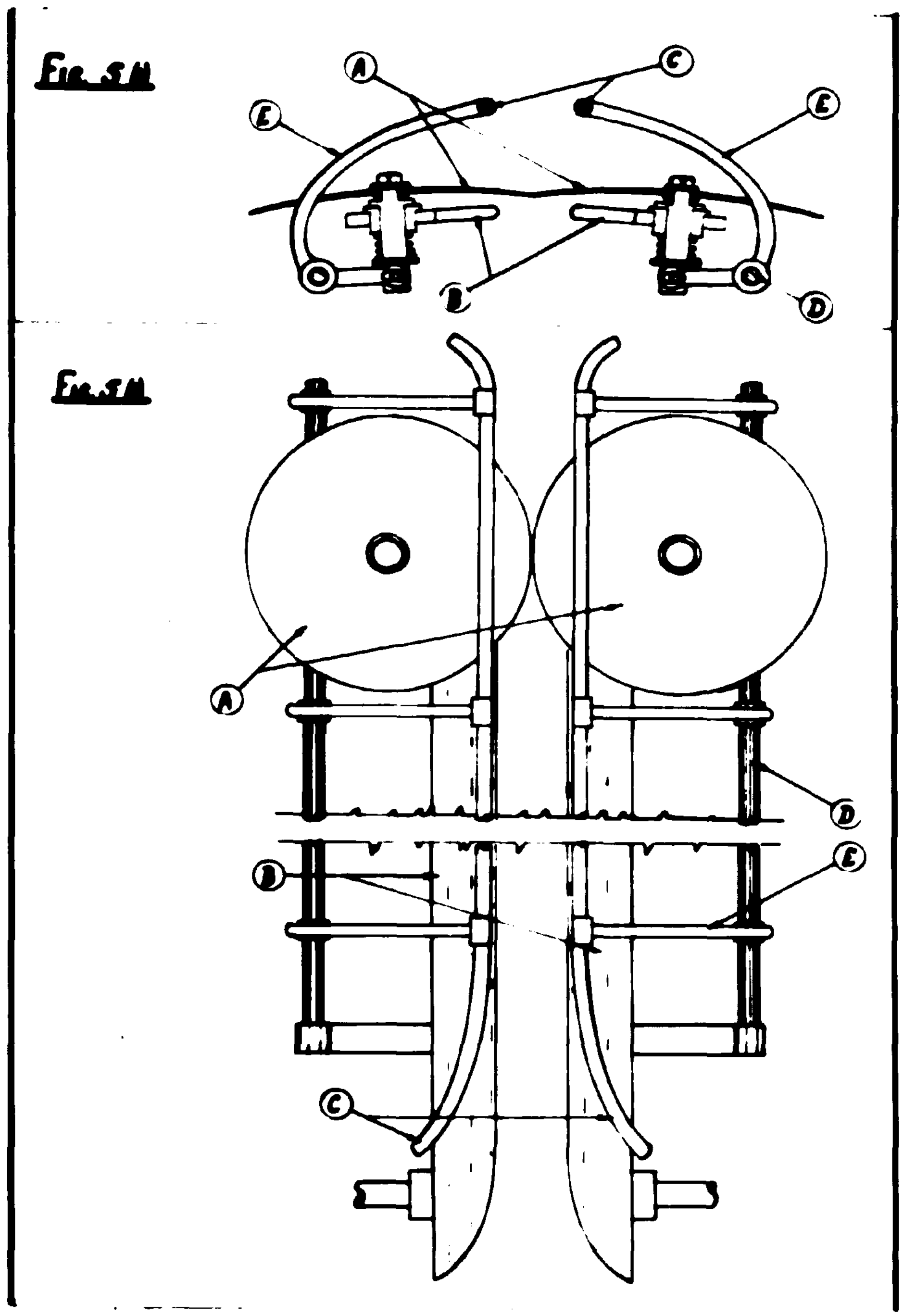


Fig. 5 (A and B)

