July 23, 1968 J. BLUMENTHAL 3,393,988

METHOD OF FORMING A MINIATURE NOZZLE FROM A GLASS TUBE

Filed March 4, 1965

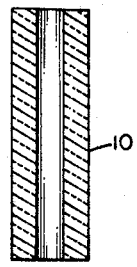

FIG. 2

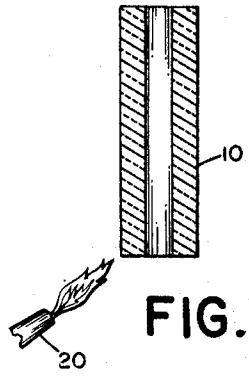

FIG. 3

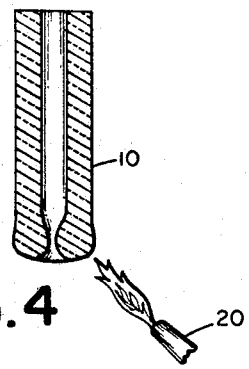

FIG. 4

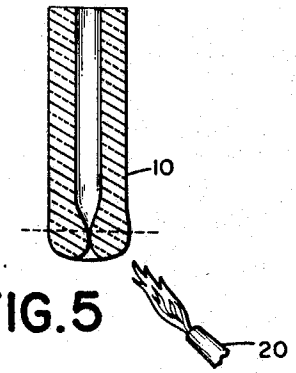

FIG. 5

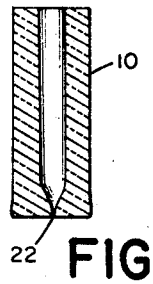

FIG. 6

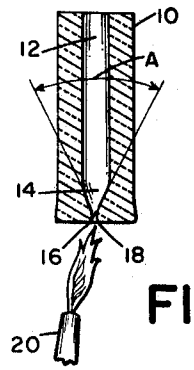

FIG. 1

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United States Patent Office 3,393,988 Patented July 23, 1968

3,393,988

METHOD OF FORMING A MINIATURE NOZZLE FROM A GLASS TUBE

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Filed Mar. 4, 1965, Ser. No. 437,037
2 Claims. (Cl. 65—61)

ABSTRACT OF THE DISCLOSURE

A miniature glass nozzle in which the outlet opening is .010" to .0004" in diameter and the ratio between the diameter of the entrance area to that of the discharge opening is approximately 100 to 1. The nozzle is formed by heating the end thereof until the same is at least partly closed and takes on a drop-like configuration. A predetermined axial portion of the enlarged end segment is then removed.

The present invention relates generally to fluid nozzles and, more particularly, to a miniature nozzle of the converging type adapted to be employed for ejecting a jet of fluid into a recording medium. The term miniature denotes herein a nozzle having a discharge opening of less than 10 mil inch in diameter.

Nozzles of the type here under consideration are normally used in recording instruments of the type described in copending application Ser. No. 399,291 now abandoned assigned to the same assignee as the instant application.

In the prior art such nozzles have been produced by gradually drawing or elongating a tubular member composed of a suitable material. This technique results in an undesirably long taper in the converging part of the fluid passageway. Generally it may be said the resulting included angle is very substantially below 60°. It is known that a gradual taper of the fluid passageway proximate to the discharge opening decreases the efficiency of fluid flow through the nozzle by giving rise to viscous losses. For converse reasons, it is desirable to effect the transition from the pressure to velocity in as short a distance as possible. The term abrupt taper as used herein refers to an average included angle of the converging passageway section generally within the range of 60° to 90°.

Another approach heretobefore used for fabricating miniature nozzles has been by way of casting or machining such a nozzle and subsequently drilling the orifice opening into the converging end thereof. While this avoids the aforestated shortcomings, it has been extremely difficult, if not impossible, with conventional means to drill an opening of 10 mil inch diameter, or less, into a nozzle of the type here under consideration. However, it has been found that a nozzle having an orifice opening with a diameter substantially in excess of 10 mil inch is not suitable for work in conjunction with recording instruments. Indeed, preferably such opening is much smaller as hereinafter further considered. The application of both prior art methods results in a fluid passageway which has relatively rough surface walls. Whereas the instant invention provides a nozzle having an inherently smooth internal contour and high finish together with a nearly perfect symmetry.

It is therefore the primary object of this invention to provide a miniature nozzle avoiding the shortcomings of the prior art.

It is another object of this invention to provide a miniature nozzle having the preferred abruptly tapered passageway and an orifice opening of the type desired for directing a controlled stream of fluid onto a recording paper.

Another aspect of the present invention resides in the method of forming a miniature nozzle of the type above described for directing a stream of fluid onto a recording medium. The method includes the steps of suspending a glass tube having a predetermined length and a central passageway with one end of the tube being suspended lower than the other. The lower end of the tube is heated and gradually softens the tube material until the opening of the tube is substantially constricted as a result of surface tension acting upon it whereby the constricted end wall portion of the annulus assumes, in cross section, a substantially drop-like configuration. The heated end is then permitted to solidify and thereafter the lower extremity of the drop-like appearing end portion up to the area of constriction is then removed to establish a converging passageway and at the narrow end thereof a central orifice.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

FIGURE 1 is a cross sectional view of the nozzle in accordance with this invention showing the nozzle in its final form; and

FIGURES 2 to 6 are cross sectional views of the miniature nozzle similar to FIGURE 1, showing the processing conditions at different stages of development.

Additionally, FIGURES 2, 3 and 4 show a flame burner which constitutes part of the method for fabricating the nozzle as hereafter further described.

Referring now to the drawing, there is shown in FIGURE 1 a nozzle formed of a capillary glass tube **10**. The nozzle is preferably composed of glass or glass-like material as this material has a very gradual softening range. This property makes it possible to produce the device. However, any other material which has a correspondingly wide softening range may also be utilized. Those skilled in the art will recognize that a number of metals fall within this category. The gradual softening of glass, upon the application of heat thereto, provides a very liberal degree of control for working the tubular material.

The nozzle includes a central passageway **12** and at the lower end thereof the passageway converges and the diameter of the passageway **12** changes abruptly between cross sectional area **14** and fluid discharge area **16**. The average included angle A is approximately between 60° to 90°. The converging passageway **12** terminates at the lower extremity of the tubular member **10** with an orifice opening **18** having a diameter in the range of .010" to .0004". Tests have shown that best results are achieved when the orifice opening **18** is held approximately between .003" to .0004" in diameter and the inside diameter of the entrance area to approximately .010" to .025". Generally, it may be said that preferred characteristics are obtained when the ratio between the diameter of the entrance area and that of the discharge opening **18** is approximately 100 to 1.

In the conventional use of the nozzle for directing fluid streams toward the recording media in a recording instrument, the axial length of such a nozzle is approximately between 1/16" and 1/2" although it is appreciated, of course, that there is no actual limit to the overall length of the nozzle member itself. The outside diameter of the nozzle on the other hand in relation to the inside diameter, is critical and the preferred diameter is between .50" and .10". The criticality of the outside diameter results from the unique process hereafter described. The tapered section of the passageway **12**, as defined between cross sectional areas **14** and **16**, increases in axial length pro-

portionally to the thickness of the walls of the tubular member **10**.

The nozzle is produced as follows. The glass tube **10**, or the like, see FIGURE 2, is cut to the predetermined length. The glass tube is then vertically suspended, see FIGURE 3, and a rotatably disposed flame burner **20** is brought in close proximity to the lower end of the tube **10** for gradually and symmetrically softening the glass until the tube is slowly melted downwardly with a tendency to form a spherical or drop-like appearing end portion, see FIGURE 4, which causes one end of the tube to close, see FIGURE 5, at which time the application of heat is terminated. Complete closing of the tube is not necessary; the heat may be turned off after the discharge opening has attained a diameter no greater than the final diameter desired. The nozzle shape as shown in FIGURE 5 results from the surface tension acting upon the tube during the heating step. The inside diameter, again because of the presence of uniform surface tension, necks down smoothly and within a very short length. For a given combination of inside and outside diameter of glass tubing, nearly identical neck shape is obtained time after time without the need for finely controlled conditions.

Thereafter a predetermined axial length of the necked down portion of the passageway **12** is cut or lapped off, note the imaginary cutting line in FIGURE 5, until an opening of the desired orifice diameter has been reached and whereby a nozzle substantially as shown in FIGURE 6 is obtained. To assure against any jaggedness in the discharge opening, or against any residual from the cutting operation it is desirable to slightly reflame the cut or lapped surfaces to round off the feather edge of the orifice opening **18** and for simultaneously effecting flame polishing of the surface.

Tests have shown that the nozzle is very effective for accommodating a very high fluid velocity ranging up to 1900" per second at comparatively low pressure levels. It will also be obvious to those skilled in the art that the nozzle herein described can be adapted for metering fluid flow.

While there have been described what are at present considered to be the preferred embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is aimed, therefore, in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. The method of forming a miniature nozzle comprising the steps of: suspending a glass tube having a predetermined length and a central passageway with one end being suspended substantially lower than the other; heating the lower end thereof to gradually soften the tube material until the opening of the tube is substantially constricted as a result of surface tension acting upon it whereby the constricted end wall portion of the annulus assumes, in cross section, a substantially drop-like configuration; solidifying said end portion; and then removing the lower extremity of said drop-like appearing end portion up to the area of constriction to establish a converging passageway and at the narrow end thereof, a central orifice.

2. The method according to claim **1**, and flame polishing said orifice for a duration effective to establish a relatively smooth and rounded off wall surface in the tube area proximate to the orifice.

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ARTHUR D. KELLOGG, *Assistant Examiner.*

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,393,988 July 23, 1968

John Blumenthal

It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 24, "into" should read -- onto --; line 29, cancel "now abandoned"; line 42, cancel "the"; line 46, "heretobefore" should read -- heretofore --.

Signed and sealed this 3rd day of February 1970.

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents