This invention relates to a novel apparatus for driving tunnels. It is another object of this invention to provide in tunnel driving apparatus of the character described novel stabilizing means associated with the plurality of extensible legs on jacks on each side of the shield for stabilizing the legs or jacks and holding them from being moved while the shield is being advanced. It is still another object of the invention, this stabilizing means permitting each leg or jack to be intentionally independently moved into positions best to support the shield but operating to prevent movement of the legs while the shield is being advanced.

Other objects and advantages of the invention will be hereinafter described or those skilled in the art, and the novel features of the invention will be defined in the appended claims.

Referring to the drawings:

FIG. 1 is a longitudinal sectional view of apparatus embodying the present invention with the elements thereof disposed for driving the shield into the face of the tunnel relative to the supporting jacks; FIG. 2 is a view similar to FIG. 1 showing the positions occupied by elements of the apparatus after the shield has been driven a full stroke into the face of the tunnel, and indicating by the dot-dash showing of one of the jacks how the jacks may be repositioned to prepare the apparatus for the next advance of the shield; FIG. 3 is a transverse sectional view taken on the line 3—3 of FIG. 1; FIG. 4 is a front elevation showing the apparatus substantially in the same position as shown in FIG. 1; FIG. 5 is an enlarged vertical sectional view of one of the extensible jacks for supporting the shield, showing schematically in association therewith the hydraulic circuit and control means for each jack; FIG. 6 is an enlarged detail view in section of the portion of the jacks to which the fluid lines are connected; FIG. 7 is a fragmentary sectional view taken on the line 7—7 of FIG. 1, on an enlarged scale; FIG. 8 is a fragmentary view of a modified form of extensible jack for supporting the shield showing the latter in section and the jack in elevation; and FIG. 9 is an enlarged fragmentary sectional view of the jack shown in FIG. 8 including the schematic view of the hydraulic circuit and manually operable pump means for extending and retracting the jack.

Apparatus embodying the present invention includes an elongate steel shield A of horseshoe shape adapted to be driven into the earth as shown in FIGS. 1 and 2, wherein F designates the face of the tunnel being formed. The forward portion 1 of the shield is suitably reinforced preferably internally thereof and contains apparatus to be hereinafter described for driving the shield into the earth. The rear portion 2 of the shield is adapted to extend as a protective shell over the tunnel lining or wall structure B that is erected progressively as the shield is advanced in the formation of the tunnel. As here shown, the forward portion 1 of the shield is reinforced by means of longitudinally spaced arcuate plates 3 welded or otherwise fixed at their outer edges to interior surface of the shield and projecting inwardly therefrom with their inner edges welded to arched ribs 4 extending to the lower edges of the sides of the shield. Just inside the downwardly and rearwardly inclined front end 5 of the shield are a series of triangular plates 6 welded to the inner surface of the shield and the foremost plates 3.

Means are provided for driving the shield into the earth and, as here shown, include four hydraulic rams.
3,250,078

3. The pistons 8 of the rams 7 extend rearwardly so as to contact the forward portion of the wall assembly B which serves as a solid base structure against which the pistons bear in actuating the rams 7 to advance the shield. Any suitable means, not shown, may be employed for supplying and controlling the application of hydraulic fluid for operating the rams 7, it being preferable, however, to operate these rams in the manner and by the means shown in my co-pending application for patent, Serial No. 678,993, now Patent No. 3,138,933, issued June 30, 1964.

The wall or tunnel structure B, as here shown, may comprise a plurality of steel H-beams or ribs 9 that are erected in the rear of shell portion 2 of the shield as shown in FIGS. 1 and 2 with suitable lagging strips 10 installed between the beams. These beams and lagging strips are added to increase the length of the tunnel wall structure B as the shield is advanced.

If a concrete lining for forming a conduit in the tunnel is to be provided, the lagging strips 10 when uncovered by advancing the shield so that the rear shell portion 2 of the tunnel portion of the structure B, may be used as the outer wall of a concrete form. However, in some instances, the structure B may be utilized as the supporting lining or wall of the tunnel and for the purpose of this description, it will be assumed that the foremost steel beam or rib 9 has been firmly installed. This firm installation of the foremost beam 9 is accomplished by use of jacks 11 as shown in FIG. 3, and the placing of base plates 12 under the beam whereby the structure B is forced against the inner surface of the rear portion 2 of the shield and is firmly secured in place, with provision, however, for the shield to be advanced relative thereto. Brace members 13 are positioned longitudinally on the structure B in line with the pistons 8 of the rams 7 and against the foremost rib 9 engaged by the pistons, these braces being securely attached in any suitable manner to the structure B so that a firm backing is provided for each piston to assure that the shield will be advanced upon actuation of the rams 7.