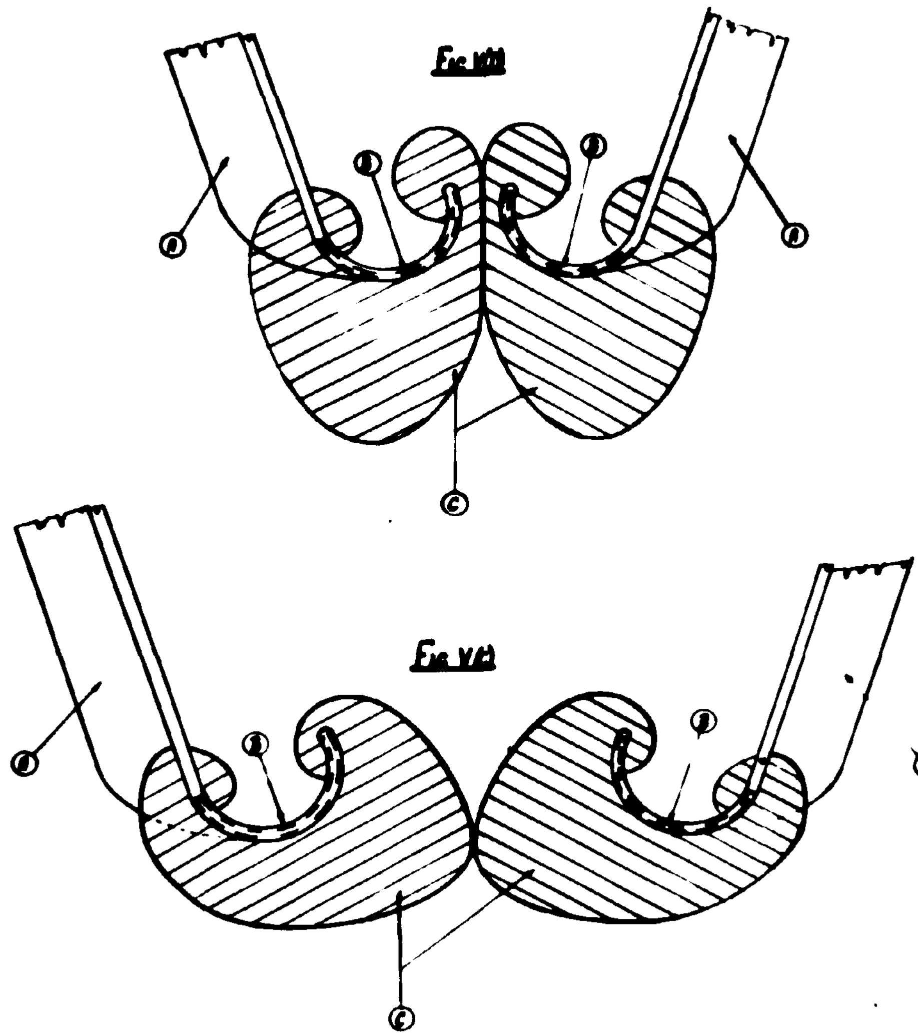


Fig. 5 (C and D)

are mounted in the same manner as in the model. Two additional guides, C, are used in this construction to change the height of cut relative to the guides, B, in accordance with the diameter of the beets. These gauge rods, C, run parallel to the guides, B, and about two inches above them. They pivot around shafts, D, which are floating with the guides, B. The rods, C, are held in position of smallest clearance between them by springs below the cutter disks, A. The rods, C, are forced open when the beets enter between them and slide up along the guides, B. The rods, when pushed open, in turn activate the cutter disks. The diameter of the beet at its point of contact with rods, C, will therefore be indicative of the amount of crown that the cutter disks will remove.

These sketches were drawn only to demonstrate the principle. Supervision should be made in the actual construction for the adjustment of various relative positions of the members concerned.

Principal Wheel Simplification:

The envisioned simplification of the large wheels, which was mentioned during the discussion of the reasons for the choice of a one-third scale model, is demonstrated in Fig. 5(C).

The flexible finger systems in the experimental model are replaced by endless rubber strips, C, of special cross-section. These rubber strips fit firmly over endless metal tubes, B, of semi-circular cross-section. Each tube is held in position by four or six spokes (of angle or T-iron cross-section), mounted on a central bush as was done in the experimental machine.

Fig. 5 (D) is a cross-section of the perimeters, at the point of maximum compression along the rear half of the circumferences, which would provide the same amount of front clearance as was accomplished by the construction used in the experimental machine.

<u>Hydraulic Pressure Lifter:</u>

A special instrument which was designed to obtain more information on the characteristics of the rubber required, that was to be used in the simplified construction of the principal wheels, is shown on Plate (9). Unit A consists of a hydraulic cylinder, and a pressure indicator with accessories. The piston of the cylinder is connected to the Unit B by a steel rod which runs inside the pipe and rack of Unit C. The cylinder rests on top of the pipe and can be lifted by the gear system in Unit C.

