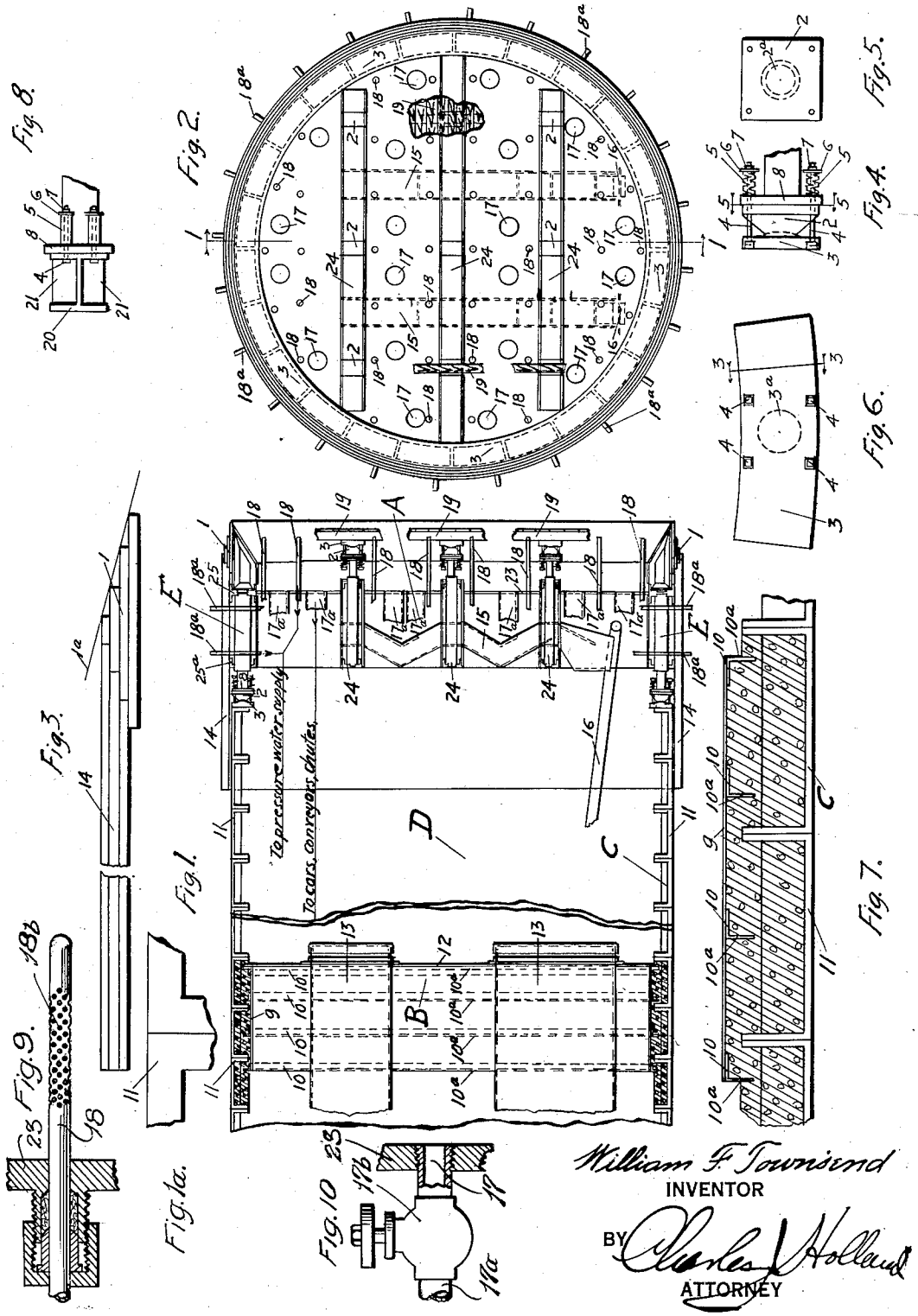
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EXCAVATION MEANS

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## EXCAVATION MEANS

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This invention relates to excavation means, and more particularly to excavation means used to drive shafts or tunnels, such as tunnel shields.

