Aug. 29, 1961 M. F. KEMPER 2,997,853

APPARATUS FOR DRIVING TUNNELS

Filed July 14, 1958 4 Sheets-Sheet 1

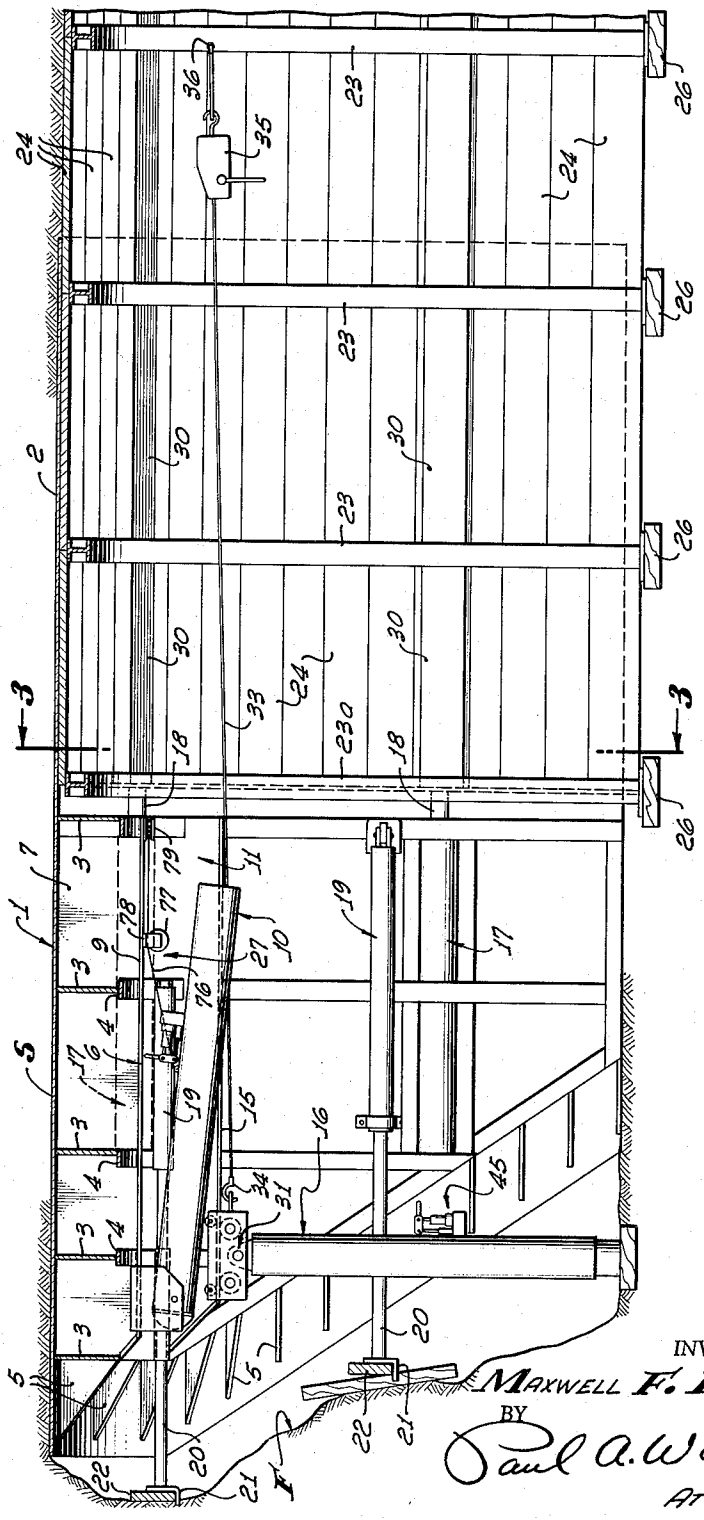


FIG. 1.

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APPARATUS FOR DRIVING TUNNELS

