May 25, 1954 S. H. ROYER ET AL 2,679,381

THERMAL ROCK PIERCING APPARATUS WITH AUTOMATIC CONTROL

Filed Dec. 28, 1950

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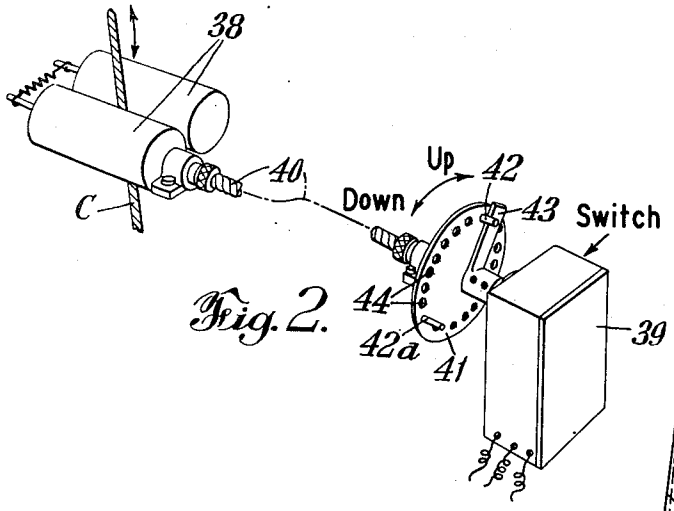


Fig. 2.

Fig. 1.

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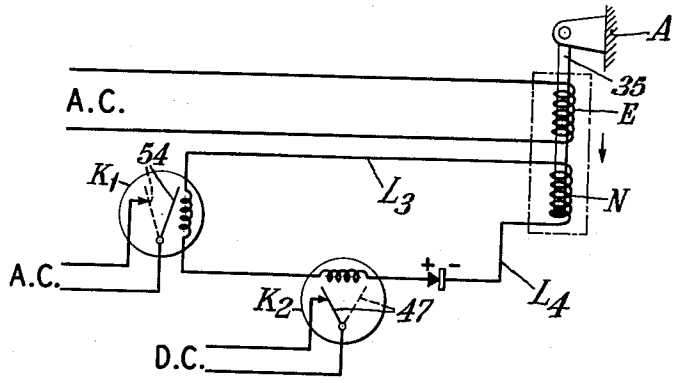
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2 Sheets-Sheet 2

Fig. 3.