One of the objects of my invention is during the excavating operation to compress the material radially outwardly by wedging-means or specially arranged cutting means around the mouth of the excavating device and then to release said material by the progression of the excavating device and thereby automatically allow it to expand into full surrounding support against the outside of the tunnel or shaft-lining previously erected in the rear end of the excavating device and from which it emerges during said releasing progression of the device.

Another object is to excavate soft ground automatically by forcing it through openings provided for the purpose in the header of the excavating device as it is forced against said material, said material being delivered through pipes or chutes in connection with said header openings to conveyances for removing and disposing of it.

Another object is to specially irrigate the material in advance of the excavating device to make said material work like soft ground in connection with my invention.

Another object is to provide improved means for forcing ahead the excavation device away from the last erected section of the tunnel-lining, said means comprising jacks having special shoes, whereby the jacks can tilt with reference to the tunnel-lining, as required by any swerving of the excavating device, but the shoes will remain squarely seated against the end section of the tunnel-lining and thereby continue to distribute the thrusts evenly over said lining as distinguished from concentrating the thrusts unevenly to the probable damage of the lining.

Another object it to provide in connection with the excavation device a chute for receiving the excavated material received into the excavating device and delivering it by gravity but with safe momentum and impact to the conveying means for conveying the material out of the excavating device.

Another object is to provide an iron or steel bulk-head construction with its air-locks in lieu of the bulk-heads, now in use, my iron or steel bulk-head being devised so as to be adapted to be anchored to the lining of the excavation so effectively and over such a wide area of the lining that it presents far greater resistance to the high air pressures involved than has been attained heretofore, and is therefore far safer than the present steel construction; and which is moreover adapted to be readily erected and knocked down in portable units and as such, moved along to successive locations and reassembled.

Another object is to make tunneling and the sinking of shafts more rapid, less costly and improved in result.

Other objects will be in part apparent to those skilled in the art or in part pointed out hereinafter.

The invention accordingly consists in the features of construction and mode of operation, combination of elements and arrangements of parts as will be exemplified in the method and structure to be hereinafter described; and the scope of the application of which will be indicated in the following claims.

In order that the invention may be readily understood and its advantages from a practical standpoint fully appreciated, reference may be had to the accompanying drawing showing one of the preferred forms of embodiment which my present invention is adapted to take.

In the drawing, Fig. 1 is a vertical longitudinal section partly in elevation of a tunnel-heading on the line 1—1 in Fig. 2 and shows a shield, a tunnel-lining and a bulk-head enclosing a compressed air chamber between them, these embodying preferred forms of parts and structures within my invention; Fig. 1*a* is an enlarged detail of the manner in which the rings of tunnel lining may be fitted together; Fig. 2 is an elevation of the front or advancing end of the shield; Fig. 3 is an enlarged longitudinal section through a form of inverted cutting edge within my invention for the mouth of the shield, said figure also showing the skin or shell of the shield and a portion of the tunnel-lining; Fig. 4 is an enlarged portion taken from Fig. 1 showing my improved pushing-shoe for one of the jacks as same would appear in side elevation when viewed from the line 3—3 in Fig. 6 looking in the direction of the arrows; Fig. 5 is a view on the line 5—5 in Fig. 4 showing the base of the socket-part of the pushing-shoe; Fig. 6 is an enlarged elevation of that part of the pushing-shoe which is at the end of the tunnel-lining; Fig. 7 is an enlarged longitudinal section through the circular girder of the bulk-head containing the air-locks and through the tunnel-lining and the concrete connection between said girder and lining; Fig. 8 corresponds to Fig. 4 except that it shows a modified form of pushing-shoe of a jack which omits the ball and socket construction shown in Fig. 4. Fig. 9 is an enlarged section of the manner in which the irrigating pipes of my invention may be con-

structed. Fig. 10 is an elevation partly in section of a gate or valve device capable of contributing toward the control of the course of the shield of the present invention.

In the drawing the invention is shown as applied to a device for driving tunnels as distinguished from a caisson for sinking shafts. However, many, if not all, of my herein improvements apply equally well to excavating devices generally, whether for driving tunnels or sinking shafts; and this is to be understood or implied in connection with the following detailed description and the claims.