Filed July 14, 1958 4 Sheets-Sheet 2

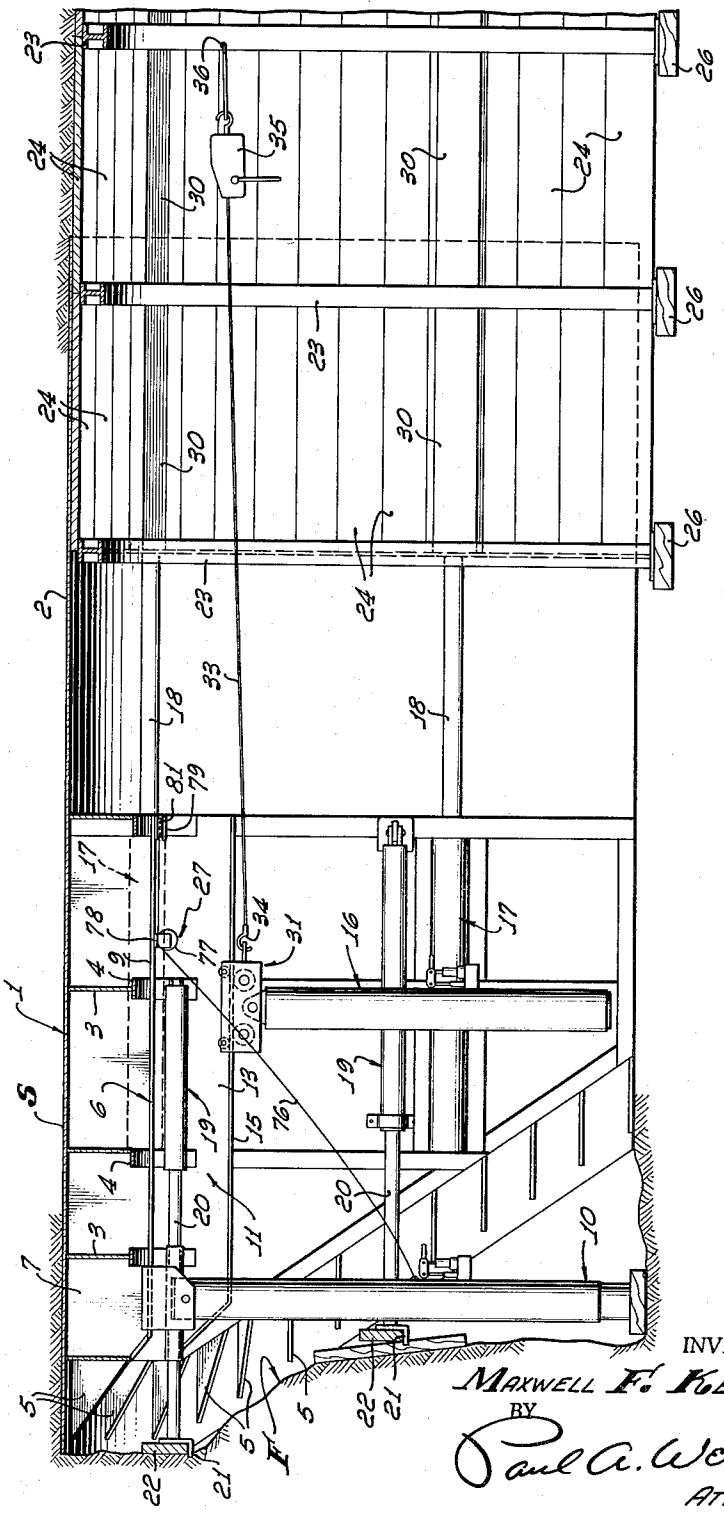


Fig. 2.

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APPARATUS FOR DRIVING TUNNELS

Filed July 14, 1958 4 Sheets-Sheet 3

Fig. 3.

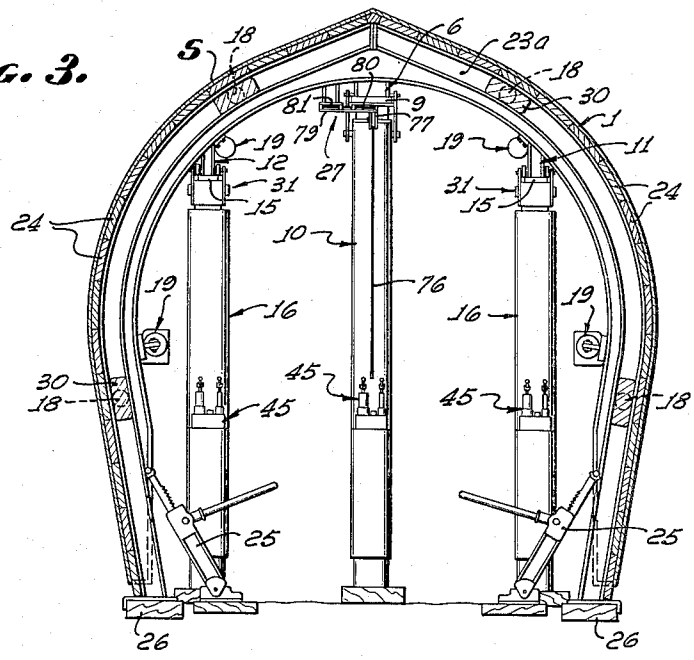


Fig. 4.

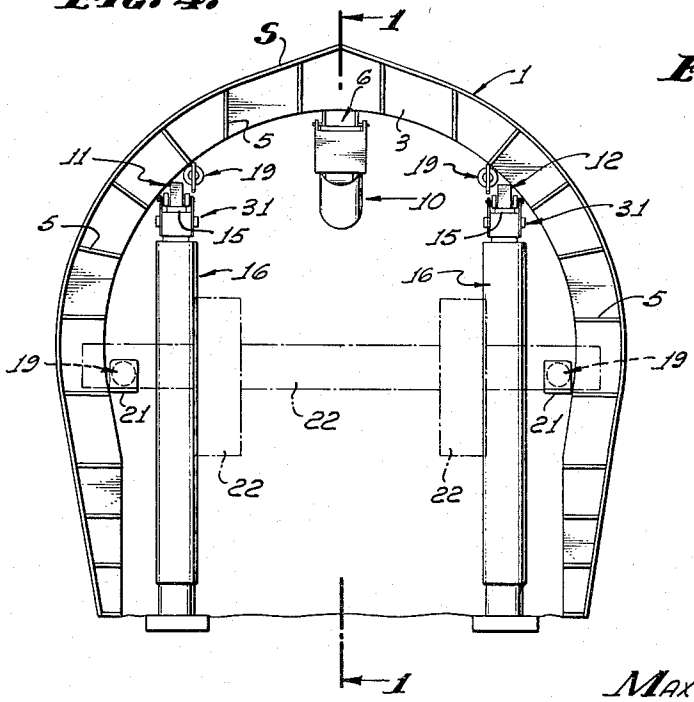
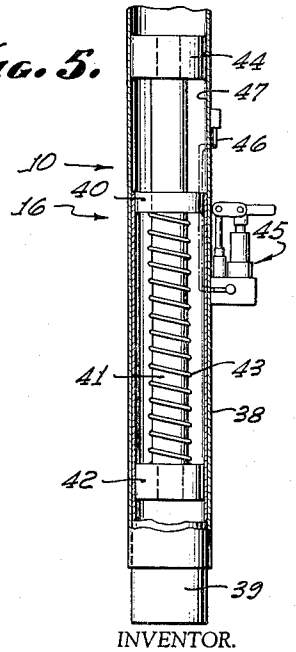


Fig. 5.



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APPARATUS FOR DRIVING TUNNELS

Filed July 14, 1958 4 Sheets-Sheet 4

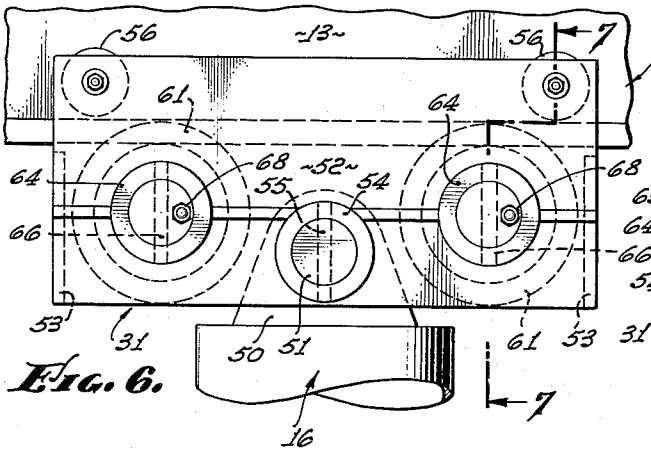


FIG. 6.

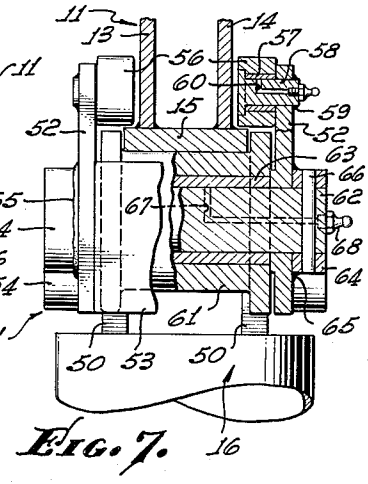


FIG. 7.

FIG. 8.

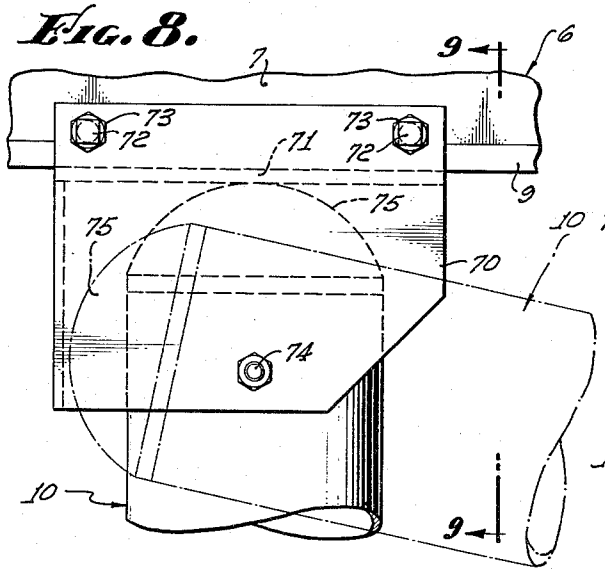
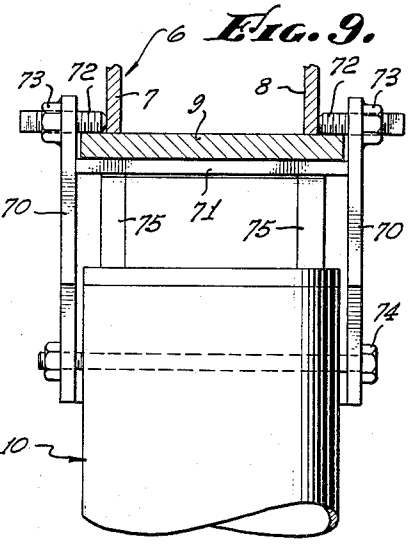


FIG. 9.



