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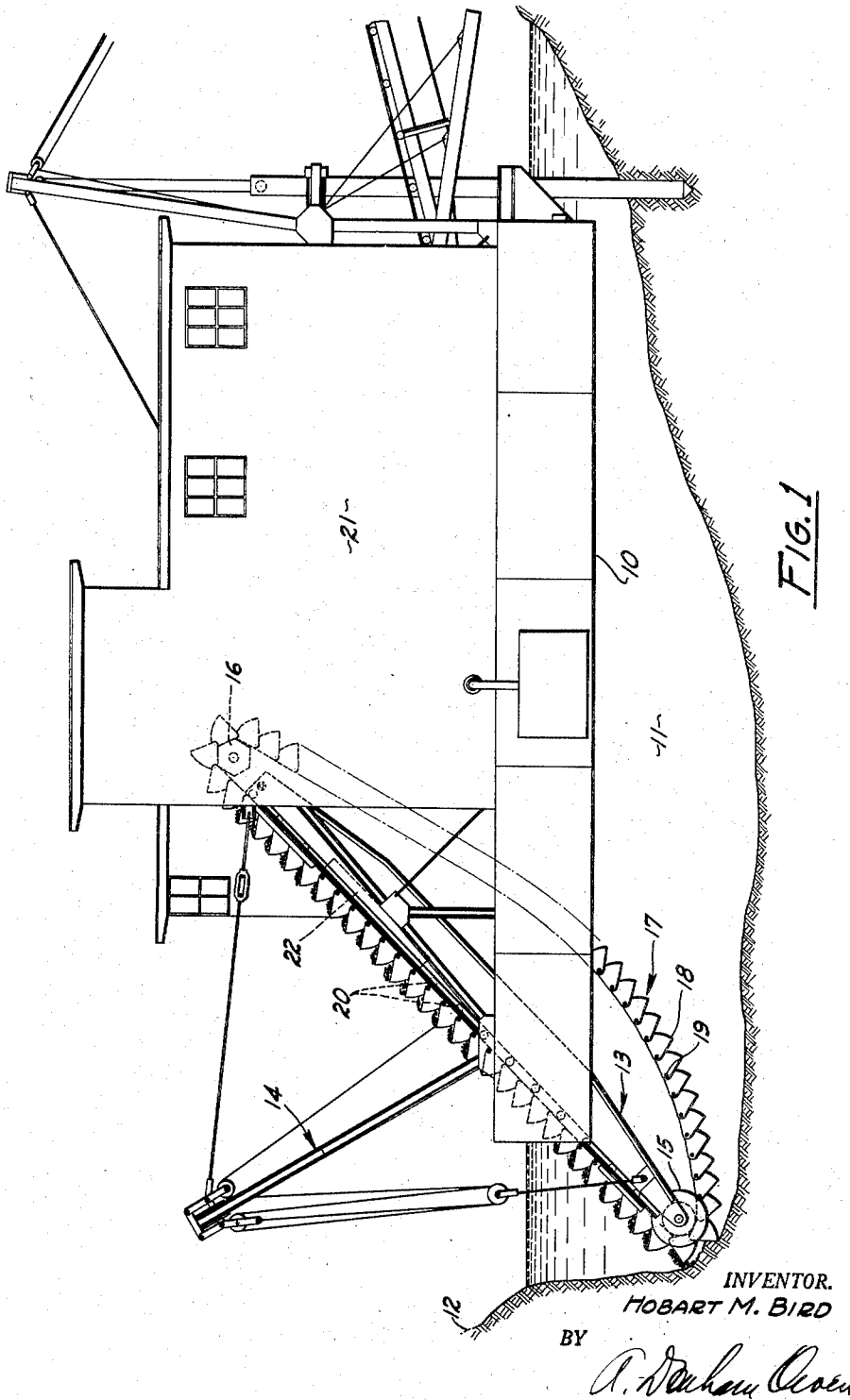
H. M. BIRD

2,620,060

DRIVE MECHANISM FOR ENDLESS BUCKET LINES

Filed Nov. 20, 1945

4 Sheets-Sheet 1



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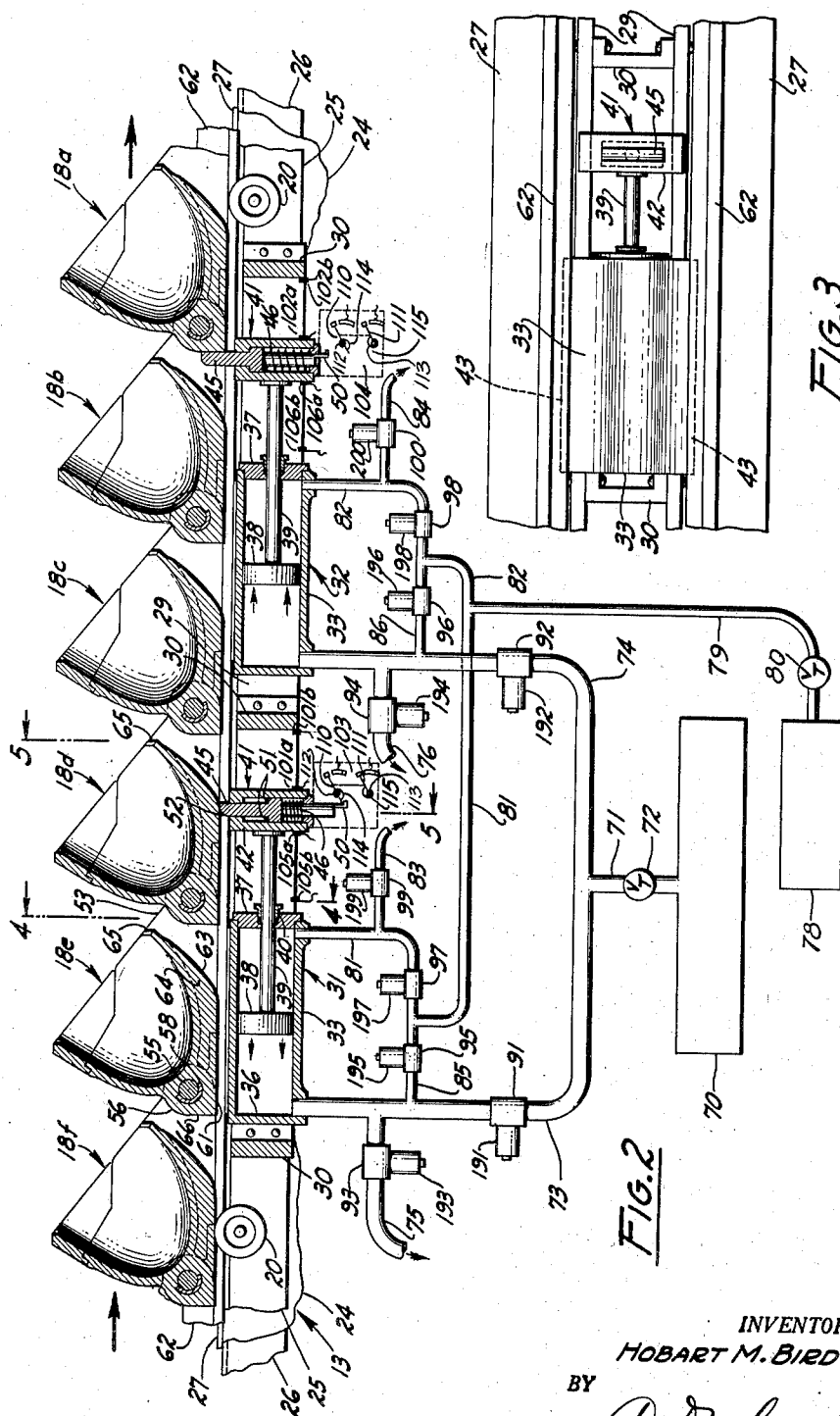
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DRIVE MECHANISM FOR ENDLESS BUCKET LINES

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4 Sheets-Sheet 2



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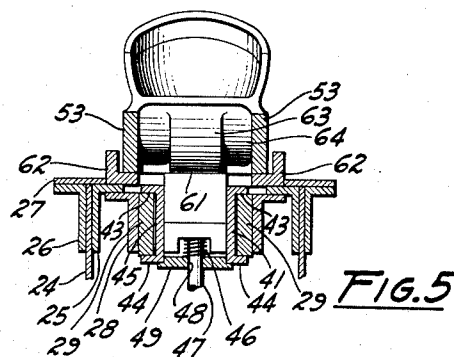
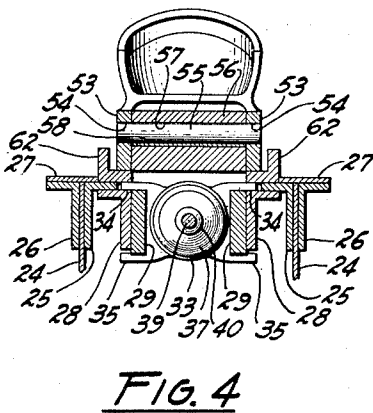
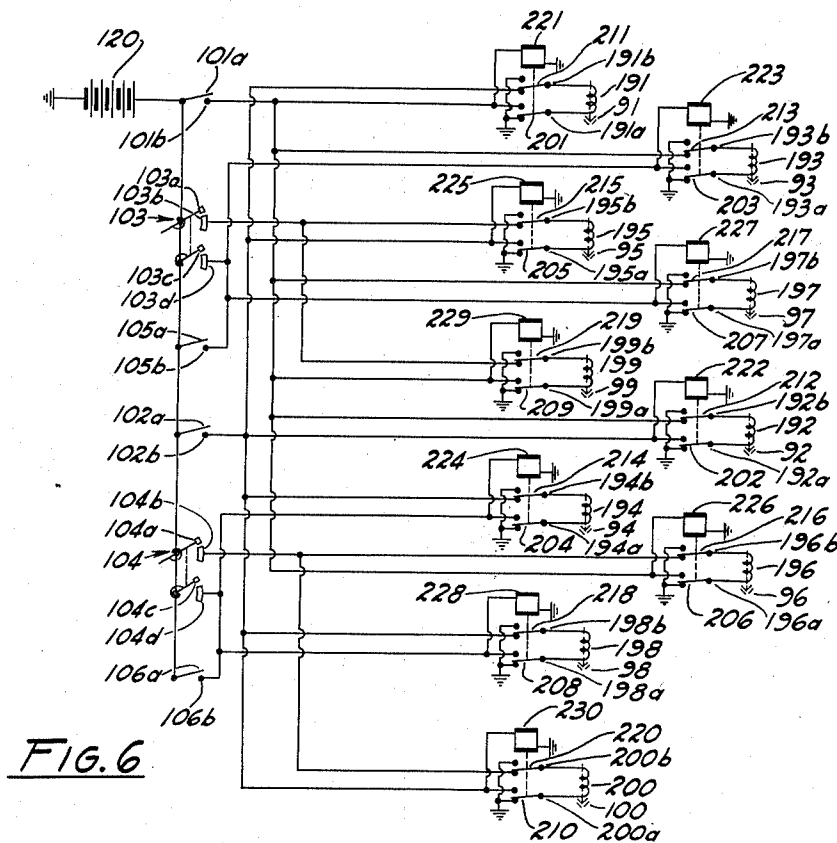
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DRIVE MECHANISM FOR ENDLESS BUCKET LINES

