March 19, 1968 M. F. KEMPER 3,373,572

METHOD OF DRIVING TUNNELS

Original Filed May 23, 1963 4 Sheets-Sheet 1

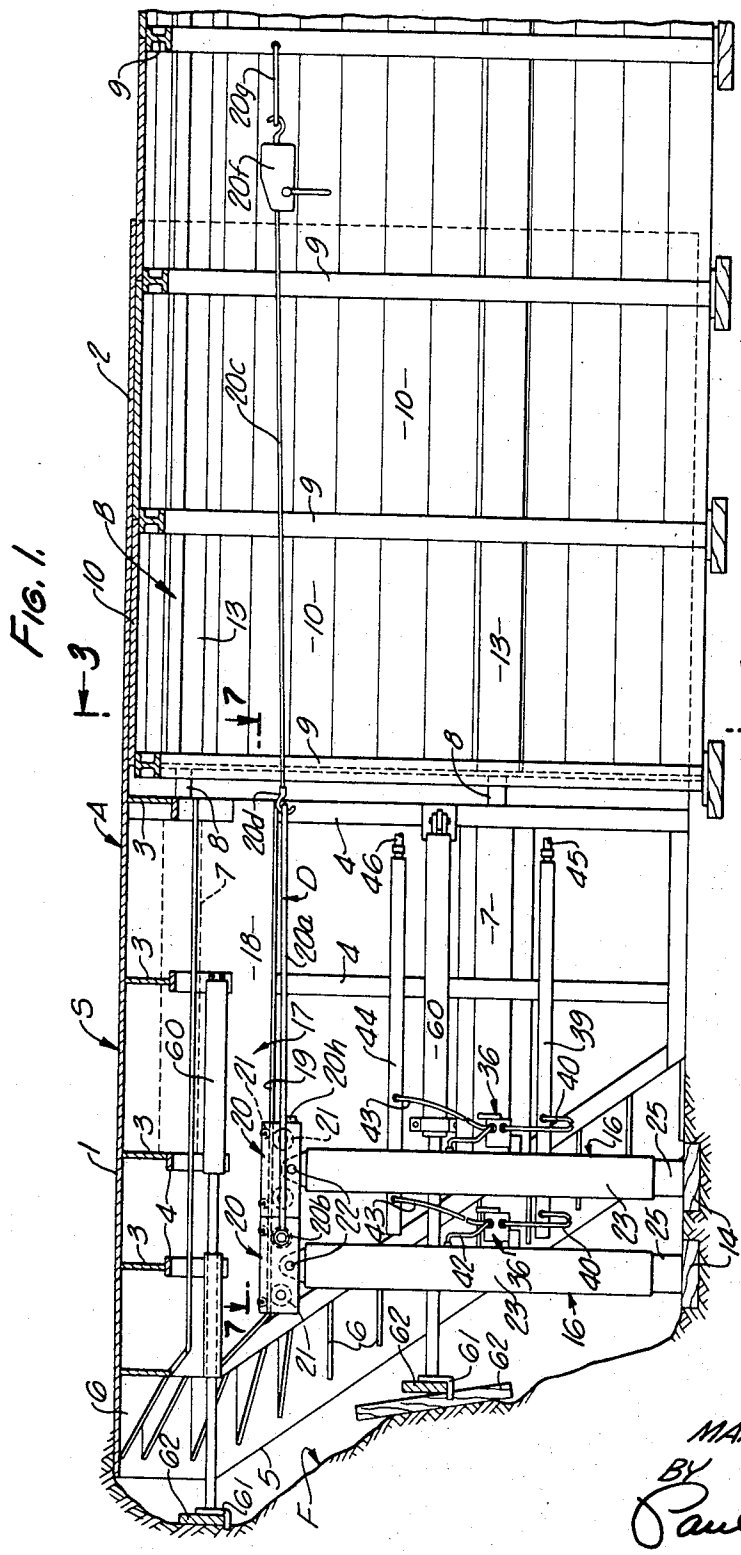


FIG. 1.