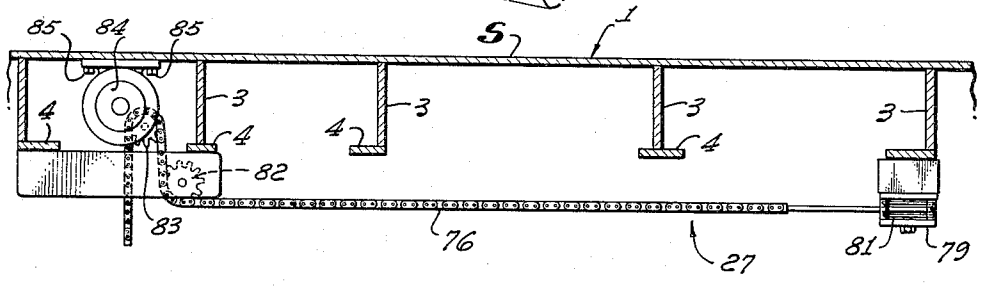


FIG. 10.

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2,997,853

APPARATUS FOR DRIVING TUNNELS

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Filed July 14, 1958, Ser. No. 748,340
8 Claims. (Cl. 61—85)

The present invention relates to novel apparatus for driving a tunnel through earth formation while supporting the overburden to prevent cave-in thereof.

In my copending application, Serial No. 678,993, there is disclosed a novel method and apparatus for driving tunnels through earth formation which contemplates a substantial advance in the art of forming tunnels, particularly in sandy soils where previously it had been the practice to provide an outside form for forming a concrete storm sewer or drain by successively supporting arched or horseshoe shaped beams or "steel supports" in spaced relation longitudinally of a tunnel as the tunnel progressed.

The method and apparatus of that application substantially facilitates the formation of such an outer form and materially lessens the need for manpower while at the same time speeding up the operation. That invention contemplated the utilization of a shell of generally horseshoe cross section which was adapted to be driven forcefully in the face of the tunnel as the tunnel progressed, so as to enable erection of suitable supporting structure within the protective cover of the shell. For supporting the shell, in accordance with my earlier invention a novel needle beam support was centrally located within the shell so as to support the latter as it was advanced into the tunnel face and prevent the overburden of earth above the shell from forcing the latter downwardly.

Though not limited thereto, the apparatus of my earlier invention is particularly adapted for use in forming tunnels for comparatively large storm drains or the like, where space limitation for the operation of auxiliary equipment and appliances within the shell during formation of the tunnel is not of particular moment.

The present invention contemplates an improved tunnel driving shell support in the sense that improved shell supporting means are provided whereby maximum head room and transverse clearance are made available for the use of such auxiliary equipment as mucking machines and the like, as would particularly be necessary and desirable when smaller tunnels are being formed.

Accordingly, a principal object of the invention is to provide novel supporting means for the shell of tunnel driving apparatus of the type broadly contemplated in my copending application previously referred to. In accomplishing this objective, a pair of supporting jacks are provided, these jacks being transversely spaced within the tunnel driving shell, so as to provide a maximum of transverse space therebetween. These side jacks are adapted to remain stationary as the shield is being fed axially into the face of the tunnel relative thereto. In addition, a central or middle jack is provided for supporting the shield as the side jacks are alternately shifted to new positions for supporting the shield as it is being advanced. When the central jack is elevated to an inoperative position as the shield is being moved into the tunnel face, the central jack occupies a minimum of space and thereby affords the maximum head room or clearance for the operation of such equipment as front-loading overhead-unloading mucking machines which are employed to load a conveyor or the like for removing earth from the face of the tunnel as the tunnel progresses.

Other objects and advantages of the invention will hereinafter be described or will become apparent to those

skilled in the art and novel features of the invention will be defined in the appended claims.

In the accompanying drawings:

FIG. 1 is a longitudinal sectional view taken through tunnel driving apparatus made in accordance with the invention with the shield disposed for movement into the face of the tunnel relative to the side jacks and with the central jack partially elevated to an out-of-the-way position;

FIG. 2 is a view similar to FIG. 1 but showing the shield in the position which it occupies after having been projected a full stroke and showing the central jack in a shield supporting position with one of the side jacks in an inoperative position and ready to be advanced to a new shield supporting position;

FIG. 3 is a transverse sectional view as taken on the line 3—3 of FIG. 1, but showing the central jack prior to its elevation to a horizontal position, and also depicting steel support jacks which are employed for jacking the horse-shoe shaped steel supports or supporting ribs into place;

FIG. 4 is a front elevational view showing the apparatus substantially in the same condition as shown in FIG. 1;

FIG. 5 is a fragmentary detail view partly in elevation and partly broken away and shown in section depicting one of the jacks;

FIG. 6 is a fragmentary view in elevation and on an enlarged scale, showing a novel roller support for one of the side jacks;

FIG. 7 is a view partly in elevation and partly in section as taken substantially on the line 7—7 of FIG. 6;

FIG. 8 is a fragmentary detail view on an enlarged scale, showing the novel connection of the central jack to the shield frame;

FIG. 9 is a view as taken substantially on the line 9—9 of FIG. 8; and

FIG. 10 is a fragmentary view on an enlarged scale depicting the central jack hoist mechanism for elevating the central jack to a horizontal position.