Unit B consists of two lever arms held together by a heavy spring. The free ends of the arms are provided with rubber pads as shown. A calibrated ruler runs parallel to the heavy spring and enables the determination of the pressure, between the rubber pads, exerted by the crank system.

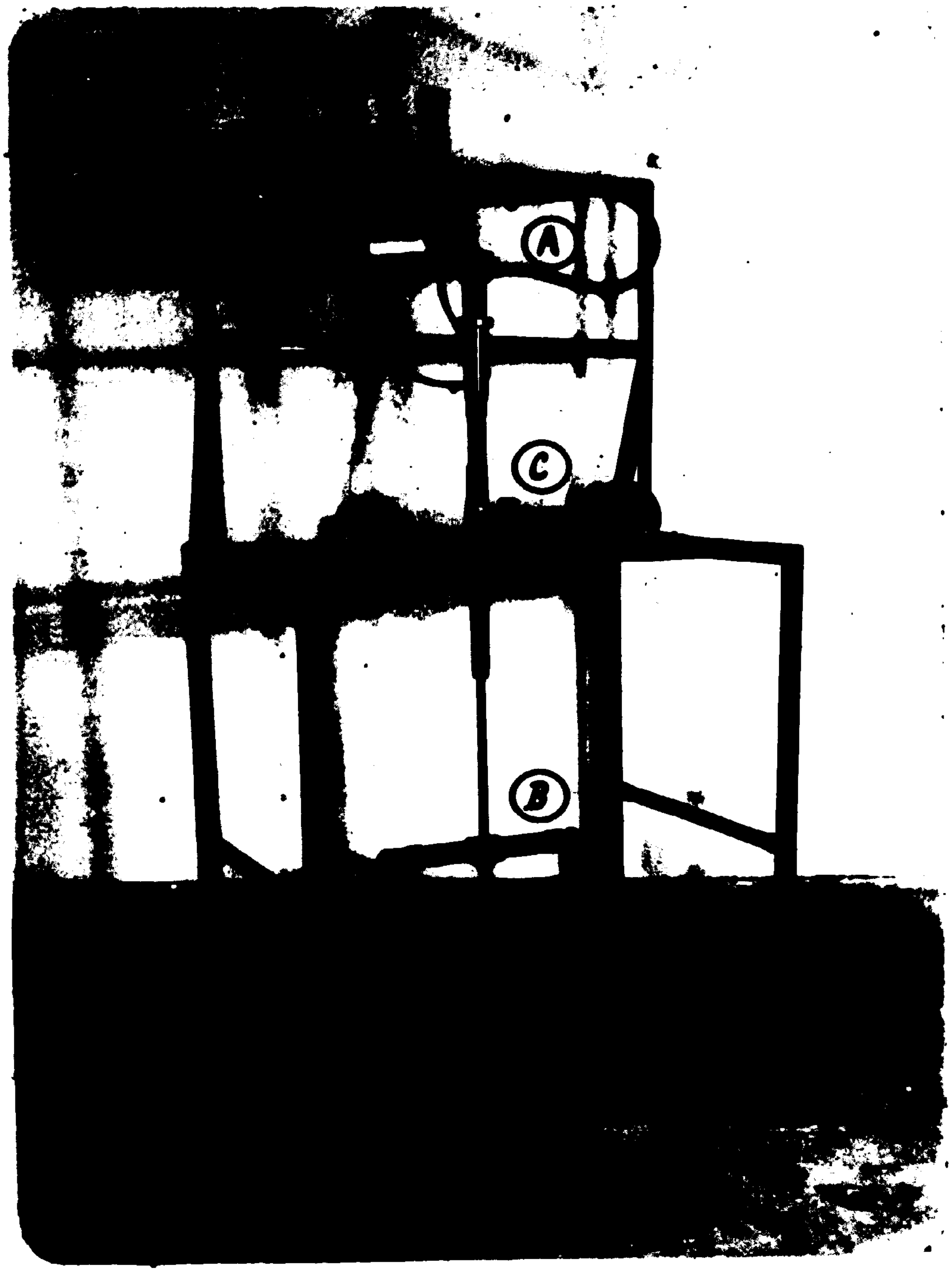


Plate 9.

