G. W. JACKSON.

ART OF CONSTRUCTING TUNNELS IN THE EARTH.

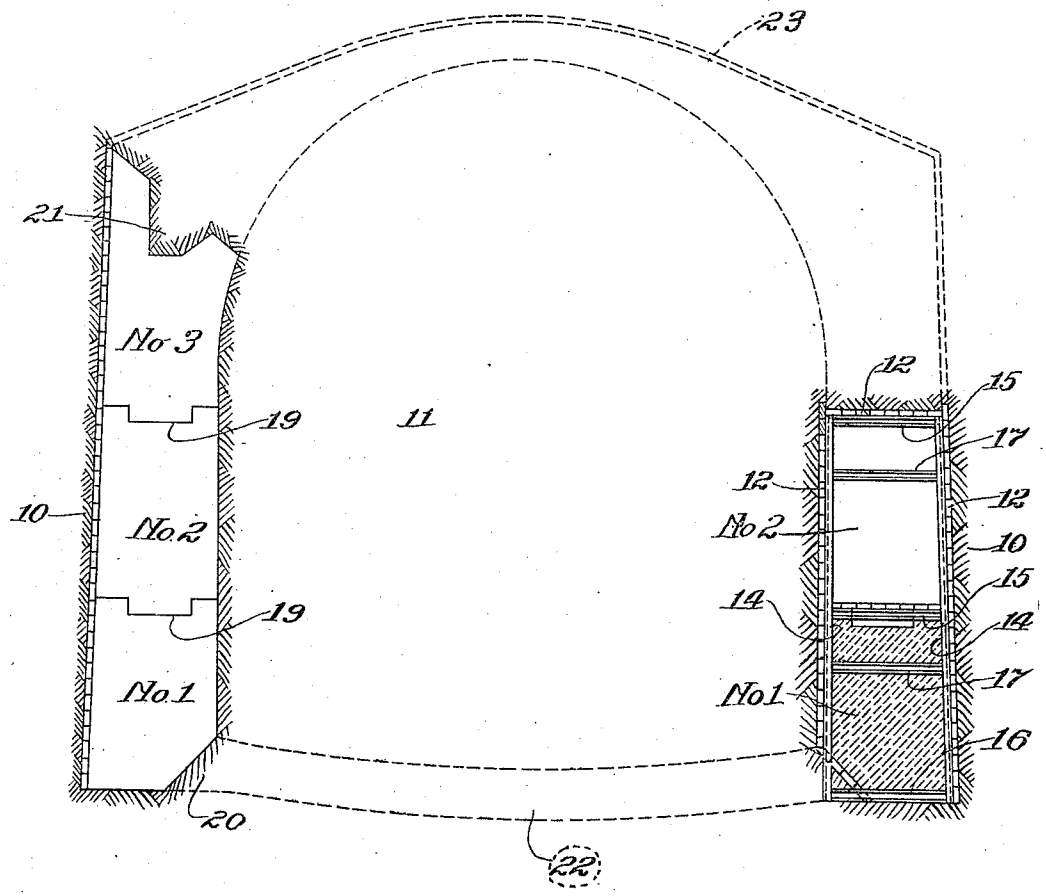
APPLICATION FILED FEB. 18, 1910.

960,940.

Patented June 7, 1910.

3 SHEETS—SHEET 1.

Fig. 1



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3 SHEETS—SHEET 2.