In accordance with the invention, a plurality of longitudinally shiftable and extensible supporting members for the shield are located in a row in longitudinally spaced relation to one another against each side wall of the shield so as to leave a large unobstructed space between the sides of the shield at the face F of the tunnel for accommodating the digging apparatus and men required to dig the tunnel, while at the same time providing for a reliable support of the shield while the shield is advanced relative to the supporting members and at all other times during the operation of forming the tunnel. A particular advantage of this arrangement of supports is that they may be moved one at a time or otherwise into position best to brace the shield for supporting the over-burden in all types of ground, while at least one of the supports of the plurality on each side of the shield will be in shield supporting position during such movement of other of the supports. No center support is required for the shield while shifting the side supports as desired to prepare the shield for advance into the tunnel face, and no undesirable tilting of the shield which was occasioned at times with use of a center support, is permitted in view of the support of the shield on opposite sides of the longitudinal center line of the shield.

The plurality of supports above referred to may consist, as here shown, of a pair of extensible hydraulic jacks 15 disposed one ahead of the other on one side of the longitudinal center line of the shield and close to one side wall of the shield, while another pair of extensible jacks 16 is arranged in like manner on the other side of the shield. Obviously, more than two jacks may be provided on each side of the shield, the number of jacks required depending upon the size of the shield and the load to be carried. In one embodiment position, the jacks 15 and 16 are set against the shield, and are then at an advantageous position for supporting the shield. As a means for mounting the jacks 15 and 16 so that the shield may be shifted relative thereto in being driven into the tunnel face and so that the jacks may be shifted longitudinally of the shield to reposition them as supports, longitudinally extending track assemblies 17 are welded or otherwise secured to the upper part of the forward portion 1 of the shield in laterally spaced relation to the longitudinal center line of the shield. Each track assembly 17 includes a plate 18 welded to and depending from the inner surface of the shield and provided at its lower edge with a rail 19 welded thereto for supporting a carriage 20 having upper and lower sets of rollers 21 which ride on the top of the rail and on the lower side of the rail. Each carriage 20 supports one of the supports which is pivoted thereto as at 22. With this arrangement the shield may be shifted relative to the jacks while the latter support the shield.

After an advance of the shield the jacks readily may be shifted longitudinally and repositioned as supports for the shield to prepare the shield for another advance into the tunnel face. The jacks may be swung on the pivotals connecting the side member of the carriage 20 to out-of-the-way positions when this is desired. Means are provided for stabilizing the jacks or legs 15 and 16 and to prevent them from being moved as the shield is being advanced. For this purpose the forward jack or leg on each side of the shield has a pair of rods 23 connected at each end to the jack and extended therefrom rearwardly along opposite sides of the carriage 20 of the next adjacent jack. At their rear ends the rods 20a have a cross member 20c fixed thereto and adapted to be secured by means of a hook 20d to a cable 20e. This cable leads to a come-along 20f anchored as at 20g to the structure B. The rods 20a are slidable supported on a cross member 20h fastened on the carriage 20 of the rearmost jack on each side of the shield. With this arrangement the rods 20a and cross member 20c comprise a frame or yoke D which embraces the plurality of supports on each side of the shield yet permit free movement of the jacks the desired extent best for supporting the shield. As shown in FIGS. 1 and 7, when the jacks are positioned forwardly to support the shield for an advance into the tunnel face, the carriages 20 abut one another and as the foremost carriage and its jack are restrained by the yoke D, cable 20e and comealong 20f, the plurality of jacks on opposite sides of the shield remain in upright position and are held against being moved as the shield is advanced relative thereto. The come-along 20e may be operated as required to release the cable to allow the foremost jack to be moved with the yoke D attached thereto. The come-along may be locked or tightened when the cable is taut and the jacks are forwardly positioned. The length of the yoke D is such that the rearmost jack or a plurality thereof, if desired, may be independently moved therein as required best to support the shield. Thus, the yokes D at each side of the assembly and each carriage allow shifting of the support means for holding the forward jack against movement with the shield in an advance direction as well as for allowing independent longitudinal positioning of the respective rearward jacks.

Each of the jacks is constructed to be hydraulically extended and retracted whereby upon retraction from engagement with the ground, the jack comes along under control to the location where it is desired to provide a support for the shield and then extended into ground engaging position. As here shown, each of the jacks 15 and 16 is of the same construction and includes a tubular body portion 23 the upper end of which is pivoted as herebefore
noted as at 22 to one of the carriages 20 and supports therein a fixed piston unit 24 and a movable cylinder 25. This cylinder extends from the lower end of the body portion 23 and is closed at its upper and lower ends by an annular member 26 and a closure 27 respectively. The piston 28 of the piston unit 24 is disposed between the closed ends of the cylinder 25 with the piston rod 29 extending through the annular member 26. A seal 30 carried by the member 26 forms a seal around the piston rod.

As shown here, the piston rod 29 is made up of concentric tubular members 31 and 32 providing fluid passages 33 and 34, leading into cylinder above and below the piston 28 respectively. The upper end of the piston rod 29 is supported by a partition 35 which is fixed in the upper part of the body portion 23. Passages 33' and 34' in the partition 35 are arranged to register with the passages 33 and 34 in the piston rod. Hydraulic fluid under pressure when directed through the passages 33' and 33 will enter the cylinder 25 above the piston 28 to cause the cylinder 25 to be retracted into the body portion 23, while fluid below the piston is exhausted through passages 34 and 34' back to the source of hydraulic fluid under pressure. When hydraulic fluid under pressure is directed through the passages 34' and 34 into the cylinder 25 below the piston 28 the cylinder will be extended while fluid above the piston will return to the source through passages 33' and 33'.

Each of the jacks 15 and 16 is controlled by a manually operable valve 36 mounted thereon and connected by means of a conduit 41 with the passages 33' and 33 in the jack. A similar conduit 42 connects the valve 36 with the passages 34' and 34 in the jack. An intake manifold 39 and a return manifold 44 are mounted on each side wall of the shield and through flexible hose lines 40 and 43 respectively are connected to the valves 36 of the adjacent pair of jacks as indicated by the schematic showing in FIG. 5. As shown in FIGS. 1 and 2, the manifolds 39 and 44 are connected to intake and return conduits 45 and 46 which may be connected to any suitable source of hydraulic fluid under pressure, not shown.

This arrangement of manifolds, conduits and control valves is merely illustrative and it is to be understood that any suitable hydraulic circuitry may be employed for the jacks provided each jack is equipped with valve means operable at will to extend or retract each jack independently of the other jacks.

Each of the jacks 15 and 16 is constructed so that piston unit 24 and the cylinder 25 may be removed and replaced relative to the body portion 23. The cylinder may so be mounted in the shield 5 in such a manner that the shield is longitudinally movable relative to the supports and the supports may be longitudinally moved relative to the shield. In supporting each side of the shield with a group of shiftable supports or jacks in accordance with this invention, the jacks may be shifted more at a time into positions best to support the shield but in all instances so that other of the jacks on each side of the shield afford adequate support for opposite sides of the shield at all times.

With this arrangement and method of disposing and shifting the jacks, a better positioning thereof for supporting the shield is also obtained. By “bad ground” may be effected. Moreover, the length of each leg may be varied while it is in ground engaging and shield supporting position by extending certain jacks and retracting others. This will make it possible to tilt or cant the shield with a nicety so as to facilitate making accurate turns of the tunnel bore while remaining on grade. It is desired to provide a greater number of jacks at a specific location on one side of the shield that is longitudinally spaced from a lesser number of jacks on the opposite side of the shield to compensate for “bad” ground or for any other purposes, this arrangement readily may be brought about. Only will the foregoing advantages be afforded by utilizing a plurality of jacks on each side of the shield in the manner herein described, without use of a center jack, but greater working space is provided at the face of the tunnel to facilitate the operation of forming the tunnel.

While specific structural elements have been shown and described, it should be understood that changes and alterations may be resorted to without departing from the spirit of the invention as defined in the appended claims.

I claim:

1. Apparatus for driving a tunnel comprising: an elongate, arched shield; means shiftable supporting said shield for axial movement; means for so moving said shield relating...
tive to said supporting means; said supporting means including a pair of longitudinally extended members carried by said shield adjacent the top of the shield in laterally opposed transversely spaced relation at opposite sides of the longitudinal center line of the shield; a plurality of extensible jacks depending from each of said longitudinally extended members; and means individually shiftable connecting said plurality of said jacks with each of said tracks, with said jacks relatively disposed thereon so that when one of the plurality of jacks on either of said tracks is moved from contact with the ground, at least one other jack on each track be disposed in contact with the ground whereby said shield will be supported on opposite sides of said center line.

2. Apparatus for driving a tunnel comprising: an elongate, arched shield; means shiftable supporting said shield for axial movement; means for so moving said shield relative to said supporting means; said supporting means including a pair of longitudinally extended members carried by said shield adjacent the top of the shield in laterally opposed transversely spaced relation at opposite sides of the longitudinal center line of the shield; at least two extensible and contractible shield supporting legs depending from each of said longitudinally extended members for contact with the ground beneath the shield; and means shiftable connecting said legs with said longitudinally extended members so that said legs on each of said longitudinally extended members are disposed one ahead of the other subject to being shifted relative to one another and relative to said shield after said advance of said shield, to occupy a different shield supporting position while at least one leg on each of said longitudinally extended members remains in shield supporting position.

3. Apparatus for driving a tunnel comprising: an elongate, arched shield; means shiftable supporting said shield for axial movement; means for so moving said shield relative to said supporting means; said supporting means including a pair of longitudinally extended members carried by said shield adjacent the top of the shield in laterally opposed transversely spaced relation at opposite sides of the longitudinal center line of the shield; a pair of extensible and contractible shield supporting legs depending from each of said longitudinally extended members for contact with the ground beneath the shield; means shiftable connecting said legs with said longitudinally extended members so that said legs on each of said longitudinally extended members are disposed one ahead of the other subject to being shifted relative to one another and relative to said shield after said advance of said shield, to occupy a different shield supporting position while at least one leg on each of said longitudinally extended members remains in shield supporting position; and means embodied in each leg operable for moving the leg into and from contact with the ground.

4. Apparatus for driving a tunnel comprising: an elongate, arched shield; means shiftable supporting said shield for axial movement; means for so moving said shield relative to said supporting means; said supporting means including a pair of longitudinally extended members carried by said shield adjacent the top of the shield in laterally opposed transversely spaced relation at opposite sides of the longitudinal center line of the shield; at least two extensible and contractible shield supporting legs depending from each of said longitudinally extended members for contact with the ground beneath the shield; means shiftable connecting said legs with said longitudinally extended members so that said legs on each of said longitudinally extended members are disposed one ahead of the other subject to being shifted relative to one another and relative to said shield after said advance of said shield, to occupy a different shield supporting position while at least one leg on each of said longitudinally extended members remains in shield supporting position; and anchoring means operatively connected with said legs to hold them against movement when said shield is moved axially.

5. Apparatus for driving a tunnel comprising: an elongate, arched shield; means shiftable supporting said shield for axial movement; means for so moving said shield relative to said supporting means; said supporting means including a pair of longitudinally extended members carried by said shield adjacent the top of the shield in laterally opposed transversely spaced relation at opposite sides of the longitudinal center line of the shield; at least two extensible and contractible shield supporting legs depending from each of said longitudinally extended members for contact with the ground beneath the shield; means shiftable connecting said legs with said longitudinally extended members so that said legs on each of said longitudinally extended members are disposed one ahead of the other subject to being shifted relative to one another and relative to said shield after said advance of said shield, to occupy a different shield supporting position while at least one leg on each of said longitudinally extended members remains in shield supporting position; and means embodied in each leg operable to vary the length of the leg while the leg is engaged with the ground.

6. Apparatus for driving a tunnel comprising: an elongate, arched shield; means shiftable supporting said shield for axial movement; means for so moving said shield relative to said supporting means; said supporting means including a pair of longitudinally extended members carried by said shield adjacent the top of the shield in laterally opposed transversely spaced relation at opposite sides of the longitudinal center line of the shield; at least two extensible and contractible shield supporting legs depending from each of said longitudinally extended members for contact with the ground beneath the shield; means shiftable connecting said legs with said longitudinally extended members so that said legs on each of said longitudinally extended members are disposed one ahead of the other subject to being shifted relative to one another and relative to said shield after said advance of said shield, to occupy a different shield supporting position while at least one leg on each of said longitudinally extended members remains in shield supporting position; and means embodied operatively connected with said legs adjacent the upper ends thereof to prevent movement of said legs during the axial movement of said shield.

7. Apparatus for driving a tunnel comprising: an elongate, arched shield; means shiftable relative to said shield for axial movement; means for so moving said shield relative to said supporting means; said supporting means including a plurality of extensible and contractible legs depending from said shield for engagement with the ground; there being a plurality of legs arranged in a row on each of opposite sides of the longitudinal center line of said shield; said rows of legs being adjacent the sides of said shield; means shiftable connecting each of said legs in each row with said shield; means engaged with the foremost leg of each row for restraining said foremost legs against axial movement during said advance of said shield; said last named means including a yoke connected to said foremost leg and connecting the legs rearwardly of the foremost legs; and means extending rearwardly from said yoke for releasably anchoring the yoke against movement.

8. Apparatus for driving a tunnel comprising: an elongate, arched shield; means shiftable supporting said shield for axial movement; means for so moving said shield relative to said supporting means; said supporting means including a pair of longitudinally extended members carried by said shield at the sides of the shield in laterally opposed transversely spaced relation at opposite sides of the longitudinal center line of the shield; a plurality of
extensible jacks depending from each of said longitudinally extended members for contact with the ground to support said shield; a track on each of said longitudinally extended members; and means individually shiftably connecting said plurality of said jacks with each of said tracks, with said jacks relatively disposed thereon so that when one of the plurality of jacks on either of said tracks is moved from contact with the ground, at least one other jack of said plurality of each track will be disposed in contact with the ground whereby said shield will be supported on opposite sides of said center line.

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