Mini-Review 73-1 John C. Rowley The Subterrene Program

Mini-Review 73-1

C2

The Subterrene Program

los alamos
scientific laboratory
of the University of California
LOS ALAMOS, NEW MEXICO 87544

The Los Alamos Scientific Laboratory invites industrial participation in the program. For further information, please contact the Office of Special Projects, LASL, P.O. Box 1663, Los Alamos, NM 87544.

UNITED STATES
ATOMIC ENERGY COMMISSION
CONTRACT W-7405-ENG. 36

MELTING HOLES IN THE GROUND

The Subterrene is a system invented and patented by the scientists of the Los Alamos Scientific Laboratory (LASL) for making vertical or horizontal holes in the ground by melting rocks and soils. The Subterrene should offer substantial advantages over conventional methods of drilling deep holes in high-temperature rocks, as are encountered in geothermal energy exploration and production wells.

POTENTIAL APPLICATIONS OF THE SUBTERRENE

Advantage of the Subterrene

LASL studies combined with a survey of potential industrial users have revealed a large number of possible Subterrene applications. Some applications are conventional, others unique. In situations where rotary drills are commonly used, two advantages of the Subterrene are simplicity of operation and longer bit life. The three major facets of excavation–rock fracturing, debris removal, and wall stabilization–are accomplished in a single integrated operation.

Another Subterrene advantage is its ability to make holes of precise diameter and depth, useful in boring holes for anchoring structures such as bridges, TV towers, and transmission-line towers. Emplacement holes for anchoring pipeline supports could be readily bored in difficult materials such as Alaskan permafrost. Loose gravel and other unconsolidated formations are difficult to drill with conventional rotary equipment. The Subterrene, which would leave a glass-lined hole, provides a solution to this difficulty.

The Geoprospector

One valuable use of the Subterrene penetrator is to produce cores. A special feature of this system is that the cores may be taken in any desired direction. With conventional techniques, only short horizontal cores can be obtained. A device, called a Geoprospector, has been designed at LASL to produce long horizontal cores. One important application would be to investigate ground materials to be expected when boring a tunnel.

The Subterrene and the Energy Program

LASL's energy development program poses two potential Subterrene uses of special interest. One has been referred to earlier: boring deep holes in hot rocks for the extraction of geothermal energy. Rock melting should be easier with increasing rock temperature because less thermal energy would be required to bring the rock up to the melting temperature.

LASL is engaged in a program for developing underground transmission lines for electrical power. At present, such lines would have to be laid in trenches which could be dug only with considerable environmental disruption. A Subterrene, however, could drive horizontal holes with minimal disturbance of the ground surface. By appropriate penetrator shaping, a hole need not be circular, but could be any desired cross section.

Excavation of Tunnels

One of the major–and most needed–contributions of the Subterrene rock-melting concept is expected to be in the technology for excavating large-diameter tunnels. In soft rock, the melting-consolidating principle would be convenient to melt an outer layer and form a thick stabilizing glass tunnel liner. The remainder of the tunnel bore could be removed by a conventional mechanical method such as a rotating boring face. In hard rock, however, a different method would be required. One possibility would be to melt an outer layer to form a glass lining, while the interior would be broken up by thermal stresses produced by an array of small diameter Subterrene penetrators advancing into the working face. Such a tunneling device is shown in Fig. 1.

The Nuclear Subterrene

It is unlikely that electrical-resistance heating, which is adequate for smaller penetrators, could economically provide the thermal power requirements of a tunneling Subterrene. Scientists and engineers at LASL have been working for several years on the idea of a nuclear Subterrene in which the thermal energy would be generated in a compact, specially designed nuclear fission reactor. The efficient transfer of energy at a high rate from the reactor to the face of the penetrator is a difficult problem, but a practical solution is being developed.

DRILLING OIL, GAS, AND WATER WELLS

Rotary Drilling and Its Problems

Rotary drilling, using bits faced with a very hard material such as hardened steel, tungsten carbide, or diamond, is the method generally used to produce relatively deep oil, gas, and water wells. This drilling method has limitations.

The drill bit is connected by a pipe, or drill stem, to the rotating machinery at the surface. When drilling deep holes, the bit cannot support the entire weight of the drill stem. The drill stem must be supported from the surface, thereby placing a limit on the weight and length of the stem.

Furthermore, rotating bits become dull and must be replaced at intervals. The bit must then be brought to the surface by uncoupling length after length of the vertical pipe to which it is attached. When deep holes are being drilled in hard, hot rock, more time is spent on bit replacement than actual drilling.

Drill Improvement

Many attempts have been made to improve rotary drills or to develop novel modes of drilling. High-pressure water-jet bits have been used to improve rotary drill penetration rates by incorporating mud circulation systems designed to operate at 10,000- to 15,000-psi pressures. Among the novel modes, only the jet-piercing drill is a commmercial success. In this device, fuel oil is burned with oxygen at the rock face, the rock is heated, and the thermal stresses created by thermal expansion cause successive thin layers to spall from the surface. Use of the jet-piercing drill is limited, however, to certain rocks that spall easily, such as taconites.

