

July 1, 1958

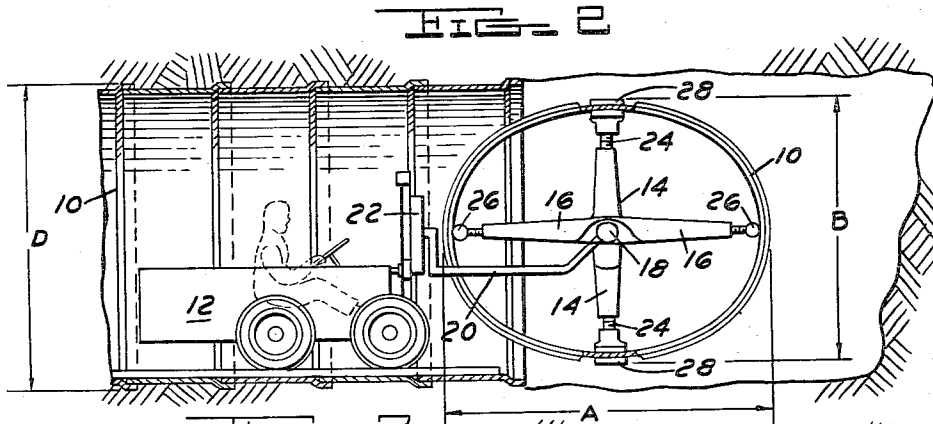
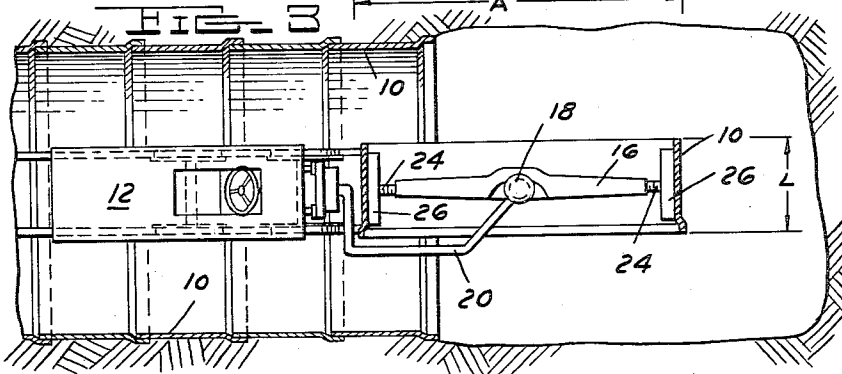
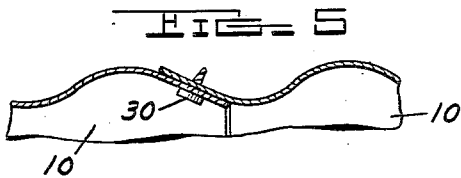
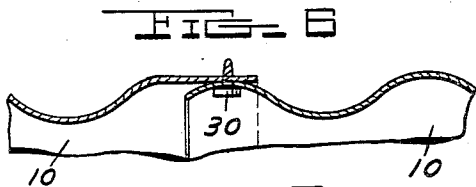
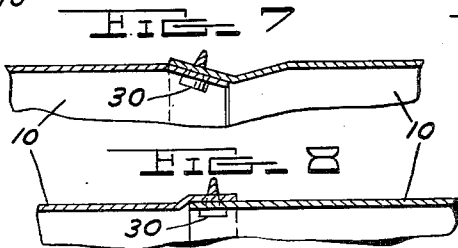
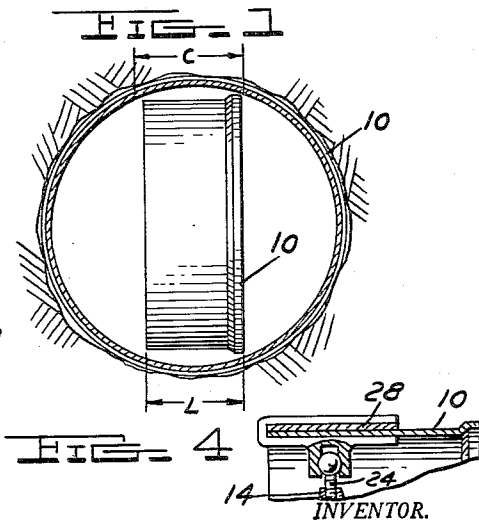
E. P. WASHABAUGH

2,841,297

METHOD OF AND APPARATUS FOR CONSTRUCTING TUNNELS

Filed Sept. 13, 1954

4 Sheets-Sheet 1



INVENTOR.
EDWARD P. WASHABAUGH
BY
Burton & Parker.
ATTORNEYS

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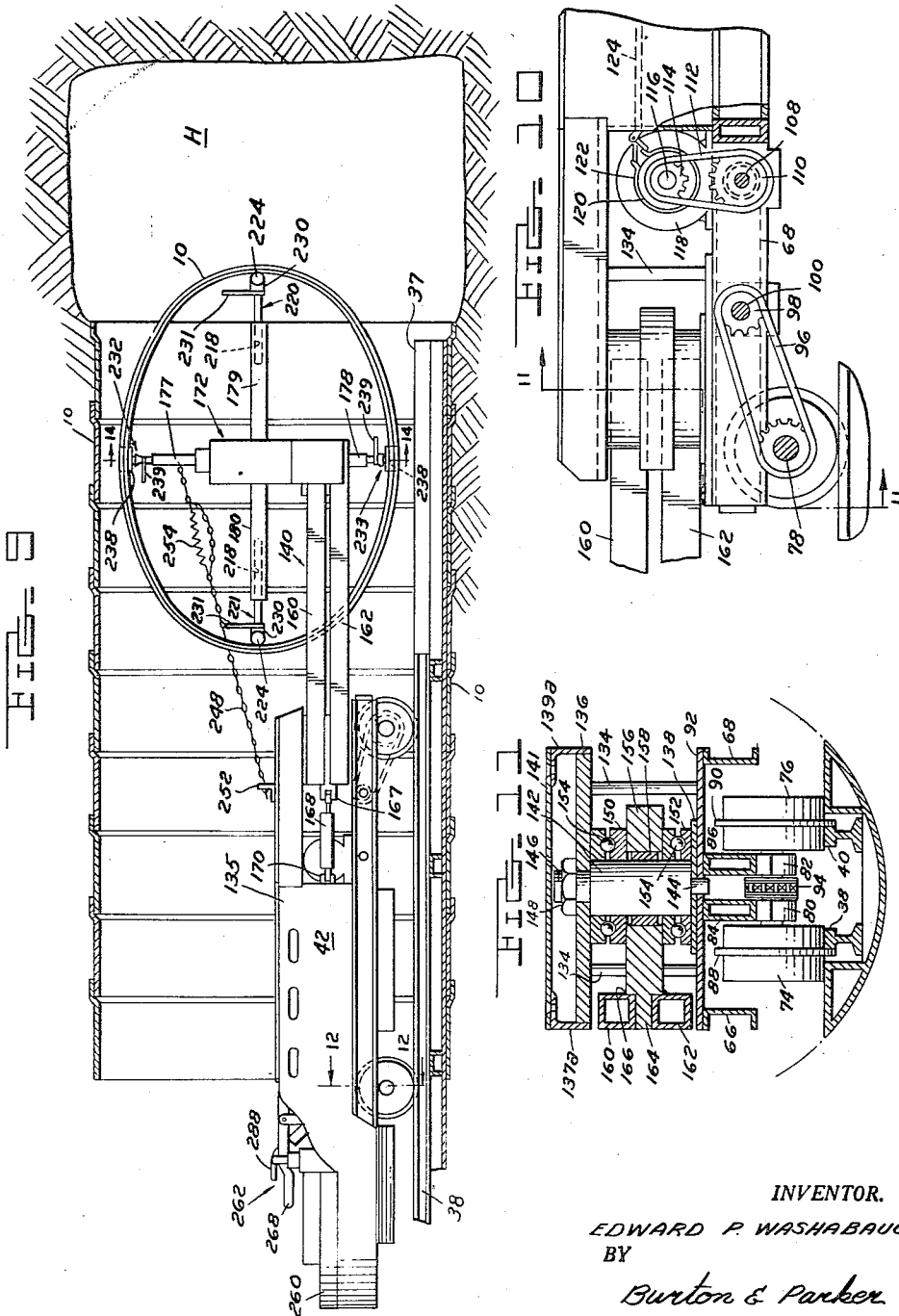
E. P. WASHABAUGH