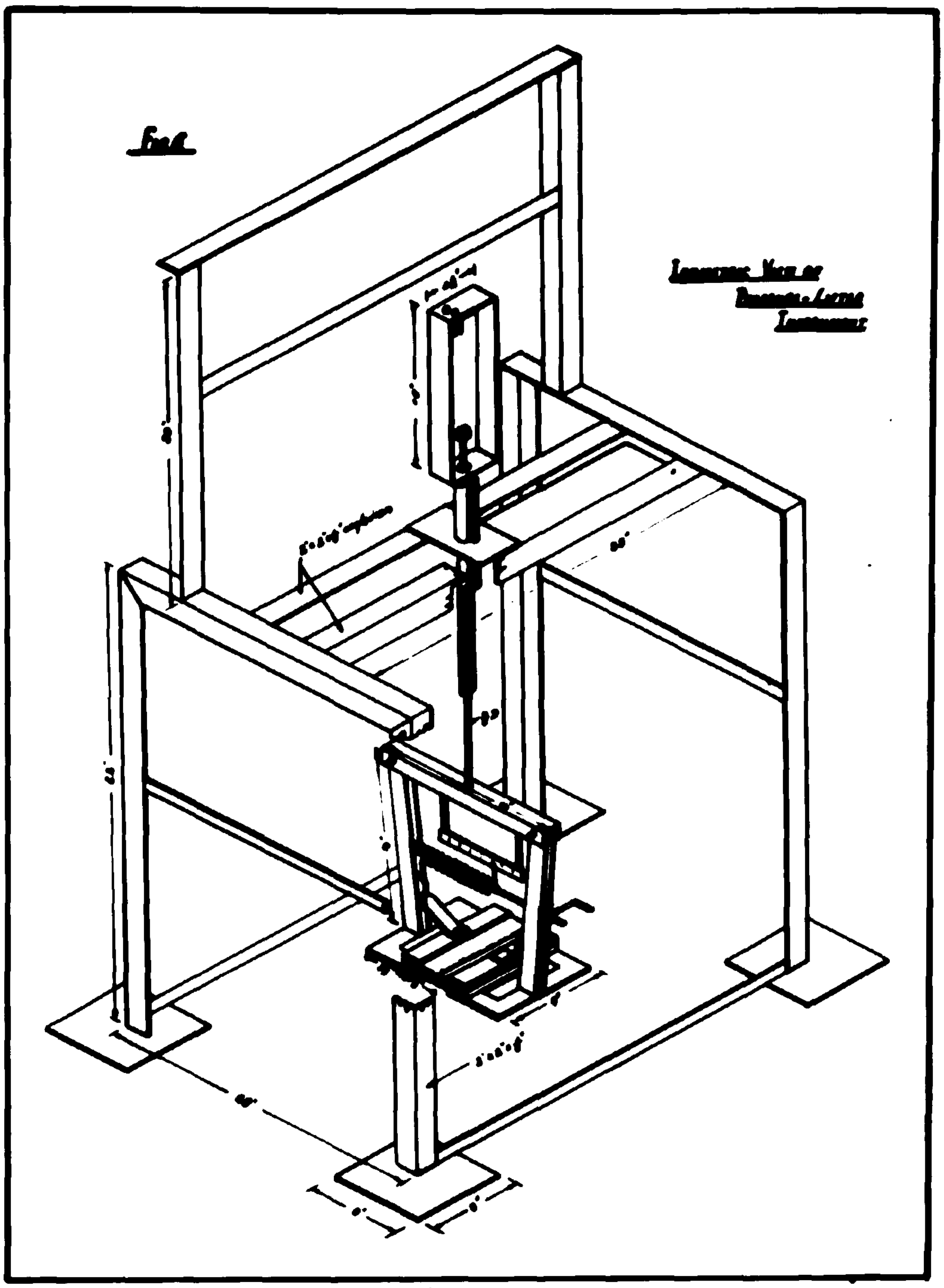


Fig. 6.

The purpose of this design was to investigate: (1) The amount of vertical pull required to lift sugar beets out of the ground when the leaves are engaged between rubber rims by which the pulling is accomplished; (2) The variation in the pull required when the soil alongside the row of beets is loosened up to depths of i.e., three, six, and nine inches; (3) The horizontal side pressures that must be exerted on the rubber rims to accomplish extirpation under the various conditions previously mentioned.

Fig. 6 shows an isometric drawing of the framework that was constructed and on which the hydraulic unit was mounted.

It was not possible to obtain any data during the 1950 season due to early snow that fell before the construction was completed, and because of the wet condition of the soil at that time.

No information concerning an investigation of this nature was found in the bibliographical review of this subject. It is felt that valuable information could be obtained with this instrument; especially in connection with the economical aspects of the power requirements of present-day sugar beet harvesting machinery.

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