United States Patent

[11] **3,542,291**

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[54] **STREAMING**
4 Claims, 3 Drawing Figs.

[52] **U.S. Cl.** **239/8,** 239/102
[51] **Int. Cl.** **B05b 3/14**
[50] **Field of Search** 239/4, 8, 102; 116/133; 181/.5

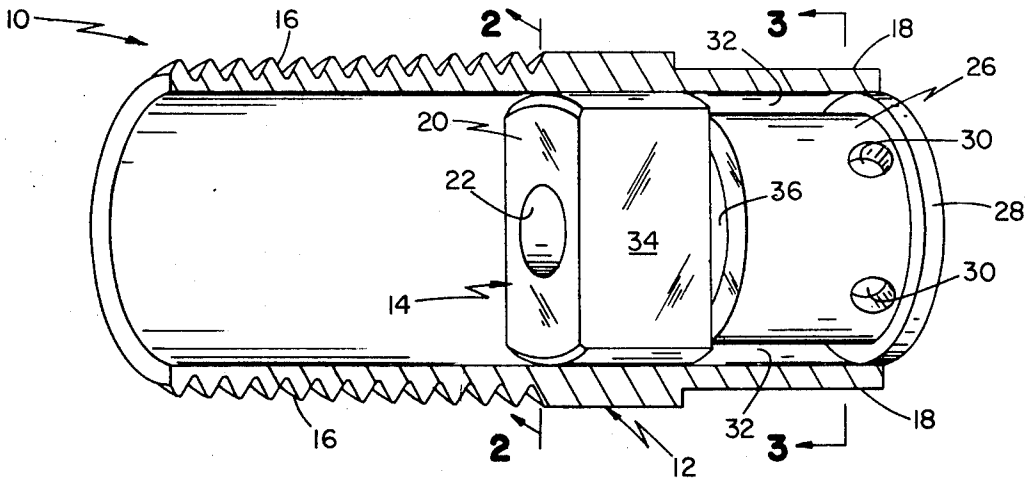
[56] **References Cited**

UNITED STATES PATENTS

3,337,135	8/1967	Blakely et al.	239/102
3,240,253	3/1966	Hughes	239/102X

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Attorney—William W. Rymer, Jr.

ABSTRACT: Streaming to supersonic speeds with small nozzles using boundary layers to define effective nozzle surfaces and inlet end implosion of gas at greater than environmental pressure to intensify shock power at the nozzle outlet.