SUBTERRENE DESIGN AND OPERATING CONCEPTS

Driving Holes with the Subterrene

The Subterrene makes holes in rocks and soils by progressive melting, instead of mechanical chipping or abrading. Figure 2 shows a Subterrene in operation. Rocks are mixtures of minerals and, therefore, have relatively low melting point–about 2200°F (1200°C). Refractory metals, such as molybdenum and tungsten, have melting points much higher than this. The rock melt can be chilled to a glass and formed into a dense, strong, firmly attached hole lining. Thus, permanently self-supporting holes can be made with a melting penetrator even in unconsolidated sediments (Fig. 3). Subterrene penetrators with electrical resistance heaters operating at a temperature of about 2700°F (1500°C) have melted rock rapidly. Eventually, heating with nuclear fission is envisaged. The energy used to form and glass-line a particular sized hole is estimated to be somewhat greater than for a conventional rotary drill, but this should be more than balanced by savings in operating costs, system simplifications, and less materials used in hole support.

The Subterrene should be particularly useful for boring holes in high-temperature rocks where rotary drill bits soon become dull and must be replaced. Because the action of the Subterrene depends on melting the rock, the rock's high temperature should help save thermal energy.

How the Subterrene Operates

The general principle of the Subterrene operation is shown in Fig. 4. The smooth-faced penetrator, which plays the role of drill bit, is made of a refractory metal. The penetrator is electrically heated by a pyrographite resistance-heating element. This part of the device is thermally insulated from the stem-advancing section by a layer of special pyrolytic graphite. The steel stem is cooled by circulating water or a gas through the interior of the stem.

There are two basic methods of operation in Subterrenes–melting-consolidation and universal extrusion.

The Melting-Consolidating Subterrene

Suppose we wish to make a vertical hole. The hot penetrator is forced into the ground. The surrounding rock is melted and the hole starts to form. The thrust (or pressure) acting on the penetrator forces the liquid rock-melt outward around the penetrator and stem. The melt then freezes to form a hard, obsidian-like glass lining on the wall of the hole. The lining helps seal and support the hole and forms a seal around the penetrator, tight enough to permit the required high pressures ahead of the penetrator to be developed in the molten rock.

The operation just described is that of the "melting-consolidating" type of Subterrene designed especially for making holes in porous rock or soft ground (Fig. 5). The glass lining formed when the rock-melt cools is more dense and occupies a smaller volume than did the original porous rock, hence the molten debris from the hole can be entirely consolidated in the dense glass lining, thus completely eliminating the necessity of removing debris.

The Universal Extruding Subterrene

Holes in dense rock would be made by the universal extruding Subterrene which could also be used in porous rocks to make holes with a thinner glass lining. The operating principle of the universal extruding penetrator is shown in Fig. 6. The universal extruding Subterrene differs structurally from the melting-consolidating design in that the heated penetrator is not a solid conical body but is a ring, or torus.

Part of the rock melt is forced upward and outward, and when cooled forms the hard glass-like lining of the hole. Most of the melt, however, is pushed up through the central hole in the penetrator into what is called the "extrusion zone." In the upper part of this zone, the melt is cooled and solidified; the extruded solid debris is then carried to the surface by the flow of the coolant.

Coring with the Subterrene

So far we have been concerned primarily with making a hole in rock or soil. For some applications, such as geophysical prospecting for oil or minerals, it is desirable to extract a relatively undisturbed core sample to identify the rock layers at various depths. Cores from either porous or dense rock formations can be obtained using a coring Subterrene penetrator. Essentially, this requires using a ring-shaped, or toroidal, penetrator with a large central hole for forming and extracting the core sample as shown in Fig. 7.

Special Features of the Subterrene

As opposed to standard drill bits, no Subterrene penetrator body is in actual contact with the rock but is separated from it by a thin layer of rock melt. Penetrator wear should thus be minimal. Another advantage of the Subterrene is that the holes are automatically lined with a hard, glass-like material. It may thus be possible to eliminate the costly and time-consuming procedure of inserting and cementing metal casings necessary in oil, gas, and water wells drilled with rotary bits.

Test of the Subterrene

Electrically heated melting-consolidating Subterrenes built at the Los Alamos Scientific Laboratory have been used successfully to make 1-, 2-, and 3-in. diam glass-lined holes in laboratory specimens of several porous materials including low-density tuff (a consolidated particulate material of volcanic origin), wet and dry alluvium (compacted particles of rock, sand, clay, etc., deposited by water over long periods of time), loose shales, and various soils. Holes 2 in. in diameter were driven vertically in tuff up to 82 ft deep, and horizontally up to 52 ft deep. Universal extruding Subterrenes have produced 2½-in. diam holes in samples of hard rock, such as granite and basalt, and in porous materials, such as tuff (Fig. 8.). A field test is planned to melt a 50-ft-deep hole in basalt.

