

June 30, 1970

M. MONTACIE

3,517,966

GUIDING SYSTEM FOR A BORING MACHINE

Filed June 6, 1968

3 Sheets-Sheet 1

FIG. 1

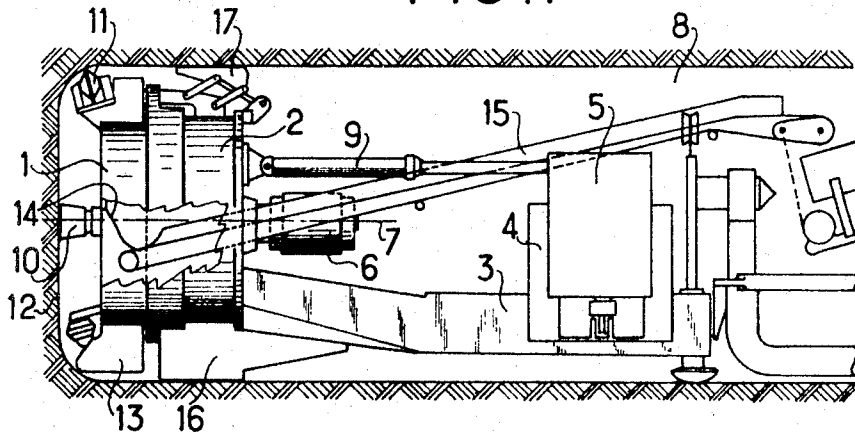


FIG. 2

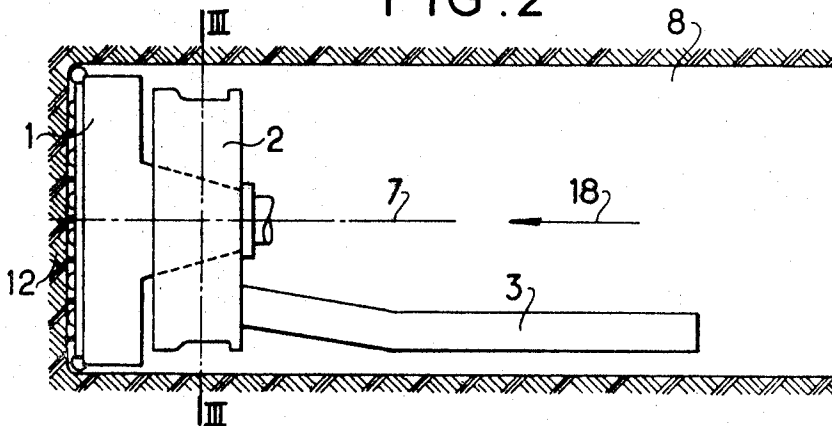
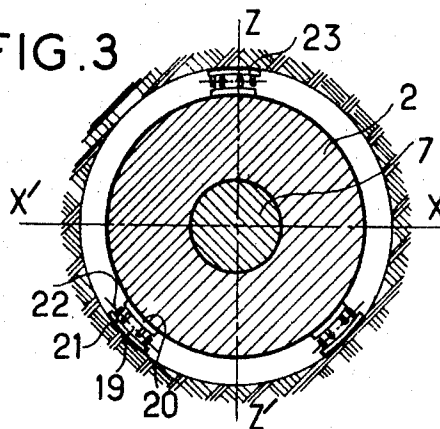