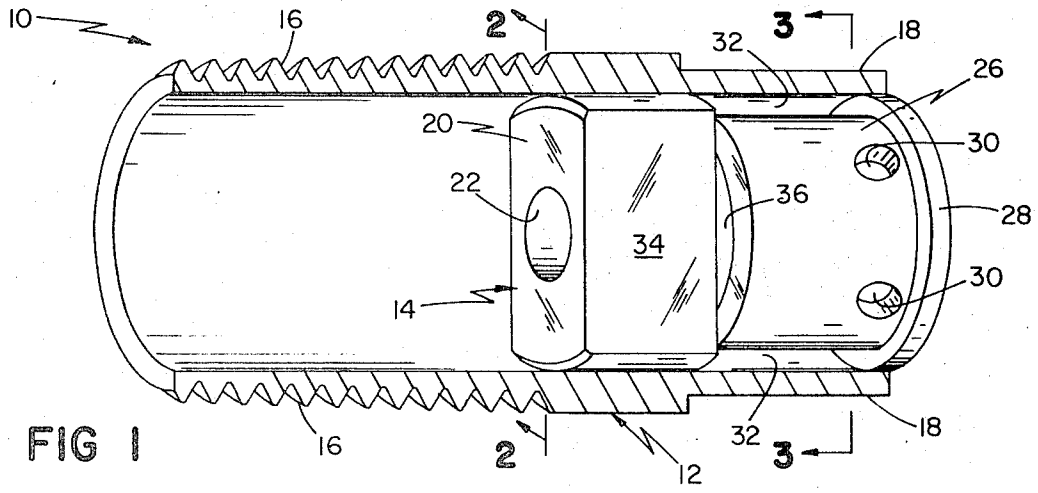


FIG 1

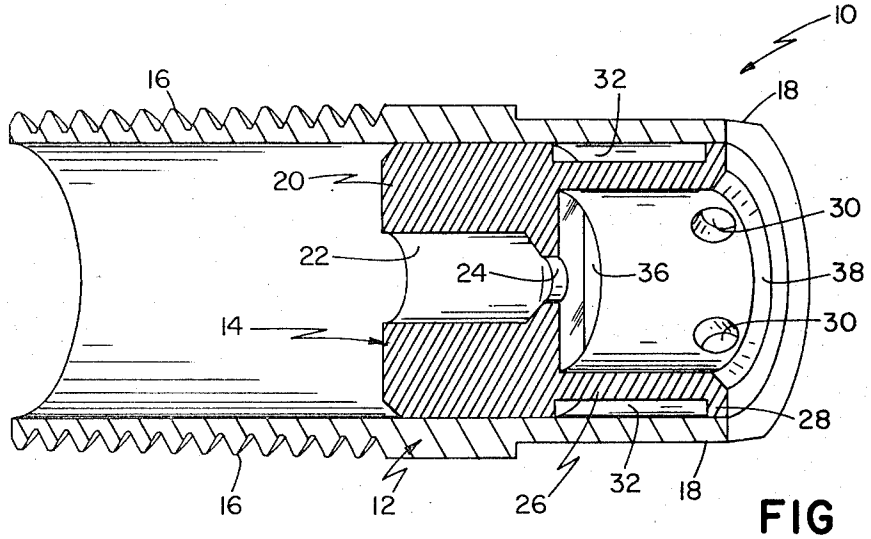


FIG 2

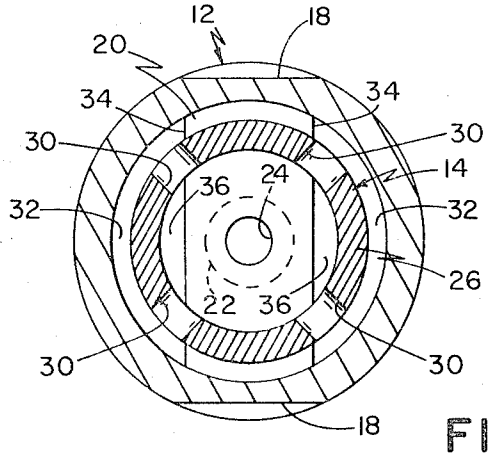


FIG 3

STREAMING

This invention relates to streaming at supersonic speeds using small nozzles in which effective nozzle surfaces are defined by boundary layer effects, and represents an improvement on the subject matter of the pending application of Nathaniel Hughes, Ser. No. 718,447, filed Apr. 3, 1968, now U.S. Pat. No. 3,531,048, "Supersonic Streaming", the contents of which are hereby incorporated by reference herein.

An object of the invention is to increase the intensity of the shock process at the outlet of nozzles embodying the invention of said Hughes application and to provide more effective sculpturing of the effective nozzle surfaces. Other objects include increasing the volume of flow in the boundary layer, and the operating pressure range of the nozzle.

In general, the invention features implosion at the nozzle inlet of gas of greater than environmental pressure into a zone intermediate the main flow stream and the inner surface of the nozzle. In preferred embodiments there is featured introduction of both a liquid and a gas upstream of nozzle inlet hole and of implosion passageways adjacent thereto, as well as of injection through throat plane stabilization holes of gas and liquid moving through said passageways.

Other objects, features, and advantages will appear from the following description of a preferred embodiment of the invention, taken in conjunction with the drawings, in which:

FIG. 1 is a perspective view, partially in section, from a first point of view, of said preferred embodiment;

FIG. 2 is a perspective sectional view, taken at 2–2 of FIG. 1, from a second point of view of said embodiment; and

FIG. 3 is a sectional view, taken at 3–3 of FIG. 1.

Referring now to the drawings, there is shown in FIG. 1 a nozzle unit indicated generally at **10**, and including a housing **12** and a body **14**.

Both housing **12** and body **14** are formed of free-machining brass, and the interrupted cylindrical outer surface of the latter press-fittedly engages the cylindrical inner surface of the former.

The housing **12** bears threads **16** for use in connecting the device in line with a source of air pressure and opposed parallel flat surfaces **18** to facilitate application of a wrench to the device.

Body **14** includes inlet portion **20** including, coaxial with said body, nozzle feed hole **22** and inlet hold **24**, the downstream end of the latter lying in the nozzle inlet plane. Downstream of said plane, the body **14** includes boundary layer confining wall **26**. The outer surface of body **14** is circumferentially relieved over most of said confining wall **26**, but not at the downstream extremity thereof, which is left unrelieved to form circumferential housing engaging ring **28**. Four holes **30** with centerlines spaced 90° and all lying in the same plane perpendicular to the body **14** axis extend through confining wall **26**.

The wall **26** defines with the inner surface of housing **12** and with the ring **28** a manifold **32** fed through the zones defined between flats **34** of the inlet portion **20** and the housing **12** inner surface.

Two symmetrical circle segments, defined by flats **34** of inlet portion **20** and the inner surface of wall **26**, lie in the plane (perpendicular to the body **14** axis) at the upstream end of wall **26**.

Wall portion **26** terminates at its downstream inner surface in 45° countersink **38**.

The inner surface of wall **26** and inlet hole **24** are concentric to within 0.001 inch.

In operation, air at a low pressure is introduced into the housing **12** at its threaded upstream end. Part of the air then passes through nozzle feed hole **22** and nozzle inlet hole **24** into the nozzle proper, which is defined by boundary layer confining wall **26**. Another part of the air moves through the two zones, segments of circles in transverse cross section, alongside the parallel and opposed flats **34**, to be divided then by the wall **26**. Part of the air passes through the two symmetrical circle segments **36** into the nozzle, to enhance boundary layer flow and energy and the work done by the outlet shocks.

The remainder moves outside wall **26** into manifold **32** and thence through holes **30** to stabilize the plane of the throat of the nozzle sculpted in boundary layer in the manner taught in the said patent application.

As the air moves downstream from the nozzle inlet plane, the boundary layer thickness rapidly increases, to effectively define the converging portion of a converging-diverging supersonic nozzle. The holes **30** are placed with their axes in the plane at which the effective nozzle diameter is smallest, the throat, at which air speed is transonic. Downstream of the throat the supersonic speeds cause steady boundary layer thickness decay, to define effectively the diverging portion of the supersonic nozzle. Countersink **38** at 45° facilitates jet entrance to the atmosphere.

Nozzle parameters are calculated in the manner set forth in said pending application.

The desired power (the product of nozzle inlet pressure P_i and flow rate V, often expressed in cubic feet per minute C.F.M.) is first chosen by fixing P_i and V to give the desired P_i V. The desired jet outlet pressure P_o is then selected. Using standard thermodynamic One-Dimensional Isentropic Compressible Flow Functions tables, the matching ratio of effective nozzle outlet area (A_o) to effective throat area ($A^=$) is selected. Nozzle length from inlet plane to holes **30** centerline $L^=$ and overall length L downstream of the inlet plane are then selected to give the appropriate, owing to boundary layer growth and decay for the nozzle inside diameter D_f chosen, effective throat diameter $D^=$ and outlet diameter D_o.

In the preferred embodiment, the parameters are:

P_i—1 p.s.i.g.
V—2.23 c.f.m.
P_o—1.0 p.s.i.a.
L*—0.152 inches.
L—0.255 inches.
D_o—0.103 inches.
D*—0.067 inches.
D_f—0.260 inches.
Hole 30 diameter—0.062 inches.
Hole 24 diameter—0.076 inches.
Hole 24 length—0.025 inches.

The resultant supersonic jet is useful for many purposes, *e.g.*, atomization, as taught in said pending application.

Provision of forced subsonic implosion from the air source through the segment-in-cross section passages alongside flats **34** and at **36** greatly increases the energy of the boundary layer and the force of the supersonic implosion into the emerging supersonic jet.

A liquid may be separately added to the air or other gas upstream of threaded end **16**, as by means of a simple tee, in a gas–liquid weight ratio of, say, **1** to **4** or **5**. Mixing begins through a rotary action that begins even upstream of hole **22**, and continues therein. Inlet hole **24**, as ordinarily, triggers nozzle operation. Although the passageways alongside flats **34** are larger in cross-sectional area than inlet hole **24**, flow rate per unit area is much less in the nozzle inlet plane than at said passageways than at hole **24**, because of the differing respective effects of adjacency of the slower boundary layer and of the faster central nozzle portion. In the nozzle, within wall **26**, the liquid portion moves, with the swirling motion, by centrifugal force into the boundary layer. More liquid enters the boundary layer, with gas, through holes **30**. All this liquid entering the boundary layer helps to form it up with less gas use, freeing more gas for work in the supersonic central portion of the nozzle. Furthermore, the liquid increases the momentum of the boundary layer molecules emerging from the nozzle, and thus intensifies shock, increasing work done. Shock intensification is further dramatically increased by raising P_i by a factor of almost the square of the amount by which P_i exceeds ambient or environmental pressure. Such great action results that chemical reactions, including burning, take place with great intensity suggesting even molecular breakdown owing to shock prior to reaction.

Furthermore, greatly increased self-regulating qualities inhere in the usage just described. With the gas supplied from a

constant C.F.M. source (*e.g.*, a ¼ H.P. carbon vane pump), P_i rises as more liquid in hole **24** and the passageways cuts their effective areas, thus supplying the added power needed to work on the added liquid. Liquid volume depends, of course, on density as well as weight–minute. Increased liquid present also acts to increase the energy input by tending to reduce $D^{=}$, resulting in a counteracting rise in P_i. Great liquid flow rate variations are thus automatically accommodated.

I claim:

1. A nozzle device comprising:

a generally cylindrical boundary layer confining wall with inlet and outlet ends;

an element defining a portion defining an inlet hole of lesser diameter than said wall generally alined with the inlet end of said wall and coaxial therewith, said inlet hole being separated radially from said wall by an implosion zone; and

a conduit connecting said zone to a source of greater than environmental pressure.

2. The nozzle device of claim **1** in which said inlet hole is connected to said source of pressure.

3. The nozzle device of claim **2** in which said wall includes a multiplicity of throat plane stabilization holes and said hole are connected to said source of pressure.

4. The method of treating a liquid with the device of claim **3** which comprises injecting it into gas from said source of pressure before said gas enters said inlet hole, said implosion zone, and said throat plane stabilization holes.