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METHOD OF AND APPARATUS FOR CONSTRUCTING TUNNELS

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4 Sheets-Sheet 2



INVENTOR.

EDWARD P. WASHABAUGH
BY

Burton & Parker

ATTORNEYS

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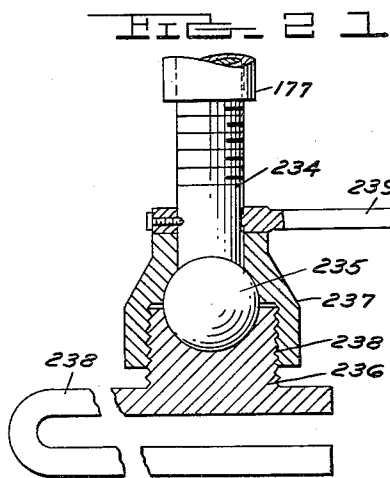
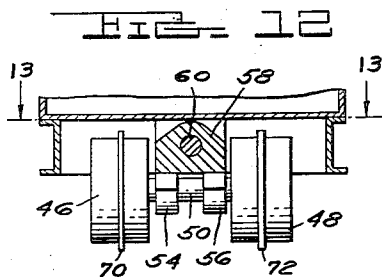
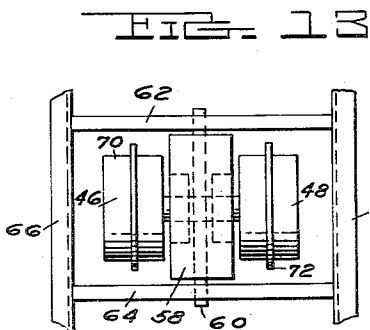
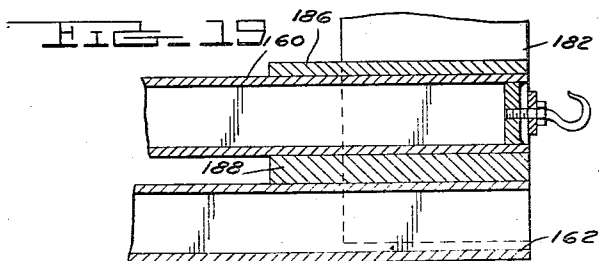
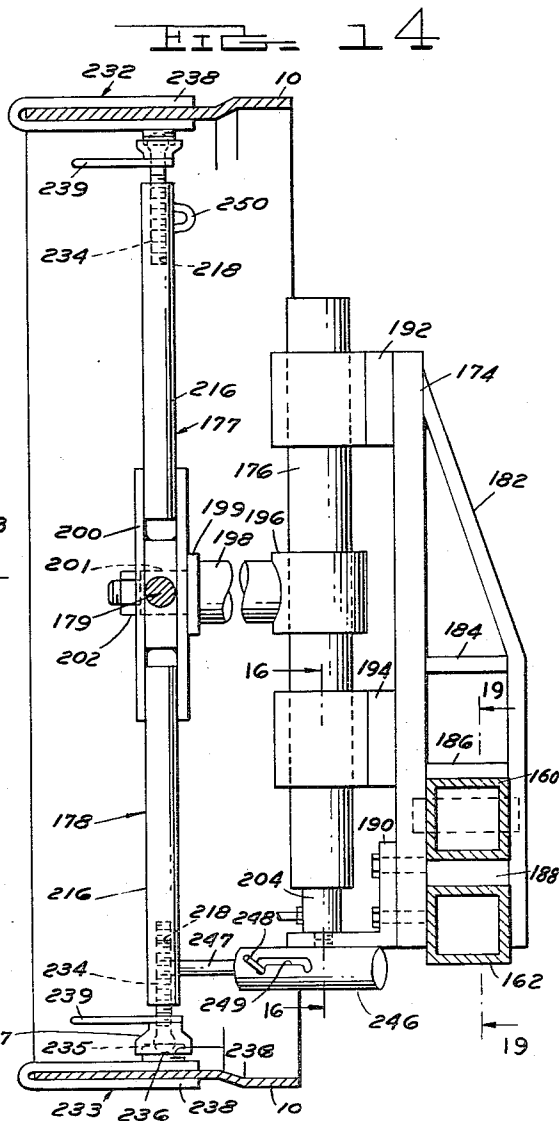
E. P. WASHABAUGH