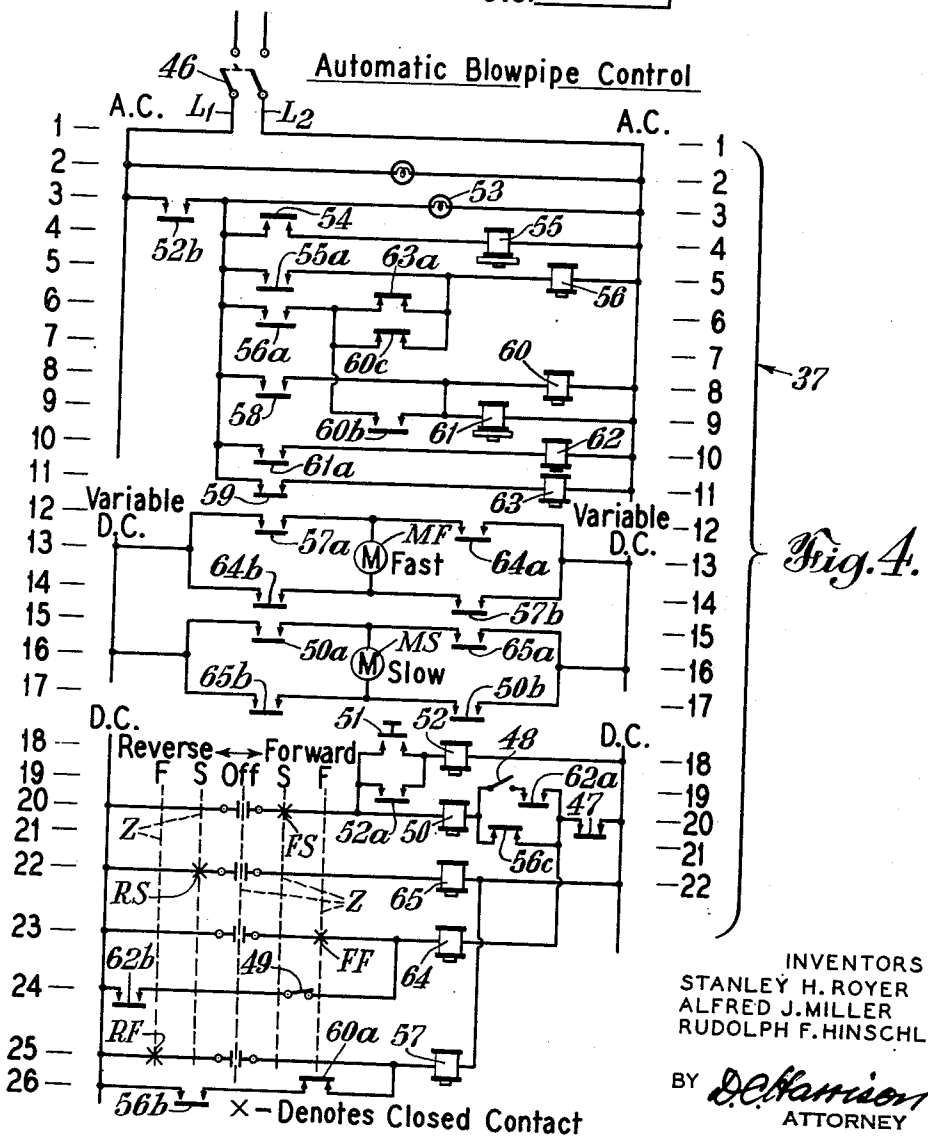


Fig. 4.

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2,679,381

THERMAL ROCK PIERCING APPARATUS WITH AUTOMATIC CONTROL

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11 Claims. (Cl. 255—36)

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The present invention relates to a thermal rock piercing apparatus of the type wherein a heating device, such as a blowpipe, is employed for directing heat against a body of rock to remove material and form a hole. More particularly, the apparatus of the invention includes an automatic control system for piercing deep blasting holes without requiring the constant attention of an operator. Another feature of the invention is a semiautomatic control system.

The thermal piercing of blasting holes in bodies of rock, such as taconite iron ore, quartzite, traprock, granite, and dolomite, has been successfully practised for a number of years with a heating device such as an oxy-fuel blowpipe, and has been described in the patent and other literature. For example, such a process has been described in detail in United States reissue patent Re. 22,964. The piercing of holes with a flame discharged from a blowpipe will be described hereinafter as exemplary of the invention but it is to be understood that the principles of the invention also apply to the piercing of holes with other heating devices.

Ideally, the thermal piercing of blasting holes should progress without physical resistance to the passage of a blowpipe because the flame normally forms a hole of considerably larger diameter than the heating device itself. Actually, however, while the flame may form the major portion of a hole with a substantially larger diameter than the blowpipe, there are often encountered obstructions in the form of annular collars where insufficient rock has been removed by the flame to allow passage of the blowpipe.

Rock piercing blowpipes are generally provided with rotating teeth which normally act only to break up oversize and agglomerated fragments of removed material, and to size the hole. Such teeth are not heavy enough nor sufficiently powered to grind their way through large obstructions such as collars. Therefore the usual procedure for removing such obstructions has been for the operator to watch the operation of the blowpipe carefully, and to reverse the motor driving the blowpipe to retract the blowpipe for a short distance when it strikes an obstruction, thus giving the flame an opportunity to play upon the obstruction and remove it. Then the operator again reverses the motor and advances

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the blowpipe to continue the piercing of the hole. Such a procedure obviously requires the constant careful attention of a highly skilled operator who can interpret the behavior of instruments, which reflect conditions at the bottom of the hole, and can manipulate the blowpipe accordingly.

If the operator's attention wanders so that he does not react quickly when an obstruction is encountered, the blowpipe nozzle may be ruined by the physical resistance of the obstruction. Furthermore, when a hole is pierced downwardly and the blowpipe is fed by a cable unwinding from a motor-driven reel, the cable will continue to pay out even though progress of the blowpipe has halted, and thus may become snarled up in the other machinery.

