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A mining research contract report
OCTOBER 1983

APPRAISAL OF DEEPER SOIL LOOSENING EQUIPMENT FOR USE IN RECLAIMING ILLINOIS PRIME FARMLAND AFTER SURFACE COAL MINING

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This study has appraised available deeper soil loosening equipment in the 1-4 ft. depth range, in the U.S. and abroad which has potential for Illinois prime farmland reclamation. The appraisal was based on written and/or oral contacts with equipment manufacturers, reclamation experts, and visiting with selected equipment manufacturers. The results indicate that several manufacturers in the U.S., West Germany, and England market static and vibratory deeper soil loosening equipment which may have potential for application in Illinois. The pertinent information concerning each equipment with potential is presented in this report.

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Foreword

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APPRAISAL OF DEEPER SOIL LOOSENING EQUIPMENT FOR USE IN RECLAIMING ILLINOIS PRIME FARMLAND AFTER SURFACE COAL MINING

by

Yoginder P. Chugh[1] and K. V. K. Prasad[2]

ABSTRACT

This study has appraised available deeper soil loosening equipment, in the 1-4 ft depth range, in the U.S. and abroad which has potential for Illinois prime farmland reclamation. The appraisal was based on written and/or oral contacts with equipment manufacturers, reclamation experts, and visiting with selected equipment manufacturers. The results indicate that several manufacturers in the U.S., West Germany, and England market static and vibratory deeper soil loosening equipment which may have potential for application in Illinois. The pertinent information concerning each equipment with potential is presented in this report.

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LIST OF ABBREVIATIONS

c/min	cycles per minute
ft	foot
g/cm^3	grams per cubic centimeter
hp	horsepower
in.	inch
mph	miles per hour
psi	pounds per square inch
rpm	revolutions per minute
yd^3	cubic yard
%	percent

CHAPTER 1

INTRODUCTION

1.0 Introductory Remarks and Study Objectives

A significant portion of the surface mined land in Illinois is reclaimed to prime farmland standards. The Surface Mining and ~~Land~~ Control Reclamation Act (SMCRA) of 1977 and the permanent regulations thereunder in Illinois require that the agricultural productivity of such reclaimed lands should be normally equal to or better than under premining conditions. A recent study by Albrecht (2)[3] for the Bureau of Mines has cited control of soil compaction to be "among the highest priority factors influencing the return of prime farmland to production". The compaction of soils occurs to a maximum depth of 4 ft and is primarily a result of the movement of high ground pressure wheel scrapers and dozers over soils during the soils replacement and regrading process. Some of the other factors affecting soil compaction are the physical properties of the soils and removal-replacement techniques for soil horizons.

One approach to the control of the soils compaction problem is to loosen the soils after replacement. Therefore, the Bureau of Mines initiated the present study (Contract No. JO225015) to appraise all available and currently under development deeper soil loosening equipment in the U.S. and abroad that may be suitable for Illinois prime farmland reclamation. The term "deeper soil" (1.0-4.0 ft depth) refers to soil depths below that which can normally be loosened by usual farm tillage equipment.[4] The specific objectives of this study were:

1) Compile data on all available and currently under development deeper soil loosening equipment with potential for application in Illinois prime farmland reclamation;
2) Appraise equipment above with emphasis on engineering specifications, performance characteristics, operational details, limitations and possible problems associated with their operation; and
3) Make pertinent recommendations regarding equipment to the Bureau of Mines.

---

[3]Underlined numbers in parenthesis refer to the items at the end of this report.

[4]The terms "Deep tillage" and "Deep soil loosening" are used interchangeably in the report.

1.1 An Overview of the Study

The study was conducted in two tasks as required by the contract. The requirements of the contract were followed explicitly. An overview of the progress made in each task is enumerated below:

Task 1

1) Reviewed pertinent literature
2) Formulated broad requirements for deeper soil loosening equipment in Illinois prime farmland reclamation.
3) Made written and/or oral contacts with major agricultural equipment manufacturers in the U.S. and abroad, coal company reclamation specialists in Illinois, agricultural research centers in the U.S. and abroad, and academic and industrial institutions involved in tillage research. Outside the U.S. written contacts were made in the Netherlands, England, W. Germany, South Africa, Australia and Japan.
4) Prepared a list of all deeper soil loosening equipment (commercial, prototype, or in the design stage) which may have potential in Illinois prime farmland reclamation.

Task 2

1) Prepared a list of important variables and considerations for appraising equipment. These were grouped under well defined headings such as principles of deeper soil loosening, engineering specifications, operational limitations and constraints, common maintenance problems, productivity, and costs.
2) Collected necessary data for appraisal of each equipment from equipment manufacturers' catalogs, telephone discussions with manufacturers and equipment users, and researchers from universities and industry who might have been involved in equipment evaluation.
3) Provided an oral briefing on the project to the Bureau of Mines personnel at the Twin Cities Research Center.
4) Visited selected equipment manufacturers in the U.S. to see the equipment and gather additional data on the performance of the equipment.
5) Visited relevant individuals and organizations in the U.S. to discuss the suitability of various deeper soil loosening equipment.
6) Prepared a summary appraisal table for all equipment with potential for application in Illinois prime farmland reclamation.
7) Prepared recommendations for additional research and equipment performance demonstration in the field.

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CHAPTER 2

REVIEW OF PERTINENT LITERATURE

2.0 Introduction

This chapter briefly reviews relevant past work in four areas: 1) soil compaction during the land reclamation process, 2) overview of currently available deep soil loosening equipment, 3) current practices/attempts in Illinois and elsewhere to alleviate soil compaction prior to revegetation, and 4) types of soils in Illinois.

2.1 Soil Compaction During the Land Reclamation Process

Soil compaction during the reclamation process is a serious problem, and it adversely affects crop productivity by 1) reducing the rate of water infiltration into the soil; 2) limiting the aeration of the soil; and 3) providing mechanical restriction to root growth. The causes of soil compaction can be broadly divided into two categories: internal and external. Natural soil characteristics, soil aeration, organic matter content, soil texture, and an increase in expandable clay mineral content in a soil are examples of internal causes. External causes are usually related to the movement of heavy machinery, such as scrapers, dozers, and trucks on soils.

Reclamation requirements on prime farmlands in Illinois specify (Sec. 1823.12, 1823.14 of the Illinois Surface Coal Mining Land Conservation and Reclamation Act, 1983) (14) soil removal and replacement in layers. This is generally accomplished in Illinois by using wheel scrapers of 25-35 yd^3 capacity, as reported by Chugh (6). During the past year or so, several mines in Illinois have been successfully using an alternative shovel-truck combination for removal and replacement of subsoil (B and C horizons). The final grading of replaced soils is generally done by using track-mounted dozers.

The use of these heavy tractive equipment for the soil replacement process with high (40-55 psi) ground pressures can result in severe soil compaction. This was documented in a recent Bureau of Mines study by Albrecht (2). The study involved two mines in Illinois which had surface soil characteristics typical of prime farmland in the state. The bulk density of replaced soils was found to be significantly higher (1.7-1.8 g/cm^3) than that for the soils in the premining condition (1.2-1.4 g/cm^3). This increase in bulk density was primarily attributed to the change in texture and the use of wheel scrapers. A cross-section of soils showing compaction of reconstructed soils using wheel scrapers is shown in Figure 1. Multiple compacted layers are observed corresponding to the number of lifts used in the soil replacement process.

Hassan (11) studied the effect of mechanization on soil bulk density and forest regeneration and observed an increase of 50% in

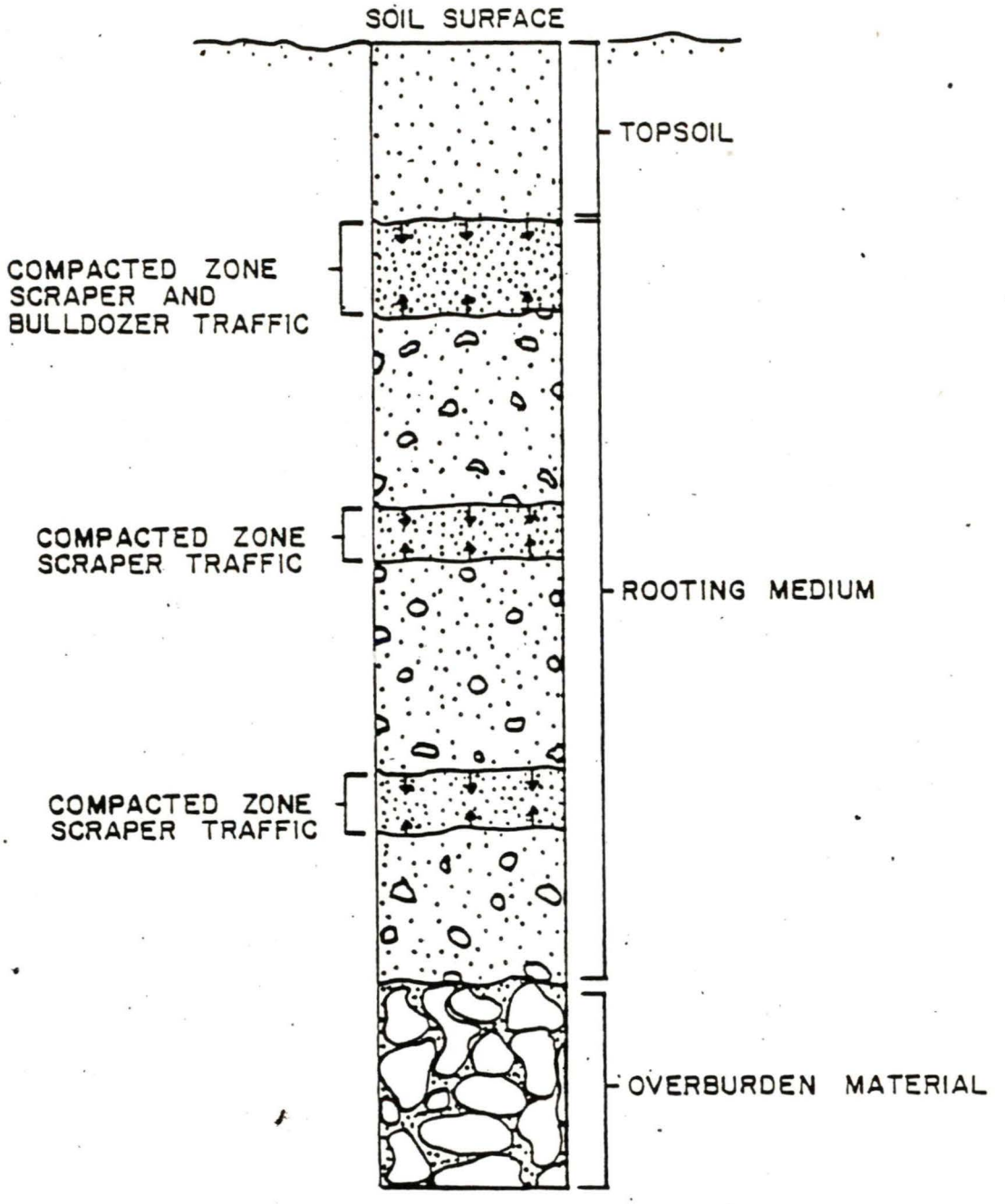


FIGURE 1: Compaction of replaced topsoil and subsoil by wheel scrapers and dozers (2)

the dry bulk density after a harvesting operation. Miles (18) determined the typical degree of compaction produced by logging and residue treatment in the central Sierra Nevada mountains and reported bulk density increases of 40 percent as common. Raghavan (21) investigated vehicle compaction problems in clay soil. He concluded that about 70% of the increase in soil density occurred within the first five passes. Raghavan (22) also studied the influence of wheel slip on clay soil compaction and reported, for 10-50% wheel slip, increases of dry densities of up to 0.25 g/cm^3.

In considering the soil compaction problem, soil characteristics such as its texture, moisture content, organic matter content, and several other factors may be as important as the type of equipment used in the soil reconstruction process. Research by Albrecht (2) has shown that sandy soils are easier to compact than clay soils, but roots can penetrate dense, sandy soils easier than clay soils. Soil moisture is also a very important factor in compaction. Sandy soils are far more likely to compact during dry conditions than clays, but clay soils are more seriously damaged during wet periods than are sandy soils. Soils with a moisture content in the range of 28-35% are most susceptible to compaction.

Adams (1) noted that organic matter had beneficial effects on soil compaction. Organic matter usually contains decaying crop or plant residues,and the decaying process leaves channels in the soil which aid in soil drainage and aeration. Hageman (10) found that soil organic matter must be maintained at the highest possible level to minimize compaction because it is inversely affected by the amount of organic matter.

The effect of tractive devices on compaction has also been studied (2), and it has been found that track mounted vehicles develop the least compaction, while mobile wheel equipment develops the most compaction. This is because ground pressures for track mounted equipment are generally much lower (8.6-22.1 psi) as compared to mobile wheel equipment (40-55 psi). Furthermore, 70-90% of the total soil compaction may occur in the first pass with heavy equipment.

2.2 Overview of Deep Soil Loosening or Deep Tillage Equipment

Soil compaction is not a new problem in agriculture. Agricultural engineers have been aware of its deleterious effects on crop production for a long time and have developed machines and soil management practices to deal with the problem.

Jamison (15), Nichols (~~19~~ 20), Cooper (7, 8), Trouse (31), Chancellor (5), and Johnson (16) have studied the compaction problems in soils which have led to the development of a variety of soil loosening machines. Subsequent research by Schafer (25) and Smith (18) has continued to improve them and make them more efficient and less expensive.

Deep soil loosening equipment is designated by a variety of names such as rippers, V-chisel, subsoilers, plows, disks, and harrows. A large variety of such equipment is available and is used in California where tillage to depths of 7 ft or more on orchards and vineyards is not uncommon. A review of the literature in this study indicated a lack of uniformity in the use of terms for deep tillage equipment. Based on a literature review and discussions with tillage experts, the authors suggest a classification in Figure 2 for tillage tools based on their soil inversion characteristics. The more important characteristics of these equipment are also presented in the figure. This approach may be useful for specifying tillage equipment for use in prime farmland reclamation.

A brief description of the major categories of deep tillage equipment, along with the advantages and disadvantages of each is presented below.

Implements Which Invert (Mix) Soil

2.2.1 Plows

Plows are primary tillage tools and are used to pulverize, aerate, and loosen the soil with partial or complete inversion of soils. The most common types of plows are: 1) moldboard plows, 2)disk plows, 3) slip plows, and 4) standard plows.

Moldboard plows (Figure 3) typically have the plow shares attached on a common frame. Each plow share is a three-sided wedge 12-20 in. wide, with the landside and cutting edge as flat sides and the moldboard as the curved side. The wedging action of the plow bottom moving through the soil exerts pressure upward and toward the open furrow. This turning causes block of soil to be sheared at regular intervals. Moreover, the blocks of soil rub and slip against each other as they move upward over the moldboard causing soil granulation. A moldboard plow is generally used to loosen soils to a depth of 10 in., although deeper depths (up to 30 in.) plows are available.

Disk plows operate similarly to the moldboard plows and consist of a series of individually mounted, frame supported, concave, rotating discs (Figure 4). When plowing with a disk plow, soil and trash are cut and moved with a rolling action. Disk plows produce a mixing action of the soil rather than soil inversion. Soil loosening to a depth of 10 in. may be achieved with a disk plow.

In a slip plow, a slip plate inclined at an angle of 25°-30° from the horizontal is attached behind a plow (Figure 5) and may be used to loosen soils to a maximum depth of 84 in. The soil cut is mixed as it travels over the slip plate and rolls down. Slip plowing is common in California. A slip plow operates more like a subsoiler (Section 2.2.5) in its cutting action.

FIGURE 2: A suggested classification for tillage equipment.

Category	Type of Tillage Equipment	Common Implements	Common Depth of Tillage	Maximum Depth	Remarks
Implements which invert (Mix) the soil	Plow	Standard Plow, Mold-board Plow Disk Plow Slip Plow	 <10 in. <36 in.	 36 in. 84 in.	100-150 hp. Rubber Tired Tractors. Multiple cutting tools on a trailing carrier. 5 to 56 cutting tools.
	Disc Harrow	Offset Disc Harrow, Tandem Disc Harrow	<10 in.	20 in.	
	Rotary	Rotary Chisel, Rotary Subsoiler Rotary Plow	< 7 in.	16 in.	Basic Chisel Shank or Plow Share on a Rotating Disk attached on a trailing carrier
Implements which do not invert the soil.	Chisel	Static Chisel, Vibratory Chisel	<12 in.	16 in.	Narrow curved shanks suited for shallow depth. Usually mounted on a trailing carrier
	Subsoiler	Static Shank Subsoiler, Vibratory Shank Subsoiler	16 in. 24 in.	30 in.	100-300 hp track mounted tractors, 3-15 shanks, Commonly mounted directly on a tool bar attached to the tractor
	Ripper	These are suited for heavy duty Work and Include the Quadripper type Implements Commonly Used in the Western USA	30 in. 36 in.	108 in.	200-800 hp track mounted tractors. 1-3 shanks mounted directly on a toolbar behind the tractor.

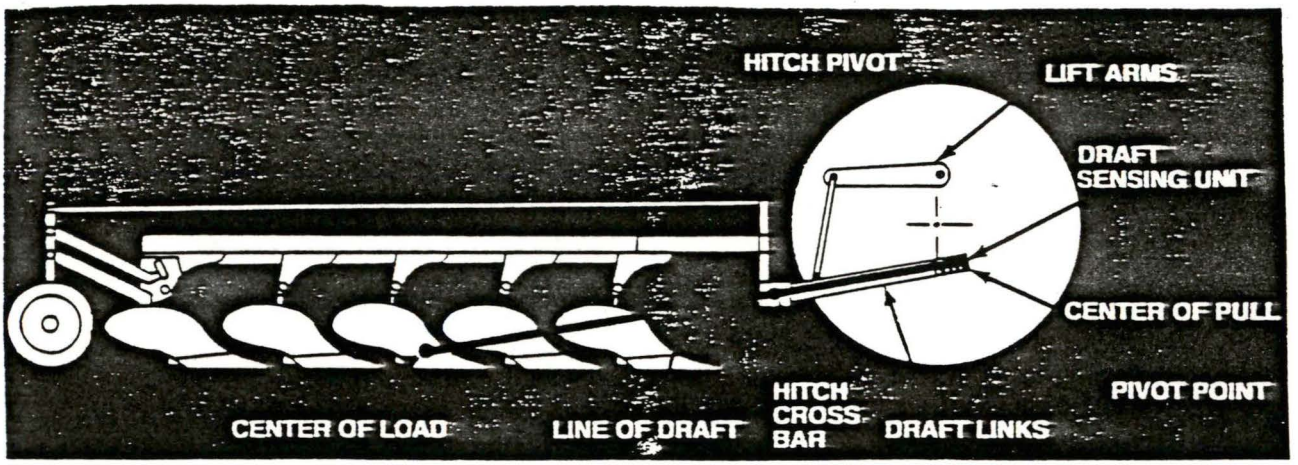


FIGURE 3: A moldboard plow (4)

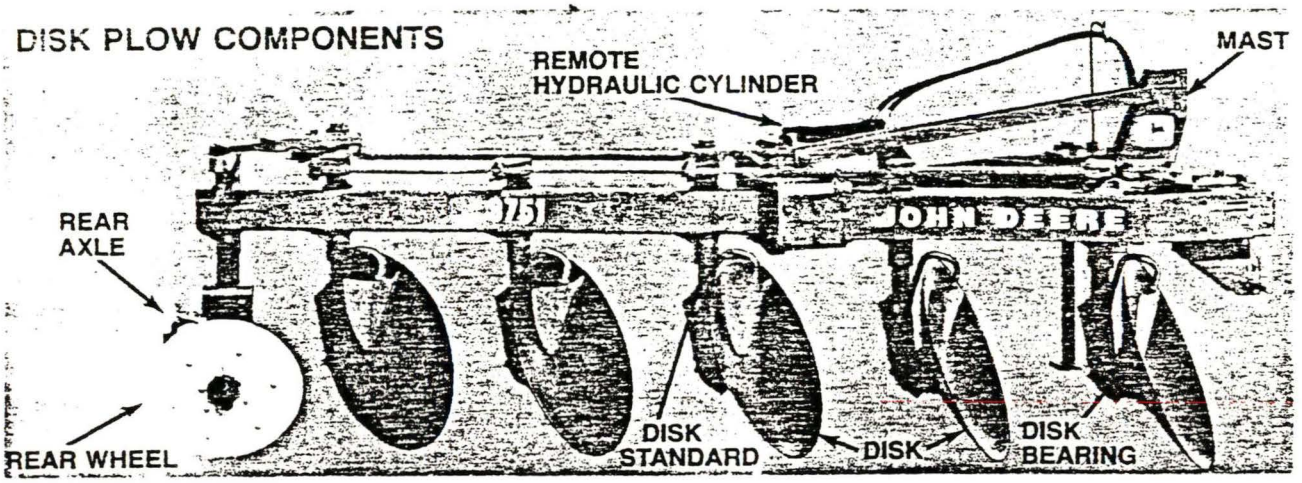


FIGURE 4: A disk plow (4)

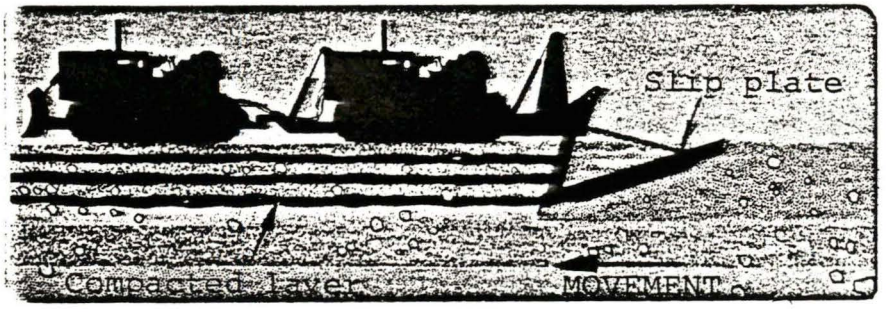


FIGURE 5: A slip plow
(Courtesy Agristruction, Inc.)

The inversion of soil by plows and consequent covering up of trash helps in reducing weeds and insects causing plant disease. Plowing also prevents the return of soil layers to their original layered characteristics by mixing the different soil layers. The water penetration characteristics of soil are also improved.

Moldboard and disk plows are shallow tillage tools working generally to a depth of 10 in. A slip plow is generally used to till to a depth of 36 in. Continual operation of a plow to the same depth each year gives rise to a plow pan which may act as an impediment to root growth. Furthermore, inversion of soil may cause erosion and soil structure problems.

A standard plow consists of a heavy steel bar shaped like a fork. It is an outmoded tool and was used in old times. Domestic animals were used to pull the plow through the soil.

Rasmussen (24) proposed that farmlands with soils containing a large clay content could be improved economically by deep plowing to a depth of 36 in. He stated that deep soil loosening by moldboard plows greatly improved the physical and chemical conditions of the soil by mixing up horizons and by breaking up hardpan and cemented layers.

Wildman (38) conducted tests to observe the effect of the width of the slip plate and the slip angle on the draft force of a slip plow. He found that the draft force decreased as the distance from the cutting edge to the standard increased. Furthermore, he observed that the draft forces were a minimum for slip angles between 25^{o}-30^{o}.