FIG. 3



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FIG. 4

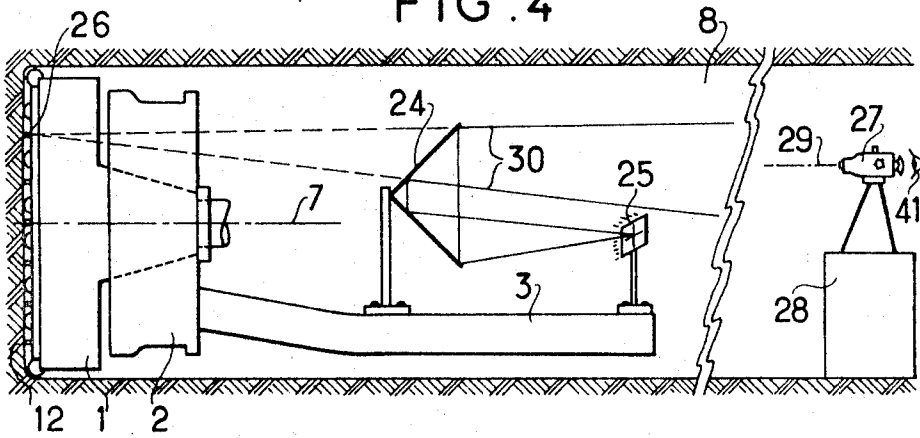


FIG. 5

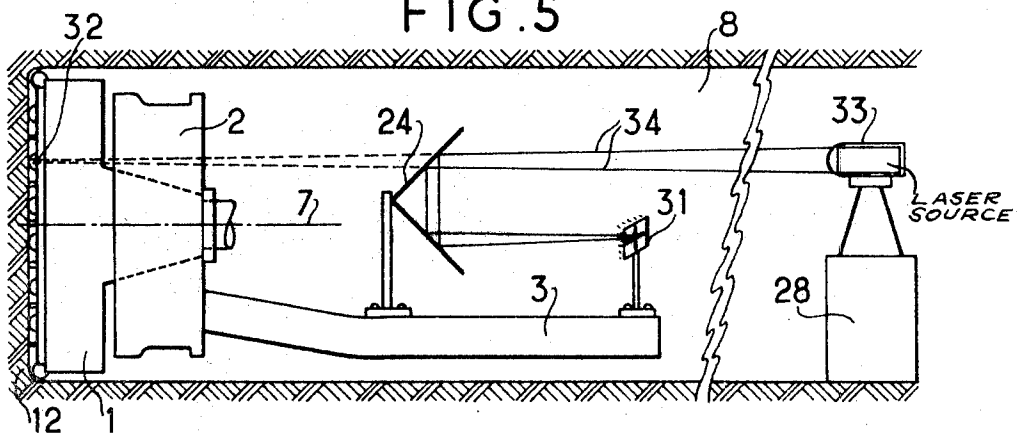
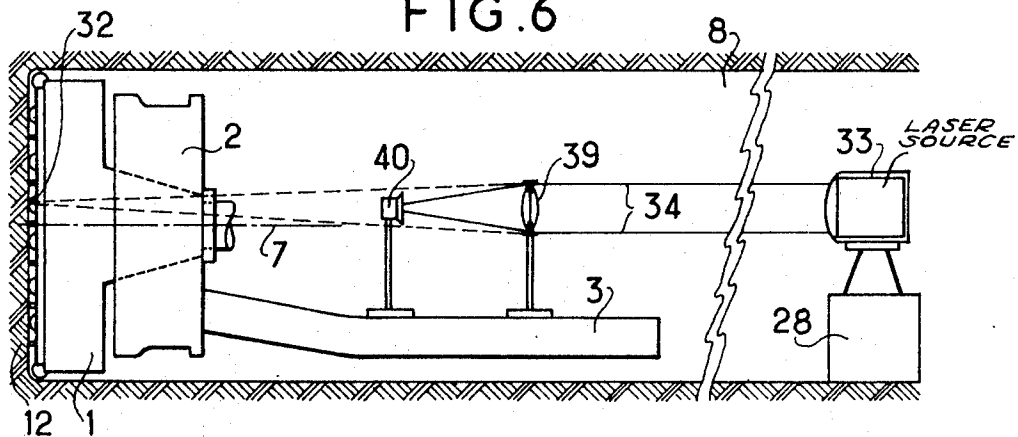


