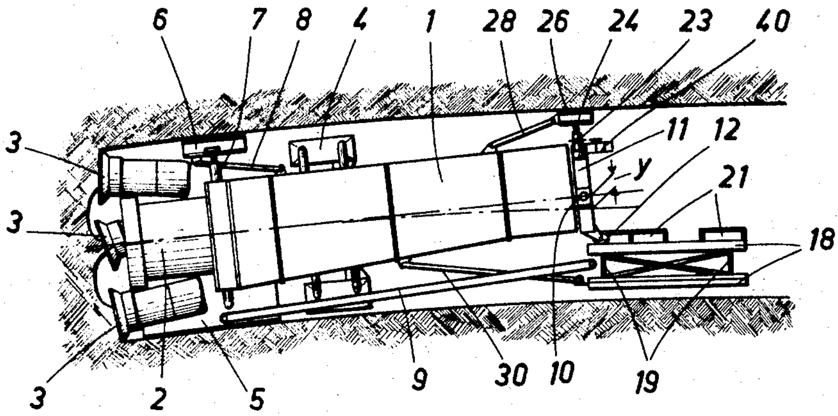
Dec. 10, 1968 E. LAUBER 3,415,574

TUNNEL DRIVING MACHINE STEERING SYSTEM

Filed March 6, 1967 3 Sheets-Sheet 1

FIG.1



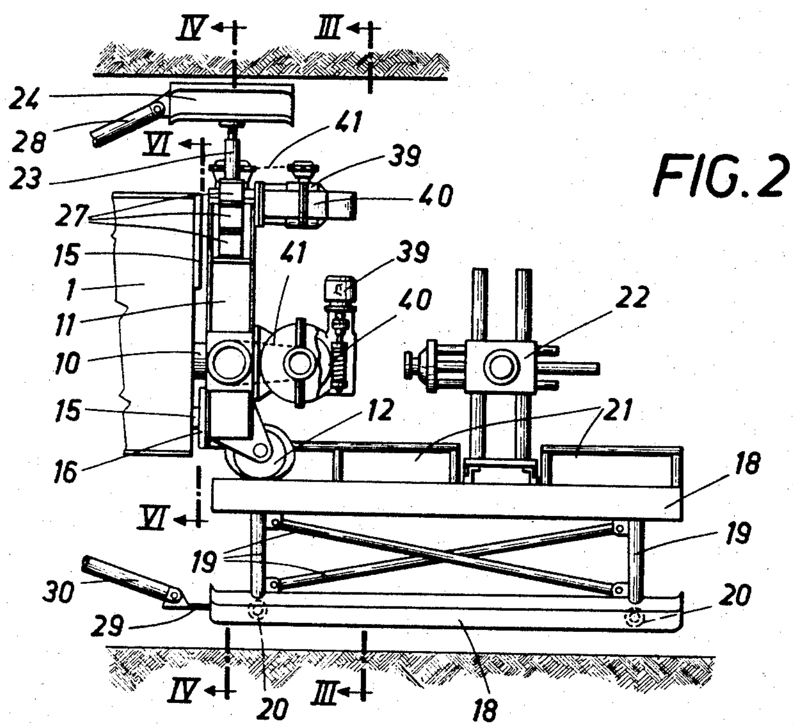


FIG.2

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TUNNEL DRIVING MACHINE STEERING SYSTEM

