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CORE AND BLAST TUNNELING METHOD

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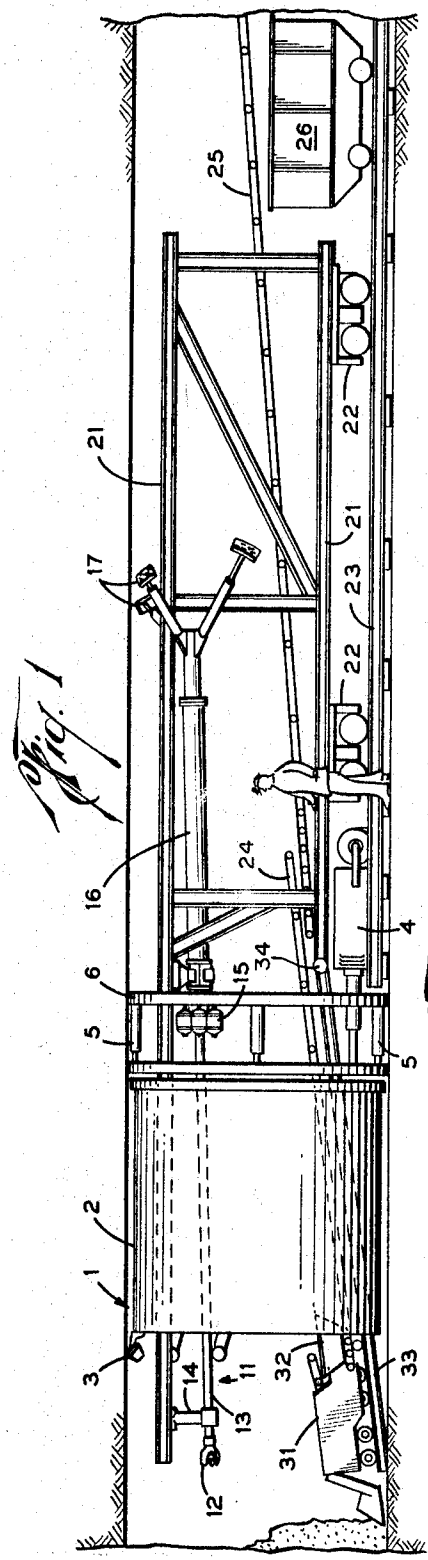


Fig. 1

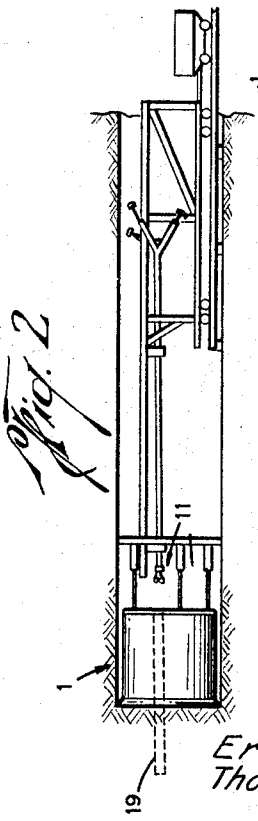


Fig. 2

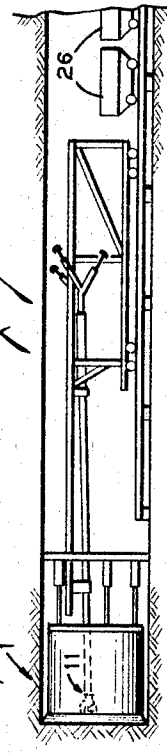


Fig. 3

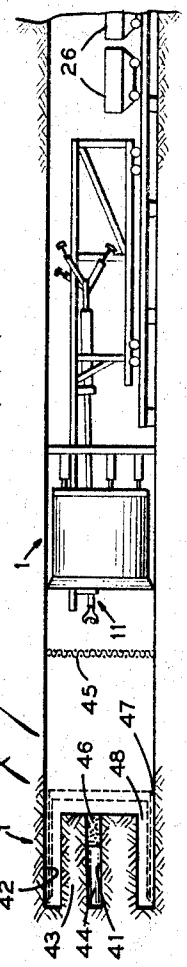


Fig. 4

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CORE AND BLAST TUNNELING METHOD

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The present invention relates to tunneling through rock formations, and in particular deals with novel processes for forming tunnels and mine entries with equipment well known in the art. The word "tunnels" as used herein is intended to cover passageways formed at various angles with respect to the earth's surface, and is thus broad enough to include even vertical shafts.

In the tunneling art, there appear to be three known approaches to the goal of forming a relatively large hole through the earth: (1) blasting, or detonating explosives placed in small holes drilled into the tunnel face in the general direction in which the tunnel is to be advanced; (2) drilling or cutting the full face of the tunnel with one form or another of machinery which cuts, chips, grinds or otherwise comminutes the rock at the tunnel face; and (3) coring, or cutting a kerf through the rock at approximately the maximum dimension of the tunnel and then breaking the core into one or more massive pieces. The present invention utilizes a combination of the coring and blasting techniques.