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4 Sheets-Sheet 3



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2,620,060

DRIVE MECHANISM FOR ENDLESS BUCKET LINES

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4 Sheets-Sheet 4

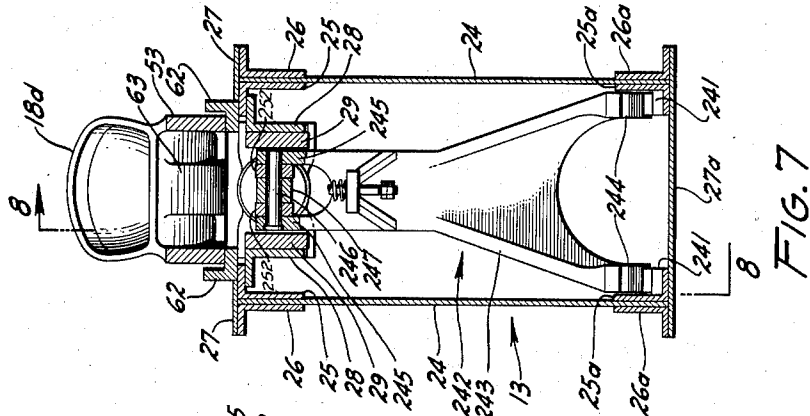


FIG. 7

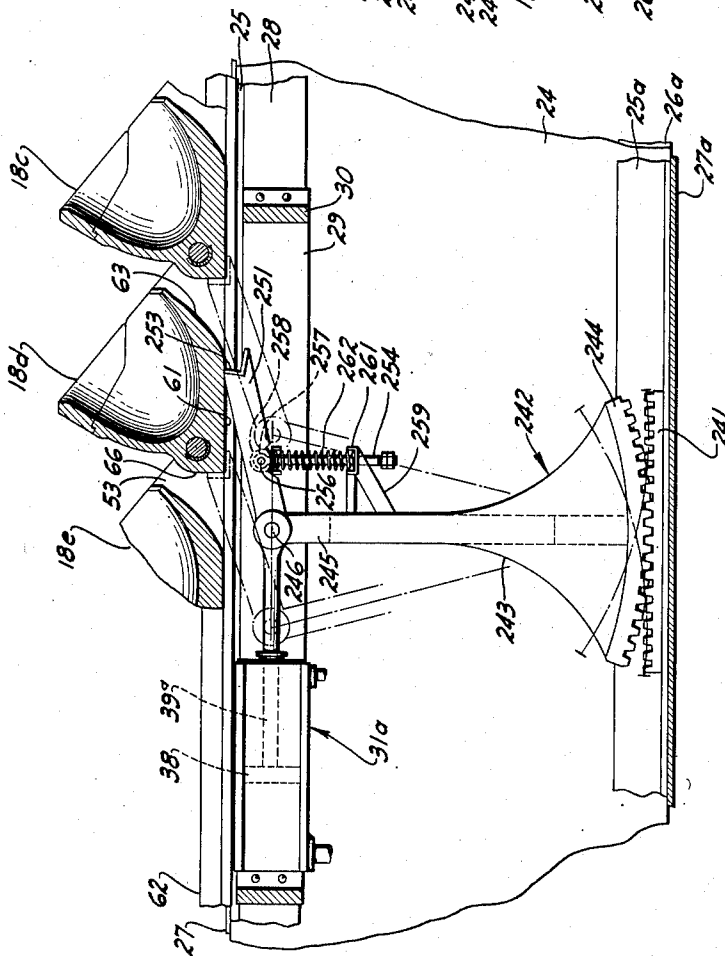


FIG. 8

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UNITED STATES PATENT OFFICE

2,620,060

DRIVE MECHANISM FOR ENDLESS BUCKET LINES

Hobart M. Bird, Portland, Oreg.; Helen Marie Bird, executrix of said Hobart M. Bird, deceased, assignor of fifty-five per cent to Helen M. Bird and forty-five per cent to Hobart M. Bird, both of Portland, Oreg.

Application November 20, 1945, Serial No. 629,830

15 Claims. (Cl. 198—203)

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This invention relates to placer mining dredges of a type widely used in mining gold, platinum, and tin from gravel deposits of the ore. More particularly, the invention relates to a new and improved endless bucket line and bucket line driving mechanism for placer mining dredges and other digging machines.

Insofar as I am aware, all of the placer mining dredges of the endless bucket line type that have been built and used commercially heretofore have employed a bucket line and driving mechanism thereof of the same basic design, such improvements as have been made over a period of many years having involved mere refinements of that design by the substitution of better materials of construction, new detail designs, improved controls, etc., and by increasing the size and capacity of the machine. The actual digging mechanism remained fundamentally the same since the first commercial dredges of this type were built. These comprised an inclined "digging ladder" supporting an endless bucket line that extended along the upper surface of the ladder, over an upper driving "tumbler" mounted on the upper end of the ladder, below the ladder in a catenary curve to a lower idler tumbler mounted on the lower end of the ladder, around the lower idler tumbler, and back to the upper surface of the ladder. The lower end of the ladder was forced against the bank of gravel being dug, generally a considerable distance below the surface of a body of water in which the entire dredge was floated on a boat, and the buckets on the bucket line bit into the bank as they were pulled around the lower idler tumbler, picking up a load of gravel. The loaded buckets were then pulled up the inclined upper surface of the ladder and were caused to dump their loads into a suitable hopper as they rounded the upper tumbler, from which point the buckets traveled back down to the lower tumbler along the catenary curve of the portion of the bucket line suspended below the ladder. To provide rolling support for the loaded buckets as they moved up the ladder, a series of transversely extending rollers were mounted in spaced-apart relation along substantially the entire upper surface of the ladder between the tumblers.

In more recent designs, the lower tumbler merely constituted a round roller or pulley of relatively large diameter, while in all designs the upper tumbler functioned as a crude driving sprocket for the bucket line in the form of a four, five, or six sided roller driven by a suitable source of power that was mounted on the dredge and connected with the upper tumbler through a gear train of massive construction. The source of power generally employed was an alternating current or direct current motor, with an A. C. to

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D. C. converter comprising a part of the power source when a direct current motor was employed.

The bucket line comprised a series of heavy, cast steel buckets pivotally secured together in end-to-end relation by large bucket pins, so that the assembly formed an endless chain in which each bucket constituted a single link. The several sides of the upper tumbler were identical with each other and were provided with replaceable wear plates that were adapted to engage the bottoms of the buckets as they were pulled around the tumbler. The intersections of the planes of the surfaces of the wear plates were spaced apart around the tumbler by distances equal to the center-to-center spacing of the forward and rearward bucket pins of each bucket, this distance being referred to as the "pitch" of the tumbler and of the bucket line. With this relation between the dimensions of the tumbler and the dimensions of the buckets, one revolution of the upper tumbler produced a travel of the bucket line, measured in bucket lengths, equal to the number of sides on the tumbler.

When driving the bucket line in this manner, the upper tumbler necessarily applied a pull of considerable magnitude to the line during normal digging operations, and the entire loaded portion of the line, from the lowermost bucket in contact with the lower tumbler to the last bucket remaining in driven engagement with the upper tumbler, was subjected to severe tensile stresses. The stresses in each bucket were concentrated adjacent the forward and rearward eyes or bearings in which the bucket pins were mounted, and these stresses reached a maximum in the buckets as they were pulled over the upper tumbler, at which time adjacent buckets were caused to rotate with respect to each other about their connecting pins. Thus, rotation of the bucket pins in their bearings occurred while they were carrying their maximum load, which was the worst possible time for them to be subjected to such loading during the entire course of their travel.

Because the working conditions to which a bucket line was subjected involved repeated immersion in the body of water in which the digging was performed, satisfactory lubrication of the pivotal connections between the buckets was not feasible. As a result, the friction in these connections reached tremendous proportions, particularly while the connections were subjected to their maximum load, and the poorly lubricated wearing surfaces of these connections produced a constant, high pitched, grinding scream that was a characteristic of all placer mining dredges of this type. This caused extremely rapid wear on the bucket pins and on the bearings in which they were mounted, and the pitch of the bucket line

was increased by the amount of this wear until the dredge was shut down for overhauling the pivotal connections. A further increase in the pitch of the bucket line frequently resulted from actual elongation of the buckets in the regions of their forward and rearward pin bearings under the great stresses applied to the bucket line. Such elongation not only increased the pitch of the bucket line directly, but also deformed the eyes in which the pin journals were mounted, which accelerated the rate of wear of both the bucket pins and bearings and, consequently, accelerated the rate of increase of the pitch of the bucket line.