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METHOD OF AND APPARATUS FOR CONSTRUCTING TUNNELS

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4 Sheets-Sheet 3



INVENTOR.
EDWARD P. WASHABAUGH
BY
Burton & Parker
ATTORNEYS

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E. P. WASHABAUGH

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METHOD OF AND APPARATUS FOR CONSTRUCTING TUNNELS

Filed Sept. 13, 1954

4 Sheets-Sheet 4

FIG. 15

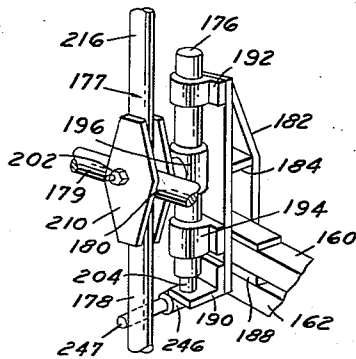


FIG. 16

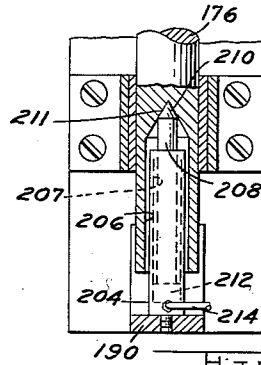


FIG. 17

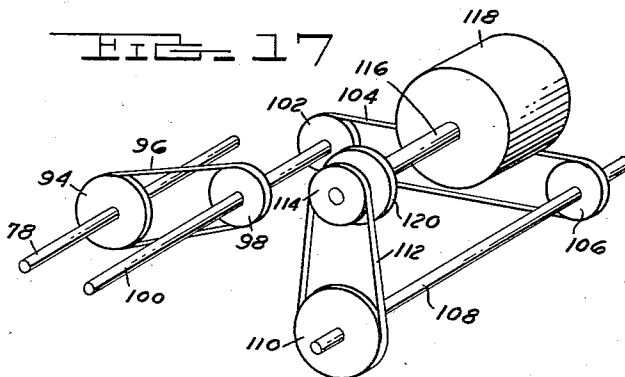


FIG. 20

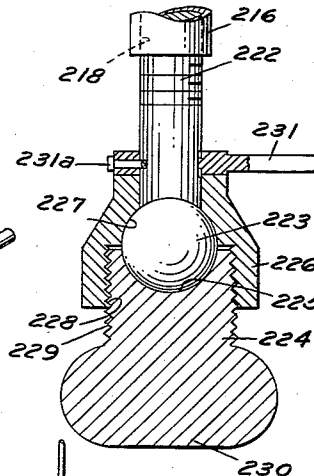
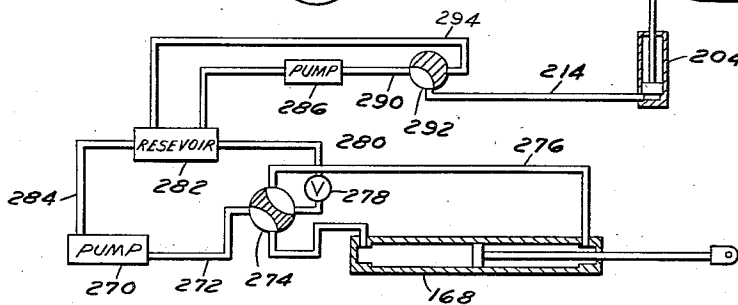


FIG. 18

INVENTOR.

EDWARD P. WASHABAUGH

BY

Burton & Parker

ATTORNEYS

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2,841,297

METHOD OF AND APPARATUS FOR CONSTRUCTING TUNNELS

Edward P. Washabaugh, Saginaw, Mich., assignor to
American-Marietta Company, Chicago, Ill., a corpora-
tion of Illinois

Application September 13, 1954, Serial No. 455,495

16 Claims. (Cl. 214—1)

This invention relates to an improved method and apparatus for constructing and lining tunnels or the like, and is a continuation-in-part application of my co-pending application, Serial No. 131,305, filed December 6, 1949, and now abandoned.

An object is to provide an improved method of constructing or lining tunnels, culverts, and other under surface conduits wherein identically shaped tubular sections are placed one ahead of the other and secured together to form a tunnel. The sections are so constructed that each section succeeding the first one installed may be temporarily distorted and in the distorted shape may be so disposed as to be passed through the installed section to be placed ahead of it as a continuation of the installed portion of the tunnel.

More particularly an object is to provide an improved method of tunnel construction wherein a tubular shaped preformed tunnel section or unit is temporarily changed in form and is so disposed relative to the similar sections of the finished portion of the tunnel that it may be passed through said finished portion. After being passed through such section is restored to its normal shape and turned in the heading ahead of the finished portion of the tunnel and placed in its final position at the end of the finished portion of the tunnel.

The preformed tubular shaped units may be made of steel, iron, copper, or other corrugated metal, or of any suitable structural material which forms a section having sufficient flexibility to permit of temporary deformation for the purpose intended.

The method is designed to permit the units to be placed in position quickly and economically and following up directly behind the excavating and generally without timbering. The method reduces or eliminates the need for temporary liner plates, timbering, shoring or other supports generally used in tunnel construction. It also reduces the total length of tunnel roof which must be supported during tunnel construction. The units may be employed as a substitute for liner plates where the walls of the excavation must be supported while a more substantial lining is being placed.

While the method shown in the drawing illustrates its application to the construction of a tunnel or conduit of circular cross section, the method is applicable for tunnels with cross sections of other shapes and the invention applies thereto.

Another object of the invention is the provision of apparatus for carrying out the above mentioned method of constructing a tunnel of deformable tubular tunnel sections, which apparatus includes a tunnel section supporting and positioning car provided with means adapted to engage and support a tunnel section for movement through the completed portion of a tunnel, and thereafter position the section at the end of such completed portion for connection with such end to form a continuation of the tunnel. A concomitant object is the provision of means of the above character which is also

2

operable to engage the tunnel section and deform the same to permit the deformed section to be carried through the tunnel, with said means operable after the section has been disposed at the end of the completed portion of the tunnel, to restore the section to its original shape and position the section against the end of the tunnel to form a continuation thereof.

Another object of the invention is the provision in a tunnel section supporting car of forwardly extending, swingably mounted boom means which exhibits at the forward end a tunnel section supporting head having tunnel section engaging arms adapted to engage and support a tubular tunnel section, with the arms movable about and along a plurality of axes, to swing and position the tunnel section for travel through the completed portion of a tunnel and swing and position the tunnel section at the end of the tunnel for placement against the end of the tunnel to form a continuation thereof.

Another object of the invention is the provision of arms of the above character which are extensible and retractable so as to expand and contract a tunnel section supported on the arms, along a plurality of axes of the section, thereby deforming the section to permit the same to be passed through the completed portion of a tunnel and operable thereafter to restore the section to its original shape so that it may be placed against the end of the completed portion of the tunnel to form a continuation thereof.

Other objects, advantages and meritorious features of the invention will more fully appear from the following description, claims and accompanying drawing, wherein:

Fig. 1 shows a cross section of a tunnel built according to my improved method taken at right angles to the tunnel;

Fig. 2 is a vertical sectional view of the tunnel taken along the longitudinal axis, and showing one embodiment of a tunnel section supporting car;

Fig. 3 is a horizontal sectional view of the tunnel taken along the longitudinal axis, and showing a top view of the tunnel section supporting car of Fig. 2;

Fig. 4 shows one type of support for the strut assembly or jack employed to maintain the tunnel liner in deformed shape and which may also be used to force the unit back into normal shape;

Figs. 5, 6, 7 and 8 show four slightly different ways in which successive tunnel units may be joined together to form the complete tunnel or conduit;

Fig. 9 is an elevation partly in section through a portion of a tunnel showing a complete tubular tunnel section being moved by a preferred embodiment of the tunnel section supporting and positioning apparatus through the completed portion of the tunnel. This is a more complete structural embodiment of the construction of the apparatus shown in Figs. 2 and 3;

Fig. 10 is a side elevation partly in section through the forward end of the tunnel section supporting car shown in Fig. 9, and showing the driving connection for the front wheels thereof;

Fig. 11 is a cross sectional view taken on line 11—11 of Fig. 10;

Fig. 12 is a cross sectional view taken on the line 12—12 of Fig. 9;

Fig. 13 is a cross sectional view taken on the line 13—13 of Fig. 12;

Fig. 14 is a cross sectional view taken on the line 14—14 of Fig. 9;

Fig. 15 is a view of the tunnel section supporting head showing the employment of a spring chain to prevent movement of a tunnel section supported on the head;

Fig. 16 is a cross sectional view taken on the line 16—16 of Fig. 14;

Fig. 17 is a schematic view of the driving connection for the tunnel section supporting car shown in Fig. 9 between the wheels thereof and the driving motor;

Fig. 18 is a schematic view of the hydraulic system of the tunnel section supporting car shown in Fig. 9;

Fig. 19 is a cross sectional view taken on the line 19-19 of Fig. 14 and showing the construction of the outer end of the tunnel section supporting boom; and

Fig. 20 is a detail cross sectional view of the end of one of the tunnel section supporting arms shown in Fig. 9.

