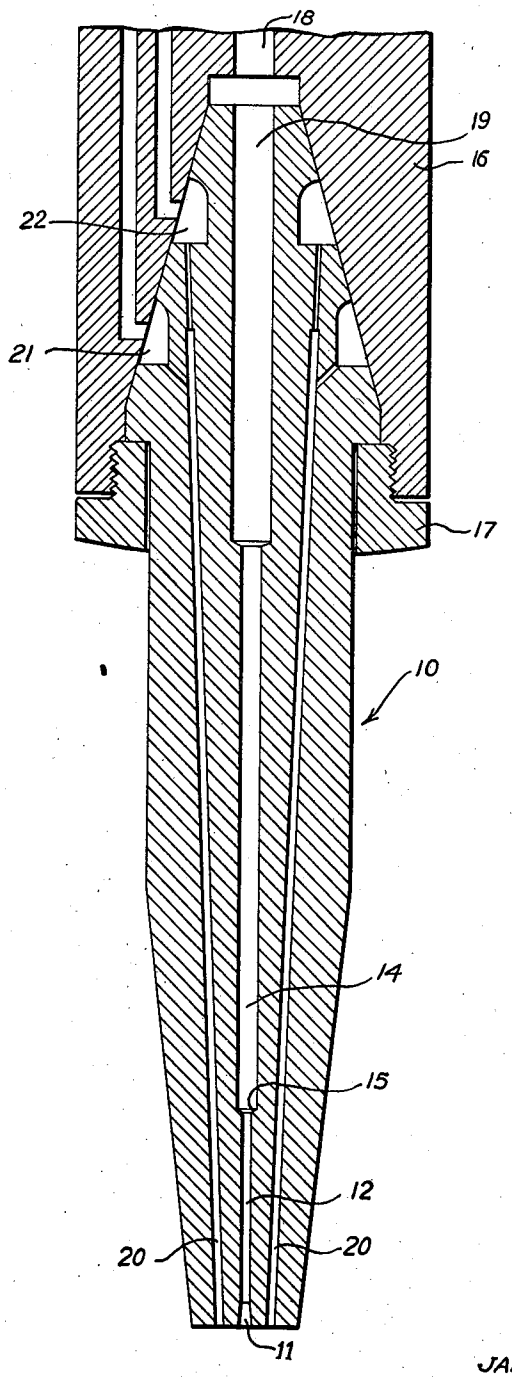
April 10, 1945. J. K. HAMILTON 2,373,309

DIVERGENT-OUTLET CUTTING TORCH

Filed May 26, 1942



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Patented Apr. 10, 1945

2,373,309

UNITED STATES PATENT OFFICE

2,373,309

DIVERGENT-OUTLET CUTTING TORCH

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Application May 26, 1942, Serial No. 444,544

7 Claims. (Cl. 158—27.4)

This invention relates to oxygen cutting torches, and especially to torches that have a divergent outlet for the cutting oxygen.

In standard cutting tips of the prior art in which the oxygen stream is discharged from a cylindrical passage and at a pressure higher than atmospheric, the gas stream expands suddenly at the discharge end of the tip to about atmospheric pressure. This sudden expansion results in extreme turbulence. It may be shown by static pressure measurements and other means that the oxygen upon leaving the tip may actually expand to a pressure below one atmosphere, later be compressed above atmospheric pressure, and then go through numerous repetitions of this cycle. The expansion of the oxygen stream increases the width of the kerf and thus increases the amount of metal that is removed in making a cut.

In a cutting tip that is constructed with a properly designed divergent outlet, the oxygen expands from a value in the throat of 0.53 of the initial pressure at the throat entrance to atmospheric pressure within the confines of the divergent portion of the tip. The pressure at the end of the tip is one atmosphere and the only turbulence in the emerging stream is the result of imperfections in the tip proper.

The velocity of a gas discharging from a nozzle is given by the following relationship

$$V=\sqrt{\frac{2gk}{K-1}RT_1\left[1-\left(\frac{P_2}{P_1}\right)^{\frac{K-1}{K}}\right]}$$

In which

V—vel. in ft./sec. at section where gas has expanded to P_2
g—acceleration of gravity
K—specific heat ratio
R—universal gas constant
T_1—initial absolute temperature—degrees F.
P_2—pressure on discharge end of nozzle—pounds/sq. in. absolute
P_1—pressure on inlet side of nozzle—pounds/sq. in. absolute

For oxygen the above equation may be reduced to the following

$$V=2390\sqrt{1-\left(\frac{P_2}{P_1}\right)^{\frac{K-1}{K}}}$$

using

K=1.405
R=48.2
T=530° F. absolute

The velocities of these equations are not exactly those obtained in practice because of heat transfer, friction, and some initial upstream velocity, but the equations do establish that the maximum velocity with a divergent tip approaches a value of about 2400 ft./sec., as the initial pressure is increased. With an initial pressure of 100 pounds/sq. in. the discharge velocity is about 1600 ft./sec. with a tip designed to discharge at a pressure of one atmosphere.

These velocity relations do not apply when standard tips having cylindrical outlet passages are considered. Since the pressure in the discharge end of a standard tip is always about 0.53 of the initial pressure, the exit velocity will always be the same regardless of what initial pressure is used. The value may be computed as about 1000 ft./sec. This does not imply that it is impossible to obtain higher velocities with standard tips after the stream leaves the tip. Sudden expansion does result in higher velocities which are less, however, than obtained with divergent tips.

Because of the higher velocity of the divergent outlet tip, sufficient oxygen for cutting a given thickness of metal can be obtained with a narrower jet than is the case with a standard tip; and the jet from a divergent outlet tip has little or no tendency to spread out since the pressure of the stream is approximately the same as that of the surrounding atmosphere. In the case of a standard tip, it is impossible to obtain a parallel stream except at very low pressures, because the discharge pressure is greater than atmospheric, thus giving a spreading exit stream.

The theoretical shape of the throat and discharge passage of a divergent outlet tip involves curved surfaces that are difficult and expensive to obtain in manufacture of the tips. I have discovered that if certain relationships are kept within determined ranges, such curved surfaces are not necessary, and that cylindrical and frustoconical surfaces are sufficient. Some of these relationships are opposed to what would be expected from theoretical considerations. For example, I have found that better results are obtained with a long throat, though the reason is obscure and, in theory, the longer throat is objectionable because it increases the frictional resistance of the passage. I have found that what is usually practiced in steam nozzle design does not give the best results when applied to oxygen cutting tips, though here again the reason is not clear.

In its broadest aspects, it is an object of this invention to provide an improved cutting torch, and a more particular object is to provide a di-

vergent outlet cutting torch that is less expensive to manufacture.

Other objects, features and advantages of the invention will appear or be pointed out as the specification proceeds.

The drawing is a sectional view taken on a central plane through the tip end of a torch embodying the invention.

The drawing shows a tip 10 with a centrally located, diverging outlet passage 11 for the cutting oxygen. The passage 11 is in axial alinement with a throat 12. The passage 11 has straight sides that comprise a frusto-conical surface that meets a straight cylindrical wall of the throat 12.

Oxygen flows to the throat 12 through an approach passage 14 that is in axial alinement with the throat. The passage 14 is cylindrical, and of larger diameter than the throat. At the downstream end of the passage 14 there is a tapered surface 15 left by the end of the drill that is used to make the passage 14. The included angle of the surface 15 is of the order of 120 degrees when a standard drill is used, and this surface provides a transition from the full diameter of the approach passage 14 to the diameter of the cylindrical throat 12. The use of this angular surface left by the drill in the transition between the approach passage and the reduced-diameter passage through the throat gives good results if the diameter of the approach passage 14 is from one-and-a-half to two-and-a-quarter times as great as the diameter of the throat. This range in diameter makes the area of cross-section of the throat between $\frac{3}{16}$ and $\frac{1}{9}$ of the cross-sectional area of the approach passage.

It is important that there be no burrs left at either the inlet or outlet ends of the throat where the tapered or frusto-conical surfaces meet the cylindrical throat surface.

In theory, a long throat would impair the performance by increasing the friction in the tip. Contrary to theory, better results are obtained by increasing the length of the throat. A length equal to from 15 to 20 times the diameter of the throat gives good results, and the performance of the tip is very much impaired if the length of the throat is made less than three times its diameter. With everything else the same in the tip structure, I find by experience that with a throat of shorter length, considerably more oxygen is required to make a given cut. The reason may be that there is some turbulence set up at the upstream end of the throat and that in a longer throat the gas stream becomes stabilized before it expands in the diverging outlet passage.

The ratio of the diameter of the outlet end of the passage 11 to the diameter of the throat 12 is the expansion ratio of the tip. I find an expansion ratio of from 1.20 to 1.35 to be most advantageous, and a range from 1.15 to 1.40 practical. This permits the torch to be used with an upstream pressure around 100 pounds per sq. in. and the gas stream discharged at approximately atmospheric pressure. This obtains a jet velocity close to 1600 ft./sec. Because of the shape of the velocity curve an increase in the pressure of gas supplied to the torch to 500 pounds/sq. in. will obtain an increase in jet velocity of only about 300 ft./sec. High expansion ratios are therefore not advantageous in practice because the benefit of the slight velocity increase is more than offset by the necessity of using regulators adjustable for high pressure, by considerations of hose strength and flexibility, and by the fact that existing oxygen installations are not generally equipped for supplying gas at such high pressure.

Although a tip constructed to operate with a supply pressure of 100 pounds/sq. in. will not deliver gas at a pressure of exactly one atmosphere with any other supply pressure, I find that some variation in supply pressure can take place without destroying the parallel sides of the jet. In describing the pressure as "around 100 pounds/sq. in.," a range of pressure from about 70 pounds/sq. in. up to about 120 pounds/sq. in. is contemplated.

The angle of divergence of the passage 11 is the angle included between the surfaces of the passage diametrically opposite each other. This angle is preferably between 4 and 10 degrees.

It is advantageous to employ the smaller expansion ratios and the larger angles of divergence with tips of larger size. Conversely, the larger expansion ratios and the smaller angles of divergence are better with tips of smaller size.

The following examples give these relations on a small and a large size tip.

Tip	Diameter outlet orifice	Throat diameter	Expansion ratio	Angle divergence
				Degrees
A	.032	.024	1.32	4
B	.083	.067	1.24	10

The tip 10 fits into a socket in a torch body 16 and is held in the torch body by a tip nut 17. The cutting oxygen flows from a conduit 18 into a passage 19 at the upper end of the tip. The passage 19 merges into the approach passage 14. The reasons for the different diameter passages 19 and 14 are practical. A single large-diameter passage 19 extending all the way to the throat 12 would have the disadvantage of producing too abrupt a change in section; above the range previously specified for the ratio of approach passage cross-section to throat cross-section. To extend the small-diameter passage 14 all the way to the top of the tip would make the drilling of the tip more difficult. The approach passage 14 should have a length ten or more times as great as the length of its diameter. With a short tip, a portion of the length of the approach passage can be in the torch body.

The tip 10 has preheating jet passages 20 arranged in a circle around the central cutting oxygen outlet 11. Oxygen and fuel gas for preheating flames are supplied to the jet passages 20 from annular chambers 21 and 22 that the tip forms with the torch body when the tip is positioned in its socket in the torch body.

It is not essential that the passages in the tip be round, and where the passages are described as round it wil be understood that others of non-circular cross-section may be considered mechanical equivalents. Terms of orientation are, of course, relative, and some features of the invention can be used without others.

I claim:

1. A cutting tip having a diverging outlet oxygen passage with a straight side wall throughout its length from its inlet end to the end of the tip, and a throat through which gas flows to the diverging passage, the ratio of the diameter of the delivery end of the diverging passage to the diameter of the throat being between 1.40 and 1.15, said throat having a straight side wall and being of uniform cross-section substantially throughout

its length and being of substantially the same diameter as the adjoining end of the diverging passage, and the length of said straight side wall of the throat being equal to more than three times the diameter of the opening through the throat.

2. An oxygen cutting torch having an approach passage, a throat that is of cylindrical cross-section and approximately fifteen to twenty times as long as its diameter, and a diverging outlet passage beyond the throat having a straight side wall throughout its length from the throat to the end of the tip, the diameter of the throat being substantially the same as the diameter of the adjoining end of the diverging passage and the ratio of the diameter of the delivery end of the diverging passage to the diameter of the throat being between 1.40 and 1.15.

3. A diverging-outlet cutting tip having a conduit that is of reduced diameter at one region to provide a throat whose length is greater than three times its diameter and that is of uniform section substantially throughout its length, said conduit being of uniformly increasing cross-section from the throat to the end of the tip and forming an outlet passage having a straight side wall throughout its length from the throat to the end of the tip, the ratio of the diameter of the delivery end of the outlet passage to the diameter of the throat being between 1.40 and 1.15, and the included angle of divergence of the uniformly increasing cross-section of the outlet passage being between 4 and 10 degrees.

4. A tip for an oxygen cutting torch, said tip having a diverging oxygen passage of frusto-conical form with a straight side wall throughout its length from its inlet end to the end of the tip, and a throat whose length is greater than three times its diameter and that is of cylindrical section substantially throughout its length and that connects with the small-diameter end of the diverging passage, the diameter of the throat being substantially the same as the diameter of the adjoining end of the diverging passage and the ratio of the diameter of the delivery end of the diverging passage to the diameter of the throat being between 1.40 and 1.15.

5. A cutting tip having a throat whose length is greater than three times its diameter and that is of uniform section throughout its length, a diverging outlet passage beyond the throat with an included angle between 4 and 10 degrees, the diameter of the throat being substantially the same as the diameter of the adjoining end of the diverging passage, the ratio of the diameter of the delivery end of the diverging passage to the diameter of the throat being between 1.40 and 1.15, and a generally cylindrical approach passage leading to the throat, the approach passage having a diameter between one-and-a-half and two-and-a-quarter times as great as the diameter of the throat and a straight frusto-conical portion connecting with the throat.

6. A cutting tip for delivering a high velocity and parallel-side oxygen stream into a kerf, said tip having an oxygen passage therethrough with a throat intermediate the ends of the tip, a diverging outlet passage on the discharge side of the throat and an approach passage on the supply side of the throat, the diverging outlet passage having a straight frusto-conical wall surface with an included angle between 4 and 10 degrees and a diameter at the discharge end of the outlet passage that is between 1.40 and 1.15 times as great as the diameter of the throat; the throat being cylindrical and communicating directly with the diverging outlet passage and having a length more than three times as great as its diameter, the approach passage having a converging portion that connects with the throat and a cylindrical portion that is from 1½ to 2¼ times as large in diameter as the throat, the length of the cylindrical portion of the approach passage being 10 or more times as great as its diameter.

7. A cutting tip for delivering a high velocity and parallel-side oxygen stream into a kerf, said tip having an oxygen passage therethrough with a throat intermediate the ends of the tip, a diverging outlet passage on the discharge side of the throat and an approach passage on the supply side of the throat, the diverging outlet passage having a straight frusto-conical wall surface with an included angle between 4 and 10 degrees and a diameter at the discharge end of the outlet passage that is between 1.40 and 1.15 times as great as the diameter of the throat, the throat being cylindrical and communicating directly with the diverging outlet passage and having a length more than three times as great as its diameter, the approach passage being cylindrical and from 1½ to 2¼ times as large in diameter as the throat, the length of the cylindrical approch passage being 10 or more times as great as its diameter.

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