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ROCK PIERCING BLOWPIPE HAVING INTERNAL COMBUSTION CHAMBER

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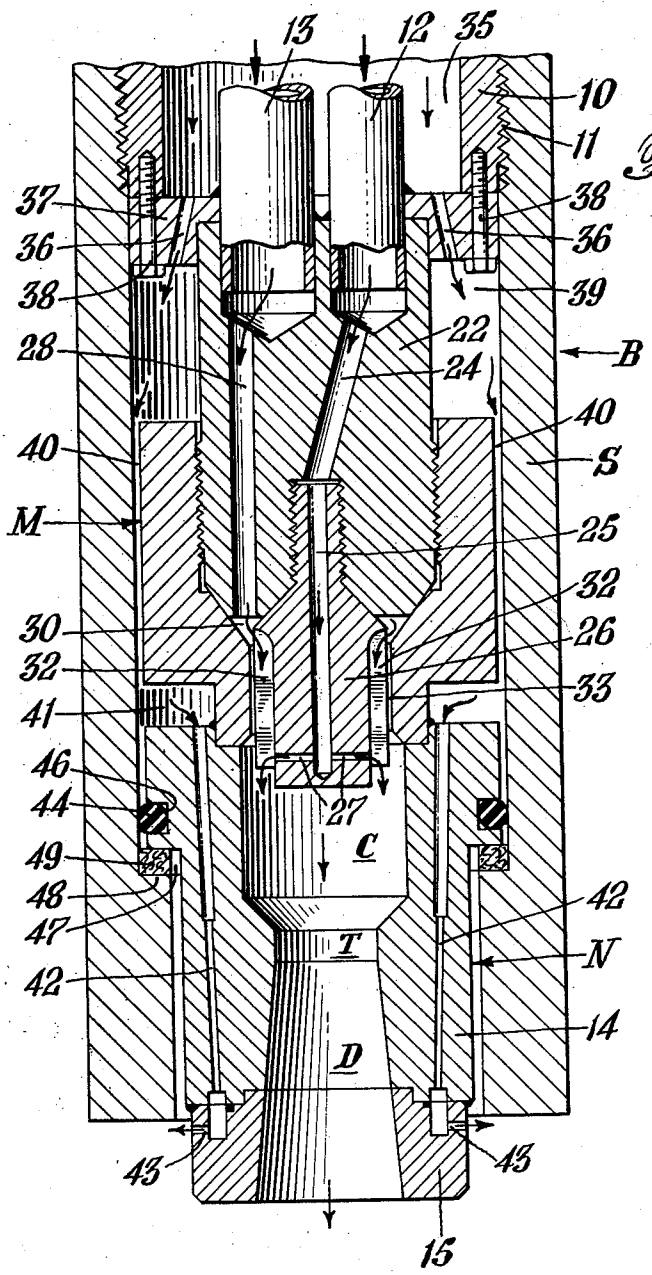


Fig. 1.

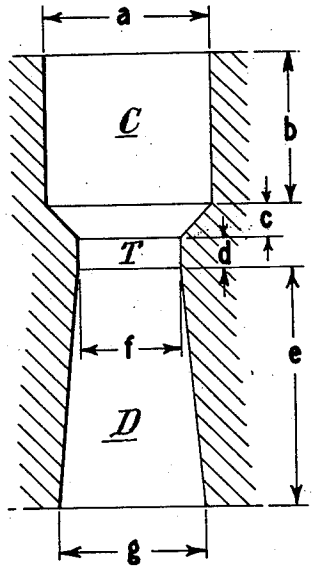


Fig. 2.

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ROCK PIERCING BLOWPIPE HAVING INTERNAL COMBUSTION CHAMBER

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Continuation of application Ser. No. 428,045, May 6, 1954. This application Apr. 4, 1956, Ser. No. 576,030
3 Claims. (Cl. 175—14)

The present invention relates to rock piercing blowpipes and, more particularly, to high velocity rock piercing blowpipes having internal combustion chambers of the jet burner type.

Heretofore, the use of blowpipes of the internal combustion chamber type has been proposed for the rock piercing of heat spallable mineral bodies. These blowpipes, such as the apparatus disclosed in U.S. Patent No. 2,628,817 to R. O. Wyland, Jr., supply a fluid fuel and an oxidant to an internal combustion chamber at a suitable pressure, there burn the mixture, and discharge the combustion products through a restricted throat section and diverging nozzle against the mineral body to be pierced. Cooling water is concurrently passed through the blowpipe around the walls of the internal combustion chamber and is discharged from the burner tip in the vicinity of the hot burner flame whereupon it flashes to steam and serves to eject spalled mineral material from the rock pierced hole. It has been found that such prior blowpipes, while they pierced holes in mineral bodies to considerable depth at hitherto unknown speeds, required that large quantities of cooling water be passed around the combustion chamber to maintain proper cooling. This large quantity of cooling water, when discharged from the blowpipe in the area of the flame, was found to be more than could efficiently be flashed to steam by the jet flame, and accordingly, tended to flood the working area at the bottom of the hole and reduce the efficiency of the flame in its normal spalling of the mineral body.

It is the main object of the present invention to provide a method of operation for a blowpipe of the high velocity internal combustion type for thermal rock piercing of mineral bodies so as to require the use of no more cooling water than can be easily flashed to steam by the jet flame and employed to remove detritus from the hole.

Another object is to provide a method of operation for such a blowpipe which will permit the use of a blowpipe more simplified in construction and more efficient in piercing a hole in a mineral body.

Other aims and advantages of the invention will be apparent from the following description and appended claims.

In the drawing:

FIG. 1 is a partial sectional view of a rock piercing burner nozzle embodying the invention; and

FIG. 2 is a schematic sectional view of a blowpipe combustion chamber, throat section and diverging discharge passage showing parameters involved in the invention.

Referring specifically to FIG. 1 of the drawing, a rock piercing blowpipe B is provided comprising a hollow cylindrical outer sleeve S enclosing inner cylindrical sleeve **10** secured to the inner walls of sleeve S by threads **11**. Conduits **12** and **13** pass through the length of hollow sleeve **10** for supplying fluid fuel, such as kerosene, and an oxidant, such as oxygen, to mixer assembly M secured within sleeve S near the lower end of blowpipe B. Mixer member M is axially aligned with and secured to nozzle member N which is positioned in sleeve S at the lower end of blowpipe B. Nozzle member N is composed of a body member **14** and a tip member

15 axially aligned therewith and contains an internal combustion chamber C, which discharges through a throat section T to a diverging passage D at the lower end of nozzle N.

Fluid fuel, such as kerosene, is passed the length of the blowpipe through longitudinal conduit **12** which is secured to upper member **22** of mixer assembly M. Boring **24** in member **22** communicates with conduit **12** and supplies the fuel to longitudinal passage **25** of atomizer **26** of mixer assembly M and in turn to radial ports **27**.

Concurrently therewith, an oxidant, such as gaseous oxygen, is passed the length of the blowpipe through longitudinal conduit **13** which is secured to upper member **22** of mixer assembly M. Longitudinal boring **28** in member **22** communicates with conduit **13** and supplies the oxidant to annular space **30** around atomizer **26** and passages **32** spaced between longitudinal fins **33** circumferentially spaced about the outer surface of atomizer **26**.

Fuel and oxidant are mixed in radial passages **32** in the region of radial ports **27** near the entrance to internal combustion chamber C. Substantially complete mixing is accomplishd by the time the gases pass into the chamber C and the combustion of the mixture takes place in chamber C, the throat section T, and diverging discharge passage D and a high velocity jet flame, having a velocity greater than sonic velocity, is discharged through diverging discharge passage D.

Cooling water is passed through the length of the blowpipe through internal passage **35** of sleeve **10** and communicates with a plurality of radially arranged longitudinal borings **36** in ring **37** which is secured to sleeve **10** as by bolts **38**. The water is then discharged from borings **36** into annular space **39** between member **22** and sleeve S. The water then flows through the space **40** between mixer M and the internal wall of sleeve S to annular space **41** between mixer M and nozzle number N. A plurality of radially arranged longitudinal borings **42** communicate with annular space **41** and carry the cooling water through nozzle member N around the combustion chamber C, throat section T and discharge passage D and discharge it through a series of water ports **43** radially arranged about the lower circumference of nozzle member N. A rubber O ring **44** is secured in annular groove **46** of the nozzle member and serves to insure a tight fit between that member and the interior surface of sleeve S to prevent leakage of the cooling water through that space. Annular space **47** is provided between lip **48** in the interior of sleeve S and nozzle member N to accommodate flame break gasket **49** of asbestos or similar material.

The present invention resides specifically in a method of operating a blowpipe having a combustion chamber, throat section, and diverging discharge passage maintained at proper dimensions.

Referring specifically to FIG. 2 of the drawing, the combustion chamber C comprises a cylindrical portion, having a diameter *a* and length *b*, and a truncated conical portion of height *c*, upper diameter *a* and lower diameter *f*. The volume of the combustion chamber C is, therefore, the sum of the volumes of the cylindrical and truncated conical portions, and can readily be determined from the dimensions *a*, *b*, *c*, and *f*. Throat section T, positioned between combustion chamber C and diverging discharge passage D and aligned therewith, is shown to have a depth *d* and a diameter *f*. Diverging discharge passage D comprises a truncated conical passage having a length *e*, an upper diameter *f* and a lower diameter *g* at the exit end of the passage.

In the prior art, flame jet nozzle construction is defined in terms of expansion ratio, which is the ratio of flame or mouth area (at the point of flame) to the area

of the throat section, and L-star ratio, which is the ratio of combustion chamber volume to throat area.

It has been found that the easiest way to increase burner efficiency is to decrease the area through which the greatest amount of energy transfer takes place, i.e. the surface area of the combustion chamber wall. The gas temperature in this chamber is in the neighborhood of 5500° R. (in the case of an oxy-kerosene fuel mixture). A reduction in chamber area offers a consequent reduction in chamber volume and L-star ratio.

The highest efficiency of combustion is effected when injection, atomization, and combustion takes place under pressure. While the first two do not require a combustion chamber of large volume, complete combustion under pressure employing low grade less volatile fluids (such as kerosene) requires a chamber having a much larger volume. Accordingly, in the apparatus of the invention combustion is initiated under pressure, although not completed in the combustion chamber, and the reduction in surface area of the chamber results in a decreased energy loss through the walls of the chamber to the cooling fluid. In this manner, the available heat content of the flame is believed to be unchanged or slightly increased.

Prior art blowpipes employed nozzles having expansion ratios on the order of 1.4 (for a chamber pressure of about 65 p.s.i.g.) resulting in the expansion of the combustion gases down to atmospheric pressure. It has been found that as the gases pass through the throat section T and are expanded in the diverging discharge section D the temperature drops. When employing a combustion chamber of reduced volume, the gases are still burning in the throat section and discharge passage and thus completion of combustion reheats the gases above the value heretofore obtainable in prior art nozzles employing normal expansion. Thus, for the same fuel and oxidant consumption, an increase in flame front area in excess of approximately 80% is obtainable. In connection with this phenomenon it has long been believed that the closer the ratio of flame or mouth area to cross-sectional area of the blowpipe is to unity, the more efficient will be the piercing results.

A ratio closer to unity is achieved by providing a method wherein for a throat dimension T, fixed by the pressures utilized, the B.t.u. capacity and the desired flow rate etc., a reduction in chamber volume C will decrease the L-star ratio and permit the utilization of an expansion ratio (flame area to area of throat) larger than heretofore obtainable for the same conditions. Thus, a larger flame area is achieved while the overall outside dimension remains constant and as a result the ratio of flame area to outside area of the blowpipe approaches unity.

Prior art rock piercing burners employed chambers and throat sections having L-star ratios between about 20 and 30, expansion ratios in the neighborhood of 1.2 to 1.5. It has been found that rock piercing burners employing combustion chambers and throat sections giving L-star ratios between about 1.0 and about 5.0, with corresponding expansion ratios, have operated at greater efficiency with a much lower cooling water rate requirement.

It is known in the prior art that when employing conventional internal combustion jet flame burners (having L-star ratios between about 20–30) the proper value of expansion required for efficient operation can be determined by the following equation:

$$\text{E.R.}=\frac{A_m}{A_t}=\frac{\left(\frac{2}{K+1}\right)^{\frac{1}{K-1}}\left(\frac{P_c}{P_m}\right)^{\frac{1}{K}}}{\sqrt{\left(\frac{K+1}{K-1}\right)\left[1-\left(\frac{P_c}{P_m}\right)^{\frac{1-K}{K}}\right]}}$$

wherein:

A_m=mouth area
A_t=throat area
K=ratio of specific heats of combustion products
P_c=chamber pressure
P_m=pressure at mouth of diverging discharge passage.