Fig. 21 is a detail cross sectional view of the end of one of the tunnel section supporting arms shown in Fig. 14.

Reference is made to my co-pending application, Serial No. 410,252, filed February 15, 1954, and now abandoned. This application illustrates methods whereby identical and rigid tunnel sections are so shaped and dimensioned that pursuing the method disclosed in the application each tunnel section may be passed through the tunnel sections already installed by disposing the section being transported in determined relative position with respect to the installed sections. After the section being transported has been passed through the installed sections, it may be shifted relative to the installed sections and brought into alignment therewith to form a continuation thereof.

This invention differs from that shown in the aforesaid application in that the tunnel sections of this invention may be transported through one or more identical tunnel sections already in place by first distorting the tunnel section to be transported, then disposing the same in a predetermined position with respect to the installed sections, and passing the same therethrough, and after it has been passed through the installed sections restoring it to its normal shape and disposing it in a position of alignment with the installed sections and withdrawing it thereagainst to form a continuation thereof.

To accomplish this temporary distortion the tunnel sections must be of a flexible character so that the desired deformation can be carried out. Such tunnel sections may be formed of flexible metal or other suitable material. In the drawing they are indicated as continuous circular sections 10.

In Fig. 1, one tunnel section 10 is shown in its final position as a part of the tunnel liner and another tunnel section 10 is shown in position to be passed therethrough. In Figs. 2 and 3 several sections are shown in their final position and a succeeding tunnel section 10 is shown as being transported therethrough. The section being transported is shown in Figs. 1, 2 and 3 as being held in a deformed shape and as being carried through the finished portion of the tunnel by a truck or a car 12.

The tunnel section supporting car 12 shown in Figs. 2 and 3 is a schematic embodiment of a car that may be employed in carrying out the method of building a tunnel herein described. Figs. 9-20 show a commercial and preferred construction of the tunnel section supporting car, and will be described later herein.

The section 10 which is being transported originally exhibited a circular form. It is being held in deformed shape to permit of its transportation through the finished portion of the tunnel. It is supported directly by two pairs of struts 14 and 16 which hold the section in an approximately elliptical shape and support it to be passed through the completed portion of the tunnel. The struts 14 and 16 are mounted upon a pivotal support 18 which is disposed at the outer end of a supporting arm 20. This arm extends forwardly from a hoisting mechanism 22 which mechanism is supported upon the forward end of the lift truck 12. The struts 14 and 16 may be lengthened or shortened by the operation of screws 24. Each strut is provided with such an adjustment screw 24. The outer ends of the two struts, for example, struts 16, may be provided with shoes 26 adapted to bear against diametrically opposite points of the inside of the ring 10 to

exert outward pressure of expansion thereon, as shown in Fig. 2. The outer ends of the two struts 14 may be provided with shoes 28 adapted to grip diametrically opposite points of the ring 10 to contract it or hold it contracted, as shown in Fig. 2. Through the operation of these two pairs of struts a circular ring 10 of flexible character may be distorted to an elongate shape, as shown in Fig. 2.

When the ring section 10 has been distorted to the oblong shape shown in Fig. 2, it will exhibit a major diameter A which is greater than its normal diameter D (Fig. 1), and it will exhibit a minor diameter B (Fig. 2) which is less than its normal diameter D. Each section 10 is so proportioned as to exhibit a length L (Fig. 1) which is relatively short so that when the section is distorted such length L is less than the chord C (Fig. 1). The diameters are of course controlled by the struts 14 and 16, screws 24, and shoes 26 and 28. As the ring is expanded along one diameter to exhibit a major diameter A it is simultaneously contracted along another diameter to exhibit a minor diameter B.

When the ring section 10 supported by the struts 14 and 16 has been distorted to an oblong shape of the desired formation it is rotated, through rotation of supporting struts about a pivot 18, until its major axis A is aligned with or extends parallel to the longitudinal axis of the installed portions of the tunnel. Such ring section 10 may then be advanced through the completed portion of the tunnel as illustrated in Figs. 1, 2 and 3, and into the heading forwardly of the completed portion of the tunnel.

The transportation of the deformed section is not limited to the precise relative position shown in the drawing but can be carried out in any position so long as the major diameter A is approximately parallel to the longitudinal axis of the tunnel and the dimensions of the deformed sections bear the desired relationship to the dimensions of the installed sections.

When the section being transported has been advanced into the heading ahead of the completed portion of the tunnel, such deformed section is restored to its original normal circular shape by force exerted thereon by struts 14 and 16. It is then rotated into alignment with the installed sections of the tunnel and withdrawn into engagement therewith and secured thereto to form a continuation thereof.

The change in form of the flexible unit can be effected by extending one strut or by shortening one strut, or by simultaneously extending one strut and shortening the other strut. A compression strut may have a head of the simple compression type, whereas a head of the general type shown in Fig. 4 may be used either for elongating or shortening a diameter. The unit may, if necessary or desirable, be forced back to its original shape by using the struts, or it may be given or left with any desired permanent deformation.

This invention applies also to any case in which the unit is not returned completely to its original form; or to any case in which it is desired to use a slightly deformed final form for the purpose of prestressing the unit for any other reason.

By releasing the pressure exerted by the struts on the unit it is allowed to return to its original circular form, after which it is placed in its final position against the last laid section (2a). The rotation and the releasing of the strut pressure may be done simultaneously or in alternate partial operations, or in any fashion so that the section clears the walls of the excavation during the combined operation.

After the unit 10 which is being installed has been withdrawn into position against the last installed unit of the completed portion of the tunnel it may be connected therewith as shown in Figs. 5, 6, 7 and 8, or by any other suitable means. In such figures, metal screws

5

30 are shown as being used to secure the tunnel sections 10 together. The holes for the metal screws may be drilled in place or they may be predrilled, as desired. Figs. 6, 7 and 8 show cooperating telescoping end portions on the tunnel sections which differ slightly from one another in the several figures but illustrate the same general idea.

In Figs. 9-20 is shown tunnel section supporting and positioning apparatus of a commercial character. The car, generally indicated at 42, is adapted to support for manipulation the deformable tunnel section 10. The car is essentially of the same construction throughout as is the car 42 described in my co-pending application Serial No. 410,252, filed February 15, 1954. As set forth in the co-pending application, the car is provided with a removable tunnel section supporting head. This head is generally indicated in both the instant and the co-pending application as 172. The head 172 of the instant application is adapted to be mounted upon boom 140 of the car in the co-pending case. Therefore the following description of the car is to some extent a duplication of the description set forth in the co-pending application, with details unimportant to the disclosure of the instant invention, omitted. For a more complete description of the car, reference should be made to the co-pending application.

In Fig. 9, the car is shown as supporting what is to be termed a "succeeding tunnel section" 10 for movement through a completed portion of the tunnel. The succeeding section is shown as supported partially within the completed portion of the tunnel and partially within the heading ahead of such completed portion. The section is shown as supported in the same plane as the succeeding section shown in Figs. 2 and 3, i. e., with the corresponding axes of the succeeding section and the installed sections being perpendicular and the major axis of the succeeding section parallel to the tubular axis of the installed sections. The forward end of the car is to be considered the right hand end as shown in Fig. 9, and the rear end of the car is to be considered the left hand, as shown in Fig. 9.