The driving surfaces of the upper tumbler and the lower surfaces of the buckets engaged thereby were likewise without lubrication, and these surfaces also wore rapidly under the drastic service conditions to which they were subjected. This wear gradually reduced the effective diameter of the upper tumbler, which meant a corresponding gradual reduction in the pitch of the upper tumbler at a time when the pitch of the bucket chain was increasing.

In order that this type of driving mechanism might operate at all satisfactorily, it was necessary that the pitch of the bucket line be quite uniform and substantially equal to the pitch of the upper tumbler. Because of the necessity for this uniformity and correspondence in pitch, the gradual increase in the pitch of the bucket line and the simultaneous gradual decrease in the pitch of the upper tumbler, made frequent shut-downs of dredges imperative for replacing bucket pins and bushings in the bucket line and for replacing wear plates on the upper tumbler. When substituting a new bucket for a worn or damaged one in the bucket line, care had to be taken that the pitch of the new bucket matched the pitch of the other buckets in the line, and this presented another troublesome maintenance problem because of the tendency of the buckets to elongate substantially between the center lines of their forward and rearward pin bearings. As a result of the characteristics described, the prior art dredges required almost constant maintenance of a most difficult and expensive type.

Even when regular and frequent pitch adjustments were made in order to keep the driving mechanism working at its best, operation of the bucket line was highly unsatisfactory because of other characteristics of the machine for which no remedy has ever been found. As the upper tumbler rotated, its non-circular contour produced an alternate rising and falling of the bucket line adjacent the tumbler, which in turn produced what is known as "whip" in the bucket line. One effect of whip was an increase in the rotation of the bucket pins, which produced still further wear in their journals and in their bearings. Also, because the digging resistance was characterized by sudden variations due to changes in the composition of the bank into which the buckets were biting, this whip had a tendency at times to build up to dangerous proportions. The normally severe stresses in the bucket line were accentuated thereby, and sudden shock loads, that frequently occurred when a bucket struck a boulder too large to handle, imposed serious over-loads on the ladder rollers and on the gear train through which the upper tumbler was driven. Because the digging stresses were carried to the upper tumbler mounted high up on the dredge, shock loads were occasionally severe enough to capsize the dredge.

As the difference in pitch between the bucket

line, or any portion thereof, and the upper tumbler increased with wear, the hammering and vibration increased in direct proportion, and this further accelerated the rate of wear both in the bucket line and on the driving surfaces of the upper tumbler. If the difference in pitch was permitted to reach a certain critical dimension, dependent to some extent upon the speed at which the bucket line was driven, the buckets had a tendency to slip on the upper tumbler, and the resulting shocks were sufficient at times to break the bucket line. When this occurred, the falling line, depending upon where it broke, was easily capable of sinking the dredge by dropping into the "well hole" of the boat. To avoid such danger, the speed of travel of variable speed bucket lines had to be reduced as the pitch differential increased until the dredge could be shut down for the difficult and expensive job of re-matching the pitch of the bucket line with the pitch of the upper tumbler. If, as was usually the case, a constant speed drive was employed, greater and greater caution had to be exercised in feeding the buckets into the gravel being dug thereby as the condition of the bucket line and upper tumbler deteriorated. By "tenderly" probing into the gravel in such a manner that the buckets would not dig too deeply into pockets of difficult ground and would tend to glance off boulders too large to handle, the danger of serious damage to deteriorating equipment could be lessened, but only at the expense of substantially decreased digging efficiency. Thus, the effective digging speed at which the dredge could be operated was dependent upon the degree to which a uniform and accurate fit of the bucket line on the driving surfaces of the upper tumbler was maintained.

Even under most favorable conditions, the digging resistance at the lower tumbler, the pounding and jarring of the loaded buckets on the upper tumbler, and the whip of the bucket line against the ladder created a tremendous, vibrating and pounding, live load that caused the dredge to tremble and shudder continuously. The structural design of the entire dredge was dictated by the extraordinarily severe service conditions to which it was subjected, and the cost of building the boat and all of the dredge structure mounted thereon was increased by these conditions.

In spite of the above mentioned defects of all of the prior art dredges of this type, and still other defects too numerous to describe, no suitable substitute for this mechanically inefficient device has heretofore been devised. Wherever placer dredging has been and is now being conducted, throughout the world, operators have had to accept the many difficulties and dangers inherent in the design, as well as the expensive, difficult, and time-consuming maintenance entailed thereby.

It is an object of the present invention to provide a placer mining dredge of the endless bucket line type having a fundamentally new and improved bucket line driving mechanism.

Another object of the invention is to eliminate most of the pounding and vibration that have been inherent in bucket line drives known heretofore.

Another object of the invention is to provide a bucket line drive that may be carried by a dredge structure of far simpler and cheaper design than has been practical heretofore.

Another object of the invention is to provide a bucket line and a drive therefor that entail

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only a small part of the maintenance time and expense formerly required.

Another object of the invention is to provide a bucket line drive of such a character that substantially all danger of breaking a bucket line may be avoided while operating the dredge continuously at higher speeds and for far longer periods of time between shutdowns for maintenance than has heretofore been possible, even while digging in the most difficult types of gravel deposits.

Another object of the invention is to provide a bucket line drive of such a character that its operation will not be materially affected by non-uniform pitch in the bucket line or by changes in its pitch, or in the pitch of the upper tumbler, or both.

Another object of the invention is to provide a bucket line drive having no tendency to whip as a result of variations in the digging resistance encountered by the buckets.

Another object of the invention is to provide a mechanism that will apply a driving force to a bucket line at points thereon below the upper tumbler.

Another object of the invention is to provide a mechanism that will apply a driving force sequentially to the buckets in a bucket line while the associated bucket pins are not rotating in their bearings.

Another object of the invention is to provide a bucket line drive that reduces the fractional part of the length of a bucket line subjected at any given moment to the total load due to digging resistance.

Another object of the invention is to provide a bucket line drive capable of applying a driving force to the bucket line uniformly and smoothly at all times and capable of being so controlled that it will never apply more than a selected, safe, maximum, driving force.

Another object of the invention is to provide a more flexible drive for a bucket line that will reduce shock loads thereon due to sudden increases in the digging resistance encountered by the buckets and that is readily adjustable to provide any desired bucket line speed up to the maximum speed of the machine.

Still other objects and advantages of the invention will become apparent from the following detailed description of presently preferred embodiments thereof, taken in conjunction with the accompanying drawings in which:

Fig. 1 is a somewhat schematic elevational view of a placer mining dredge of the type to which the present invention relates, and shows in a general way how the digging ladder and its associated bucket line are mounted on the dredge barge or boat that is floating in a body of water, and how the digging ladder holds the lowermost buckets against a gravel bank into which the buckets are caused to dig as they pass around the lower idler tumbler;

Fig. 2 is a fragmentary, vertical, sectional view taken longitudinally through the portion of the digging ladder that carries a bucket line drive embodying the present invention, and show a portion of the upper reach of the bucket line, the relation between the driving mechanism and the buckets to which the driving force is applied, a schematic representation of a hydraulic system for supplying the driving power, and a number of electrical contacts employed in an electrical circuit by means of which the hydraulic system is controlled;

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Fig. 3 is a plan view of a portion of the driving mechanism shown in Fig. 2, the buckets in the bucket line being eliminated in order to show the driving mechanism more clearly;

Fig. 4 is a fragmentary, transverse, sectional view along a plane indicated by the line 4—4 in Fig. 2, and shows the construction of a portion of one of the buckets in the bucket line and how it may be supported with respect to the driving mechanism while traveling above it along the digging ladder, and also how one part of the driving mechanism may be secured to the digging ladder on which the driving mechanism is mounted;

Fig. 5 is a fragmentary, transverse, sectional view along a plane indicated by the line 5—5 in Fig. 2, and shows one of the buckets in front elevation, a reciprocable part of the driving mechanism in section, and how this part of the driving mechanism may be mounted for movement longitudinally of the digging ladder and parallel to the path of travel of the buckets in the upper reach of the bucket line;

Fig. 6 is a wiring diagram for an electric circuit by means of which the various valves in the hydraulic power supplying system may be operated in response to the closing of the various pairs of electrical contacts shown in Fig. 2 while the bucket line drive passes through different steps in its cycle of operation;

Fig. 7 is an elevational view, largely in transverse section, of a portion of a digging ladder in which a modified mechanism is provided for transmitting force from a reciprocating piston to the buckets in the bucket line; and

Fig. 8 is a longitudinal, vertical, sectional view of the mechanism shown in Fig. 7, the section being taken as indicated by the line 8—8 in Fig. 7.

I want it clearly understood that the present description of my invention is made for the purposes contemplated in Revised Statutes Sec. 4388 and not with any idea that my invention is to be limited to the specific forms of mechanisms used herein to illustrate its principles. Broadly viewed, the invention comprises a reciprocable form of drive applied to the bucket chain along its length at the point of greatest effectiveness and the least wear and strain.

Referring first to Fig. 1, the barge or boat 10, upon which the entire dredge assembly is carried, is shown floating in a body of water 11 while anchored in position for digging into a gravel bank 12. An inclined digging ladder, generally designated 13, which may be of any conventional design except in particulars described hereinafter, is supported on the barge in the usual manner by a hoist and associated rigging, generally designated 14; and the digging ladder is provided at its opposite ends with a round lower tumbler 15 and an upper tumbler 16 having a suitable number of mating surfaces disposed about its perimeter. The lower tumbler 15 may be mounted for free rotation about its axis in the customary manner; and the upper tumbler 16, instead of being mounted in association with the usual bull gear driven through a gear reduction system by an electric motor, is likewise mounted for free rotation about its axis.