In the drawing, the tunnel excavating device or so-called shield, generally designated by the letter A, comprises a tubular shell 14, a bulkhead or header 23 preferably supported within and carried by said shell, and cutting means 1 at the mouth of the forward end of the shell.

The shield A; the air-lock bulk-head, generally designated B; and the tunnel-lining generally designated C enclose between them the space D which is the compressed air chamber in which the men work to carry on the tunneling operation, the compressed air, of course, serving to keep the water out of the working space as well as to supply the men with air to breathe.

Jacks, generally designated E, serve to force the shield endwise towards the right in Fig. 1 into the ground or material to be excavated which is either excavated by hand or is automatically delivered into the shell in accordance with my invention, and thence delivered through the locks in the bulk-head B for final disposal thereof. The space in the shell of the excavating shield behind its header forms part of the compressed air working space and permits the men to erect the successive rings 11 of the tunnel-lining C within the tail end of the shield as the latter is pushed forward and the material is excavated to form the tunnel.

These jacks extend lengthwise of the shell in a circumferential series around the interior thereof; and they operate between the end of the last erected ring of the tunnel-lining C and the header 23 of the shield, or more specifically the ring-shaped girder 25 to which the shell 14 and the peripheral portion of said header 23 are secured. Fig. 1 shows the last rings 11 of the tunnel-lining that have been erected within the tail end of the shell against which the jack-shoes bear as aforesaid to force the shield forward into the material to be excavated. Fig. 1a shows in detail the manner in which these rings may be placed together.

The forward end of the shell is provided with cutting means 1 at its mouth which is inverted as compared to previous practice, that is to say, the inclined face 1a of said cutting means is located towards the outside of the shell, said face sloping forwardly and inwardly. This has the effect, as will be hereinafter explained, of excavating less material than that actually displaced by the outer cross-section of the shell 14 and of compressing the remaining material radially outwardly and holding it in compression by the outside of the shell 14 as the latter is advanced by the jacks through the material. This compression is only released when the tail-end of the shell has passed beyond it, whereupon the compressed material expands inwardly into contact with the outside of the tunnel-lining sections or rings 11 as they emerge from the tail-end of the shell due to its advance into the material.

It will be understood that the aforesaid metallic cutting edge 1 completely surrounds the perimeter or mouth of the shield and the front or bottom of a caisson. For convenience of application, removal and replacement, this cutting edge is usually made up in sections secured end to end an and to the skin or shell or other frame work of the shield or caisson.

The openings 17 are provided through the header 23 of the shield or other excavating device from which preferably chutes, designated 17a, lead rearwardly into the shell. The material from in front of the header is automatically forced through these openings and chutes by the operation of forcing the shield and header against the material by means of the jacks. Thus, the openings 17 and chutes 17a form part of an efficient means for automatically excavating the soft material in front of the header and for automatically delivering it into conveyances at the shield such as cars, conveyors, etc., for subsequent removal.

The foregoing assumes that the ground ahead of the shield or the like is sufficiently soft and plastic for the purpose. If not, irrigation means is provided comprising the pipes 18 adapted to be projected through suitably provided holes in the header into the material in front of it in order to deliver water or liquid under pressure from any suitable source of supply into said material to soften it so that the material will be sufficiently soft to squeeze or flow through the aforesaid openings 17 during the advance of the shield. Similarly, in such case, pipes 18a are provided for irrigating the material at the periphery of the shield, these being adapted to be projected into said material through holes provided for the purpose in the shell or skin of the shield.

The holes in the pipes for delivering this liquid consist of a large number of fine holes 18b through the walls of the pipes for the distance the pipes enter the ground; whereas the end of each pipe is plugged up or closed. Moreover, said holes in the walls are countersunk slightly at the outside of the walls to prevent them from being plugged when pushing or projecting them into the ground as heretofore described. This construction is clearly indicated in Fig. 9 which also shows a simple manner in which the pipes may be housed for reciprocating movement through the header 23.

On the other hand, I do not limit myself to impregnating the ground with liquid by pipes projected or forced ahead of the shield bulk-head 23 because in some grounds, such as sand, the pipes may end at the bulk-head or header and the water may be simply forced through the ends of pipes directly into the ground in front of said bulk-head.