As is more particularly shown in Figs. 9 and 11, a track 37 comprising a pair of rails 38 and 40 is laid in the bottom of the completed portion of the tunnel. The car, generally indicated as 42, is adapted to travel over this track. Four wheels mounted upon a pair of trucks are adapted to support the car upon the track. One pair of wheels, 46 and 48, shown in Fig. 12, is mounted upon opposite ends of an axle 50 which is secured by a pair of bearings 54 and 56 to a block 58 journaled upon a shaft 60.

As shown in Figs. 12 and 13, the rectangular block 58 is pivotally mounted upon the shaft 60 which is supported between a pair of cross members 62 and 64 which form a part of the car. The car 42 is provided with a pair of longitudinal frame members 66 and 68 which extend along the opposite sides thereof and to which the cross members 62 and 64 are secured. The wheels 46 and 48 (Figs. 12-13) exhibit peripheral flanges 70 and 72 which overlie the outside edges of the rails 38 and 40. The wheels 46 and 48 thus pivotally support the car at the rear end thereof.

The forward end of the car is supported by a second pair of wheels 74 and 76 (Fig. 11) which are fixedly mounted upon an axle 78 (Fig. 10) which is in turn rotatably mounted in the bearing blocks 80 and 82. The bearing blocks are spaced apart as shown in Fig. 11 and are secured to the rectangular frame members 84 and 86 mounted on the underside of the car 42. The wheels 74 and 76 are provided with peripheral flanges 88 and 90 which overlie the outside edges of the rails 38 and 40 and thereby keep the car on the track. A plate 92 rests upon and is secured to the side frame members 66 and 68 of the car and it is to this plate

6

that the rectangular frame members 84 and 86 are secured.

By virtue of the wheels at the rear of the car being carried by a swivelled truck, the car can travel on all four wheels over rails which are not necessarily always in a horizontal plane. One rail may be higher at one point than its parallel corresponding rail and still all four wheels of the car will remain on the track. It is highly important that all four wheels of the car remain at all times upon the rails because when a succeeding tunnel section weighing a substantial amount is supported, as here, forwardly of the car and is revolved and displaced to position it against the end of the completed portion of the tunnel to form a tubular continuation thereof, as is more particularly pointed out hereinafter, a firm support for the succeeding section is essential if the section is to be accurately positioned and aligned with the end of the completed tunnel. The pivotal support of the rear end of the car upon wheels 46 and 48 will allow for any unevenness of the track and ensure the constant contact of all four wheels of the car with the rails.

As shown in Figs. 10, 11 and 17, a driven sprocket 94 is fixed upon the axle 78 which carries the wheels 74 and 76. This sprocket is disposed between the bearing blocks 80 and 82. A drive chain 96 passes around this sprocket and up over a sprocket 98 mounted on a shaft 100 which shaft extends across the car and is rotatably supported in bearings on opposite sides thereof on the frame members 66 and 68. A second sprocket 102 is also mounted upon shaft 100. Chain 104 couples sprocket 102 with sprocket 106 mounted on shaft 108 which shaft extends across the car and is rotatably supported in bearings within the frame members 66 and 68. The shaft 108 carries a sprocket 110 mounted thereon opposite a sprocket 114 carried by motor shaft 116. A drive chain 112 passes over sprockets 110 and 114 whereby the mechanism is driven by the motor 118.

Mounted on the shaft 116 adjacent the sprocket 114 is a brake drum 120. A brake band 122, Fig. 10, passes around the drum 120 and may be actuated by linkage 124 to grip the drum. This brake serves as the brake for the car and by locking the brake the car may be held stationary on the track.

Electric batteries supply electricity to the motor 118. The batteries may be housed within the shield 135, shown in Fig. 9. The batteries serve in part to counterweight a tunnel section supported ahead of the car.

As shown in Figs. 10 and 11, a plurality of vertical rods 134, mounted upon plate 92 of the car, support a second plate 136 spaced above the plate 92. Inverted L-shaped frame members 137a and 139a support a third plate 141 spaced above the plate 136. At the forward end of the car (Fig. 11) supported upon the plate 92 by the washer 138 is a bearing shaft support 142 for the tunnel section supporting boom generally indicated as 140, Fig. 9. The bearing shaft support comprises the vertical shaft 142 provided at its lower end with a stud 144 which extends through aligned holes in the washer 138 and the plate 92. The upper end of the shaft exhibits a threaded stud portion 146 with a nut 148 threadedly secured thereto and adapted to lock the shaft to the underside of the plate 136.

Encircling the shaft is a pair of bearing members 150 and 152 each comprising upper and lower halves separated by ball bearings 154 adapted to run in bearing grooves formed in the opposed faces of the upper and lower halves. Journaled upon the shaft between the bearings 150 and 152 is the boom supporting block 156, provided with a bearing sleeve 158 which sleeve bears directly against the shaft 142. The block 156 is thereby rotatably supported on the car through being journaled by bearing sleeve 158 upon the shaft 142 between the bearings 150 and 152.

The tunnel section supporting boom 140 comprises a

pair of parallel rectangularly shaped in cross section hollow boom members 160 and 162. These two boom members are welded as at 166, or otherwise secured to the block upon opposite sides of a projection 164 of the block 156 as shown in Fig. 11.

At the rear side of projection 164 is secured the link member 167 which link is pivotally coupled with the hydraulic cylinder and piston combination 168, as shown in Fig. 9. The opposite end of the cylinder piston combination is swiveled by a pivotal connection 170 to the shield 135. This cylinder piston combination 168 is adapted to swing the tunnel section supporting boom laterally of the car about the shaft 142.

At the outer end of the boom 140 is mounted the tunnel section supporting head 172 shown in Figs. 9 and 14. The head comprises a bracket portion replaceably receivable over the end of the boom and a tunnel ring section supporting portion pivotally mounted upon the bracket. The bracket consists of a vertically extending member 174 and a bracing member 182 connected at its upper end to the top of the member 174 and diverging from member 174 as it extends downwardly until meeting strut 184, after which bracing member 182 parallels member 174, spaced therefrom by the width of the parallel boom members 160 and 162. The strut 184 is welded or the like to members 174 and 182. Two additional struts 186 and 188 parallel strut 184 and are welded at each end to the members 174 and 182. Struts 186 and 188 are spaced apart by the cross sectional height of boom member 160, with the vertical dimension of strut 188 being such as to permit it to slidably fit within the space between the boom members 160 and 162.

By virtue of the particular relationship of bracing member 182 to the member 174, and the interposition of struts 186 and 188 between the bracket and through the bracket, the entire supporting head 172 may be slidably received upon the end of the supporting boom. Such slidable connection between the supporting head and the boom permits ready interchangeability of supporting heads and allows heads of varying sizes to be mounted on the boom, thereby utilizing the same tunnel section supporting car for handling different sizes of tunnel ring sections.

The overlapping relation of struts 186 and 188 with the parallel boom members is shown in Figs. 14 and 19. Blocks 187 and 189 fixed on the boom members limit the rearward slidable movement of the supporting head. A plate 191 welded inside the end of boom member 160 is adapted to threadedly receive a hook 193. A bar 195, receiving therethrough the shank of hook 193, overlies the end of boom member 160 and is adapted to overlies the edges of bracket member 174 and 182, thereby detachably securing the supporting head to the end of the boom. The hook 193 is also adapted to be coupled to a mud car so that the tunnel section supporting car may be employed as a locomotive to haul the mud car, loaded with earth removed from the heading, out of the tunnel.

This bracket assembly mounted on the end of the boom carries the tunnel ring section engaging and supporting mechanism. Fixed to the lower end of the bracket member 174, as shown in Fig. 14, is an L-shaped bearing bracket 190. At the opposite or upper end of the member 174 is fixed a bearing block 192. Intermediate the bearing bracket 190 and the bearing block 192 is fixed a second bearing block 194. The bearing blocks 192 and 194 and bracket 190 are adapted to rotatably support a vertical shaft 176. Approximately midway between the ends of shaft 176 is fixed a part 196 provided with a horizontal stub axis or spindle 198 over which is rotatably mounted a hub 200 which hub carries the radially extending, angularly perpendicularly related tunnel ring engaging arms 177, 178, 179 and 180. A nut 202 is threadedly received over the reduced end of the spindle 198 and is adapted to hold the hub thereon. The spindle

is provided with a flange 199 and a hub supporting portion 201 adjacent to the flange as shown in Fig. 14.

The rotatable shaft 176 is also axially slidable within its mounting on the bracket. A part 204 is telescopically received in the lower end of shaft 176 as shown in Fig. 16, and the shaft is adapted to reciprocate linearly of the part. This part 204 is seated at one end upon the bracket 190. The part 204 and associated mechanism is adapted to impart slidable movement to the shaft 176. The details of the part 204 in the lower end of the shaft 176 are shown in Fig. 16. The shaft is interiorly bored out as at 206 to receive the part 204. The part itself is interiorly bored out as at 207 to receive slidably the plunger 208. The plunger at its upper end is tapered as at 210. The upper end of the bore 206 in the shaft is shaped to complement the upper end of the plunger to form therewith a bearing contact such as illustrated at 211.

The lower end of the plunger 208 is provided with packing 212 which encircles the plunger and bears against the inside wall of the bore 207 of the part 204. A hydraulic line 214 communicates with the interior of the bore 207 of part 204 at the lower end thereof and is adapted to feed hydraulic fluid into the bore and urge the plunger 208 upwardly to raise the shaft.

As can now be readily appreciated, if hydraulic fluid is fed through line 214 to the part 204, the shaft 176 will be slidably raised, carrying with it the spindle 198 and the hub 200 with its arms 178 and 180. Because the shaft 176 is rotatably as well as slidably mounted in the bearing blocks 192 and 194, and because the hub 200 provided with the arms 177, 178, 179 and 180 is rotatably mounted upon the spindle 198, and because the boom itself is laterally swingable, substantially universal movement of a tunnel section, carried by the arms 177, 178, 179 and 180 about and along a plurality of axes, may be accomplished.

More specifically the arms may be revolved about the horizontal axis of spindle 198, which horizontal axis may be vertically displaced through raising and lowering shaft 176. Such horizontal axis is also revoluble about the axis of shaft 176 parallel to the line of vertical displacement thereof. When together with such universal movement of the arms 178 and 180 is also considered the lateral displacement of the boom 140, it can be appreciated that a succeeding tunnel section supported on the arms 178 and 180 can be tilted and rotated both about horizontal and vertical axes and also bodily displaced along horizontal and vertical axes. Therefore universal movement may be imparted to a tunnel section mounted upon the arms.

The tunnel section engaging arms 177, 178, 179 and 180 are shown in Figs. 9, 14, and 15. They extend radially away from the spindle 198 and are disposed at right angles to one another and lie in a common plane, though they could be offset from one another to lie in two parallel planes. Each arm is interiorly bored and threaded as at 218. Threadedly received within the ends of the arms 179 and 180 are the section engaging elements 220 and 221. Each element includes a threaded stem 222 as shown in Fig. 20, which is threadedly received within the bore 218 of the shank 216 of the arms 179 and 180. The stems are shaped at their outer ends to exhibit a ball 223. The ball is adapted to be received within the block 224 which is hemispherically recessed as at 225 to rotatably seat the ball in the block. A cup-shaped member 226 is slidably received over the stem rearwardly of the ball and is recessed as at 227 to be seated over the ball. The cup-shaped member is threaded adjacent its lower end and at the shoulder portion 228 to be received in threaded engagement over the block 224. The block 224 is circular in cross section and threaded as at 229 so that the cup-shaped member may be threaded thereupon. Attached to each block is a tunnel section abutment member 230, which is similar to the member

26 shown in Fig. 3, and is adapted to bear against the inside of the tunnel section. An actuating lever 231 encircles the stem above the cup-shaped member 226, and is adapted to be secured to the stem by the set screw 231a. By means of the actuating lever the stem may be threaded into or outwardly of the shank of the arms, thereby deforming a tunnel section mounted upon the arms. The deformation of the tunnel section by the elements 220 and 221 is along what becomes the major axis of the section as shown in Fig. 9.

Threadedly received within the outer ends of the arms 177 and 178 are the tunnel section engaging elements 232 and 233. Each of these elements includes a threaded stem portion 234 which is threadedly received within the ends of the arms 177 and 178. The outer ends of the stems are shaped to exhibit balls 235. The balls 235 at the end of the stems 234 are adapted to be received within a hemispherically recessed block member 236. A cup-shaped member 237 is received over each stem 234 and interiorly hemispherically recessed to be received over the ball. The interior of each cup-shaped member is threaded about a shoulder 238 to be threadedly engaged with the block 236. The block 236 is circular in cross section and is threaded so as to threadedly receive the cup-shaped member. The block and cup-shaped member cooperate to hold the ball of each stem rotatably within the cooperating hemispherical recesses of the block and the cup-shaped member. The blocks 236 are fastened in any suitable manner to the inner leg of the U-shaped elements 238. The legs of the U-shaped members are adapted to slip over the edge of a tubular tunnel section to support it on the arms. An actuating lever 239 surrounds each stem 234 and is secured thereto after the fashion of the attachment of the actuating levers 231 to the stems 222. The actuating levers 239 may be employed to thread the stems 234 into or outwardly of the arms 177 and 178.

The tunnel section engaging arms are extensible and contractable by virtue of the adjustability of the elements 220, 221, 232 and 233. With a tunnel section disposed on the arms, by threading the engaging elements 220 and 221 outwardly, and threading the elements 232 and 233 inwardly, the circular section may be deformed to assume the elliptical shape shown in Fig. 9. The section has been expanded along a horizontal major axis, which lies on the axis of arms 179 and 180, and contracted along a vertical minor axis which lies on the axis of arms 177 and 178, and is of a shape to permit it to be carried through the completed portion of the tunnel. It will be noted that the section must be deformed along the major and minor axes to an extent such that the minor axis is sufficiently less than the diameter of an undeformed and circular tubular section so that the deformed section will pass through the undeformed section. The tubular axial dimension of the section is of importance here, because the amount of deformation necessary to pass one section through another depends in part upon this dimension. Considering Fig. 1, if the tubular axial dimension L is greater, the deformation of the section 10 being passed through the undeformed section must also be greater.

When the section is mounted on arms 177, 178, 179 and 180, both before and after the deformation, it is supported at substantially its center of mass with the section engaging elements at the ends of the arms engaging the sections at diametrically opposite points. That is, the center of mass of the section coincides with the axis of the spindle 198 of the tunnel section supporting head. By supporting the section at its center of mass, it may be easily revolved about the axis of the spindle. A miner working in the heading H ahead of the tunnel, may manually grasp the section and rotate it about the axis of the spindle 198. The section may also be revolved about the axis of the shaft 176 of the head.

After the deformed section has been carried through

the tunnel and disposed a sufficient distance in the heading to permit restoration to its original shape, the actuating levers 231 and 239 are operated to retract the section engaging elements 220 and 221 toward the arms 179 and 180, and extend the U-shaped engaging elements 136 outwardly of the arms 177 and 178. Upon extension of the latter elements the section is forced to assume its original circular shape. After the section is restored to its original shape, it may be revolved about the axis of the spindle 198 and shaft 176, and by means of the hereinafter more fully described hydraulic system, the section is raised or lowered or moved horizontally laterally of the tunnel by the swing of the boom 160, so that its tubular axis is aligned with the completed portion of the tunnel. By backing up the car 42 the section is drawn back against the end of the previously installed tunnel section and fastened in place thereagainst. The restoration of the deformed section to its original shape is preferably accomplished before the section is revolved about the axis of the shaft 176 or, in other words, before the section is swung around to align its tubular axis with the axis of the tunnel. This will permit of a smaller heading because the section may be revolved about a vertical axis in a smaller space if it is circular in shape rather than elliptical. However, the restoration of the section to its original shape may be carried on while it is being revolved about the axis of the spindle 198 and while it is being carried into the heading. When the section is disposed in the position shown in Fig. 9, it may be revolved slightly about the axis of the spindle 198. As the section is moved farther into the heading this degree of rotation may be increased, and at the same time the minor axis may be lengthened and the major axis shortened. As the movement of the section into the heading is continued, and the section is lengthened along its minor axis, it is eventually restored to its original circular shape, and thereafter is rotated about the axis of shaft 176 and aligned with the completed portion of the tunnel.

To prevent the rotation of arms 177, 178, 179 and 180 about the spindle 198, as the tunnel section is being carried by the car through the completed portion of the tunnel, a chain such as that shown in Figs. 9 and 15 may be employed. A stop 246 is mounted upon the underside of the bracket 190. The stop serves to keep the arms in the position shown in Figs. 9 and 15 as a tunnel section is being carried through a completed portion of the tunnel. The stop is provided with a spring loaded plunger 247 having an actuating and locking pin 248, and a slot 249 formed in a wall of the stop to receive therethrough the actuating and locking pin. The slot exhibits at its opposite ends an offset portion into which the pin may be moved to lock the plunger in the extended or retracted position. The plunger of the stop when extended abuts the arm 178. The plunger may be retracted such that it will be clear of the arm 178 and of the other arms.

A chain 248 is coupled by a link 250 to the arm 177. The chain extends around the tunnel section mounted on the arms, and is removably coupled at its other end to the car by means of a bracket 252 mounted on the forward end of the car, as shown in Fig. 9.

The bracket is provided with a V-shaped notch into which a link of the chain may be dropped to lock the chain in the bracket. A coil spring 254, having its ends fastened to the chain with a slack portion of the chain between the ends in the spring, is adapted to maintain a tension on the chain and hold the tunnel section in the position shown in Fig. 9. The chain and spring exert a tension which tends to revolve the arms in a direction such that the arm 178 is constantly held against the stop 246. The chain also tends to prevent the tunnel section from revolving about the axis of shaft 176. The chain tends to hold the section against the supporting boom 140 and keep it from bumping against the inside

of the completed tunnel as the section is carried there-through.

The rear end of the car is weighted as at 260 behind the cockpit generally indicated as 262, to counterbalance the weight of a tunnel section suspended ahead of the car. Within the cockpit are the control levers for operating movement of the car and of the tunnel section supporting head, and are more fully described in my co-pending application 410,252.

One of the control levers is the lever 268 which is coupled with the piston of the hydraulic pump 270 shown in Fig. 18. Upon actuation of this lever, hydraulic fluid pressure is built up within the pump and the fluid under pressure is led through a line 272 into a valve 274 and thence into the cylinder piston combination 168. With the valve 274 in the position shown in Fig. 18, hydraulic fluid from the pump enters the cylinder-piston combination to urge the piston thereof outwardly of the cylinder and thereby move the supporting block 156 and laterally position the tunnel section supporting boom 140.

The tunnel section supporting boom is moved in the opposite direction by a reversal of valve 274 from the position shown in Fig. 18 to one in which hydraulic fluid from pump 270 passes through line 272 and thence through line 276 into the opposite end of the cylinder-piston combination. A valve 278 is provided in the line 280 through which exhaust fluid from the cylinder-piston combination is led to the reservoir 282. This valve is adapted to maintain a back pressure against the piston such that the piston may be locked in any desired position merely by closure of the valve 278. When the valve 278 is closed and a pressure is built up in pump 270, hydraulic fluid cannot escape from the cylinder-piston combination and the piston will be locked in position. The reservoir 282 feeds the fluid through line 284 to the pump 270.

The piston of a second pump 286 is adapted to be actuated by the lever 288. This pump is connected by line 290 to valve 292. The line 214 leads from valve 292 to the part 204 at the lower end of the shaft 176 in the tunnel section supporting head. Upon actuation of the pump by lever 288, and with the valve 292 in the position shown in Fig. 18, the plunger 208 in the part 204 in the tunnel section supporting head is raised and the shaft 176 consequently raised. With a tunnel ring section mounted on the arms 177, 178, 179 and 180, upon actuation of the lever 288 the tunnel section is raised.

A second line 294 extends from valve 292 back to the reservoir 282. This line is a drain for the hydraulic fluid within the bore 297 of the part 204 which has raised the plunger. With the valve 292 rotated approximately 90° from the position shown in Fig. 18, the hydraulic fluid will pass under pressure of gravity back through line 214, through valve 292 and line 294 into the reservoir.

It will be understood that the hydraulic system shown in the various figures of the drawings, and above described, is merely an illustrative embodiment and a mechanical linkage might equally well be used in its stead.

What I claim is:

1. Tunnel section supporting and positioning apparatus for the purpose described comprising, in combination: a wheeled vehicle, tunnel section supporting mechanism mounted upon the vehicle and projecting forwardly thereof and exhibiting at the outer end radially extending tunnel section engaging and supporting means adapted to engage and support interiorly a deformable tunnel section, said means being journaled upon the mechanism for rotation relative thereto to permit rotation of the section while supported upon the mechanism and being extensible and retractable along a radial axis to deform the tunnel section carried by said means.

2. Tunnel section supporting and positioning apparatus for the purpose described comprising, in combination: a wheeled vehicle, tunnel section supporting mechanism mounted on the vehicle and projecting forwardly

thereof, tunnel section engaging and supporting arms journaled upon the mechanism for rotation about an axis angularly related to the supporting mechanism to permit rotation of a tunnel section carried by the arms, and at least one of the arms being extensible and retractable to deform a deformable tunnel section outwardly and inwardly along the axis of such arm when the tunnel section is engaged by and supported upon the arms.

3. The invention as defined in claim numbered 2 characterized in that the arms are mounted on the supporting mechanism for lateral shiftable displacement to adjusted positions along a line angularly related to the axis of the supporting mechanism.

4. Tunnel section supporting and positioning apparatus for the purpose described comprising, in combination: a wheeled vehicle, a boom mounted at one end upon the vehicle and extending forwardly thereof, a plurality of tunnel section engaging arms journaled upon the boom and extending radially therefrom for rotation about an axis angularly related to the axis of the boom, said arms provided with extensible and retractable tunnel section engaging end portions adapted to engage interiorly a tunnel section and support the same ahead of the vehicle with said extensible and retractable portions movable against the section to urge it outwardly along one axis and inwardly along another axis to deform the section, and movable inwardly from such extended position and outwardly from said retracted position to permit restoration of the section to its undeformed shape.

5. Tunnel section supporting and positioning apparatus for the purpose described comprising, in combination: a wheeled vehicle; a boom mounted at one end upon the vehicle and extending forwardly thereof; a plurality of perpendicularly related radially extending tunnel section engaging arms journaled upon the free end of the boom for rotation about an axis angularly related to the axis of the boom; said arms exhibiting at their outer ends extensible and retractable tunnel section engaging elements with some of the elements adapted to interiorly engage and some adapted to exteriorly engage a tunnel section to support the section upon the arms; those elements interiorly engaging the tunnel section being extensible to expand the tunnel section along the axes of the arms provided with such elements, and those elements exteriorly engaging the tunnel section being retractable to contract the tunnel section along the axes of the arms provided with such elements to deform the tunnel section outwardly along a major axis and contract it along a minor axis.

6. Tunnel section supporting and positioning apparatus for the purpose described comprising, in combination: a wheeled vehicle; a boom swingably mounted at one end upon the vehicle and extending forwardly thereof; radially extending tunnel section engaging arms journaled upon the boom for rotation about an axis angularly related to the axis of the boom, with the arms adapted to engage interiorly and exteriorly and support for rotation a tunnel section upon the boom; each arm exhibiting at its outer end a tunnel section engaging member adjustable linearly of the arm to increase or decrease the effective length of the arm; and means coupled with the arms and operable to impart such linear movement thereof.

7. Tunnel section supporting and positioning apparatus for the purpose described comprising, in combination: a wheeled vehicle, a boom mounted at one end upon the vehicle and extending forwardly thereof, two perpendicular pairs of diametrically opposed tunnel section engaging and supporting arms mounted upon and extending radially from a hub journaled upon the boom, said hub and arms being swingable about an axis substantially perpendicular to the axis of the boom, each arm having a tunnel section engaging end member movable linearly of the arm and adapted to interiorly engage and support a tunnel section, means coupled with the members and with the arms including an actuating device operable to urge the mem-

bers on one pair of arms linearly outwardly of the arms to deform a tunnel section outwardly along the axis of such pair of arms with the actuating device and means on the other pair of arms being operable to retract the members coupled therewith to permit contraction of the tunnel section along the axis of such latter pair of arms, thereby effecting an expansion and contraction of the tunnel section along perpendicularly related axes.

8. The invention as defined in claim numbered 7 characterized in that the tunnel section engaging members at the ends of one pair of arms are generally U-shaped with the legs of the U shape adapted to overlie the inside and outside surfaces of the wall of the tunnel section.

9. Tunnel section supporting and positioning apparatus for the purpose described comprising, in combination: a wheeled vehicle, a boom mounted at one end upon the vehicle and extending forwardly thereof, a plurality of radially extending tunnel section supporting arms journaled upon the end of the boom for rotation from a position lying in a plane substantially parallel to the axis of the boom to a position lying in a plane substantially perpendicular to the axis of the boom, said arms being extensible and contractable to engage and deform along the axis of the arms a tunnel section mounted on the ends of the arms, and the end portions of some of said arms being shaped to extend around an edge of a tunnel section to grip the section and hold it on the ends of such arms.

10. Tunnel section supporting and positioning apparatus comprising, in combination: a wheeled vehicle, a boom mounted at one end on the vehicle to extend forwardly thereof, tunnel section engaging and supporting means journaled on the opposite end of the boom and adapted to extend through the tunnel section and around the far end thereof and shaped to grip the section externally and hold it on the boom spaced therefrom for rotation relative thereto.

11. Tunnel section supporting and positioning apparatus comprising, in combination: a wheeled vehicle, a boom mounted at one end on the vehicle to extend forwardly thereof, tunnel section engaging and supporting arms journaled on the opposite end of the boom and adapted to extend through the tunnel section, some of said arms adapted to extend around the far end of the section and shaped to grip the section externally, and the remainder of the arms adapted to engage and grip the section interiorly, with the arms holding the section on the boom spaced therefrom for rotation relative thereto.

12. The method of lining a tunnel which comprises positioning a tubular tunnel section within a tunnel, deforming an identical tunnel section by applying contracting and expanding forces thereto at a plurality of circumferentially spaced points, passing said second tunnel section in deformed condition through said first tunnel section, restoring said second tunnel section to its normal shape, aligning said second tunnel section with said first tunnel section, and moving said second tunnel section into engagement with said first tunnel section to form a continuation thereof.

13. The method of lining a tunnel which comprises positioning a cylindrical tunnel section within a tunnel, deforming an identical tunnel section by applying con-

tracting and expanding forces thereto at a plurality of circumferentially spaced points, passing said second tunnel section in deformed condition through said first tunnel section, restoring said second tunnel section to its cylindrical shape, aligning said second tunnel section with said first tunnel section, and moving said second tunnel section into edge to edge abutting engagement with said first tunnel section to form a continuation thereof.

14. The method of lining a tunnel which comprises positioning a tubular cylindrical tunnel section within a tunnel, deforming an identical tunnel section by applying contracting forces against said second section at two diametrically opposed points and expanding forces against said second section at two diametrically opposed points spaced circumferentially from said first mentioned points, passing said second section through said first section, restoring said second section to its normal shape, aligning said second section with said first section, and moving said second section into engagement with said first section to form a continuation thereof.

15. Tunnel section supporting and positioning apparatus for the purpose described comprising, in combination: a wheeled vehicle, a boom mounted at one end upon the vehicle and extending forwardly thereof, a plurality of tunnel section engaging arms journaled upon the boom and extending radially therefrom for rotation about an axis angularly related to the axis of the boom, said arms provided with retractable tunnel section engaging end portions adapted to engage a tunnel section and support the same ahead of the vehicle with said retractable portions movable against the section to urge it inwardly along one axis to deform the section, and movable outwardly from such retracted position to restore the section to its undeformed shape.

16. Tunnel section supporting and positioning apparatus for the purpose described comprising, in combination: a wheeled vehicle, a boom mounted at one end upon the vehicle and extending forwardly thereof, a plurality of tunnel section engaging arms journaled upon the boom and extending radially therefrom for rotation about an axis angularly related to the axis of the boom, said arms provided with extensible and retractable tunnel section engaging end portions adapted to engage interiorly a tunnel section and support the same ahead of the vehicle, certain of said extensible and retractable portions movable against the section to expand it outwardly along one axis while the remaining portions are retractable inwardly to permit contraction of the section along another axis, and said portions being reversely movable to expand the section along the previous axis of contraction and contract the section along the previous axis of expansion to restore the section to its undeformed shape.

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