The chief disadvantage of the pure blasting method lies in the inherent difficulty of maintaining an accurately defined wall. Either the blasted tunnel is made undersize and cutting techniques are utilized to ream the tunnel to gage, or the blasting results in "overbreak", i.e., an oversize hole which must be filled in to obtain a smooth hole. The overbreak problem becomes particularly costly when the tunnel is to be lined or when the tunnel is to be roofed to prevent cave-ins. However, overbreak is undesirable even in tough, impervious, non-sloughing formations which require no cementing, e.g., granite.

In addition, pure blasting is limited by the depth of effective blasting, e.g., about 8 feet per "cut" (blast) in forming a tunnel of 12-foot diameter in geologically competent rock and 25 feet per cut in a 40-foot tunnel of the same type rock.

The pure coring technique was developed in part because the tunnel thereby formed is of accurate and uniform cross-section. Its chief disadvantage lies in the difficulty of disposing of the core pieces which are periodically broken off. As such pieces have nearly as large a section as the tunnel itself, it is difficult to remove them to the rear because of the presence of the tunneling machine and various other obstructions. One method that has been used to drill short lateral shafts at regular intervals and dump the severed core pieces therein. This technique may become quite expensive, particularly in the harder, more abrasive formation, as the total length of all the laterals must equal the total length of the tunnel itself.

It should also be noted that neither the pure coring method nor the full-face cutting method provide any advance warning against drilling into dangerous formation fluids such as water or gas, which may constitute extreme hazards to personnel working in a tunnel.

It is the primary object of the present invention to provide a tunnel forming method which obviates or ameliorates the above disadvantages of the pure blasting and pure coring methods and exploits the best features of each.

A second object is to provide a method of tunneling in which a smooth tunnel wall is formed in the first instance, without the necessity for either further removal of material or for filling in overbreak.

A third object is to provide a tunneling method which obviates the difficult task of disposing of large pieces of core.

A fourth object is to provide a tunneling method which includes a blasting operation in which the quantity of rock disintegrated in such step is larger than in the pure blasting methods heretofore known.

A fifth object is to provide a tunneling method which includes a coring operation but which avoids the necessity for breaking off and disposing of large pieces of core.

A sixth object is to provide a tunneling method which includes a blasting operation wherein the likelihood of overbreak is reduced and wherein the fraction of explosive energy used to disintegrate the rock in the projected tunnel is larger than in pure blasting methods heretofore known.

A seventh object is to provide a tunneling method which provides temporary shielding or support for the tunnel roof when the tunnel is being formed in a formation likely to cave in or requiring permanent support.

An eighth object is to provide a tunneling method which provides advance warning against dangerous formation fluids, in contrast to cutting the full face of the tunnel or a substantial portion thereof into a region containing such water or gas.

The above and further objects are achieved according to the present invention by the operations of (1) cutting a kerf which defines the wall of the tunnel and leaves an uncut core, (2) drilling one or more blast holes in such core, (3) detonating explosive charges in the blast holes and (4) removing the resulting debris back through the tunnel. Operations 1 and 2 may be performed at the same time or carried on stepwise, with either operation being performed before the other. When there is any possibility of encountering dangerous fluids in the formation, it is preferable to form the blast hole in advance of the kerf, either by predrilling the blast hole or by drilling both together with the blast hole drill in the lead. While the kerf may be cut by any known method and with any known equipment, in a preferred method a core drill is used which includes a core barrel having the cutting structure mounted on the forward end. This drill may be removed during the blasting operation, in which event the kerf serves as a barrier to prevent the propagation of waves of explosive energy from the core to the surrounding rock and also provides a volume into which the exploding rock may expand. Alternately, the core drill may be left in place surrounding the rock, particularly where the type of rock formation increases the likelihood of overbreak. In this alternate method, the core drill cuts a kerf having a large annular gap between the core and the inside surface of the core barrel to provide the necessary room for rock expansion.

The methods of the present invention will be more readily appreciated by reference to the attached drawing illustrating the several operations thereof with typical equipment in which drawing:

FIGURE 1 illustrates the various items of equipment in a tunnel during the debris-removal operation, the final step in a complete cycle;

FIGURE 2 depicts most of the same apparatus with the core drill extended into the formation during a succeeding cycle, and also indicates in phantom the optional technique of forming the blast hole ahead of the kerf;

FIGURE 3 shows both core drill and a blast hole drill extended into the formation, the blast hole drill forming a hole in the core defined by the core drill; and

FIGURE 4 shows alternate dispositions of the same equipment just prior to detonating a charge in the blast hole, solid lines being used to indicate the core drill in withdrawn disposition and phantom lines to show its optional disposition in the kerf.

The core drill **1** comprises a barrel **2** having a multiplicity of rolling cutters **3** mounted on the forward end thereof, such cutters being preferably uniformly distributed about the circumference of the drill (only 3 shown). The relative dimensions and disposition of parts are such that cutters **3** define in the rock an annulus having an outside diameter greater than that of core barrel **2** and an inside diameter less than that of the core barrel, to avoid any possibility of binding the drill. Drill **1** is rotated by prime mover **4** through suitable mechanical linkage, and is urged into the tunnel face through jacks **5** acting against anchor ring **6**.