FIG. 6



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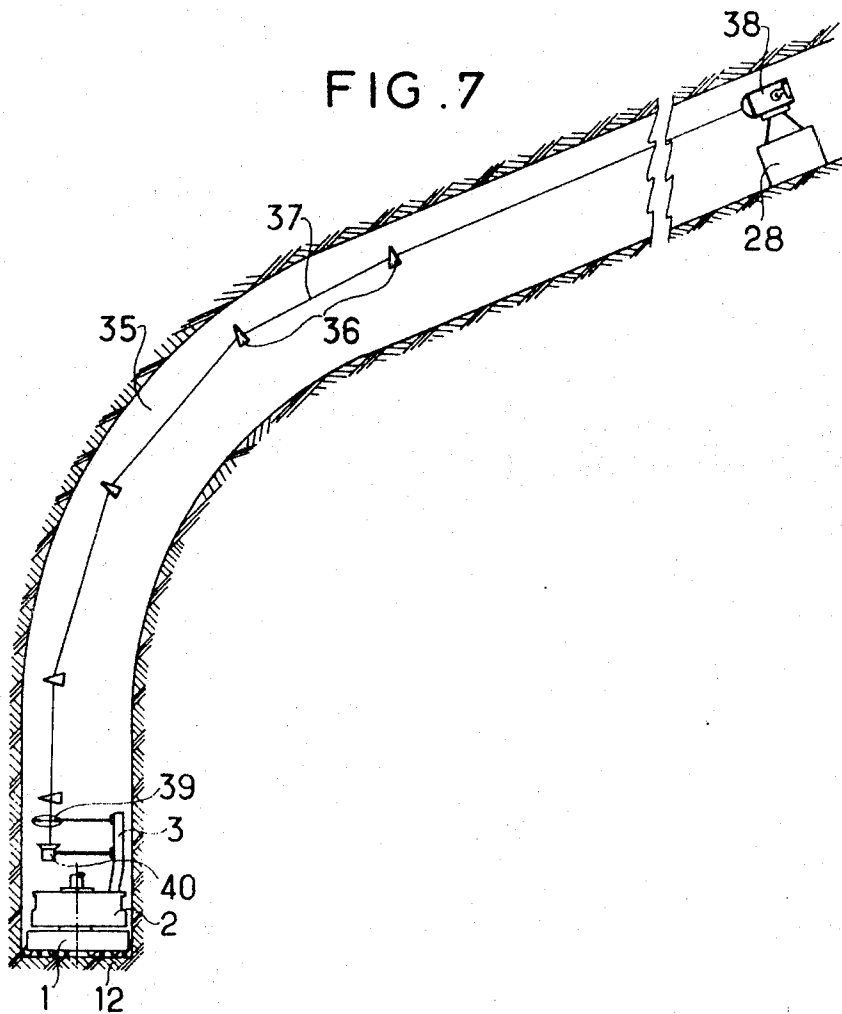
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GUIDING SYSTEM FOR A BORING MACHINE
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109,354

Int. Cl. E01g 3/04

U.S. Cl. 299—1

7 Claims

ABSTRACT OF THE DISCLOSURE

A guiding system for a continuous tunnel-boring machine, comprising a rotatable boring head supported by sliding shoes fixed to the head carrier forming the front part of the frame and on which is exerted the advancing thrust from anchoring shoes on the wall, disposed at the two ends of a transverse element carrying a steering cabin connected resiliently to a sliding caisson, on which are displaced the sliding faces parallel to the axis of rotation of the head and presented by bearers forming the rear part of the said frame, characterized in that at least two sliding shoes are disposed on either side of the vertical plane of symmetry of the machine and insuring its stable steering with the help of an optical system associated with a sighting device, both of which being fixed toward the rear end of the frame and disposed in such a manner that the cutting front is approximately the optical image of the said sighting device in the said optical system and has an optical connection with an optical apparatus placed toward the entrance to the tunnel and participating in the control.

The present invention relates to a continuous boring machine operating by the combined action of the rotation of the boring head and of a thrust exerted on the latter along its axis from the lateral walls of the already excavated tunnel; it is more particularly concerned with a machine in which the stability of the head and the permanent control of the position of the latter increase the precision of the boring operation.