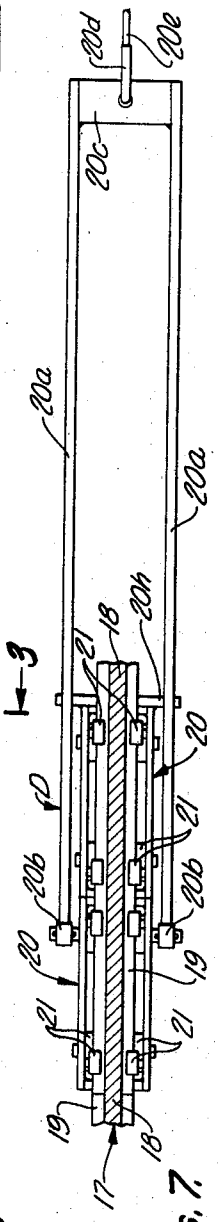


FIG. 7.

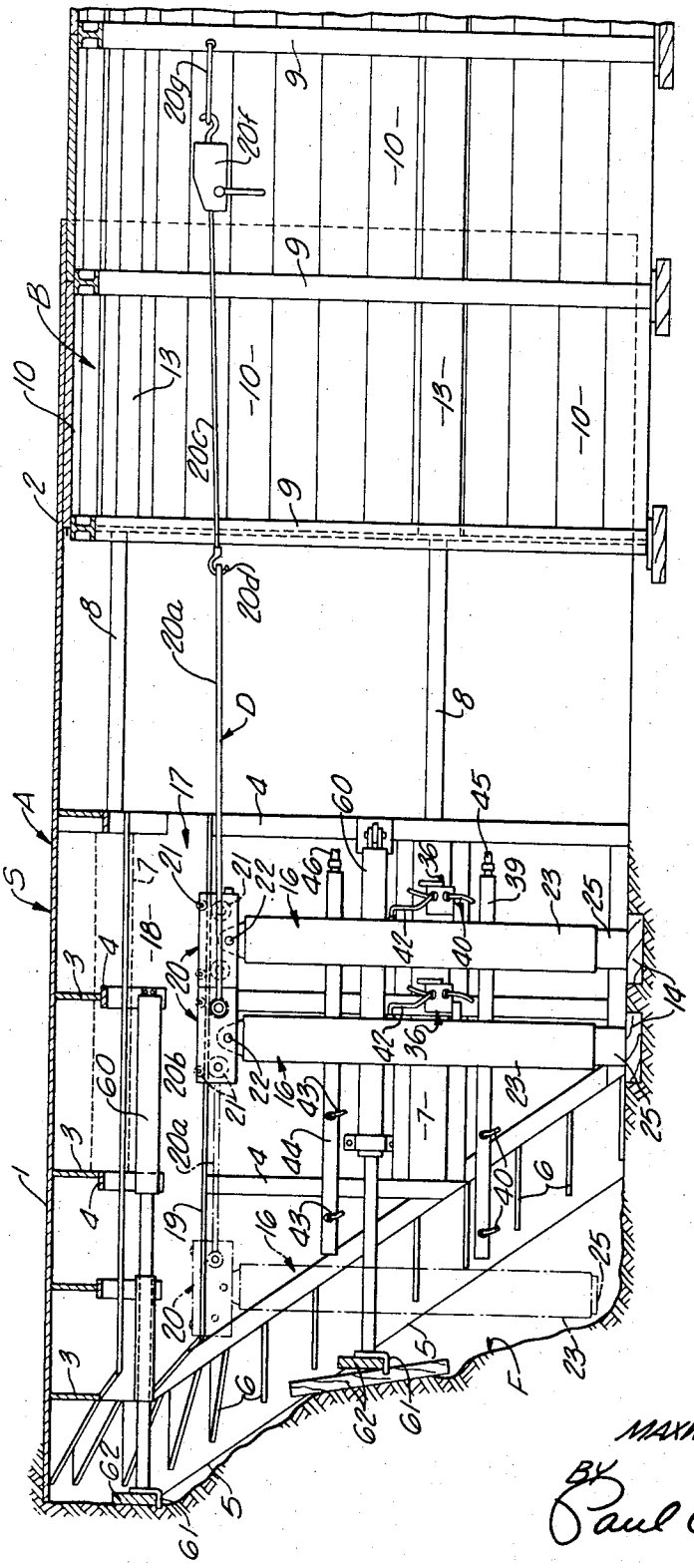
INVENTOR
MAXWELL F. KEMPER
BY
Paul A. Weilein
ATTORNEY

March 19, 1968 M. F. KEMPER 3,373,572

METHOD OF DRIVING TUNNELS

Original Filed May 23, 1963 4 Sheets-Sheet 2

FIG. 2.