Filed March 6, 1967 3 Sheets-Sheet 2

FIG. 3

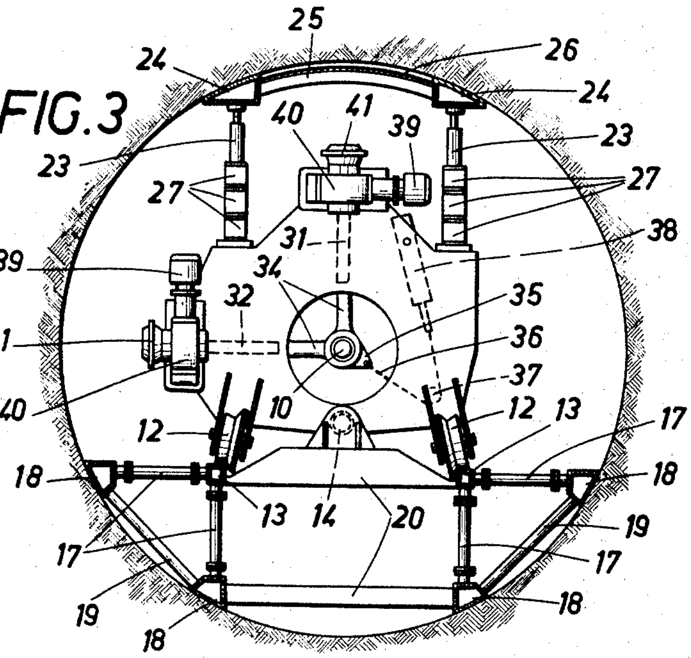
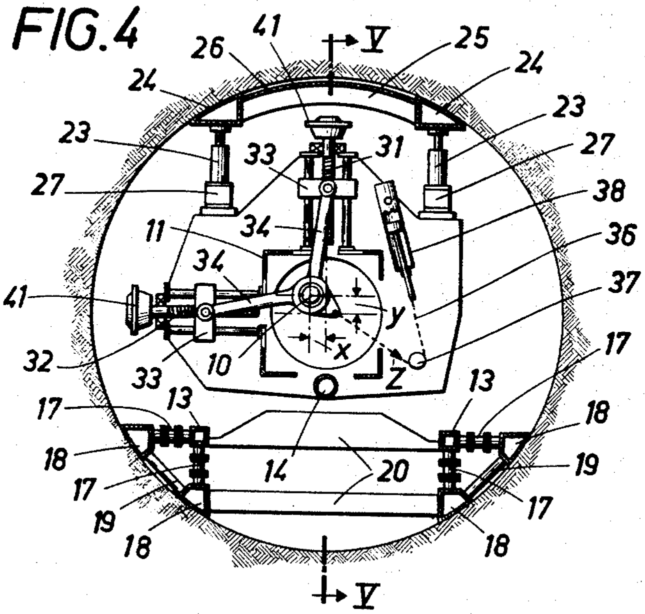


FIG. 4



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3 Sheets-Sheet 3

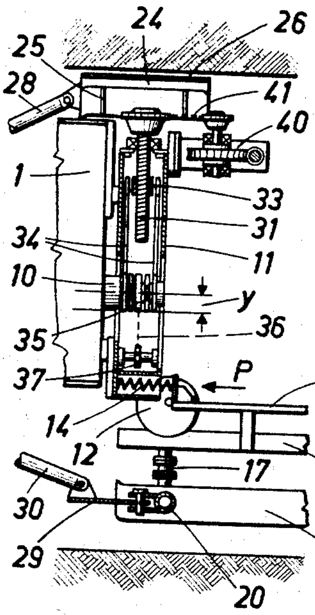


FIG. 5

FIG. 6

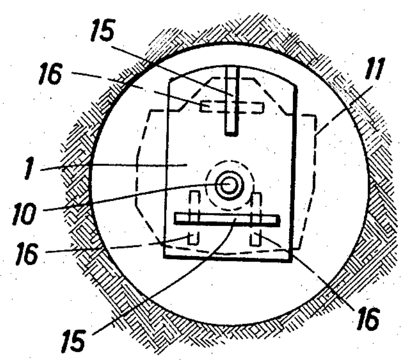


FIG. 7

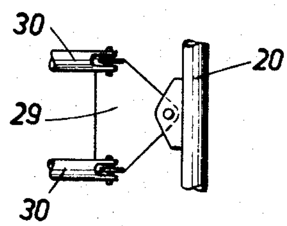
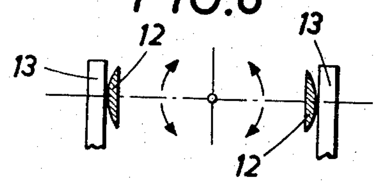