This irrigation operation takes place while the shield is at rest to prevent damage to the last named radially projecting pipes 18a which should be withdrawn before the shield is set in motion. On the other hand, it is not necessary to withdraw the irrigation pipes 18 that project through the header, because the advancing shield will automatically bring these back into the shell without damage thereto.

Platforms 24 are supported by the circular or ring-shaped girders of the shield behind the header 23. Vertical chutes 15 for the excavated material are supported in the shell behind the header by these platforms and have openings into them at said platforms whereby the excavated material coming through the openings 17

and chutes 17a may be delivered either directly into the aforesaid vertical chutes 15 or onto the platforms, whence it can be shovelled into the openings of the chutes 15. An important novelty of the chutes 15 is their zig-zag form whereby the flow of the material down the chutes is impeded at each elbow therein with the result that it is delivered at low velocity to the car or mechanical conveyor 16 without damaging the latter which cannot be done where the material is delivered from an upper platform of a large tunneling shield unless the chute be made extra long so as to be inclined at a small angle, in which event it takes up too much room and involves the further disadvantages hereinafter more particularly pointed out. For the same purpose of retarding the drop of the material, ribs hereinafter more particularly described may be provided on the interior of the chutes to further reduce the impact of the material upon the conveyor or car.

Gates or valves 17b, for instance, as shown in Fig. 10, are provided in connection with each opening 17 and chute 17a whereby the opening and closing of these openings can be controlled selectively. If the shield in the given operation has begun to swerve out of its true course, this can be corrected by appropriately closing some of the openings at one side of the shield and opening some on the other side; or the shield can be deliberately made to swerve with the object of forming a bend in the tunnel by selectively manipulating said closures for the openings 17 or chutes 17a.

The heretofore referred to jacks E embody pushing-shoes within my invention whereby said pushing-shoes of the jacks always remain in full or square contact with the adjacent tunnel ring instead of being tilted out of square contact when the shield swerves. Two forms of these pushing-shoes are shown in Figs. 4 and 8 respectively, the former embodying substantially a ball and socket joint.

The jacks E are supported all around the inside of the shield in the channels of the ring-like girders 25 and 25a of the shield. Each extends through a hole in the web of the girder 25a and pushes against the web of the girder 25.

Describing first the ball and socket form shown in Figs. 1, 4, 5 and 6, each of these pushing-shoes comprises an arcuate plate 3 shown in plan in Fig. 6 adapted to bear against the end of the last tunnel-lining ring 11. Each of these plates has a boss 3a, shaped in the form of the exterior surface of a portion of a sphere and acting as the ball part of the joint. The socket part consists of a concave boss 2a shaped in the form of the interior surface of a portion of a sphere, disposed upon another plate 2 and forming a seat to receive and coact with the partially spherical boss 3a. These plates 2 and 3 with their coacting ball and socket portions comprise what I have conveniently called the pushing-shoe and are yieldingly held together and, at the same time, attached to and supported by the base 8 of the related jack by bolts 4. These bolts project freely through suitably located holes in the plate 3 with their heads counter-sunk in the back of the plate and with their shanks passing freely through enlarged holes in the plate 2 and the base 8 of the jack. The free ends of these bolts beyond the base 8, are provided with spiral springs 5 held thereon by washers 6 and nuts 7, the latter engaging the screw-threaded free ends of the bolts.

In other words, the circular girders 25 and 25a of the shield, operatively support the jacks and these in turn support the ball and socket shoes with their arcuate plates 3 at the end of the last tunnel ring 11 or other form of tunnel-lining; and it will be understood that the arcuate plates 3 of all the jacks form an end-to-end series, so that the collective thrust of the jacks is distributed practically over the entire end of the tunnel ring including its outer peripheral portion. Moreover, these arcuate plates 3 of the shoes always remain squarely seated against the end-section of the tunnel-lining in spite of any swerving vertically or laterally of the shield as it is pushed forward. When this happens, the combined jack and shoe construction accommodates for the swerving by permitting the jacks to tilt out of line with the shoes but without taking the latter out of square, full-face contact with the end-section of the tunnel-lining.