INVENTOR
MAXWELL F. KEMPER
BY
Paul A. Weilein
ATTORNEY

March 19, 1968 M. F. KEMPER 3,373,572

METHOD OF DRIVING TUNNELS

Original Filed May 23, 1963 4 Sheets-Sheet 3

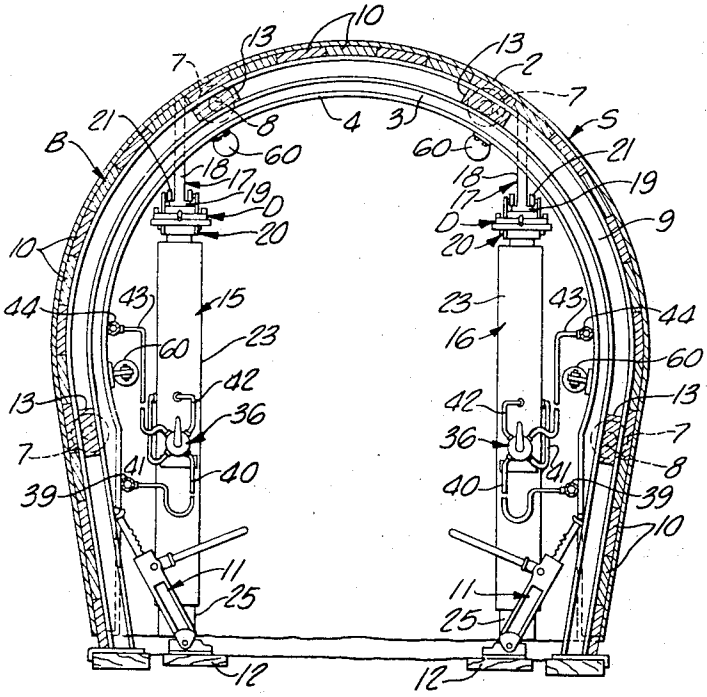


FIG. 3.

FIG. 4.

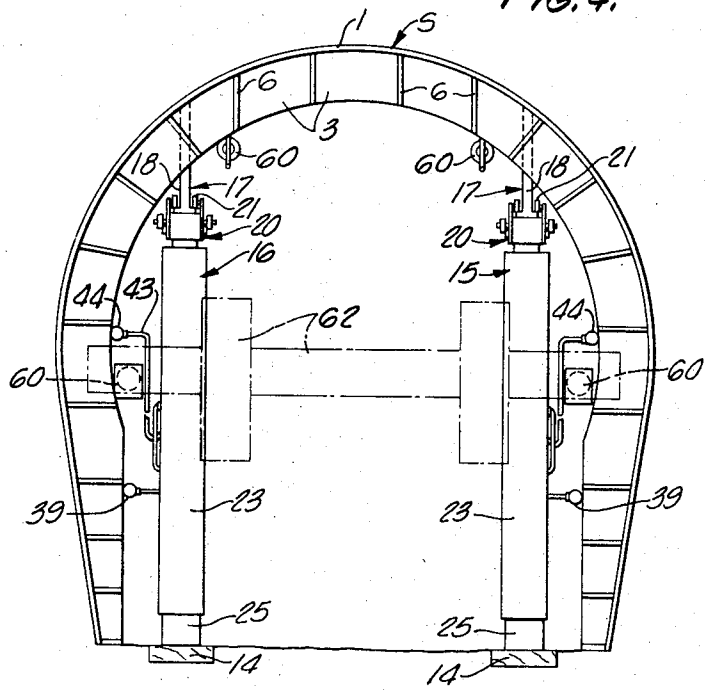
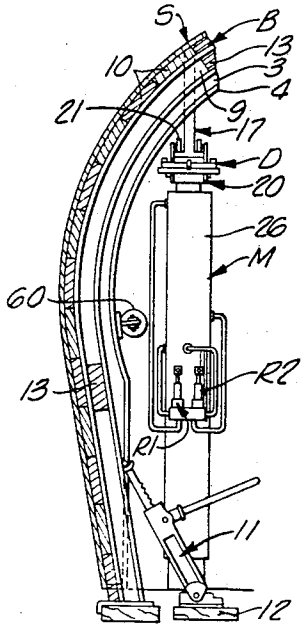


FIG. 8.



INVENTOR
MAXWELL F. KEMPER
BY
Paul A. Weilein
ATTORNEY

March 19, 1968 M. F. KEMPER 3,373,572

METHOD OF DRIVING TUNNELS

Original Filed May 23, 1963 4 Sheets-Sheet 4

FIG. 5.

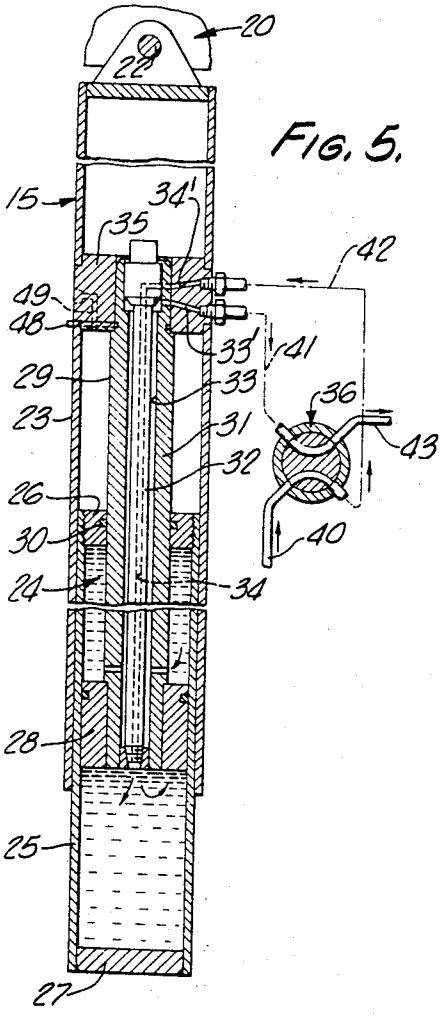


FIG. 9.

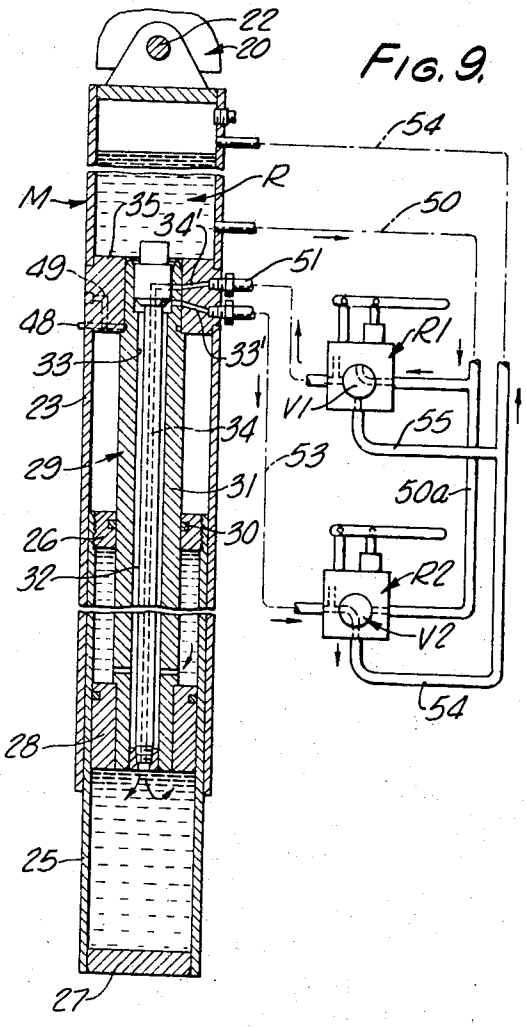
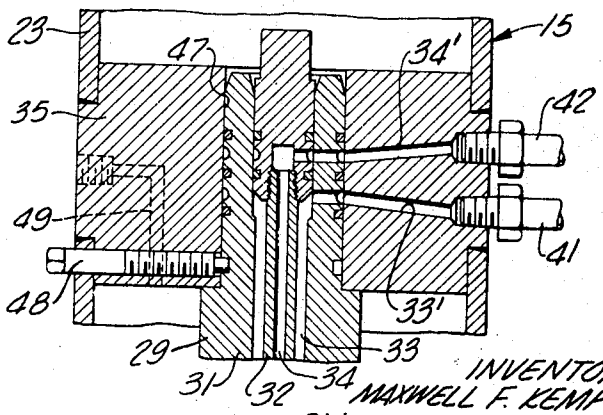


FIG. 6.



INVENTOR
MAXWELL F. KEMPER
BY
Paul A. Weilein
ATTORNEY

United States Patent Office 3,373,572
Patented Mar. 19, 1968

3,373,572

METHOD OF DRIVING TUNNELS

Maxwell F. Kemper, 3701 Overland Ave., Los Angeles, Calif. 90034

Original application May 23, 1963, Ser. No. 282,771. Divided and this application Oct. 12, 1965, Ser. No. 511,007

9 Claims. (Cl. 61—85)

This application is a division of my application Ser. No. 282,771, filed May 23, 1963, for Method and Apparatus for Driving Tunnels and now Patent No. 3,250,078.

This invention relates to a novel method and apparatus for driving tunnels.

Apparatus of the type to which this invention relates is discolsed in my U.S. Letters Patent No. 2,997,853 issued Aug. 29, 1961, and includes an elongate arched shield adapted to be progressively driven into the earth while shiftably supported by a sereis of extensible jacks or legs likewise shiftably connected to the shield in order to be positioned best to support the shield for sustaining the load of the overburden in the operation of driving the tunnel.

It is desired in driving tunnels with apparatus generally of the type above described to provide in the shield as much working room as possible in the area adjacent the face of the tunnel for the men and equipment required in digging the tunnel, and at the same time to position the supporting jacks at locations assuring that the shield safely will sustain the load of the overburden in different types of ground, without tilting, sinking or otherwise moving off grade and so that accurate turns in the tunnel bore may be more readily made while remaining on grade.

It is an object of this invention to provide a novel tunnel driving method which will achieve the above noted and other objectives of this invention in a particularly safe and efficacious manner.

It is another object hereof to provide novel tunnel driving apparatus which readily lends itself to carrying out the method hereof and constitutes an improvement in this art in that it includes a particularly novel construction and relative arrangement of the shield and supporting jacks making it possible to achieve the advantages herein noted.

A further object of this invention is to provide a novel method of driving a tunnel that is particularly safe and highly efficient by reason of including the steps of: positioning the shield so that it may be progressively driven into the tunnel face; positioning on each side of the longitudinal center line of the shield and at predetermined locations adjacent each side of the shield, a plurality of supports in contact with the ground and the upper part of the shield at longitudinally spaced locations on the latter; applying a force to move the shield relative to the supports and drive the shield into the tunnel face; and then repositioning said supports to prepare for the next drive of the shield, by lifting the supports one at a time from contact with the ground and shifting each support thus lifted itno a new supporting position relative to the shield while maintaining other of the plurality of supports on each side of the longitudinal center line of the shield in position to provide a reliable and safe support of the shield.

Further, it is an important object of this invention to provide novel tunnel driving apparatus of the character described wherein the elongate shield is provided with a pair of longitudinally extended tracks disposed in laterally spaced opposed relation on opposite sides of the longitudinal center line of the shield and adjacent the sides of the shield with a plurality of extensible ground-engageable jacks slidably joined to each track so that when the jacks are in engagement with the ground, the shield may be moved or shifted relative to the jacks and be driven into the tunnel face. With this arrangement any one or more of the plurality of jacks on either side of the shield may be shifted to a location best suited to support the shield according to the nature of the ground in which the shield is being driven, or a plurality of jacks may be grouped on one side of the shield at locations spaced laterally and longitudinally relative to a group of jacks on the opposite side of the shield or the jacks otherwise disposed, and in all cases so that when any one jack is out of engagement with the ground, at least one other jack of the plurality on each side of the shield will serve as an adequate support for the shield.