A further difficulty is that obstruction of the flame outlets may cause a reversal of the burning combustants in the blowpipe, resulting in severe damage to the blowpipe. Still another disadvantage of full manual control by the operator is that the optimum speed of piercing may not be realized as a result of either the operator's unwillingness, or his inability, to let the blowpipe progress at its maximum speed.

In accordance with the present invention there is provided novel thermal rock piercing apparatus including a fully automatic control system which permits a blowpipe to advance steadily and progressively into a hole, as formed, to deepen the hole. When an obstruction such as a collar is encountered in the hole, the automatic control system operates to retract the blowpipe in the hole a predetermined distance so that the flame from the blowpipe will play upon the obstruction in a concentrated fashion to remove it. The automatic control system also may include time-delay means for briefly delaying retraction of the blowpipe after it encounters an obstruction, so that the forward progress of the blowpipe will continue uninterruptedly if the obstruction is burned out promptly. Also there may be included time-delay means which causes the blowpipe to dwell in its fully retracted position, so that the flame will burn out the obstruction.

The automatic control system also acts to return the blowpipe from its retracted position to its original position. If the obstruction has been successfully burned out, the blowpipe continues its forward advance until another obstruction is

encountered. If not, the blowpipe again strikes the obstruction and the cycle of retraction and return is repeated as before.

The semiautomatic control system of the invention acts to stop the blowpipe advancing mechanism if the operator fails to reverse it manually when an obstruction is encountered.

The apparatus of the invention will be described in detail below with reference to the drawings, wherein:

Fig. 1 is a schematic side elevational view showing automatically controlled thermal rock piercing apparatus embodying the invention;

Fig. 2 is a perspective view of a cable-operated friction limit switch, shown schematically in Fig. 1;

Fig. 3 is a wiring diagram showing details of the reel position limit switch, which appears schematically in Fig. 1; and

Fig. 4 is a wiring diagram showing the automatic blowpipe control, which appears schematically in Fig. 1.

Referring to Fig. 1 of the drawings, there is shown an elongated rock piercing blowpipe B which is suspended by a cable C in a hole H extending vertically downward in a body of rock R. Cable C passes over sheaves on the top of a vertical mast M, which is mounted on the front of a mobile rig A, and extends from the mast down to a reel or drum **30** carried on a floating support **31** pivotally mounted on a stanchion at **32** for movement in a vertical plane. Reel **30** can be driven by either of a pair of selectively operable motors, MS operable over a low speed range, and MF operable over a higher speed range. The motors MS and MF drive the reel **30** through a conventional planetary gear transmission PG which permits either motor to stand idle while the other motor is operating.

Blowpipe B and support **31** are approximately evenly balanced against one another. For example, a blowpipe B weighing 2200 pounds should be counterbalanced with a support **31** exerting a force of about 2200 pounds on cable C. As a result, the predominant upward force exerted on support **31** by the blowpipe and by a coil spring **45** normally holds the support in raised position.

During the piercing of a hole the blowpipe B is held steady by a shoe **33** which slides on the mast M. Also, the teeth **29** of the blowpipe are rotated by mechanism **34** of the type described in United States Patent 2,338,093, wherein a turntable carries keys which fit slidingly in long keyways on the outside of the blowpipe.

When an obstruction, such as a collar D, is encountered in the hole H the lower end of the blowpipe rests upon the collar and thus relieves the cable C of a substantial part of its weight. Meanwhile, reel **30** continues to pay out cable so that the floating support **31** tilts downwardly about its pivot **32** in response to the reduced force exerted thereon by the blowpipe, which causes the predominant force on the support to be in a downward direction.