Like reference characters on the several figures of the drawings and in the following description designate corresponding parts.

In accordance with the invention, the apparatus comprises a generally U-shaped shield S having an outer skin plate 1 providing an elongated skirt 2. Extending inwardly from the skin plate 1 are a suitable number of longitudinally spaced plates 3, which are welded or otherwise suitably secured to the skin plate 1 and at their inner margins are provided with ribs 4. Gussets 5 are welded into the angle formed at the foremost structural plate 3 and the forward end of the shield S, which is at the left hand end of the shield as viewed in FIG. 1. On the longitudinal center of the shield S there is an assembly providing supporting rail means 6, which, as best seen in FIG. 9, comprises a pair of vertical, laterally spaced plates 7 and 8, which are interconnected at their base by means of a rail 9 adapted to shiftably support the central jack assembly 10. At opposite sides of the rail assembly 6 the shield is also provided with vertically disposed rail assemblies 11 and 12, respectively, which, as best seen in FIG. 7, also comprise a pair of vertically disposed plates 13 and 14 interconnected by a rail 15 which is adapted to support one of a pair of side or operating support jacks 16, 16. Extending axially through a number of the rearmost structural plates 3, is a suitable number of generally equi-distantly spaced rams 17, having rearwardly extending pistons 18. These rams 17 serve the purpose of propelling the shield into the face of the tunnel as generally designated at F.

Since tunnels are ordinarily driven into rather sandy soils when the shields of the type concerned are employed,

means are also preferably provided for supporting the tunnel face, and in the illustrative embodiment a plurality of air operated rams **19**, having pistons or rods **20**, are disposed in spaced relation about the shield and are provided with breastboard supporting brackets **21** at their outer extremities for supporting breastboards **22**. Inasmuch as the rams **19** are air operated, air therein will form a resilient cushion enabling the rods or pistons **20** to be pushed back into the rams as the shield advances, while the breastboards **22** will be held out firmly against the tunnel face F, thus preventing cave-in.

In forming a tunnel into earth formation, FIG. 1 illustrates the shield in a tunnel which has been partially formed, where it will be seen that a series of generally horseshoe shaped H beams or steel supports **23** have been mounted in place with lagging strips **24** installed between the steel supports **23** and the skirt **2** of the shield S and as the shield progresses axially into the face of the tunnel, the lagging is uncovered and constitutes the outer form for a concrete conduit to be constructed in the tunnel. However, it will be understood that for some applications such as mining or the like it may be desirable to construct the steel supported wooden frame for containing the earth in a mine tunnel. For the purpose of description it will be assumed that the steel support designated **23***a* has been firmly installed.

This is accomplished by means of a pair of manual jacks **25** or the like (see FIG. 3), which are employed, following installation of the lagging between the steel support **23***a* and the next adjacent steel **23**, to jack the steel **23***a* firmly toward the shell or skirt **2**, whereupon a base plate **26** may be installed beneath the opposite lower extremities of the steel support **23***a* to prevent its settling upon release of the jacks **25**.

Elevating means generally designated **27**, which will hereinafter be more particularly described, are employed to elevate the central jack **10** from a vertical position as shown in FIG. 3, to the horizontal position as shown in FIG. 1. With the shield in the condition shown in FIG. 1, hydraulic fluid under pressure may be admitted to the rams **17**, thus forcing the pistons **18** therefrom. These pistons are engaged with the steel support **23***a* which is firmly backed up by collar braces **30**, the latter being interposed between the respective steel supports or ribs **23**.

Fluid under pressure may be admitted to the rams **17** by means of the hydraulic system disclosed and claimed in my copending patent application referred to above, or if desired other fluid pressure operating systems may be employed. In any event, fluid under pressure in the rams **17** will force the pistons **18** therefrom, which will effect axial movement of the shield S into the face of the tunnel until the shield reaches a position such as that shown in FIG. 2, with the pistons **18** of rams **17** fully extended. Whereupon, the central jack **10** will be lowered to the position shown in FIG. 2 and operated so as to partially support the shield S at which time an additional shield support **23** and lagging **24** may be installed. As the shield S is advanced, the earth at the tunnel face F may be removed by mucking equipment (not shown), as more particularly described in my above-mentioned copending application, but the breastboards **22** will prevent the face of the tunnel from falling in while the rams **19** permit the shield to move relative to the rods or pistons **20**, as air in the rams **19** is compressed. These rams **19** may also be operated by means of the pneumatic system disclosed in my copending application above referred to, or if desired the rams **18** may be purely spring loaded or other pneumatic operating systems may be employed. During the advance of the shield S into the tunnel roller support assemblies generally designated **31**, and more particularly shown in detail in FIGS. 6 and 7, will permit the shield to move axially upon the side jacks **16**, which will be firmly based upon the tunnel floor, as illustrated in FIGS. 1, 3 and 4.