The other form of less expensive pushing-shoe shown in Fig. 8, may be used for the sake of economy with jacks pushing against wooden lining or breasting and working against comparatively light loads. The pushing-shoe of said Fig. 8 is made of a heavy structural steel section such as an H-beam 20 with its plate stiffeners 21. In this form of the pushing-shoe, I omit the ball and socket joint, but use the previously described bolts 4, springs 5 and fastenings 6 and 7 as in Fig. 4 to connect the H-beam with the bases of the jacks. When the jack using the pushing-shoe of Fig. 8 is called upon to yield laterally, the base 8 of the jack can tilt relatively to the pushing-shoe due to the yielding of the springs 5, but the pushing-shoe itself will still bear squarely against the tunnel ring as in the other form of pushing-shoe construction.

These pushing-shoes of my present invention avoid the damage often done by the ordinary jacks to the tunnel-lining arising from the swerving of the shield which causes the ordinary jacks not provided with my pushing-shoes to tilt and thereby no longer bear squarely against the tunnel-lining end-section over an area equal to the entire base of the jacks. On the contrary, the reaction from the ordinary jacks is often concentrated under these circumstances on a small area of the tunnel-lining and is the common cause of cracked and broken sections of tunnel-lining so frequently met with and which must be removed and replaced, resulting in increased cost. All of this is avoided by equipping the jacks with my pushing-shoes.

When the material to be excavated is of the nature of pebbles and requires breasting and excavation by hand, I use jacks equipped with pushing-shoes of either kind located in the hollow platforms 24 of the shield so as to project forwardly from the interior of said platforms with their pushing-shoes bearing against a timber bulk-head 19, so as to operate it in the usual manner in excavating practice where timber bulk-heads or breasting are used.

Instead of employing the usual bulk-head ordinarily built of concrete and some times of steel to form the rear end of the compressed air chamber D, I provide an improved construction for this bulk-head of the metal or steel type, my object being to make this bulk-head safe from break-down and blow-outs when in use and at the same time make it easier to assemble and reassemble this bulk-head as called for by the progression of the tunnel.

My steel bulk-head construction B comprises a strong tubular shell or web 9 secured to and surrounded by a plurality of circular or ring-like

structural members 10 having annular outwardly directed flanges 10a. These flanges 10a project toward the tunnel-lining and are imbedded as shown in concrete which is suitably applied in any well known manner between the tunnel-lining and the outside of the shell 9 of the bulk-head so as to form a concrete joint extending all around the periphery of the bulk-head between it and the tunnel-lining for the entire length or depth of the bulk-head, which may have any desired length such as that shown which is equal to two or more widths of the tunnel-lining rings 11. Preferably, wherever the conditions permit, the outside diameter of the bulk-head shell 9, conforms closely to the interior of the tunnel-lining so that the outwardly directed flanges 10a project into the channels of the tunnel rings 11 between their flanges and are there imbedded in the concrete contained in said channels. This inter-leaving of the flanges 10a with the flanges of the tunnel-rings gives increased strength and resistance against blow-outs to the concrete union between the bulk-head and the tunnel-lining. In either event, my bulk-head construction has great strength and resistance against displacement applied over a large area of the tunnel-lining making it essentially adequate to cope with the great pressures amounting at times to 45 pounds to the square inch upon the bulk-head.

The header 12 of my bulk-head is also preferably made of steel construction properly supported by the aforesaid members 9 and 10 and is equipped with the air locks 13. The structural steel framing for supporting this bulk-head 12 from the parts 9 and 10 are omitted from the drawing for the sake of simplicity, since these are engineering details which will vary with the particular size and construction of the given bulk-head.

In any event, the structural members 9 and 10, the header 12, and the inter-connecting parts of the bulk-head B in practice will be made up in sections adapted to be readily assembled and whenever necessary knocked down and reassembled to enable the position of this bulk-head to be changed and advanced with the progress of the shield.

The tunnel-lining C in the particular form illustrated consists of a series of ring-shaped girders 11, circular in this particular instance to correspond to the shell of the excavating device which in this case happens to be cylindrical to excavate a cylindrical tunnel. These ring-like girders are secured together side by side and each consists of an annularly flanged plate with its flanges directed radially inwardly. The channel space in each girder is adapted to be filled with concrete.

In the event that other forms of tunnel-lining are used such as a lining made up of concrete blocks or a monolithic lining be used, I still anchor my steel bulk-head B to the tunnel-lining by the concrete joint as heretofore described by keying said concrete joint on the outside with suitably provided recesses in the concrete blocks or monolithic tunnel-lining; and by keying it on the inside with the flanges 10a of my bulk-head construction B.

I will now amplify the foregoing description with additional comments and details as follows:—In previous excavating practice, the bevelled or sloping face of the cutting edge was located toward the longitudinal axis or interior of the shell, whereas, I have inverted the construction so that its bevelled or sloping face is directed towards the outside of the shell. By my inverted cutting edges, I, I cut and take into the shield, as it is forced forward by the jacks, a smaller amount of material or ground than the displacement of the shield requires. This difference in quantity of intake of material, although relatively small compared to the displacement of the shield, is nevertheless important in the operation of my shield or excavating device with its inverted cutting edge.

The aforesaid material forced radially outwardly by the inverted cutting edge is compressed against the ground or material immediately about it, which latter is also compressed, whereby the moisture is forced from it farther into the surrounding ground as the material is compressed to the line of the outside of the shell or skin 14 of the shield. This compression is maintained as long as the advancing shell is in contact with it, but is released as soon as the tail of the shell passes by, whereupon the compressed material expands radially inwardly both because of its release from compression and because it can now reabsorb its quota of moisture from the surrounding ground, the result being that it automatically fills up the void left at the tail of the shell and is forced into supporting contact all around with the peripheral surface of the adjacent portion of the tunnel-lining.

Previous methods which do not employ my inverted cutting device required the space left by the thickness of the shell to be filled by a special operation consisting in forcing grout, sand or gravel into this space by means of compressed air applied through holes in the tunnel-lining.

Thus, my inverted cutting edge when used in soft ground eliminates these previous methods and their cost which is considerable and not always effective in filling the voids about the tunnel-lining which, if allowed to remain, result in settlement of the ground at the surface and of any constructions in or supported by said ground.

The use of my inverted cutting edge is also applicable advantageously in connection with caissons for sinking shafts in soft ground.

By soft ground I mean to include ground that contains or is saturated with a liquid, or ground that can be moved or compressed by external force applied, for example, by jacks; or ground that is plastic, such as clay, silt, sand, or mixed sand and pebbles, or loam, with a greater or less degree of moisture content.

My inverted cutting edge is made of such a slope, or may be stepped similarly to a flight of flat stairs, to force outwardly and prevent entrance into the mouth of the shell of the shield, a quantity of material sufficient to fill the void left behind the shield at the outside of the tunnel-lining. I do not limit myself to any particular slope or projection of the cutting edge or to any particular material of which it is made, as these matters are capable of wide variation.

Referring to the pipes or chutes 17a, these direct the soft ground delivered sausage-like thereby from the front of the header in any desired or suitable direction to the cars, conveyors or buckets in the shield behind the header, thereby saving the labor cost of handling this material at this point. This saves the great cost of excavating by previous methods of digging, breasting, cutting and loading cars with the excavated material all by hand labor.

I do not limit myself to the number, size or position of the chutes 17a or openings 17 through the header or of the irrigating pipes 18.

In practice, I provide suitable means for con-

trolling each opening through the header 23 or the delivery end of each chute 17ª; and this means may consist of any suitable form of gate or valve, for instance, such as that indicated in Fig. 10. By selectively operating these gates for the different openings 17, it becomes possible to make the shield offer greater resistance to advance at one part thereof than at other parts and thereby makes it possible to direct the progress of the shield as to line and grade.

In connection with my improved bulk-head B, attempt has been made heretofore to make a steel bulk-head wherein, however, the steel supports of the face or header of the bulk-head were connected directly at isolated points to the tunnel-lining and had the effect of concentrating the very heavy air pressures on the bulk-head say up to 45 lbs. per square inch, upon isolated parts of the tunnel-lining, which not infrequently caused the tunnel-lining to break-down and the bulk-head to give way with resulting loss in life and property.