The floating support **31** carries a pair of axially aligned induction coils, E which is energized, and N which is non-energized. A stationary iron core **35** is mounted on the rig A above coils E and N. During the normal operation of the blowpipe, when support **31** is fully raised, coils E and N both encircle the core **35** causing an induced current in coil N which flows through conductors L_3 and L_4 to a reel position limit switch **36** in which a switch contact **54** of a contact meter K_1 is normally held open by the current. When the floating support **31** tilts downwardly, the coil N moves down and at least part way off of core **35**, thus causing the amperage of the current induced in coil N to decrease. When the floating support **31** has tilted a predetermined amount so that the current in coil N decreases to a predetermined value the normally open reel position limit switch contact **54** closes to start the automatic blowpipe control **37**. The latter will be described more in detail hereinafter.

Then the reel **30** is reversed automatically to wind up cable, and the blowpipe B rises in the hole H so that the flame plays upon the collar D. As the cable C is wound upon the reel **30** it rotates a pair of pinch rolls **38** to turn a flexible shaft **40** and change the position of the electrical contacts in a friction limit switch **39** so as to limit the distance the blow pipe is raised in the hole. Switch **39** is turned by a rotating disk **41** mounted on the end of flexible shaft **40** and having a peg **42** which engages and operates an arm **43** to change the position of the contacts in the switch. Conversely, when cable C is payed out to advance the blowpipe down into the hole, disk **41** rotates counter-clockwise until a second peg **42***a*, which is spaced circumferentially from peg **42**, engages arm **43** and changes the switch contacts back to their original position.

Switch **39** acts through the automatic blowpipe control **37** to stop the reversed reel **30** and the rising blowpipe B when the length of cable C which has passed between the rolls **38** is such as to change the contacts. The distance the blowpipe is raised can be adjusted at will between limits by moving pegs **42** and **42***a* to any selected ones of a large number of holes **44** which are arranged in a circle in the disk **41**. For example, peg **42** can be positioned so that the blowpipe is raised as little as three inches or as much as twelve inches before reel **30** stops.

The friction limit switch **39** can be of any desired type, such as the Zero Speed Switch, Bulletin 10256 of Cutler-Hammer, Inc. (Cat. No. 10,256 H 1), described in U. S. Patent 1,964,199.

It will be evident to those skilled in the art that arrangements other than those specifically described can be employed for changing the current in conductors L_3 and L_4, either by increasing or decreasing it when the support **31** falls and rises. For example, the core **35** can be stationary while one or both of the coils move, or the core can move while one or both of the coils are stationary. Also the fall of the support **31** can be made to increase or decrease the current in the conductors L_3 and L_4 to operate the reel position limit switch **36**.

To prevent undesirable bobbing of the floating support **31** when only minor obstructions are encountered which are quickly burned out without requiring retraction of the blowpipe, the movement of the floating support about its pivot **32** is resisted by a coil spring **45**. Spring **45** may be of any selected strength, for example one requiring a weight of 600 pounds to compress it one inch to the point at which the reel position limit switch **36** is actuated.

The voltage of the output from the non-energized coil N is indicated by a meter V. Variable resistor G is for varying the input voltage to coil E for calibration and setting the meter reading of V for any indication desirable. The degree to which the support **31** must tilt before a given current will be induced in coil N can be adjusted by adjusting resistor G. When the op-

erator is manually controlling the blowpipe, without the automatic control, he can judge conditions at the bottom of a hole by observing voltmeter V.

Referring to Figs. 3 and 4 of the drawings, the first step in initiating the operation of the mechanism for advancing the blowpipe B to pierce a hole is for the operator to close manually a switch 40 (see Figs. 1 and 4) which energizes the automatic blowpipe control 37 through conductors L_1 and L_2.

The operator's next step is to move the master switch Z, shown in Fig. 4, from its off position to its forward slow or fast position at which the contact FS in line 20 or the contact FF in line 23 is closed. Master switch Z may be a conventional drum switch such as Type SD–4– Mill Master Jr. Master Switch described in Bulletin 101–SD of the Clark Controller Company. Assuming that contact FS in line 20 is closed, relay 50 in line 20 is then energized and closes contacts 50*a* and 50*b* in lines 15 and 17 to start the operation of a low-speed-range motor MS in line 16. Motor MS operates cable reel 30 to advance the blowpipe B in the manner described previously herein. Suitable conventional variable voltage control means such as a motor-generator set (not shown) may be provided for regulating the speed of motor MS within the selected speed range, which for example may be such as to move the blowpipe at some speed between 2 and 18 inches per minute. As the blowpipe advances the cable C rotates the two pinch rolls 38 and causes the disk 41 to rotate in a counter-clockwise direction so that the peg 42*a* is held in contact with and rotates the arm 43 to hold closed the friction limit switch contact 59 in line 11 of Fig. 4. When the contact 59 is closed, the relay 63 in the same line is energized and opens a contact 63*a* in line 6.