Fig. 2

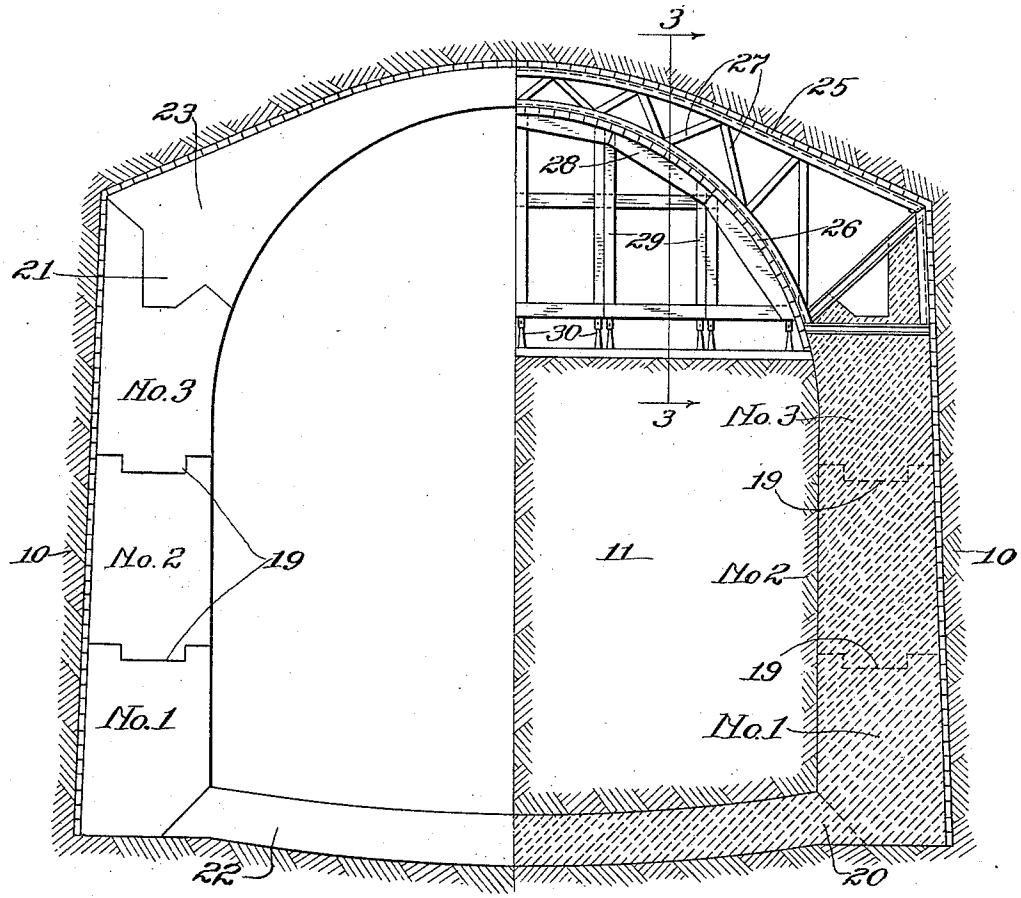
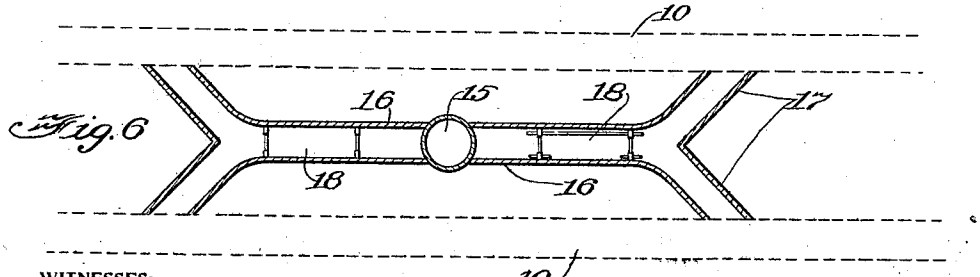


Fig. 6



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3 SHEETS—SHEET 3.

Fig. 3

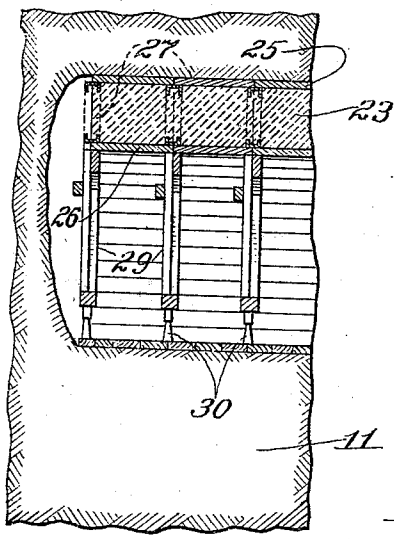
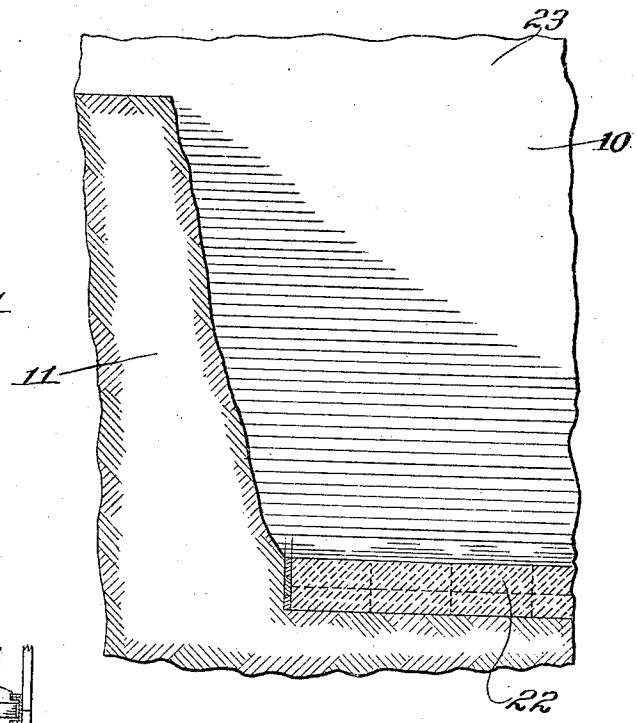


Fig. 4



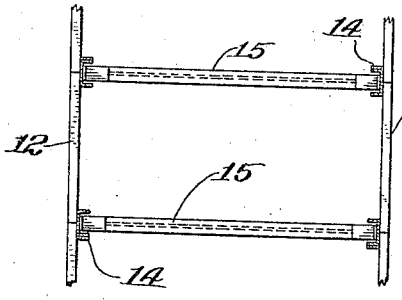


Fig. 5

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UNITED STATES PATENT OFFICE.

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ART OF CONSTRUCTING TUNNELS IN THE EARTH.

960,940. Specification of Letters Patent. **Patented June 7, 1910.**

Application filed February 18, 1910. Serial No. 544,528.

To all whom it may concern:

Be it known that I, GEORGE W. JACKSON, a citizen of the United States, and a resident of Chicago, in the county of Cook and State of Illinois, have invented certain new and useful Improvements in the Art of Constructing Tunnels in the Earth; and I do hereby declare that the following is a full, clear, and exact description thereof, reference being had to the accompanying drawings, and to the characters of reference marked thereon, which form a part of this specification.

This invention relates to improvements in the art of constructing tunnels in the earth, and refers more specifically to an improved method of construction designed to facilitate the building of tunnels in relatively soft or unstable earth where extraordinary provisions are required to avoid the tunnel bore caving in or to prevent injury to building foundations along the line of the tunnel due to lateral shifting of the earth toward the tunnel bore. My improved method is especially applicable to the construction of relatively large tunnels when excavated in earth of this character.

The object of the invention is to provide a simple and safe mode of constructing tunnels of this general character, and one which is relatively inexpensive as compared to present methods of tunnel construction.

The invention consists in the matters hereinafter set forth and more particularly pointed out in the appended claims.

In constructing a tunnel in accordance with my improved method, I first construct the side walls thereof wholly beneath the surface of the earth as separate, independent walls and of considerable length, depending upon the nature and supporting character of the earth. I thereafter excavate the area or section between the walls in relatively short lengths and build in the concrete arch and invert between the finished side walls as each section of the central section or core is excavated.

As an improved method of constructing the concrete side walls, I propose to construct the side walls in separately formed, successively higher courses, beginning at the bottoms of the walls, the courses being joined to constitute vertically continuous wall structures. I may effect this result by excavating the earth along the lines of the proposed walls in successively higher wall section tunnels, beginning at the lower side of the areas of the proposed walls, bracing and lagging the tunnels thus formed and filling each wall section tunnel with concrete, preferably before the next higher wall section tunnel is excavated. After a lower wall section tunnel is excavated and the excavation filled or concreted, the next upper section is excavated, braced and lagged and filled as before. The number of wall section tunnels to complete a wall will depend upon the height of the wall and somewhat also upon the character of the earth being excavated, it being evident that the firmer the earth the greater the height it is practicable to excavate the wall section tunnels. After the two side walls of the tunnel have been thus constructed, the middle section of the tunnel between the side walls is excavated or mined, beginning at the point of commencement of the wall tunnel. The roof section and middle section are excavated rearwardly in short sections and the arch and invert are placed, by the use of suitable forms as each section is completed. Usually the roof sections will be excavated and the arch placed before the main body of the middle section is excavated, and in this instance the bracing and lagging for the roof or arch section will be supported on the unexcavated main body of the middle section.

As a means of gaining access to the level of the lower courses of the proposed side walls of the tunnel, I may sink a working shaft, located between the lines of the proposed tunnel walls, to or slightly below the level of the lowermost courses of the tunnel walls or that first to be excavated and concreted. From this shaft I may extend, at the level of the lowermost courses of the proposed side walls, small tunnels or bores which open laterally toward both of the lines of the side walls, and arranged to communicate with the lower wall section tunnels. It is through these shaft tunnels that access is had to the level at which the first courses of the side walls are to be built and

said shaft and connected tunnels afford means for the operatives and material to enter and leave the wall section tunnels. When the character of the earth being excavated is such as to require internal air pressure to assist in holding or supporting the walls of the wall section tunnels during the excavating operation, the said tunnels leading from the entering shaft may contain the air locks through and by which air pressure is maintained in the working excavations, while permitting the operatives and materials to be taken into and removed from the wall section tunnels.

As shown in the drawings, Figure 1 is a cross section of a partially completed tunnel made in accordance with my improved method, showing one of the side walls completed and the other in a process of construction, and indicating in dotted outlines the arch and invert. Fig. 2 is a similar section, with one lateral half complete and the other half partially completed, showing the method of excavating the roof section to construct the arch. Fig. 3 is a fragmentary longitudinal section on line 3—3 of Fig. 2. Fig. 4 is a fragmentary longitudinal section, indicating the manner of excavating or mining the main body of the central section and placing the invert. Fig. 5 is a detail of the ribs and lagging for supporting the walls of the sectional wall tunnels. Fig. 6 is a diagrammatic view, indicating the manner of arranging the ingress and egress shaft and connecting tunnels with relation to the courses of the side walls of the tunnel.

As shown in Fig. 2 of the drawings, 10, 10 designate the complete side walls of the tunnel, each of which is therein shown as made of three separately formed, superposed sections or courses, further designated as courses No. 1, No. 2 and No. 3. The left side of the tunnel in Fig. 2 is shown as completed, and the roof section at the right side in course of construction, but with the central section or core 11 at the right side thereof unexcavated. The side wall at the right of Fig. 1 is illustrated in the process of construction. As therein shown, the lower section or course, which is designated as No. 1, has been excavated throughout the predetermined length and has been filled with a filling body of concrete. The next upper section, or that which is designated as section No. 2, is shown as excavated but not filled or concreted. The area for the third or top section of the right hand wall shown in Fig. 1 is unexcavated.

The earth removed for the wall sections is excavated in the manner of small tunnels throughout the length of the tunnel section which is to be built from one vertical starting shaft. Section No. 1 of the right hand wall (Fig. 1) has thus been excavated and has been filled with concrete, the filling beginning at the far or blind end of the wall section tunnel back to the point of its beginning. As each wall section tunnel is excavated it is lagged and braced to support the tunnel walls against caving in. The lagging 12 is supported by suitable metal ribs or bracing having the form of open, generally rectangular frames, comprising the side uprights 14, 14 and the top and bottom cross members 15 and 16 respectively. The uprights may be further braced or stiffened by cross members 17 arranged between the upper and lower ends thereof. In setting the bracing of an upper excavation it is attached rigidly to the bracing of the next lower section, and the top cross members 15 of the bracing frame of a lower section may constitute the bottom member of the bracing frame of the next upper section. After the wall section tunnel No. 2 at the right of Fig. 1 has been filled with concrete in the manner of section No. 1, the area thereabove will be excavated, braced and lagged throughout the predetermined length of the section and thereafter filled with concrete, whereupon the side wall will be completed.

It will be understood that when the lower course of each wall has been completed and the next superjacent wall section tunnel excavated, the top lagging of the lower completed course will be removed before the concrete of the next upper course is placed. The outer courses of lagging at the outer sides of the walls of the sectional wall tunnels and the bracing frames will be left in place, the latter constituting reinforcement for the tunnel wall. The inner courses of lagging at the inner sides of the walls will be removed when the central section 11 is excavated away.

The level of the lower wall section tunnels may be reached through a vertical shaft 15 as indicated in Fig. 6, which shaft is connected by small horizontal tunnels 16 with the line of the proposed walls. As shown in said Fig. 6, the horizontal tunnels 16 connected with the shaft 15 extends in opposite directions from the shaft and both ends thereof are formed to provide branching or twin tunnels 17, 17 which extend laterally in opposite directions for intersection with the lines of the side walls at the level of the lower courses thereof. With this arrangement it is practicable to have access to four cuts from a single shaft. This shaft and the horizontal tunnels leading therefrom afford access for the operatives and material to the wall section tunnels and egress therefrom. When working in earth which requires to be supported by air pressure, the horizontal tunnels 15 may be

equipped with suitable air locks, indicated as a whole by 18, and made of any usual or suitable construction such as will permit the passage of material and operatives therethrough, while maintaining the working pressure in the excavations beyond the air locks.

The manner of reaching the successively higher wall section tunnels levels after the lower sections or course of the walls have been completed from the shaft tunnel 15, may be arranged like that shown in my companion application filed of even date herewith, Serial Number 544,527.

There will preferably be left at the top of each body of concrete of each wall course a longitudinal depression of suitable cross section to form, when the next course is applied, a key 19 to bond or connect the upper and lower courses together. Preferably also like openings or recesses will be left at the inner sides of the side walls near the bottoms thereof and at the tops of the upper courses to receive the connecting or joining keys 20 and 21 of the invert and arch 22 and 23, respectively. After the side walls have been completed as described, the earth at the roof section will be excavated in convenient widths and lengths and the upper and lower courses of the supporting and form lagging 25, 26 will be placed in position with the bracing 27 between same. Thereafter the space between the supporting lagging and form lagging is filled to constitute the arch 23 of the tunnel. The roof section may be excavated or mined in suitable widths, convenient to operate, and in depths or lengths dependent upon the character of the earth being worked. In a tunnel of the size herein shown the roof section may be conveniently divided into eight cuts, four at each side of the center, and excavated in lengths of from three to four feet. The form lagging 26 is supported by an arch frame 28 and an underframing or timbering 29, which latter is supported on the center, unexcavated section 11 of the tunnel, the roof section being excavated and concreted before the center section is excavated. The said underframing or timbering 29 may be supported from the center section 11 by jack screws 30 in a manner to maintain the proper contour of the lower course of supporting lagging 26 to properly form the arch. The space between the upper and lower course of lagging 25 and 26 is filled from the rear, as indicated in Fig. 3, the wall forming material being passed through the space beneath the lower course of the form lagging that supports the concrete filling of the arch already placed. After the arch has been completed in the manner described, the lower or main portion of the center section 11 is excavated in suitable lengths, and the invert 22 placed in position by the use of suitable forms.

It will be apparent that the novel method described enables a tunnel to be built with less cost of bracing, as compared to the method of excavating the full course section of the tunnel at one time. Moreover the excavations being but a fractional part of the area of the side walls of the tunnel, the danger of lateral shifting of the earth at the sides of the line of the tunnel, and consequent injury to building foundations, is greatly reduced if not wholly overcome. The length which it is practicable to excavate the wall section tunnels in the formation of the side walls will depend upon the character of the earth in which the work is being carried on and also upon the local conditions, as for instance, the loading on the ground above and at the immediate sides of the tunnel. For each length or section a new starting shaft may be sunk and connected to the wall sections by the connecting tunnels. When starting from a tunnel already built, or from the side of a hill, or like location, the starting shaft may not be required. The earth excavated from the roof and middle sections of the tunnel may be removed through a section of tunnel already completed, or through any suitably located shaft leading to the ground level or other place for the disposal of the excavated earth.

The improved method for tunnel construction is also useful in the construction of tunnels beneath a body of water, as a river. Such method makes it unnecessary to cut away the earth, as an open cut construction, above the level of the covered portion of the tunnel, beyond the open cut approaches thereof, thus avoiding the handling of a large amount of earth heretofore necessary in the construction of such tunnels by the open cut method.

The method herein specifically outlined is capable of some variation within the spirit and scope of the invention. For instance access may be had to the wall section tunnels through the arrangement of side drifts or tunnels shown in my pending application for Letters Patent, Serial Number 550,529, filed March 19th, 1910.

I claim as my invention:—

1. The improvement in the art of constructing tunnels in the earth, which consists in first building the side walls of the tunnel complete without open cut excavations, thereafter excavating the earth at the roof section and between the side walls and constructing the arch and the invert or floor.

2. The improvement in the art of constructing tunnels in the earth, which con-

sists in excavating narrow tunnels wholly beneath the surface of the earth along the lines of the side walls of the proposed tunnel, filling said narrow tunnels with wall forming material from within to constitute the side walls of the tunnel, excavating the earth between the side walls so constructed, and lining the upper and lower walls of the excavation to constitute the roof and floor respectively of the tunnel.

3. The improvement in the art of constructing tunnels in the earth, which consists in first forming the side walls of successively higher courses, beginning at the bottoms thereof, thereafter excavating the earth between the side walls and constructing the arch or roof wall and laying the invert or floor.

4. The improvement in the art of constructing tunnels in the earth, which consists in first building the side walls by excavating successively higher wall section tunnels along the lines of the proposed side walls, beginning at the lower level of the walls, and separately filling each tunnel with concrete or other wall forming material before the next higher wall section tunnel is excavated, thereafter excavating the earth from the roof section and forming the arch or roof wall of the tunnel and finally excavating the earth beneath the roof section and between the side walls and laying the invert or floor.

5. The improvement in the art of constructing tunnels in the earth, which consists in first building the side walls of the tunnel complete without open cut excavation, thereafter excavating the earth from the roof section between and above the level of the side walls in short lengths, thereafter placing supporting and form lagging beneath the roof of the excavation as the short lengths are mined and supporting said lagging from the middle or unexcavated earth section between the side walls, thereafter filling the space between the supporting and form lagging with wall forming material to form the arch or roof of the tunnel wall and finally excavating the middle earth section in short lengths and laying the invert.

6. The improvement in the art of constructing tunnels in the earth, which consists in first building the side walls of the tunnel by excavating successively higher wall section tunnels of considerable length along the lines of the proposed side walls, beginning at the lower levels of the walls, filling each wall section tunnel with wall forming material before the next higher wall section tunnel is excavated, excavating the roof section in short lengths, placing supporting and form lagging at the roof section and supporting the same on the middle or unexcavated earth between the side walls, filling the space between the supporting and form lagging with wall forming material to form the arch or roof of the tunnel wall, and finally excavating the middle section in short lengths and laying the invert.

7. The improvement in the art of constructing tunnels in the earth, which consists in first building the side walls of the tunnel by excavating successively higher wall section tunnels of considerable length along the lines of the proposed side walls, beginning at the lower levels of the walls, bracing and lagging said tunnels as the excavation progresses, filling each wall section tunnel with wall forming material before the next higher wall section tunnel is excavated, excavating the roof section in short lengths, placing supporting and form lagging, spaced by bracing, at the roof section and supporting the same on the middle or unexcavated earth between the side walls, filling the space between the supporting and form lagging with wall forming material to form the arch or roof of the tunnel wall, leaving the bracing in the side wall tunnels and arch or roof excavations to constitute wall reinforcements, and finally excavating the middle section in short lengths and laying the invert.

8. The improvement in the art of constructing tunnels in the earth, which consists in first sinking a shaft to or below the level of the bottoms of the proposed side walls of the tunnel, extending a tunnel from said shaft to the lines of the proposed walls, excavating successively higher wall section tunnels along said lines, beginning at the level of the shaft tunnel, separately filling each wall section tunnel before the next higher wall section tunnel is excavated, thereafter excavating the roof and middle sections and forming the arch and the invert or floor.

9. The improvement in the art of constructing tunnels in the earth, which consists in first sinking a shaft to or below the level of the bottoms of the proposed side walls of the tunnel, extending a tunnel from said shaft to the lines of the proposed walls, inserting an air lock in the shaft tunnel between said shaft and the outer end of the latter tunnel, excavating successively higher wall section tunnels along said lines, beginning at the level of the shaft tunnel, separately filling each wall section tunnel before the next higher wall section tunnel is excavated, thereafter excavating the roof and middle sections between the side walls and constructing the arch and the invert or floor.

10. The improvement in the art of constructing tunnels in the earth, which consists in first sinking a shaft to or below the level of the bottoms of the proposed side walls of

the tunnel and between said side walls, extending tunnels in opposite directions from the foot of said shaft and branching their outer ends to constitute twin tunnels which extend laterally in opposite directions to the lines of the proposed walls, excavating successively higher wall section tunnels along the lines of the proposed walls, beginning at the level of the twin shaft tunnels, separately filling each tunnel with wall forming material, thereafter excavating the roof and middle sections between the side walls and forming the arch and the invert or floor of the tunnel.

In testimony, that I claim the foregoing as my invention I affix my signature in the presence of witnesses, this 8th day of February A. D. 1910.

GEORGE W. JACKSON.

Witnesses:
GEORGE R. BENNETT,
J. M. SINGLETON,
L. WEBSTER STACKPOLE.