In order to stabilize the side jacks **16**, they are preferably tied as by means of a line **33** provided with a hook **34** for engagement with the roller support **31**, and engaged at its other end with a come-along **35**, which in turn is securely connected as at **36** to a previously installed steel support **23**. Such an arrangement is employed with each of the side jacks **16** so that they are firmly held against any tendency to move along with the shield S as it is urged into the tunnel face by the rams **17**. Following movement of the shield S from the position shown in FIG. 1 to the position shown in FIG. 2, and following the installation of lagging **24** and an additional steel support **23**, the central jack **10** will be retracted by means presently to be described, and elevated by the mechanism **27** to a position extending substantially horizontally and disposed closely adjacent to the rail **9**. However, prior to retracting and elevating the central jack **10**, the side jacks **16** will have been shifted forwardly to the position shown in FIG. 1. One of the jack mechanisms is more particularly shown in detail in FIG. 5, and the structure illustrated in FIG. 5 is representative of each of the jacks **16** as well as the central jack **10**.

Referring particularly to FIG. 5, which is representative of the jacks **10** and **16**, it will be noted that the jacks comprise an upper cylindrical housing or body **38**, which is relatively stationary and an internal cylindrical member **39** which is movable axially in the body **38**. At its upper extremity the cylindrical member **39** is provided with a closure **40** through which extends a rod **41** having at its lower extremity a spring seat **42** interposed between the closure or head **40** of the member **39** and the seat **42**, and disposed about the rod **41**, is a return spring **43**. At its upper extremity the rod **41** is secured in any suitable manner to a fixed head **44**, which in turn is securely mounted within the cylindrical body **38** in sealed relation thereto. Mounted externally of the body **38** is a hand pump **45** adapted to supply hydraulic fluid through a line **46** to a jack pressure chamber **47** whereby manipulation of the pump **45** will pressurize the chamber **47**, thus acting upon the head **40** of the member **39** to shift the same downwardly and compress the spring **43** between the head **40** and the seat **42**. Any of the jacks **10** and **16** may be operated in the foregoing manner so as to exert the strong vertical force tending to support the overburden of earth on the shield S as the shield is being shifted into the tunnel face, or as the jacks **16** are being shifted from the position shown in FIG. 2 to the position shown in FIG. 1 in preparation for a further advance of the shield.

During movement of the shield S into the tunnel, as has been previously pointed out, the shield is shiftably supported upon the side jacks **16** by means of the roller supports **31**. Referring more particularly to FIGS. 6 and 7, the details of a representative roller support are more particularly shown. Upstanding from the upper extremity of the respective side supports **16** is a pair of spaced supporting ears **50** through which is extended a pivot pin **51**. The pivot pin **51** is journalled in the central body section of a supporting frame having opposed side walls **52** interconnected by transversely extended plates **53** at the opposite ends of the side walls. The pivot pin **51** extends through the side walls and is retained in place as by collars **54** and pins **55** which extend through the collars **54** and thence through the pivot pins **51**, so that the respective side supports **16** are freely pivotally mounted on the side walls **52** of the roller supports **31**.

Adjacent the opposite ends of the respective side walls **52** of each roller support **31**, is an internal roller **56**, and as best illustrated in FIG. 7, each roller **56** is journalled upon a bushing **57** surrounding a retainer pin or axle **58**, having a stem extending through an opening in the side wall **52** and secured therein as by welding at **59**. Preferably the retainer pin **58** is provided with a lubricant passage **60** for enabling lubrication of the bushing **57**. Thus it is seen that opposed pairs of the rollers **56** pro-

ject laterally inwardly towards the vertical plates **13** and **14** upon which is secured the horizontal rail **15**. The rollers **56** overlie the outwardly projecting edges of the rail **15** so as to hang the roller support **31** thereon. These rollers **56**, it will be understood, are not required to support loads during use of the invention but instead are merely required to sustain the weight of the respective side supports **16** when they are disengaged from the floor of the tunnel.

Load bearing rollers **61** are disposed beneath the rail **15** at opposite sides of the pivotal center of the roller support **31**. The rollers **61** are preferably flanged so as to straddle the rail **15** as clearly indicated in FIG. 7, and each roller **61** is journalled upon a pin or axle **62** extending transversely between the side walls **52—52** of the roller support **31** with a bronze or other bushing **63** interposed between the roller and the pin **62**. Collars **64** are disposed about the opposite extremities of the pins **62** and are welded to the side walls **52** as at **65**, while the pins **62** are secured to the collars **64** as by means of a pin **66**. In addition, each pin **62** is also provided with a lubricant passage **67** and a grease fitting **68** for each roller **61**, to enable lubrication of the rollers which should be maintained well lubricated in view of the heavy loads imposed thereon as the shield is progressing into the tunnel.