FIG. 8



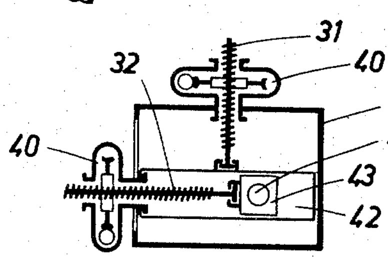


FIG. 9

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TUNNEL DRIVING MACHINE STEERING SYSTEM

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19 Claims. (Cl. 299—31)

ABSTRACT OF THE DISCLOSURE

A tunnel driving system comprises a tunnel driving machine adapted to be guided by the walls of a tunnel being driven, a steering device consisting of a self-contained unit, and towing means detachably connecting said steering device as a trailer to said tunnel driving machine. The rear end of the tunnel driving machine has a rearwardly extending trunnion, which is adjustable in two different directions which are normal to the axis of the trunnion and at an angle to each other. The steering device comprises adjusting means which engage the trunnion and are operable to adjust the trunnion in said two directions.

This invention relates to a tunnel driving machine, which is guided by the wall of the tunnel behind the tools disposed on the forward face of the machine. When a tunnel is driven by a machine, it must be possible to correct an unintended deviation from the required direction of the tunnel as well as to drive a curved tunnel. For these purposes, the main axis of the machine must be laterally displaced relative to the axis of the tunnel in a horizontal direction to the left and right and in a vertical direction upwardly and downwardly.

A machine is known which has a central axial main tube, which is provided in each of two spaced apart transverse planes with four hydraulic jacks, to which running gears are secured in such a manner that respective running gears roll along the tunnel floor, the tunnel roof and the two side walls of the tunnel. During a steering operation, the pistons of the rear jacks remain in an intermediate position and the running gears of these jacks define a point of reference whereas one of the forward jacks is extended and the opposite one is retracted so that the axis of the machine follows a curve. Owing to the cylinder assembly, this steering system requires a special design of the overall machine. It is unfavorable that the steering jacks are relatively close to the drilling or cutting tools, where the highest cutting forces are effective. The adjustment of the jacks requires an expensive and complicated hydraulic control system and the operation is complicated and difficult.

Another known machine comprises a control shoe closely behind the drum which carries the cutting tools, and a supporting shoe at the rear portion of the machine. For a steering operation, the position of the control shoe is changed with the aid of a hydraulic jack whereas the supporting shoe serves as a point of reference. In this case too, the steering conditions are not clearly apparent and the steering device is very close to the cutting zone so that the possibility of an occurrence of errors during the correction is increased. The same remark is applicable to a modification, in which adjustable running gears comprising rollers are used rather than the control shoe which slides on the floor of the tunnel.

Another known steering device, which has been used originally with the so-called shield jacking machines, comprises advancing jacks, which are used also for a change in direction. In the jacking machines, the advancing jacks are laterally disposed in most cases, a steering is possible only in a horizontal plane whereas vertical changes in direction are effected by a vertical adjustment of the control shoe or running gears which have been described. As in all steering systems which comprise hydraulic jacks, the design and operation are relatively complicated. Besides, the advancing jacks are in most cases obliquely arranged between the body of the machine and the lateral abutment plates so that difficult geometrical conditions result during the driving of a tunnel along a curve and render an accurate steering almost impossible. Difficult corrections must then be made by hand in accordance with special calculations, and an automatic control with this system is not possible.

It is an object of the invention to eliminate these disadvantages and to provide a tunnel driving machine with a steering device, which is simple and suitable for a simple and automatic operation and which is suitable for use with tunnel driving machines regardless of the type of tools and of the carrying body of the machine and results in a highly accurate steering and can be adjusted to different tunnel diameters.