Another object of this invention is the provision of apparatus such as described wherein by reason of having the shield supported along each side of the longitudinal center thereof by a plurality of the jacks, it is possible to lengthen a jack on one side of the shield and to decrease the length of a jack on the other side of the shield in order to tilt or cant the shield to facilitate making a turn with the shield while maintaining it on grade and with the advantage of having other of the plurality of jacks on each side of the shield afford adequate support for the shield.

An additional object of this invention is the provision of tunnel driving apparatus such as described which in having a plurality of axially shiftable jacks close to each of the opposite side walls of the shield in rows extending longitudinally of the shield makes it unnecessary to provide a support or jack between the side jacks and thereby provides unobstructed working room at the face of the tunnel for men and equipment to the end that an efficient and comparatively economical tunnel digging operation may be carried out.

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 in the formation of the tunnel, 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 will become apparent to 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 the 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 **7** extended longitudinally of the interior of the front section **1** of the shield and securely fastened thereto in equidistantly spaced relation, there being a ram on each side of the top center portion of the shield and one on each side wall of the shield as will be apparent with reference to FIG. 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 copending application for patent, Ser. No. 678,993.

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 or 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** exposes a large portion of the structure B, may serve as the outer wall of a concrete forms. 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 shell 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 thereof.

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 it is required to sustain. When in supporting position, the jacks **15** and **16** are rested on blocks **14**.

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 jacks 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 pivotal connections thereof with the carriages **20** to out-of-the-way positions when this is desired.

Means are provided for stabilizing the jacks or legs **15** and **16** 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 **20***a* connected as at **20***b* to the carriage **20** of the jack and extended therefrom rearwardly along opposite sides of the carriage **20** of the next adjacent jack. At their rear ends the rods **20***a* have a cross member **20***c* fixed thereto and adapted to be secured by means of a hook **20***d* to a cable **20***e*. This cable leads to a comealong **20***f* anchored as at **20***g* to the structure B. The rods **20***a* are slidably supported on a cross member **20***h* fastened on the carriage **20** of the rearmost jack on each side of the shield. With this arrangement the rods **20***a* and cross member **20***c* comprise a frame or yoke D which embraces the plurality of jacks 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 **20***e* and comealong **20***f* 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 comealong **20***e* 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 its come-along, constitute 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, each jack may be shifted 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 position **23** the upper end of which is pivoted as hereinbefore 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 here shown, the piston rod **29** is made up of concentric tubular members **31** and **32** providing fluid passages **33** and **34**, leading into the 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 **23** 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 **4'** 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** for 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 tubular body portion **23** of the jack, also so that an air blast may be applied to the interior of the body to clean out any foreign matter that may collect between the opposed walls of the body portion **23** and the cylinder **25**. Accordingly, as best shown in FIG. 6, the piston rod **29** is held in an opening **47** in the partition **35** by means of a set screw **48**, the removal of which makes it possible to remove the piston unit and the cylinder. With reference to use of an air blast for removing foreign matter, a normally plugged passage **49** leading through the partition **35** into the portion of the tubular body **23** below the partition provides for this operation. When the plug in the outer end of the passage **49** is removed an air blast may be directed into the body **23** through passage **49** for the purpose above stated.

A modified form of jack M embodying this invention which may be used in groups of two or more on each side of the shield is shown in FIGS. 8 and 9, if desired, in place of the jacks **15** and **16**. This jack is similar to the jacks **15** and **16** shown in FIG. 5, except for the use of the upper part thereof as a reservoir R for hydraulic fluid and the use of two manually operable pumps R1 and R2 mounted on the jack and operable for effecting extension and retraction of the jack. The pumps R1 and R2 are provided with valves V1 and V2, respectively, for controlling flow through the pumps. As the jack M is otherwise of the same construction as the jacks **15** and **16** and mounted on the shield **5** in the same manner as the jacks **15** and **16**, the same reference characters that are applied to the jacks **15** and **16** and to the mounting means therefor are applied to the jack M.

The hydraulic circuit shown in FIG. 9 includes a supply line **50** leading from the reservoir R on the top of the jack M to the hand pump R1, which latter, when the valve V1 is in the position shown, may be operated to force fluid under pressure through a line **51** to passages **34'** and **34** and below the piston **29**, thereby extending the cylinder **25**. The return fluid from the above piston **29** passes through passages **33** and **33'**, and line **53** leading to the pump R2, which latter, in view of the position of valve V2, will route the return fluid through return line **54** leading to the reservoir R. When the pump R2 is operated with the valve V2 turned to occupy the position of the valve V1 shown in FIG. 9, fluid from supply line **50***a* leading from line **50** is pumped through line **53**, passage **33'** and **33** into the cylinder **25** above the piston **29**, thereby retracting the cylinder **35** and causing return flow from below the piston through passages **34** and **34'**, line **51**, valve V1. At this time the valve V1 is turned to occupy the same position as the valve V2 in FIG. 9 so the return flow will pass through lines **55** and **54** leading to reservoir R.

The apparatus of this invention includes a plurality of air operated rams **60** securely anchored to the shield S and provided with brackets **61** for supporting breast boards **62**. These rams in being air operated rams will yield as the shield is advanced as the breast boards **62** are firmly held by the rams against the tunnel face F and thereby prevent cave-in of this face.

With reference to the foregoing description and accompanying drawings, it will be apparent that this invention provides a novel method of driving a tunnel into the earth with an elongate arched shield and a plurality of supports disposed on each side of the longitudinal center of the shield 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 one or 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 sup-

port of the shield in soft, wet or what is known as "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. If 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 purpose, this arrangement readily may be brought about. Not 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 details 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. A method of driving an elongate, arched shield into the ground in the formation of a tunnel comprising: positioning the shield so that one end thereof may be progressively driven into the ground; providing on each side of the longitudinal center line of the shield and adjacent said end and each side of the shield a plurality of supports in contact with the ground and with the upper portion of the interior of the shield at longitudinally spaced locations on the shield; applying a force for moving said shield longitudinally relative to said supports to advance the shield into the ground; removing the supports one at a time from contact with the ground: moving each support longitudinally of the shield to a new position when free of the ground while other of said supports on opposite sides of said center line remain in contact with the ground; and reengaging each support with the ground following repositioning thereof.

2. A method of driving an elongate, arched shield into the ground in the formation of a tunnel comprising: positioning the shield so that one end thereof may be progressively driven into the ground; providing on each side of the longitudinal center line of the shield and adjacent said end and each side of the shield a plurality of supports in contact with the ground and with the upper portion of the interior of the shield at longitudinally spaced locations on the shield; applying a force for moving said shield longitudinally relative to said supports to advance the shield into the ground; removing the supports one at a time from contact with the ground alternately from opposite sides of said center line; moving each support longitudinally of the shield to a new position when free of the ground while other of said supports on opposite sides of said center line remain in contact with the ground; and reengaging each support with the ground following repositioning thereof.

3. A method of driving an elongate, arched shield into the ground in the formation of a tunnel which includes the steps of: positioning the shield so that one end may be driven progressively into the ground; providing beneath the shield along each side of the longitudinal center line thereof and adjacent said end and opposite sides of the shield a plurality of supports in engagement with the interior or the upper part of the shield as well as in supporting engagement with the ground beneath the shield; applying a force for moving said shield longitudinally relative to said supports to cause said shield to advance into the ground; and intermittently moving said supports one at a time forwardly toward said end of the shield while the other supports remain fixed for supporting the shield on opposite sides of said center line.

4. The method of driving an elongated tunnel shield including: supporting said shield on a pair of transversely spaced rows of vertical supports adjacent the sides of said shield; moving said shield longitudinally relative to said supports; and then moving said supports one at a time to a new position in its row while the shield is supported adjacent said sides thereof by the other of said supports and maintained in its proper position transversely of the tunnel.