If the operator were not using automatic control he would also use switch Z to reverse the motors MS or MF for raising the blowpipe. Thus, moving switch Z so as to close contact RS in line 22 energizes a relay coil 65 in line 22 to close contacts 65*a* and 65*b* in lines 15 and 17 to reverse motor MS; and moving switch Z so as to close contact RF in line 25 energizes relay 57 to close contacts 57*a* and 57*b* in lines 12 and 14 to reverse motor MF.

Assuming fully automatic control of the blowpipe feed is wanted, the operator's next step is to place the automatic control system in operation by manually closing the switch 51 in line 18. Relay 52 in line 18 is then energized and closes shunt contact 52*a* in line 19 and contact 52*b* in line 3, as indicated by the lighting of lamp 53 in the same line.

The operator also manually selects the speed range over which he wishes the blowpipe to operate during its retraction, and during its return from retracted position to piercing position, by appropriately setting switch 48 in line 19 and switch 49 in line 24. When switch 48 is opened and switch 49 is closed the blowpipe will both be retracted and be returned from retracted position at a speed in the high-speed range of motor MF; when the switch 48 in line 19 is closed and the switch 49 in line 24 is opened the blowpipe will be retracted at a speed in the high-speed range of motor MF and will be returned at a speed in the low-speed range of motor MS. The latter positions will be assumed for this description.

The apparatus now is ready for completely automatic operation. When the blowpipe B bottoms in the hole H, as by striking an obstruction such as a collar D, the floating support 31 tilts down as described previously and the current is reduced in the coil N. When the current in coil N has dropped sufficiently switch contact 54 (see Fig. 3 and line 4 of Fig. 4) is closed.

An adjustable timing relay 55 in line 4 is energized when contact 54 closes and after a short time delay, for example about 3 seconds, relay 55 closes contact 55*a* in line 5 and energizes a relay 56 in the same line which controls the variable direct current (D. C.) circuits of the fast and slow-speed-range motors MF and MS alternatively. However, if the flame from the blowpipe B burns through the obstruction D in less than the time delay period of relay 55 the free weight of the blowpipe is again impressed upon the floating support 31 through cable C and causes the core 35 to pass further into coil N and increase the current therein, thus reopening contact 54 in line 4, and de-energizing timing relay 55 before the contact 55*a* in line 5 closes.

Assuming that the blowpipe does not burn through the collar D, relay 56 in line 5 is energized and closes shunt contact 56*a* in line 6, closes contact 56*b* in line 26 to energize motor-reversing relay 57 in line 25, and opens contact 56*c* in line 21 to de-energize relay coil 50 in line 20 and stop the low-speed-range motor MS by opening contacts 50*a* and 50*b* in lines 15 and 17.

When motor-reversing relay 57 in line 25 is energized it closes contacts 57*a* and 57*b* in lines 12 and 14 to start the rotation of high-speed-range motor MF in line 13 in a reverse direction to raise the blowpipe at a speed in the high-speed range, which may be 6 to 60 feet per minute.

As soon as the blowpipe B is raised from the obstruction D its free weight causes the floating support 31 to rise and move the core 35 further into coil N, thus again opening switch contact 54 (Fig. 3 and Fig. 4, line 4) which deenergizes timing relay 55, thus reopening contact 55*a* in line 5. However, relay 56 in line 5 remains energized through the closed contacts 56*a* and 63*a* in line 6.

As the blowpipe B rises in the hole H the cable C operates the pinch rolls 38 to rotate the disk 41 in a clockwise direction. After a predetermined length of the cable has passed through the pinch rolls the pin 42 is brought into contact with the arm 43 and operates the friction switch 39 to open contact 59 in line 11 and close contact 58 in line 8. The opening of contact 59 in line 11 de-energizes relay coil 63 and opens contact 63*a* in line 6. However, relay 56 in line 5 remains energized through closed contacts 60*c* in line 7 and 56*a* in line 6.