The invention is essentially characterized in that the tunnel driving machine is provided with a steering device, which consists of a self-contained unit, which is independently supported in the tunnel and disposed behind the tunnel driving machine and is detachably connected to it by towing rods or the like, and the tunnel driving machine is provided at its rear end with a preferably central trunnion, which extends rearwardly and is held in the steering device for adjustment in two directions, which are at an angle to each other and normal to the axis of the trunnion, preferably in vertical and horizontal directions. As the steering device is designated as an independent unit, it is not influenced by the design of the tunnel driving machine and the latter may have carrying bodies of various types, e.g., an assembly of tubular sections or a lattice structure or a central axial main element. It is sufficient if the tunnel driving machine is provided with the rearwardly extending, central trunnion. The steering device may be disconnected from the tunnel driving machine in the tunnel and can be separately transported too. It will be understood that an adjustment of the trunnion in one direction and/or the other will result in a change of the position of the axis of the machine relative to the tunnel axis so that the desired steering to both sides and upwardly and downwardly is enabled. The movement of the trunnion is resolved into two components so that all directions can be obtained whereas the control is restricted to two straight-line movements so that the control device can be simple and clearly arranged. The steering movement is transmitted to a point which is spaced as far as possible from the forward guide means for the tunnel driving machine so that the steering can be effected with a higher accuracy and the rigid guidance of the tunnel driving machine in the tunnel is improved by the large length in which the machine is fixed. Such rigid guidance is required for drilling in hard rock. The tunnel driving machine can be guided and supported substantially by rigid parts.

Two screws, which are adapted to be driven independently of each other, are provided for adjusting the trunnion. These screws may be driven by respective worm gearings, e.g., from an electric stop motor or a hydraulic motor. In contrast to hydraulic jacks, the screws can be controlled in a simple manner so that the possibility of errors in operation is much reduced. If a self-holding bushbutton control system is employed for generating the adjusting commands, a first pair of pushbuttons for one movement, e.g., the horizontal movement, and another pair of pushbuttons for the other movement, e.g., for the vertical movement, are sufficient. The pushbuttons may be mounted on a control panel which is remote from the machine and disposed, e.g., at the station where the direction of the tunnel axis is controlled so that the steering is remotely controlled. In contrast to other steering systems, the design according to the invention enables an automatic control of the adjustment of the trunnion. For this purpose, a gyro compass provided with a course recorder may be mounted on the tunnel driving machine so that the deviation of the direction of the machine axis from the desired direction is indicated and transmitted to a surface integrator. The integrator and the electronic control circuitry convert then the deviations from the course into control commands for switching the motors for driving the screws so that steering of the machine is fully automatic. When a switching from automatic steering to manual steering is enabled, the operator of the machine may steer by a direct actuation of the pushbuttons. In the case of automatic steering, the adjusting commands required for steering along an arc or a pregiven curve may be stored as a program in the electronic control circuitry.

A particularly suitable design of the adjusting mechanism will be obtained if the screws are rotatably mounted in a housing or the like and held against axial displacement, each spindle carries a crosshead, which is guided so as to be non-rotatable and provided with female screw threads, and a connecting-rod is connected to the crosshead and is formed at its other end with a bearing eye for the trunnion. In this case the trunnion is held in the two connecting-rods, each of which leads to a crosshead, and the trunnion can be adjusted as desired by a displacement of the crossheads by means of the screws. To eliminate backlash throughout the system, the trunnion carries a bearing ring or the like, to which a tension element is connected, which extends approximately in the bisector of the angle between the screws and is connected to a hydraulic jack, to which pressure fluid is constantly applied.

In another design, a carriage is provided, which is displaceable by one of the screws in a guide frame, and the trunnion is received by a bearing body, which is mounted in the carriage for displacement by the other screw in a direction which is transverse to the direction of movement of the carriage.

For a reliable supporting of the steering device in the tunnel so as to avoid a loosening of the device during the adjustment of the trunnion, the housing or the like which contains the means for adjusting the trunnion is mounted with two rollers on rails which are carried by a lower carriage, and, by means of hydraulic jacks, to which pressure is constantly applied, the housing is urged against a skid which engages the roof of the tunnel. As the housing is mounted on the two rollers, it can follow the vertical adjustment of the trunnion and the resulting inclination of the machine axis and of the trunnion while the rollers perform slight movements along the rails. To enable also a lateral pivotal movement of the trunnion during a horizontal adjustment, whereby the housing or the like is also somewhat pivotally moved relative to the carriage, the axes of the rollers are inclined relative to each other and the rollers have conical treads and conical flanges. A force-transmitting connection between the housing or the like and the tunnel driving machine in the axial direction of the trunnion is obtained by the provision of at least one compression spring, which acts between the lower carriage and the housing or the like, and cooperating pressure and slide bars are mounted on the rear end face of the tunnel driving machine and the forward end wall of the housing.

Each of the rails for the carriage is supported by vertical and horizontal supports against two runners, which are interconnected by diagonal struts, and the supports and diagonal struts are exchangeable against similar elements, which are shorter or longer. It is thus possible to use the same carriage for tunnels which differ in diameter, provided that the supports and struts are exchanged against longer or shorter ones. To enable the same adjustment of the top supporting structure, supplemental members can be inserted between the housing or the like and the jacks which provide for the top support, or between these jacks and the sliding shoe. In this case, the sliding shoe consists suitably of two lateral skids, which are connected by ribs, and of a cover sheet.

Without change in the design of the steering device, the carriage and the skids as well as the sliding shoe may be replaced by rollers or by crawler systems.

An embodiment of the invention is shown by way of example on the accompanying drawings, in which

FIG. 1 is a side elevation showing a tunnel driving machine provided with a steering device,

FIG. 2 is a similar view showing the steering device on a larger scale,

FIG. 3 is a transverse sectional view taken on line III—III of FIG. 2,

FIG. 4 is a transverse sectional view taken on line IV—IV of FIG. 2 in a tunnel which is smaller in diameter.

FIG. 5 is a longitudinal sectional view taken on line V—V of FIG. 4.

FIG. 6 is a transverse sectional view taken on line VI—VI of FIG. 2 on a smaller scale,

FIG. 7 is a top plan view showing the towing rod assembly at the lower carriage.

FIG. 8 is a sectional view taken on the level of the top of the rails and showing the rollers, and

FIG. 9 is a diagrammatic view showing another means for adjusting the steering device.

The tunnel driving machine shown in FIG. 1 comprises a machine body **1**, which is composed of a plurality of tube sections, and a drum **2**, which is rotatably mounted on the front end of the machine body and carries the tool units **3**. A propulsion unit **4** comprising hydraulic jacks is provided for propelling the machine. The tunnel driving machine comprises a sliding shoe **5**, which bears on the floor of the tunnel. A top sliding shoe **6** is forced by hydraulic jacks **7** against the roof of the tunnel and is connected by thrust rods **8** to the machine body **1**. A belt conveyor **9** serves for the removal of material.

A rearwardly extending, central trunnion **10** is provided at the rear end of the tunnel driving machine **1** and is held in the steering device for adjustment in vertical and horizontal directions. The steering device comprises a support in the form of a housing **11**, which consists of end plates and of spacing angles, which connect the end plates. The housing **11** carries on the underside track rollers **12**, which are mounted between oblique carrying plates and by which the housing is mounted on rails **13** of a lower carriage. The track rollers **12** have conical treads and conical flanges so that the housing can be pivotally moved laterally, as is apparent from FIG. 8, and the housing **11** can also be forwardly and rearwardly inclined on the rails **13** with a slight rolling movement of the track rollers **12** on the rails **13**. A compression spring **14** bears on the carriage and produces a force P to force the housing **11** against the rear end wall of the tunnel driving machine **1**. Pressure bars **15** and slide bars **16** (FIG. 6), which cross the pressure bars, are provided on the rear end wall of the machine **1** and on the forward end wall of the housing, respectively.

Each of the two rails **13** of the carriage is supported by struts **17** on two skids **18**, which are interconnected by diagonal struts **19**. Cross-connectors **20** are provided between the rails **13** and the lower skids **18**. The supports **17** and the diagonal struts **19** may be replaced by similar elements, which are shorter or longer. This is apparent from a comparison of FIGS. 3 and 4. In this way, the carriage can be adapted to different tunnel diameters. A walk-on platform **21** may be provided on the carriage and may be used in applying gunite to the tunnel wall or for drilling holes for anchors to be inserted into the rock. A core drilling machine **22** may be mounted on the carriage for transverse movement. Core drilling or probing operations before the tunnel driving machine may be carried out with this core drilling machine through the hollow trunnion **10**, the machine body **1**, and the drum **2**, which has a central bore. Such core drilling operations furnish valuable geological information concerning the nature of the rock and the occurrence of water during the tunnel driving operation.

The housing **11** is supported at the top by hydraulic jacks **23**, to which pressure fluid is constantly applied, against a sliding shoe, which contacts the roof of the tunnel and consists of two lateral skids **24**, which are connected by ribs **25**, and of a cover sheet **26**. A plurality of supplemental members **27** are inserted between the jacks **23** and the housing **11** (FIGS. 2 and 3). In tunnels which are smaller in diameter, the number of these supplemental members, which are entirely identical, is correspondingly reduced, as is shown in FIG. 4. The skids **24** are articulatedly connected to the body **1** of the tunnel driving machine by towing rods **28**. A swing beam **29** is pivoted to the forward transverse tube **20** of the lower carriage and the lower towing rods **20** and pivoted to the swing beam **29** and connected to the machine body **1** (FIG. 7).

Two screws **31, 32** are provided for adjusting the trunnion **10**. The screws extend in vertical and horizontal directions, respectively, and are rotatably mounted in the housing and held against axial movement relative thereto. Each screw **31, 32** carries a crosshead **33**, which is provided with female screw threads and guided on side bars so as to be held against rotation. A rotation of the screws will thus result in a corresponding displacement of the associated crosshead. Each crosshead **33** has connected to it a two-part connecting rod **34**, which is formed at the other end with a bearing eye for the trunnion **10**. A bearing ring **35** is mounted on the trunnion **10** between the connecting rods. A roller chain **36** is connected to the bearing ring **35** and extends around a reversing roller **37** and then approximately in the bisector of the angle between the two connecting rods **34** to a piston drive **38**. Oil under pressure is constantly applied to the rod end of the piston of the piston drive **38** so that a tensile force Z is exerted on the trunnion **10** and the entire adjusting device is held free of backlash. This is essential for a firm fixation of the tunnel driving machine.

FIG. 3 shows the trunnion in an intermediate position, in which the axis of the tunnel driving machine coincides with the axis of the tunnel. In FIG. 4, the trunnion is horizontally adjusted by a distance Y in a vertical direction and by a distance X in a horizontal direction so that the axis of the tunnel driving machine deviates in vertical and horizontal directions from the tunnel axis. As is shown in FIG. 1, the tunnel can be driven with a downward inclination and at the same time with a curvature to the right. This adjustment with the aid of the screws is required not only for driving curved portions of the tunnel but also for a correction of unintended deviations from the intended axis of the tunnel.

Each of the two screws **31, 32** is driven from an electric stop motor **39** by means of a flexible coupling, a worm gearing **40** and a chain drive **41**. The motor must be a stop motor so that the rotor is immediately braked when the adjusting command has ceased, and the rotor is then blocked so that an unintended adjustment is prevented. Alternatively, a hydraulic motor may be provided, to which oil under pressure is applied and which has such a small rotor mass that it is immediately stopped when the supply of oil has been shut off. Just as with electric stop motors, the control may be effected by electric contacts with the aid of magnetic valves, which shut off the supply and discharge of hydraulic oil to and from the motor to block the same when the valves are in an intermediate position.

FIG. 9 shows a different means for adjusting the trunnion **10**. This means is similar in operation to a compound slide. A carriage **42** is mounted in the housing **11** for upward and downward displacement by a screw **31**. The worm wheel of the worm gearing **40** is formed with the female screw threads and the screw **31** is held against rotation. A bearing body **43** is mounted in the carriage **42** and receives the trunnion **10**. The bearing body **43** can be reciprocated in a horizontal direction, transversely to the direction of movement of the carriage **42**, by the screw **32**. Each of the worm gearings **40** is driven by an electric or hydraulic motor.