Plows have a limited application in deeper soil loosening in prime farmland reclamation because of their soil inversion characteristics and limited depth of loosening.

2.2.2 Rotary Tillage Tools

Rotary tillage tools include plows, chisels and subsoilers. They basically consist of a series of disks mounted on a horizontal rotor. Each disk has 4 or 6 plowshares/chisels/L-shaped blades attached to it as shown in Figure 6. Power is transmitted from the tractor to the rotor through a Power Take Off (PTO) shaft and a gear box. The rotor operation result in the plowshares/chisels biting into the soil and causing shattering and mixing of soil layers (Figure 7).

Rotary tillage equipment has the advantages that 1) power can be transmitted to the chisel rotor via PTO shaft more efficiently than it can be transmitted through a drawbar, 2) the rotating blades tend to push the tractor forward as the soil is tilled, thereby reducing the draft force, 3) soil compaction problems are reduced because lighter equipment is required, and 4) a low draft

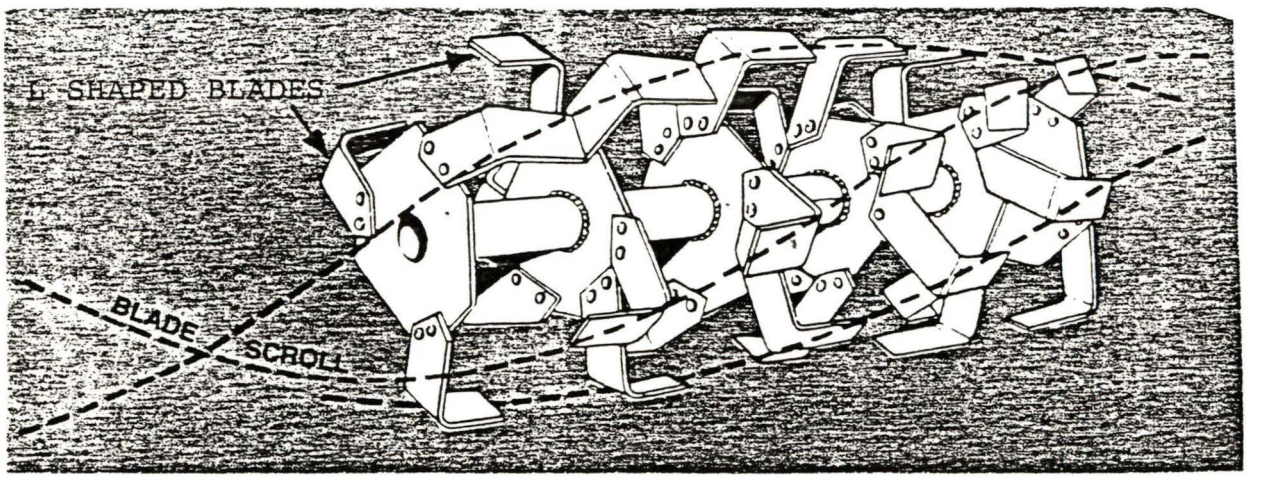


FIGURE 6: Rotary Tillage Tool (4)

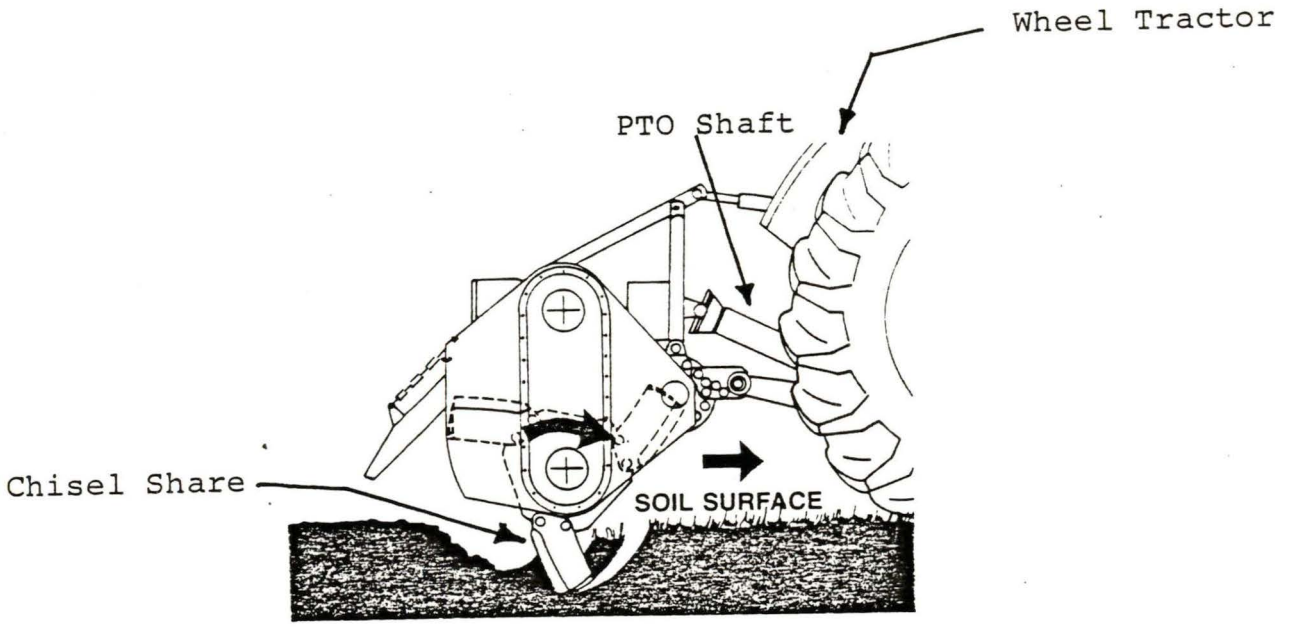


FIGURE 7: Soil Loosening With A Rotary Tillage Tool

force requirement allows operation in more difficult traction conditions.

Rotary tools mix soil layers and therefore may not be applicable in prime farmland reclamation. Furthermore, mixing of soil leads to erosion and acid mine drainage problems, because more erodable and more toxic soils may be brought close to the surface. Hendrick (13) discussed the design and testing of an experimental rotary chisel. He found better power transmission, reduced draft force (allowing tillage under difficult traction conditions), better soil breakup and a 30% increase in cross-sectional area of soil disturbed.

2.2.3 Disk Harrows

Disk harrows basically consist of a set of concave disks mounted on a common shaft, as shown in Figure 8. Each such unit is called a disk gang. When the disc gang is operated at an angle to the direction of travel, the disks scoop and roll soil as they rotate. Operation at high speeds up to 7 mph results in soil pulverization, along with lifting and mixing of soils. Some factors important in disk harrow operation are the curvature of the disk, shape of the cutting edge, and the gang angle. Disks may be used to loosen soils to a maximum depth of 20 in.

Disks harrows are generally used as a secondary tillage tools and can be attached behind a plow or subsoiler to prepare the seedbed simultaneously. They are efficient in cutting trash and mixing it into the soil. Disks are not suitable for deep soil loosening in land reclamation because of their soil inversion characteristics. Secondly, because of their sharp edges they tend to form a compact layer at the bottom and along the sides similar to a plowpan.

Singh (27) determined the effect of various soil, implement and operating parameters on the depth of penetration of a disk harrow. Results showed that the depth of penetration increased linearly with the gang angle of the harrow and also with the speed of operation.

Implements Which Do Not Invert Soils

2.2.4. Chisels

Chisels are primary tillage tools which break, stir, and aerate the soil with negligible inversion or mixing of soil layers and are used to loosen soils to a maximum depth of 16 in. A chisel utilizes narrow curved multiple shanks as shown in Figure 9. The unit is generally mounted on a trailing carrier unit behind a tractor. Chiseling at depths greater than 16 in. is generally called subsoiling. Erosion and acid mine drainage problems are minimized because the soils are not inverted.

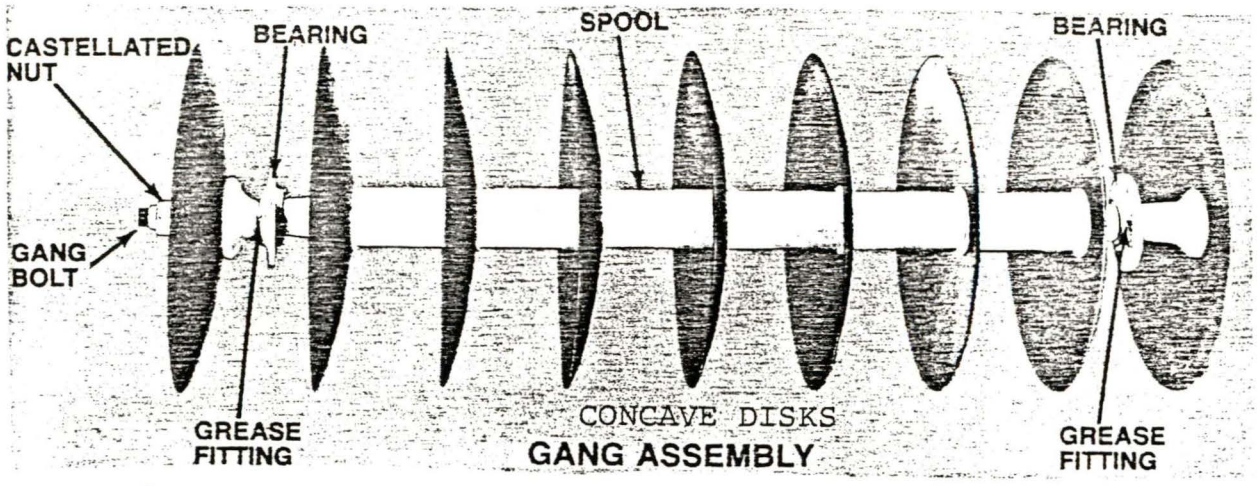


FIGURE 8: A disk harrow (4)

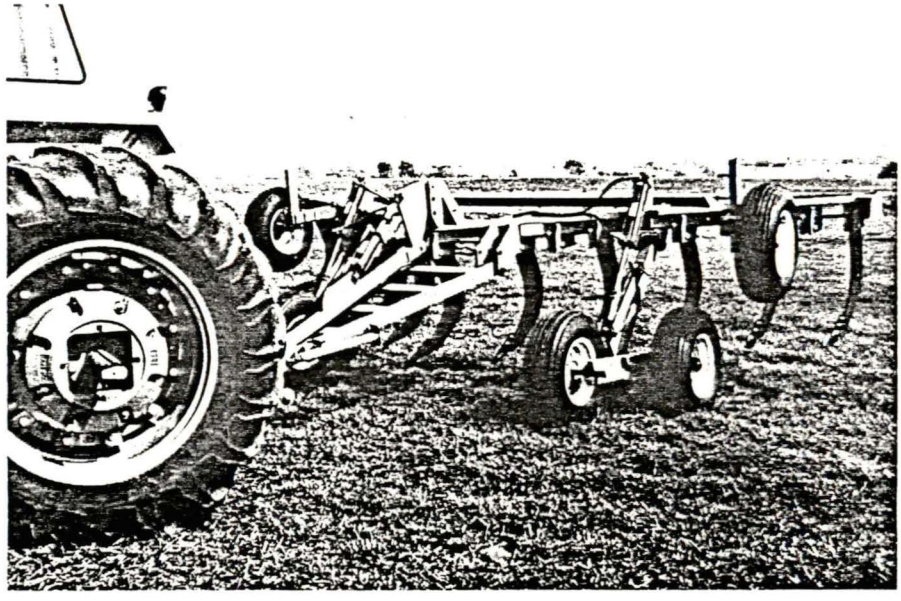


FIGURE 9: Chisel (Courtesy Landoll Manufacturing Co.)

2.2.5 Subsoilers

A typical static subsoiler is shown in Figure 10 and is used for tillage to a maximum depth of 30 in. The soil loosening is done by a cutting tool called the shank, share or standard. The shape of the shank is very important because it affects the draft force, soil shattering, and ease of penetration into the ground. Several common shank shapes are shown in Figure 11. A shank inclined forward lifts and breaks the soil much better than if it is vertical. Curved shanks work better by lifting the compacted soil and shattering the soil ahead of and between shanks. A parabolic shank requires the least draft force for tillage and penetrates itself into the ground easier than other shank shapes. Straight shanks are strong structurally and are therefore better in loosening rocky soils. A single shank moving through soil loosens a triangular area (area of influence). A sweep/s may be atttached to a shank (Figure 12) to increase the area of influence of a shank or to increase the shattering effect. Multiple shanks appropriately spaced are necessary to effectively loosen soil over the entire area.

Each shank is attached at the top to a common toolbar which may be straight or V-shaped. The V-shaped bar has the advantage that all shanks are not located in the same vertical plane which significantly reduces the draft force. The spacing between shanks is another important variable and is a function of the depth of tillage, soil characteristics and moisture content in soils. Spacing between shanks generally varies from 20 to 30 in. The vertical clearance of subsoilers is also an important parameter. The vertical clearance is defined as the clearance between the ground and the toolbar when the shank is operating at its rated depth (Figure 11).

Chiseling/subsoiling has the disadvantage that it can only be done under relatively low moisture conditions. When the soil is moist, it may flow plastically around the shank tip or point and is pushed to one side and compacted instead of being shattered. Secondly, power requirements are higher compared to other tillage tools and increase nonlinearly with increasing depth of tillage (19). The use of parabolic curved shanks can considerably reduce the draft force.

Nichols (19) conducted field and laboratory tests on a wide range of subsoiler types and observed that as a subsoiler advanced, a portion of the soil moved forward with the subsoiler and became part of it, acting as a cone or wedge. They also observed that the vertical angle of the face of the subsoiler shank with the horizontal was an important factor in subsoiling because it affected the cone shape or dimensions. They reported that some designers claimed a substantial reduction in draft force with an angle in the neighborhood of 15°. They also observed that the ratio of the upward pressure applied by the subsoiler point to the horizontal pressure applied to the soil by the shank was important for draft

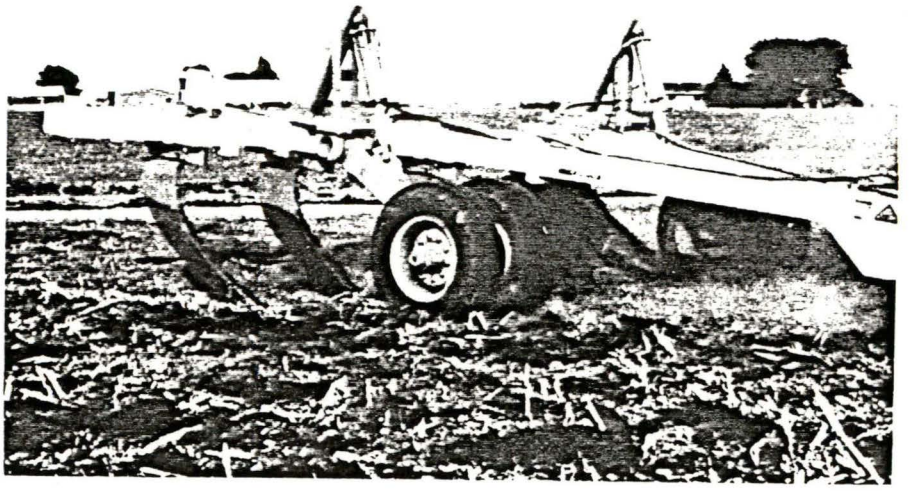


FIGURE 10: Subsoiler (30)

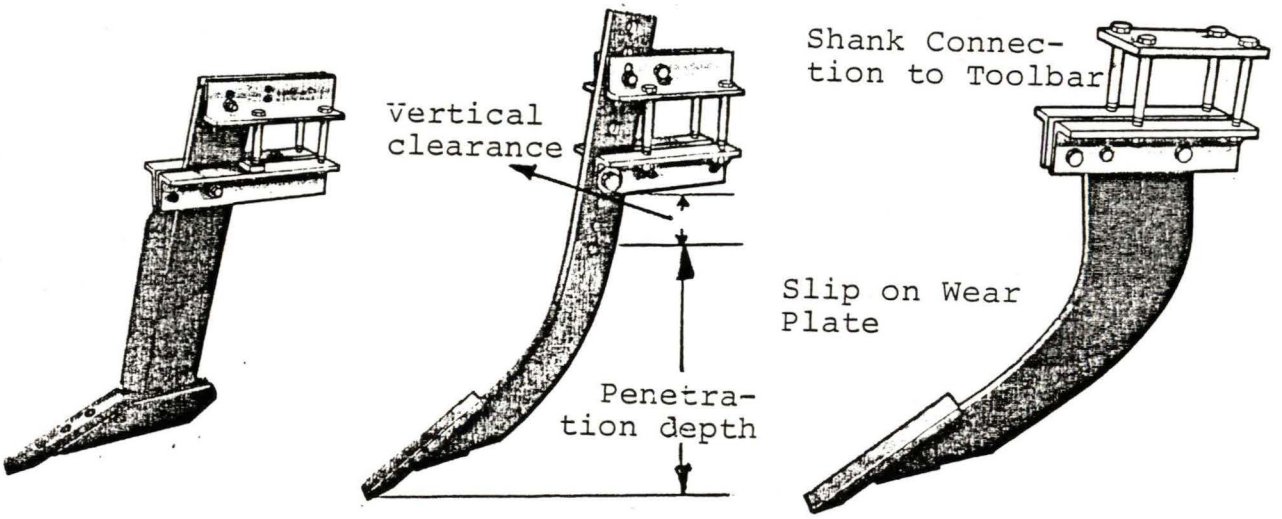
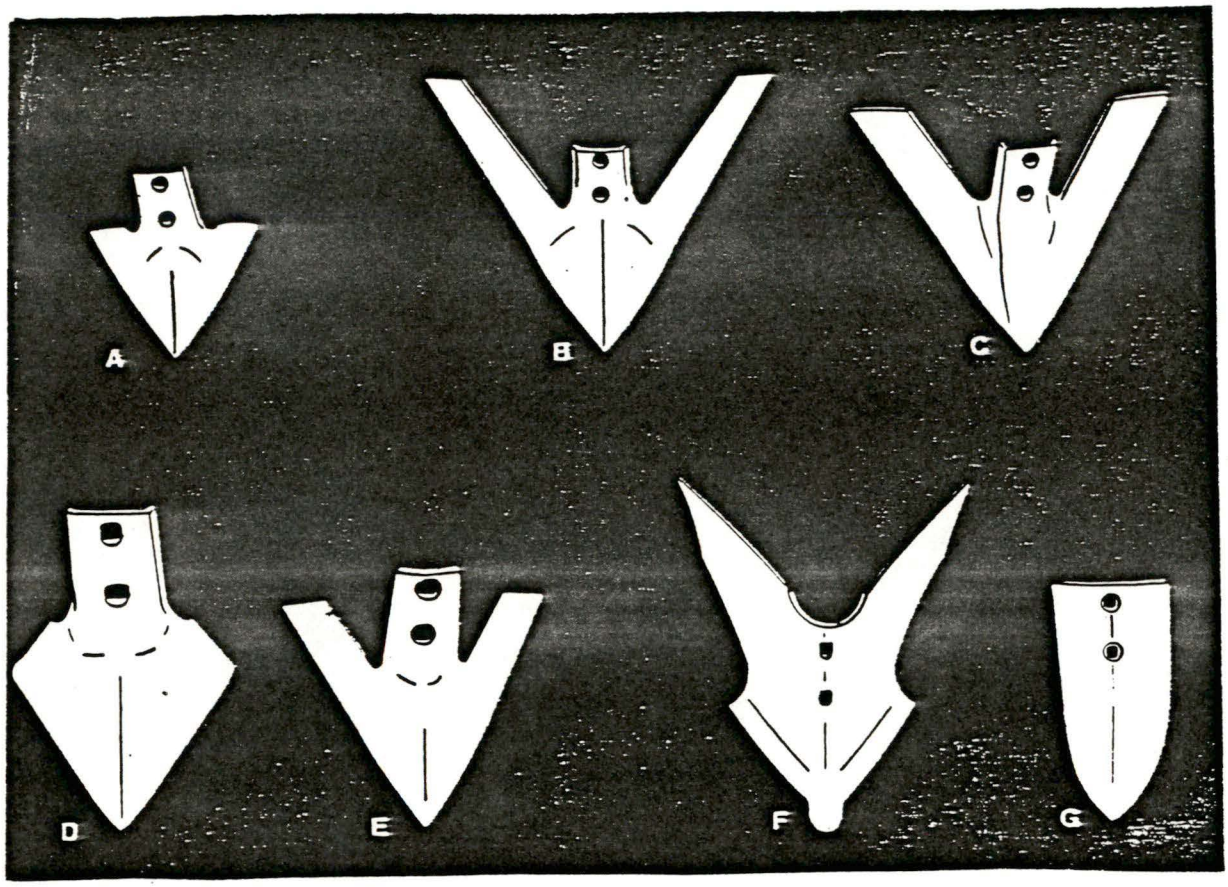


FIGURE 11: Available shank geometries for use on subsoilers (Courtesy Landoll Manufacturing Co.)



A. Regular sweep

B. High crown sweep

C. Heavy duty low crown sweep

D. Chisel sweep

E. Heavy duty regular sweep

F. Furrow opener

G. "Beavertail" shovel

FIGURE 12: Sweep/wing attachments for subsoiler shanks (4)

force requirements. These observations led to the development of parabolic and curved shanks.

Wildman (37) compared the performance of a straight shank, a curved shank and a curved shank with a sweep/wing attachment. He observed that a curved shank required the least force for effective subsoiling. The wing attachment did not increase the draft force significantly and gave a much better soil loosening than the other types.

Goyal (9) compared chiseling with moldboard plowing and stated that chiseling was much more economical and offered a higher capacity than moldboard plowing. Trouse (32) stated that under the row subsoiling is a practical technique to increase crop production and random subsoiling is seldom beneficial. Under-the-row subsoiling implies subsoiling only along the rows where planting will be done. Therefore, subsoiler shanks are spaced a row width apart and subsoiling is done just deep enough to assure breaking the deepest compacted layer. Random subsoiling represents loosening soils without specifically considering where planting will be done.

In a vibratory subsoiler, the cutting edge/shank in a vibratory tillage equipment is subjected to forced vibration usually forward and backward in the direction of travel as shown in Figure 13. Shear planes tend to develop ahead of the cutting edge with each oscillation, thereby reducing draft force. Vibratory subsoilers have the advantage that, for the same depth of tillage, the draft force requirements are significantly reduced. Thus, loosening can be done deeper with available power. Soil compaction may also be reduced because smaller tractors may be used which generally have lower ground pressures.

Larson (17) indicated that rotary tillage and direct power utilization with forced vibration of the tillage tool had promise in reducing draft force requirements. Verma (36) reported a 50-60% reduction of cutting resistance using mechanical vibrations. Working along similar lines, Venter (34) stated that the efficiency of a vibratory tillage toolwas dependent entirely on the frequency and amplitude of vibration and the ratio of the vibration speed to forward speed. Venter (35), continuing on his previous studies, recommended that the addition of a stiff spring element could give a reduction in the energy requirements of a vibratory system provided that the natural frequency of vibration is more or less identical to the forced vibration frequency. Moreover, the vibratory elements on different shanks should preferably be out of phase with respect to each other to reduce peak loads. A vibratory subsoiler (Kaelble Gmeinder TLG-12),[5] included in our survey, has some of these features incorporated in its design.

