Jan. 3, 1967 D. F. WINBERG ETAL 3,295,892

STEERABLE TUNNEL-DRILLING MACHINE

Filed March 30, 1964 4 Sheets-Sheet 1

FIG. 1

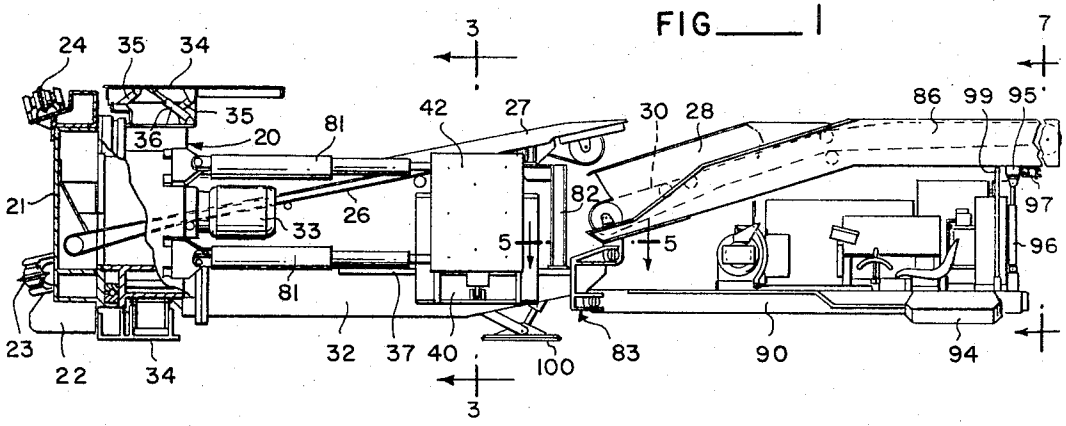
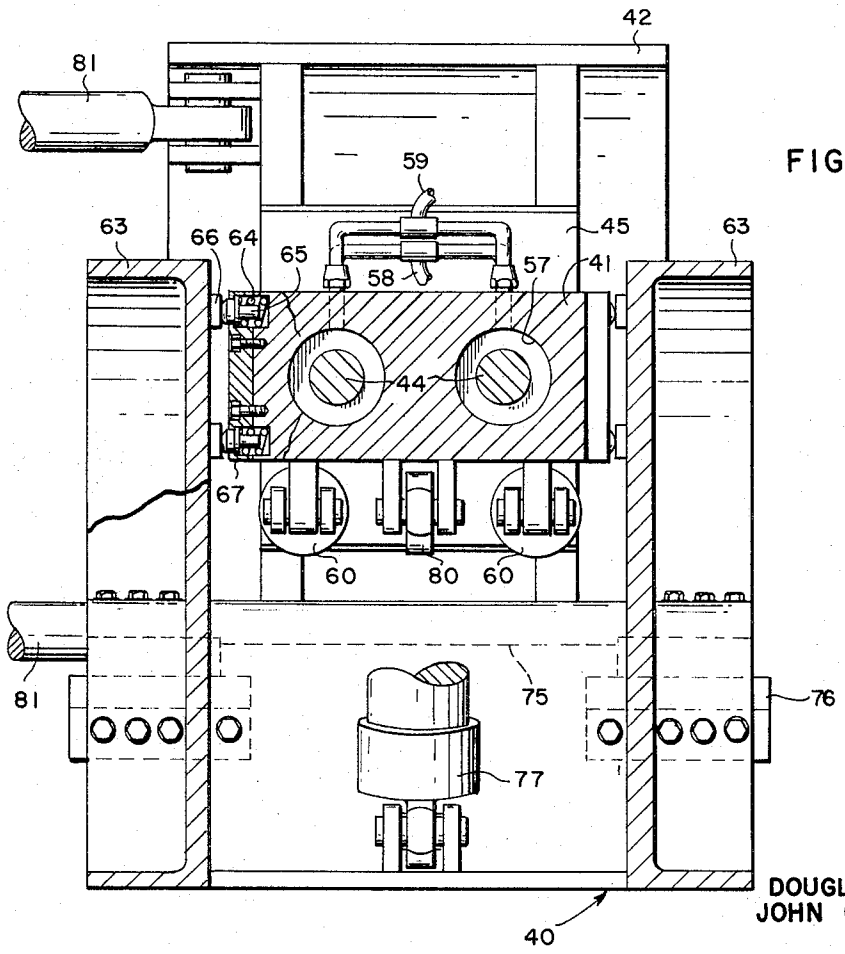


