United States Patent

Vik

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[54] SLIT TRENCH DIGGING APPARATUS

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[22] Filed: **Aug. 6, 1970**

[21] Appl. No.: **61,828**

Related U.S. Application Data

[63] Continuation of Ser. No. 732,970, May 29, 1968, abandoned.

[52] **U.S. Cl.** **37/98**, 37/193, 37/DIG. 18, 172/40, 173/49

[51] **Int. Cl.** **E02f 5/02**

[58] **Field of Search**.....37/98, 193, DIG. 18; 173/49; 172/40; 299/14; 61/72.1, 72.5, 72.6, 72.7

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[57] **ABSTRACT**

An excavating blade projects downwardly from a framework into the earth with an energizing mechanism connected to the blade for intermittently forcing portions of the blade laterally against the sidewalls of the trench to compress the earth adjacent to the blade. The trench is in this way formed by lateral pressure. The blade can be mounted for oscillation through an arc of 20° about a vertical axis. A motor oscillates the blade about this axis at a frequency of about 150–400 cycles per minute.

9 Claims, 14 Drawing Figures

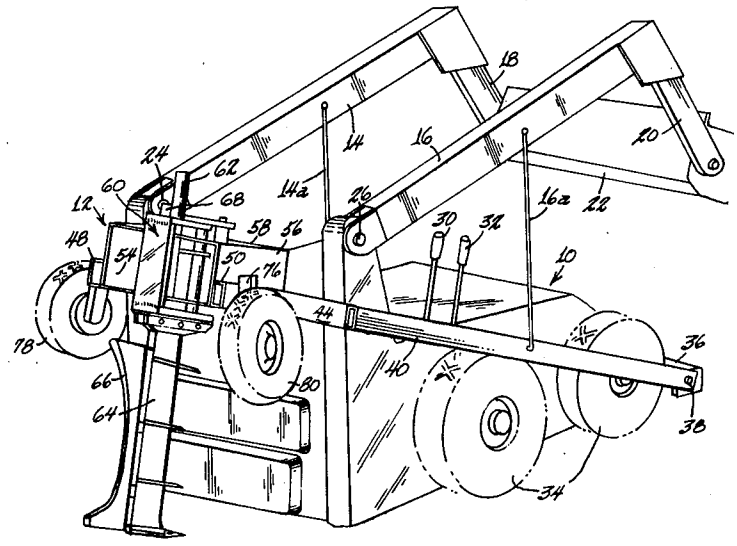


FIG. 1

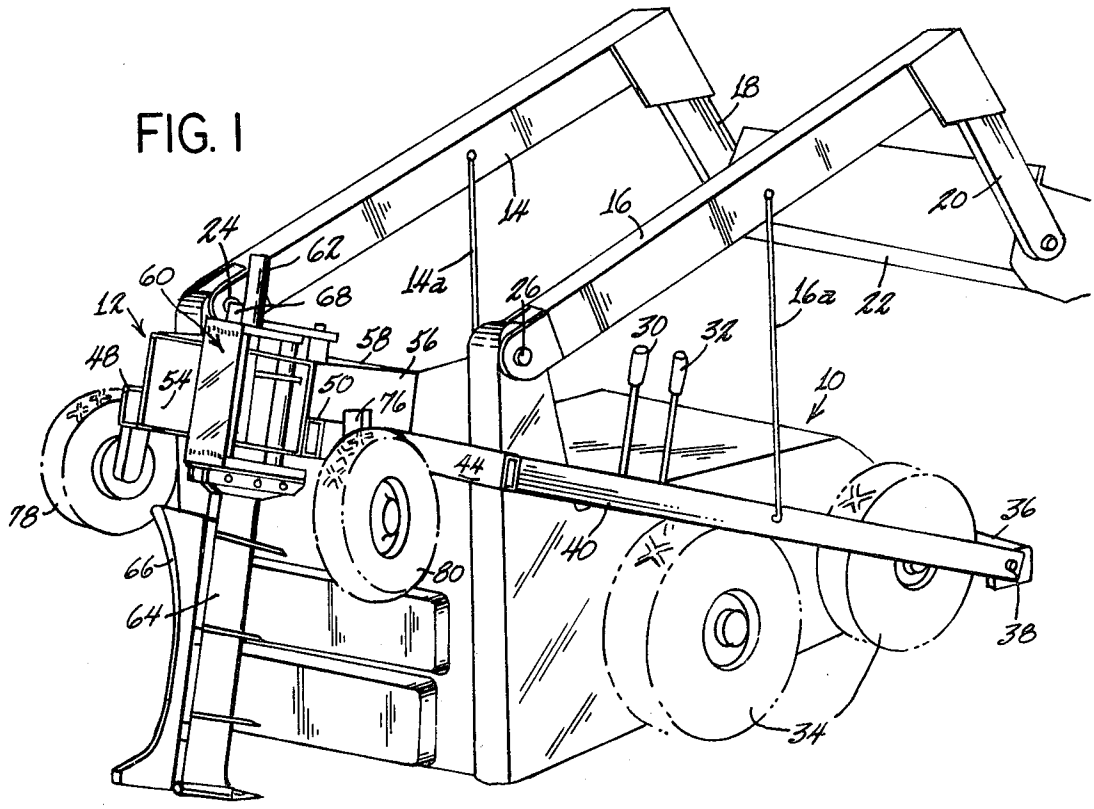
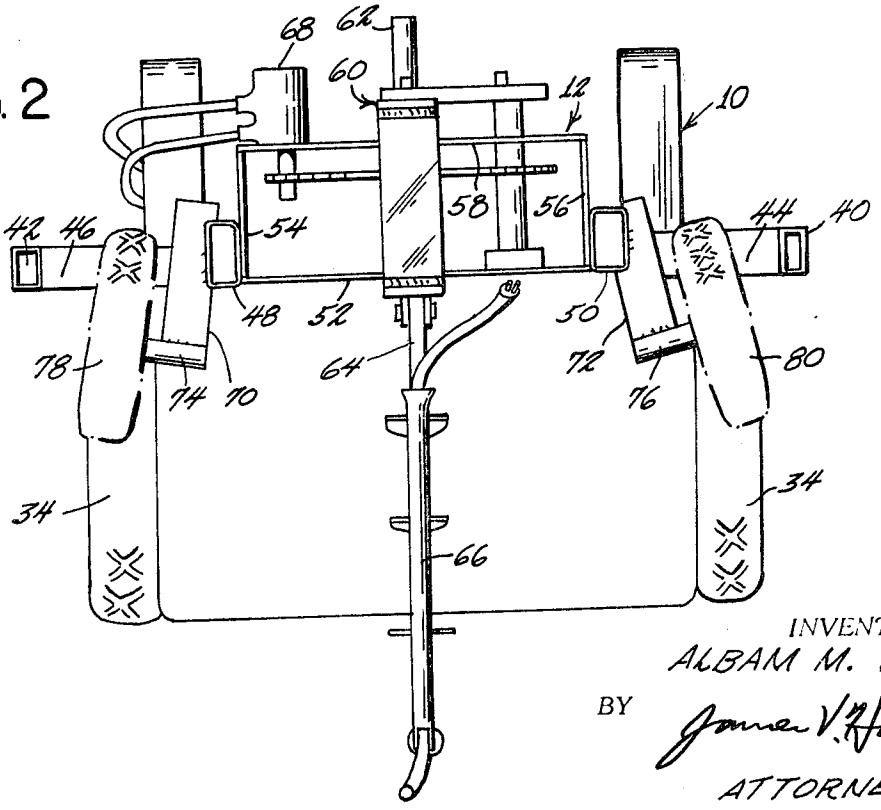