The means for supporting the center support or jack **10** on the rail **9** of the supporting rail means **6** is more particularly illustrated in FIGS. 8 and 9. A pair of depending brackets **70** interconnected beneath the rail **9** by a horizontal plate **71**, are adapted to be adjustably connected to the rail by means of set screws **72** which extend through the brackets **70** into overlying relation to the rail **9** and into engagement with the rail supporting plates **7** and **8**. The set screws **72** are threaded in nuts **73**, which are preferably welded to the brackets **70**. Center jack **10** is pivotally disposed between the brackets **70** as by means of a pivot pin or bolt **74**, so that the jack **10** may be swung from a substantially horizontal position as shown in FIG. 1, and as shown in broken lines in FIG. 8, to the vertical position, as shown in FIGS. 2, 3, 8 and 9. At the upper extremity of the jack **10**, it is provided with a pair of upstanding arcuate plates **75**, which when the jack **10** is disposed in a vertical position, bear beneath the horizontal plate **71** at points vertically beneath the rail supporting plates **7** and **8**. Thus the load of the shield S is not borne upon the jack supporting means when the side jacks **16** are disengaged from the tunnel floor, but instead the load is borne directly through the rail **9**, horizontal plate **71**, and arcuate brackets **75**.

In order to swing the central support jack **10** from a vertical position to a horizontal position, a flexible chain **76** is connected to the jack **10** and is threaded over a sheave **77** of the elevating means, which is generally designated **27**, and which has been previously referred to. As shown in FIG. 1, sheave **77** is supported on a bracket **78** secured beneath the center rail **9** at a point spaced forwardly from the rearward extremity of the rail **9**. Adjacent the rear extremity of the rail **9** is a sheave support **79** having a pair of transversely spaced sheaves **80** and **81** carried thereby and rotatable upon vertical axes. The chain or cable **76** is passed from sheave **77** over sheave **80** and thence over sheave **81**, from whence it extends longitudinally in parallel relation to the rail **9** and thence, as best seen in FIG. 10, over a guide sprocket **82**, and a drive sprocket **83** of an air or other suitably powered motor **84** mounted as at **85** upon skin plate **1**. Any suitable means may be employed for powering the motor **84** so as to feed the chain **76** in a direction to allow the center jack **10** to gravitate to an upstanding position or to retrieve the chain **76** so as to elevate the jack **10** as will now be apparent.

In the use of the shield of the present invention after a tunnel has been commenced, such as by appropriately backing up the shield exteriorly of the tunnel entrance

and commencing the progressive advancing of the shield and installation of lagging and steel supports, the operation is substantially as follows. Referring to FIG. 1, the shield is in condition for being advanced into the tunnel face F, and the breast boards **22** will effectively preclude cave-in of the tunnel face.

The application of power fluid from a suitable source to the rams **17** will force the shield S into the tunnel face as the shield is supported upon the side jacks **16** and moves relatively easily thereon upon the roller supports **31**. When the shield rams **17** have been fully extended, as for example as shown in FIG. 2, the center jack **10** will be lowered by the motor **84** and an additional generally horsehoe-shaped steel support **23** will be installed in spaced relation to the last installed steel support. Before jacking up the newly installed steel support into final position, lagging **24** will be installed between the newly located steel support and the steel support last installed following which the jacks **25** will be employed to jack the steel support into firm engagement with the lagging and press the latter into supporting engagement with the inner surface of the skirt **2** of the shell S. A base plate **26** will be disposed beneath the newly installed steel support **23**, following which the jacks **25** will be removed. Whereupon, with the shell rigidly supported upon the center jack **10**, the side support jacks may be elevated and shifted to their forward position, as shown in FIG. 1, from their rearward position as shown in FIG. 2, and then repressurized to sustain the load of the shell. At this time the center jack **10** will again be elevated to a horizontal position for recommencement of the shifting cycle.

It should be observed that with the center jack **10** elevated to an out-of-the-way position, and with the shell supported upon the side jacks **16**, a maximum of headroom is provided, and in addition the side jacks **16** are disposed in laterally spaced relation to the greatest extent possible for enabling freedom of movement of mucking equipment or other apparatus as well as the crewmen working at the tunnel face.

While the specific details of the invention have been herein shown and described, changes and alterations may be resorted to without departing from the spirit thereof as defined in the appended claims.

I claim:

1. Apparatus for digging a tunnel in the earth comprising: a generally horseshoe-shaped elongated shield; means shiftably supporting said shield for axial movement; and means for advancing said shield; said supporting means including a pair of longitudinally extended members carried by said shield adjacent the top of said shield and disposed in laterally opposed transversely spaced relation at opposite sides of the longitudinal center of said shield; a pair of extensible jacks disposed in spaced relation transversely of said shield; means operatively connecting the respective jacks to said members for permitting relative longitudinal movement of said shield and said jacks; said supporting means for each of said jacks including a track extending longitudinally of the shield; and a roller support shiftably carried by said track and operatively connecting its jack to said track.