Preservation of Historic Ruins

A simple but practical application of the Suberrene was making drainage holes for the Indian ruins at the Bandelier National Monument (Fig. 9). After heavy rains, fairly common in the late summer, water tends to remain in certain locations causing the ruins to erode. Several vertical, glass-lined holes have been bored to drain away this water using a mobile Subterrene demonstration unit.

One important advantage of the Subterrene in this respect is that it operates without destructive vibrations that might damage nearby structures.

Larger Penetrators

The penetrators that have been made and tested so far have fairly small diameters. Theoretical studies and laboratory experiments suggest that Subterrenes can be used for boring much larger diameter holes. Plans are being made to build larger experimental penetrators.

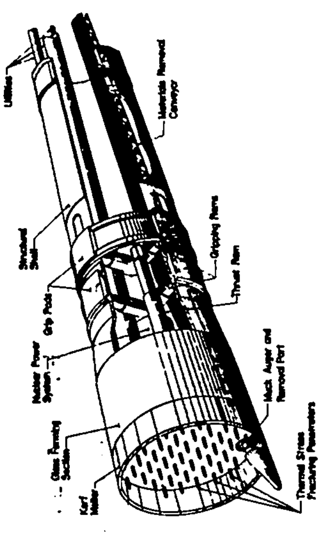

Fig. 1

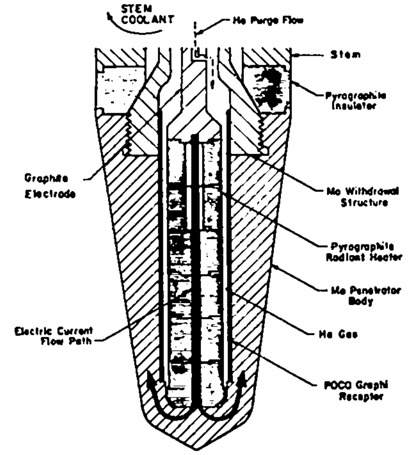

Fig. 4

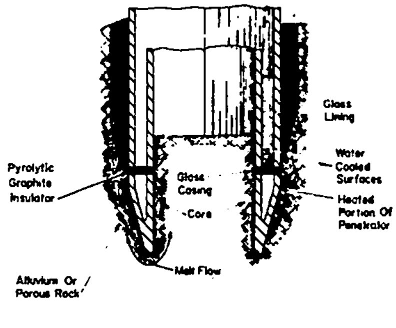

Fig. 7

Fig. 2

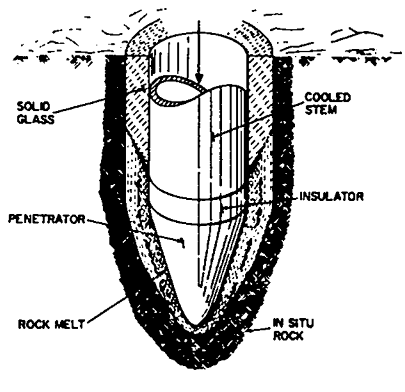

Fig. 5

Fig. 8

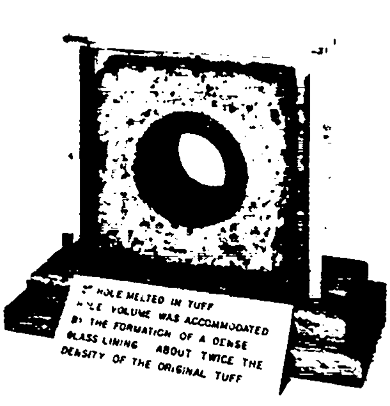

Fig. 3

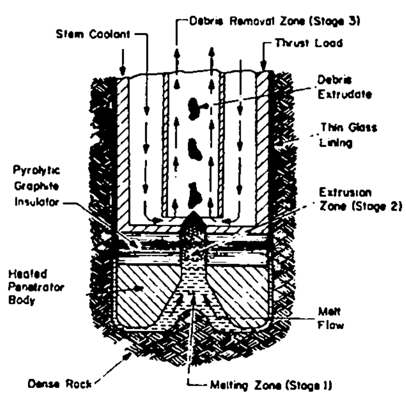

Fig. 6

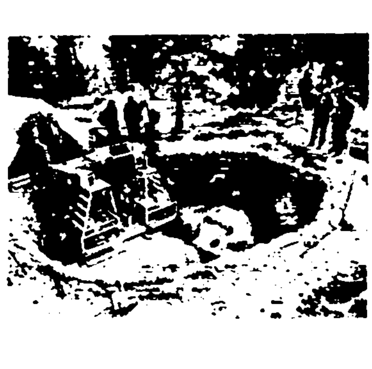

Fig. 9

This paper describes research previously reported in Los Alamos Scientific Laboratory report LA-4547, copies of which may be purchased from the National Technical Information Service, US Department of Commerce, 5285 Port Royal Road, Springfield, VA 22151.

October 1973