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[5]Reference to specific equipment in this report is made to facilitate understanding and does not imply endorsement by the Bureau of Mines.

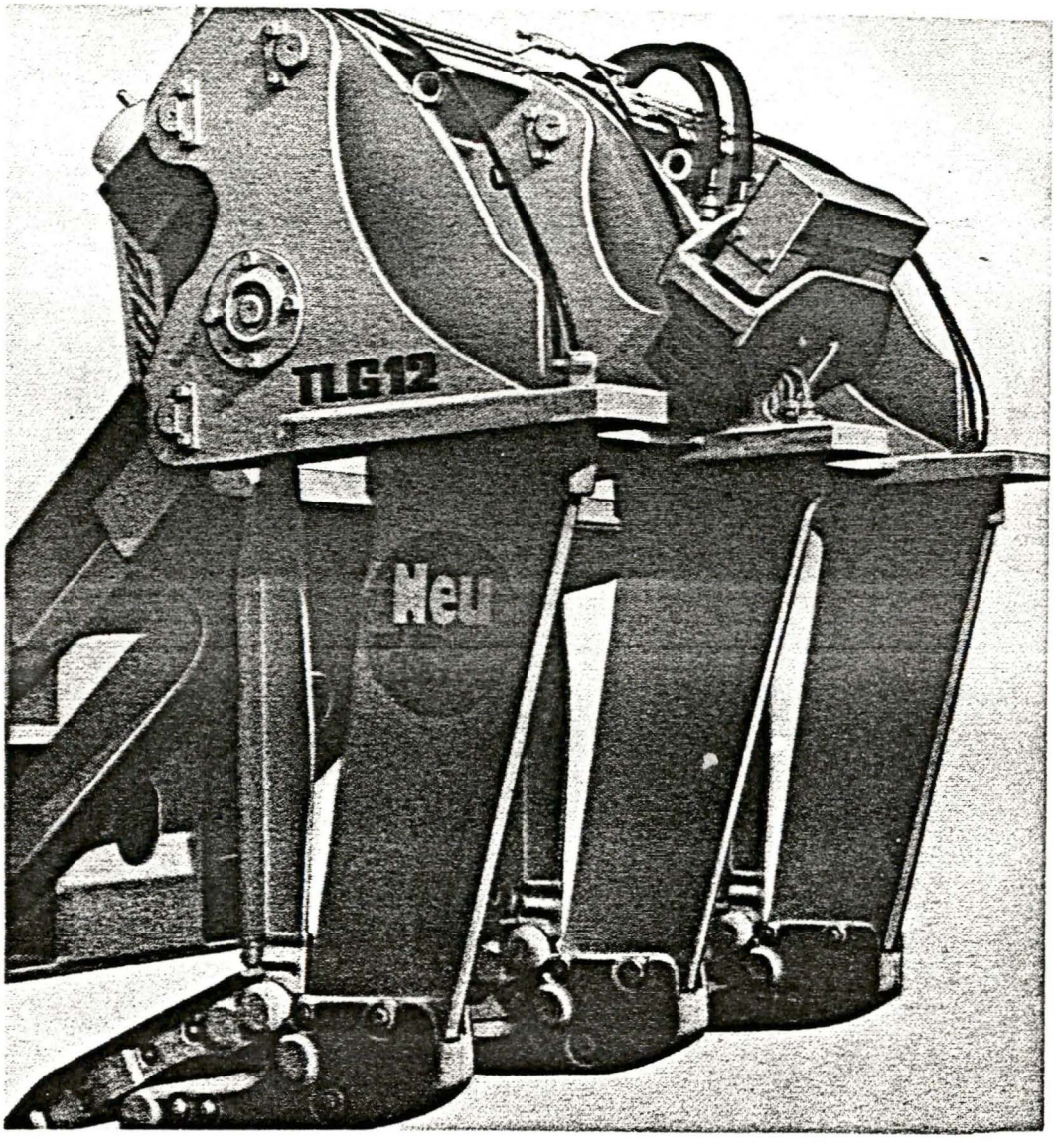


FIGURE 13: Vibratory Subsoiler (Courtesy Kaelble Gmeinder Co.)

Sommer (29) conducted a model study to compare the performance of a vibrating subsoiler and a static subsoiler. Their results indicated that forced vibration of shanks resulted in a decreased draft force by about 25%.

2.2.6 Rippers

These are basically heavy duty subsoilers (Figure 14) and depend upon a large amount of power and their weight to shatter soil. Most rippers utilize only 1-3 shanks because of their large penetration depth (> 48 in.). Rippers are generally mounted directly on the rear of a dozer through standard hitches. Straight or curved shanks are rigidly mounted on a tubular section toolbar which may be straight or V-shaped. Shanks have wear resistant replaceable protection on their leading edges. Hydraulic cylinders on the toolbar provide for applying a downward vertical pressure and to pull shanks out of the ground. One or more large sized dozers are utilized in tandem during the ripping operation.

2.3 Current Practices/Attempts in Illinois and Elsewhere to Alleviate Soil Compaction Prior to Revegetation on Reclaimed Prime Farmland

Disking or chiseling to a depth of 12 in. is commonly utilized on reclaimed lands prior to revegetation as reported by Chugh (6). Discussions with coal company reclamation specialists in Illinois indicated relatively few attempts at deeper soil loosening in land reclamation. One company experimented with a five-shank subsoiler, manufactured by Murray Manufacturing Company of California (Section 4.4) for subsoiling to a depth of 30 in. in southern Illinois and had limited success. The area subsoiled had a fairly large percentage of coarse materials in the soils and the straight shanks on the subsoiler had a tendency to pull out of the ground. This experiment was discussed with the equipment manufacturer. The manufacturer indicated that a significant improvement in performance could have been attained by proper selection of shanks and operating procedures.

Another coal company used a Bushhog V-subsoiler with five parabolic shanks (Section 4.4) to loosen about 54 acres of reclaimed prime agricultural land in southern Illinois to a depth of 24 in. A 120 hp tractor was used in this experiment. The coal company considered this experiment a success and was generally satisfied with the operation of the subsoiler even in relatively rocky soils. Wear and tear on the subsoiler teeth due to rocky soil was the only major problem encountered.

Two coal companies attempted using modified ripper blades of a conventional CAT D-9 dozer for deeper soil loosening with limited success.

A midwest-based coal company demonstrated publicly in central Illinois in November 1982 the use of a vibratory subsoiler (Model TLG-12) manufactured by Kaelble Gmeinder Company of West Germany

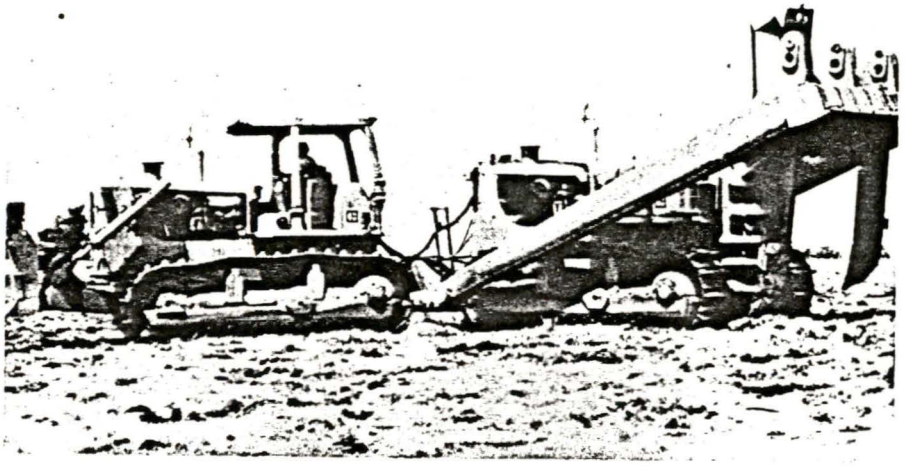


FIGURE 14: Ripper (Courtesy Agristruction, Inc.)

(Section 4.4). The equipment proved effective in loosening soils to a depth of 30 in. Discussions with coal mine operators and deep tillage experts from throughout the U.S. indicated a very positive response to the application potential of this equipment in prime farmland reclamation in Illinois and elsewhere.

A large coal producer in the Powder River Basin in Wyoming has successfully used a subsoiler with five (5) parabolic shanks manufactured by R & R Agriproducts, Inc. (Section 4.4) to loosen soils to a depth of 24 in.-26 in. Although the nature and inherent moisture content of the soils there is different than in Illinois, the equipment may offer a potential in Illinois also.

Deeper soil loosening to a depth of 30 in. is currently practiced in land reclamation in English and West German coal mines with considerable success.

In agricultural production, deep tillage is practiced in California, Indonesia, S. Africa, Australia and the Middle East. A major market for deep tillage equipment manufactured in California is outside of the United States.

2.4 Types of Soils in Illinois

Strippable coal reserves in Illinois lie in the central portion of the state and along the southern and eastern boundaries of the state. A considerable portion of these reserves lie under potential farmland or under soil suitability classes I, II, and III (2) all or part of which may be prime farmland, as shown in Figure 15.

A typical cross-section of soils in Illinois, along with their textural classes is shown in Figure 16. In southern Illinois, topsoil(A_1 + A_2) horizon generally consists of silty loams with an organic content less than 1.5%. The B-horizon generally consists of silty clay loams with good structure to it. The C-horizon generally consists of silty loams to heavy silt loams with relatively massive structure. The C-horizon is generally underlain by glacial till which vary from loams to silty clay loams in texture.

In central Illinois, the topsoil (A_1 + A_2) horizon is much thicker than in southern Illinois. Its texture may be classified as silty loam with an organic content varying from 4-5%. The B-horizon consists of heavy silt loams with relatively good structure. The C-horizon and underlying glacial till texture is very similar to that observed in southern Illinois.

The percentage of clay, silt, and sand in the basic soil, textural classes referred above are shown in Figure 17 (33).

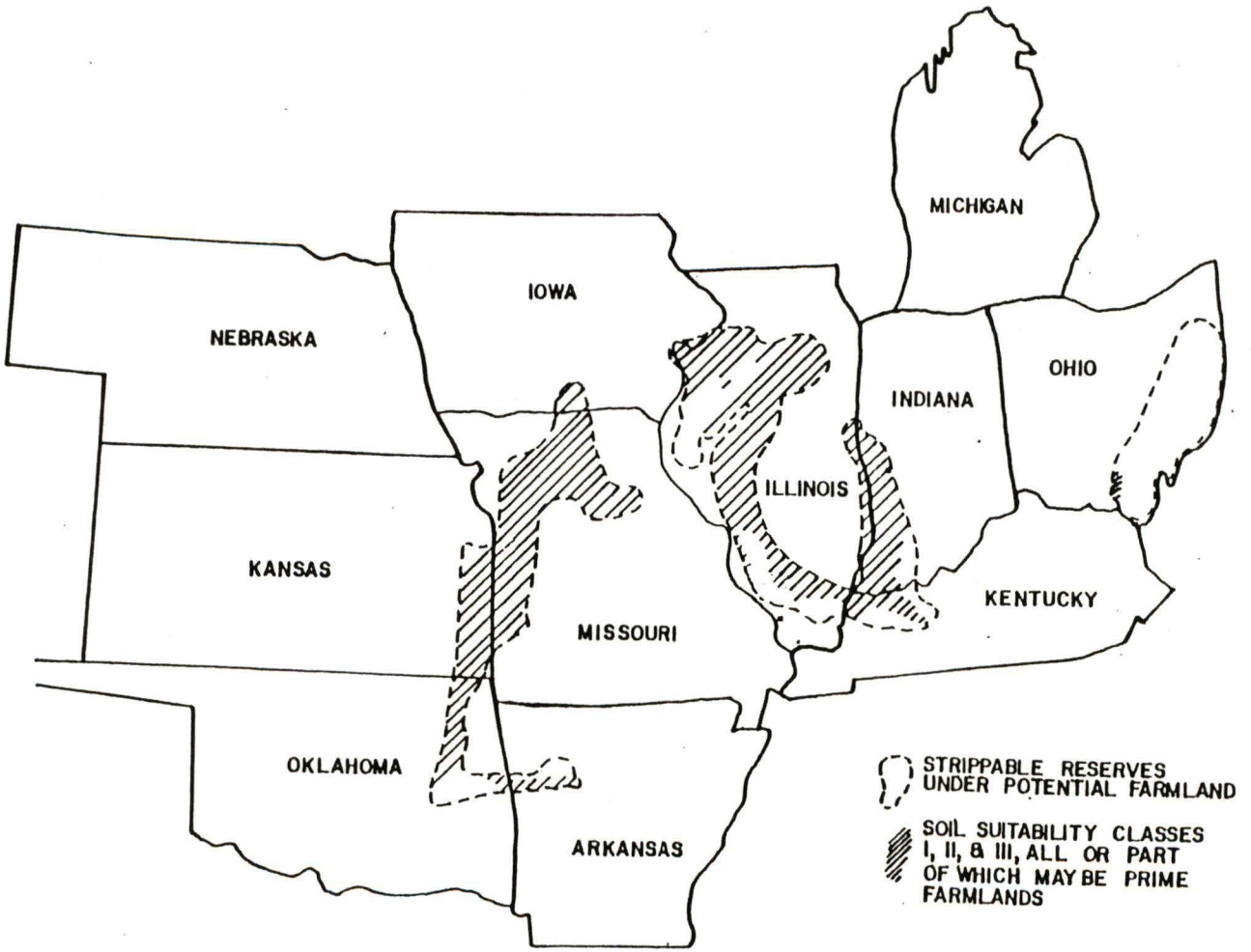
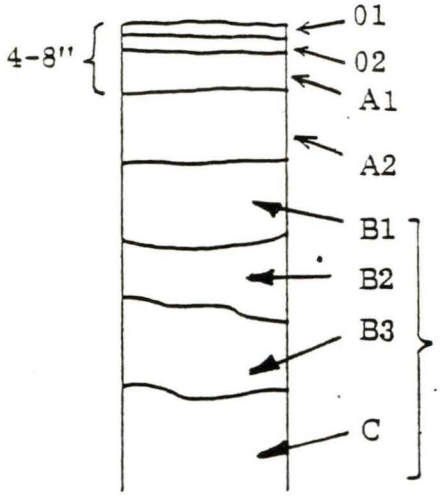
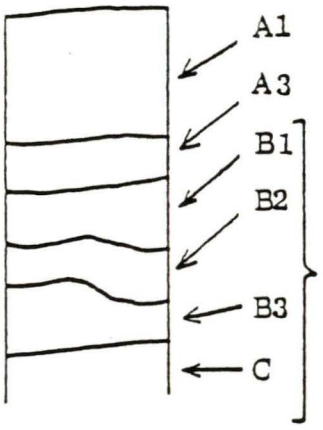


Figure 15: Location of strippable coal reserves under potential farmland in the Midwest (2).



Horizon sequence	Typical Color	Texture	Structure
01	Vegetation brown		
02			
A1	Dark brown		Granular
A2	Light ashy gray	Sandy, high silica	Platy
B1	Reddish brown or	High clay	Blocky or prismatic
B2			
B3	Gray or		
C	Mottled yellow & gray		Prismatic or massive



Horizon sequence	Typical Color	Texture	Structure
A1	Dark brown		Granular
A3	Brown		Granular
B1	Reddish brown or	High clay	Granular, blocky or prismatic
B2	Gray or		
B3	Mottled yellow & gray		Blocky, prismatic or or massive
C			

B. Central and Northern Illinois

FIGURE 16: Typical soil profiles in Illinois

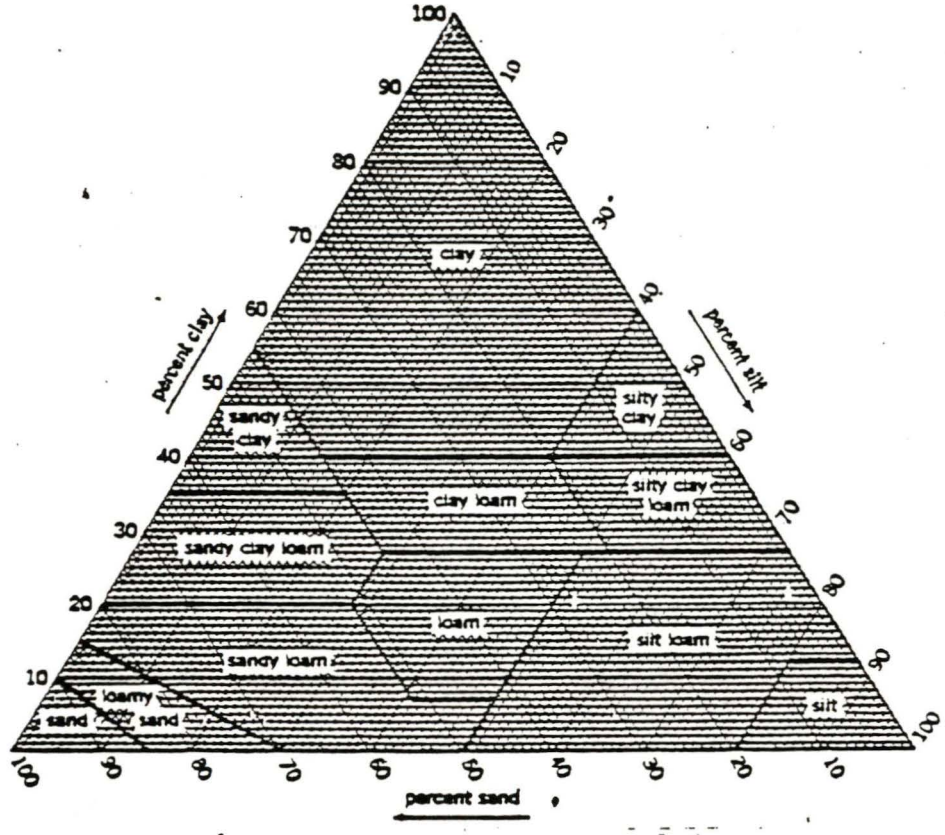


FIGURE 17: Percentage of clay, silt and sand in basic soil textural classes (33)

CHAPTER 3

DATA COLLECTION AND EQUIPMENT APPRAISAL

3.0 Data Collection:

The study was initiated by simultaneously reviewing published literature and making written and/or oral contacts with major agricultural equipment manufacturers in the U.S. and abroad, coal company reclamation specialists in Illinois, agricultural research centers in the U.S. and abroad, and academic and industrial research centers involved in tillage research. Information on deep tillage concepts, and currently available and/or under development equipment were requested. In all, over 60 individuals or organizations were contacted. Two major equipment manufacturers and two well recognized deep tillage experts were visited personally within a month after initiation of the study to discuss the project. Most of the researchers from the U.S. interested in deeper soil loosening were present at the public demonstration (November 1982) of a vibratory subsoiler (Manufactured by Kaelble Gmeinder Co. of West Germany) at a central Illinois mine. At that time, discussions were held with key persons regarding the requirements for deeper soil loosening equipment, and approaches that may be taken to alleviate the soil compaction problem on reclaimed prime farmlands in Illinois.

Based on initial discussions with reclamation specialists and research contract specifications, data requirements for detailed appraisal of equipment were formulated and are shown in Table 1. All available data for each equipment with potential application in Illinois were collected by written and/oral contacts with the manufacturer of the equipment. Very limited data were available for items 3-7.

In addition to the discussion of the above information, the more important engineering specifications of different equipment were also presented using the format in Table 2.

Based on equipment appraisal as above and equipment performance reviews (where available), recommendations were formulated field demonstration of equipment.

Table 1

Variables Considered In The Appraisal of Each Deeper Soil Loosening Equipment

1.0 Principle of deeper soil loosening
2.0 Engineering specifications
  2.1 Tractor specifications
    1. Horsepower requirement
    2. Type of ground traction
  2.2 Operational specifications
    1. Penetration depth
    2. Working width
    3. Vertical clearance
  2.3 Shank characteristics
    1. Shape of shank
    2. Shank spacing
    3. Width of shank
    4. Material of shank and shank teeth
    5. Vibratory or static
3.0 Operational limitations and constraints
  3.1 Soil parameters
    1. Ability to handle rock material
    2. Type of soil
    3. Moisture content in soil
    4. Potential erosion problems
  3.2 Maneuverability
    1. Problems around curves
4.0 Common maintenance problems
  4.1 Mechanical availability of tractor and ripper
  4.2 Mean interval between breakdowns
  4.3 Time taken to remove or attach implement from tractor
  4.4 Vulnerable points from breakdown point of view
    1. Hydraulics
    2. Shank mount structure
    3. Disfiguration of shank
    4. Shank life
    5. Wear points
5.0 Productivity
  5.1 Acres loosened/hour
  5.2 Machine utilization
6.0 Costs
  6.1 Cost of implement and tractor
  6.2 Life of implement
  6.3 Cost breakdown
    1. Labor operating costs
    2. Supply operating costs
    3. Maintenance costs
  6.4 Owning and operation cost/operational hour
7.0 Possible equipment modification for use in various sites

Table 2. Summary of engineering specifications for selected deeper soil loosening equipment.

Manufacturer	Model No.	Maximum Penetration Depth (in.)	No. of Shanks	Shank Spacing (in.)	Working Width (ft)	Tractor Horsepower hp	Shank Characteristics				Remarks
							Shank shape	Shank Thickness (in.)	Shank Height (in.)	Vertical Clearance (in.)	

CHAPTER 4

RESULTS

4.1 Future of Deeper Soil Loosening Practices in Illinois Prime Farmland Reclamation

Almost all mine operators contacted in Illinois agreed that deeper soil loosening would be required to meet the productivity requirements on reclaimed prime agricultural lands after mining. Furthermore, it was the general consensus of the operators that deeper soil loosening should be done in a single stage after the topsoil had been replaced. Several reasons were given for that: 1) loosening of subsoil and topsoil separately would add an additional step in the reclamation process; 2) loosening during the reclamation process might not yield desirable results because soils may be too wet; and 3) loosening of topsoil and subsoil separately might not eliminate the need for loosening the subsoil after the topsoil was replaced.

Most agricultural and reclamation experts contacted agreed that legumes should be planted for two or three years after reclamation to draw the moisture out from the subsoil before deeper soil loosening is attempted (23). Soil loosening may be necessary every 6-8 years after it is initially loosened.

Discussion with mine operators and deep tillage equipment manufacturers generally indicated a lack of communication between the two groups. Only two equipment manufacturers had worked with the mining industry and were aware of the deeper soil loosening problems. Most mine operators were not cognizant of the available deep tillage equipment. Some of the large coal companies are now putting in a considerable effort to learn about deeper soil loosening equipment and practices.

4.2 Requirements for Deeper Soil Loosening Equipment in Illinois

Some of the factors considered important by mine operators in the selection of deeper soil loosening equipment were: 1) productivity (acres/hour), 2) depth of loosening, 3) consistency of loosening, 4) nature of soils/moisture content that the equipment can handle, 5) ability to handle rocky soils, 6) owning and operating cost, although this was not considered to be very important, and 7) horsepower requirements.

4.3 Availability of Deep Tillage Equipment - An Overview

Most of the deep tillage equipment in the world is manufactured in the U.S. in the state of California. Outside of the U.S., deep tillage equipment is manufactured in West Germany, England, Italy, and South Africa. Some of the equipment is, however, very similar to that in the U.S. A significant market exists for the U.S. made deep tillage equipment in countries such as Indonesia,

Mexico, South Africa, the Middle East, and some of the West European countries. In the U.S., most deep tillage is currently practiced in California and Florida.

Almost all equipment manufacturers contacted indicated that they had no new deep tillage equipment in the planning stages. Several of them indicated that they would be getting out of the business of producing deep tillage equipment. Most large equipment manufacturers indicated that deep tillage equipment was a specialty area and smaller companies could do a better job of producing it more economically than the larger companies.

4.4 Appraisal of Deep Tillage Equipment With Potential For Application in Illinois Prime Farmland Reclamation

Most available deeper soil loosening equipment has not been demonstrated in Illinois in surface mine reclamation. Sometimes the available deep tillage equipment is used in agricultural production every 4 to 5 years to break up and loosen soils to a depth of 20 in. to 24 in. Discussions with reclamation specialists in Illinois indicated that most of the heavy duty static or vibratory subsoilers may have potential for application in prime farmland reclamation. After screening available data from all manufacturers, the equipment shown in Table 3 were selected for a detailed appraisal, as required by the contract. The variables such as penetration depth, horsepower requirements, performance reviews at mines or elsewhere, and productivity were considered in selecting equipment for detailed appraisal.

Important engineering specifications of appraised equipment are summarized in Table 4. In addition, an appraisal report on each slected equipment is also presented here.

Table 3

Equipment Selected for Detailed Appraisal

Manufacturer	Type of Equipment	Model Number
Agristruction, Inc.	Static Rippers	Little Brute Big Brute
American Tractor Equipment Corporation	Radial and Parallel Action Rippers	VRAR-1 VRAR-3 PR
Bushhog	Static Subsoiler	V-Plow
Carl Kaelble U. Gmeinder GmbH & Co.	Vibratory Subsoiler	TLG-12
DMI, Inc.	Static Subsoiler	Turbotiger Coltertiger
F. W. McConnel Ltd.	Vibratory Subsoiler	Commando Shakaerator
Landoll Manufacturing Co.	Static Subsoiler	513-V Deep Chisel Plow
Marvin Landplane Co.	Static Subsoiler	630-V 640-V
Murray Manufacturing Co.	Static Subsoiler	M 37 M 53 M 55 M 55S
R & R Agri-Products, Inc.	Static Subsoiler	Medium Duty Heavy Duty Extra Heavy Duty
Rome Industries	Static Subsoiler	4TAC-6000 4TAC-1110B 3TAC-6000A 11J-154R
Towner Manufacturing Co.	Static Subsoiler	

Table 4. Summary of engineering specifications for selected deeper soil loosening equipment.

Manufacturer	Model No.	Maximum Penetration Depth (in.)	No. of Shanks	Shank Spacing (in.)	Working Width (ft)	Tractor Horsepower hp	Shank Characteristics				Remarks
							Shank shape	Shank Thickness (in.)	Shank Height (in.)	Vertical Clearance (in.)	
Agristruction Inc.	Big Brute	24	19	18	30	770	Parabolic	1.5	49	10	Each shank is shear bolt protected
	Little Brute	32	7	28	16.5	385	Curved	3.0	48	6	
ATECO	V-RAR-1	60	1	-	4.25	200-400	Straight	1.75-4.5	115	12	Each shank is shear bolt protected with rubber brackets for cushioning against peak loads. Two hydraulic cylinders apply downward pressure to keep shanks in the ground.
	V-RAR-3	32	3	44	8.25	300-370	Straight	1.75-4.5	75	12	
	PR	21	3-5	21 or 42	7	140	Straight	1.75	34.5	13.5	Each shank is shear bolt protected. The unit is designed especially for use with the John Deere 850 crawler tractor.
Bushhog	V-plow	24	3 or 5, 5 or 7, 9 or 11	20 or 30	3.3-16.7	60-175	Curved	1.25	26.5	10.5	The carrier is a V-frame and each shank is shear bolt protected.

Table 4 (Continued)

Manufacturer	Model No.	Maximum Penetration Depth (in.)	No. of Shanks	Shank Spacing (in.)	Working Width (ft)	Tractor Horsepower hp	Shank Characteristics				Remarks
							Shank shape	Shank Thickness (in.)	Shank Height (in.)	Vertical Clearance (in.)	
Carl Kaelble Gmeinder GmbH & Co.	TLG-12	30	3	32	8	105 to 150 hp tractor with 65 - 110 hp auxiliary engine	Straight	1.5	45	15	Vibratory subsoiler with a spring trip center shank and ±3° articulation on outer shank. Power trip off arrangement on encountering total resistance.
DMI Inc.	Colter-tiger	18	7,9 or 11	20 or 30	11.7 - 16.7	200-255	Curved	1.5	38	20	The trailing carrier is a V-frame with each shank having a spring trip or automatic reset protection. Each unit has a hydraulic cylinder for depth control.
	Turbo-tiger	24	5 or 7	30	12.5 - 17.5	200-250	Curved	1.5	38	14	
	Turbo-tiger	20	5 or 9	20	6.7 - 13.3	200-250	Curved	1.25	32	12	
F. W. McConnel Ltd.	Commando Shakaer-ator	24	2-13	27-36	4.1 - 14	175	Curved	1.5	18,24 or 30	4-5	Vibratory subsoiler.

Table 4 (Continued)

Manufacturer	Model No.	Maximum Penetration Depth (in.)	No. of Shanks	Shank Spacing (in.)	Working Width (ft)	Tractor Horsepower hp	Shank Characteristics: Shank shape	Shank Thickness (in.)	Shank Height (in.)	Vertical Clearance (in.)	Remarks
Landoll Manufacturing Company	513V Deep Plow	20	5,7,9, 11 or 13	20,30 or 40	8.3-21.7	100-260	Curved	1.25	30	12	Trailing carrier with surface hardened shanks.
Marvin Landplane Company	620-V	20	3,5, or 7	19 to 40	8-17.3	75-150	Parabolic	1.0	30	10	The trailing carrier is a V-frame and each shank is shear bolt protected. Depth control is accomplished by tractor booster lever or gauge wheels.
	630-V	26	3,5, or 7	30 or 40	8-17.3	200	Parabolic	1.5	36	10	
	640-V	26	7,9 or 13	30 or 40	17.3-22	300	Parabolic	1.5	36	10	
Murray Manufacturing Company	M37	24,30 or 36	3	30,36 or 42	5-7	60-80	Straight	2.0	30,36 or 42	6	Each shank is shear bolt protected and each unit has a manual screw arrangement for depth control.
	M53	24	3-5	20 or 40	5-6.7	80-130	Straight	2.0	30	6	
	M55	24 or 30	3-5	28 or 56	7-9.3	120-200	Straight	2.5	36 or 42	6	
	M55S	30	3	28 or 56	7-9.3		Straight	2.5	36	6	
R & R Agriproducts	Medium Duty Sub-soilers	22	5,7,9	24 or 36	9-18	100-300	Parabolic	1.5	32	10 or 14	Each shank is shear bolt protected or has automatic reset capabilities
	Heavy Duty Sub-soilers	26	7,9 or 11	24 - 120	13.1 - 21	250-450	Parabolic	2.0	36 or 42	10 or 16	
	Extra Heavy Duty Sub-Soilers	32	7,9 or 11	30	17 - 26	250-500	Parabolic	2.0	36 or 42	10	

Table 4 (Continued)

Manufacturer	Model No.	Maximum Penetration Depth (in.)	No. of Shanks	Shank Spacing (in.)	Working Width (ft)	Tractor Horsepower hp	Shank Characteristics				Remarks
							Shank shape	Shank Thickness (in.)	Shank Height (in.)	Vertical Clearance (in.)	
Rome Industries	4TAC-6000	35	3 to 5	30 to 60	14-16	385	Curved	2.5	35	6	Each shank is shear bolt protected.
	4TAC-1100B	34	3 to 5	30 to 80	14-16	385	Straight	2.5	34	6	Each shank has ±15° articulation capability with automatic reset arrangement.
	3TAC-6000A	26	3 to 5	30 to 108	8-18	385	Curved	1.25	26	6	
	11J-154R	26	3 to 5	30 to 108	8-18	385	Curved	1.25	26	6	Each shank is shear bolt protected. Number of shanks and shank spacing can be varied depending on the amount of breakage required.
Towner Manufacturing Company	Sub-soiler	32	3-9	10-30	8-12	90-270	Straight	1.5	32 or 38	8	All subsoilers are mounted directly on the tractor through a three point hitch.

AGRISTRUCTION INC.

Big Brute and Little Brute

I. Manufacturer, Address and Phone Number

Agristruction, Inc.
8135 E. Dinuba Avenue
Selma, CA 93662
Telephone: (209) 896-7500

II. Model Number and Cost

Model Number	Cost	Additional Comments
Big Brute	$72,000	None
Little Brute	$38,000	

III. Equipment Photograph (Figure 18A, 18B)

IV. Equipment Specifications

The Big Brute - It has 19 shanks on 18 in. spacing and is capable of penetrating to a maximum depth of 24 in. The shanks are 1 1/2 in. thick, 49 in. long and a vertical clearance of 10 in. is available when operating at the rated penetration depth. The shanks are parabolic in shape and the equipment permits a maximum working width of 30 ft.

The Little Brute - This unit has 7 shanks mounted on a 16.5 ft. toolbar with 28 in. shank spacing. The shanks are 3 in. thick, 48 in. long and curved. The maximum penetration depth of this model is 32 in. Because of the lesser number of shanks, the maneuverability of the equipment is good and permits operation in tight places.

V. Equipment Operating Details

Big Brute - The carrier is directly connected to the tractor. The initial set up time for this model is one day. The attachment or detachment of the implement to the tractor takes about 90 minutes. The Big Brute is operated with two tractors with horsepower requirements of 770 hp. An ejection ram similar to that on a CAT 641 scraper is used to raise the tool carrier when necessary and also to apply downward pressure during the operation. Each shank is protected with a shear pin. The manufacturer claims a productivity of 160 acres per day with this model.

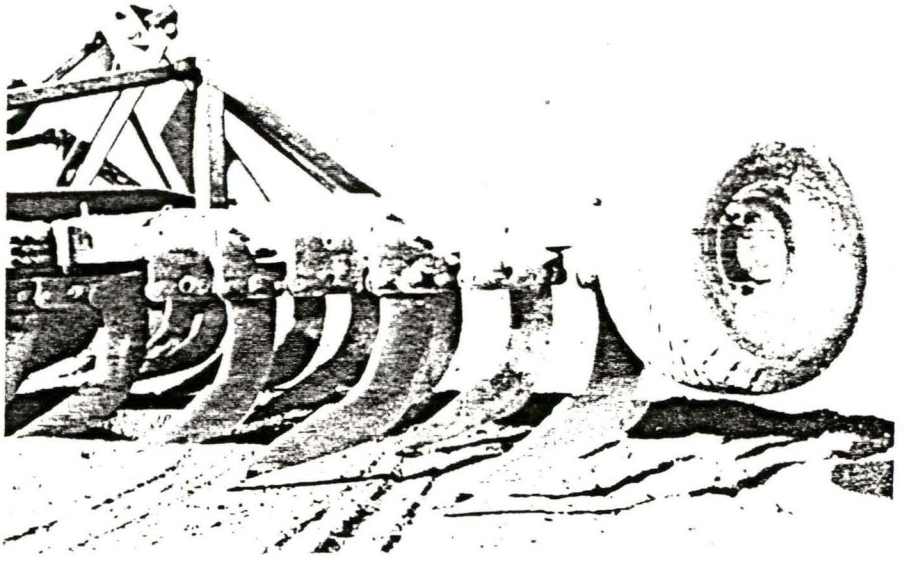


FIGURE 18A: Model "The Big Brute"
(Courtesy Agristruction, Inc.)

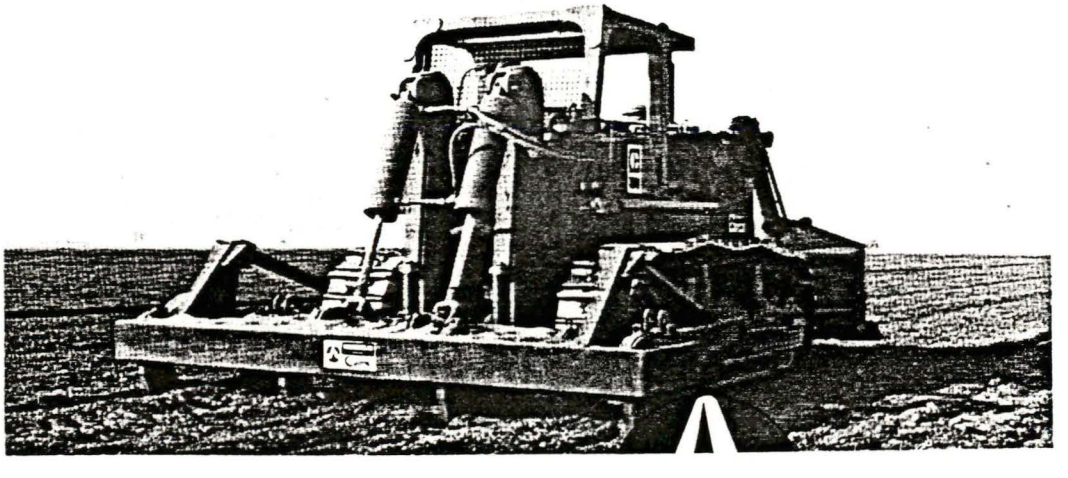


FIGURE 18B: Model "The Little Brute"
(Courtesy Agristruction, Inc.)

The Little Brute - The tool carrier of the Little Brute is directly connected to the tractor. The initial set up time for this model is three hours with one hour required to attach or detach the implement from the tractor. To keep the shanks in the ground, two American Tractor Equipment Corporation (ATECO) 8 in. diameter hydraulic cylinders are used. The shanks do not have any shear bolt protection and the manufacturer feels that the shanks are rugged enough to stand the high draft forces encountered during subsoiling. This model is operated with a single tractor with a horsepower requirement of 385 hp.

VI. Safety Features

The Big Brute -All shanks are shear bolt protected.
The Little Brute -None.

VII. Limitations

The Big Brute - 1. The shear bolts tend to break very often in rocky ground thus lowering productivity.

VIII. Locations of Illinois surface coal mines where equipment is currently in use or planned to be used.

None.

AMERICAN TRACTOR EQUIPMENT CORPORATION (ATECO)

Radial Action Rippers

I. Manufacturer, Address, and Phone Number

American Tractor Equipment Corporation, Inc.
9029 San Leandro Street
Oakland, CA. 94603
Telephone (415) 638-2466

II. Model Number and Cost

Model Number	Cost	Additional Comments
V-RAR-1	$43,000	None
V-RAR-3	$32,710	

III. Equipment Photograph (Figure 19A, 19B)

IV. Equipment Specifications

The Model V-RAR-1 is a heavy duty single shank ripper capable of deeper soil loosening to a maximum depth of 60 in. The toolbar has a 15 in. x 26 in. box section and is made of high strength alloy steel. The straight shanks are made of forged alloy steel and feature replaceable shin plates and points. The shanks are 115 in. long and permit a maximum penetration depth of 60 in. with a 12 in. vertical clearance. The shank bottom portion makes an angle of 28° with the horizontal. The shanks are attached to the toolbar with four 4 1/2 inch hinge pins and each shank is protected with a shear bolt. The shanks also have rubber brackets mounted on the backside. If a shank encounters excessive resistance during subsoiling operations, the bracket acts as a cushion and absorbs shock loads. In returning to its original position, the bracket spring imparts compressive energy to the shank and increases fragmentation. The V-RAR-1 weighs 15,030 lbs. and the power requirements vary from 200 to 400 hp, depending on soil conditions.

The Model V-RAR-3 has the same basic construction except that 1) it features three shanks 2) the toolbar has a 14 in. x 13.5 in. box section, 3) shanks are 75 in. long with a penetration angle of 20.5°, 4) shanks are spaced 44 in. apart and have a maximum penetration depth of 32 in., 5) hydraulic cylinders are 8 1/8 in. x 22 3/8 in., and 6) it weighs 10,760 lbs.

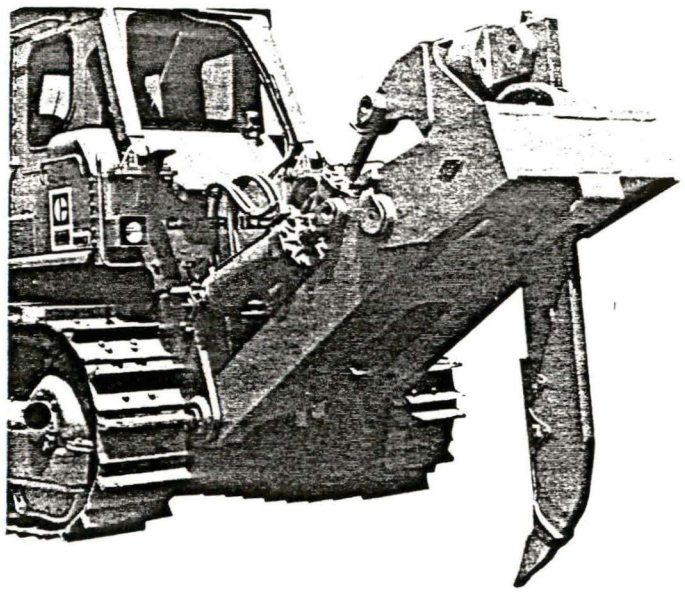


FIGURE 19A: Model "V-RAR-1" Ripper (Courtesy American Tractor Equipment Corporation)

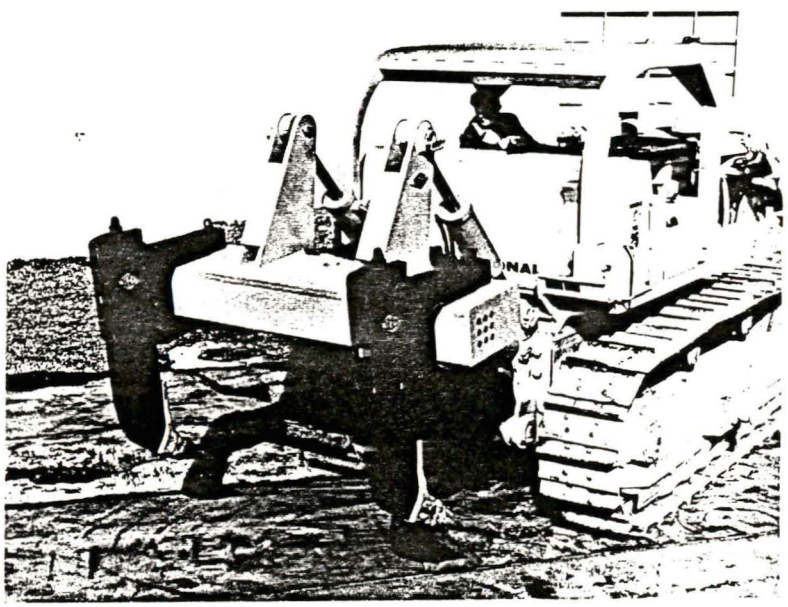


FIGURE 19B: Model "V-RAR-3" Subsoilers (Courtesy American Tractor Equipment Corporation)

The radial action rippers feature a rotatable tool bar to which one, two, or three shanks may be attached. ATECO research has found that the weight of the machine and the angle of penetration of the shank are the two most important factors in subsoiling. The rotation of the toolbar facilitates adjustment of the angle of attack. In addition to the radial action, the shanks themselves can be articulated $\pm$ 15^{o} in the horizontal plane permitting circumvention of large boulders and other obstacles. Most of the radial action rippers provide for shank articulation. However, this arrangement is not standard and fixed shank brackets are available for working in soils with little or no rocks.

The articulation is achieved with two double acting articulating cylinders. There are two more identical cylinders for lifting the tool bar out of the ground. These cylinders can also apply downward pressure on the shanks to keep them in the ground.

V. Equipment Operational Details

The V-RAR-1 and V-RAR-3 ripper models are connected to the tractor through a toolbar carrier. The initial time required to connect and disconnect the ripper to the dozer is about 32 man-hours.

The ripper is initially penetrated into the ground by using the downward pressure from the hydraulic cylinders and weight of the machine. The tractor is generally run at 2/3rd throttle at about 1.2 mph. The widths of the pass for Models V-RAR-1 and V-RAR-3 are 4.25 and 8.25 ft. A loosening productivity of 4.8-9.6 acres per day may be expected. The company recommends a 20 in. wide wing foot on the shank to further improve fragmentation.

The two hydraulic cylinders can generate 200,000-250,000 lbs. of lift force to raise the shanks out of the ground. The subsoiling/ripping depth can be easily varied.

The ripper is well built and the company management felt one could get 2000 hours of maintenance free service per year except for changing the shank guard and shank points. Lubrication is recommended after every 10 hours of use. The shanks are rigidly mounted on the toolbar and except for shear bolt protection for each shank no additional safety features are provided.

VI. Safety Features

1. The four oversized hinge pins connecting the shank to the toolbar are designed to take transient peak loads.
2. The rubber bracket on the rear of each shank acts as as a cushion absorbing shock loads and reducing shank wear.
3. The articulation capability of shanks permits ripping in soils with large amounts of coarse material (rocks).

VII. Limitations

1) Productivity varies from 4.8 to 9.6 acres/day.

VIII. Location of Illinois surface coal mines where equipment is currently in use or planned to be used.

None.

AMERICAN TRACTOR EQUIPMENT CORPORATION

Parallel Action Rippers

I. Manufacturer, Address, and Phone Number

American Tractor Equipment Corporation
9029 San Leandro Street
Oakland, CA 94603
Telephone (415) 638-2466

II. Model Number and Cost

Model Number	Cost	Additional Comments
PR	$10,690	None

III. Equipment Photograph (Figure 19C)

IV. Equipment Specifications

In this class of rippers, the toolbar is rigidly mounted parallel to the ground and can not be rotated. Other equipment specifications are similar to those for radial action rippers.

The Model PR parallel action subsoiler has a 11 3/4 in. x 9 1/2 in. box section toolbar and provides for mounting of 3 or 5 shanks. The shanks are 34.5 in. long and permit a maximum penetration depth of 21 in. The shank spacing is set at 42 in. for 3-shank operation and 21 in. for 5-shank operation. A shank penetrates the ground at an angle of 32°. A single hydraulic cylinder 6 in. x 13 in. provides force to lift the shanks out of the ground. The three shank ripper weighs 3525 lbs. while the five shank ripper weighs 4035 lbs.

V. Equipment Operational Details

Same as for radial action rippers.

VI. Safety Features

Same as for radial action rippers except that the shanks are not articulated.

VII. Limitations

The presence of boulders and obstacles are likely to stall the tractor or damage shanks because there is no shank articulation. Therefore, these rippers are not readily suitable for highly rocky soils.