An endless bucket line, generally designated 17, comprises a series of identical buckets 18 pivotally secured together in end-to-end relation by a series of bucket pins 19. The bucket line is mounted on the digging ladder 13 so as to form a substantially straight upper reach extending

along the upper surface of the ladder between

the tumblers 15 and 16, and a lower reach hanging below the ladder from the tumblers and having the approximate contour of a catenary curve. At opposite ends of its upper and lower reaches, the bucket line passes over the two tumblers, which serve as pulleys or sprockets and permit the loaded buckets to move up the ladder along the path of the upper reach of the bucket line, around the upper tumbler for dumping their loads, back down along the curved path of the lower reach of the bucket line to a digging position, and around the lower tumbler as they dig into a gravel bank to pick up new loads. By manipulating the hoist 14 in a well known manner, the buckets are forced against the gravel bed 12 as they round the lower tumbler.

A series of transversely extending rollers 20, mounted in spaced-apart relation along a substantial portion of the length of the upper surface of the ladder between the tumblers, provide rolling support for the loaded buckets as they move up the ladder. The upper end of the ladder, adjacent the upper tumbler, projects into a dredge house 21 that contains a hopper for receiving gravel dumped from the buckets as they round the upper tumbler and that also contains other conventional equipment for receiving and processing gravel from the hopper, which equipment bears no direct relation to the present invention, and therefore, has not been shown in the drawings.

A mechanism for driving the bucket line in accordance with the present invention may be mounted directly on the ladder 13 between opposite sides thereof, and its preferred position along the length of the ladder is shown in Fig. 1 by the dotted outline designated 22. A preferred form of such mechanism is shown in more detail in Figs. 2, 3, 4, and 5. The digging ladder may be constructed in the form of a "built up" box girder having a pair of laterally spaced-apart side plates 24, a pair of upper interior stiffening angles 25, a pair of upper exterior stiffening angles 26, and a pair of top stiffening plates 27. (See Figs. 4 and 5.) With such a ladder construction, the bucket line driving mechanism may be mounted in any suitable manner between the side plates 24 and between the interior stiffening angles 25. In the present instance, the bucket line driving mechanism is supported within the framework of the ladder by a pair of parallel, spaced-apart, heavy angles 28 that are respectively welded or otherwise rigidly secured to the interior stiffening angles 25. To lend added rigidity to these supporting angles 28 and to provide true sliding surfaces for a reciprocating member described hereinafter, two heavy bars 29 are respectively secured to vertically disposed legs of the supporting angles in laterally spaced-apart relation. The supporting angles 28 and the bars 29 preferably extend the full length of the bucket line driving mechanism and are laterally braced at their opposite ends and midway between their ends by three cross-braces 30 having flanged ends that may be riveted or bolted directly to the opposed inner surfaces of the bars 29. (See Figs. 2 and 3.)

Between the first and second cross-braces 30 and between the second and third cross-braces, two identical devices, generally designated 31 and 32, are mounted for alternate operation in synchronized relation for applying a driving force sequentially to each bucket in the bucket line, whereby the upper reach of the bucket line is pushed along its path of travel up the ladder 13.

(See Fig. 2.) Since these two force-applying devices described to illustrate one form of my invention are identical, the following detailed description of one of them will be understood to apply also to the other, to which identical reference characters have been applied in the drawings for distinguishing certain corresponding parts.

Referring to the lowermost force-applying device 31 (Figs. 2, 3 and 4), a cylinder 33 is supported between the bars 29 adjacent one end thereof by means of a pair of upper flanges 34 and a pair of similar lower flanges 35 that extend the full length of the cylinder and may be formed integrally therewith as parts of a single casting. (See Fig. 4.) The upper flanges 34 respectively rest upon the upper edges of the two bars 29, and the lower flanges 35 respectively underlie and bear against the lower edges of the bars 29, the upper flanges being spaced from the lower flanges just enough for the bars to fit snugly therebetween. The casting forming the cylinder 33 and flanges 34 and 35 is preferably of such width that its opposite sides are respectively disposed in snug contact with the opposed inner surfaces of the bars 29. Thus, by welding or by other suitable attachment, the cylinder 33 may readily be rigidly anchored against movement in any direction with respect to the ladder 13 and be made capable of resisting large forces tending to cause such movement.

The cylinder 33 is closed at its lower end by an end wall or cylinder head 36 (Fig. 2), that may be cast integrally with the body of the cylinder, and is closed at its upper end by a removable cylinder head 37, that is secured in place in any suitable manner so as to resist a substantial force tending to dislodge it. A piston 38 is mounted within the cylinder 33 for reciprocating movement longitudinally thereof, and a piston rod 39 is connected at one end to the piston and projects therefrom through an aperture therefor in the removable cylinder head 37 and through a suitable packing gland and associated packing 40 secured in the aperture.

At its opposite end, the piston rod 39 is secured to a crosshead, generally designated 41, that is adapted to reciprocate with the piston 38 and piston rod 39. (See Figs. 2, 3 and 5.) The crosshead 41 comprises a hollow block 42 (Figs. 2 and 3) having a pair of oppositely and outwardly extending upper flanges 43 (Fig. 5) and a pair of similar lower flanges 44. These upper flanges respectively rest upon the upper edges of the bars 29, and the lower flanges respectively underlie the lower edges of the bars 29, thus providing supporting and guiding surfaces for restraining the crosshead to rectilinear movement along the ladder 13.

Partially within the hollow block 42 of the crosshead 41, a detent type of pushing element 45 is mounted for projection and retraction under the influence of a helical spring 46 in a direction normal to the path of travel of the crosshead and of the upper reach of the bucket line. (See particularly Figs. 2, and 5.) The lower part of the pushing element 45 includes a cylindrical shaft 47 (Fig. 5) that projects with a sliding fit through an aperture 48 in a bottom plate 49 of the block 42 and beyond the bottom plate a substantial distance when the pushing element is fully retracted against the spring 46. The bottom plate 49 is removable but is firmly secured to the bottom of the block 42 in any desired man-

ner, as by suitable bolts (not shown), and the spring 46 surrounds the shaft 47 and is held under compression between the bottom plate 49 and the main body portion of the pushing element 45. Thus, the spring 46 continually urges the pushing element toward the upper reach of the bucket line, the movement of the pushing element in this direction to a fully projecting position being limited by contact between a pair of shoulders 51 on the pushing element and a pair of inwardly projecting flanges 52 on the upper portion of the block 42. (See Fig. 2.) A switch tripping arm 50 may be carried by and may project beyond the lower end of the shaft 47 of the pushing element 45 for tripping a double switch, that may be mounted on the crosshead block 42 and that is described in detail hereinafter.

Each bucket 18 in the bucket line is partly of conventional design and includes the usual, laterally spaced-apart, forwardly-projecting ears 53 through which aligned eyes 54 are drilled to serve as bearings for a bucket pin 55, and also includes a single rearwardly projecting boss 56 through which a single eye 57 is drilled for accommodating another bucket pin 55. (See Figs. 2, 4, and 5.) A removable, half-cylindrical bushing 58 is mounted in a seat within the single eye 57 and is disposed so as to carry substantially the entire bearing load. (See Figs. 2 and 4.) The ears 53 of each bucket straddle the boss 56 of the preceding bucket with the two eyes 54 and the single eye 57 aligned to receive the common bucket pin, whereby each bucket is pivotally connected to the immediately preceding and succeeding buckets in the bucket line. The bucket pins 55 may be secured in any suitable manner in the forward eyes 54 with which they are associated so that relative rotation between the pins and the forward eyes is prevented, relative rotation being permitted only between these pins and the associated bosses 56 containing the replaceable bushings 58.

The bottom of each bucket is flat over a considerable area, whereby there is provided a supporting surface 61 (Figs. 2 and 5) adapted to slide smoothly along a pair of laterally spaced-apart track members 62 (Figs. 2, 4 and 5) that may extend the full length of the ladder between the upper and lower tumblers, and adapted to ride smoothly over the bucket supporting rollers 20. This flat supporting surface preferably extends forwardly along a portion of the length of each of the two ears 53, whereby the length of the supporting surface in the direction of travel of the buckets is increased. Midway between the two ears 53 (see Figs. 2 and 5), each bucket is provided with a curved cam surface 63 on a rib 64 formed integrally with the bucket, the cam surface extending rearwardly and downwardly from adjacent a forward lip 65 of the bucket into tangency with the sliding surface 61. The cam surface 64 on each bucket is adapted to engage the upper ends of the pushing elements 45 of the force applying devices 31 and 32 for depressing them to permit the bucket to pass thereby. The rearward side of each boss 56 is also flat for the full width of the boss, the plane of the surface thereof being normal to the adjacent sliding surface 61 of the bucket. (See Figs. 2, and 4.) This side of each boss 56 forms a driving surface 66 adapted to be engaged sequentially by the forward sides of the pushing elements 45 in their fully projected positions and while they are moving forwardly along their respective paths of travel.

After each pushing element has performed its pushing operation against one bucket while moving forwardly along its path of travel with the bucket line, the direction of movement of that pushing element is reversed, and the element is cammed to its retracted position as it passes rearwardly under the rib 64 of the succeeding bucket. The instant this pushing element has passed rearwardly beyond the driving surface 66 of the succeeding bucket, it is urged to a fully projecting position again by the spring 46 associated therewith. Reversal of the direction of movement of this pushing element at this point, places the element again in driving engagement with the bucket line. By causing the rearward stroke of each pushing element to occur more rapidly than its forward driving stroke, the operation of the two driving mechanisms 31 and 32 may readily be coordinated in such a manner that one pushing element always completes its rearward stroke and arrives in a position for driving the bucket line again before the other pushing element has completed its driving stroke. Thus, at all times, one of the pushing elements may be maintained in driving engagement with the bucket line, and the bucket line may be driven at a uniform speed under a uniform driving force.

Any other form of pusher foot for engaging the buckets may be used since they will accomplish the same result.

In order to drive the pistons 38 of the two driving mechanisms 31 and 32 in a readily controllable manner, whereby the pistons may be reversed at different points along their paths of travel according to the timing requirements of the driving arrangement, I prefer to employ hydraulic pressure within the two cylinders 33, alternately on both ends of the pistons 38 therein. A suitable hydraulic system for feeding a controlled supply of hydraulic fluid to these cylinders will now be described with reference to the schematic representation thereof included in Fig. 2 of the drawing.

A reservoir 70 containing a suitable hydraulic fluid, maintained under high pressure in any conventional manner, is connected by means of a high pressure header 71, having a throttling valve 72 therein, to a pair of distributing conduits 73 and 74 that respectively communicate with the interiors of the cylinders 33 of the force-applying devices 31 and 32 at corresponding ends of the cylinders for supplying fluid under high pressure to one end of the pistons 38 contained in the cylinders. The end of each cylinder to which fluid under high pressure is supplied will hereinafter be referred to as the high pressure end thereof. For exhausting fluid from the high pressure ends of the cylinders 33, a pair of exhaust conduits 75 and 76 are respectively connected to the distributing conduits 73 and 74 at points therealong closely adjacent the cylinders.

A reservoir 78 containing the same type of hydraulic fluid, maintained under a relatively low pressure in any conventional manner, is connected by means of a low pressure header 79, having a throttling valve 80 therein, to a pair of distributing conduits 81 and 82 that respectively communicate with the interiors of the cylinders 33 at the ends thereof, hereinafter referred to as the low pressure ends, opposite their high pressure ends. For exhausting fluid from the low pressure ends of the cylinders 33, a pair of exhaust conduits 83 and 84 are respectively connected to the low pressure distributing conduits

81 and 82 at points therealong closely adjacent the cylinders.

In order that hydraulic fluid under low pressure may also be supplied to the high pressure ends of the cylinders 33 for a purpose to be described in due course, an interconnecting low pressure conduit 85 is connected at its opposite ends with the low pressure distributing conduit 81 and with the high pressure distributing conduit 73 at points therealong adjacent the low and high pressure exhaust conduits 83 and 75. Similarly, an interconnecting low pressure conduit 86 is connected at its opposite ends with the low pressure distributing conduit 82 and with the high pressure distributing conduit 74 at points therealong adjacent the low and high pressure exhaust conduits 84 and 76.

A number of valves are disposed in the various distributing conduits, exhaust conduits, and inter-connecting conduits described above for controlling the flow of fluid therethrough. For this purpose, any of many well known forms of such valves may be employed, the only critical requirements being that they be quick acting from fully open to fully closed positions, and vice versa, and that they remain in either their fully open or fully closed positions until actuated to the opposite condition. A preferred and well known type of valve-actuating mechanism is one employing compressed air cylinders for power with the compressed air supply to and exhaust from the cylinders controlled by solenoid-actuated valves. However, the most suitable form of valve and actuating mechanism therefor is obviously a matter of choice best determined in view of the specific hydraulic pressures and volumes of fluid to be handled in any specific bucket line drive. For simplicity in describing the present invention, the various valves are merely schematically illustrated in Figs. 2 and 6, and respective solenoid controls therefor are schematically shown in association therewith.

A pair of these valves, designated 91 and 92, are respectively disposed in the high pressure distributing conduits 73 and 74 between the high pressure header 71 and the high pressure exhaust conduit 75 or 76 and low pressure inter-connecting conduit 85 or 86 associated therewith; another pair of these valves, designated 93 and 94, are respectively disposed in the high pressure exhaust conduits 75 and 76; another pair of these valves, designated 95 and 96, are respectively disposed in the low pressure interconnecting conduits 85 and 86; another pair of these valves designated 97 and 98, are respectively disposed in the low pressure distributing conduits 81 and 82; and still another pair of these valves, designated 99 and 100, are respectively disposed in the low pressure exhaust conduits 83 and 84.

Solenoids 191 to 200, operatively associated with the valves 91 to 100, respectively, may be energized at appropriate times for operating the pistons 38 in the desired coordinated relation by means of three sets of electrical contacts on each of the force-applying devices 31 and 32. Each of these sets of contacts comprises one or more movable contacts and a corresponding number of stationary contacts suitably arranged in the electrical circuit shown in Fig. 6 for energizing selected ones of the valve solenoids when contact is made between the movable and stationary contacts of the set.

While the piston 38 of the upper force-applying device 32, for example, is moving forward on a working stroke, as indicated by arrows in Fig. 2, the associated high pressure supply valve 92 and

low pressure exhaust valve 100 are open, and the associated high pressure exhaust valve 94, inter-connecting valve 96, and low pressure supply valve 98 are closed, whereby fluid under high pressure is supplied from the high pressure reservoir 70 to the high pressure end of the cylinder 33 of this force-applying device and whereby fluid may be freely exhausted from the low pressure end of this cylinder. At the same time, the piston 38 of the other force-applying device 31 is at first moving rearwardly on its return stroke, as indicated by arrows in Fig. 2, with the associated high pressure exhaust valve 93 and low pressure supply valve 97 open and with the associated high pressure supply valve 91, inter-connecting valve 95, and low pressure exhaust valve 99 closed, whereby fluid under low pressure is supplied from the low pressure reservoir 78 to the low pressure end of the cylinder 33 of this force-applying device and fluid may be freely exhausted from the high pressure end thereof.

Before the piston 38 of the upper force-applying device 32 reaches the end of its working stroke, the pushing element 45 of the other force-applying device 31 will have passed under the bucket 18d in the moving bucket line while being cammed to a fully retracted position, and will have moved far enough with respect to the bucket 18d to have been fully projected again behind the driving surface 66 of this bucket. On moving to its fully projected position behind the bucket 18d, this pushing element 45 carries its associated switch tripping arm 50 past an adjacent double switch 103, carried by the crosshead block 42 and described hereinafter, for completing two circuits momentarily by swinging one movable contact 103a into contact with a stationary contact 103b and another movable contact 103c into contact with a second stationary contact 103d. (See Fig. 6.) Completion of these circuits energizes the appropriate solenoids for closing the high pressure exhaust valve 93 and low pressure supply valve 97 and for opening the interconnecting valve 95 and low pressure exhaust valve 99, whereby fluid under low pressure is supplied from the low pressure reservoir 79 through the interconnecting conduit 85 and through a portion of the high pressure distributing conduit 73 to the high pressure end of the cylinder of the lower force-applying device 31, and whereby fluid may be freely exhausted from the low pressure end of this cylinder. Under these conditions, the direction of travel of the piston 38 and crosshead 41 of the lower force-applying device 31 is reversed, and the associated pushing element 45 is caused to follow the bucket 18d in contact with the driving surface 66 thereof, without, however, applying any substantial driving force thereto because of the low pressure exerted on the driving piston.

When the piston of the upper force-applying device 32 reaches the end of its working stroke, another circuit is completed momentarily by contact of a movable contact 102a, carried by the crosshead 41, with a stationary contact 102b, mounted on the uppermost cross-brace 30 of the ladder 13. (See Figs. 2 and 6.) Completion of this circuit energizes the appropriate solenoids for closing the high pressure supply valve 92, interconnecting valve 95, and low pressure exhaust valve 100 and for opening the high pressure supply valve 91, high pressure exhaust valve 94, and low pressure supply valve 98, whereby fluid under low pressure from the low pressure reservoir 78 is supplied to the low pressure end of the

cylinder 33 of the upper force-applying device 32 and fluid may be freely exhausted from the high pressure end thereof, and whereby fluid under high pressure from the high pressure reservoir 70 is supplied to the high pressure end of the cylinder 33 of the lower force-applying device 31. Under these conditions, the direction of travel of the piston of the upper force-applying device 32 is reversed, and the pushing element 45 on the associated crosshead 41 is cammed to its retracted position as it moves rearwardly from a driving position with respect to the bucket 18a toward a new driving position with respect to the next succeeding bucket 18b. Simultaneously, the increased pressure of the fluid supplied to the high pressure end of the cylinder of the lower force-applying device 31 causes the associated pushing element 45 to exert its full driving force on the driving surface 66 of the bucket 18d, so that a continuous driving force is applied to the bucket line as a whole.

When the pushing element 45 of the upper force-applying device 32 has been moved rearwardly with respect to the bucket 18b sufficiently to be fully projected behind the driving surface 66 thereof, the projecting movement of the pushing element causes its associated switch tripping arm 50 to pass an adjacent double switch 104, similar to the double switch 103, for completing two circuits momentarily by swinging one movable contact 104a into contact with a stationary contact 104b and another movable contact 104c into contact with a second stationary contact 104d. Completion of these two circuits energizes the appropriate solenoids for closing the high pressure exhaust valve 94 and low pressure supply valve 98 and opening the interconnecting valve 96 and low pressure exhaust valve 100, whereby fluid under low pressure is supplied from the low pressure reservoir 78 through the interconnecting conduit 86 and through a portion of the high pressure distributing conduit 74 to the high pressure end of the cylinder of the upper force-applying device 32, and whereby fluid may be freely exhausted from the low pressure end of this cylinder. Under these conditions, the direction of travel of the piston 38 and crosshead 41 of the upper force-applying device 32 is reversed again, and the associated pushing element 45 is caused to follow the bucket 18b in contact with the driving surface 66 thereof, without, however, applying any substantial driving force thereto because of the low pressure exerted on the piston.