It is the structural steel beam and channel supports of the header of the bulk-head which developed these heavy concentrated loads at their ends and it is where these ends were connected directly to the tunnel-lining that the failures occur. Also it is here that I depart from the previous practice by connecting the structural members carrying the heavy concentrated reactions of and from the header not directly to the tunnel-lining but to the tubular or web member 9 and the surrounding circular flanges 10 and 10ª of the bulk-head and thence to the tunnel-lining through the heretofore described intermediate concrete-joint connection.

In order to form this concrete-joint, I assemble my steel bulk-head in the tunnel out of its component parts and then build forms around the ends of the space between the bulkhead and the tunnel-lining. I then force by compressed air concrete or grout into said enclosed space through holes in the tubular member 9 of the bulk-head and through holes in the forms enclosing the space. When the space is entirely filled and the concrete or grout has set, the annular flanges of the chord angles and of the bearing angles are embedded in the concrete that is now between the outer peripheral surface of the bulk-head and the inside of the tunnel-lining; and I thereby obtain support along the entire perimeter of each angle ring and the flanges of the beams or channels when they are used instead of the structural members 9 and 10 in connection with the bulk-head construction. The concrete or grout in turn transmits the load to the tunnel-lining over every inch of its circumference and for the length of the bulk-head used. Therefore, with a proper design of the bulk-head B for stiffness, the large concentration of loads on said bulk-head is distributed over an exceedingly large area of the tunnel-lining equalling the distribution attained by the solid, deep, concrete bulk-heads now used but which are so inconvenient and expensive to move and rebuild and besides have other serious disadvantages.

Of course, I do not limit my improved bulk-head B to its application to cylindrical tunnels as illustrated in the drawing as the tunnel and bulk-head may have any particular cross-sectional shape to correspond with each other, nor to the thickness of the concrete joint between the bulk-head and the tunnel-lining although this latter should be as small as conveniently possible. My improvement makes for safety in using steel bulk-heads for tunnels and has the advantage that the bulk-heads can be dismantled and used repeatedly.

As a further improvement, I coat or paint the surfaces of the flanges 10ª and other parts of the bulk-head that contact with the concrete or grout with paraffin or other equivalent substance which will prevent the concrete from adhering thereto, said coating thus permitting easy withdrawal of the spliced sections of the bulk-head when dismantled.

The following refers to the chutes 15:—When excavating a large diametered tunnel with a large shield, such shield may have several working platforms, three being shown in the drawing. The material excavated at the upper levels must be dropped to the lower level where cars or conveyors are usually placed. The great height through which the material is dropped in large shields through an ordinary chute causes the material to gather large momentum which is destructive to the conveyors and cars when the material strikes them, or if this is avoided by using a small slope for the chute, the material does not slide and the chutes become choked. Also, the small sloped chute must be very long and is always in the way of other work. The novel chute 15 of my invention overcomes these difficulties and saves time, space and expense, as well as damage to the conveyors. I am able to reduce the number of chutes required to at least one-third, none of which are required to be removed and replaced when erecting the rings of the lining. My chute has an opening at each platform to receive the material thrown or fed into the chute, thence the chute slopes downwardly at a sharp angle sufficient to cause the material to move quickly to a point midway between this and the next lower platform where the slope of the chute is reversed which slows up the fast movement of the material by stopping it and immediately starting it again down an opposite incline to the next platform. The same checking of the momentum is repeated until finally the material is delivered into the car or onto the conveyor with only substantially the same momentum that it had when it was first dropped into the chute at the top platform. A gate is provided at the delivery end of the chute to shut off the flow when a car is full; or the last incline of the chute may be in one or two parts and the end part may be hinged and raised up into a vertical position to shut-off the flow of the material; and the whole chute up to the top platform may thereby be used as a storage for the excavated material while a ring of the tunnel-lining is being erected, etc.

The chute of my invention may also be used for dropping mixed concrete or other mixtures of granular or large particles with a liquid from a height such as down the shaft to the tunnel to prevent and control the segregation of the ingredients.