FIG. 2



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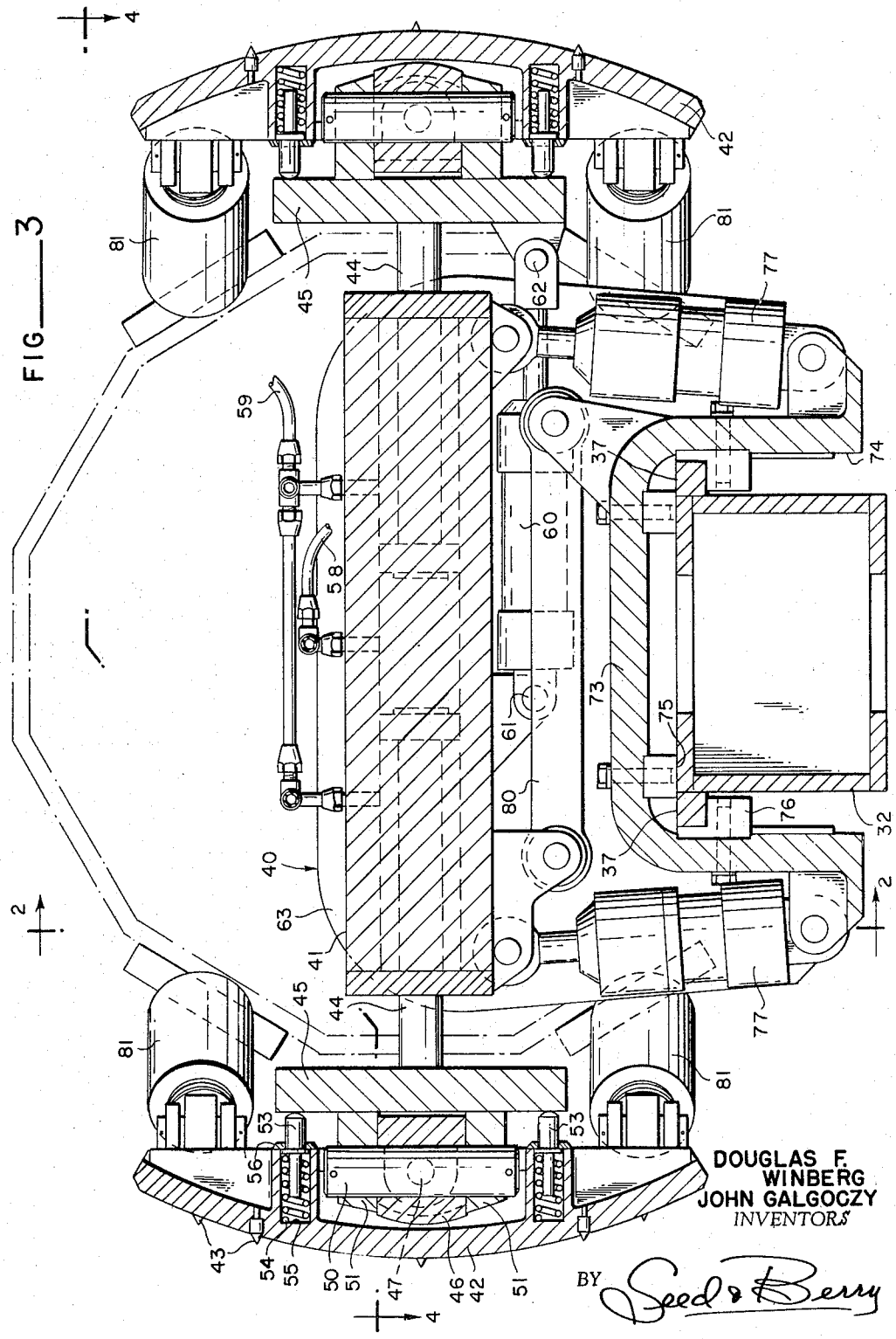
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STEERABLE TUNNEL-DRILLING MACHINE

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FIG. 3



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STEERABLE TUNNEL-DRILLING MACHINE