When the piston of the lower force-applying device 31 reaches the end of its working stroke, another circuit is completed momentarily by contact of a movable contact 101a, carried by the crosshead 41, with a stationary contact 101b, mounted on the intermediate cross-brace 30 between the two force-applying devices. Completion of this circuit energizes the appropriate solenoids for closing the high pressure supply valve 91, interconnecting valve 96, and low pressure exhaust valve 99 and for opening the high pressure supply valve 92, high pressure exhaust valve 93, and low pressure supply valve 97, whereby fluid under low pressure is supplied to the low pressure end of the cylinder of the lower force-applying device 31 and fluid may be freely exhausted from the high pressure end thereof, and whereby fluid under high pressure is supplied to the high pressure end of the cylinder of the upper force-applying device 32. Under these conditions, the direction of travel of the piston of

the lower force-applying device is again reversed, and the pushing element 45 on the associated crosshead 41 is cammed to its retracted position as it moves rearwardly from a driving position with respect to the bucket 18d toward a new driving position with respect to the next succeeding bucket 18e. Simultaneously, the increased pressure of the fluid supplied to the high pressure end of the cylinder of the upper force-applying device 32 causes the associated pushing element 45 to exert its full driving force on the driving surface 66 of the bucket 18b, thus again maintaining the continuity of the driving force applied to the bucket line as a whole.

The foregoing detailed description of the normal sequential operation of the solenoid controlled valves and the manner in which the two force-applying devices respond thereto, carried the entire mechanism through one complete cycle, during which each of the two force-applying devices moved through a full working stroke and a full return stroke, and the bucket line moved one full bucket length along its path of travel. From this it will be seen that each force-applying device moves the bucket line along its path of travel only half of one bucket length before the other force-applying device takes over the driving function and permits the former to execute its return stroke. Continued operation of the bucket line drive causes the force-applying devices to execute the same cycle of operation repeatedly, with the bucket line moving along its path of travel one full bucket length during each cycle.

While I have used two power-applying means for illustration, it is possible to employ more. For example, if three were employed, the controls could be set up so that at all times two of the power means could be working while the third was on its return stroke. This would tend to give a smoother operation.

Depending upon whether or not a proper ratio is maintained between the pressures in the high pressure reservoir 70 and in the low pressure reservoir 78, the crosshead 41 of one force-applying device 31, for example, may move too fast on its return stroke and reach the end thereof before the next bucket to be driven thereby has moved forward far enough for the pushing element 45 of this force-applying device to be projected into its driving position behind the driving surface 66 of this bucket. Should this occur, the crosshead 41 of this force-applying device would ram against the removable cylinder head 37 in its path, or the associated piston 38 would ram against the closed end of the cylinder in which it is mounted, unless means are provided for stopping the rearward movement of crosshead and piston in some other manner. For this purpose, a movable contact 105a is mounted on the rearward side of the crosshead of the lower force-applying device 31, and a stationary contact 105b is mounted in the path of travel of the contact 105a adjacent the associated removable cylinder head 37 in any suitable manner. When the crosshead of this force-applying device has moved rearwardly far enough to bring these two contacts 105a and 105b together, a circuit is completed that energizes the appropriate solenoids for closing all the then open valves in communication with this force-applying device, these valves being the high pressure exhaust valve 93 and the low pressure supply valve 97. This locks the associated piston 38 against further movement in either direction until con-

tinued forward movement of the upper reach of the bucket line permits the pushing element associated with this piston to be projected behind the bucket next to be driven thereby. Then, since the above mentioned valves 93 and 97 are already closed, subsequent tripping of the double switch 103 does not affect them and merely opens the interconnecting valve 95 and the low pressure exhaust valve 99 for causing the pushing element to follow the bucket next to be driven thereby in the usual manner until completion of the working stroke of the other force-applying device.

In order to protect the upper force-applying device 32 in the same manner, a movable contact 106a and a stationary contact 106b, are similarly associated therewith. When the crosshead of this force-applying device has moved rearwardly far enough to bring the two contacts 106a and 106b together, a circuit is completed that energizes the appropriate solenoids for closing all the then open valves in communication with this force-applying device, these valves being the high pressure exhaust valve 94 and the low pressure supply valve 98. This locks the associated piston 38 against further movement in either direction until continued forward movement of the upper reach of the bucket line permits the pushing element associated with this piston to be projected behind the bucket next to be driven thereby. Then, since the above mentioned valves 94 and 98 are already closed, tripping of the double switch 104 does not affect them and merely opens the interconnecting valve 96 and the low pressure exhaust valve 100 for causing the pushing element to follow the next bucket to be pushed thereby in the usual manner until completion of the working stroke of the lower force-applying device 31.

For more convenient reference, the relation between the various switches and the valves of the hydraulic system is summarized in the following table:

Switch Contacts	Valves Opened	Valves Closed
101a and 101b.....	92, 93, and 97....	91, 96, and 99.
102a and 102b.....	91, 94, and 98....	92, 95, and 100.
103a and 103b.....	95 and 99.....	
103c and 103d.....		93 and 97.
104a and 104b.....	96 and 100.....	
104c and 104d.....		94 and 98.
105a and 105b.....		93 and 97.
106a and 106b.....		94 and 98.

Referring now to the two double switches 103 and 104 carried by the crosshead blocks 42 and actuated by the switch tripping arms 50 on the shafts 47 of the pushing elements 45, each of these double switches comprises a pair of switch arms 110 and 111 that are respectively pivotally mounted on a pair of pins 112 and 113 and are constrained to swing together, as schematically illustrated in Figs. 2 and 6. The switch arm 110 is provided with an extension disposed in the path of the adjacent switch tripping arm 50 so that downward movement thereof will cause both switch arms 110 and 111 to swing through a small arc in a counterclockwise direction about their mounting pins (see Fig. 2) and upward movement of the switch tripping arm will cause them to swing through a small arc in a clockwise direction about their mounting pins. A pair of spiral springs 114 and 115 are respectively mounted on the pins 112 and 113 and are connected to the respectively associated switch arms 110 and 111 so that the springs are oppositely wound with respect to the pins and cooperate in

resisting swinging movement of the switch arms in either direction from a position of equilibrium. The switch arms 110 and 111 respectively carry the two movable contacts of the double switch for movement into contact with the associated stationary contacts only when the switch arms are swung clockwise. With this arrangement, upward movement of the switch tripping arm 50 functions to close momentarily both sets of switch contacts, while downward movement of the switch tripping arm momentarily swings the contacts of each set farther apart without closing either set. Thus, the double switches 103 and 104 are closed only in response to projection of the respectively associated pushing elements 45 into their driving positions and remain open as the pushing elements are cammed to their retracted positions.

Referring now to the wiring diagram in Fig. 6, an electrical system is shown in which the several sets of electrical contacts associated with the two force-applying devices 31 and 32 are connected with the appropriate solenoids of the various valves in the hydraulic system for opening and closing the valves as required by the above described mode of operation of the force-applying devices. In this wiring diagram, the ten solenoids respectively associated with the ten valves 91-100 are identified by reference characters 191-200.

The solenoid 191 of the valve 91 has a pair of end terminals 191a and 191b respectively connected to the movable contacts of a pair of mechanically interlocked double-throw switches 201 and 211 that are in turn mechanically connected to a relay 221 for simultaneous actuation thereby. Similarly, the solenoid 192 of the valve 92 has a pair of end terminals 192a and 192b respectively connected to the movable contacts of a pair of mechanically interlocked double-throw switches 202 and 212 that are in turn mechanically connected to a relay 222 for simultaneous actuation thereby. In a like manner, the other eight solenoids 193-200 have end terminals 193a-200a and 193b-200b respectively connected to the movable contacts of mechanically interlocked pairs of double-throw switches 203, 213-210, 220, the eight pairs of double-throw switches being in turn mechanically connected to relays 223-230 for simultaneous actuation thereby.

To open the valve 91, the end terminal 191a of its solenoid 191 is connected through ground to the negative terminal of a battery or the like 120, and the other end terminal 191b is connected by means of a switch to the positive terminal of the battery 120. To close the valve 91, the connections of the end terminals of the solenoid to the battery are reversed. Similarly, connection of the solenoid terminals 192a-200a through ground to the negative terminal of the battery and connection of the other solenoid end terminals 192b-200b to the positive terminal of the battery open the valves 92-100, and reversal of those connections closes those valves.

When the switch 101 is closed, the solenoids 192, 193, and 197 are energized to open the valves 92, 93, and 97 by having their terminals 192a, 193a, and 197a connected through ground to the negative terminal of the battery and their terminals 192b, 193b, and 197b connected to the positive terminal of the battery through the switch 101; and the solenoids 191, 196, and 199 are energized to close the valves 91, 96, and 99 by energization of the respectively associated relays 221, 226, and 229, whereby the pairs of

double-throw switch 201, 211 and 206, 216, and 209, 219 are actuated to connect the solenoid terminals 191b, 196b, and 199b through ground to the negative terminal of the battery and the other solenoid terminals 191a, 196a, and 199a to the positive terminal of the battery through the switch 101.

Similarly, when the switch 102 is closed, the solenoids 191, 194, and 198 are appropriately connected to the battery for opening the valves 91, 94, and 98; and the solenoids 192, 195, and 200, on energization of the relays 222, 225, and 230, are appropriately connected to the battery for closing the valve 92, 95, and 100.

When the double switch 103 is closed, the solenoids 195 and 199 are appropriately connected through ground and through the switch contacts 103a and 103b to the battery for opening the valves 95 and 99; and the solenoids 193 and 197, on energization of the relays 223 and 227, are appropriately connected to the battery through ground and through the switch contacts 103c and 103d for closing the valves 93 and 97.