When the contact 58 in line 8 closes at the top of the stroke of the blowpipe the relay 60 in line 8 is energized to open contact 60*a* in line 26, thus de-energizing relay 57 in line 25 and opening motor control switches 57*a* and 57*b* in lines 12 and 14 to stop motor MF. Energized relay 60 also closes shunt contact 60*b* in line 9 and opens contact 60*c* in line 7, thus de-energizing relay 56 in line 5 to open contacts 56*a* in line 6, 56*b* in line 26, and 56*c* in line 20.

The closing of friction limit switch contact 58 in line 8 when the blowpipe reaches the top of its stroke also energizes an adjustable timing relay 61 in line 9 which, after a predetermined time interval such as about 15 seconds, during which the blowpipe dwells at the top of its stroke to burn out the obstruction, closes contact 61*a*

in line 10 and energizes a relay 62 in the same line.

Energized relay 62 in line 10 closes contacts 62a and 62b in lines 19 and 24. Relay 50 in line 20 is thus reenergized and closes low-speed-range motor contacts 50a and 50b in lines 15 and 17 to start the blowpipe slowly forward again. The friction limit switch contact 58 in line 8 opens as the blowpipe starts down again.

When the blowpipe reaches its original position the cable C acting through the pinch rolls 38 and the disk 41 closes the friction limit switch contact 59 in line 11 and reenergizes relay 63 in the same line to reopen contact 63a in line 6. All relays and their contacts thus are restored to the condition which existed when the manual switches 46 and 51 were originally closed. The system then is in condition for a repetition of the cycle the next time the blowpipe encounters an obstruction in the hole.

If the blowpipe were to be returned from its retracted position to its piercing position at a speed in the high-speed range, the operator should open switch 48 in line 19 and close switch 49 in line 24 at the start of operations. Thus when relay 62 in line 10 is energized at the top of the blowpipe's stroke and contact 62b in line 24 closes, relay 64 in line 23 is energized and closes contacts 64a and 64b in lines 12 and 14 to start the high-speed-range motor MF and return the blowpipe rapidly to piercing position. Thereafter, the blowpipe will advance at the speed initially set by the master switch Z.

A semiautomatic feature also is incorporated in the control system of the present invention such that even when the advance and retraction of the blowpipe is solely within the control of the operator through his manipulation of the master switch Z, the blowpipe and equipment will not be damaged if the operator does not react promptly when an obstruction is encountered. When this occurs the floating support 31 tilts down, as described previously, and the current is reduced in the coil N.

When the current in coil N has been reduced to a predetermined value, which is less than the value required to operate switch contact 54, a normally closed switch contact 47 (see Fig. 3, and Fig. 4, line 20) in a second contact meter K_2 opens, thus immediately de-energizing the relays 50 in line 20 or 64 in line 23 to stop the motor MS or MF by opening the contacts 50a and 50b in lines 15 and 17, or 64a and 64b in lines 12 and 14, respectively. The contact meters K_1 and K_2 can be constructed to operate at any desired currents in conductors L_3 and L_4, such as 2 milliamperes and 1 milliampere, respectively.

What is claimed is:

1. Apparatus for thermally piercing a body of rock comprising, in combination, a heating device for directing heat against said body of rock to form a hole therein; a frame having thereon an upwardly extending portion supporting cable guiding means above the hole to be made; a cable supported by the guiding means and operably connected to said heating device; feed mechanism on the frame for taking up and paying out said cable for moving the heating device in and out of the hole; said feed mechanism including a rotary element around which the cable passes and which is rotatably mounted in a support movably mounted on said frame, such rotary element support being movable between first and second positions in response, respectively, to normal and lower tension of the cable, said feed mechanism also including reversible drive motor means controlled by a motor-controller and operable to pay out the cable and lower the heating device at a predetermined feed rate, to stop the feed, and to take up cable for retracting the heating device, in response to signal impulses; a first signal device for initiating signal impulses operably connected between said frame and the rotary element support; means to transmit such impulses to said motor controller for stopping and reversing the drive motor means when tension in the cable is reduced to elevate said heating device; a second signal device constructed and arranged for operation by movement of said cable through a desired distance after reversal for initiating a further signal impulse when the heating device is raised a predetermined distance; and means to transmit said further signal impulse to said motor controller for stopping the drive motor means and for restoring the forward movement thereof for again moving the heating device toward the bottom of the hole.