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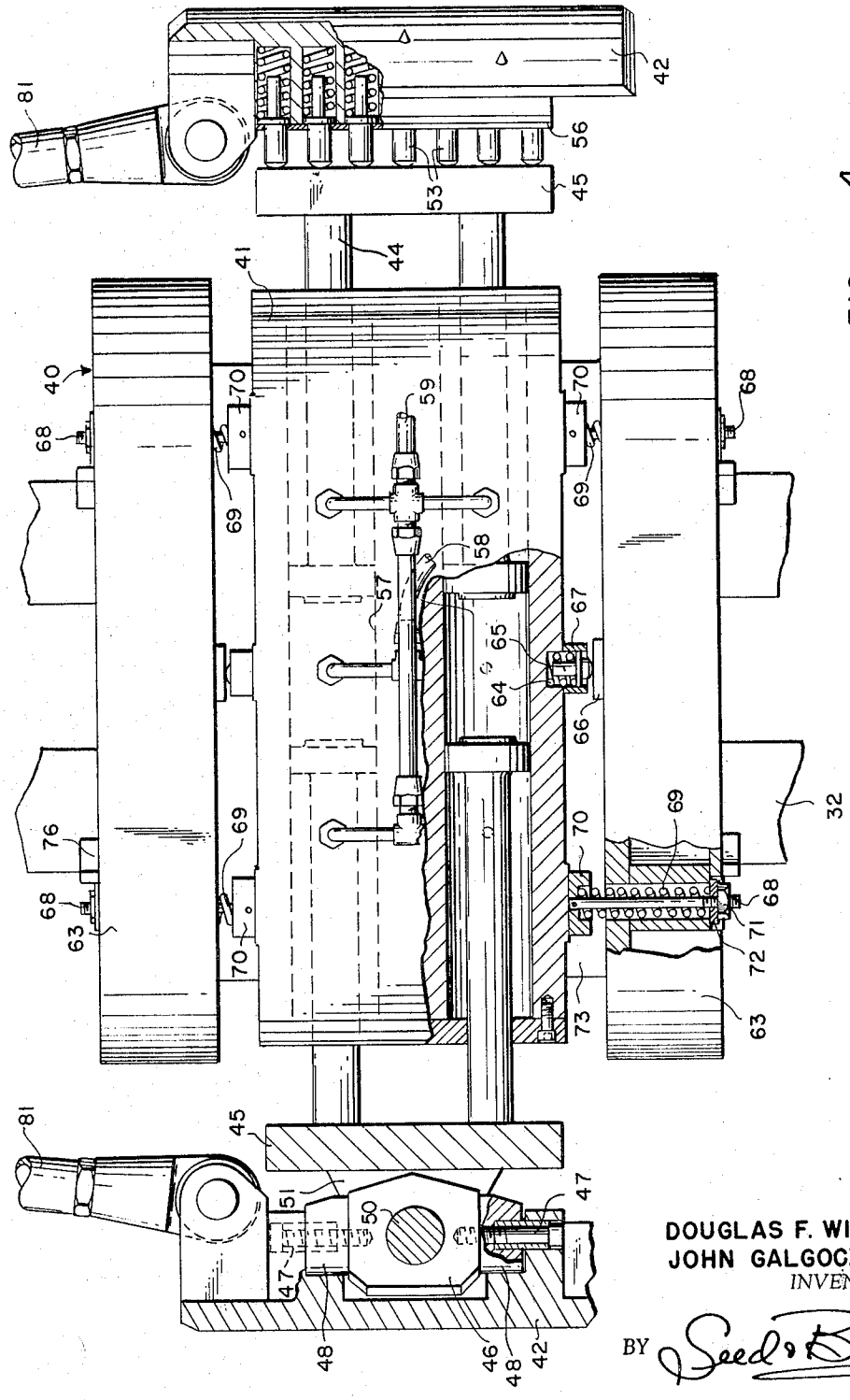


FIG. 4

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STEERABLE TUNNEL-DRILLING MACHINE

Filed March 30, 1964 4 Sheets-Sheet 4

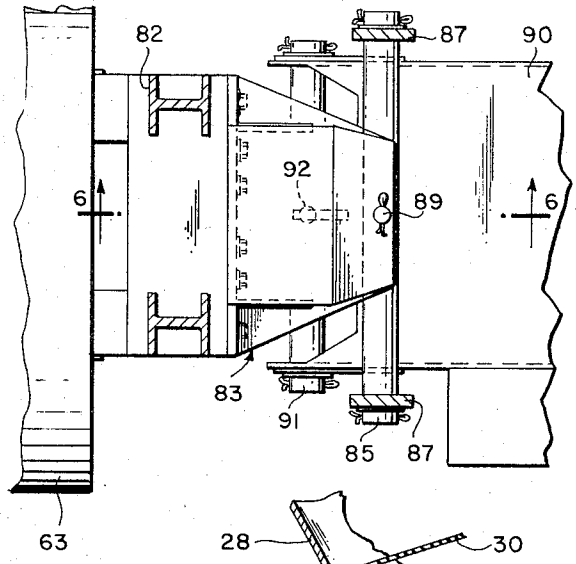


FIG. 5

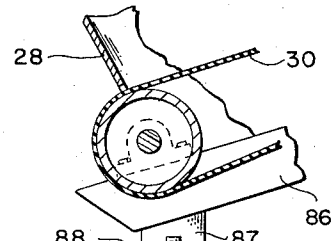
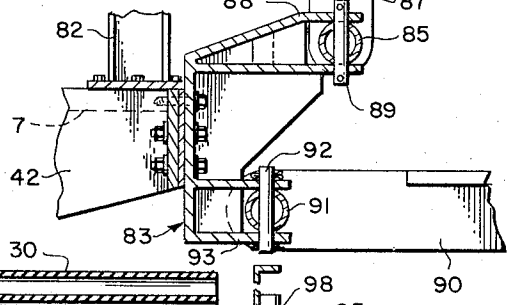