It is known that the reactions of the rock to the cutting action of the multiple tools carried by the boring head of the machine are of greater violence as the said rock is harder and are all the more difficult to contain as the structure of the said rock is less homogenous. These difficulties are partly overcome by the known machines, of which it is possible to modify the direction during the boring operation. These machines have a frame structure in two parts: a main part elongated axially of the tunnel and capable of sliding with its rear part in a transverse element carrying at its two ends the anchoring shoes serving as fixed bearing points on the wall and from which are exerted firstly the thrust on the boring head and secondly the control of the change in direction of the axis of rotation of this latter, both operations being effected by hydraulic means.

Nevertheless, the existing machines still raise several problems of which the two main ones are firstly that of the lack of stability of the front portion of the main part forming the base carrying the boring head and secondly that of the lack of visibility of the attacking front of the tools when concealed by the head which carries them.

The object of the present invention is to provide a solution to each of these problems.

In the known machines, there are actually three sliding shoes which are mounted radially on the head-carrying base and which are hydraulically controlled: one is disposed beneath the machine and the other two at the ends of a horizontal diameter. The underneath shoe is rigid and supports the major part situated at the front of the

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weight of the machine and slides during the advance of the said machine during the boring operation; however, this sliding movement is frequently impeded by the falls of waste rock which particularly strike against it during operation. The latter then compresses them before their subsequent removal by collecting buckets situated at the periphery of the boring head. As a result, the guiding of the machine is found to be interfered with.

The stability of the machine according to the invention is found to be decidedly improved by the replacement of these three sliding shoes by only two shoes which are disposed symmetrically on either side of the vertical plane of symmetry, which shoes are sufficiently spaced to avoid them having any contact with the boring debris and of which the articulated structure participates in the stability of the machine. In the case of vibrations, the stability is improved by providing a third shoe exerting an appropriate thrust by means of a jack, on the top of the gallery and situated in the same cross-sectional plane of the tunnel as the other two.

In addition, with the known machines, it is not possible to excavate a gallery with a sufficient precision, because the usual topographical means only make it possible to know the corrections to be made a long time after the change in orientation which make them necessary, the attacking plane of the tools not being visible to the operator.

The control arrangement according to the invention, based simultaneously on the rigidity of the machine frame and on the properties of optical systems, makes it possible to know at any instant the position of a point of the boring head situated in the cutting plane and as a consequence to take instantaneously the appropriate measures for bringing this point back to the reference line of the datum points provided for the tunnel along the topographically established path.

For this purpose, a sight facing the cutting front is arranged on the main part of the frame, towards the end opposite to the boring head, while an optical system fixed to the same part and ending in a reflecting face is interposed between the sight and cutting front, said reflecting face providing a virtual image of the sight on the cutting front and returning the light towards the tunnel entry, that is to say, towards a control apparatus.

In this manner, firstly the optical arrangement installed on the frame of the boring machine permanently indicates, by means of the virtual image established on the cutting front, the absolute position of a single point of the boring head in contact with the said cutting front, and secondly, by means of the control apparatus, the position of the said point in relation to the optical axis of the latter is established, and it is thus possible to regulate the advance of the machine so as constantly to maintain this position.

A continuously operating tunnel-boring machine according to the invention, comprising a rotary boring head, the weight of which is supported by sliding shoes fixed to the head-support forming the front part of the frame and on which is exerted the advancing thrust from anchoring shoes on the wall disposed at the two ends of a transverse element carrying a steering cabin resiliently connected to a caisson with slide members, on which the sliding faces are displaced parallel to the axis of rotation of the head and presented by beams or bearers forming the rear part of the said frame, is characterized in that at least two sliding shoes are disposed on either side of the vertical plane of symmetry of the machine and in that an optical system, associated with a sight, is fixed toward the rear of the frame and disposed in such a way that the cutting front is conjugate with the said sight in the said optical system and has optical

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connection with an apparatus positioned towards the entry to the tunnel and participating in the control.

The objects and advantages of the present invention will be apparent from the following description, taken in conjunction with the drawings, wherein:

FIG. 1 is an elevational view of a known tunnel-boring machine.

FIG. 2 is an outline of a boring machine in action in a straight cylindrical tunnel.

FIG. 3 is a section on the line III—III of FIG. 2, showing the sliding shoes according to the invention.