For an oxy-kerosene mixture, as is commonly employed in rock piercing blowpipes, the value of $K=1.21$. By substituting this value for K in the above equation, the formula simplifies to:

$$\text{E.R.}=\frac{0.1872\left(\frac{P_c}{P_m}\right)^{0.833}}{\sqrt{1-\left(\frac{P_c}{P_m}\right)^{-0.166}}}$$

Therefore, with conventional prior art blowpipes employing an oxy-kerosene fuel mixture, it can be seen that, once the chamber and discharge (mouth) pressure are determined by fuel flow rates, etc., the value of expansion ratio required for proper operation can be determined.

It has been found that with blowpipes embodying the invention the operable value of expansion ratio employed may vary between the value obtained from the first equation set forth hereinabove and 2.5 times that value, with most efficient expansion occurring at a value approximately 80% greater than that obtained from the formula. For example, a five inch blowpipe burning an oxy-kerosene fuel mixture with a chamber pressure of 65 p.s.i. and a mouth pressure of about 15 p.s.i. was found to operate with greatest flame stability with an expansion ratio of about 2.5 for an L-star ratio of about 2.0, as shown in the table below.

The factor K, which is important in most perfect gas calculations, is defined by the textbooks on thermodynamics as the ratio of specific heats. In the case of gaseous substances it is customary to define K as the ratio of specific heat for a constant pressure process Cp to the specific heat for a constant volume process Cv. The K value given in column 4 above as 1.21 is merely an example of a typical K value obtained when the specific heats of the products of combustion for an oxy-kerosene reaction are proportioned according to the mols of product present. For example, consider the following reaction:

$$C_{10}H_{20}+22O_2\rightarrow 8CO_2+2CO+18H_2O+H_2+4O_2$$

The total mols of product are 33. The specific heats of each of the products of combustion, at the appropriate temperature, is proportioned according to mols of such product present relative to the total mols to give a weighted specific heat ratio (K) for the entire combustion product. For example, the weighted specific heat ratio for oxygen would be 4/33 of the specific heat ratio for oxygen at the proper temperature. This value added to the weighted specific heat ratios of the other combustion products gives the total weighted specific heat ratio. In the example given above this weighted specific heat ratio (K) was calculated to be 1.21.

As a consequence of the improved chamber and throat section construction in accordance with the invention it has been found that the cooling water required by the process is reduced by approximately 50% over the flow required to cool the nozzles of prior art burners. This reduction in required cooling water flow rate has increased the overall efficiency of the thermal rock piercing operation by reducing the quantity of water to an amount which can easily be flashed to steam and prevent an excess of water build-up in the hole. It is believed that the reduction in the required cooling water flow rate is accomplished by the great reduction in area of extremely high temperature walls of the combustion chamber, thereby reducing the heat transfer area between the hot combustion products and the cooling water. It is also

believed that the spreading out of complete combustion over the entire flame path accomplishes better cooling efficiency with less water than was required around the extremely hot large area combustion chamber walls of prior art blowpipes.

The following table sets forth data for a five inch rock piercing burner embodying the present invention and also contains equivalent data relating to a five inch rock piercing blowpipe built in accordance with prior art teachings.

Table

Dimension	Units	Blowpipe Embodying the Invention	Prior Art Blowpipe
Throat Dia	in.	0.951	0.951
Throat Area	in.^{2}	0.7103	0.7103
Max. Chamber Dia	in.	1.500	2.750
Chamber Length	in.	0.87	3.875
Chamber Volume	in.^{3}	1.5	14.25
Mouth Dia	in.	1.330	1.120
Mouth Area	in.^{2}	1.389	0.985
Angle of Divergence	deg.	13	9
Nozzle Length	in.	1.625	1.250
L-Star Ratio	in.	2.0	20
Expansion Ratio		2.0	1.39
Water Flow	g.p.h.	325	750
Oxygen Flow	c.f.h.	10,000	10,000
Fuel Rate	lb./hr.	275	275
Chamber Pressure	p.s.i.g.	65	65

It can be seen that for identical fuel and oxidant flow rates the blowpipe embodying the invention requires less than half the cooling water flow rate required for the prior art blowpipe. It was also found that, due to a higher flame temperature and approximately 80% greater flame front, the overall efficiency and piercing rate for the burner embodying the invention greatly exceeded that of the prior art burner.

In an actual rock piercing operation in a granitic gneiss quarry a standard five inch prior art blowpipe, having dimensions as set forth in the table above, was employed to pierce the first 255 feet of hole. The piercing rate average 22.0 feet per hour. For the next 388 feet of hole a five inch blowpipe embodying the invention was employed and the average piercing rate obtained was 31.5 feet per hour. It was found that the water cooling rate required with the blowpipe embodying the invention was approximately half of that required by the prior art blowpipe.

As employed herein, all pressures are absolute pressures unless specified to the contrary.

This is a continuation of my copending application Serial No. 428,045, filed May 6, 1954, now abandoned.

What is claimed is:

1. A mineral working blowpipe comprising, an elongated body member having first and second ends; a flame nozzle member at said first end thereof having an internal combustion chamber capable of sustaining combustion at greater than critical pressure and discharging a high velocity flame jet through a restricted throat section and a diverging passage to an exit port at an external surface of said nozzle member; inlet means positioned near said second end for supplying fluid fuel, oxidant and cooling fluid to said blowpipe; internal passage means in said elongated body member for individually transmitting said fluid fuel, oxidant and cooling fluid from said inlet means to said nozzle member; atomizing means in said nozzle member for mixing said fluid fuel and oxidant and passing the as-formed mixture into said internal combustion chamber; said internal combustion chamber having a

volume, and said restricted throat section and diverging passage an exit area, so proportioned to provide an L-star ratio of between about 1.0 and 5.0 and an expansion ratio between about one and two and one-half times the value obtained from the equation:

$$E.R.=\frac{\left(\frac{2}{K+1}\right)^{\frac{1}{K-1}}\left(\frac{P_c}{P_m}\right)^{\frac{1}{K}}}{\sqrt{\left(\frac{K+1}{K-1}\right)\left[1-\left(\frac{P_c}{P_m}\right)^{\frac{1-K}{K}}\right]}}$$

wherein:

$$\text{L-star ratio}=\frac{\text{Combustion chamber volume (cu. in.)}}{\text{throat section area (sq. in.)}}$$

E.R.=expansion ratio

K=ratio of specific heats of combustion products

P_c=chamber pressure (p.s.i.)

P_m=mouth pressure at diverging discharge passage exit (p.s.i.)

2. A mineral working blowpipe according to claim 1 in which said internal combustion chamber and said restricted throat section are so proportioned to provide an L-star ratio of between 1.5 and 3.5.

3. In a mineral working blowpipe comprising a flame nozzle member having an internal combustion chamber capable of sustaining combustion at greater than critical pressure and discharging a high velocity flame jet through a restricted throat section and a diverging passage to an exit port at an external surface of said nozzle member; means for supplying fluid fuel, oxidant, and cooling fluid to said nozzle member; and means in said nozzle member for mixing said fluid fuel and oxidant and passing the as-formed mixture into said internal combustion chamber the improvement which comprises providing said internal combustion chamber with a volume, and said restricted throat section and diverging passage with an exit area, so proportioned to provide an L-star ratio of between about 1.0 and 5.0 and an expansion ratio between about one and two and one-half times the value obtained from the equation:

$$E.R.=\frac{\left(\frac{2}{K+1}\right)^{\frac{1}{K-1}}\left(\frac{P_c}{P_m}\right)^{\frac{1}{K}}}{\sqrt{\left(\frac{K+1}{K-1}\right)\left[1-\left(\frac{P_c}{P_m}\right)^{\frac{1-K}{K}}\right]}}$$

wherein:

$$\text{L-star ratio}=\frac{\text{Combustion chamber volume (cu. in.)}}{\text{throat section area (sq. in.)}}$$

E.R.=expansion ratio

K=ratio of specific heats of combustion products

P_c=chamber pressure (p.s.i.)

P_m=mouth pressure at diverging discharge passage exit (p.s.i.)

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