FIG. 2



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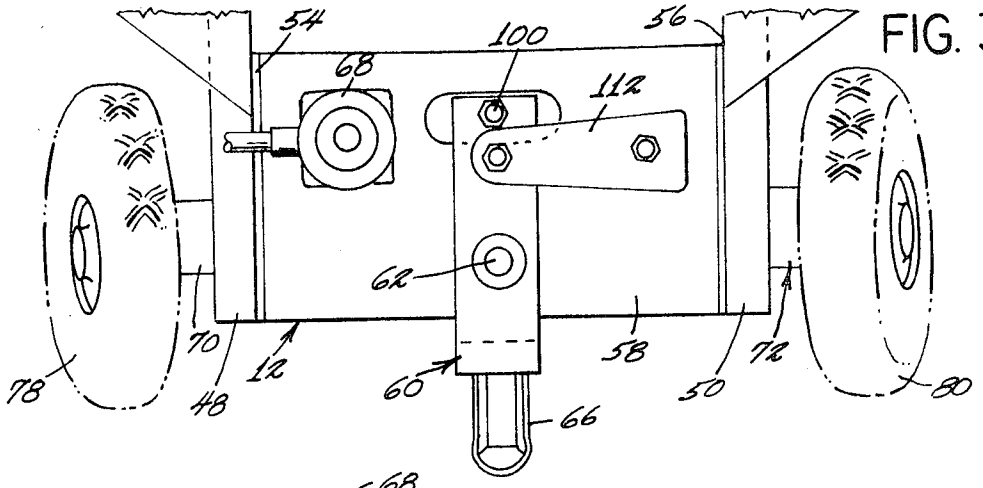


FIG. 3

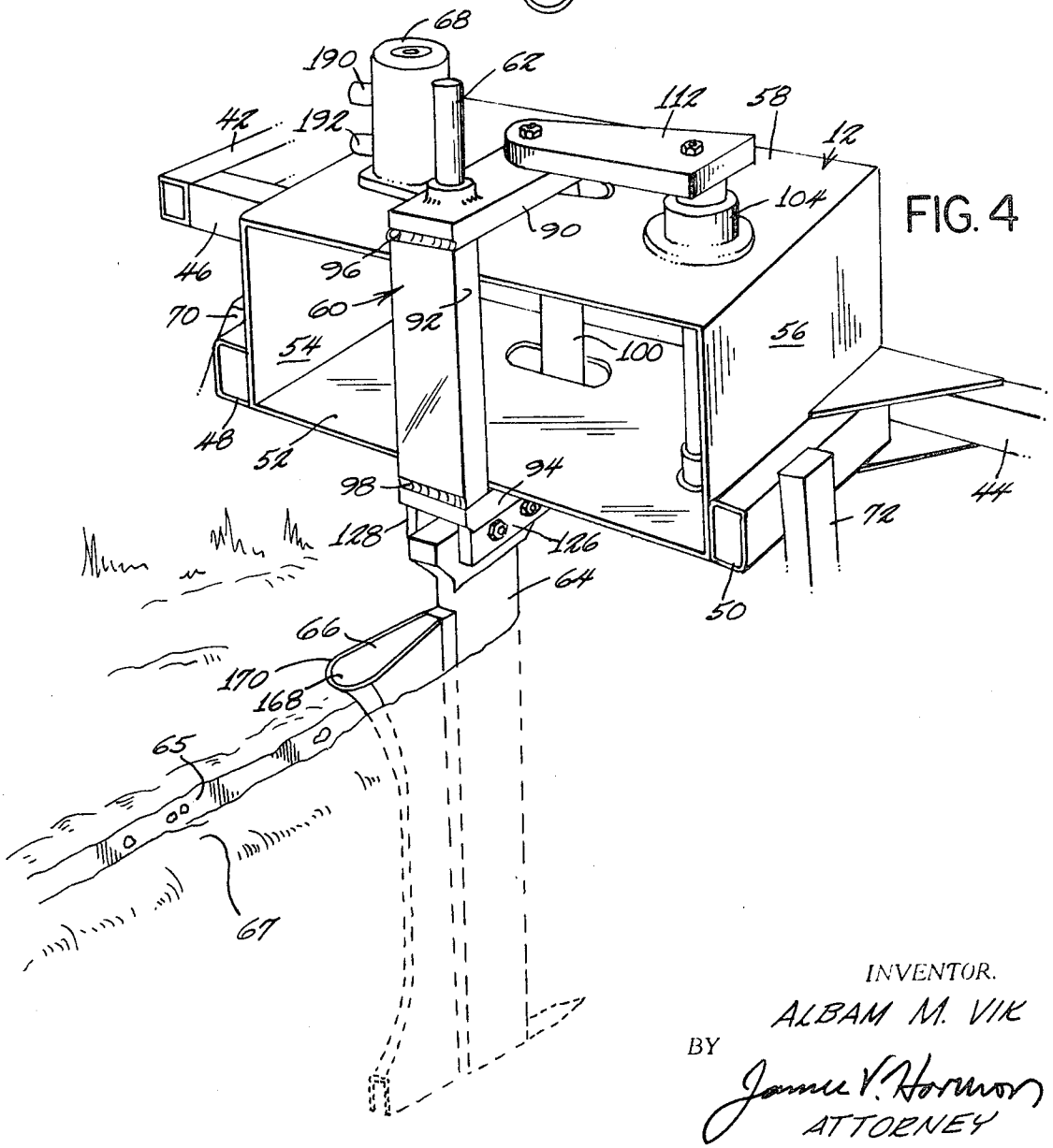


FIG. 4

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FIG. 5

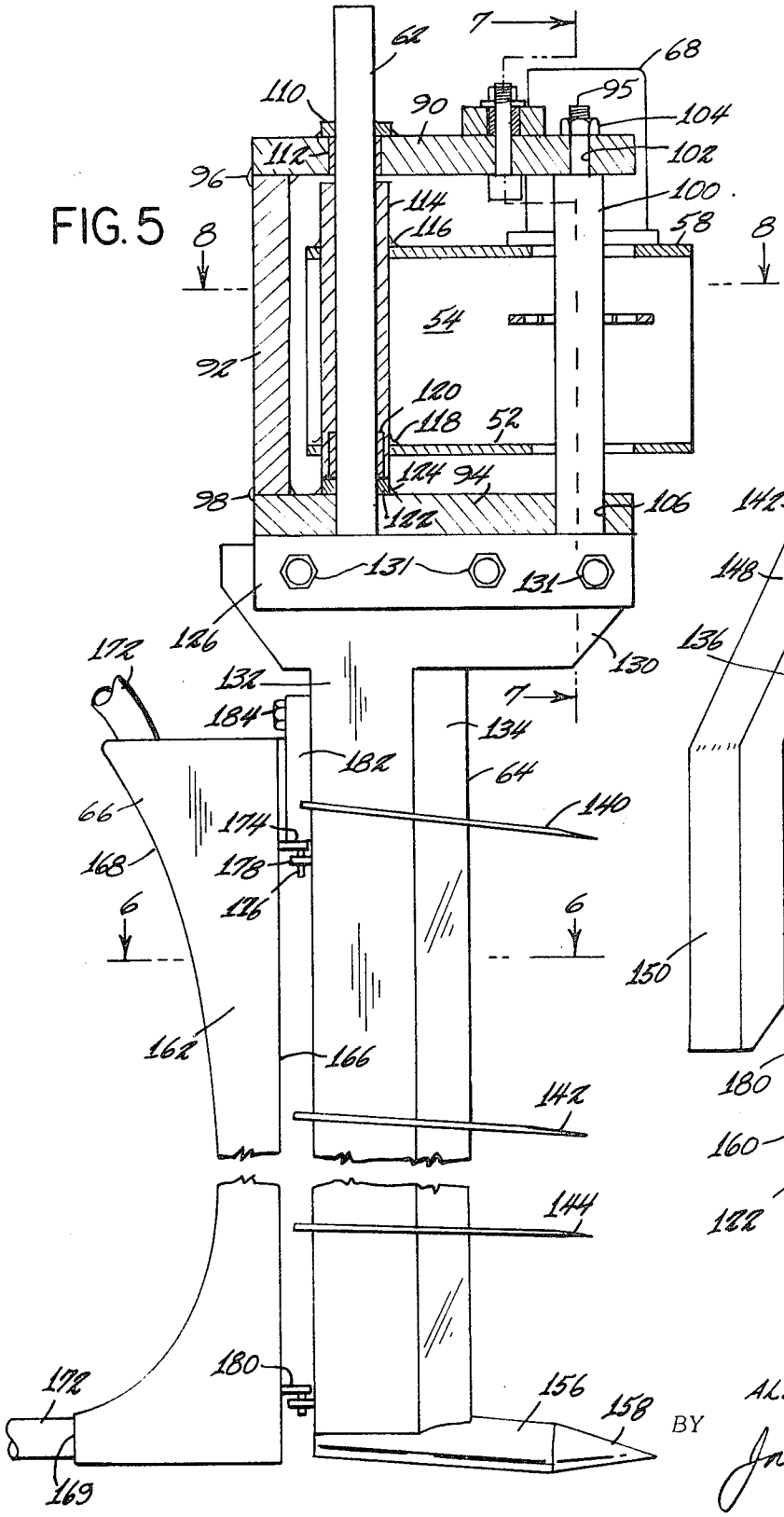
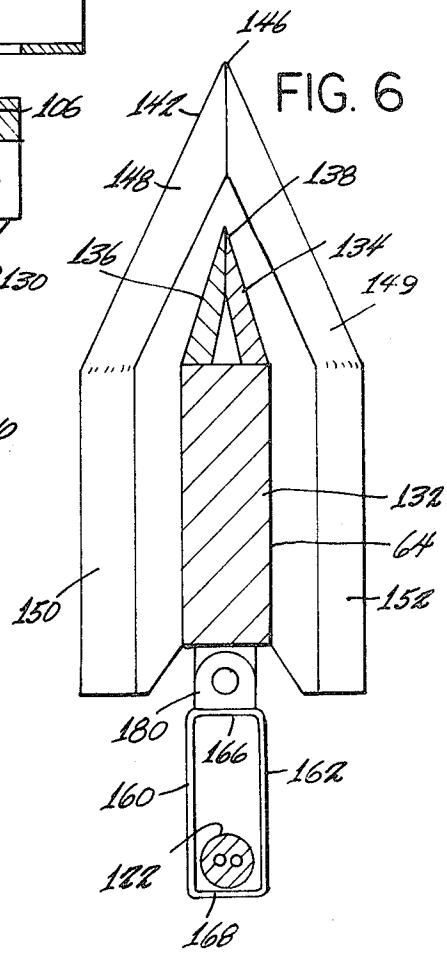


FIG. 6



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FIG. 7

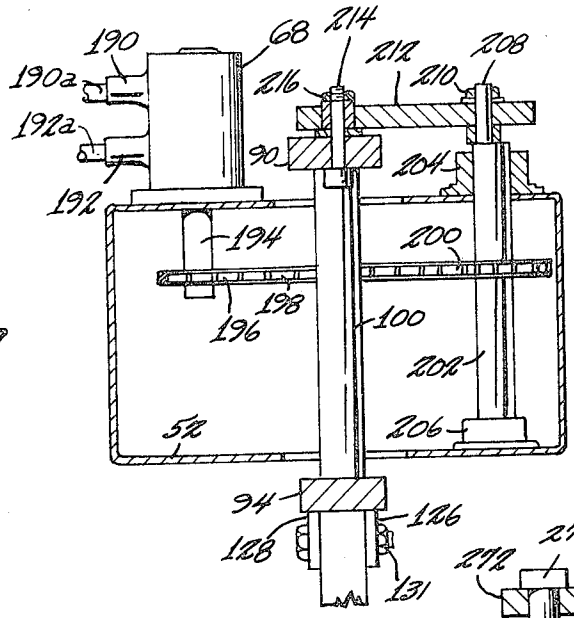


FIG. 9

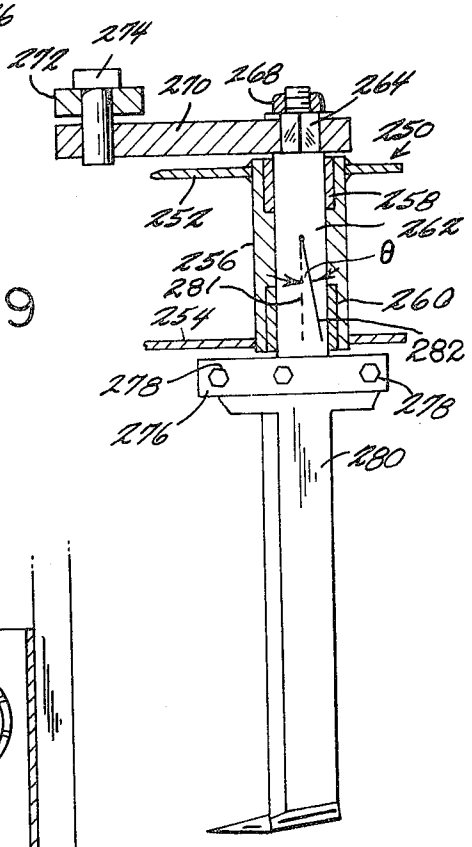
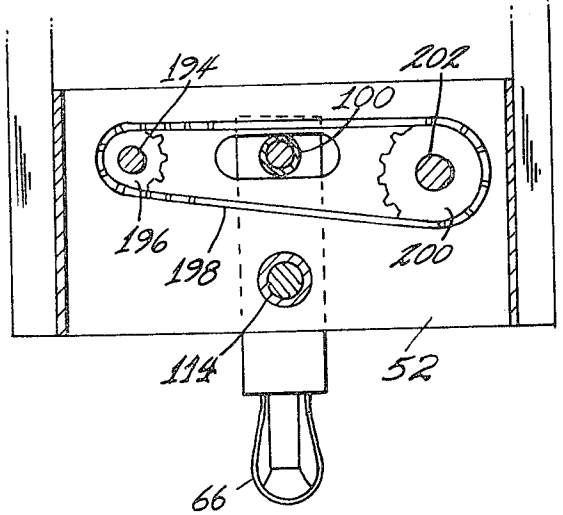


FIG. 8



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FIG. 11

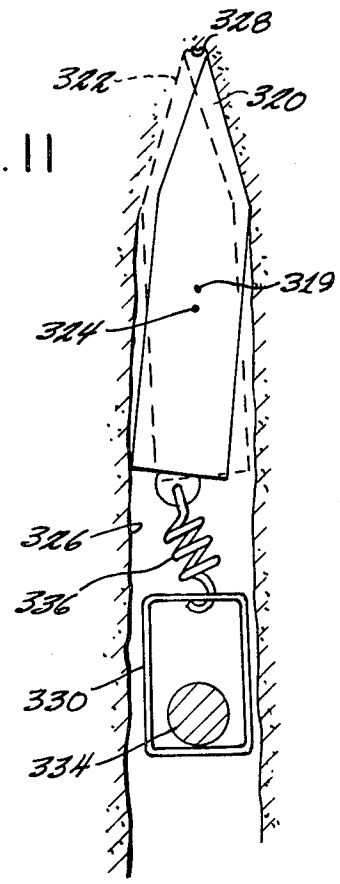


FIG. 10

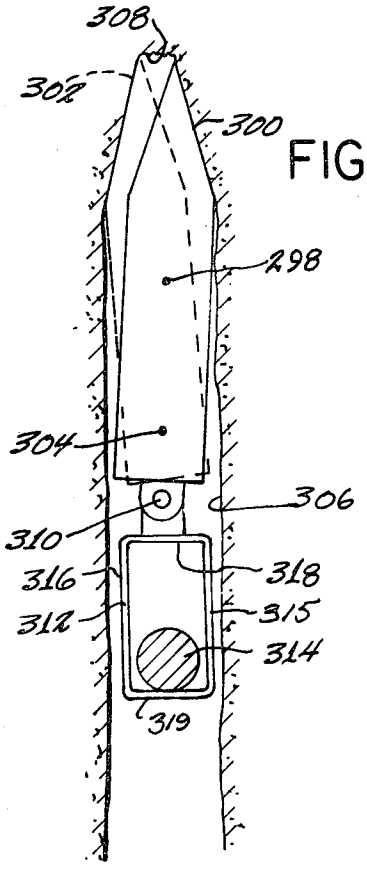


FIG. 12

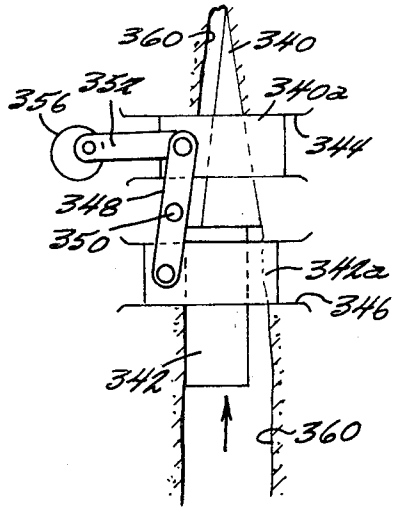


FIG. 13

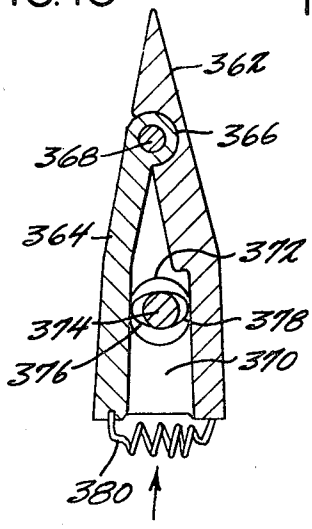
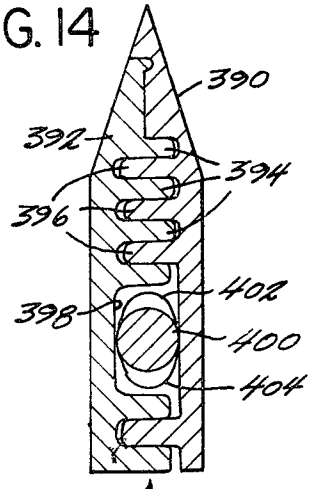


FIG. 14



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SLIT TRENCH DIGGING APPARATUS

This application is a continuation of application Ser. No. 732,970, filed May 29, 1968, now abandoned.

The present invention relates to excavating equipment and more particularly to an apparatus for digging slit trenches by applying forces normal to the walls of the trench (laterally of the direction of travel) to thereby compress the earth adjacent the trench walls.

Many devices have been previously proposed for digging trenches. In some of these devices a vertically disposed blade is drawn forwardly through the earth by means of a vehicle located above it on the ground. For the purpose of cutting away the earth from the area ahead of the blade, the blade is provided with teeth and a provision is made for vibrating or oscillating the blade in a vertical plane. One of the most significant deficiencies of these devices is that the vibration or oscillation of the blade has not been particularly effective in removing earth from the area ahead of the blade. A large draft force must therefore be applied by the vehicle in order to draw the blade through the earth.

One reason a vertically oscillating blade is to some extent ineffective is the tendency for the bottom edge of the blade during its downward movement to press loose earth and gravel downwardly and thereby pack loose earth against the bottom of the trench. This compressed mass of fallen earth tends to force the blade out of the trench which is, of course, undesirable. The teeth, moreover, are only partially effective in raising earth to the top of the trench where it can be ejected. Consequently, there is a substantial amount of friction between the sidewalls of the blade and the walls of the trench.

Still another difficulty encountered with vibratory and oscillatory blades of the type described is the tendency for a combination of earth, roots and weeds to accumulate in front of the blade at the point where it emerges from the ground. This necessitates stopping the vehicle to periodically remove the mass of packed debris.

Another design previously proposed includes a mechanism for nutating a blade about a vertically disposed axis with the bottom of the blade describing a circular path in the earth. An extremely high torque must, however, be applied to the blade to produce an effective compressing force within the trench. Thus, at a depth of 36 inches to apply a force of 100 pounds per square inch over a 4 square inch area, it is necessary to apply a torque of 1,200 foot pounds. Not only are the power requirements for this equipment very high but the relatively long lever arm will produce an extremely high bending moment within the blade.

In addition to the above shortcomings of prior equipment, other types of difficulties are encountered. A primary shortcoming of oscillatory or vibratory equipment is the fact that the vertical vibrations tend to impart like vibrations to the cable as it is laid. These vibrations tend to bend and sometimes kink the cable at the point where the cable emerges from the guide located at the rearward edge of the blade.

In view of these and other deficiencies of the prior art it is one object of the present invention to provide an improved slit trench-forming apparatus which is rugged in construction, economical to manufacture and can be pulled forwardly through the earth with a reduced draft force.

Another object of the invention is the provision of an improved slit trench-producing apparatus which can be drawn forwardly through the earth with relatively lightweight equipment such as a rubber tire driven vehicle.

Another more specific object of the invention is the provision of an improved slit trench-digging apparatus of the type adapted for use in laying telephone lines or plastic pipe which is capable of being drawn through the earth at a depth of as great as 40 inches while producing a trench having a width of 2 inches or more with a sufficiently low draft force to be drawn by a four-wheel tired vehicle such as a farm tractor or front end loader.

Still another object of the invention if the provision of a slit trench-forming apparatus including a substantially vertically disposed blade and a provision for intermittently forcing portions of the blade laterally against the sides of the trench to thereby compress the earth on each side of the blade to provide a cavity for the blade and its attached cable laying guide.

Another object of the invention is the provision of an improved oscillatory slit trench-forming apparatus wherein at least portions of the blade can be forced laterally against the sidewalls of the trench without producing a large bending movement on the blade during operation.

Still another object of the invention is the provision of an improved trench-forming apparatus including a trench forming blade mounted for oscillatory movement on a vertical bearing with a provision for supporting the bearing at both its upper and lower ends and for imparting motion to the blade at points located both above and below the bearing.

Another object of the invention is the provision of an improved oscillatory trench-forming apparatus of the type described including a bearing having a reinforcing yoke at least partially surrounding it to distribute the oscillatory forces to both the upper and lower ends of the bearing.

Another object of the invention is the provision of an improved slit trench-forming apparatus wherein a relatively small amount of power, e.g., less than 5 horsepower can be used to impart energy to the blade for forming a cavity to which the blade can be drawn as it is pulled forwardly by the supporting vehicle.

Another object of the invention is the provision of an improved trench-forming apparatus of the type described which is adapted to form smooth compressed walls having a trowelled surface that will tend to remain intact while the cable is being laid.

A still further object of the invention is the provision of an improved slit trench-forming apparatus to be used in cable laying operations which is characterized by having no tendency to vibrate the cable or form links in the cable during operation.

Still another object of the invention is the provision of an improved trench-forming apparatus for laying cable in which the cable is brought into the trench at a gradual angle with a relatively large bending radius at its lower end and is protected from damage by contact with the sidewalls of the trench as it is being laid.

These and other more detailed and specific objects of the present invention will become apparent in view of the following specification and drawings wherein:

FIG. 1 is a perspective view of a trench-forming apparatus in accordance with a preferred form of the invention as it is seen when mounted upon a vehicle and withdrawn from the ground.

FIG. 2 is a rear elevational view of the apparatus of FIG. 1 on a slightly enlarged scale.

FIG. 3 is a partial plan view of the apparatus of FIGS. 1 and 2 on a slightly enlarged scale relative to FIG. 2.

FIG. 4 is a perspective view of the trench-forming apparatus as seen when in the operating position within a trench.

FIG. 5 is a side elevational view of the trench-forming apparatus partly in section on a greatly enlarged scale relative to FIG. 4.

FIG. 6 is a horizontal sectional view taken on line 6—6 of FIG. 5.

FIG. 7 is a partial vertical sectional view taken on line 7—7 of FIG. 5 on a somewhat reduced scale.

FIG. 8 is a horizontal sectional view taken on line 8—8 of FIG. 5 on a somewhat reduced scale.

FIG. 9 is a vertical sectional view of another form of apparatus embodying the invention.

FIG. 10 is a diagrammatic horizontal sectional view of an apparatus embodying the invention as seen during operation to illustrate the operating principle thereof.

FIG. 11 is a view similar to FIG. 10 of another form of apparatus embodying the invention with the pivot axis moved slightly forward of that illustrated in FIG. 10.

FIG. 12 is a diagram illustrating the operation of a modified form of the invention as seen from above.

FIG. 13 is a diagrammatic horizontal sectional view of a modified form of blade.

FIG. 14 is a diagrammatic horizontal sectional view of another modified form of blade.

To the accomplishment of the foregoing and related ends the invention then comprises the features hereinafter fully described and particularly pointed out in the claims, the following description setting forth in detail certain illustrative embodiments of the invention, these being indicative, however, of but a few of the various ways in which the principles of the invention may be employed.

Briefly stated, the present invention provides a slit trench-digging apparatus having a supporting framework adapted to be transported over the ground as the trench is formed. A trench-forming blade which is usually elongated has a longitudinal axis of symmetry that is disposed substantially vertically when the apparatus is in operation. The blade is secured at its upper end to the framework and projects downwardly from the framework into the earth. A connection is provided between the blade and the framework that allows a certain amount of movement between them. A drive means such as a motor is operatively associated with the blade for intermittently pressing at least portions of the sides of the blade laterally against the earth surrounding the blade the same amount at every point along lines parallelling the axis of symmetry so that the earth is compressed laterally the same distance and to the same degree at each elevation within the trench as the blade is moved by the drive means normal to the sidewalls of the trench. Because of variations in the slope of the ground and the preference of different operators, the angle of the longitudinal axis of symmetry with reference to the vertical will vary substantially. The term "substantially vertical" as used herein means within about 35° of the vertical.

Refer now to the drawings and particularly to FIGS. 1–4. As seen best in FIG. 1 a vehicle **10** is used for supporting and drawing the trench-forming apparatus **12** forwardly through the earth. The vehicle **10** in this instance is a front end loader which includes a motor (not shown) and a pair of parallel forwardly extending arms **14** and **16** having downwardly directed terminal portions **18** and **20** between which is pivotally secured a loading scoop **22**. The arms **14** and **16** are raised and lowered by any conventional power unit such as hydraulic cylinders (not shown). The rearward end of the arms **14** and **16** are pivotally secured upon pins **24** and **26** as can be seen in FIG. 1. Extending downwardly from the arms **14** and **16** are connectors **14***a* and **16***a* respectively which can consist of cable or chain. The lower ends of the connectors **14***a* and **16***a* are secured to the center of longitudinally extending parallel draw bars **40** and **42** that are secured to a laterally extending crossbar **36** by means of two pivots **38**, only one of which is shown. The crossbar **36** is rigidly secured to the forward end of the vehicle **10**. The drawbars and the trench-digging apparatus **12** can thus be raised and lowered by raising and lowering the arm members **14** and **16**. Rigidly secured as by welding to the rearward ends of drawbars **40** and **42** are coaxial supporting bars **44** and **46** and it is upon these bars that the frame of the trench-digging apparatus **12** is mounted.

The vehicle will normally be provided with suitable controls such as the lever arms **30** and **32** that can be operated for changing the position of the arms **14** and **16**. Thus, by raising the arms **14** and **16** the upward force exerted by the connecting elements **14***a* and **16***a* will raise the trench-digging apparatus **12** by swinging the rearward ends of the drawbars upwardly about the pivot pins **38**. It will be apparent that any of a variety of mechanisms can be employed for raising and lowering the framework of the trench-digging apparatus. The assembly shown is merely exemplary. If a farm tractor or the like is employed as a transporting vehicle, an entirely different form of raising and lowering mechanism would normally be used. In that instance it might be most convenient to mount the trench-digging apparatus **12** at the rearward ends of the three-point hitch normally provided as a component of such tractors. The elevating mechanism for the digging apparatus **12** does not by itself form a part of the present invention.

As mentioned briefly above, the vehicle **10** can comprise any of a variety of power vehicles of the type suited for off-the-road use. One such vehicle is a front end loader of the type illustrated. This vehicle is normally provided with four relatively large air inflated tires **34** with power being provided to all four tires. A variety of vehicles can, however, be used including, but not limited to, farm tractors, garden tractors and track vehicles.

As seen best in FIGS. **3** and **4**, the supporting framework for the trench-forming apparatus **12** includes a pair of parallel laterally spaced longitudinally extending supporting frame members **48** and **50** which are rigidly secured in any suitable manner as by welding to the central ends of the crossmembers **44** and **46**. Secured as by welding in a horizontal plane between the frame elements **48** and **50** is a rectangular mounting plate **52**. Extending upwardly from the side edges of the plate **52** are laterally spaced parallel spacers **54** and **56** between the upper ends of which is welded a rectangular plate **58**. The plates **52–58** together comprise a chassis upon which a blade and drive mechanism for the blade is mounted as will be described hereinbelow.

Mounted upon the center of the chassis is a trench-forming blade supporting yoke **60**. The yoke **60** is mounted for oscillation upon a substantially vertical axis by the provision of a bearing pin **62** which extends vertically through the midline of the plates **52** and **58**. The bearing will be described more fully hereinbelow. Rigidly secured to the lower edge of the yoke **60** is a trench-forming blade **64** which during operation as seen in FIG. **4** will be almost entirely located within a vertically disposed linear slit trench **65**. On the rearward edge of the blade **64** is mounted a cable-laying guide **66** through which the cable or other elongated element that is to be placed in the trench is transferred while the equipment is in operation. As can also be best seen in FIG. **4** a hummock **67** is raised on each side of the trench **65** as it is formed. This raised earth is composed of a part of the soil that has been displaced as the trench is formed.

The drive mechanism for the trench-forming apparatus consists in part of a motive power unit such as a rotary hydraulic motor **68**. The drive motor **68** is in turn suitably coupled to the yoke **60** so as to oscillate the yoke about the vertical bearing upon which it is mounted.

While the trench-digging apparatus is in operation it is supported at a constant height above the surface of the ground by wheels **78** and **80** for rotation on inclined axles **74** and **76** suitably affixed as by welding to the lower ends of struts **70** and **72** which are themselves welded to the frame members **48** and **50** respectively. The sheels are tilted in such a manner that their upward edges are located centrally of their lower edges. In this way, the lateral oscillations are in part resisted by the tires **78** and **80**. The tires **78** and **80** may be located in a variety of positions on the framework and can even be eliminated entirely if provision is made for maintaining the trench-forming apparatus at the proper elevation.

The yoke **60** and associated structures will now be described with particular reference to FIGS. **4** and **5**. The yoke **60** is composed of a vertically oriented rectangular box frame consisting of a horizontally disposed longitudinally extending frame element **90**, vertically disposed frame element **92** positioned slightly to the rear of the chassis, a lower longitudinally extending horizontally disposed frame element **94** located beneath the chassis and a vertically disposed frame element composed of a bolt **94** (FIG. **5**) that extends through frame elements **90** and **94** and a spacing tube **100**. The upward end of the bolt **95** extends through a bored opening **102** and a yoke element **90**. When a nut **104** is threaded tightly against the upper surface of the element **90** it will be drawn downwardly against the spacing tube **100** thereby securely locking the forward end of elements **90** and **94** together.

The yoke elements **90**, **92** and **94** are rigidly affixed together as by welding at **96** and **98** preferably consist of relatively heavy materials such as 3½×1½ inch bar stock. As can be clearly seen in FIG. **5** the forward end of the yoke element **94** is bored at **106** to receive the lower end of the spacing tube

100. The head of the bolt 95 is suitably engaged upon the lower surface of the bar 94.

The vertical bearing upon which the yoke 60 and the trench-forming blade 64 is mounted will now be described with reference to FIGS. 1, 7 and 8. Rigidly secured to the upper surface of element 90 is a sleeve 110. Below the sleeve 110 is mounted a vertically disposed bushing 112 through which pin 62 extends. A bearing tube 114 is rigidly secured as by welding at 116 and 118 to the chassis plates 52 and 58.

Within the lower end of the bearing tube 114 is a bushing 120. Rigidly secured by welding 124 to the upper surface of the frame member 94 is a sleeve 122. The bearing pin 62 is, during assembly, dropped into place as shown in FIG. 5 after the yoke has been placed in position on the supporting framework. The yoke 60 can be quickly removed for repair by withdrawing the pin 62, removing nut 104 and withdrawing the bolt 95. As seen in FIGS. 4 and 5, suitable transversely elongated openings are provided in the chassis to accommodate the element 100.

As seen in FIGS. 4 and 5, a pair of vertically disposed parallel and longitudinally extending blade mounting bars 126 and 128 are rigidly secured as by welding to the lower surface of the element 94. The mounting bars 126 and 128 are bored at longitudinally spaced points to receive laterally extending bolts 131 which secure an enlarged head 130 of the blade 64 and placed between the plates 126 and 128. The blade 64 is provided with a shaft 132 which is generally rectangular in cross section and a leading edge portion which in this instance is composed of plates 134 and 136 welded at their rearward edges to the leading edge of the shaft 132. The plates 134 and 136 form a sharpened cutting blade having a cutting edge 138 which is preferably hardened by heat treatment.

Distributed vertically along the length of the blade 64 are three earth-lifting blades or plows 140, 142 and 144. The plow blades are preferably welded to the shaft of the blade 64. Each of the blades 140, 142 and 144 as seen in FIG. 6 includes a point 146 at its forward end, diverging cutting edges 148 and 149 and parallel side cutting edges 150 and 152. As seen in FIG. 5, the forward edge of each of the plow blades 140, 142 and 144 is located below the rearward edge thereof so that each is positioned on an inclined angle relative to the axis of the blade 64. In this way, the earth will be thrown upwardly by each blade as it moves forwardly through the earth. While the angle of each of the blades 140, 142 and 144 can be varied considerably, it is preferred that plate 144 be inclined at the most gradual angle relative to the axis of the blade 64, blade 142 inclined at an intermediate angle and blade 140 be inclined at the greatest angle relative to the axis of the blade 64. The blades 140, 142 and 144 help to elevate earth that has been compacted by the blade 64 from the area adjacent to the trench but should be considered optional.

Rigidly secured as by welding to the bottom of the blade 64 is a probe 156 composed of a horizontally disposed cylinder having a sharpened forward end 158. The probe 156 helps to form a cavity in the earth for the cable as it is being laid.

The guide 66 secured to the rearward edge of the blade 64 is composed of sidewalls 160 and 162, a forward wall 166 and a rearward wall 168. As best seen in FIG. 5, the rearward wall 168 curves rearwardly at the top and the bottom thereof to provide a relatively large radius of curvature for the cable 172 to follow as it is being laid.

While the guide 66 can be secured to the blade 64 in a number of ways, it is conveniently attached by the provision of a forwardly extending tongue 174 provided with a downwardly extending pivot pin 176 that projects through a tongue 178 extending rearwardly from the rearward edge of the blade 64. In this way the upward end of the guide 66 is pivotally secured to the blade 64. A similar pivotal connection 180 is provided between the lower end of the guide 66 and the blade 64. In this manner the guide 66 is mounted for pivotal movement on a generally vertically disposed axis parallel to the axis of the blade 64 so that during operation as the blade 64 oscillates within the trench the rearward edge of the guide 66 will be able to remain in one location as the forward end thereof swings laterally from side to side. The guide 66 is held in place on the blade 64 by the provision of a holddown block 182 secured against the upper edge of the tongue 74 of the top pivot by means of a bolt 184.

Refer now to FIGS. 7 and 8 with reference to the drive system for energizing the blade 64. The drive motor 68 consists in this instance of a hydraulic motor having at least about 5 horsepower capacity and including usual hydraulic inlet and outlet ducts 190 and 192 to which hydraulic hoses 190*a* and 192*a* are connected. The motor 68 is provided with a drive shaft 194 to which is secured a sprocket 196 over which is entrained an endless drive chain 198. The chain 198 is engaged at its other end around sprocket 200 which is itself secured to a shaft 202 mounted for rotation within journals 204 and 206 that are secured to plates 58 and 52 respectively of the chassis. The shaft 202 is provided with an eccentric crankpin 208 to which is secured one end of a pitman arm 212. The other end of the pitman arm 212 is pivotally secured to the element 90 of yoke 60 by means of a bolt 214 and 216. In this manner, as the motor 68 rotates sprocket 196 thereby driving chain 198, rotation will be imparted through sprocket 200 and shaft 202 thereby causing the pin 208 to revolve thus imparting reciprocating motion to the pitman arm 212. This motion is in turn imparted to the yoke 60 and blade 64 through pivot 214.

A variety of different kinds of driving units can be provided. If an eccentric weight drive or vibratory drive is employed, it should be connected directly to the blade rather than between the blade and the supporting framework.

Refer now to FIG. 9 which illustrates an alternative form of mounting construction for the trench-forming blade. As seen in the figure there is provided a trench-forming apparatus indicated generally at 250 including a supporting framework composed of horizontally disposed vertically spaced parallel plates 252 and 254 between which is welded a vertically disposed bearing tube 256 provided at its upper and lower ends respectively with bushings 258 and 260. Journaled for oscillatory movement within the bushings is a vertically disposed shaft 262 having a square upward end 264. A bolt 268 securely retains a lever arm 270 rigidly in place on the upper end of the shaft 262. To the free end of the arm 270 is pivotally secured by means of pin 174 a pitman arm 272, only a portion of which is shown. Reciprocatory motion is imparted to the pitman arm 272 in the same manner as the pitman arm 212 described hereinabove. The drive motor is not shown in this instance.

Rigidly secured at the lower end of the shaft 262 is a mounting bracket 276 to which a vertically disposed trench-forming blade 280 is secured by means of bolts 278. During operation, the reciprocation of the pitman arm 272 will impart oscillatory movement to the arm 270 and will thereby oscillate the blade 280 about an axis extending through its centerline and also through its approximate midline along the fore and aft axis. When the apparatus is in use, the axis of the blade indicated by dotted line 281 is oriented at an inclined angle with its lower end positioned forwardly relative to the vertical indicated by solid line 282. The angle θ between the axis of oscillation and the vertical is preferably between about 12° and 20°.

Refer now to FIGS. 10 and 11 which illustrate diagrammatically the operation of the apparatus. For the purpose of this description, it will be assumed that a hole has been dug in the earth into which the blade can be lowered to begin the operation. After this has been done, the operator by actuating levers 30 and 32 lowers the arms 14 and 16 and in turn the drawbars 40 and 42. This will drop the cutting blade 74 and guide 66 into the hole provided for this purpose. The drive motor 68 is then started to thereby oscillate the cutting blade about its longitudinal axis of symmetry 298 which is substantially vertical (generally from about 12°–35° of the vertical). As seen in FIG. 10, a cutting blade 300 is caused to swing back and forth about an oscillation axis 304 also extending longitudinally of the blade. The axis of oscillation 304 is preferably relatively close to the rear edge of the blade and behind the axis of sym-

metry 298. The axis of oscillation is preferably but not necessarily parallel to the axis of symmetry 298. The axis 304 in this instance is located relatively close to the rearward edge of the blade, for example, about 1–2 inches from its rearward edge. As the forward edge of the blade swings from side to side, a trench 306 will form as the earth on each side of the blade is forced laterally and is compressed on each side thereof. As the sharpened forward edge of the blade 300 swings from side to side, earth will be scraped from the leading edge of the trench 308. As seen in the figure, the primary contact area between the blade 300 and the trench will be at the forward edge of the blade due to the close proximity between the axis 304 of oscillation and the rearward edge of the blade 300. As described above in connection with the embodiment of the invention illustrated in FIGS. 1–8, a guide 312 is secured by means of a pivotal connection 310 to the rearward edge of the blade 300. The guide as described above includes the usual sidewalls 315 and 316, forward wall 318 and a rearward wall 319. A cable 314 or other elongated body is fed downwardly through the guide as the trench 306 is formed.

Refer now to FIG. 11 illustrating the operating conditions that occurs when the axis of oscillation is moved forwardly to a position close to the longitudinal axis of symmetry designated 319. The trench-forming blade is in this figure oscillated between the solid line position 320 and dotted line position 322 about a substantially vertically disposed axis of oscillation 324 which is located very close to and parallel with the longitudinal axis of symmetry 319. Oscillation of the blade will compress the earth the same amount at every elevation within the trench because the blade moves the same distance laterally at every point along lines parallelling the axis of symmetry.

In the apparatus of FIG. 11 both the forward and rearward edges of the blade will contact the trench 326 as it is formed. As the blade oscillates, earth will be periodically scraped from the forward edge 328 of the trench. Simultaneously, the sides of the trench will be compressed and compacted laterally thereby forming a narrow trench slightly wider than the blade itself and characterized by having a relatively smooth compacted surface hereinafter referred to as "trowelled surface."

Again, the blade has secured to it a guide 330 through which is fed a hose, cable or other elongated element 334. The guide 330 is in this instance connected to the blade by means of a plurality of vertically spaced springs 336.

Refer now to FIG. 12 which illustrates diagrammatically another form of the invention. In this instance a vertically disposed trench-forming blade having a sharpened forward edge is divided into forward and rearward sections 340 and 342, to the upper ends of which are secured parallel horizontally disposed followers 340*a* and 342*a* mounted for lateral reciprocation within suitable guides 344 and 346. During operation intermittent lateral motion is imparted to the blade sections 340 and 342 in opposite directions by means of a crank 356 connected by means of pitman 352 and link 348 to the followers 340*a* and 342*a*. The link 348 is itself pivotally secured to the framework of the apparatus by means of a pivot pin 350 at its center. In this manner alternate lateral movement of the blade section 340 and 342 will alternately compress opposite walls of the trench 360 laterally as the apparatus is moved forwardly through the earth in the direction indicated by the arrow. The apparatus of FIG. 12 will not be suited for operation at the relatively great depths that can be achieved with the apparatus of FIGS. 1–11 due to the relatively high bending moments that will be encountered as the blade sections reciprocate.

Refer now to FIG. 13 which illustrates still another form of the invention. As seen in the figure there is provided a vertically disposed trench-forming blade composed of a blade section 362 having a sharpened forward edge and a blade section 364 which is aligned substantially parallel to section 362 and is provided at its forward end with a hinge 366 which is coupled to the blade section 362 by means of a vertically disposed pivot pin 368. A horizontally disposed plate 370 is rigidly affixed to the lower end of blade section 362 below the lower edge of blade 364. Inside the plate 370 is mounted a bearing 372 within which is journaled the lower end of a vertically disposed operating shaft 374 on which are mounted laterally extending cam lobes 376 and 378. A tension spring 380 is connected between the rearward edges of the plates 364 and 362. During operation, rotation of shaft 374 will cause the cam lobes 376 and 378 to periodically force the rearward edges of the plates 362 and 364 apart against the force of spring 380 thereby forcing the earth laterally on each side of the blade so as to compress the earth on each side thereof and thereby form a trench as the blade is moved forwardly through the ground in the direction of the arrow.