What is claimed is:

1. A tunnel driving system, which comprises a tunnel driving machine adapted to be guided along the walls of a tunnel being driven, a steering device consisting of a self-contained unit, towing means connecting said steering device as a trailer to said tunnel driving machine, and means for supporting said tunnel driving machine and said steering device independently of each other in said tunnel, said tunnel driving machine having a rear end, which carries a rearwardly extending trunnion and which is adjustable in two different directions, which are normal to the axis of said trunnion and at an angle to each other, said steering device comprising adjusting means, which engage said trunnion and are operable to adjust said trunnion in said two directions.

2. A tunnel driving system as set forth in claim **1**, in which said towing means comprise towing rods.

3. A tunnel driving system as set forth in claim **1**, in which said trunnion is centrally disposed at said rear end of said tunnel driving machine.

4. A tunnel driving system as set forth in claim **1**, in which said two directions are vertical and horizontal, respectively.

5. A tunnel driving system as set forth in claim **1**, in which said adjusting means comprise two screws respectively extending in said directions, and means for driving said screws independently of each other.

6. A tunnel driving system as set forth in claim **5**, which comprises a bearing ring mounted on said trunnion, a hydraulic piston drive, means for permanently applying pressure fluid to said piston drive, and a tension element which connects said bearing ring to said piston drive and extends substantially in the bisector of the angle between said two screws.

7. A tunnel driving system as set forth in claim **5**, which comprises a guide frame, a carriage, which is displaceable in said guide frame by means of one of said screws, and a bearing body, which is mounted in said carriage and displaceable relative thereto by the other of said screws in a direction which is transverse to the direction of movement of said carriage, said trunnion being held in said bearing body.

8. A tunnel driving system as set forth in claim **5**, in which said means for driving said screws comprise two worm gearings.

9. A tunnel driving system as set forth in claim **8**, in which said screws are rotatable and in engagement with non-rotatable, axially fixed nuts and said worm gearings are operatively connected to said screws to rotate the same.

10. A tunnel driving system as set forth in claim **8**, in which said screws are non-rotatable and in engagement with rotatable, axially fixed nuts, and said worm gearings are operatively connected to said nuts to rotate the same.

11. A tunnel driving system as set forth in claim **5**, in which said steering device comprises a frame, in which said screws are rotatably and axially non-displaceably mounted, each of said screws carries a crosshead, which has female screw threads engaging the respective screw, guide means are provided in engagement with said crossheads to hold the same against rotation, and two connecting rods are provided, each of which is connected at one end to one of said crossheads and is formed at its other end with a bearing eye engaging said trunnion.

12. A tunnel driving system as set forth in claim 11, which comprises a lower carriage, which is provided with rails, track rollers carried by said frame and adapted to roll on said rails, a slide shoe adapted to engage the roof of said tunnel, hydraulic jacks interposed between said frame and said slide shoe, and means for permanently applying hydraulic pressure to said jacks.

13. A tunnel driving system as set forth in claim 12, in which said track rollers have conical treads and conical flanges and are rotatable on axes which are relatively inclined.

14. A tunnel driving system as set forth in claim 12, which comprises at least one compression spring interposed between said lower carriage and said frame, and which comprises cooperating pressure and slide bars carried by the tunnel driving machine at its rear end and by said steering device at its forward end.

15. A tunnel driving system as set forth in claim 12, which comprises two pairs of skids, diagonal struts connecting the skids of each pair, and vertical and horizontal supports interposed between each of the rails of the carriage and the skids of one of said pair, said supports and diagonal struts being detachably mounted.

16. A tunnel driving system as set forth in claim 12, which comprises at least one supplemental member detachably interposed between said frame and each of said hydraulic jacks.

17. A tunnel driving system as set forth in claim 12, which comprises at least one supplemental member detachably interposed between each of said hydraulic jacks and said slide shoe.

18. A tunnel driving system as set forth in claim 12, in which said slide shoe consists of two lateral skids, ribs connecting said skids, and a cover plate.

19. A tunnel driving system as set forth in claim 12, which comprises crawler means connected to said frame and adapted to support the same in the tunnel.

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U.S. Cl. X.R.

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