Slightly raised strips may be placed flat on the inside of the bottom plates of the chute and at angles with the sides of the chute, but not extending entirely across to the sides. These strips also cooperate to retard the drop of the material. These strips retard the momentum of the solid particles of the mixture but because they are inclined and do not extend fully to the sides of the chute, the mortar of the concrete or the more finely divided portion of the mixture can flow along the sides of these strips and around their ends. The slope of the chute and the number and

height of the strips and the angle which these make with the side of the chute are capable of wide and varied application, and it is these variations that control the flow of the ingredients to suit different mixtures and different conditions of placing and moving the mixtures, the slope of the different sections of the chute and the position of the strips may be arranged in such a manner as to be adjustable to the conditions encountered.

The metal beams, braces and other structural parts for supporting and bracing the bulk-head or header 23 with respect to the rest of the shield have been omitted from the drawing for the sake of simplicity and because these are merely engineering details which will vary with the size and shape of the shield.

It will be understood that this invention is not limited to the preferential embodiment herein illustrated and described and that modifications and changes may be made therein in addition to those already indicated without departing from the scope and spirit of the claims.

What I claim is:—

1. In combination, a lining and a bulk-head construction for an excavated passage-way, said lining comprising ring-like girders substantially fitting the cross-sectional shape of the passage, said girders comprising flanged webs located with their flanges projecting inwardly, the channels formed between said webs and their flanges being adapted to be filled with concrete; and said bulk-head construction comprising a header surrounded by a tubular shell, said shell having external annular ribs projecting towards the channels of the lining and seated in concrete anchored in said channels.

2. In combination, a lining and a bulk-head construction for an excavating passage-way, said lining comprising ring-like girders substantially fitting the cross-sectional shape of the passage, said girders comprising flanged webs located with their flanges projecting inwardly, the channels formed between said webs and their flanges being adapted to be filled with concrete; and said bulk-head construction comprising a header surrounded by a tubular shell, said shell having external annular ribs projecting towards the channels of the lining and seated in the concrete anchored in said channels, said bulk-head construction consisting of parts adapted to be knocked down into portably separate parts.

3. In combination, a lining and a metal bulk-head construction for an excavated passage-way, said lining comprising ring-like metal channels adapted to be filled with concrete; and said metal bulk-head construction filling the cross-section of said lining and having a plurality of external annular ribs projecting towards the channels of the lining and seated in concrete anchored in said channels.

4. In an excavating device, in combination, a substantially tubular shield, means for forcing the shield through the ground, and a cutting edge at the mouth of said shield whose outer face slopes forwardly and inwardly, the tail end of said shield having an inner diameter which is not materially smaller than the corresponding inner diameter of the aforesaid cutting edge.

5. In an excavating device, in combination, a tubular shell, means for forcing the shell endwise, and a cutting edge at the mouth of the shell whose face slopes forwardly and inwardly from the outside thereof, the tail end of the shell having an inner diameter which is not materially smaller than the corresponding inner diameter of the aforesaid cutting edge.

6. In an excavating device, in combination, an open-ended tubular shell, and means for forcing the shell endwise, the forward edge of the shell sloping from the outer peripheral surface thereof forwardly and inwardly to form a cutting edge, the opening at the tail end of the shell having substantially the same diameter as that at the cutting edge and being unobstructed to permit the erection therein of a tunnel lining with its outer peripheral surface closely adjacent the inner peripheral surface of the tubular shell.

7. In an excavating device, in combination, a circumferentially continuous tubular shell, means for advancing the shell endwise, and wedging means on the forward end of the shell adapted to wedge and compress the material to be excavated radially outwardly during the advance of the shell, the body of the shell being dimensioned and arranged to maintain said compression.

8. In an excavating device, in combination, a tubular shell, a header supported and carried by said shell, means for forcing the shell endwise through the ground, wedging means on the forward end of the shell adapted to wedge and compress the material to be excavated radially outwardly as the shell advances, the body of the shell being dimensioned and arranged to maintain said compression and to release same after the tail end of the shell has passed a predetermined point, the tail end of the shell being hollow and having an inner diameter which is not materially smaller than the corresponding inner diameter of the aforesaid wedging means.

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