FIG. 4 is a diagrammatic view of the arrangement according to the invention for controlling by a tachymeter the position of the boring head mounted on the machine.

FIG. 5 is a diagrammatic view of the boring machine provided with a control arrangement having a projector providing a beam of parallel light rays.

FIG. 6 is a diagrammatic view of a machine equipped with a modification of the previous control arrangement having a lens and mirror fixed on the frame.

FIG. 7 is a diagrammatic view of a non-linear tunnel equipped with means serving for the optical deviation of the controlling light beam and disposed at intervals along its wall.

The boring machine comprises a rotary head 1 (FIG. 1) turning in the head carrier 2 forming the front end of the machine frame, while the rear end 3 slides in a caisson 4 resiliently connected to the steering box 5 carried by a transverse portion terminated at its two ends by anchoring shoes on the wall of the tunnel and not shown.

The rotary head 1 is driven by the motor 6 and its axis of rotation 7 is coincident with that of the straight cylindrical gallery 8 already excavated. Power jacks 9 bearing on the side wall of the tunnel transmit the thrust through the head carrier 2 to the tools of the head 1, which are respectively a triple cone 10 at the centre and milling rollers such as 11, thus bearing on the cutting front 12. The tools cut circular recesses into the rock, causing the latter to be progressively broken away, the waste dropping to the floor of the cutting front 12 before being collected by the peripheral buckets 13, which then discharge the said waste at the top of their travel into a channel 14, by which it is conveyed on to the conveyor belt 15 for the discharge thereof. A rigid sliding shoe 16 fixed to the head or shield carrier 2 supports the major part of the weight of the machine situated in front of the latter. The said shoe is thrust forwards by the jacks 9 during the boring operation and frequently upsets the stability of the head or shield 1 by the pressure which it exerts on the rock waste before it is discharged; furthermore, despite the coupled action of sliding jacks disposed at the two horizontal ends of the same cross-section and also that of the deformable sliding jack 17 bearing against the upper part of the gallery, the stability of the boring head or shield is not assured.

In addition to the resulting defects in stability, the shoe 16, by the compression of the waste material which it causes, leads considerable power demands on the mains in order to permit the driving motor to overcome such a suddenly encountered resistance.

Moving forwardly in the direction of the arrow 18 (FIG. 2), the boring machine according to the invention, of which the main parts are indicated diagrammatically, avoids this defect, the space situated under the head support 2 being free.

The sliding shoe 16 (FIG. 1) of the conventional machines has in fact been eliminated.

Two identical sliding shoes 19 (FIG. 3), responding particularly to one of the objectives of the invention, are disposed on either side of the vertical plane of symmetry of the machine, forming the same angle with the latter, which can be between 40 and 60°. The bottom of the machine thus being freed, the jerking movements

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due to the hazards of compression of the rock waste are then avoided. A shoe 19 comprises two parts, a part 20 bolted on the head carrier 2 and another part 21 matching the form of the gallery on which it slides, and these two parts are connected to one another by a shaft 22, situated in a plane perpendicular to the axis 7 of the gallery and perpendicular to the plane of symmetry passing through the axis 7 of the said shoe. The bearing surfaces of the shoes 19 are adapted to the weight of the machine and to the mechanical resistance of the earth to be traversed, so that the boring head is very stable, but during the boring operation, vibrations can be set up, and in order to damp these vibrations, there is provided an articulated jack 23 placed in the same section as the shoes 19 and exerting a thrust on the top of the gallery by means of a hydraulic jack, the pressure of which is maintained by an oleopneumatic accumulator connected in parallel therewith.

In order to cut a gallery or tunnel with a strict precision of the implantation, it is necessary to be able at any moment to correct the position of the boring head exactly to the height of the attacking plane of the tools on the cutting front. For this purpose, action is taken by the direction jacks, some being horizontal and the others being vertical, on the rear part 3 of the machine frame towards the end furthest from the boring head.

The boring head forms an opaque screen and prevents the checking of its position at the level of the cutting front by the conventional topographical sighting means. In actual fact, it is only possible to check the position as far as the cross-sectional plane of the sliding shoes: this affects only that portion of the gallery already produced for a certain time and situated at a distance from the cutting front which is equal to the axial thickness of the head and of the part of the head carrier situated in front of the sliding shoes.