FIG. 6



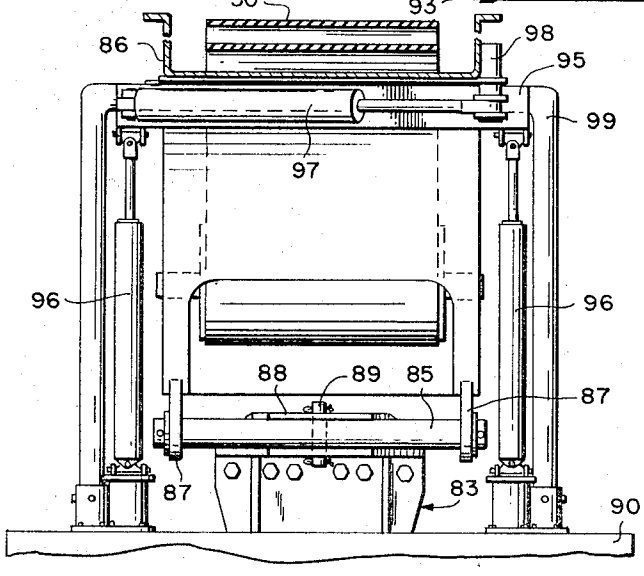


FIG. 7

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United States Patent Office

3,295,892

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STEERABLE TUNNEL-DRILLING MACHINE

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Filed Mar. 30, 1964, Ser. No. 355,775

21 Claims. (Cl. 299—31)

This invention relates to a tunnel-boring machine; and particularly a machine of the type which performs its boring function by the action of wedge-shaped cutters which are presented on the front surface of a rotary cutting head to produce closely spaced concentric kerfs in the rock face of the tunnel being bored, the wedge shape of the cutters creating progressively increasing compressive forces on the rock between the kerfs to cause fracturing thereof. A mounting body lying to the immediate rear of the head provides a rotary journal for the head. Such body carries electric motors for driving the head, and also centers the head by means of shoes which slide along the walls of the tunnel. A trunk rigid with the body extends rearwardly therefrom. The trunk, while a boring operation is in progress, receives a slide journal from a steering box which is localized by wall-gripping shoes against motion endwise to the tunnel while allowing for adjusting freedoms in directions other than said endwise motion.

A machine of the above-described type is illustrated and described in pending application for Letters Patent of the United States filed Mar. 18, 1963, Ser. No. 265,812 now Patent No. 3,203,737. Such machine was engineered, however, for the boring of tunnels of quite large diameter, 16 foot for example, and the cross-section thereof allows considerable liberty in the design and placement of the machine's structural parts. A tunnel of, say 7 foot diameter is considerably more restricted. A machine for boring a 7 foot tunnel must be more compact than one for boring a 9 foot tunnel. If adjusting freedoms comparable to those of the larger machine are to be provided, the mechanisms therefor must operate within a compass giving full consideration to the space needs which other necessary parts of a boring machine require. These mechanisms should, moreover, be equally as rugged as those of the larger machine, and admit of being operated with a minimum of attention.

Having the foregoing in mind, it is a principal object of the present invention to provide a machine of perfected design permitting full adjusting freedoms and one which, while applicable to the boring of a large-diameter tunnel, peculiarly adapts itself to tunnels of relativey small diameter.

It is a further and important object to provide a tunnel-boring machine of an articulated nature so that connecting sections can swing, one relative to another, and thus permit the machine to negotiate curves the minimum arc of which is limited only by the length of a single one of the articulating sections rather than by the overall length of the machine.

These and other more particular objects and advantages will appear and be understood in the course of the following description and claims, the invention consisting in the novel construction and in the adaptation and combination of parts hereinafter described and claimed.

In the accompanying drawings:

FIGURE 1 is a fragmentary side elevational view illustrating a tunnel-boring machine embodying preferred teachings of the present invention.

FIGURE 2 is a fragmentary longitudinal vertical sectional view thereof drawn to an enlarged scale on line 2—2 of FIG. 3.

FIGURE 3 is a transverse vertical sectional view on line 3—3 of FIG. 1, employing the same scale as that of FIG. 2, and representing in phantom the main body of the machine on which the rotary cutting head is journaled.

FIGURE 4 is a fragmentary top plan view of the machine.

FIGURE 5 is a fragmentary horizontal sectional view on line 5—5 of FIG. 1, with the scale larger than that of FIG. 1 but smaller than the scale of FIGS. 2 through 4, inclusive.