2. Apparatus as claimed in claim 1, said supporting means for each of said jacks including a track extending longitudinally of the shield; and a roller support shiftably carried by said track and operatively connecting its jack to said track; said track having free lateral edges; and said roller support having rollers disposed above and below said lateral edges.

3. Apparatus as defined in claim 1, wherein the supporting means for each of said jacks including a track extending longitudinally of the shield; and a roller support shiftably carried by said track and operatively connecting its jack to said track; said roller support having side walls disposed at opposite sides of said track; a load supporting roller disposed beneath said track and extending between said side walls; and a jack supporting roller

disposed above said track and carried by one of said side walls.

4. Apparatus for digging a tunnel in the earth comprising: a generally horseshoe-shaped elongated shield; means shiftably supporting said shield for axial movement; and means for advancing said shield; said supporting means including a pair of longitudinally extended members carried by said shield adjacent the top of said shield and disposed in laterally opposed transversely spaced relation at opposite sides of the longitudinal center of said shield; a pair of extensible jacks disposed in spaced relation transversely of said shield; means operatively connecting the respective jacks to said members for permitting relative longitudinal movement of said shield and said jacks; said supporting means for each of said jacks including a track extending longitudinally of the shield; and a roller support shiftably carried by said track; said shield having means supporting said track thereon; and said track projecting laterally from said supporting means; said roller support having rollers disposed on said track at opposite sides of said supporting means and engaging said laterally projecting track to support said jack; and a roller disposed beneath said track for supporting said shield.

5. Apparatus for digging a tunnel in the earth comprising: a generally horseshoe-shaped elongated shield; means shiftably supporting said shield for axial movement; means for advancing said shield; said supporting means including a pair of extensible jacks disposed in spaced relation transversely of said shield; and means connecting the respective jacks to said shield and providing for relative longitudinal shifting movement of said shield and said jacks; wherein the supporting means for each of said jacks including a track extending longitudinally of the shield; and a roller support shiftably carried by said track; said roller support having opposed side walls; a pivot pin extending between said side walls; said jack being pivotally mounted on said pin; a pair of load sustaining rollers disposed on opposite sides of said pivot pin and journalled in said side walls; said rollers being engaged beneath said track; and means carried by said side walls and engaged with the top of said track for supporting said jack on said track.

6. Apparatus for digging a tunnel in the earth comprising: a generally horseshoe-shaped elongated shield; means shiftably supporting said shield for axial movement including a pair of vertically disposed members disposed at opposite sides of the longitudinal center of said shield and operatively engaged with said shield adjacent the top of the latter; means for advancing said shield; said supporting means including means operatively connecting said supporting means to said shield for relative longitudinal shifting of said shield and said supporting means; and means for supporting said shield while said supporting means are being shifted, including a centrally disposed jack; means pivotally connecting said centrally disposed jack to said shield; said connecting means including a track extending longitudinally of said shield at the longitudinal center of the shield; and means adjustably mounting said jack on said track for movement longitudinally of said track.

7. Apparatus for digging a tunnel into the earth comprising: a generally horseshoe-shaped shield having an elongated skirt; and means for advancing said shield into the tunnel face; said shield having laterally opposed vertical plates depending therefrom and extending longitudinally of the shield adjacent the top of the shield in transversely spaced relation at opposite sides of the longitudinal center of said shield; shield supporting jacks shiftably carried by said plates so as to permit relative longitudinal shifting of said shield and said jacks; and a central jack carried by said shield; means pivotally connecting said supporting jacks to said plates including roller supports operatively connecting said jacks and said plates for longitudinal movement of said jacks; and means pivotally connecting said central jack to said shield.

8. Apparatus as defined in claim 7 wherein each of said jacks is extensible by fluid pressure and including means for supplying fluid under pressure to said jacks; each jack including means for resiliently retracting said jacks.

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UNITED STATES PATENT OFFICE

CERTIFICATION OF CORRECTION

Patent No. 2,997,853 August 29, 1961

Maxwell F. Kemper

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 6, line 61, strike out "Apparatus as claimed in claim 1," and in line 63, strike out "Apparatus as defined in claim 1, wherein" and insert instead, in each occurrence, the following:

> Apparatus for digging a tunnel in the earth comprising: a generally horseshoe-shaped elongated shield; means shiftably supporting said shield for axial movement; and means for advancing said shield; said supporting means including a pair of longitudinally extended members carried by said shield adjacent the top of said shield and disposed in laterally opposed transversely spaced relation at opposite sides of the longitudinal center of said shield; a pair of extensible jacks disposed in spaced relation transversely of said shield; means operatively connecting the respective jacks to said members for permitting relative longitudinal movement of said shield and said jacks;

Signed and sealed this 27th day of February 1962.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents