June 4, 1957 C. S. ARNOLD ET AL 2,794,620

ROCK-PIERCING BLOWPIPE

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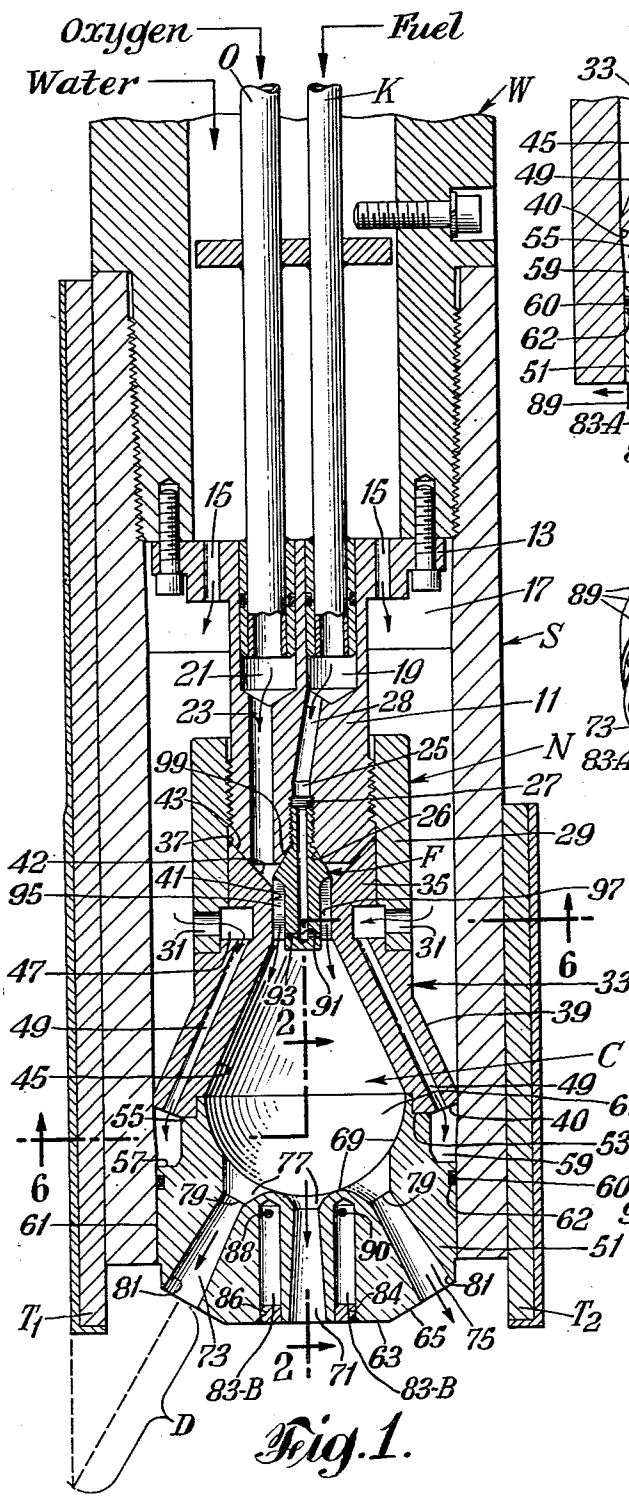


Fig. 1.

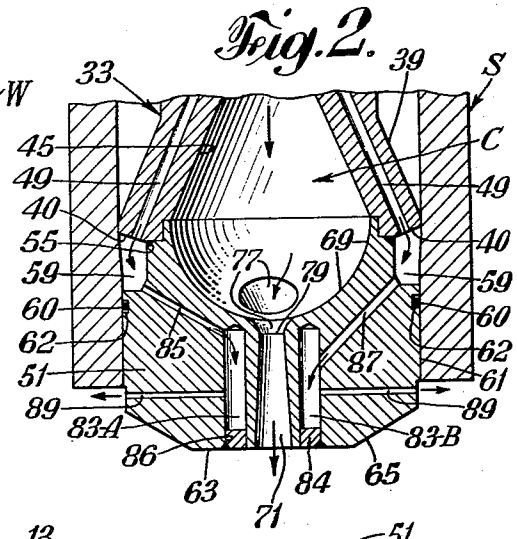


Fig. 2.

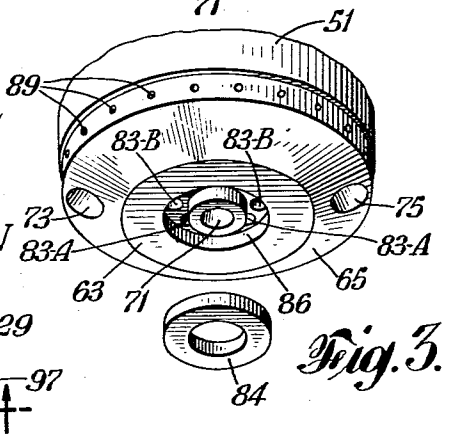


Fig. 3.

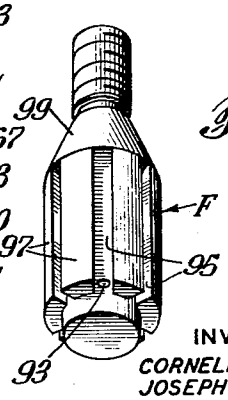


Fig. 4.

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Fig. 5.

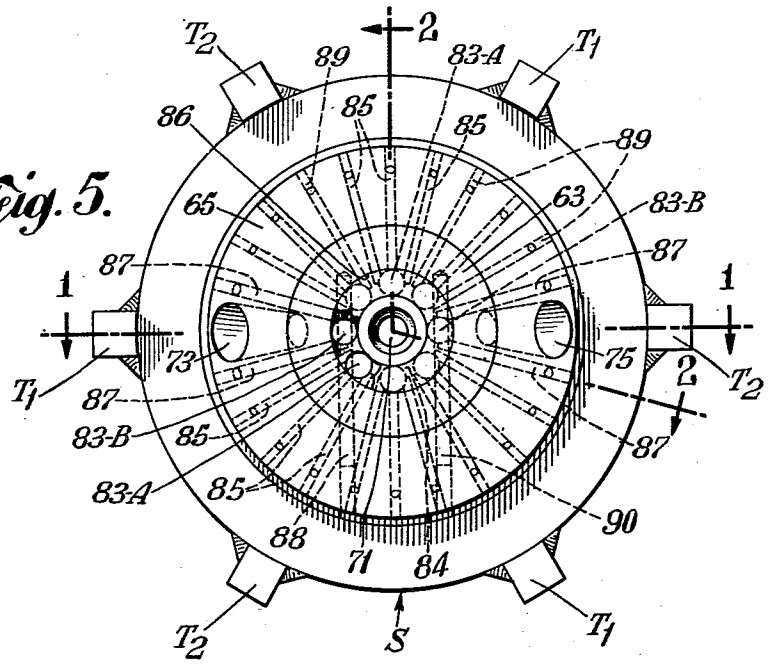
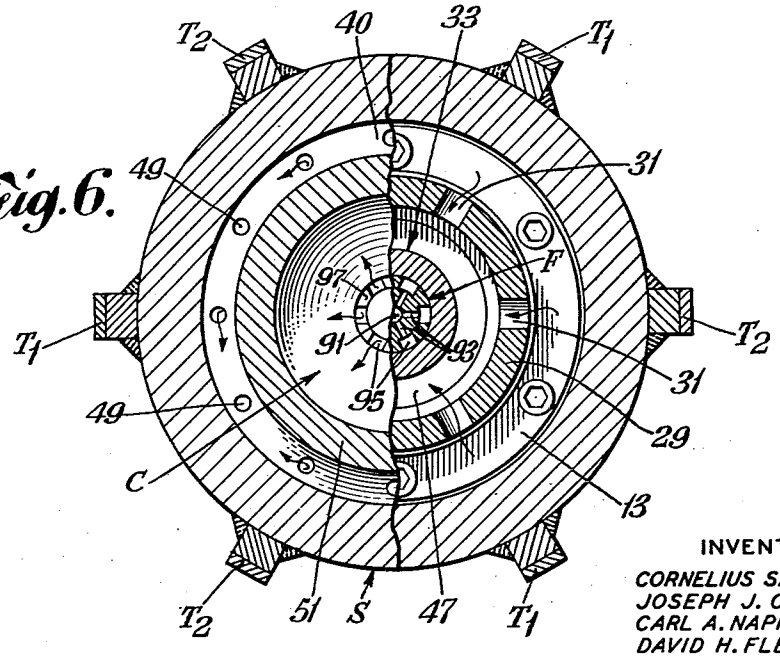


Fig. 6.



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ROCK-PIERCING BLOWPIPE

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2 Claims. (Cl. 255—36)

This invention relates to a novel rock-piercing blowpipe, and to a novel method for operating such a blowpipe.

Among the objects of the invention are: to extend the useful life of a rock-piercing blowpipe, to reduce erosion within such a blowpipe, to improve the efficiency of water cooling, and to improve the efficiency of mixing oxygen with a liquid fuel. Other objects are to increase the speed of piercing a hole in rock, and to improve the action of reamer teeth on such a blowpipe by reducing drag of such teeth on the sides of a hole.

In the drawings:

Fig. 1 is a longitudinal sectional view of the front end portion of a rock-piercing blowpipe embodying the invention, taken along the line 1—1 in Fig. 5;

Fig. 2 is a sectional view taken along the line 2—2 in Fig. 5;

Fig. 3 is an exploded perspective view of the front end of the blowpipe;

Fig. 4 is a perspective view of the fuel injector of the blowpipe;

Fig. 5 is a front end view of the blowpipe, looking from the bottom in Fig. 1; and

Fig. 6 is a sectional view taken along the line 6—6 in Fig. 1.

In accordance with the present invention, there is provided a novel rock-piercing blowpipe comprising a nozzle N having an internal combustion chamber C which is supplied with oxygen by a longitudinal tube O, and with a fluid fuel such as kerosene or fuel oil by a second longitudinal tube K alongside of tube O. Nozzle N is desirably formed of metal having high heat conductivity, such as copper or bronze.

A steel reamer sleeve S is threaded at its rear end over a longitudinal water tube W surrounding both of the tubes O and K, and extends forwardly over nozzle N to a position a short distance in back of the nozzle front end. Longitudinally extending radial teeth T_1 and T_2 on the outside of sleeve S project forwardly therefrom to a position about even with the front end of nozzle N for grinding up and disintegrating detritus and for sizing a hole. Drag on the sides of a hole is reduced, with a commensurate increase in piercing rate, by having alternate teeth T_1 about the same length as the sleeve S, e. g about 14 inches, and the other teeth T_2 about half that length; and by having the rear ends of the long teeth T_1 lying on a circle of slightly smaller diameter than the circle upon which the front ends lie, for example 6⅜ inches at the rear and 6½ inches at the front. The difference in diameter can be effected by a gradual taper, or by steps.

All three of the tubes, W, O, and K extend rearwardly to a swing joint (not shown) which may be of the type disclosed and claimed in United States application Serial No. 140,296, filed January 24, 1950, by Ray O. Wyland, Jr., issued as United States Patent No. 2,628,817 on February 17, 1953. Such a swing joint supplies fuel, oxygen and water to the respective tubes while permitting

the tubes, the sleeve S, and the nozzle N all to rotate as a unit during the piercing of a hole in rock.

More specifically in accordance with the invention, the nozzle N includes a cylindrical header 11 having an annular flange 13 at its upper end fitting against the lower end of water tube W and bolted thereto. Water ducts 15 extend through flange 13 for conducting cooling water from tube W into an annular water chamber 17 between nozzle N and sleeve S.

Two parallel longitudinal bores 19 and 21 extend down from the top of header 11 for receiving the fuel and oxygen supply tubes K and O, respectively. An eccentrically arranged oxygen duct 23 leads from bore 21 to an orifice in the front face of header 11. A fuel duct 25 leads from bore 19 to an axially arranged conical orifice 26 in the front face of header 11, and includes a threaded axial front portion 27 and a rear inclined portion 28 connected to bore 19.

Nozzle N also includes a coupling sleeve 29 threaded over the lower portion of header 11 and having a series of circumferentially arranged radial water ducts 31 extending therethrough below the header.

A hollow atomizer body 33 comprises a cylindrical rear portion 35 fitting within coupling sleeve 29 and secured tightly thereto, as by a silver soldered joint 37, and a generally frusto-conical front portion 39 flaring forwardly from sleeve 29 and terminating at its front end in an annular shoulder 40 which engages at its outer edge the inside wall of the sleeve S. The interior of atomizer 33 comprises a cylindrical axial entrance bore 41 opening at its rear end into a conical axial rear counterbore 42 which engages a conical external shoulder 43 on the front end of header 11, and opening at its front end into a large conical axial front counterbore 45 which is symmetrical about the longitudinal axis of the nozzle and forms the rear portion of combustion chamber C. A fuel injector F extends into the atomizer 33. The tapered conical shape of counterbore 45 reduces erosion by combustion gases to a minimum and increases chamber life over previous blowpipes.

Cooling of atomizer 33 is accomplished by passing water from annular space 17 through radial ducts 31 into an annular water-distributing passage 47 surrounding bore 41. Passage 47 is formed by an annular external groove in the cylindrical atomizer portion 35 which registers with ducts 31. Water is conducted thence through a series of circumferenially arranged equally spaced bores 49 in the frusto-conical front portion 39 which extend parallel and close to the wall of counterbore 45 and terminate in orifices in the annular shoulder 40. Cooling of the atomizer 33 and injector F in the way described has increased its life to from 10 to 20 times that obtained with previous constructions.

Nozzle N is completed by an orifice tip 51 which has an annular rear shoulder 53 engaging the inner edge of atomizer shoulder 40 and secured thereto, as by silver soldering at 55. From shoulder 53 the orifice tip 51 extends forwardly in spaced relation to the inside wall of sleeve S to a rearwardly facing annular shoulder 57 which defines, with the shoulder 40, an annular external groove 59 for receiving cooling water from the bores 49. The tip 51 extends forwardly from shoulder 57 as a cylindrical section 61 which closely engages the inside wall of sleeve S, and projects forwardly therefrom. A gasket 60, such as a rubber O-ring in an annular groove 62, prevents water leakage past the tip. The front or bottom end of tip 51 comprises a flat central surface 63 normal to the blowpipe axis, surrounded by a frusto-conical beveled surface area 65.

The rear end of tip 51 is provided with a cavity 67 having a smooth rounded hemispherical wall 69 which is symmetrical about the longitudinal axis of nozzle N, and

joins smoothly with the frusto-conical wall **45** to complete the internal combustion chamber C. Wall **69** could also have the shape of any other conic section, such as a paraboloid or ellipsoid. The important factor is a shape without abrupt changes in cross section, which permits smooth streamline flow of combustion gases to reduce erosion of the nozzle to a minimum.

Pressures between 10 and 250 pounds per square inch (gauge) can be maintained in combustion chamber C, but for best results pressures from 50 to 150 pounds per square inch are used, with a combustion temperature of about 5500° Rankine for oxy-kerosene. These relatively low chamber pressures facilitate operations and decrease costs by reducing the pressures which must be maintained in oxygen and fuel supply conduits. Previous burners had to be operated at 150 and 200 pounds per square inch and required commensurately high pressures in the fluid supply system.

For discharging burning gases from internal combustion chamber C at supersonic velocity the tip **51** is provided with an axial flame discharge passage **71** having an outlet located centrally in its end surface **63**, and two symmetrically arranged divergent flame discharge passages **73** and **75** on opposite sides of the axial passage **71** having their outlets located on its frusto-conical end surface **65**. The passages **73** and **75** should diverge from the blowpipe axis at an angle not more than 45° to keep the piercing component of the flame jet greater than the lateral component. All of the flame discharge passages **71**, **73**, and **75** have their longitudinal axes located in the same common plane, which also includes the longitudinal axis of the blowpipe. Each flame discharge passage includes a relatively short inner conical section **77** having a wall which merges smoothly with the hemispherical wall **69**, all junctions being smoothly rounded to induce stream line flow from chamber C and thereby reduce erosion and overheating to a minimum. The walls of each conical section converge to a relatively narrow throat **79**, after which comes a relatively long conical section **81** whose wall diverges to an exit. Machining cost is reduced by having the three flame discharge passages **71**, **73**, and **75** all the same size. The divergent section **81** facilitates lighting of the burner, but a cylindrical section can also be used successfully.

The volume of combustion chamber C is related to the discharge orifice area by the L ratio, which is the ratio of chamber volume in cubic inches to total discharge orifice area in square inches. The improved atomization and combustion characteristics of the present blowpipe make possible an L ratio in the range of 14 to 121, and preferably in the range of 20 to 80.

Since the tip **51** is subjected to tremendous heat during operation of the blowpipe, it is essential that a network of water conduits be provided and that cooling water be circulated at high velocity. About 25 gallons of water are used for each gallon of kerosene burned. The central flame discharge passage **71** is surrounded by a series of closely spaced parallel longitudinal drillings **83**–A and **83**–B arranged in a ring below combustion chamber C to act as water header passage means. Drillings **83**–A and **83**–B are drilled in from the front face of tip **51** and are closed at their front ends by a metal ring **84** which fits within an annulus **86** and is tightly secured to the tip, as by silver soldering. Water is supplied to the drillings **83**–A by a series of circumferentially arranged inclined radial ducts **85** extending from the annular groove **59** to the rear ends of the several drillings, three ducts entering each drilling. A second smaller series of inclined radial ducts **87** extends from groove **59** to a position between the ends of two drillings **83**–B which are located between, and in the same plane as, the several flame discharge passages, two ducts entering each drilling.

Circulation of cooling water in the parts of the orifice tip **51** which are subjected to the greatest heat is improved by providing a lateral bore **88** which interconnects three adjoining drillings **83**–A and **83**–B between the flame discharge passages **71** and **75**, and a second lateral bore **90** which interconnects three adjoining drillings **83**–A and **83**–B between the flame discharge passages **71** and **73**.

The number and sizes of coolant passages described above should be such that water circulates at velocities between 15 and 30 feet per second, and that the velocity increases in steps in order to eliminate air pockets by keeping the water under pressure. High velocity water cooling increases the nozzle life considerably compared with tank-type low velocity water cooling. It is also desirable that cooling passages be separated from the combustion chamber by about ⅛ inch of metal.

Water leaves the drillings **83**–A and **83**–B through a series of circumferentially arranged radial water ejection ports **89** which extend to orifices in the peripheral surface of the nozzle N just ahead of the forward end of reamer sleeve S in position to discharge cooling water against the reamer sleeve and the teeth T_1 and T_2, thus lengthening their lives considerably by preventing burn off and scarfing. Ports **89** desirably are either normal to the longitudinal axis of the blowpipe, or inclined slightly rearwardly and outwardly. The water quenches the detritus and renders it more friable for disintegration, and is then vaporized to steam by the heat of the flame and acts in concert with the gaseous products of combustion to eject particles of detritus from the hole being pierced.

A combustible mixture can be introduced through the cylindrical bore or entrance **41** into combustion chamber C in any desired way. However, it has been found especially advantageous to direct a ring of longitudinally flowing oxygen streams at high velocity toward the chamber while concurrently directing into the oxygen streams from within the ring a plurality of radial streams of liquid fuel, such as kerosene, flowing substantially normally to the oxygen streams. The latter streams shear off and atomize the liquid fuel streams to form a combustible mixture which is then injected into the combustion chamber and burned. Injecting the fuel in a number of jets increases the surface area available for atomization and this, coupled with the shearing action of the oxygen streams, improves mixing and fuel utilization over previous procedures.

The foregoing method of operation is accomplished by supplying liquid fuel from the header duct **25** to an axial longitudinal bore **91** in the fuel injector F which is threaded into the front portion **27** of duct **25** and has an annular conical seat **99** abutting against header **11**. Bore **91** terminates short of the front end of injector F and fuel is discharged therefrom through a series of circumferentially arranged equispaced radial ports **93** whose outer ends severally open into a plurality of longitudinal grooves **95** formed between longitudinal lands **97** which fit snugly within the cylindrical nozzle bore **41**. While only one radial port has been shown as entering each groove **95**, it is apparent that more ports can be used. The injector can be operated successfully without the lands **97**, so that the fuel is discharged into an annulus.