Similarly, when the double switch 104 is closed, the solenoids 196 and 200 are appropriately connected through ground and through the switch contacts 104a and 104b to the battery for opening the valves 96 and 100; and the solenoids 194 and 198, on energization of the relays 224 and 228, are appropriately connected to the battery through ground and through the switch contacts 104c and 104d for closing the valves 94 and 98.

When the switch 105 is closed, the solenoids 193 and 197 are energized to close the valves 93 and 97 by energization of the respectively associated relays 223 and 227, to effect appropriate connection of the terminals of these solenoids to the battery.

Similarly, when the switch 106 is closed, the solenoids 194 and 198 are energized to close the valves 94 and 98 by energization of the respectively associated relays 224 and 228 to effect appropriate connection of the terminals of these solenoids to the battery.

To place the above described bucket line in operation, it is merely necessary, after building up the pressure in the two reservoirs 70 and 78, to open the throttling valves 80 and 72, in that order, for permitting the hydraulic fluid to flow into the hydraulic system. The above described electrical system will then automatically control the various valves that in turn control the operation of the two force-applying devices. By opening the throttling valve 80 before opening the throttling valve 72, the latter may readily be adjusted so that the pressure of the high pressure fluid admitted to the cylinders 33 will not drive the pistons 38 too fast on their working strokes for the low pressure system to maintain the necessary relative speed of the pistons on their return strokes. To shut off the bucket line drive, it is merely necessary to close the throttling valves 72 and 80 in that order.

Referring now to Figs. 7 and 8, a modified structure is shown therein for transmitting forces from a reciprocating piston to the buckets in a bucket line. It is contemplated, of course, that two such structures would respectively be associated with the two force-applying devices 31 and 32 shown in Fig. 2. For simplicity, however, only one such structure has been shown in Figs. 7 and 8 in association with one force-applying device 31a. When employing this modified structure, the digging ladder 13 and force-applying devices 31 and 32, as shown in Figs. 2 to 5, may

be employed substantially without change except as modified parts are illustrated in Figs. 7 and 8. To avoid unnecessary repetition, the reference characters previously employed to identify parts of the digging ladder and force-applying devices will be used again in Figs. 7 and 8 to identify substantially identical parts, and these parts will be referred to hereinafter without again describing them or their functions.

The structure of the digging ladder 13, partially detailed in Figs. 4 and 5, is shown more fully in Figs. 7 and 8, with a pair of lower, interior, stiffening angles 25a, a pair of lower, exterior, stiffening angles 26a, and a lower stiffening plate 27a, all joined to the lower edges of the side plates 24 to complete the box-like structure. Two identical racks 241 extend a short distance longitudinally of the ladder 13 and rest upon the upper surfaces of flanges of the two lower, interior, stiffening angles 25a, respectively. The racks 241 are slightly longer than the maximum path of travel of the piston 38 of the force-applying device and are rigidly secured to the angles 25a in any suitable manner, as by welding.

A structure 242, that may appropriately be termed a "walking beam," is disposed within the ladder 13 and comprises a frame 243 mounted on two laterally spaced-apart gear segments 244 that are respectively mounted in turn in mesh with the two racks 241, whereby the walking beam 242 may rock or oscillate upon the racks. The upper end of the walking beam is constructed in the form of a yoke having a pair of upwardly projecting, laterally spaced-apart ears 245, and a pin 246 is suitably mounted at its opposite ends in the ears 245, respectively. The pin 246 is located with its longitudinal axis passing through the centers of oscillation of the gear segments 244, whereby rocking of the walking beam causes the pin 242 to reciprocate along a straight line path parallel to the upper reach of the bucket line; and the entire walking beam structure is so designed that the straight line path of travel of the pin 246 is aligned with the path of travel of the piston 38 and an associated connecting rod 39a. The opposite end of the connecting rod 39a from its point of attachment to the piston 38 is provided with a bearing structure 247 surrounding the central portion of the pin 246. Thus, reciprocation of the piston 38 and associated connecting rod 39a causes the walking beam 242 to rock back and forth on the rack 241.

An arm 251 is provided at one end with a yoke structure comprising two spaced-apart ears 252 that are apertured to accommodate the pin 246, whereby the arm 251 may be hingedly mounted at the yoke end thereof for swinging movement about the center of oscillation of the gear segments 244. The opposite end of the arm 251 is provided with an integrally formed, angularly shaped seat 253 that is adapted to contact both the supporting surface 61 and the driving surface 66 of a bucket, such as 18d, adjacent the intersection of these surfaces and between the ears 53 of a succeeding bucket for sequentially driving the various buckets forwardly along the path of the upper reach of the bucket line.

At a suitable point between the ends of the arm 251, a rod 254 is hingedly secured thereto by means of a pin 256 and a cooperating eye 257 formed on the upper end of the rod 254. The arm 251 is preferably formed with a downwardly opening cavity 258 disposed therein adjacent the point where the rod 254 is secured thereto, and the upper end of the rod projects into the cavity 258 where it is secured by the pin 256 mounted

in and spanning opposite side walls of the cavity. Below the pin 246, a bracket 259 is secured to the frame 243 of the walking beam so that it projects forwardly therefrom. A seat 261 is formed on the projecting end of the bracket 259 to accommodate one end of a helical compression spring 262, and the seat is suitably apertured to permit the rod 254 to pass freely therethrough with substantial clearance. The helical spring 262 surrounds the rod 254 and is provided with a cap 263 at its upper end, the cap being adapted to bear against the lower side of the arm 251, which is contoured to provide a suitable curved bearing surface therefor. With this arrangement, the spring 262 is supported by and compressed between the arm 251 and the bracket 259 in a manner permitting limited swinging movement of the arm 251 about the pin 246 under the influence of the spring.

With the spring 262 mounted as described, the arm 251 will be urged upwardly at all times and the seat 253 will be held in driving engagement with a bucket, such as 12d, until the piston 38 reaches the end of a working stroke, as illustrated by a phantom outline of the arm 251 in Fig. 3.

The piston 38 is reversed immediately upon reaching the end of a working stroke, and while it is moving rearwardly on its return stroke, the walking beam 242 will rock rearwardly, and the forward end of the arm 251 will pass under the next succeeding bucket while being cammed downwardly by the cam surface 63 thereof. When the angularly shaped seat 253 of the arm 251 reaches the rearward end of this bucket, it will be forced upwardly by the spring 262 into driving engagement with the bucket, as shown by another phantom outline in Fig. 8. The piston 38 is then immediately reversed again, and as it moves forwardly on another working stroke, the walking beam 242 will rock forwardly, and the bucket engaged by the seat 253 will be driven forwardly until the piston 38 again reaches the end of its working stroke.

Because the pin 246 travels along a straight line path, the angular position of the arm 251 with respect to a bucket driven thereby will remain unchanged throughout a working stroke of the piston 38, and there will be no relative movement between the seat 253 and the bucket surfaces 61 and 66 engaged thereby.

A particular advantage of the structure illustrated in Figs. 7 and 8 lies in the elimination of the crosshead 41 and the sliding track type of guide structure for the crosshead, illustrated in Figs. 2 to 5. In the first embodiment of the invention described herein, the lack of alignment between the force applied to the crosshead 41 by the connecting rod 39 and the force applied to the various buckets by the pushing element 45 causes a turning moment to be applied to the crosshead that must be resisted by pressure between the upper and lower edges of the bars 29 and the cooperating upper and lower flanges 43 and 44 of the crosshead, respectively. Since the steel guiding surfaces of this type of crosshead guide structure are exposed to a constant drip of water carrying suspended abrasive particles, these surfaces would be subjected to wear that would limit the durability of an otherwise extremely rugged and efficient type of drive. With the walking beam mechanism illustrated in Figs. 7 and 8, less severe conditions are encountered because the walking beam is ideally designed to resist the forces normal to the axis of the connecting rod 39a that are applied to the pin 246 by the angu-

larly disposed arm 251. As a result, lower pressures exist between sliding surfaces of the last described mechanism than in the mechanism illustrated in Figs. 2 to 5. In addition, the surfaces in the last described mechanism that are subjected to relative sliding engagement are more readily shielded by hoods from water carrying suspended abrasive material that constantly drips from the various buckets.

Suitable switches and a suitable electrical circuit, not shown, may readily be associated with the mechanism shown in Figs. 7 and 8 for controlling the cycle of operation of the force-applying device 31a and causing it to perform in the same manner as the force-applying devices 31 and 32 shown in Figs. 2 to 5. The hydraulic circuit and valve arrangement shown in Fig. 2 may be employed without change for operating a pair of driving mechanisms such as the one illustrated in Figs. 7 and 8.

From the foregoing disclosure, it will be apparent that I have provided a drive for the bucket line of a placer mining dredge and a new bucket for the bucket line that are adapted for cooperative association in a manner that eliminates substantially all of the above described dangers and disadvantages of the conventional type of bucket line drives in the prior art. However, as before noted, it is to be understood that the details of the foregoing disclosure have been given solely for illustrative purposes and that the invention is not limited thereto except as may be required by the appended claims.

I claim:

1. In a digging machine having an endless bucket line including a load-carrying reach and a return reach, a drive for said bucket line comprising a plurality of bucket line engaging means mounted for reciprocating travel along respective paths parallel to and adjacent to said load-carrying reach, a corresponding plurality of means respectively associated with said plurality of engaging means for effecting engagement of said engaging means with the load-carrying reach of said bucket line in driving relation thereto while said engaging means are traveling in one direction only along their respective paths, a corresponding plurality of power-applying means respectively associated with said engaging means for driving them along their respective paths at a substantially constant rate of speed during the time they are engaged, and means for operating said power-applying means in coordinated timed relation such that at all times at least one of said engaging means is in driving engagement with said load-carrying reach.