FIG. 6 is a fragmentary longitudinal vertical sectional view on line 6—6 of FIG. 5; and

FIGURE 7 is a fragmentary transverse vertical sectional view on line 7—7 of FIG. 1.

Referring to said drawings, the numeral 20 generally denotes the main frame of the machine, and 21 the cutting head journaled for rotation upon the frame at the extreme front end of the latter. The head has a multiplicity of cutting wheels mounted upon its front face, and about the periphery at circumferentially spaced intervals presents scoop buckets 22. For simplicity in illustration, only a single "wedge" cutting wheel 23 and a single "gauge" cutting wheel 24 are shown. The scoop buckets have a mouth facing toward the direction of travel of the bucket as the head rotates, and a lip extends forwardly from the mouth to scoop into the mouth rock fragments and other debris cut from the end wall of the tunnel. Each of the buckets has an inner opening and at the upper limit of travel the contents of the bucket are dumped through this opening onto the forward end of the upper run of a power-driven endless conveyor 26. A frame-work 27 supports the conveyor, locating the latter so that the same rises on a moderate incline from said forward receiving end to a rear discharge end whereat the conveyed matter is delivered into a 3-sided bin 28 having for its floor the forward end on a second power-driven endless conveyor 30 with discharges at the extreme rear end of the machine. Such second or tail conveyor receives its support from an afterbody attached as a substantial trailer to a trunk 32 extending rearwardly as a rigid prolongation of the main frame. The structural nature of said afterbody and the manner of its attachment will be hereinafter described.

The main frame is generally cylindrical and at diametrically opposite sides carries a respective one of two electric motors 33. Pinions driven from these motors mesh a bull gear to impart rotary motion to the cutting head. The main frame also carries four guide shoes 34—located at the top, the bottom, and the two sides—adapted to have slide contact with the wall of the tunnel as a boring operation proceeds, for maintaining the head in centered relation to the tunnel. These shoes are mounted for radical movement by sets of parallel-motion links 35, and are set in radically adjusted positions by double-acting hydraulic jacks 36.

The trunk 32 is a fabricated structure comprised of two paralleling beams rigidly joined by cross-webs. Longitudinal ribs 37 flush with the top face project laterally as shoulders from the outer face of each of the beams. The function of the truck is to steer the head and this is accomplished by shifting the after end of the trunk. The trunk lies parallel with the rotary axis of the head, being offset below such axis to provide space in the central area of the tunnel for a steering assembly. The steering assembly includes a steering box 40 providing for the trunk a slide-way which constrains the trunk to travel a guided linear path which is fixed in relation to the box. The box is suspended from a carriage 41. Through the mechanism of this suspension and the mounting of the carriage from anchoring shoes 42 which

grip the tunnel wall at diametrically opposite sides thereof the box admits to a plurality of adjusting freedoms, and namely shifting motions transversely and vertically of the tunnel and rolling motions about axes longitudinal to the trunk. By these freedoms said guided travel path may be altered between a normal position occupied when a straight section of tunnel is being bored and positions angled in selectively variable degrees with respect thereto. Double-acting hydraulic jacks permit the adjustments to be made while a cut is in progress.

The wall-engaging outer faces of the anchoring shoes **42** are generally rectangular in plan configuration, and have projecting spikes **43** for augmenting the wall purchase. When viewed from an end said outer faces are convex to conform to the curvature of the tunnel wall, and as a compensation to wall irregularities each shoe is so universally attached to a related mounting stem that the shoe can rock about both a longitudinally extending horizontal axis and a vertical axis. Each stem presents twin cylindrical piston elements **44** extending as parallel branches from a shoulder part **45**. These two sets of pistons are journaled in the carriage **41** for opposing slide motion in a direction transverse to the tunnel.

The slide axes of the pistons **44** coincide as between the two shoes. The respective planes occupied by said horizontal and vertical rocker axes also coincide as between the two shoes. For said universal rocker movement longitudinally spaced sockets are provided at the rear of the shoe. A knuckle **46** has stub ends **48** pivoted in these sockets for wrist movement about a longitudinal axis located substantially on the longitudinal median plane of the shoe. Auxiliary trunnion sleeves **47** hold the stubs against dislodgment when the shoes are not pressing against a tunnel wall. The shoulder **45** presents an outwardly extending yoke which straddles the top and bottom faces of the knuckle, and a pivot pin **50** connects the arms **51** of the yoke to the knuckle for wrist motion of the knuckle about a vertical axis.