Grooves **95** communicate at their rear ends with the first conical counterbore **42** so that oxygen entering the latter from header duct **23** passes at a high velocity (between 200 and 300 feet per second with a pressure drop of 2–5 pounds per square inch have been used successfully, but velocities up to or greater than 1500 feet per second with proportionately larger pressure drops can also be used) through the several grooves and shears off the fuel streams from radial ports **93**, atomizes the fuel, and forms an intimate mixture for combustion in chamber C. Only about 300 feet of hole could be pierced in rock when using former conical injectors due to erosion of the injector face. With the described injector 900–1200 feet of hole have been pierced without difficulty.

When piercing a hole in a mass of rock with a blowpipe it is essential to reduce to a minimum the formation of annular obstructions or collars which prevent passage of the blowpipe. Every time such a collar is formed time

is lost in burning it out because special manipulation of the blowpipe is required. It has been found that the collar-cutting efficiency of a rock piercing blowpipe is highest when at least one flame discharge passage diverges from the longitudinal axis of the blowpipe at an angle such that the distance is between 2 and 4 inches from the outlet of the flame discharge passage to the point at which the longitudinal axis of the flame discharge passage intersects a forward projection of an imaginary circle upon which the outer surfaces at the front ends of reamer teeth T_1 and T_2 lie. This distance, called the standoff distance, is shown at D in Fig. 1. In one specific example a pair of oppositely divergent flame discharge passages **73** and **75**, as shown in Fig. 1, each diverged at 30° from the blowpipe axis and the standoff distance was 3¼ inches when teeth T_1 and T_2 lay on a circle of 6½ inches diameter.

The blowpipe described in detail above has a considerably longer useful life than rock piercing burners available previously. It also makes possible higher piercing rates than heretofore. Furthermore it makes possible the piercing in rock of an easily loadable hole of quite uniform diameter and contour while providing a maximum of explosive-loadable hole volume per unit of oxygen consumed. Also, it is rugged in construction, and can easily be taken apart and reassembled for the replacement or repair of parts.

What is claimed is:

1. A rock-piercing blowpipe comprising a nozzle having a longitudinal axis, and having therein an internal combustion chamber, a longitudinal flame discharge passage leading from said chamber to an outlet in a face of said nozzle, entrance means to said chamber, and a fuel injector in said entrance means; said nozzle also having an annular external groove between the ends of said combustion chamber, and a pair of opposed annular shoulders on opposite sides of said groove; said nozzle also having therein an annular internal water-distributing passage near the top of said combustion chamber surrounding said injector, radial water ducts extending therefrom to the outside of said nozzle, and internal longitudinal water conduits arranged in a ring around said combustion chamber and connecting together said groove and said water-distributing passage for carrying cooling water at high velocity; said nozzle also having header passage means for cooling water arranged in a ring around said flame discharge passage below said internal combustion chamber, a plurality of circumferentially arranged water supply ducts extending from said groove to said header passage means below said combustion chamber, and a plurality of radial water ejection ports extending from said header passage means to orifices in the peripheral surface of said nozzle for discharging water jets from said blow pipe; said blowpipe also comprising a sleeve over said nozzle engaging said opposed shoulders and spaced from the outside of said nozzle above said shoulders, providing an annular water chamber in communication with said radial water ducts.

2. A rock-piercing blowpipe comprising a nozzle body having a longitudinal axis, and having therein an internal combustion chamber, a plurality of flame discharge passage means leading from said chamber to an outlet in a face of said nozzle, entrance means to said chamber, and a fuel injector in said entrance means; said nozzle also having an annular external groove between the ends of said combustion chamber, and a pair of sealing annular shoulders adjacent said groove; a sleeve over said nozzle engaging water tightly with said shoulders and spaced from the outside of said nozzle above said groove, providing an annular water chamber around the nozzle; said nozzle also having longitudinal water conduit means arranged around and thermally integral with said combustion chamber having their inlet portions communicating with the annular water chamber above said groove and connecting into said groove for carrying cooling water at relatively high velocity; said nozzle also having header passage means therein for cooling water arranged around and between said flame discharge passage means below said internal combustion chamber, a plurality of circumferentially spaced water supply ducts extending from said groove to said header passage means below said combustion chamber, and a plurality of radial water ejection ports extending from said header passage means to orifices in the peripheral surface of said nozzle for discharging water jets from said blowpipe.

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