2. In a digging machine having an endless bucket line including a load-carrying reach and a return reach, a drive for said bucket line comprising a plurality of pistons mounted for reciprocating travel parallel to and adjacent to said load-carrying reach, a corresponding plurality of detents respectively associated with said pistons for reciprocating travel therewith and adapted to engage said load-carrying reach in driving relation thereto while they are traveling in one direction only, a corresponding plurality of power-applying means for respectively driving said pistons, and means for coordinating the operation of said power-applying means so that at all times at least one of said detents is in driving engagement with said load-carrying reach.

3. In a digging machine having an endless bucket line including a load-carrying reach and a return reach, a drive for said bucket line com-

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prising a plurality of pistons mounted for reciprocating travel parallel to said load-carrying reach, a corresponding plurality of detents respectively associated with said pistons for reciprocating travel therewith, a corresponding plurality of means respectively associated with said detents for holding them in driving engagement with the load-carrying reach of said bucket line while they are traveling in one direction only, means mounted on said bucket line for effecting retraction of each detent while it is traveling in the opposite direction, power-applying means for driving said pistons, and means for coordinating the operation of said power-applying means so that at all times at least one of said detents is in driving engagement with said load-carrying reach.

4. In a digging machine having an endless bucket line including a load-carrying reach and a return reach, a drive for said bucket line comprising a plurality of pistons mounted in tandem for reciprocating travel parallel to said load-carrying reach, a corresponding plurality of detents respectively associated with said pistons for reciprocating travel therewith, a corresponding plurality of means respectively associated with said detents for holding them in driving engagement with the load-carrying reach of said bucket line while they are traveling in one direction only, a corresponding plurality of power-applying means for driving said pistons, and means for coordinating the operation of said power-applying means so that at all times at least one of said detents is in driving engagement with said load-carrying reach.

5. In a digging machine having an endless bucket line, a drive for said bucket line comprising a plurality of reciprocating means respectively operative while traveling in one direction only for engaging the bucket line in driving relation thereto, a corresponding plurality of hydraulically powered pistons respectively associated with said reciprocating means in driving relation thereto, a source of liquid under high pressure for driving the pistons in one direction while their respectively associated reciprocating means are in driving engagement with the bucket line, a source of liquid under low pressure for driving the pistons in the opposite direction, and means for controlling the application of said high and low pressure liquids to said pistons so that their movement is coordinated with the engagement of the bucket line by the respectively associated reciprocating means and so that at all times at least one of said reciprocating means is in driving engagement with the bucket line.

6. In a digging machine having an endless bucket line including an inclined load-carrying reach and a return reach, a drive for said bucket line comprising a plurality of crosshead guide structures disposed below and extending parallel to said load-carrying reach, a crosshead mounted on each said guide structure for reciprocating movement therealong parallel to said load-carrying reach, a detent mounted on each said crosshead for translation with respect thereto into and out of a bucket line driving position along said load-carrying reach, spring means yieldably urging each said detent toward its driving position, and means for driving said crossheads back and forth along said guide structures so that each structure moves said bucket line at a substantially constant rate of speed while it is in driving position.

7. In a digging machine having an endless

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bucket line mounted for travel around a closed inclined path and including a series of substantially identical buckets pivotally secured together in end-to-end relation around the bucket line and forming a load-carrying reach and a return reach, each bucket having a driving surface adjacent its trailing end, a plurality of crosshead guide structures disposed below and extending parallel to said load-carrying reach, a crosshead mounted on each said guide structure for reciprocating movement therealong parallel to said load-carrying reach, a detent mounted on each said crosshead for translation with respect thereto into and out of a driving position behind the driving surface of an adjacent bucket on said load-carrying reach, means yieldably urging each said detent toward its driving position, and means for driving said crossheads back and forth along said guide structures in a phase relation that causes said load-carrying reach to move continuously.

8. In a digging machine having an endless bucket line mounted for travel around a closed inclined path and including a series of substantially identical buckets pivotally secured together in end-to-end relation around the bucket line and forming a load-carrying reach and a return reach, a plurality of crosshead guide structures disposed below and extending parallel to said load-carrying reach, a crosshead mounted on each said guide structure for reciprocating movement therealong parallel to said load-carrying reach, a detent mounted on each said crosshead for translation with respect thereto into and out of a driving position behind an adjacent bucket on said load-carrying reach, spring means yieldably urging each said detent toward its driving position, and means for driving said crossheads back and forth along said guide structures, the movement in the driving direction being at a substantially constant rate of speed, each of the buckets in said bucket line being provided with a driving surface at the trailing end thereof for engagement by one of said detents in its driving position while its said crosshead is moving in one direction and also being provided with a cam surface extending from the forward to the trailing end thereof for forcing said detent out of driving position while said crosshead is moving in the opposite direction.

9. In a digging machine having an endless bucket line including a load-carrying reach and a return reach, a drive for said bucket line comprising a rack mounted below and extending parallel to said load-carrying reach, a gear segment mounted between said load-carrying reach and said rack for oscillating movement in mesh with the rack, a bucket line engaging arm hingedly mounted at one end on said gear segment for swinging movement about the axis of oscillation thereof, means yieldably urging said arm about said axis into engagement with the bucket line, and means for causing said gear segment to oscillate.

10. In a digging machine having an endless bucket line including a load-carrying reach and a return reach, a drive for said bucket line comprising a rack mounted below and extending parallel to said load-carrying reach, a gear segment mounted between said load-carrying reach and said rack for oscillating movement in mesh with the rack, a bucket line engaging arm hingedly mounted at one end on said gear segment for swinging movement about the axis of oscillation thereof, said arm being provided at its opposite end with a bucket engaging surface conforming

to the trailing lower edge of a loaded bucket for engaging the bucket in driving relation thereto, means yieldably urging said arm about said axis for maintaining the bucket engaging end of the arm in engagement with said load-carrying reach, and means for causing said gear segment to oscillate.

11. In a digging machine having an endless bucket line mounted for travel around a closed path and including a series of substantially identical buckets pivotally secured together in end-to-end relation around the bucket line and forming a load-carrying reach and a return reach, a driving surface adjacent the trailing end of each bucket, a rack mounted below and extending parallel to said load-carrying reach, a gear segment mounted between said load-carrying reach and said rack for oscillating movement in mesh with the rack, a bucket line engaging arm hingedly mounted at one end on said gear segment for swinging movement about the axis of oscillation thereof, said arm being provided at its opposite end with a bucket engaging surface conforming to the driving surfaces of the buckets for engaging the buckets in driving relation thereto, means yieldably urging said arm about said axis for maintaining the bucket engaging end of the arm in engagement with said load-carrying reach, and means for causing said gear segment to oscillate.

12. In a digging machine having an endless bucket line mounted for travel around a closed path and including a series of substantially identical buckets pivotally secured together in end-to-end relation around the bucket line and forming a load-carrying reach and a return reach, a rack mounted below and extending parallel to said load-carrying reach, a gear segment mounted between said load-carrying reach and said rack for oscillating movement in mesh with the rack, a bucket line engaging arm hingedly mounted at one end on said gear segment for swinging movement about the axis of oscillation thereof into and out of a driving position behind an adjacent bucket, said arm being provided at its opposite end with a bucket engaging surface for engaging the buckets in driving relation thereto, and means for causing said gear segment to oscillate, whereby the hingedly mounted end of said arm will reciprocate along a path parallel to said load-carrying reach, each of the buckets in the bucket line being provided with a driving surface at the trailing end thereof conforming to the bucket engaging surface of said arm and adapted to be engaged thereby while said gear segment is oscillating in one direction and also being provided with a cam surface extending from the forward to the trailing end thereof for forcing said arm to swing out of driving position while said gear segment is oscillating in the opposite direction.

13. In digging machine having an endless bucket line, a drive for said bucket line comprising a plurality of reciprocating means respectively operative while traveling in one direction only for engaging the bucket line in driving relation thereto, a corresponding plurality of hydraulically-powered pistons respectively associated with said reciprocating means in driving relation thereto, a source of fluid under pressure for driving the pistons in one direction while their respectively associated reciprocating means are in driving engagement with the bucket line, means for driving the pistons in the opposite direction, and means for coordinating said pistons with the en-

gagement of the bucket line by the respectively associated reciprocating means and so that at all times at least one of said reciprocating means is in driving engagement with the bucket line.

14. In a digging machine having an endless bucket line, a drive for said bucket line comprising a plurality of reciprocating means respectively operative while traveling in one direction only for engaging the bucket line in driving relation thereto, a corresponding plurality of hydraulically-powered pistons respectively associated with said reciprocating means in driving relation thereto, a source of fluid under pressure for driving the pistons in one direction while their respectively associated reciprocating means are in driving engagement with the bucket line, a source of fluid under pressure for driving the pistons in the opposite direction, and means for controlling the application of said fluids to said pistons so that their movement is coordinated with the engagement of the bucket line by the respectively associated reciprocating means and so that at all times at least one of said reciprocating means is in driving engagement with the bucket line.

15. In a digging machine having an endless bucket line, a drive for said bucket line comprising a plurality of reciprocating means respectively operative while traveling in one direction only for engaging the bucket line in driving relation thereto, a corresponding plurality of hydraulically powered pistons respectively associated with said reciprocating means in driving relation thereto, a source of fluid under pressure for driving the pistons in one direction while their respectively associated reciprocating means are in driving engagement with the bucket line, a source of fluid under pressure for driving the pistons in the opposite direction, electrically operated means for controlling the application of said fluid to said pistons, fixed switch contacts associated with the cylinder of each said piston at a distance apart from each other corresponding to the stroke of each said piston, cooperating switch contacts associated with said pistons so as to alternately close one of each said fixed switch contact at each end of said stroke and actuate said electrically operated means, said pistons being coordinated out of phase so that at all times at least one of said reciprocating means is in driving engagement with the bucket line.

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