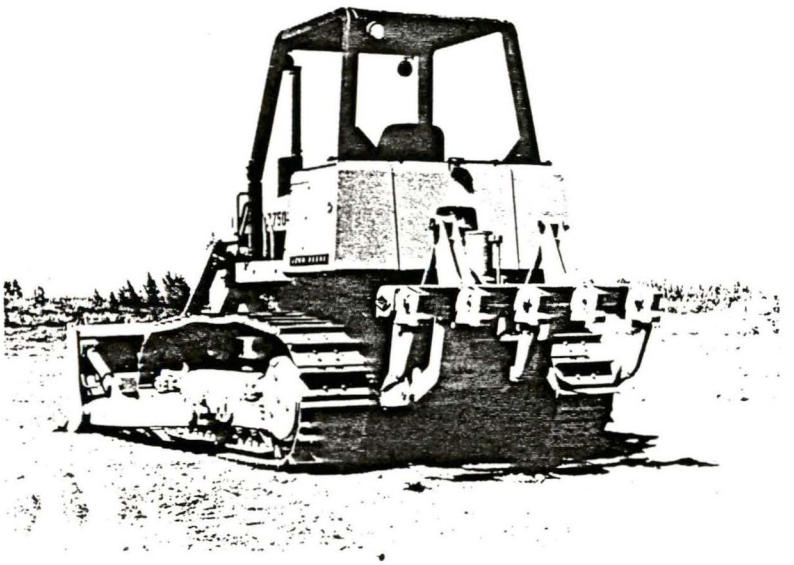


FIGURE 19C: Model "PR" Subsoiler (Courtesy American Tractor Equipment Corporation)

VIII. Location of Illinois surface coal mines where equipment is currently in use or planned to be used.

None.

BUSHHOG, INC.

V-Plows

I. Manufacturer, Address and Phone Number

Bush Hog, Inc.
Junction of Highway 20 and 169
Fort Dodge, Iowa 50501
Telephone (515) 576-1185

II. Model Number and Cost

Model Number	Cost	Additional Comments
170-001 V Plow	$1800	None
170-002 V Plow	$1800	
170-003 V Plow	$3800	
170-004 V Plow	$3800	
170-005 V Plow	$3800	
170-006 V Plow	$3800	

III. Equipment Photograph (Figure 20)

IV. Equipment Specifications

Bushhog V-plow is a static shank chisel/subsoiler capable of soil loosening up to a depth of 24 in. The V-plow manufactured by the company features 3-11 curved shanks on a trailing V-frame. The shanks are made of tough, alloy steel and are 26.5 in. long and 1.25 in. thick. The shanks have replaceable tips.

Depending upon the conditions, the shank spacing can be varied from 20 in. to 30 in. The variable shank spacing option is available only on the 3, 5, or 7 shank models. For models with 9 or 11 shanks, spacing is fixed at 20 in. The horsepower requirement for the V-plows vary from 60 hp to 175 hp depending on the number of shanks. The V-plows have a gauge wheel at either end of the V-frame, which can be adjusted to control the depth of penetration.

V. Equipment Operational Details

The trailing V-frame of the Bushhog plow is made of high strength steel tubing. The unit is connected to a tractor through a 3-point hitch with a quick coupler. The connect and disconnect time of the unit to the tractor is less than 10 minutes. The manual screw arrangement at each end of the frame must be adjusted to a specific penetration depth.



FIGURE 20: Model "V-Plow" Subsoiler (Courtesy Bushhog)

The unit penetrates into the ground due to its own weight. No hydraulic cylinders are provided to lift the unit out of the ground. Colters or choppers may be attached behind the unit to work in conjunction with the V-plow.

VI. Safety Features

1. Each shank is protected with a shear bolt. When excessive resistance is encountered during subsoiling, the shear bolt breaks, and protects the shank from breaking.

VII. Limitations

1. It should not be used in rocky soils.
2. Time is lost whenever a shear bolt fails.

VIII. Locations of Illinois surface coal mines where equipment is currently in use or planned to be used.

This equipment was used on a trial basis at two Consolidation Coal Company mines in southern Illinois. The addresses of these mines are:

Burning Star #2 Mine
Consolidation Coal Company
Duquoin, IL 62832
Telephone 618-357-9211

Burning Star #5 Mine
Consolidation Coal Co.
R.R. #1
Desoto, IL 62924
Telephone 618-987-3211

APPRAISAL OF KAELBLE GMEINDER

TLG-12 Vibratory Subsoiler

I. Manufacturer, Address and Phone Number

Carl Kaelble U. Gmeinder GmbH & Co.
P.O. Box 1260
D-6950 Mosbach
West Germany
Telephone (06261) 4041

II. Model Number and Cost

Model Number	Cost	Additional Comments
TLG-12	$130,000	Includes auxiliary engine but excludes the tractor

III. Equipment Photograph (Figure 21A)

IV. Equipment Specifications

The TLG-12 is a three shank vibratory subsoiler which is used in conjunction with a crawler tractor for deeper soil loosening to a maximum depth of 30 in.

The shank assembly on the subsoiler consists of two shanks (Figure 21A and 21B); a rigid heavy shank "A" at the rear and an oscillating light shank B/C in the front. The oscillation frequency of B/C varies between 40 c/min. to 200 c/ min. The shanks are straight with an inclined foot at the bottom. The foot is inclined at an angle of 25° to the horizontal.

Each rigid shank is 19.7 in. x 6.5 in. in cross section and 45 in. long. They are spaced 32 in. apart on a carrier behind the tractor and permit soil loosening to a depth of 30 in. and a working width of 8 ft. The carrier has a parallelogram guiding system and a hydraulic cylinder for vertical feed so that variable height adjustment of the shanks is possible. This cylinder operates at a pressure of about 2500 psi. The hydraulic cylinder is also used to raise the shanks out of the ground. An automatic depth stop may be installed if desired. A 105-150 hp crawler tractor with an auxiliary engine of 65-110 hp mounted on the tractor front is necessary for operating the TLG-12. It is presently being used with a John Deere 750 tractor and a 60 hp Deutch engine but

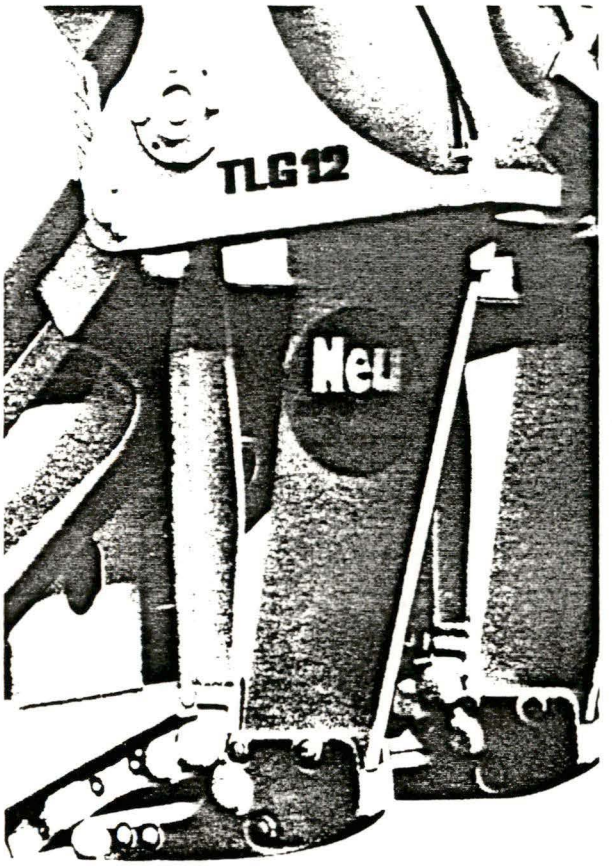


FIGURE 21A: Model "TLG-12" Vibratory Subsoiler
(Courtesy Kaelble Gmeinder Co.)

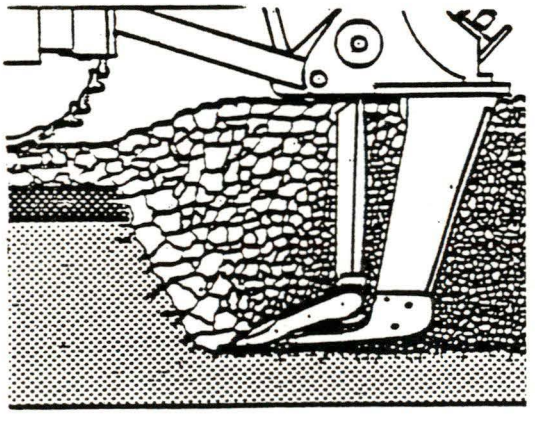


FIGURE 21B: "TLG-12" Shanks

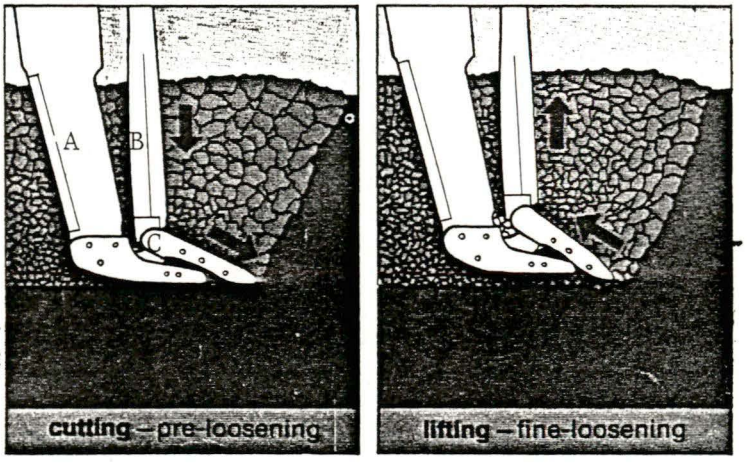


FIGURE 21C: Cutting action of the "TLG-12" shanks

(Courtesy Kaelble Gmeinder Co.)

a 120 hp auxiliary engine is planned in the future. The TLG-12 weighs about 8000 lbs.

V. Equipment Operating Details

The TLG-12 uses the patented "Melioration Technique" (26) to loosen soils. The vertical portion "B" of the oscillating shank is driven by an eccentric cam arrangement which imparts up and down reciprocating motion to "B". Part "B" has a knife-like pointed edge on the front to separate soil layers and distribute them between the shanks as they rise up. The inclined portion "C" of the oscillating shank is connected to the base of "B" by two rocker arms. Therefore as "B" moves up and down, "C" moves forward and backward along an inclined plane. During the downward and forward motion of the oscillating shank, the soil ahead of a shank is fractured coarsely. During the upward and backward motion, the soil is lifted upward causing further fracturing and finer loosening of the soil (Figure 21C). The "C" has a hardened tip at the front which is replaced when its thickness reduces to less than 2 in. due to wear. There are 10 hydraulic seals on each shank i.e. a total of 30 seals on a unit. Operation of the TLG-12 in the field has shown that the hydraulic seals tend to leak. A leakage of 3 liters per day is considered tolerable beyond which seals must be replaced.

Initial penetration of the shanks in the ground is accomplished by applying a portion of the total weight of the tractor on the TLG-12 shanks. After the shanks have penetrated the required depth, the hydraulic cylinder is used to apply downward pressure to keep the shanks in the ground. The hydraulic cylinder is powered by the tractor engine. The auxiliary engine provides the hydraulic drive for the vibration of three shanks. An axial piston engine transfers its power output through a gear to a three fold eccentric shaft which is linked to the shanks by means of blades. The hydraulic drive also provides protection against overloads by means of a pressure limit valve.

The auxiliary engine can also be used to drive any accessories such as rotary tillers which may be used in conjunction with the TLG-12 for simultaneous seedbed preparation. Where excessive brush is encountered, a disc or a chopper may be installed ahead of the shanks. A combination of the TLG-12, rotary tiller and seeder is presently in use at a central IIlinois surface coal mine. The power distribution of the

auxiliary engine is typically 70% to the TLG-12 shanks and 30% to the rotary tiller. If a seeder is also used, it usually requires 10 hp.

Efforts are under way to introduce a twin TLG-12 (two TLG-12s in juxtaposition) with a tractor so that the effective working width can be increased to 16 ft instead of the 8 ft possible with a single TLG-12.

VI. Safety Features

1. The center shank is spring loaded and the spring trips whenever it is overloaded.
2. The hitch arrangement of the TLG-12 to the tractor allows for a $\pm 3^{o}$ articulation of the outer shanks. This comes in handy when big rocks or boulders are encountered.
3. There is a bypass pressure limit valve to protect the roto tiller (when used in conjunction with the TLG-12) from overloading.
4. When the TLG-12 encounters total resistance or when the shanks stop vibrating due to some reason, the tractor loses traction, thus protecting the shank assembly.

VII. Limitations

1. The TLG-12 loses effectiveness when working in wet subsoils.
2. It is inappropriate for use on extremely steep slopes and very stony or rocky grounds.
3. The hydraulic seals on the shank present a maintenance problem.
4. The equipment has difficulty negotiating curves with the shanks in the ground.
5. When the TLG-12 is operated in wet top soils, the soil tends to stick to the shanks and rises up along them, thus filling up the space between the tractor and the TLG and eventually stalling the tractor. Efforts are being made to attach a mudguard type arrangement to the shanks to alleviate this problem.

VIII. Locations of Illinois surface coal mines where equipment is currently in use or planned to be used.

The TLG-12 is currently being demonstrated at the Sunspot mine of AMAX Coal Company. A demonstration may also be planned for the Delta Mine of AMAX Coal Company which is located in southern Illinois.

1. Sunspot Mine
   P.O. Box 336
   Vermont, IL 61484
   Telephone (309)-784-8411

2. Delta Mine
   P.O. Box 336
   Marion, IL 62959
   Telephone (618)-982-2101

DMI INC.

Turbotiger and Coltertiger Subsoilers

I. Manufacturer, Address and Phone Number

DMI Inc.
Route 150 East, Box 65
Goodfield, IL 61742
Telephone: (309) 965-2233

II. Model Number and Cost

Model Number	Cost	Additional Comments
Turbotiger	$16,568	Includes 5 shanks and spring trip arrangement
	$18,486	Includes 5 shanks and spring trip with automatic reset arrangement
Coltertiger	$ 9,868	Includes 7 shanks
	$10,175	Includes 9 shanks

III. Equipment Photograph (Figures 22A, 22B)

IV. Equipment Specifications

The two Turbotiger subsoiler models are variable number shank subsoilers capable of loosening soils to a maximum depth of 24 in. One model utilizes 5 or 7 shanks on 30 in. centers. The shanks are 38 in. long and 1.5 in. thick. The shank tips have replaceable, surface hardened wings attached to them to increase the area of influence of loosening and shattering effect. The second model utilizes 5, 7 or 9 shanks on 20 in. centers and has a maximum penetration depth of 20 in. The shanks are 32 in. long, 10 in. wide and 1.25 in. thick.

Both models have hydraulic cylinders for penetration depth control. The shanks are protected with a spring trip mechanism and with or without an automatic reset arrangement to ride over rocks and other obstacles.

The Coltertiger model has the same basic structure as the Turbotiger except that it uses 7, 9, or 11 shanks. Shanks are 38 in. long, 10 in. wide and 1.5 in. thick and can be put on 20 in. or 30 in. centers. The maximum penetration depth for this model is 18 in. The Colter attachments in front of the shank shown in Figure 22B provide the basis for its name.



FIGURE 22A: Model "Turbotiger" Subsoiler
(Courtesy DMI, Inc.)

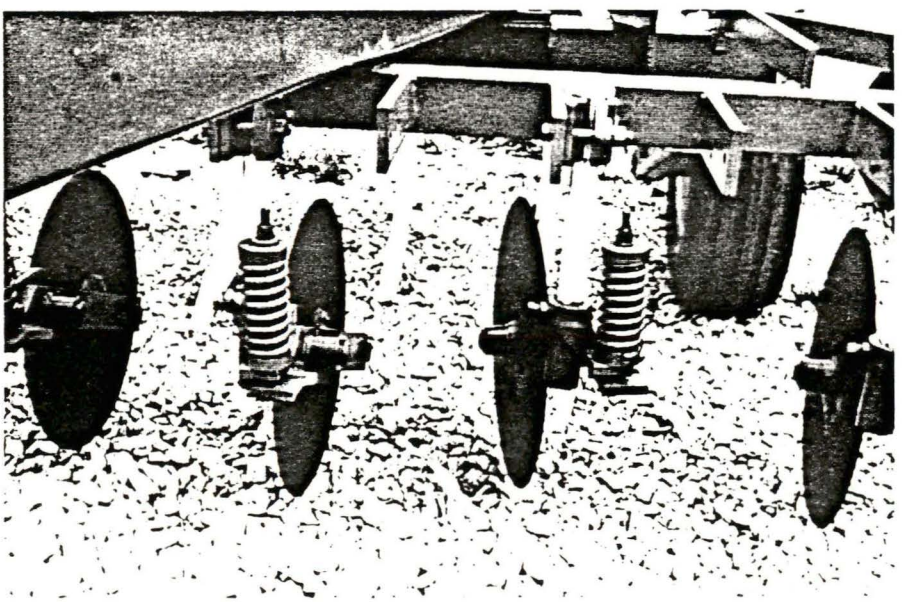


FIGURE 22B: Model "Coltertiger" Subsoiler
(Courtesy DMI, Inc.)

V. Equipment Operating Details

The Turbotiger has a foldable trailing carrier on which the shanks are mounted. It is generally used in conjunction with 24 in. spring loaded disks. Sweep wings may be attached to each shank for wider soil disturbance. The Turbotiger has a hydraulic cylinder equipped with depth stops for depth control. Each shank features either a spring trip with or without automatic reset arrangements.

VI. Safety Features

1. Turbotigers have spring trip with or without automatic reset shank options to protect shanks from being overloaded in rocky soils.
2. For Turbotigers with disk attachment in the rear, there is a hydraulic stress sensing device which enables the disk frame to rise and pass over large obstructions or rock boulders.

VII. Limitations

1. They may not be effectively used in wet soils.
2. The weight of the trailing carrier frame may not be enough to keep the shanks down at the required depth.

VIII. Locations of Illinois surface coal mines where equipment is currently in use or planned to be used.

None.

F. W. MCCONNEL, LTD.

Commando Shakaerator Vibratory Subsoiler

I. Manufacturer, Address and Phone Number:

F. W. McConnel Ltd.
Temeside Works
Ludlow, Shropshire SY8 1JL
England
Telephone: Ludlow 3131 Std. 0584)

II. Model Number and Cost

Model Number	Cost	Additional Comments
Commando Shakaerator	$45,000 (2 shank model) $12,000 (13 shank model)	Cost includes 18 in. shanks, 540 rpm vibratory unit, digging points and depth wheels.

III. Equipment Photograph (Figure 23)

IV. Equipment Specifications

The Commando Shakaerator is a variable shank, vibratory subsoiler capable of soil loosening up to a maximum depth of 24 in. The commando Shakaerator gets its power directly from the tractor power take off (PTO) shaft. The toolbar for the Shakaerator comes in different lengths, depending on the number of shanks being used. The toolbar is 4.1 ft long for 2 shanks, 5.5 ft long for 5 shanks, 8.7 ft long for 7 shanks, 9.9 ft long for 9 shanks, and 14.75 ft long for 13 shanks. The shanks are arranged in a staggered pattern on the toolbar so that they are not all in one vertical plane. Shanks are available in three lengths, 18 in., 24 in., and 30 in. All shanks are 1.5 in. thick and are made of molychrome steel with wear resistant shins and points. The shank spacing varies from 1.2 to 1.5 times the working depth. The shanks are straight with curved bottoms. Either narrow or wide sweep wings may be attached to the shank panels. Depth control is usually through the gauge wheels on the toolbar. The shanks are vibrated through a rotating eccentric shaft arrangement. The frequency of vibration varies from 540 to 1000 c/min.

V. Equipment Operating Details

The Commando Shakaerator has a 3-point hitch arrangement for connection to a tractor and a 3-point linkage kit to attach ancillary devices like disk harrows, power harrows,

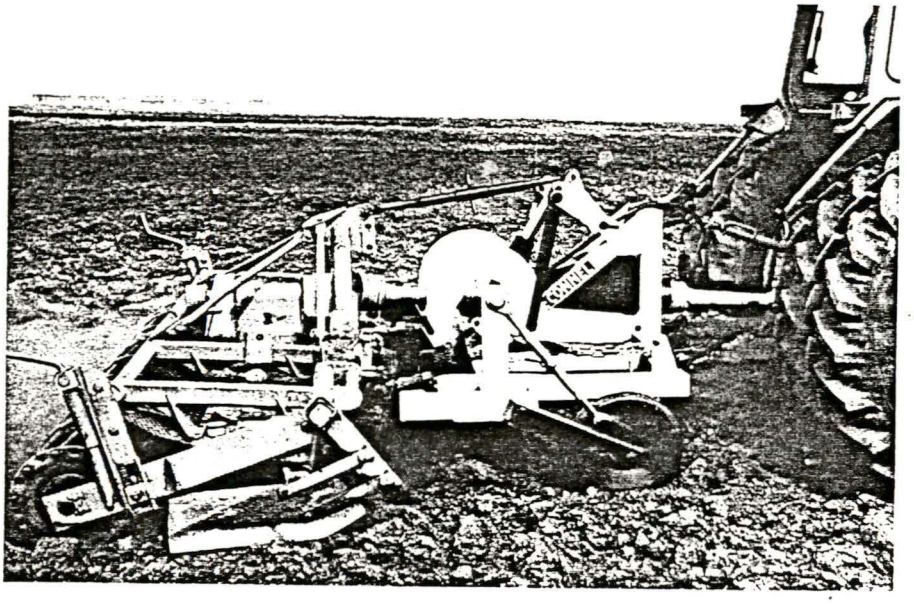


FIGURE 23: Model "Commando Shakaerator" Vibratory Subsoiler
(Courtesy F. W. McConnel Ltd.)

rotary spikes, rotary hoes, and drills while the Shakaerator is subsoiling.

The manufacturer recommends a horsepower requirement of one hp per inch of penetration depth per shank which can be reduced up to 10% depending on the vibration frequency. Operation of the Shakaerator in fields has shown that a productivity of four acres per hour may be attained in reasonable soil conditions working to a depth of 14 in. In heavily compacted soils a productivity of 2 acres per hour may be expected.

VI. Safety Features

1. Each shank is protected by four shear bolts.

2. There is a speed overrun protection on the PTO shaft.

3. When a crumbler roller is used in conjunction with the Shakaerator, the depth control ratchet of the crumbler roller is protected with a shear pin.

VII. Limitations

1. The Shakaerator cannot handle rocky soils where rocks bigger than 12 in. diameter are present. Its performance is significantly reduced by the presence of corals, bedrock and heavy loose trash in the soil being loosened.

VIII. Locations of Illinois surface mines where equipment is currently in use or planned to be used.

None

LANDOLL MANUFACTURING COMPANY

513-V Deep Chisel Plow

I. Manufacturer, Address and Phone Number:

Landoll Manufacturing Company
1700 May Street
Marysville, KA 66508
Telephone: (913) 562-5381

II. Model Number and Cost

Model Number	Cost	Additional Comments
513-V Deep chisel plow (subsoiler)	$5012 7 shanks $4740 5 shanks	Cost includes shanks and 3 point hitch arrangement.

III. Equipment Photograph (Figure 24)

IV. Equipment Specifications

The 513-V deep chisel plow is a static subsoiler mounted on a trailing V-frame capable of soil loosening up to a depth of 20 in. (Figure 24). The trailing carrier for 513-V is available in two basic frames which use 5 in. x 7 in. tubular steel i) 5 or 7 shank unit with 3/8 in. wall thickness or ii) 9 shank unit expandable to 11 or 13 shank units with 1/2 in. wall thickness and a reinforcing tie bar. The 11 and 13 shank models can be folded back for facilitating transport.