The apparatus of FIG. 13 is, however, somewhat more complicated than that of FIGS. 1–11 and will be somewhat more subject to wear within the bearing 366 and the area of the cams 374 and 378.

Refer now to FIG. 14 which illustrates still another embodiment of the invention. As seen in FIG. 14 the blade consists of two vertically disposed elongated blade sections 390 and 392 positioned in side-by-side relationship closely adjacent to one another. The blades are provided with interdigitating laterally extending centrally directed vertically disposed parallel flanges 394 and 396 which provides a sliding connection between blades 390 and 392. The blade 390 is provided with a sharpened forward edge as described in connection with FIGS. 1–11. A vertically disposed operating shaft 400 extends within a pocket 398 between the blades 390 and 392 and is provided with opposed cam lobes 402 and 404 so that during rotation of the vertically disposed shaft 400 the lobes 402 and 404 will intermittently contact sidewalls of the pocket 398 thereby intermittently forcing the two portions of the blade apart against the sidewalls of the trench formed as the blade is moved forwardly through the earth in the direction of the arrow. The apparatus of FIG. 14 will be satisfactory for many applications but the blade will not have as much strength as that described in FIGS. 1–11. The transfer of earth into the sliding connections between the parts 390 and 392 will cause a certain amount of wear to take place between them.

A unit constructed in accordance with FIGS. 1–8 of the invention proved highly effective in operation and was able insofar as I could determine perform much better than available equipment. As the blade oscillates it will by cavitation form an opening having compressed sidewalls into which the blade can be moved. The operation of the blade is thus characterized by forming an opening or cavity larger than itself without being moved forwardly. This was found to be highly effective in reducing horsepower requirements and the required forward draft necessary to draw the unit through the earth. For example, in a prototype apparatus mounted upon a front end loader of the type illustrated in FIGS. 1 and 2, and employing a hydraulic drive motor 68 having a 5 horsepower capacity, it was possible to run at a forward speed of about 5 feet per minute with the blade measuring 1½×4×40 inches. It was also surprising to find that much thicker blades could be used than in prior equipment thereby forming a much wider trench which is, of course, desirable since it will accommodate larger diameter pipe or cable. For example, with the blade having a width of about 3½ inches a trench having a width of about 4 inches was formed to a depth of 24 inches. Again a 5-horsepower drive motor 68 was employed for imparting oscillation to the blade.

An important advantage of the invention in addition to the low draft forces required is the relatively smooth compressed condition of the sidewalls of the trench which I prefer to as being "trowelled." Since the walls are tightly compacted, the earth will have little tendency to fall to the bottom of the trench. Accordingly, the cable can be reliably laid in a variety of different kinds of soil at a constant depth since there is little tendency for falling earth to accumulate periodically in piles at the bottom of the trench.

Another important benefit obtained through the use of the invention is its surprising of the ability to clear obstacles such

as rocks and boulders. While the reason for this unusual ability is not known with certainty, it is believed to be due to the tendency for the forward edge of the blade when contacting a boulder located, for example, on its left side to force the supporting framework towards the right as the forward edge of the blade moves towards the left. During the next half cycle, the supporting framework tends to remain stationary as the forward edge of the blade swings toward the right. Then on its next half cycle while swinging towards the left, contact between the forward edge of the blade and the boulder will again force the framework a short distance towards the right. In this way the blade and the entire apparatus tends to work its way around the boulder. The unit also was found to be effective in cutting through tree roots up to 4 inches or more in diameter. The apparatus has no tendency to damage or kink cables and the large radius of the rearward edge of the guide will subject the cable to a minimum of stress as it is laid.

The size of the arc through which the blade oscillates is not considered critical but in general the stroke of the pitman arm should be sufficient to swing the forward edge of the blade from the full right position to the full left position a total distance which is at least as wide as the width of the blade itself. Thus, if the blade is 2 inches wide the forward edge of the blade should sweep through an arc of about 2 inches in width. It should be understood, however, that this is merely a rule of thumb and is not to be considered limiting. It should also be understood that any lateral movement of the forward edge of the blade will compact the earth on either side of the leading edge of the blade and will accordingly provide a small cavity into which the blade can be moved as the vehicle travels over the ground. However, under most ground conditions I prefer to employ a wider swing, i.e., a greater arc of oscillation about equal to the blade thickness along the lateral axis.

In a typical cable laying operation at depths of from 30–40 inches, the arc of oscillation will usually be from about 10°–45° with about 20° being typical.

The oscillating frequency of the blade can be varied greatly but good results have been achieved in typical operating conditions with a frequency of from about 100–500 cycles per minute with 150–400 cycles per minute being preferred. It should be understood, however, that the frequency is related to the linear speed over the ground and that when the vehicle speed is increased the frequency of the blade oscillation should increase accordingly.

It is apparent that many modifications and variations of this invention as hereinbefore set forth may be made without departing from the spirit and scope thereof. The specific embodiments described are given by way of example only and the invention is limited only by the terms of the appended claims.

What is claimed is:

1. A slit trench-digging apparatus comprising:

a. a supporting framework adapted to be transported in a direction over the ground to produce a trench which extends in that direction;

b. a vertically disposed, elongated, trench-forming blade adapted to extend down into the earth from said framework;

c. means supporting said blade on said framework for alternating leftward and rightward lateral oscillation about a generally vertical axis within the blade, said axis being coplanar with the longitudinal axis of the blade, the blade being substantially symmetrical about the plane containing said longitudinal axis and said generally vertical axis;

d. drive means for producing said alternating leftward and rightward lateral oscillation of said blade about said generally vertical axis, so that diagonally opposite portions of said blade ahead of and behind said generally vertical axis alternately compact and retreat from opposite sidewalls of the trench being formed as said framework is transported in said direction.

2. The apparatus of claim 1 wherein the two recited axes are parallel.

3. The apparatus of claim 2 wherein said blade has means defining a leading edge and additionally comprises an elongated probe rigidly secured at the lower end of the blade, extending forwardly of said leading edge in said plane at a substantially right angle to the longitudinal axis of the blade.

4. The apparatus of claim 1 wherein said drive means comprises motive power means having a rotatable output shaft; a throw on said shaft; a pitman arm mounted between said throw and said blade for imparting said alternating leftward and rightward lateral oscillation to said blade.

5. The apparatus of claim 4 wherein said supporting means includes a substantially vertically disposed bearing means between said blade and said framework, said bearing means being configured to allow limited articulation between the blade and the framework about the longitudinal axis of the bearing means.

6. The apparatus of claim 5 wherein said bearing means comprises a vertically elongated bearing element rigidly secured to the supporting framework; and a plurality of bearing members distributed vertically within the vertically elongated bearing element; and an elongated bearing part connected to the blade and to said bearing members.

7. The apparatus of claim 6 wherein the vertically elongated bearing element comprises a tube, said bearing members comprise bushings and the elongated bearing part comprises a pin connected to the upper end of the blade and extending through the bushings.

8. The apparatus according to claim 1 wherein a rigid yoke is rigidly connected to the upper end of the blade and the bearing means extends from the top of the yoke to the bottom thereof, said framework including portions rigidly connected to the bearing means at points located between the upper and lower edges of the yoke.

9. The apparatus according to claim 8 wherein the yoke comprises a rigid rectangular framework connected to the top of the blade and the bearing means is connected at its lower end to the bottom of the yoke and at its upper end to the top of the yoke.

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