Spring-loaded pins **53** evenly spaced in two horizontal rows one above and the other below the yoke and extending equal distances fore and aft of the transverse vertical plane occupied by the pin **50** exerts balancing thrust from the shoulder **45** to the shoe **42** to normally hold the shoe in a plane normal to the common slide axis of the two stems. The springs, denoted by **54**, occupy pockets **55** which are provided in the shoulder part and exert their thrust upon flanges which are formed upon the pins, yieldingly urging the latter to bear against a keeper plate **56** which is fixedly attached to the shoulder.

The carriage **41** is or may be in the form of an elongated right prism placed so that its major axis extends transversely of the machine. Parallel through-bores **57** placed symmetrical to the longitudinal median line of the prism provide the slide journals for the twin pistons **44**. The through-bores with the pistons which slide therein function as the components of a pair of double-acting hydraulic jacks exerting opposing thrust forces through the shoes upon the walls of the tunnel. Hydraulic fluid is supplied under pressure to and dumped from the cylinders **57** of the jacks through drill-holes **58** and **59**. The carriage is shiftable in the manner of a cross-head into selected positions adjusted transversely of the tunnel by means of a pair of double-acting hydraulic jacks **60** extending transversely in an approximate horizontal plane between the carriage and the shoulder **45** of one of the shoe stems, connecting with suitable mounting lugs by pivot pins **61** and **62**.

The steering box **40** has a U-shape when viewed from the side. Legs **63** of such U overlie the front and the back faces of the carriage with a moderate spacing therebetween. A multiplicity of springs occupy this space, and perform a balance function in much the same manner as the springs **54**, to normally maintain the carriage in a position centered between the legs. A pair of upper and lower springs **64** are placed at the center of the space,

and vertical rows of closely spaced springs **69** are located adjacent each of the two ends. Springs **64** each surround the stem of a headed pin **65** within a pocket formed in the carriage, and exert outward thrust upon a flange of the stem to yieldingly press the exposed head of the pin against the flat surface of a boss **66** presented by the concerned leg of the steering box. A keeper for the pins **65** is fixedly attached to the carriage. Bottoming action of the stems against the floor of the concerned pockets limit the degree to which the pins **65** can be depressed. The springs **69** each occupy a cylindrical pocket which extends front to back through the concerned leg **63** of the steering box, each surrounding a respective rod **68**. Inner ends of the several springs **69** in each vertical row seat in a respective socket presented by a flat-faced vertical bar **70**. The rods **68** have their inner ends pinned to the bar and have a nut **71** threaded upon the exposed outer end. Springs **69** take their purchase against a keeper plate **72** which is secured to the legs **63**. Bars **70** perforce act as spring-pressed bumpers, bearing against slide faces which are presented by the carriage.

The cross-arm **73** of the steering box has an inverted U shape when viewed from the end to produce a downwardly facing channel **74** which serves as the slide-way for the trunk. Internal slippers **75** and **76** secured by cap-screws to the sides and top of the channel produce the slide surfaces on which the trunk bears, the slippers **76** being lipped to catch under the ribs **37** of the trunk. The steering box is raised, lowered or rolled relative to the carriage by means of double-acting hydraulic jacks **77** extending vertically between said box and carriage. One such jack is provided at each of the two sides of the box, located central to the fore-and-aft length of the box and having ball-joint end connections. The steering box is guided in said raising, lowering, and rolling motions by a radius arm **80** extending longitudinally of the carriage from the carriage to the box on substantially the median line of the carriage. As with the jacks **77**, said linking radius arm **80** has ball-joint end connections.

It will be understood that the carriage and the steering box function only to locate the axis along which the main frame of the machine slides as a cutting operation proceeds, and to resist torque loads created by the rotary motion of the cutting head. No thrust loads exerted by the rock face on the rotary cutting head are carried back through the trunk. These thrust forces are passed from the head through suitable bearing supports (not shown) into the head portion of the main frame, and thence are carried directly to the wall-gripping shoes through two pairs of horizontal longitudinally extending double-acting hydraulic thrust jacks **81**. One such pair is located at each of the two sides of the machine. The thrust jacks have ball-joint end connections.

The trunk, at its rear end, is surmounted by a strand **82**. The overhanging rear end of the framework **27** which supports the endless conveyor **26** seats on and is rigidly secured to this stand.

The afore-mentioned afterbody which is attached as a trailer to the extreme rear end of the trunk is a 2-deck structure and receives a mounting from a bracket **83** bolted to said trunk. The two decks are each connected to said bracket for swing motions independently of one another about both vertical and transverse horizontal axes. In the instance of each deck, the vertical swing motion is about the center of a respective transverse horizontal hinge pin as an axis, and the horizontal swing motion is about the center of a respective king pin as an axis. The hinge pin **85** for the upper deck **86** is journaled through depending arms **87** of a terminal yoke. The hinge pin lodges in a rearwardly facing slot provided by an upper-level fork **88** of the bracket **83**. The related king pin **89** traverses the hinge pin at the substantial center thereof and has upper and lower ends journaled in the arms of the fork. A substantially similar mounting is provided for the lower deck **90**, with

the hinge pin and the king pin being in this instance denoted by **91** and **92**, respectively, and having the fork **93** therefor stepped below and in forwardly spaced relation to the upper-level fork.