The shanks are curved and each shank is 30 in. long, and 1.25 in. thick with 7/8 in. shear bolts on each shank for protection. The shank spacing can be varied from 20 in. to 40 in., depending on the number of shanks. All shanks are hardened on the front face for long wear and have replaceable points of high carbon steel that are 1 in. thick and 2 in. wide.

V. Equipment Operating Details

The trailing carrier for the 5 and 7 shank models features two guage wheels for depth control, one on either side of the carrier. The 9, 11, and 13 shank models have four gauge wheels, two on either side of the carrier.

The trailing carrier has a 3-point hitch arrangement for attachment to the tractor. Two wheel or four wheel drive tractors are recommended for use with the 513-V deep

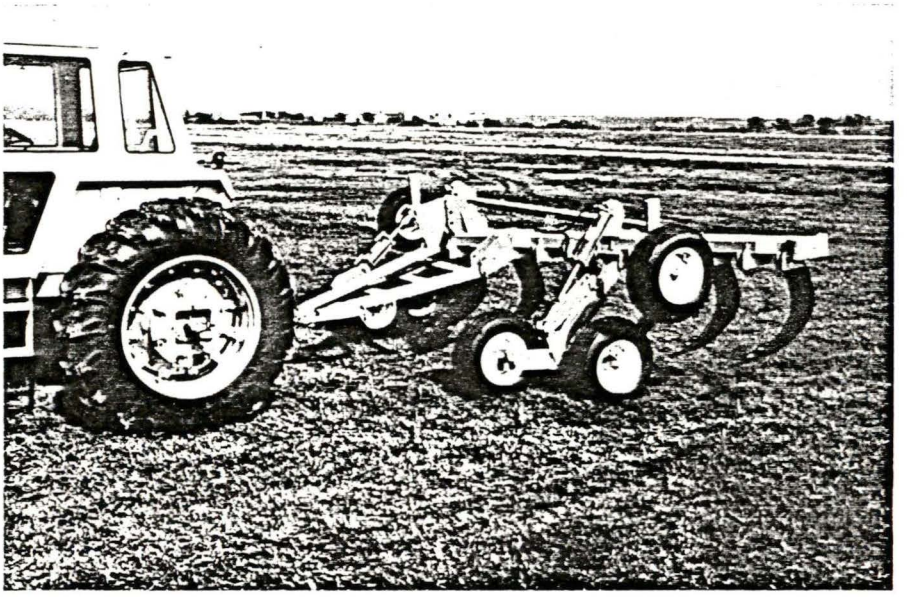


FIGURE 24: Model "513 V Deep Chisel Plow" Subsoiler
(Courtesy Landoll Manufacturing Co.)

plow by the manufacturer. The horsepower requirements vary from 75 to 100 hp for the 5-shank model to 195 to 260 hp for the 13-shank model. The usual speed of operation varies from 3.5 mph to 5 mph depending on soil conditions.

VI. Safety Features

1. Each shank is protected by a 7/8 in. shear bolt.

VII. Limitations

1. This equipment should not be used on rocky soil.

VIII. Locations of Illinois surface coal mines where equipment is currently in use or planned to be used.

None

MARVIN LANDPLANE COMPANY

Subsoilers

I. Manufacturer, Address, and Phone Number:

Marvin Landplane Company
P.O. Box 880
Woodland, CA 95695
Telephone (916) 662-2871

II. Model Number and Cost

Model Number	Cost	Additional Comments
620-V (3 shanks)	$ 5423.00	Cost includes sub-
630-V (5 shanks)	$ 9419.00	soiler, hitch and
640-V (7 shanks)	$13221.00	guage wheels.

III. Equipment Photograph (Figure 25A, 25B, 25C)

IV. Equipment Specifications

Marvin Landplane Company manufactures three models of subsoilers: 620-V, 630-V, and 640-V. All models are static, variable shank, V-bar trailing carrier units. The 620-V subsoiler is capable of loosening soil to a maximum depth of 20 in. whereas 630-V and 640-V subsoilers have a penetration depth capability of 26 in. All models are equipped with an adjustable 3-point hitch arrangement for connecting it to the tractor.

Model 620-V Subsoiler:

The maximum recommended working depth of the 620-V subsoiler is 20 in. This model is available in three toolbar sizes:

1. It has an 8.0 ft toolbar with 3 shanks at 40 in. spacing or 5 shanks at 20 in. spacing. The toolbar is made of 4.5 in. x 8 in. welded box construction in a "V" configuration.

2. It has a 12.4 ft wide toolbar with 5 shanks at 19 in. to 35 in. spacing or 7 shanks at 19 in. to 23 in. spacing. The toolbar is made of 4.5 in. x 8 in. welded box construction in a "V" configuration.

3. It has a 17.3 ft wide toolbar with 7 shanks at 30 in. to 32 in. spacing or 9 shanks at 24 in. spacing or 11 shanks at 19 in. spacing. The toolbar is made of 4.5 in. x 8 in. welded box construction in a "V" configuration. For added strength, this toolbar has a reinforcing tube across the V-frame.

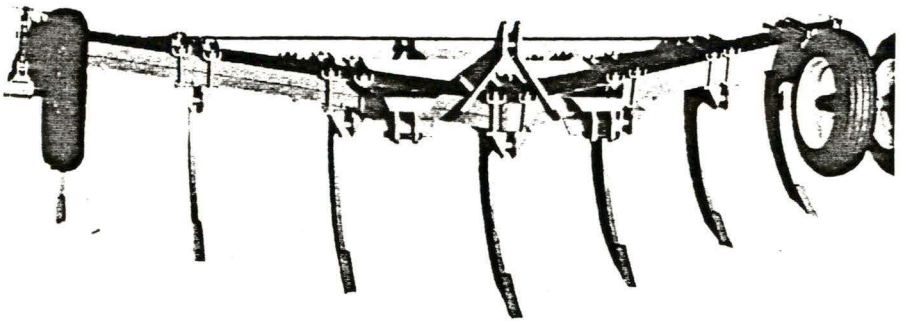


FIGURE 25A: Model 620-V Subsoiler (Courtesy Marvin Landplane Co.)

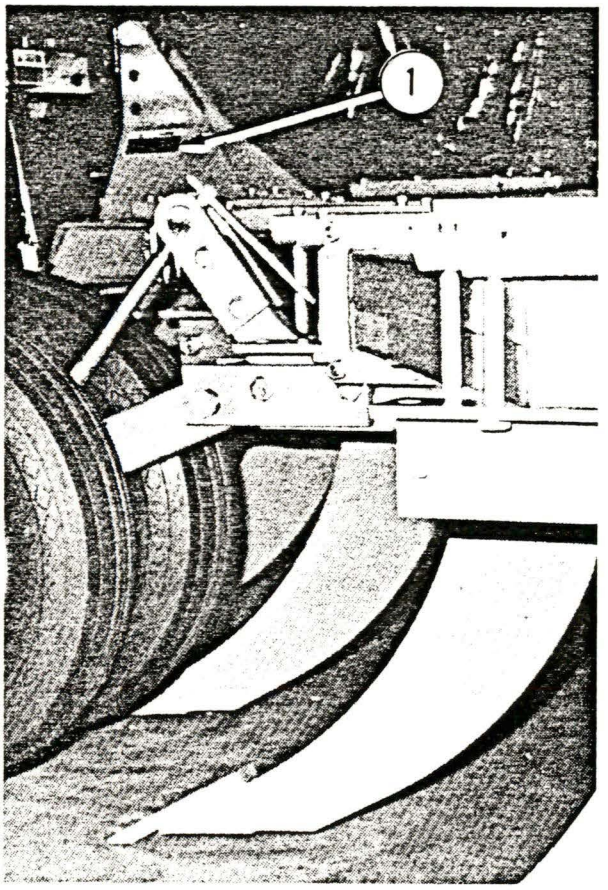


FIGURE 25B: Model 630-V Subsoiler (Courtesy Marvin Landplane Co.)

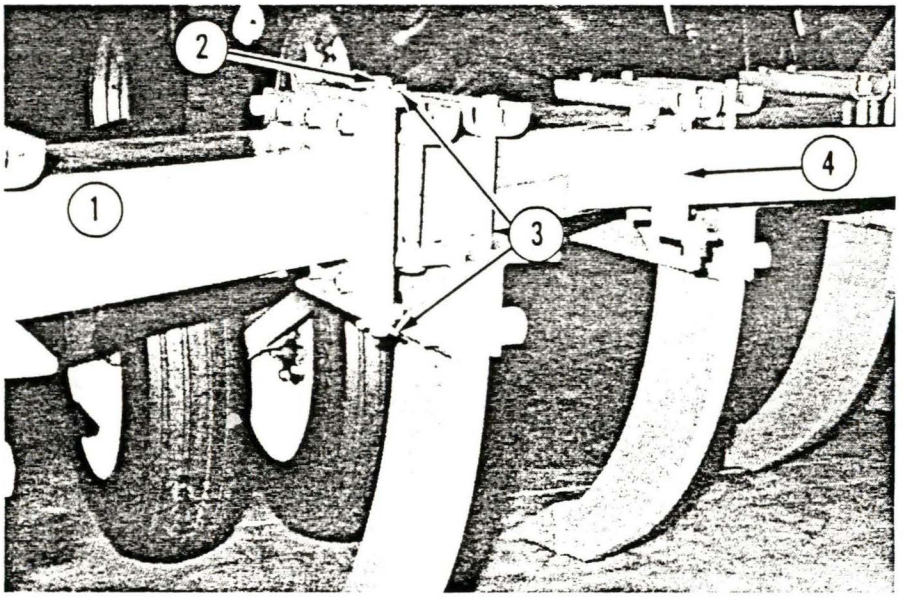


FIGURE 25C: Model 640-V Subsoiler (Courtesy Marvin Landplane Co.)

The shanks on the 620-V subsoiler are made of heat treated steel and are parabolic in shape. They are 30 in. long , 8 5/8 in. wide and 1 in. thick giving a vertical clearance of 10 in. when operating at the rated depth of 20 in. The shank points and shin plates are replaceable and each shank is protected with a special 3/4 in. shear bolt.

The 620-V subsoiler is recommended for use with two wheel type tractors with horsepower ratings of 75 to 150 hp (30 to 35 hp per shank). A tractor speed of 3.5 mph is recommended and this results in a productivity of 3.2 to 9.9 acres per hour, depending on the shank spacing.

The operating depth of the subsoiler can be controlled by the traction booster level or draft control lever on the tractor. If the unit is equipped with gauge wheels, they can be used for depth control.

Model 630-V Subsoiler

The maximum recommended operating depth of 630-V subsoiler is 26 in. This model is available in two sizes of toolbars:

1. The toolbar is 8.0 ft wide and may have 3 shanks at 30 to 40 in. spacing or 5 shanks at 20 in. spacing. The toolbar is made of 6 in. x 12 in. welded box construction in a "V" configuration.

2. The toolbar is 12.4 ft wide and may have 3 shanks at 40 in. spacing or 5 shanks at 30 in. spacing or 7 shanks at 20 in. spacing. The toolbar is made of 6 in. x 12 in. welded box construction in a "V" configuration.

The shanks on the 630-V subsoiler are made of heat treated steel and are parabolic in shape. They are 1.5 in. thick, 10 in. wide and 36 in. long, giving a vertical clearance of 10 in. when operating at the rated depth of 26 in. The shank points and shin plates are replaceable and each shank is protected with a special 1 in. shear bolt.

The 630-V subsoiler is recommended for use with either 2 or 4 wheel drive tractors up to 200 hp (30 to 35 hp per shank). The usual speed of operation is 3.5 mph and productivity ranges from 3.2 to 9.9 acres per hour, depending upon shank spacing.

The Operating depth of the subsoiler can be controlled by the traction booster level or draft control lever on the tractor. Guage wheels are not available with a 3-shank frame.

640-V Subsoiler

The 640-V subsoiler is similar to the 630-V subsoiler with the following exceptions:

1. It is a 7 shank unit and has a 17.3 ft wide toolbar. This unit has 7 shanks on 30 in. spacing or 9 shanks on 20 in. spacing or 5 shanks on 40 in. spacing. It also has a variation of the base model with wing attachments. The 640-V subsoiler with wings provide for 7 shanks at 40 in. spacing or 9 shanks at 30 in. spacing or 13 shanks at 20 in. spacing. The toolbar of the 640-V subsoiler has a reinforcing tube across the V-frame for added strength.
2. The 640-V subsoiler is recommended for use with either 2 or 4 wheel drive tractors up to 300 hp (30 to 35 hp per shank).

V. Equipment Operational Details (for all models)

As a first step in operation, the tractor wheel width must be set narrow enough to keep the tractor wheels within the working width of the subsoiler frame. Weights must be added to the front of the tractor to prevent tractor instability and rear wheel slippage. The sway blocks near the tractor drawbar are set wide apart to allow for required sidewise movement of the trailing frame. The depth control adjustments must also be made.

The productivity with these models varies from 3.2 to 9.9 acres per hour and the horsepower requirements from 75 to 300 hp.

IV. Safety Features

1. All units have a replaceable shank point and guards and each shank is protected with a shear bolt.

VII. Limitations

1. All units are trailing units and hence rocky material or other obstacles in the subsoil can cause stalling of the tractor or the shanks riding out of the soil.

VIII. Locations of Illinois surface coal mines where equipment is curently in use or planned to be used.

None

MURRAY MANUFACTURING COMPANY

Shank Rooter

I. Manufacturer, Address, and Phone Number:

Murray Manufacturing Company
510 River Road
Modesto, CA 95350
Telephone (209) 529-0551

II. Model Number and Cost

Model Number	Cost	Additional Comments
M37	$ 9900	None
M53	$10418	
M55	$11638	
M55s	$16756	

III. Equipment Photograph (Figure 26A, 26B, 26C, 26D)

IV. Equipment Specifications

All Murray shank rooters are static subsoilers on trailing units with solid steel gauge wheels. The shanks are straight with angled bottoms and feature replaceable wear plates and hard surfacing. There are no hydraulic cylinders for applying downward pressure since the weight of the toolbar and shank is considered adequate to keep the shanks in the ground. The shanks are attached in a staggered pattern on the toolbar. A more detailed discussion of engineering specifications for each model follow.

Model M37

This model has 2 in. x 9 in. shanks with lengths 30 in., 36 in., or 42 in. allowing penetration depths of 24 in., 30 in., or 36 in., respectively. The shank spacing is adjustable and can be 30 in., 36 in., or 42 in. This model features a full swivel, steel alloy hitch and a single 6 in. bore hydraulic cylinder. The M37 weighs 4750 lbs.

Model M53

This model has 3 or 5 shanks 30 in. long, 9 in. wide and 2 in. thick. It permits a maximum penetration depth of 24 in. The shank spacing varies 20 to 40 in. depending on the number of shanks. This model features full swivel, steel alloy hitch and a single 6 in. bore hydraulic cylinder. The M53 weighs 4800 lbs.

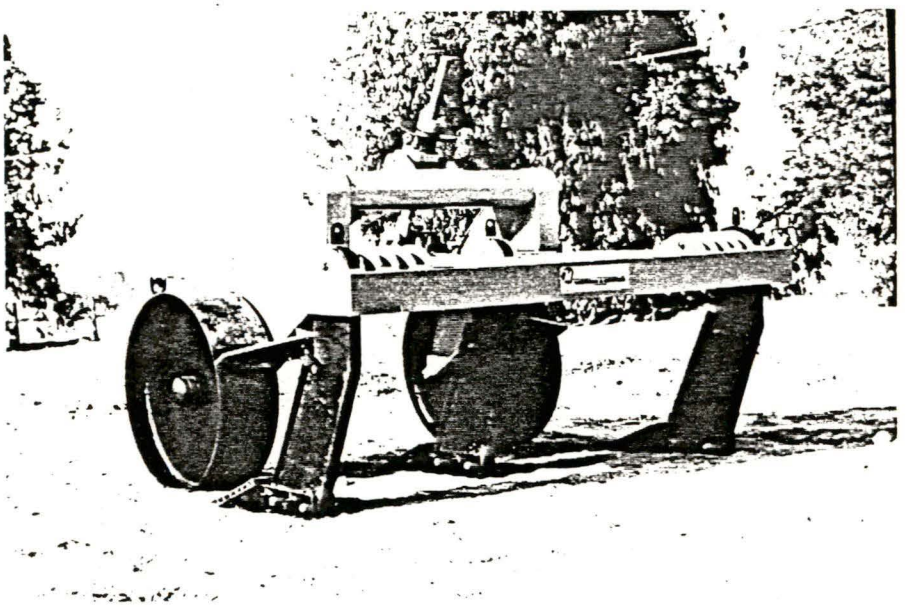


FIGURE 26A: Model "M-37" Shank Rooter (Courtesy Murray Manufacturing Co.)

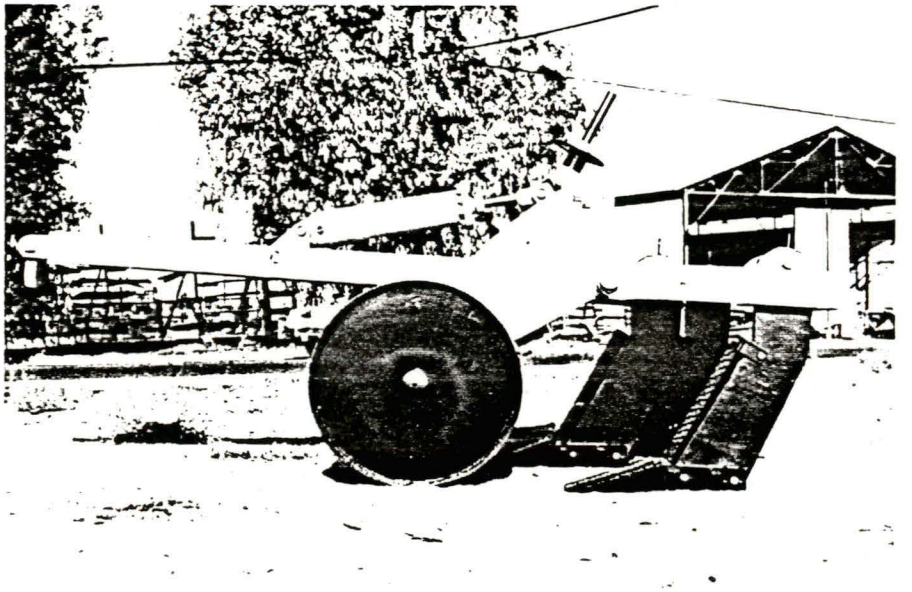


FIGURE 26B: Model "M-53" Shank Rooter (Courtesy Murray Manufacturing Co.)

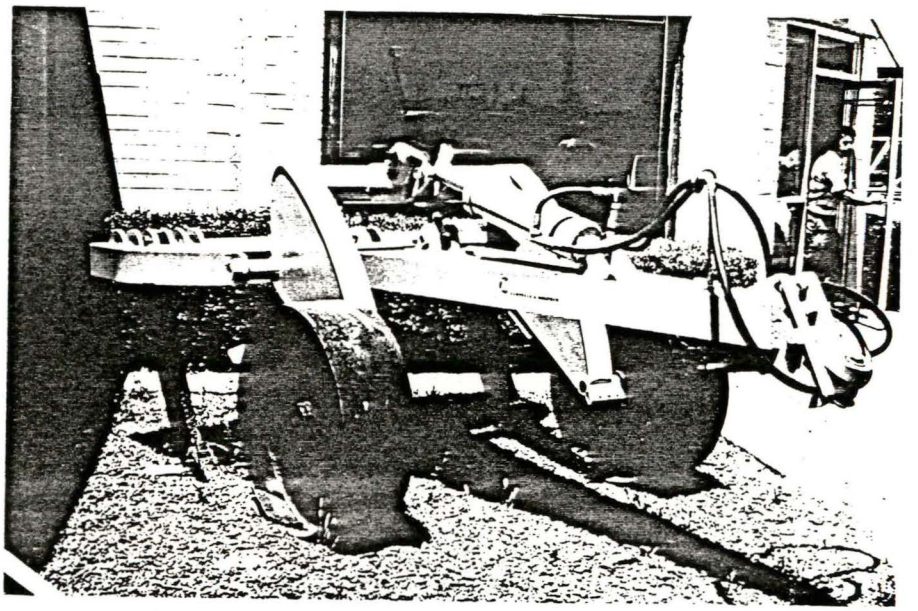


FIGURE 26C: Model "M-55" Shank Rooter (Courtesy Murray Manufacturing Co.)

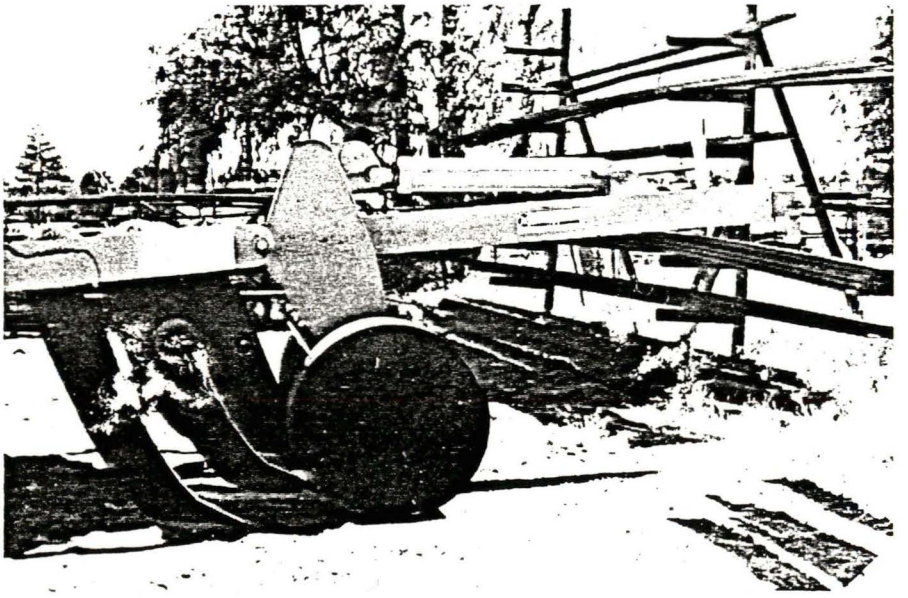


FIGURE 26D: Model "M-55S" Shank Rooter (Courtesy Murray Manufacturing Co.)

Model M55

This model has the same specifications as the M53 except that it has an option to have a shank 36 in. long, 9 in. wide and 2.5 in. thick. The unit weighs 6500 lbs.

Model M55s

This model features 3 or 5 shanks 36 in. long, 9 in. wide and 2.5 in. thick. It allows a maximum penetration depth of 30 in. The shank spacing varies from 28 to 56 in. depending on the number of shanks. This model features a full swivel, steel alloy hitch and a single 6 in. bore hydraulic cylinder. The Model M55s weighs 9000 lbs. The company recommends this model for use in prime farmland reclamation.