Blast hole drill **11** comprises the rotary rock bit **12** and drill stem **13** slidably and rotatably supported from framework **21** by bracket **14**. Drill **11** is rotated by a suitable prime mover **15** and is extendable forwardly through jack **16**, the rearward end of which is secured to the wall of the tunnel by anchors **17**.

Mucker **31**, a self-propelled vehicle which serves to pick up the rock debris resulting from a blasting operation and deposit it in a hopper **32** feeding onto one end of conveyor **24**, operates on platform **33** pivotably connected at **34** to the forward end of framework **21**. This framework is mounted on trucks **22** rolling on rails **23** and also serves to support conveyors **24** and **25**, which ultimately deposit the rock debris in one of the cars **26** for transport to the rear and out of the tunnel. When the passage being formed is more nearly vertical, bucket elevators may be used for the removal of the rock fragments.

At the time indicated by the position of the equipment in FIGURE 1, the rock debris from the previous blast have been partially removed. In FIGURE 2, the clean-up has been completed and a new drilling cycle has been started by pushing core drill **1** against the tunnel face and rotating it (the debris removal apparatus is not shown in this figure or those following in the interest of simplicity). FIGURE 2 also shows in phantom a blast hole **19** drilled ahead of the kerf as a probe for dangerous formation fluids. In FIGURE 3, both the core drilling and the blast hole drilling operations have been at least partially completed. Usually one blast hole drilled centrally is sufficient, but more may be used if necessary for fragmentation. As previously indicated, optional methods are to drill the kerf first, the blast hole or holes before the kerf, or preferably, to drill both simultaneously to speed up the overall process, the blast hole drill preferably leading the core drill as a probe.

In FIGURE 4, the solid outlines indicate one preferred disposition of the equipment when a charge **44** covered with clay packing **46** is being exploded in the blast hole **41** formed by drill **11**, core drill **1** being withdrawn so that the expanding rock can swell into kerf **42**. The phantom outline of core drill **1** indicates the alternate disposition when charge **44** is exploded in blast hole **41**, surrounding core **43**. In either arrangement a removable wire screen **45** may be secured to the tunnel wall to protect the equipment against flying rock. When the core drill is left in the kerf **42** during the explosion step, the barrel **2** separates the kerf into two parts, a smaller annulus **47** between barrel and formation wall and a larger annulus **48** between barrel and core.

With one exception, the invention defined in the appended claims is independent of the apparatus used in practicing the same, and hence the apparatus as above described should be regarded only as illustrative of the means for putting the present invention into effect. The exception is that indicated above in discussing the phantom outline of FIGURE 4, leaving the core drill in place around the core while detonating the explosives in the

blast holes. In the practice of this method, the kerf must be cut by a drill which includes a member which not only extends substantially the length of the kerf and has sufficient clearance **47** from the tunnel wall to avoid binding, but also is sufficiently spaced from the core to provide a relatively large gap **48** for expansion of exploding rock. When so used, the core drill serves as a temporary shield against cave-ins, and the drilling machinery and personnel are followed by appropriate equipment and workers to install a permanent roof.

The methods of the present invention are capable of producing effective cuts of up to at least twice the footage obtained per cut in the prior art pure blasting technique. They also produce smoother walls than in pure blasting, and avoid filling in or additional rock removal and the danger of cave-ins which accompany such methods. The present methods also provide a probe for the detection of fluids and avoid the problem of disposing of massive pieces of core.

What is claimed is:

1. A method of tunnel drilling in rock formations comprising a first step which includes the operation of drilling an annular kerf with a core drill which includes a barrel supporting the necessary cutting structure on its forward end, extending substantially the length of such kerf and defining an appreciable radial gap between its inner surface and the core thereby formed, and the operation of drilling at least one blast hole in the core, a second step of exploding a charge in such blast hole prior to removing the core drill from said kerf, and a third step of removing the rock fragments resulting from such explosion.

2. In a tunnel forming method wherein a kerf is to be formed in a rock formation with an inner boundary substantially defining the balance of the rock to be removed, the improvement comprising forming a blast hole in said rock balance prior to forming said kerf to serve as a probe for dangerous fluids, and explosively disintegrating such balance after said kerf forming operation.

3. A method of tunneling in rock formations of a type likely to cave in, comprising a first step which includes the operation of drilling at least one blast hole generally centrally in the face of the tunnel and the operation of forming a kerf having an outer boundary substantially defining the wall of the tunnel with a core drill having cutting structure on its forward end and a barrel rearwardly thereof, such cutting structure and barrel being proportioned so that the inner boundary of the kerf defines an appreciable radial gap with said barrel, detonating an explosive charge in such blast hole while leaving such core drill in place in such core, and removing the resulting rock fragments, whereby said core drill serves as a temporary shield against caving in of the tunnel roof until a more permanent roof is installed.

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