The lower deck **90** has skid shoes **94** projecting diagonally downwardly from each side at the rear end to sustain such rear end from the side walls of the tunnel. Such lower deck provides a station for the operator, with the necessary controls and gauges for the operation of the machine. A motor-driven pump for the machine's hydraulic system is also mounted upon such lower deck. The electric power for driving this motor and the motors which rotate the cutting head is carried to the control station by trailing cords. Flexible hoses extend between the control station and the several hydraulic jacks.

The length of the afterbody's lower deck is approximately half that of the upper deck **87**. A stand **99** surmounts the rear end of the lower deck to form a stationary rest for the overhanging rear end of such upper deck. A cross-bar **95** also functions as a sustaining member for said rear end. Hydraulic jacks **96** permit such bar **95** to be raised or lowered, and a double-acting hydraulic jack **97** extending transversely from the bar to a post **98** depending from the upper deck permits the upper deck to be shifted in either lateral direction.

It is thought that the manner in which the machine operates will have been largely apparent from the foregoing description. When the anchor shoes **42** have been retracted from the tunnel wall incident, say, to moving the shoes forward for taking a grip at a new location, the machine is supported by the front-end guide shoes **34** and by a rear foot **100**. This rear foot is operated by a hydraulic jack and during working periods of the machine is kept retracted. For said forward movement of the shoes (the present machine being engineered for a 2-foot stroke) the four thrust jacks **81** are retracted. This draws the disengaged shoes ahead, causing the steering box to slide upon the trunk in concert with such advance. Upon reaching the forward limit of this resetting "step," the operator charges pressure fluid into the cylinders **57** of the carriage **41**, forcing the pistons outwardly within said cylinders to cause the anchor shoes to be again firmly planted against the tunnel wall.

With the pistons now localized relative to the tunnel, the rotary axis of the cutting head may be placed in selected adjusted positions by manipulation of the steering assembly, and namely by operation of the horizontal jacks **60**, the vertical jacks **77**, and the longitudinal jacks **81**, an adjustment of one most usually dictating a complementing adjustment of the others. These adjustments can perforce be performed either when the machine is stationary or while a cut is in progress. It will be apparent that the hydraulic pressure which exerts outward wall-gripping force upon the anchor shoes is in no wise affected by adjustments given to the carriage causing the latter to slide upon the pistons **44** toward or from either shoe **42**. The universal connections at the ends of the radius arm **80** and at the ends of the vertical jacks **77** allow the steering box to cock itself relative to the carriage when adjustments made to the steering assembly locate the slide axis of the trunk in an abnormal condition, or which is to say any condition other than one midway. Between the shoes normal to a transverse vertical plane occupied by the shoes. Should the anchor shoes "creep" circumferentially of the tunnel during the progress of a cut in consequence of the purchase having been taken upon a faulty surface, counter activation of the two vertical steering jacks **77** brings the steering box **40** back to a level position. It will be understood that each of the vertical jacks **77** may be operated independently of each other and of course independently of the carriage-shifting jacks **60**. Thus any compounding of lateral and vertical movements, within prescribed limits, may be obtained. All thrust forces are passed through the jacks **81** from the main body directly to the

anchor shoes. Torque is passed from the trunk into the vertical steering jacks **77**.

The trailing afterbody, being hinged for swing motion, permits the machine to negotiate curves of considerably shorter radius than would otherwise be permitted. The machine must have a greater length than machines which are engineered to bore larger tunnels in that space limitations do not permit the operator's station to be located close to the front of the machine.

It is believed that the invention will have been clearly understood from the foregoing detailed description of our now-preferred illustrated embodiment. Changes in the details of construction may be resorted to without departing from the spirit of the invention and it is accordingly our intention that no limitations be implied and that the hereto annexed claims be given the broadest interpretation to which the employed language fairly admits.

What we claim is:

1. In a tunnel-boring machine, a power-driven rotary cutting head, a main body having said head journal-mounted thereon, a trunk extending rearwardly from said body, a box proxiding a slide-way for the rear end of said trunk, anchor means movable into and out of gripping engagement with the wall of a tunnel being bored, means supporting said box from the anchor means for adjustment of the box both vertically and transversely relative to the anchor means, and a trailing afterbody hinged to the rear end of the trunk.

2. A tunnel-boring machine according to claim **1** in which the hinge connection permits the afterbody to swing in two planes at right angles to one another.

3. A tunnel-boring machine according to claim **1** in which the afterbody supports an operator's platform and controls for the operation of the machine.