2. Apparatus in accordance with claim 1 in which said second signal device includes a movement transmission mechanism which is adjustable within limits to adjust the amount of movement caused by the taking up of the cable before the signal device is activated to the further signal impulse providing condition.

3. Apparatus in accordance with claim 1 in which said means for transmitting said first signal impulses includes an interposed time delay device for effecting a desired delay of the reversal of the drive motor means before the heating device is elevated.

4. Apparatus in accordance with claim 1 in which the means to transmit said further signal impulse to said motor controller includes an interposed time delay means for effecting a predetermined period of stoppage of the drive motor means before restoring the forward movement; whereby the heating device is held in retracted position long enough to burn away an obstruction in the hole which had caused interruption of the downward travel.

5. Apparatus in accordance with claim 1 in which the reversible drive motor means includes a first drive mechanism for actuating the feed mechanism in a relatively high-speed range, a second drive mechanism for actuating the feed mechanism in a relatively low-speed range, and means for selectively bringing said first and second drive mechanisms into driving relation with said feed mechanism.

6. Apparatus for thermally piercing a body of rock comprising, in combination, a heating device for directing heat against said body of rock to form a hole therein; a frame having thereon an upwardly extending portion supporting cable guiding means above the hole to be made; a cable supported by the guiding means and operably connected to said heating device; feed mechanism on the frame for taking up and paying out said cable for moving the heating device in and out of the hole; reversible drive motor means for driving said feed mechanism; a motor controller to control the drive motor means and operable to pay out the cable for lowering the heating device at a desired feed rate, to stop the feed, and upon reversal to take up cable for retracting the heating device in response to signal impulses; tension responsive mechanism associated with said cable and feed mechanism, said tension responsive mechanism including a movable element which is maintained in a first posi-

tion by normal tension in the cable when the heating device is being lowered at said desired feed rate, said movable element being shiftable to a second position in response to a predetermined reduction of tension in the cable when the heating device encounters an obstruction in said hole sufficient to interrupt the lowering of the heating device at said desired feed rate; a first signal device operable by said movable element and connected to said motor controller for initiating a signal impulse and transmitting same to the controller when the movable element is shifted to the second position for stopping and reversing the drive motor means and elevating said heating device; and a second signal device connected for operation by the movable cable and connected to said motor controller for initiating a further signal and transmitting same to said controller when said cable has moved through the desired distance after reversal to stop the drive motor means and restore the forward movement thereof for again moving said heating device toward the bottom of the hole.

7. Apparatus in accordance with claim 6 in which said second signal device includes a movement transmission mechanism which is adjustable within limits to adjust the amount of movement caused by the taking up of the cable before the signal device is activated to the further signal impulse providing condition.

8. Apparatus in accordance with claim 6 in which said means for transmitting said first signal impulses includes an interposed time delay device for effecting a desired delay of the reversal of the drive motor means before the heating device is elevated.

9. Apparatus in accordance with claim 6 in which the means to transmit said further signal impulse to said motor controller includes an interposed time delay means for effecting a predetermined period of stoppage of the drive motor means before restoring the forward movement; whereby the heating device is held in retracted position long enough to burn away an obstruction in the hole which had caused interruption of the downward travel.

10. Apparatus in accordance with claim 6 in which the reversible drive motor means includes a first drive mechanism for actuating the feed mechanism in a relatively high-speed range, a second drive mechanism for actuating the feed mechanism in a relatively low-speed range, and means for selectively bringing said first and second drive mechanisms into driving relation with said feed mechanisms.

11. Apparatus in accordance with claim 6 wherein said first signal device includes an induction coil mechanism having relatively movable elements, one such element being associated with said frame and the other element being associated with said tension responsive mechanism.

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