V. Equipment Operational Details

All the Murray shank rooters are trailing units and hence their operation consists basically of attaching the trailing rig to the tractor drawbar. There is an adjustment screw on the trailing toolbar which permits depth adjustment. All shanks are shear bolt protected. The horsepower requirements for different models are as follows:

Model	Horsepower
M37	60 to 80 hp
M53	80 to 130 hp
M55	80 to 130 hp
M55s	120 to 200 hp

VI. Safety Features

1. The shanks are rigidly mounted but are protected by shear bolts.

VII. Limitations

1. The trailing carrier weight may not be sufficient to keep the shanks down at rated depth especially when operating at depths greater than 18 in.

2. The solid steel gauge wheels may lead to undesirable compaction because of their weight.

VIII. Locations of Illinois surface coal mines where equipment is currently in use or planned to be used.

The equipment was used on a trial basis at Leahy mine of AMAX Coal Company. The address for the mine is:

Leahy Mine
P.O. Box 165
AMAX Coal Company
Campbell Hill, IL 62916
Telephone: (618) 497-2151

APPRAISAL OF R & R AGRI-PRODUCTS, INC.

Medium Duty Subsoilers

I. Manufacturer, Address, and Phone Number:

R & R Agri-Products, Inc.
Rt. 1, Box 121
Wilbur, Washington 99185
Telephone: (509) 647-5707

II. Model Number and Cost

Model Number	Cost	Additional Comments
R-13 532	$ 9,629	Priced as a complete machine, including shank assemblies standard T-1 points, two wheels with tires, hydraulic system with 4 x 16 in. cylinders, steel depth stops and travel stops. Upgraded machines and options cost extra.
R-13 732	$10,625	
R-16 732	$11,155	
R-16 932	$12,151	

III. Equipment Photograph (Figure 27A)

IV. Equipment Specifications

The R & R "Drawn V" medium duty subsoiler is available in two model widths. Model R-13 is 13.2 ft wide and Model R-16 is 16.9 ft wide. The main frame is constructed of 8 in. x 12 in. x 3/8 in. heavy wall rectangular steel tubing. Tongue and tower assemblies are constructed of 6 in. x 8 in. x 1/8 in. heavy wall steel tubing. The Americal Society of Agricultural Engineering (ASAE) hydraulic cylinders are 2.4 in. x 16 in. with 2 in. heavy duty shafts. All cylinders are provided with depth control and travel stops.

The equipment utilizes original "Stoneville Parabolic Shanks"(30) and units with 5, 7, or 9 shanks are available. All shanks are fabricated from a 1.5 in. thick high strength steel plate. All shanks are shear bolt protected and come with a replaceable shin guard. The shanks are 32 in. high, weigh 220 pound, and provide a working depth of 18 to 22 in.

Each shank has a 22° working angle face permitting easy penetration. The parabolic curve behind the 22° point is designed to lift, roll, and shatter the subsoil. The shank design permits deep penetration in all types of compacted soils. The shanks stay in the ground at the working depth selected. The Stoneville Parabolic Shank

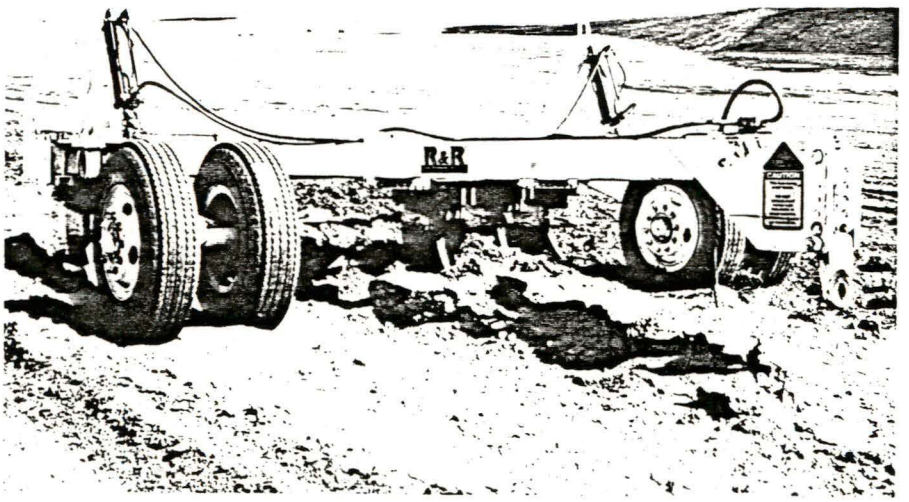


FIGURE 27A: Model "Medium Duty Drawn V Subsoiler" (30)
(R & R Agriproducts)

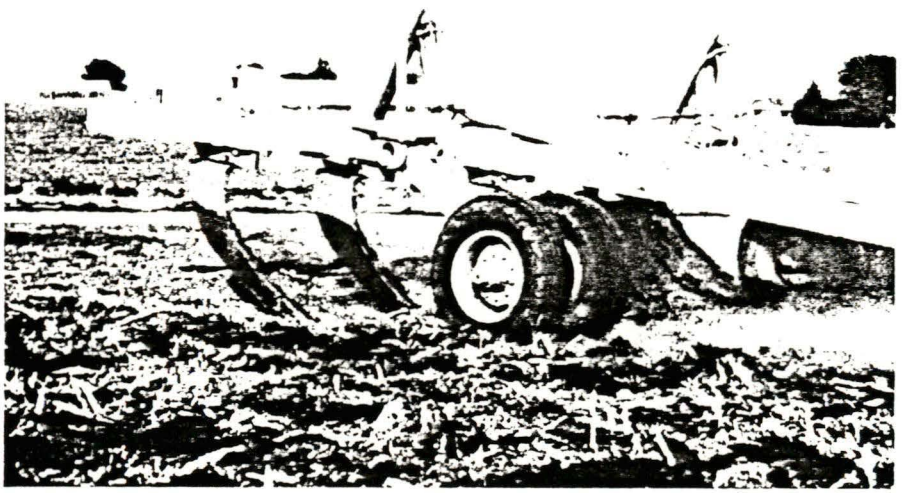


FIGURE 27B: Model "Heavy Duty Drawn V Subsoiler" (30)
(R & R Agriproducts)

design may reduce the draft requirements up to 60% over other conventionally designed shanks. (30).

V. Equipment Operational Details

The subsoiler is attached to the tractor with an adjustable flapper pull piece through a clevis pin. The flapper pull piece permits up to about 18 in. of upward and downward movement. The time to connect and disconnect the subsoiler, including hydraulics, to the dozer is five (5) minutes. Quick disconnect hydraulic couplings are utilized. As the pressure in the hydraulic cylinders is released, the weight of the machine acts on the subsoiler shanks and penetrates them into the ground. The recommended horsepower requirements for the R & R 5-shank subsoilers are:

Medium Duty	-	100 to 300 hp
Heavy Duty	-	200 to 450 hp
Extra Heavy Duty	-	250 to 500 hp

The recommended speed of tractor movement during subsoiling is 4 to 6 mph. Subsoiling experience over a wide range of soil conditions has shown that a productivity of 50 to 150 acres per day may be achieved.

The subsoiler shanks penetrate themselves into the ground due to the weight of the machine and shape of the shanks. The hydraulic cylinders are utilized only to pull the shanks out of the ground. The cylinders operate at a hydraulic pressure of 2000 psi and can exert a total of 78,000 lbs. (two cylinders) of upward thrust. Depth of subsoiling can be varied by adjusting a manually operated screw arrangement connected to the rubber-tired wheels. The vertical clearance at the maximum penetration depth varies 10 to 12 in.

Standard wear points on a shank last 250 to 300 acres per set under average soil conditions. Optional chrome points may last 500 to 5000 acres per set, depending upon abrasiveness and rockiness of the soils encountered.

The manufacturer as well as the mine operator in Wyoming using the machine indicated no vulnerable breakdown points in the machine.

VI. Safety Features

1. Each shank is protected by a shear bolt. A spring loaded resettable trip shank assembly is available as an option. The resettable trip shank assembly significantly reduces down time due to shear bolt failure.

VII. Limitations

1) The shank attachment assembly does not permit any shank movement in the horizontal plane to go around large rock pieces.

VIII. Locations of Illinois surface coal mines where equipment is currently used or planned to be used.

None

R & R AGRI-PRODUCTS INC.

Heavy Duty Subsoilers

I. Manufactuer, Address, and Phone Number:

R & R Agri-Products, Inc.
Rt. 1. Box 121
Wilbur, Washington, 99185
Telephone: (509) 647-5707

II. Model Number and Cost

Model No.	Cost	Additional Comments
R-13	$10,991	The prices are for the frame without attachments or options.
R-18 H	$11,675	It includes wheels and tires, hydraulic system with 4 in. x
R-17	$11,134	16 in. cylinders, steel depth stops, and travel stops. Up-
R-21 H	$11,762	graded machines and options cost extra. The attachment costs are given below.

Attachment Item	Cost
36 in. Shank Assembly	$521 each
36 in. Resettable Trip Shank Assembly	$968
42 in. Shank Assembly	$612 each
42 in. Resettable Trip Shank Assembly	$1034
Standard Shank-Point (T-1) Steel	$ 41 each
R & H Chrome Point	$ 93 each

III. Equipment Photograph (Fig. 27B).

IV. Equipment Specifications

The R & R "Drawn V" heavy duty subsoilers are available in standard widths of 13.2 ft and 17.0 ft. Hinged extension assemblies provide for increased widths to 18 ft or 21 ft which can be folded to provide transport widths of 13.2 ft and 17.0 ft respectively. The main frame is constructed of 12 in. x 8 in. x 3/8 in. heavywall rectangular tubing. Tongue and tower assemblies are 8 in x 6 in. x 3/8 in. heavy steel tubing. The ASAE hydraulic cylinders, 4 in. x 16 in. with 2 in. diameter heavy duty shaft are standard with 36 in. shank machines. All cylinders have steel depth control and aluminum travel stops. Heavy duty cylinders, 5 in. x

16 in. with 2 in. diameter shaft, are optional with 42 in. shanks.

The equipment utilizes "The Stoneville" parabolic shanks 36 in. or 42 in. long. The shank design is similar to that mentioned earlier. A 36 in. shank is standard and provides for 18 in. to 26 in. working depth. A 42 in. shank provides for additional trash clearance with working depth of 18 in. to 26 in. Shanks are fabricated from a 2 in. thick high strength steel plate and are protected with a replaceable shin guard. Self sharpening (which sharpen points as shank moves through soil) slip on T-1 points at the ends of shank are standard. Optional chrome alloy points provide up to 5 to 10 times the wear of standard T-1 points and reduce draft requirements but are not recommended under rocky conditions. Spring steel sweep shank assembly is optional for adjustable shallow tillage between shanks. The sweep shanks are made of 1.25 in. x 2 in. x 32 in. spring steel.

Resettalbe trip shank assembly is an available option. Adjustable spring loaded, cam operated trip shanks provide protection for shank and shank brackets. The shanks may be rotated fully back to reset. It eliminates shear bolt replacement and downtime.

The equipment is mounted on a 42,000 lb. split axle assembly. Special highway 11 - 22.5 tubeless recap tires with rib implement tread are utilized.

A standard 13.2 ft wide machine with seven (7) 36 in. shanks weighs approximately 10,000 lbs. The estimated horsepower requirements are 60 hp per shank.

The company can also manufacture on a custom order basis, models R-26H and R-31H capable of providing working widths of 26 ft and 31 ft respectively.

V. Equipment Operational Details

Same as the Medium Duty Drawn Subsoiler.

VI. Safety Features

Same as for Medium Duty Subsoilers.

VII. Limitations

Same as for Medium Duty Subsoilers.

VIII. Locations of Illinois surface coal mines where equipment is currently used or planned to be used.

None

Experience with a R & R Heavy Duty Drawn Subsoiler in a Wyoming Surface Coal Mine

The Subsoiler used is a 5 shank unit. It is attached to a 320 hp rubber tired dozer and is used to rip to a depth of 32" in. The unit did not have the optional resettable trip shank assembly when purchased initially, and considerable time was lost in replacing shear bolts. With the resettable trip shank assembly installed, the downtime has been significantly reduced. The mine operator expressed satisfaction with the performance of the machine.

The depth of penetration can be easily controlled by two hydraulic cylinders attached to gauge wheels. The unit does penetrate by itself, due to the weight of the machine, as pressure is released in hydraulic cylinders. The shanks are hard faced and facing needs to be replaced quite frequently depending upon the abrasiveness of the soil.

Soils are high in clay content (70%) and highly bentonitic. The texture of the soil, however, is very coarse unlike Illinois soil. The soils are relatively dry because the total rainfall is only 12 to 15 in. annually.

In addition to deep soil loosening, the mine also utilizes 30 in. disc harrows to prepare a seed bed prior to revegetation. Mining is not being done on prime agricultural lands and revegetation primarily consists of native grasses.

R & R AGRI-PRODUCTS, INC.

Extra Heavy Duty Subsoiler

I. Manufacturer, Address, and Phone Number

R & R Agri-Products, Inc.
Rt. 1, Box 121
Wilbur, Washington 99185
Telephone: (509) 647-5707

II. Model Number and Cost

Model No.	Cost	Additional Comments
R-13	$13,491	Prices effective April 15, 1981.
R-18H	$14,175	The prices are quoted as for
R-17	$14,134	heavy duty subsoilers.
R-21H	$15,262	
R-26H	$15,762	

III. Equipment Photograph (Not Available)

IV. Equipment Specifications

The standard extra-heavy duty subsoiler utilizes a reinforced 17 ft center section with 7 shanks on 30 in. spacing (Model R-17). This section can be expanded to widths of 21 ft with 9 shanks on 30 in. or 26 ft for 11 shanks on 30 in. spacing (R-21H or R-26H). A modified 13 ft wide model (R-13) with 7 shanks on 24 in. is also available where narrow travel width or 24 in. shank spacing is desirable. The modified model can be expanded to 18 ft with 9 shanks on 24 in. (R-18H).

The main frame is constructed of 12 in. x 8 in. x 1/2 in. heavy wall rectangular tubing on the main frame with a 6 in. x 6 in. x 3/8 in. rear spreader bar. The tongue assembly is 8 in. x 6 in. x 1/2 in. heavy wall steel tubing. All cylinder mounting brackets feature hardened bushings for reduced wear. Hydraulic cylinder specifications are similar to those on the heavy duty subsoiler. The frame will withstand 100 hp or 8000 lbs. of drawbar pull per shank.

The subsoiler is designed to be pulled behind a large crawler or wheel tractor up to 650 hp. A minimum of 250 hp is required. Smaller tractors may be used by incorporating less number of shanks.

A standard R-21 subsoiler with seven 36 in. shanks weighs 11,400 lbs. Most of the remaining specifications are similar to those for the heavy duty subsoiler.

V. Equipment Operational Details

Same as the Medium Duty Drawn Subsoiler.

VI. Safety Features

Same as for Medium Duty Subsoilers.

VII. Limitations

Same as for Medium Duty Subsoilers.

VIII. Locations of Illinois surface coal mines where equipment is currently used or planned to be used.

None

ROME INDUSTRIES

Subsoilers

I. Manufacturer, Address, and Phone Number:

ROME Industries
P.O. Box 48
Cedartown, GA 30125
Telephone: (404) 748-4450

II. Model Number and Cost

Model Number	Cost	Additional Comments
4TAC 6000	$8115	Cost includes 3 shanks and 14 ft toolbar only.
4TAC 1100B	$3750	A 16 ft toolbar is available for $1010 extra
3TAC 6000A	$6810	and sweep wing attachments cost $600 each.
11J-154R	$3015	

III. Equipment Photograph (Figure 28A, 28B, 28C)

IV. Equipment Specifications

Rome Industries manufactures toolbar and subsoiler attachments for use with Caterpillar tractors. The draft member and clamp assemblies are standard on all subsoilers and inlcude, trunnion and cylinder mounts attached to the tractor track frame. The draft arms are attached to trunnions and lift cylinders are connected between mounts and draft arms to raise and lower the toolbar. Two sizes of toolbars are manufactured; one is a 6 in. x 9 in. section toolbar which comes in lengths of 14 ft and 16 ft. This toolbar is of 1 in. thick welded steel construction. A high strength 6 in. x 9 in. toolbar in lengths of 14 ft and 16 ft is also available.

The following shanks may be mounted on a 6 in. x 9 in. toolbar.

1) Model 4TAC-6000 is 2 1/2 in. x 10 in. in cross section with a maximum penetration depth of 35 in. The shanks are curved and the suboilers are equipped with a wear resistant point, ± 15° articulation capability and an automatic reset shear bar. Each shank weighs 1035 lbs.

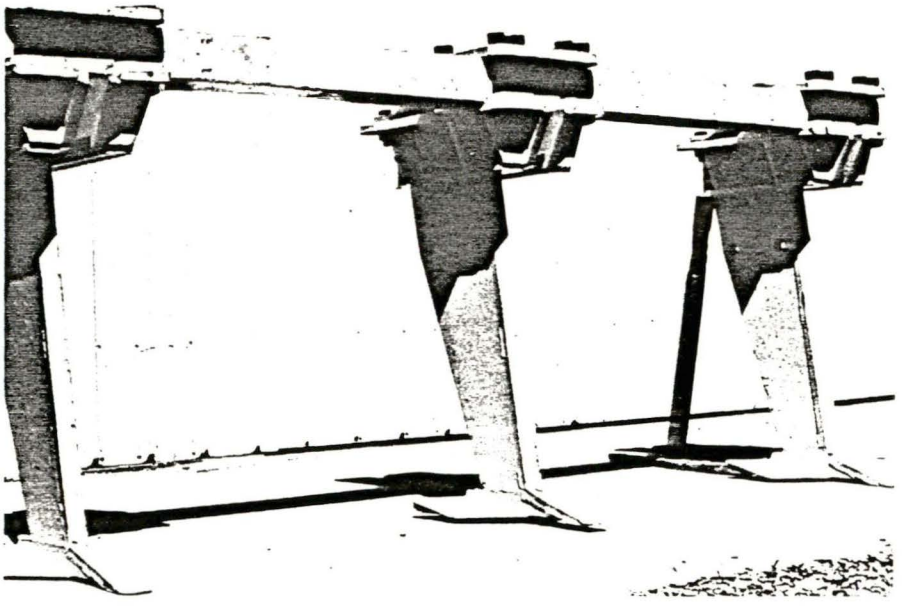


FIGURE 28A: A subsoiler with a 4½ in. x 7½ in. toolbar (Courtesy Rome Industries)

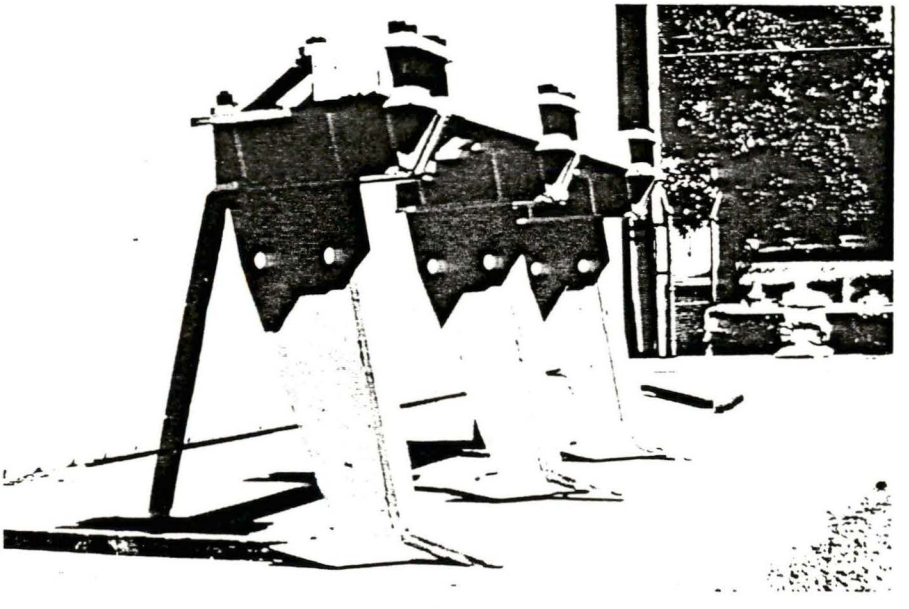


FIGURE 28B: A subsoiler with a 6 in. x 9 in. toolbar (Courtesy Rome Industries)

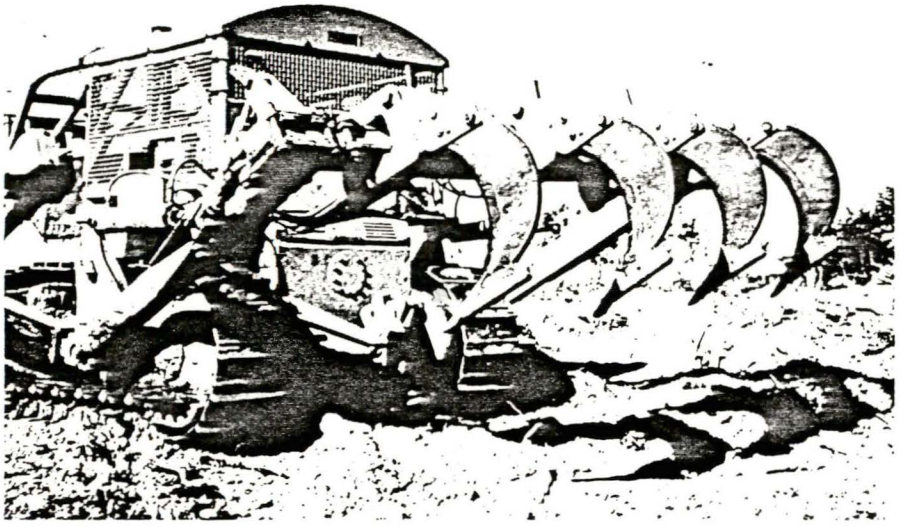


FIGURE 28C: A curved shank subsoiler
(Courtesy Rome Industries)

2) Model 4TAC-1100B curved shanks are 2 1/2 in. x 10 in. in cross section with a maximum penetration depth of 34 in. The shanks are equipped with replaceable wear points and are rigidly mounted on the toolbar.

For both models above, the shanks can be located in the form of a "V" on the toolbar. Wings are optional. The 11J-588R shanks weigh 320 lbs. each, 11J-589R shanks weigh 430 lbs. each, and 11J-590R shanks weigh 500 lbs. each.

The 4 1/2 in. x 7 1/2 in. section toolbar is of welded steel construction and is available in 8 ft, 10 ft, 12 ft, 14 ft, and 18 ft lengths. High strength steel toolbars in 12 ft and 14 ft lengths are also available.

The following shanks may be mounted on the 4 1/2 in. x 7 1/2 in. toolbar:

1) Model 3TAC-6000A is 1 1/4 in. x 10 in. in cross section and has a maximum penetration depth of 26 in. The shanks are curved and are equipped with a wear resistant point, ±15° articulation arrangement and automatic shear reset bar arrangement. Each 3TAC-6000A shank weighs 660 lbs.

2) Model 11J-154R is 1 1/4 in. x 10 in. in cross section with a maximum penetration depth of 26 in. The shanks are curved and equipped with a wear resistant point and a fixed bracket arrangement. Each 11J-154R shank weighs 305 lbs.

For both models above, 18 in. wings are optional.

V. Equipment Operating Details

All Rome subsoilers are directly mounted on the tractor. A 6 in. x 9 in. subsoiler toolbar is generally mounted on Caterpillar D7 or D8 size tractors. Subsoilers with a 4 1/2 in. x 7 1/2 in. toolbar are generally mounted on Caterpillar D5 or D6 size tractors. The mechanical availability of the units averages 75%. The ± 15° articulation permits operation around curves at the end of a straight pass with shanks in the ground. The speed of operation is 2 mph, which results in a productivity of about 2 acres per hour.

Rome Industries manufactures 50 in. penetration depth subsoilers on special order. They also manufacture large diameter (36 in.) disk harrows.

VI. Safety Features

1. The ± 15° articulation permits going around boulders without damage to the shank.

2. For rigidly mounted shanks, each shank is protected with a shear bolt.

3. The automatic reset shear bar protects shank assembly and reduces downtime.

VII. Limitations

1. In rocky soils use of fixed clamp for shank mounts results in lost time when a shear bolt breaks.

VIII. Location of Illinois surface coal mines where equipment is currently in use or planned to be used.

None

TOWNER MANUFACTURING COMPANY

Subsoilers

I. Manufacturer, Address, and Phone Number

Towner Manufacturing Company
2111 West 17th Street
Santa Ana, CA 92706
Telephone: (714) 542-6767

II. Model Number and Cost

Model Number	Cost	Additional Comments
Subsoiler	$11,500	7 in. x 9 in. toolbar, 3-point hitch, 5 shanks, 24 in. penetration depth
Subsoiler	$12,500	7 in. x 9 in. x 1 in. toolbar, 3-point hitch, 5 shanks, 28 in. penetration depth
Subsoiler	$18,500	7 in. x 9 in. x 1 in. toolbar with carrier, 5 shanks, 32 in. penetration depth

The company does not have model numbers for subsoilers. They have model numbers for different parts.

The above costs are based on quotes from the company on July 14, 1983.

III. Equipment Photograph (Figure 29A, 29B)

A 3-shank subsoiler mounted on a tool carrier and capable of penetrating to a depth of 24 in. is shown in these figures.

IV. Equipment Specifications

All Towner subsoilers are static with straight shanks and are directly attached to a track mounted dozer through a carrier for heavy duty subsoiling. Towner subsoilers are available in 8 ft , 10 ft , or 12 ft width tool bars. A tool bar may be 4 1/2 in. x 7 1/2 in. x 3/4 in. or 7 in. x 9 in. x 1 in. in size. The tool bars are sometimes braced at intervals. The company indicated that they recommended 7 in. x 9 in. tool bar with Caterpillar dozers while 4 1/2 in. x 7 1/2 in. tool bars are common with Komatsu and John Deere tractors.

The subsoiler shanks are straight 1 in. thick with penetration depth capabilities of 24 in., 26 in., 28 in., and 32 in.



FIGURE 29A: A subsoiler with a three-point hitch
(Courtesy Towner Manufacturing Co.)

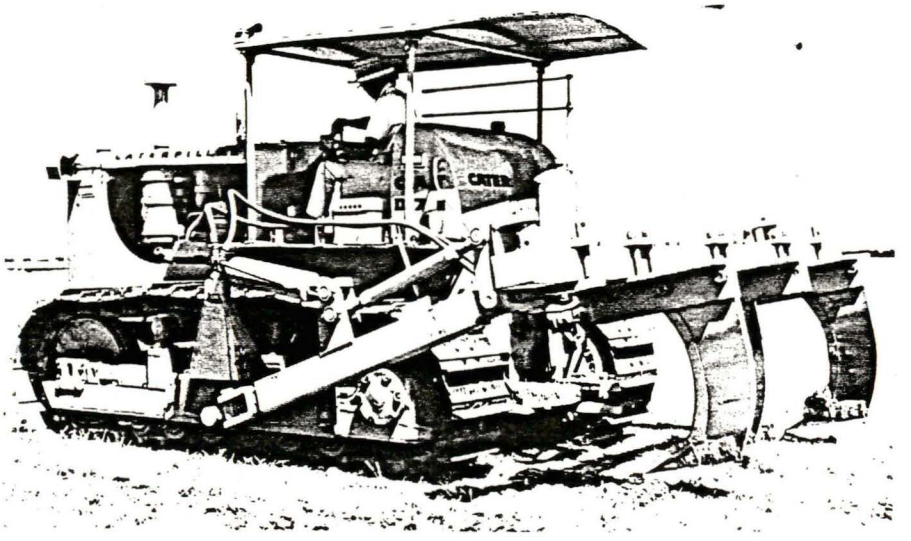


FIGURE 29B: A subsoiler with a tool bar carrier
(Courtesy Towner Manufacturing Co.)

Diagrams of heavy duty, 24 in. penetration depth shanks are shown in Figure 29C. The shanks are constructed of C-10-45 carbon steel. The shanks have 2 in. thick protection plates to prevent damage to the shanks. The height of the shanks is not adjustable. The shanks have reversible replacement points and wear shins. The shanks also provide for attachment of crowder wings although they are not commonly used in subsoiling. The subsoiler design provides for 8 in. clearance between the shank at maximum penetration and bottom of the toolbar.

A line diagram of the quick disconnect 3-point hitch is shown in Figure 29D. It has two hydraulic cylinders operated by the hydraulic system of the dozer to raise or lower the unit. The hydraulic cylinders have a relief valve to prevent excessive down pressure and tilting of the dozer. Two screw adjustments as shown in the diagram provide for proper lateral leveling. A topline screw is provided to vary the tilt. Instead of the 3-point hitch described above, other standard hitches may sometimes used with 4 1/2 in. x 7 1/2 in. or a 7 in. x 9 in. toolbar.

A toolbar carrier shown in Figure 29E may be used instead of a 3-point or A-frame hitch. The toolbar carrier is also provided with a hydraulic system to apply a downward thrust.

V. Equipment Operational Details

The subsoiler is connected to the dozer through a 3-point hitch or a toolbar carrier as discussed earlier. The manufacturer does not recommend using a 3-point hitch for tractor sizes over 200 hp. An estimate of the time required to connect and disconnect a subsoiler to a tractor through a 3-point hitch is 10 minutes, while it is four hours through a toolbar carrier.

A speed of 3.0 to 3.5 mph is recommended during subsoiling operations which results in a productivity of about 25 acres per shift. A 2000 psi pressure is recommended for hydraulic cylinders with a 5 in. diameter piston or a 1200 psi pressure for a 6 in. diameter piston.

Replaceable slip on wear points on the subsoiler shanks need replacement after 300 to 5000 acres, depending upon soil conditions and rockiness of the soil. Spreader wings or sweeps are not commonly used. In California, a common practice is to disc to a depth of 12 in. after deeper soil loosening.

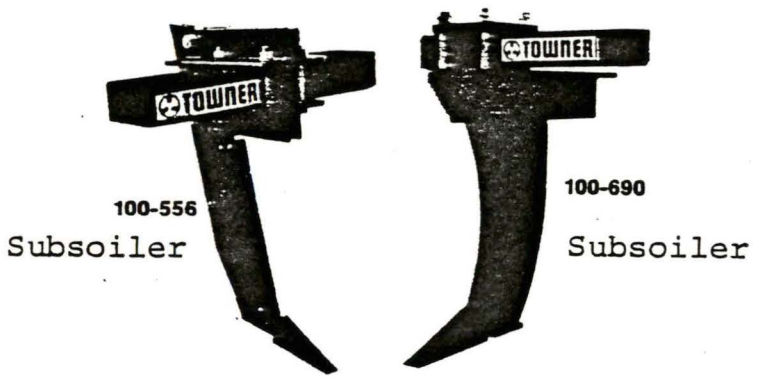
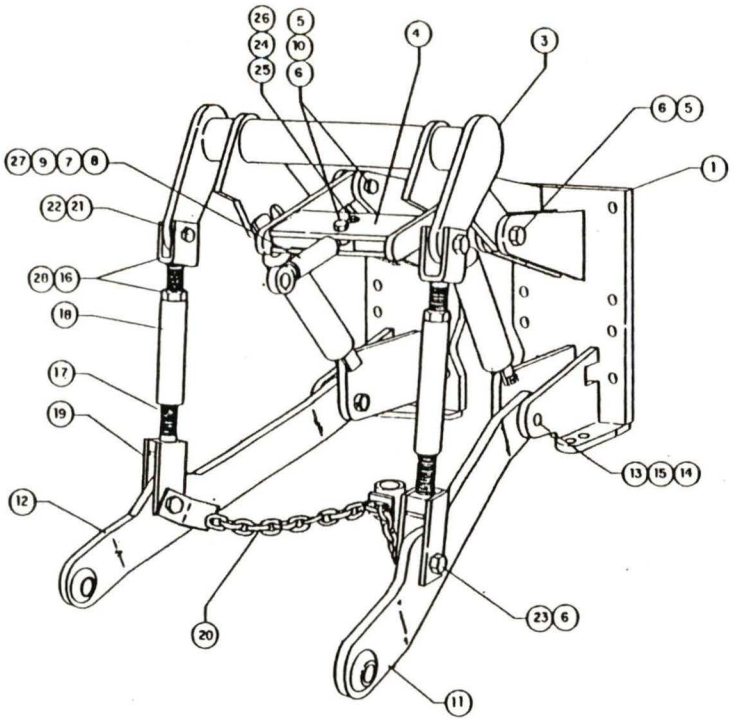
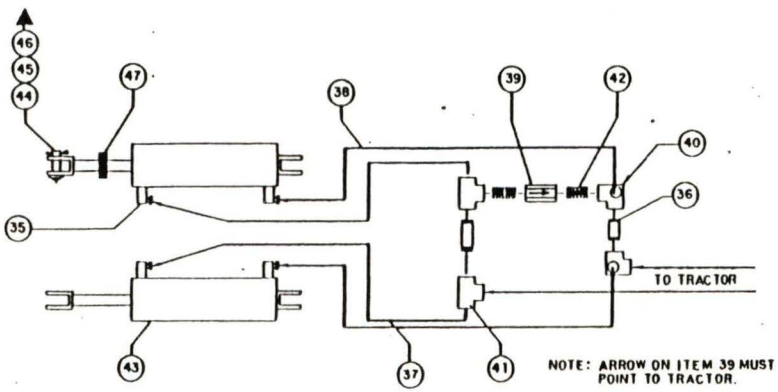


FIGURE 29C: Heavy duty subsoiler shanks
(Courtesy Towner Manufacturing Co.)





ITEM	DESCRIPTION	PART NUMBER	100 962	100 963
1	MOUNTING BRACKET L.H.	72527	1	
	MOUNTING BRACKET L.H.	72516		1
2	MOUNTING BRACKET R.H.	72521	1	
	MOUNTING BRACKET R.H.	72517		1
3	LIFT FRAME	72506	1	1
4	UPPER LINK	72508	1	1
5	BOLT 1 x 3-1/2 NC Gr5	13716-28	5	5
6	LOCKNUT 1in. NC	22553	7	7
7	TURNBUCKLE	71957	1	1
8	SCREW CLEVIS R.H.	71958	1	1
9	SCREW CLEVIS L.H.	71959	1	1
10	BUSHING	28767	1	1
11	DRAFT LINK R.H.	72518	1	1
12	DRAFT LINK L.H.	72519	1	1
13	PIN	28749	2	2
14	BOLT 5/8 x 2-1/2 NC	10706-20	2	2
15	LOCKNUT 5/8in. NC	36552	2	2
16	SCREW CLEVIS R.H.	71962	2	2
17	SCREW CLEVIS L.H.	71963	2	2
18	TURNBUCKLE	71964	2	2
19	CLEVIS	71961	2	2
20	SWAY CHAIN	72523	1	
	SWAY CHAIN	72526		1
21	BOLT 1-1/8 x 4-1/2 NC Gr5	13718-56	2	2
22	LOCKNUT 1-1/8in NC	22509	2	2
23	BOLT 1 x 5 NC Gr5	13716-40	2	2
24	BOLT 3/4 x 3-1/2 NC Gr5	13712-32	1	1
25	LOCKNUT 3/4in. NC	21260	1	1
26	FLATWASHER 3/4in.	11112-00	2	2
27	JAM NUT 1-1/2in. NC	12024-99	1	1
28	JAM NUT 1-3/4in. NC	12028-99	2	2
	HYDRAULICS			
35	PIPE SWIVEL 90° 3/4M-1/2F	23901	4	4
36	PIPE NIPPLE 1/2 x 3in.	20266	2	2
37	HYDRAULIC HOSE 3/8 x 24in. (M/1/2in.END)	72465	2	2
38	HYDRAULIC HOSE 3/8 x 36in. (M/1/2in.END)	72495	2	2
39	CHECK VALVE	20267	1	1
40	SIDE OUTLET ELBOW 1/2in.	19053	2	2
41	TEE 1/2in.	6227	2	2
42	PIPE NIPPLE 1/2 x CLOSE	19052	2	2
43	HYDRAULIC CYLINDER 5 x 8	26667	2	2
44	CYLINDER PIN	71666	4	4
45	SPRING PIN	1191-1	4	4
46	GREASE FITTING	1013-1	4	4
47	STOP SET	54586	2	2

FORM 401-06

TOWNER MANUFACTURING CO.

FIGURE 29D: A quick disconnect three-point hitch (Courtesy Towner Manufacturing Co.)

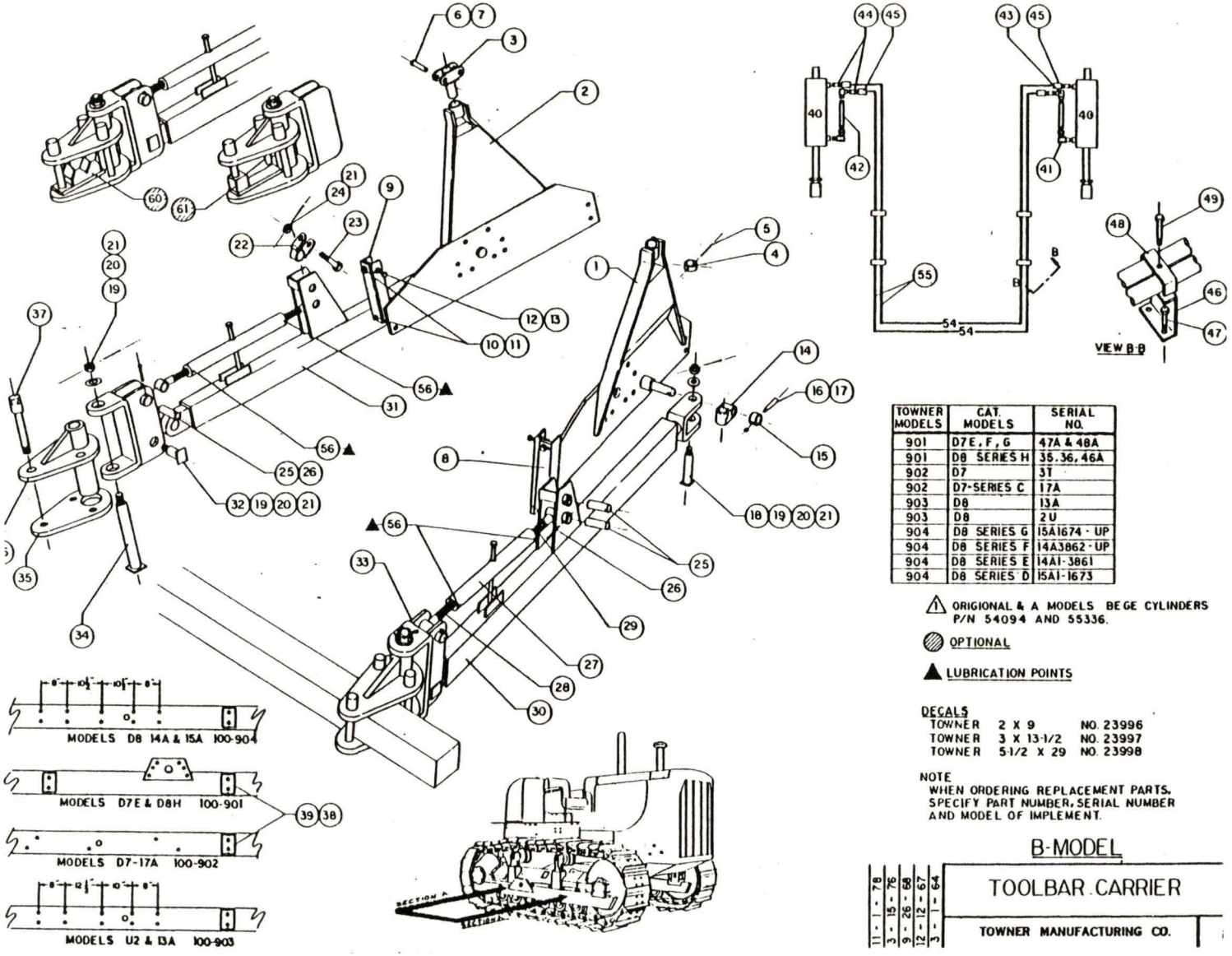


FIGURE 29E: A toolbar carrier for a subsoiler (Courtesy Towner Manufacturing Co.)

VI. Safety Features

1. The hydraulic cylinders on a 3-point hitch have a relief valve to prevent downward excessive thrust and tilting of the dozer.

VII. Limitations

1) Shanks are rigidly connected to the toolbar without shearbolt protection, safety trip mechanism or lateral sway capabilities in the horizontal plane to go around large rock pieces.

2) Height of the shanks is not adjustable.

3) The most common breakdown points are breaking of shanks and crack formation in the toolbar where the shank is connected.

4) The equipment can maneuver only large radius curves with shanks in the ground.

5) The equipment is not suitable for deeper loosening in soils containing a large percentage of rocks.

VIII. Locations of Illinois surface coal mines where equipment is currently used or planned to be used.

None

IX. Miscellaneous Comments

1) Most of the subsoiling equipment is sold outside of the U.S. in the Middle East, Indonesia, S. Africa and S. America.

2) The company also manufactures chisel plows and disc harrows.

4.5 Novel Subsoiling Concepts

Some novel ideas in subsoiling have been researched in Japan and Russia which are briefly described here.

In Japan, research is being carried out on a subsoiler that introduces fluid under pressure into the soil layers through a port in the shank foot (3). Results of field studies have indicated that the pressurized fluid breaks up soil layers ahead of the subsoiler and substantial draft force reduction can be achieved. The operating depth of this subsoiler is 24 in.

The Russians have investigated the effectiveness of a stepped sweep wing as opposed to the conventional sweep wing commonly used in the U.S. (12) The design of the sweep wing is such that the steps of sweep wing decrease in width with depth. This results in less confinement and shear failure of soil rather than plastic deformation at lower depths. This tool is specially designed for "Trenchless Drain Laying" in USSR and the penetration depths of up to 17 ft are possible.

CHAPTER 5

SUMMARY AND RECOMMENDATIONS

5.0 Summary

This study has appraised all available deeper soil loosening equipment in the 1-4 ft depth range in the U.S. and abroad which has potential for Illinois prime farmland reclamation. The appraisal was based on 1) written and/or oral contacts with equipment manufacturers and data supplied by them, 2) discussions with reclamation experts in Illinois and elsewhere in the U.S., 3) visits to selected equipment manufacturers to see the equipment, and 4) reviewing the performance of equipment in actual operation or obtaining feedback from others who had used it or evaluated it. Some of the more important conclusions of this study are given below.

1. Several manufacturers market deeper soil loosening equipment which may have potential for application in Illinois. Subsoilers, with static or vibratory multiple shanks, appear to have the most potential because of their high productivity, non-inversion of soils characteristic, and ability to handle different types of soils.

2. Most subsoilers for deeper soil loosening are manufactured in the U.S. However, almost all utilize stationary shanks. Two manufacturers, one from West Germany (Kaelble Gmeinder Co.) and one from England (F. W. McConnel Corporation) have developed vibratory shank subsoilers which may have significant potential. A summary of important engineering and operational specifications for all appraised equipment were given in Table 4.

3. Deeper soil loosening equipment manufactured in the U.S. have very similar engineering specifications and operational details. The available equipment in the U.S. may have potential for reclamation work as is or with slight modifications.

4. Most of the available deeper soil loosening equipment has not been demonstrated in Illinois prime farmland reclamation. There is a definite lack of communication between mine operators and deep tillage equipment manufacturers. As far as we know, only two equipment manufacturers had worked with the mining industry and were aware of the deeper soil loosening problems in the industry.

5. Almost all mine operators in Illinois agree that deeper soil loosening, to alleviate soil compaction problems, will be required to meet the productivity requirements on reclaimed prime agricultural lands after mining.

6. Illinois reclamation experts generally agree that deeper soil loosening should be done in a single stage several

years after the topsoil has been replaced. It was recommended (23) that legumes should be planted for two or three years after reclamation to draw the moisture out from the subsoil before deeper soil loosening is attempted.

7. Considerable time (15 to 20 minutes) is lost in replacing a shear bolt where a shank is protected against overload with such a device. Spring loaded trip mechanism with an automatic reset arrangement would be generally required on subsoilers to be used in prime farmland reclamation.

8. Cost of deep soil loosening requirements increase non-linearly (19) with increasing depth of loosening. Consideration should be given to replacing soils in thick lifts (where possible) to reduce the maximum depth of loosening.

5.1 Recommendations

1. A meeting should be organized between the deep tillage equipment manufacturers and reclamation specialists in Illinois under the sponsorship of the Bureau of Mines of the U.S. Department of the Interior. This meeting should include technical presentations from both groups as well as opportunities for formal and informal discussions.

2. Technical papers on the requirements for deeper soil loosening equipment in Illinois prime farmland reclamation should be presented at the agricultural equipment manufacturers' shows and technical meetings. A similar approach should be taken to make Illinois mine operators cognizant of available deep tillage equipment.

3. Deep tillage equipment manufacturers should be encouraged to demonstrate the use and effectiveness of their equipment in Illinois. They may work through local equipment dealers or directly interact with mine operators. The performance of the demonstrated equipment should preferably be monitored by unbiased groups.

4. Consideration should be given to demonstrating the use and effectiveness of some or all of the following equipment in Illinois prime farmland reclamation. This recommendation is based on the appraisal of equipment conducted during this study. The listing of equipment is not prioritized.

   (i) Model TLG-12 vibratory subsoiler manufactured by Kaelble Gmeinder Company of West Germany.

   (ii) Heavy Duty and Extra Heavy Duty "V-Drawn" subsoilers manufactured by R & R Agri-Products, Inc.

   (iii) "Little Brute Ripper" manufactured by Agristruction, Inc.

(iv) Model 4TAC-6000 Subsoiler manufactured by Rome Industries.

(v) Model 630-V Subsoiler manufactured by Marvin Landplane Company.

(vi) Model Turbotiger manufactured by DMI, Inc.

(vii) Model V-RAR-3 Ripper manufactured by ATECO, Inc.

(viii) Model M-55S Subsoiler with "curved shanks" manufactured by Murray Manufacturing Company.

(ix) Model "Commando Shakaerator" manufactured by F. W. McConnel, Ltd. of England.

(x) A subsoiler with 7 in. x 9 in. tool bar and 1.5 in. thick curved shanks manufactured by Towner Manufacturing Company.

5. Laboratory studies should be initiated on the mechanics of deep subsoiling with static and vibratory subsoilers and rippers in different types of soils with varying amounts of moisture and mutliple compacted layers at different depths.

6. Research and development on vibratory deep subsoilers should be initiated in the U.S. Vibratory subsoilers should result in effective deep soil loosening with minimum power requirements.

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