This method of operating with the known machines results in a considerable inaccuracy in the implantation of the gallery and the said inaccuracy will be greater as the ground is harder and consequently as the machine requires more time to reassume its exact position after a deviation.

The arrangement forming the subject of the invention obviates this disadvantage by forming the virtual image 26 of a sighting device 25 on the cutting front 12 by means of an optical system 24 (FIG. 4). As the optical system 24 ends in reflecting surfaces facing towards the entrance to the gallery, this permits the visual observation of the image 26 by means of the tachymeter 27 mounted on a base 28.

The sighting device 25 being a luminous cross and the optical system 24 being a pair of plane mirrors disposed at an inclination of 45° on either side of the axis 7 of the gallery, the image 26 is a virtual luminous cross of the same dimensions as the sighting device and its centre has coordinates a and b in the cross-sectional plane of the cutting front: a is the abscissa and b is the ordinate measured along axes parallel to the respective horizontal axis xx' and vertical axis zz' of FIG. 3, the origin being positioned on the axis 7 of the gallery. On starting to cut the gallery, the observer, having placed his eye at 41 behind the tachymeter 27, ensures the focusing of the luminous spot 26 and adjusts the positioning so as to make the centre of the cross coincide with the intersection of the reticle in the eyepiece of the tachymeter.

Under these conditions, the centre of the image 26 is situated on the optical axis 29 of the tachymeter.

The checking of the cutting of the straight cylindrical tunnel consists in ensuring that, during operation, the centre of the image 26 remains on the axis 29 and, as soon as it deviates therefrom, in giving the driver of the machine instructions for correcting this deviation. The axis 7 of the tunnel as thus cut is then parallel to the optical axis 29.

A single mirror disposed in a cross-sectional plane of

the gallery at an equal distance from the sighting device 25 and the cutting plane 12 would have been sufficient to give the virtual image necessary for checking purposes; however, the assembly of two mirrors has been used in order to raise the image 26 towards the upper part of the tunnel, so that the reflected rays 30 are directed towards the tachymeter without encountering any obstacles during their passage.

The optical system 24 can also be more complex: it is in fact known that an optical system ending in a reflecting surface is equivalent to a spherical mirror, which can always be arranged so as to give a virtual image of the sighting device 25 on the cutting plane; however, this image will then no longer be of dimensions equal to those of the sighting device.

This method of control presumes the presence of two men, one on the machine for driving it and the other towards the entry to the tunnel, making the observations with the topographic apparatus. These two operators have to be connected by telephone in order to communicate with one another; otherwise, it would be necessary to have a closed circuit television system so that the driver of the machine would be able to see, on a television receiver situated in front of him, the image of the observation plane of the eyepiece, retransmitted by a corresponding television transmitter replacing the observer.

In order to avoid this, the light-emitting sighting device is replaced by a ground glass 31 (FIG. 5), on which are drawn two opaque lines, the point of intersection of which gives an image point of coordinates *a* and *b* by means of the two plane mirrors 24, forming part of the image 33 of the ground glass on the cutting front 12. On the other hand, in place of the tachymeter, a projector 33 is situated at the entrance to the gallery, on the base 28, said projector producing a beam 34 of light rays which are substantially parallel to one another and parallel to the axis of the tunnel, striking the upper plane mirror of the group 24 and, after double reflection, the rays of the beam 34 converge on the ground glass 31, on which they form the image projected by the said projector and which, in the absence of the plane mirrors 24, would be formed at 32 on the cutting front 12.

The checking of the position of the boring head thus consists, as regards the driver of the machine, in observing the ground glass situated in front of him and in controlling the correction to be made as soon as the centre of the circle of impact of the light beam is displaced from the point of intersection of the lines drawn on the ground glass.

If a projector 33 with a conventional light source of limited scope is used, it will be necessary frequently to change its station, and this on each occasion takes time, if it is desired to eliminate a large part of the inaccuracy which is caused.

If a laser emitter is used as light source of the projector, there is then obtained a fine beam of parallel rays and of very great range.

As the energy conveyed is very great, the possibility is then provided of automating the boring operation in place of the ground glass, there is then provided a group of photoelectric cells which have their maximum of sensitivity for the wavelength of the monochromatic light of the laser beam and, by means of the necessary relays, the direction jacks are directly controlled.

A modification of this arrangement (FIG. 6) comprises a projector 33 mounted on a base 28 towards the entrance of the tunnel regulated in such a way that the beam 34 gives a projected image at 32 on the cutting front 12 in the absence of a convergent lens 39; when this latter is arranged in the axis of the beam, it then forms a virtual image 32 synchronized therewith on the photoelectric receiver 40 forming the first link of an automating chain of the boring machine.

It is obvious that the convergent lens 39 can be re-

placed by any appropriate objective and the assembly comprising the optical system and the photoelectric receiver is advantageously mounted on a rigid block fixed solidly on the frame 3. With the initial adjustment, the axis of the light beam of the projector coincides with the axis 7 of rotation of the boring head 1 and the subsequent corrections maintain the said two axes being kept in coincidence.

It is pointed out that the invention is not limited to the particular embodiments which have just been described but that it comprises all the possible variations in conformity with the general definition which has been given in respect thereof. Thus, any other machine tool, shielding the cutting front, can be equipped with a guiding arrangement, particularly comprising a projector and a virtual image on the said cutting front.

This control system not only permits rectilinear galleries being cut, such as those indicated on the preceding figures, but also the cutting of curved galleries 35 (FIG. 7). Actually, in order to maintain the control of the position of the boring head while the machine is turning, either in a horizontal plane or in a vertical plane, it is sufficient to arrange along the path of the observation or projection light beam, a device which deviates the latter. The interval separating each device and also the value of each deviation are determined as a function of the curvature of the turn to be made.

Small-angle prisms 36 are disposed along the axis 37 of the control beam emitted or received by the control apparatus 38, a projector or tachymeter, respectively, which is located on the base 28.

Fixed on the frame 3, the optical system 39 forms an image on the receiver 40. The optical system 39 as illustrated is a lens receiving the light beam in order to cause it to converge in front on the receiver 40; it is quite obvious that it is also possible to use an optical system with a reflecting surface, and in this case the receiver is disposed behind on the return path of the reflected beam.

It is equally possible to use appropriate spectrometric screens as beam deviators.

I claim:

1. A guiding system for a mobile machine such as a tunnel boring machine having machine support means adapted to be rigidly secured within a tunnel, frame means movably mounted on said support means, boring means having a cutting plane transverse to the axle of said tunnel mounted on said frame means and means for moving said frame means relative to said support means; comprising a first device fixedly mounted in said tunnel for defining the path of travel of said machine, a second device mounted on said movable frame means and an optical device mounted on said movable frame means for forming a virtual image of one of said first and second devices at said cutting plane of said boring means when viewed from the location of the other of said first and second devices.

2. A guiding system as set forth in claim 1 wherein said optical device is comprised of a lens intermediate said first and second devices.

3. A guiding system as set forth in claim 1 wherein said optical device is comprised of two planar mirrors inclined with respect to each other and disposed between said second device and said cutting plane.

4. A guiding system as set forth in claim 3 wherein said first device is a tachymeter having an optical axis defining the desired path of travel of said machine and said second device is an illuminated screen.

5. A guiding system as set forth in claim 3 wherein said first device is a light beam source for producing a light beam having an axis of symmetry defining the desired path of travel of said machine and said second device is a target screen having suitable coordinate markings.

6. A guiding system as set forth in claim 1 wherein one of said first and second devices is a light beam source

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and the other of said first and second devices is a photoelectric receiver.

7. A guiding system as set forth in claim 6 wherein said first device is a light beam source for producing a light beam having an axis of symmetry defining the desired path of travel of said machine said second device is a photoelectric receiver and said optical device is a converging lens disposed intermediate said first and second devices in alignment therewith.

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U.S. Cl. X.R.

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