4. A tunnel-boring machine according to claim **1** in which the afterbody is comprised of upper and lower sections hinged by their front ends so that each can swing independently of the other both horizontally and vertically, the lower section providing means sustaining the rear end of the upper section in elevated relation to the lower section.

5. A tunnel-boring machine according to claim **4**, means being provided for shifting the rear end of the upper section relative to the lower section into selected positions within given ranges of transverse and vertical adjustment.

6. A tunnel-boring machine according to claim **1** in which the trunk and the afterbody respectively support a front and a rear endless conveyor acting as successive carriers for moving fractured rock and other debris from the machine's front end to the extreme rear end thereof.

7. A tunnel-boring machine according to claim **6** in which the front endless conveyor has its receiving front end located at the approximate mid-height of the rotating head so that rock fragments picked up by scoop buckets rotating with the cutting head can be dumped by gravity onto said conveyor, and slopes upwardly from said receiving end to a discharging rear end which overhangs the receiving front end of the rear conveyor, the trunk having a surmounting stand upon its extreme rear end giving support to the rear end of the front conveyor, the box in which said trunk slides lying to the front of the stand.

8. In a tunnel-boring machine, a power-driven rotary cutting head, a main body having said head journal-mounted thereon, anchor means movable into and out of gripping engagement with the wall of a tunnel being bored, operative interconnection between said anchor means and the main body for positioning the main body within the tunnel, and an afterbody hingedly connected in trailing relation to the main body for both horizontal and vertical swing motion relative to the main body, said afterbody comprising upper and lower sections having said hinge connnection with the main body located

at the respective front end and being characterized in that each section can swing independently of the other.

9. A tunnel-boring machine according to claim 8 in which the hinge connection comprises a trunnion having its ends journaled for rotation about a transverse horizontal axis in the arms of a yoke fixed to the afterbody, and a king-pin traversing the trunnion midway between said journaled ends of the tunnion and having its own ends journaled for rotation about a vertical axis in the arms of a fork fixed to the main body.

10. A tunnel-boring machine according to claim 9 having means at the rear end of the lower section sustaining the rear end of the upper section in elevated relation thereto.

11. In a tunnel-boring machine, a main body having a rotary cutting head journaled for rotation thereon, a trunk rigid with and extending rearwardly from the body presenting slide faces paralleling the axis of rotation of the head, anchor shoes movable into and out of gripping engagement with the wall of a tunnel being bored at a position spaced a substantial distance to the rear of the head, piston elements attached to and extending inwardly from each of said anchor shoes on a substantial diameter of the tunnel, a block serving as a carriage occupying a position between the shoes and bored from its ends on a coinciding axis to provide cylinders in which the pistons are received, said cylinders forming journals for sliding motion of the carriage endwise to the pistons, means for moving the carriage to and setting the same at selected points within a permitted range of said slide motion, a steering box providing a slide-way for said slide faces of the trunk constraining the trunk to travel along a guided linear path which is fixed in relation to the box, at least two upright arms independently adjustable as to length each supporting a respective one of the two sides of the box from the carriage, and a linking connection between the carriage and box disposed transversely of the tunnel to prescribe a guided path in which the box moves upon adjusting the length of the hanger arms.

12. A tunnel-boring machine according to claim 11 having a trailing afterbody hinged to the extreme rear end of the trunk.

13. A tunnel-boring machine according to claim 11, a matching set of at least two paralleling pistons being attached to each of said shoes.

14. A tunnel-boring machine according to claim 13 in which the co-axial bores for at least one of the two pistons of said sets of pistons are in communication, hydraulic fluid from a pressure source being supplied thereto for forcing the pistons outwardly and responsively pressing the shoes against the tunnel wall.

15. A tunnel-boring machine according to claim 11 in which the means for moving and setting the carriage comprises a double-acting hydraulic jack.

16. A tunnel-boring machine according to claim 11 in which the hanger arms for the steering box are comprised of double-acting hydraulic jacks.

17. A tunnel-boring machine according to claim 11 in which the piston elements are universally attached to the anchor shoes.

18. A tunnel-boring machine according to claim 11 in which the box provides upstanding cheek sections which overlie front and back faces of the carriage in spaced normally parallel relation thereto, and spring-pressed means carried by one and pressing against the other of said normally parallel faces for yieldingly urging said faces into said parallel condition.

19. A tunnel-boring machine according to claim 11 in which the linking connection is a radius arm.

20. A tunnel-boring machine according to claim 11 in which said upright arms are comprised of double-acting hydraulic jacks.

21. A tunnel-boring machine according to claim 11 in which the means for moving and setting the carriage comprises at least one double-acting hydraulic jack extending as a connection between the carriage and one of the anchor shoes.

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