5. A method of forming a tunnel comprising the steps of: positioning an elongate, arched shield so that it may be progressively driven into the ground; providing on each side of the longitudinal center line of the shield a plurality of extensible and retractible supports for engaging the ground and the shield to support the shield; erecting a tunnel wall structure within one end of the shield rearwardly of said supports; applying a force to said shield to move it longitudinally relative to said supports and said wall structure so as to advance the shield into the ground; retracting said supports one at a time from engagement with the ground following said advance of said shield and while other of said supports on opposite sides of said center line support opposite sides of the shield; moving each retracted support longitudinally to a new position while other of the supports on opposite sides of said center line support the shield; extending each support when repositioned into engagement with the ground; erecting an addition to said wall structure in said shield rearwardly of said repositioned plurality of supports on opposite sides of said center line; and again applying a force for further advancing said shield into the ground relative to said repositioned supports and said wall structure.

6. A method of forming a tunnel comprising: positioning an elongate, arched shield so as to be progressively driven into the ground; providing within the shield in laterally spaced relation to the longitudinal center line of the shield and adjacent each side wall of the shield a plurality of supports extending longitudinally in a row with the supports in each row engaged with the shield and the ground therebeneath on opposite sides of said center line in the forward portion only of said shield; applying to the shield a force for moving it longitudinally relative to said supports to advance the shield into the ground; moving said supports one at a time after said advance of said shield to a new shield supporting position while other of said supports in each row remain in position to support opposite sides of the shield; erecting a tunnel wall structure within the rearward portion of said shield; and applying a force to again advance said shield into the ground.

7. A method of driving a shield into the earth in the formation of a tunnel including the steps of: positioning an elongate, arched shield so that it may be driven into the earth; providing within the shield in laterally spaced relation to the longitudinal center line of the shield along each side wall of the shield a plurality of supports extending in a row with the supports of each row engaged with the shield and the ground therebeneath on opposite sides of said center line; applying to the shield a force for moving it relative to said supports to advance the shield into the earth; moving said supports to reposition them relative to said shield one at a time after said advance of the shield, alternately from the rows on opposite sides of said center line while at least one of said supports in each row remains in position to support opposite sides of said shield; and thereafter applying a force to further advance the shield into the earth.

8. The method of driving a shield into the earth in the formation of a tunnel including the steps of: positioning an arched shield so that it may be driven into the earth; providing within the shield in laterally spaced relation to the longitudinal center line of the shield adjacent each side wall of the shield a plurality of supports extending in a row axially of the shield with each support engaged with the shield and the ground therebeneath; applying to the foremost of said supports in each of said rows a force for restraining said support and the supports rearwardly thereof in each row against forward movement during advance of the shield into the earth; applying to the shield

a force for advancing it into the earth relative to said supports and independently and selectively applying to the supports rearwardly of the foremost supports of each row a force for restraining the rearward supports against movement while repositioning the forward supports.

9. The method of driving a shield into the earth in the formation of a tunnel including the steps of: positioning an arched shield so that it may be driven into the earth; providing within the shield in laterally spaced relation to the longitudinal center line of the shield adjacent each side wall of the shield a plurality of supports extending in a row axially of the shield with each support engaged with the shield and the ground therebeneath; applying to the foremost of said supports in each of said rows a force for restraining said support and the supports rearwardly thereof in each row against forward movement upon advance of the shield into the earth; applying to the shield

a force for advancing it into the earth relative to said supports; and moving said supports to reposition them relative to said shield one at a time after said advance of said shield, alternately from the rows on opposite sides of the center line while at least one of said supports in each row remains in position to support the shield.

References Cited

UNITED STATES PATENTS

2,997,853	7/1961	Kemper	61—85

FOREIGN PATENTS

910,770	1954	Germany.
1,089,710	1960	Germany.

JACOB SHAPIRO, *Primary Examiner.*

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,373,572 March 19, 1968

Maxwell F. Kemper

It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 5, line 26, "position" should read -- portion --; line 51, "4'" should read -- 34' --.

Signed and sealed this 19th day of August 1969.

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents