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Colamussi et al.

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[54] COMPRESSED AIR FEED SYSTEM FOR PURE FLUID DEVICES

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[73] Assignee: **Consiglio Nazionale Delle Ricerche,** Rome, Italy

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[30] **Foreign Application Priority Data**

Nov. 20, 1968 Italy 53972 A/68

[52] **U.S. Cl.** **137/13,** 137/81.5, 417/50
[51] **Int. Cl.** **F17d 1/14**
[58] **Field of Search** 137/81.5, 13; 417/54

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Primary Examiner—Samuel Scott
Attorney—Sughrue, Rothwell, Mion, Zinn and Macpeak

[57] **ABSTRACT**

A jet ejector-type device for feeding compressed air to pure fluid devices is supplied by mains air at a pressure of about 6 atmospheres. The mains air passes through a Laval nozzle into a mixing chamber into which open a plurality of inlets from the atmosphere. Atmospheric air is drawn into the mixing chamber, is mixed with the mains air, and the resulting stream passes through an outlet conduit having a portion of enlarged section to feed the pure fluid devices.

4 Claims, 5 Drawing Figures

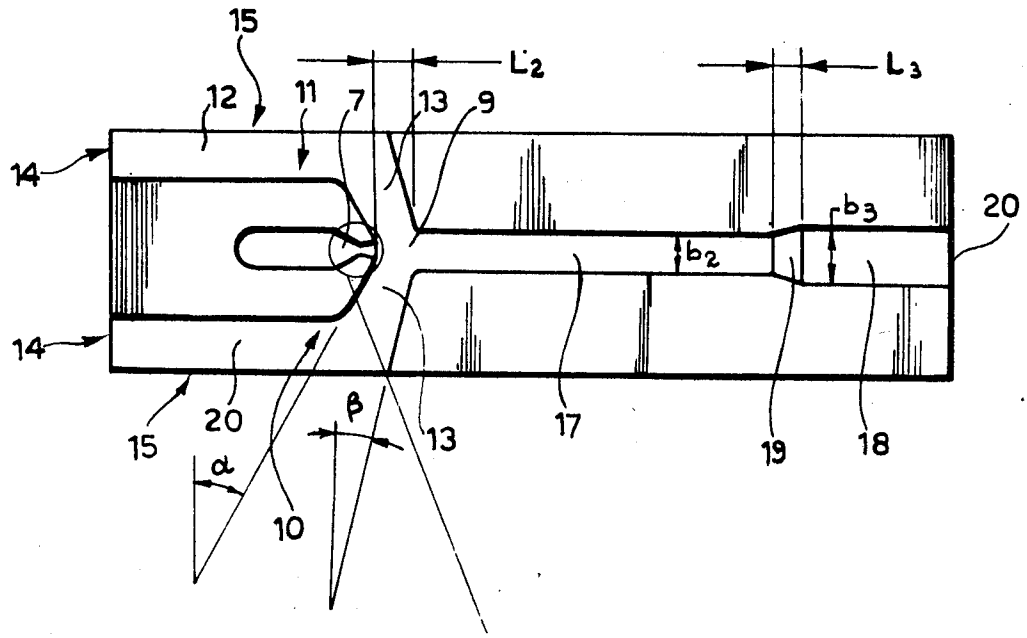


Fig.1

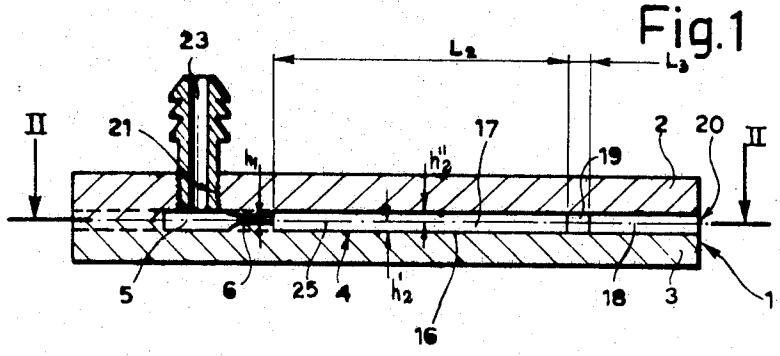


Fig. 2

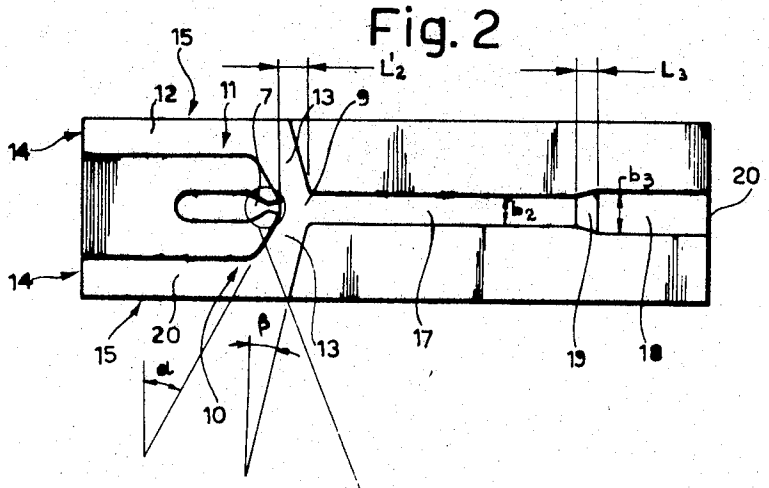


Fig.3

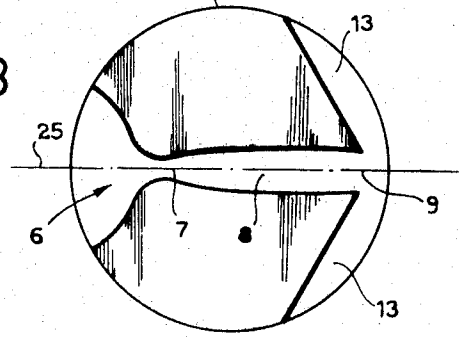


Fig. 4

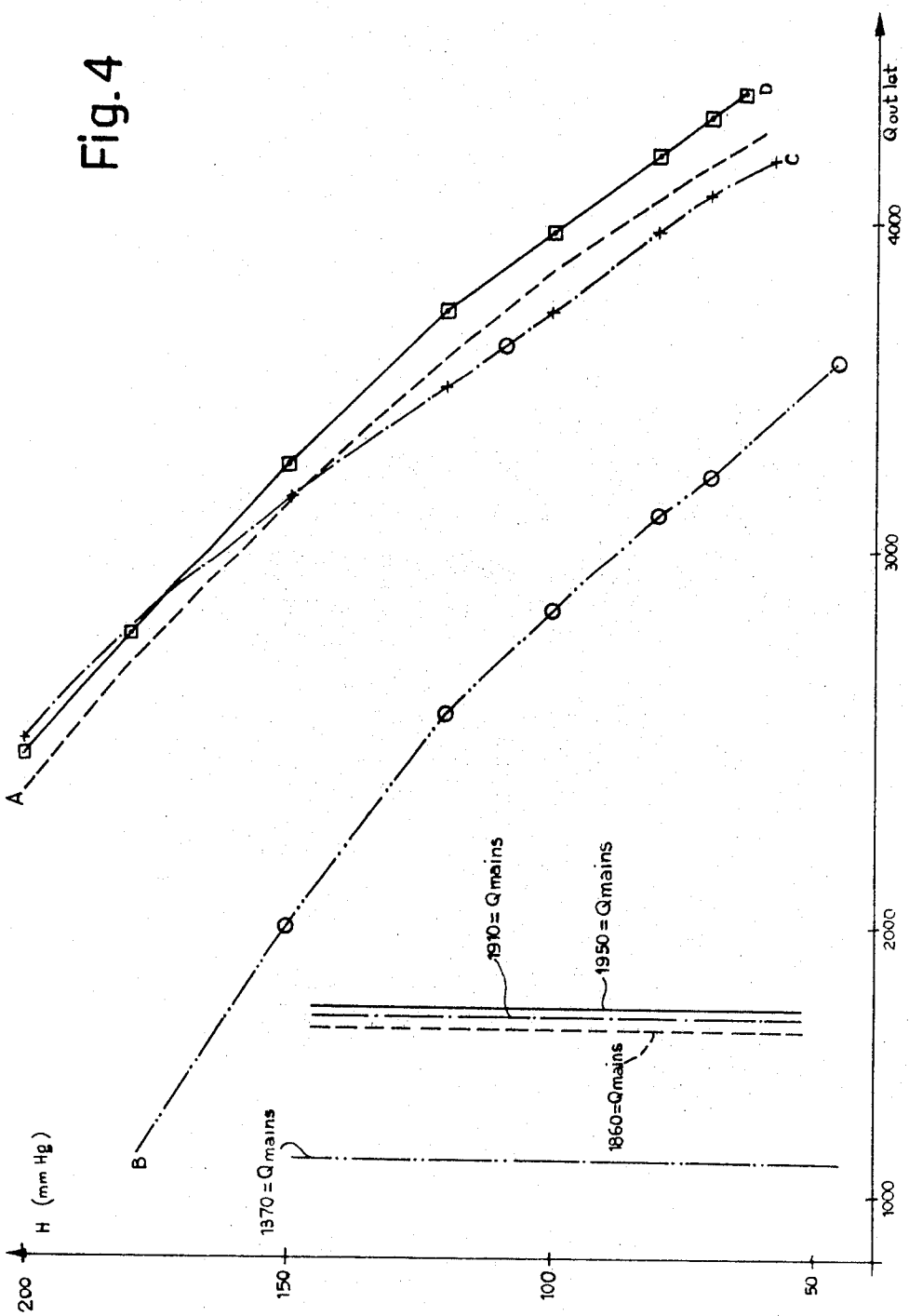
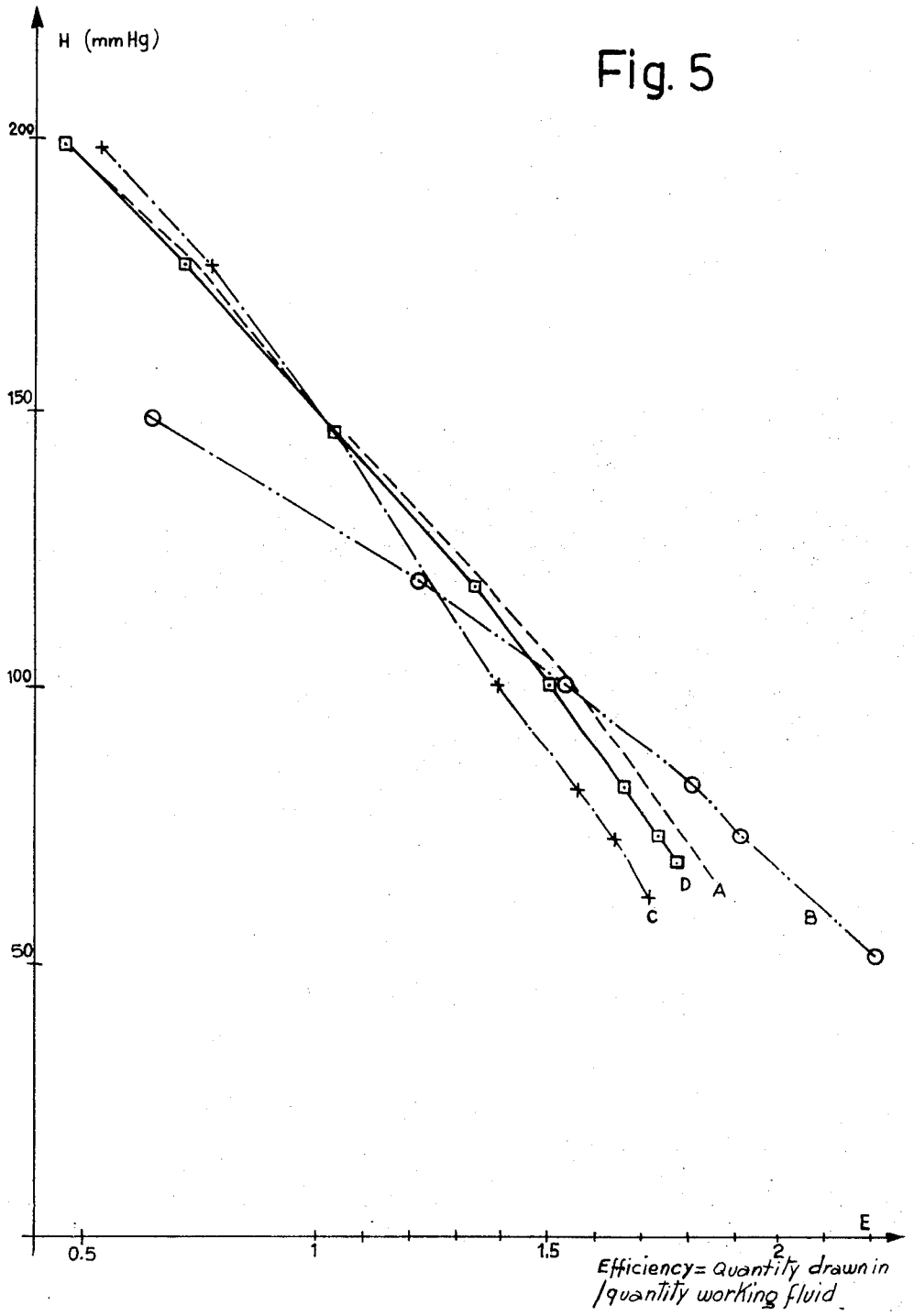

A
B
C
D
1910 = Q mains
1950 = Q mains
1860 = Q mains
1370 = Q mains
H (mm Hg)
200
150
100
50
Q out let
4000
3000
2000
1000

Fig. 5


H (mm Hg)
200
150
100
50
0.5
1
1.5
2
E
A
B
C
D
Efficiency = Quantity drawn in / quantity working fluid

COMPRESSED AIR FEED SYSTEM FOR PURE FLUID DEVICES

This invention relates to systems for feeding compressed air to pure fluid devices, otherwise called pure fluid logic components, particularly for such uses as the control of programmed automatic machine tools.

In order to use pure fluid devices for programmed automatic machine tools, it is essential to have a large supply of pure feed air at the correct constant pressure, which is generally in the range 50–100 mm. of mercury above atmospheric pressure. These criteria are particularly strict when boundary-layer-type pure fluid devices are used.

With increasing complexity of the control circuit, that is to say of the number of devices used, the quantity of compressed air required necessarily increases. Purity, considered in terms of the almost complete absence of dust and above all of traces of oil, is always difficult to achieve because of the nature of air compressors, and particularly because of the tendency for lubricating oil to pollute the air during the compression phase. These two factors, quantity and purity, cannot be considered separately because, in known systems, the quantity supplied cannot generally be increased without a reduction in the purity; and vice versa.

In practice, air with a low oil content can be obtained from reciprocating compressors provided with adequate tanks, but in this case the relationship between the supply generated and the installed power, or the cost of the machine, is extremely low, and the operation is therefore uneconomic.

Rotary volumetric compressors are capable of providing large quantities of air at a low pressure (115 to 230 mm. of mercury above atmospheric pressure) but the large quantities of oil entrained in the air completely excludes their use in pure fluid device circuits, at least without the use of filters that are difficult to install and operate.

Little is known about centrifugal compressors for feeding pure fluid devices, but they have the characteristic of supplying air at a fixed low pressure, hence making them inherently unsuitable as a source of pneumatic energy for the control circuits of automatic machine tools, in which it is essential to be able to vary the pressure for different circuits.

It has been shown above that the main types of known compressor have severe disadvantages when considered as potential sources of compressed air for directly feeding pure fluid devices. However, standard industrial or mains sources of compressed air, at a pressure of about 6 atmospheres, are generally provided by reciprocating compressors, and the object of the invention is to utilize the high enthalpy or energy of the air in mains sources to generate an adequately large supply of compressed air at the required pressure and of satisfactory purity to operate pure fluid devices, and particularly such devices as flip-flop and OR-NOR boundary layer devices.

According to the invention, a supply device for feeding compressed air to pure fluid devices comprises a supply conduit adapted to be connected to a mains source of compressed air, a Laval nozzle connected in the supply conduit, a mixing chamber into which the Laval nozzle discharges, at least one inlet conduit leading from the atmosphere into the mixing chamber and adapted to admit air to be mixed with the mains air, and an outlet conduit from the mixing chamber, the outlet conduit being adapted to be connected to the pure fluid devices.

Preferably, there are a plurality of inlet conduits for atmospheric air, adapted to admit approximately twice the quantity of air to the mixing chamber as is admitted from the mains. Also preferably, the outlet conduit has a diverging end, and is adapted to deliver air for pure fluid devices at a pressure in the range between 50 and 100 mm. of mercury.

An embodiment of the invention is described below with reference to the accompanying drawings, in which:

FIG. 1 is a sectioned longitudinal view in elevation of a device of the invention;

FIG. 2 is a section on the line II—II of FIG. 1;

FIG. 3 is a detail from FIG. 2, enlarged for the sake of clarity;

FIG. 4 is a constant-temperature diagram in which are shown the outlet volume per unit of time as a function of the outlet pressure for our prototypes of the device shown generally in FIGS. 1 and 2, and

FIG. 5 is a diagram showing efficiency (as defined later) as a function of the outlet pressure for the four prototypes of FIG. 3.

The device of FIGS. 1 and 2 is formed by an upper plate 2 and a lower plate 3 that are performed with grooves out by milling and then joined to each other to form a cavitied body. The cavity, indicated by 4, is composed of a mains inlet chamber 5 ending in a Laval nozzle 6 having a restricted section 7 which, through a divergent part 8, opens into a mixing chamber 9 of constant section. Into the mixing chamber 9 there also open two lateral conduits 10 and 11 which place the chamber 9 in communication with the atmosphere. The conduits 10 and 11 are located one on each side of the longitudinal axis 25 (indicated by chain lines in FIGS. 1 and 3) of the cavity 4 and are each composed of a branch 12 (FIG. 2) of rectangular section, parallel to the longitudinal axis 25, and by a branch 13 forming an oblique angle to the longitudinal axis 25 of the cavity. The branch 12 extends through the back wall 14 and the external sidewalls 15 of the body so as to form an air intake from the atmosphere in the form of a slit. The branch 13 is of tapered rectangular section and of constant height equal to that of the chamber 9.

The mixing chamber 9 communicates at its front with an outlet conduit 16 of rectangular section and size equal to that of the chamber 9. The conduit 16 includes a mixing channel 17 of constant section, a divergent zone 19, and a final zone 18 of constant section greater than that of the channel 17. The final zone 18 communicates with the pure fluid devices, not illustrated, through an outlet port 20.

The cavity 4 communicates with the compressed air mains system by means of a threaded hole 21 in which is screwed a sleeve 22 whose internal passage 23 acts as a mains supply conduit.

The functioning of the device described above is as follows. Air from the compressed air mains, fed by reciprocating compressor means, flows at a pressure of about 6 atmospheres into the chamber 5 through the passage 23. The Laval nozzle 6 determines the expansion of the air which flows into the mixing chamber 9 at a speed of about Mach II. This supersonic current draws atmospheric air into the chamber 9 through the conduits 10, 11. In the mixing channel 17 a turbulent current is obtained which expands the mixed mains and atmospheric air to the required working pressure through the divergent zone 19 and the constant-section zone 18 of the outlet conduit 16.

To carry out the design or dimensioning of the various parts of the preferred device, the ratio between the weight of the supply of atmospheric air as drawn in and the supply of mains air is fixed approximately at the value of 2. The size of the mixing chamber 9 and the pressure required from the outlet conduit are also known and are fixed. The nozzle in which the working fluid expands from the pressure of 6 atmospheres to the pressure of the mixing zone is dimensioned by the "-method of characteristics" (see Puckett A. E., "Supersonic Nozzle Design," Journal of Applied Mechanics, December 1946, page A–256 to A–270 and Kaufman R., "Fluid Mechanics," McGraw-Hill Book Co., New York, 1963), with the precaution that there must be taken into account, in dimensioning the aspect ratio of the critical narrow section 7, the fact that there is a lower practical limit to the width of this section. This limit is set by the minimum width which can be cut by a milling cutter, and if the width calculated by the method of characteristics falls below this limit, an appropriate modification must be introduced.

The dimensioning of the section of the mixing channel 17 is carried out by the method of "maximization of the inlet supply" (Elrod H. G., "The Theory of Ejectors," Journal of Applied Mechanics, September 1945, page A–170 to A–174) while the length of the mixing channel 17 is calculated experimentally (Deleo R. V., Rose R. E., Dart R. S., "An Experi-

mental Investigation of the use of Supersonic Driving Jets for Ejector Pumps," Trans. of ASME, April 1962, page 204 to 212.

Finally, the dimensioning of the final divergent zone **19** is carried out by means of the classic equations of fluid movement, adiabatic conditions being assumed.

Regarding the distance between the final section of the nozzle **6** and the beginning of the mixing channel **17**, universally valid dimensional criteria have not been found, and the same can be said of the form of the inlet channels; therefore it is necessary to experiment in order to optimize the ratio between the weight of the supply of air drawn in from the atmosphere and the supply of mains air taking as constants the mains pressure (6 atmospheres) and the final required (50 to 100 mm. of mercury). For this purpose four prototypes A, B, C, and D of the device of the invention were made, whose geometric characteristics are set out hereunder, the parameters listed in the extreme left-hand column being identified in FIGS. **1** and **2**:

	A	B	C	D	
b_2	3.73	3.73	3.73	3.73	mm.
b_3	4.075	4.075	4.075	4.075	mm.
h_1	0.765	0.550	0.775	0.780	mm.
h_2	1.370	1.280	1.365	1.370	mm.
h''_2	0.585	0.715	0.610	0.625	mm.
L_2	34.4	34.4	34.4	34.4	mm.
L'_2	3.26	3.26	3.26	1.63	mm.
L_3	2.45	2.45	2.45	2.45	mm.
α	30°	30°	30°	30°	
β	15°	15°	15°	15°	

With the experimental data obtained in test with the above-mentioned prototypes, the diagrams of FIGS. **4** and **5** were constructed. FIG. **4** is a constant-temperature Cartesian diagram having as abscissa the supply mains outlet of air discharged through the outlet **20** in liters/hour, and as ordinate the outlet pressure H in mm. of mercury, representing the feed pressure to the pure fluid devices. The diagrams of FIG. **4** reflect tests carried out at an ambient temperature of 200° C., and for each prototype tested, there are shown on the diagrams the values of the quantities mains fluid supplied.

In order to carry out a comparison of the data obtained with the various prototypes tested, the "efficiency of the compressor" E was defined as the ratio between the constant-temperature supply drawn in from the atmosphere and the constant-temperature mains supply.

FIG. **5** shows a diagram reflecting, for the four prototypes tested, the efficiency E as abscissa and the outlet pressure H as ordinate.

From a comparison of the diagrams of FIG. **5** it is possible to see that, at a pressure in the vicinity of 100 mm. of mercury, the efficiencies are only very slightly different from each other, and are concentrated around a value of 1.5. Consequently, it may be said that the parameters which were varied in the tests had little influence on the functioning of the device, at least in the range of the variations tested.

However, if one considers the fact that the outlet pressure, i.e., the feed pressure of the pure fluid devices, should be capable of reduction without prejudicing the sound functioning of those devices, then the dimensioning of the prototype B, having a mixing channel with a section greater than that calculated (Elrod H. G., "The Theory of Ejectors," Journal of Applied Mechanics, September 1945, page A-170 to A-174) is without doubt the best because, for pressures of 50 to 60 mm. of mercury, one obtains efficiencies of 2 to 2.2.

As regards the problem of oil vapor condensation downstream of the mixing zone of the devices, it was established during the tests that, even with the use of a lubricated reciprocating compressor supplying the mains source, no difficulty was encountered. During the tests no difficulties arose from the entrainment of dust from the surrounding atmosphere by the jet compressor device of the invention, probably because of the absence of condensed oil.

Because of the design and construction of the mixing chamber and mixing channel, flow through the outlet conduit is two-dimensional. This is an important advantage for the sound functioning of the pure fluid device.

Naturally, within the principle of the invention, details of construction of the device can be widely varied with respect to those described and illustrated without thereby departing from the scope of the invention.

We claim:

1. A method of feeding compressed air into a pure fluid device comprising compressing air in a lubricated compressor thereby providing compressed air having a significant amount of lubricating oil entrained therein, passing said compressed air through a Laval nozzle which discharges into a mixing chamber admitting atmospheric air to the mixing chamber to mix with the compressed air, said atmospheric air being admitted in sufficient quantity to prevent the formation of oil on the surface of the pure fluid device and feeding the mixed air to the pure fluid device.

2. A method as set forth in claim **1** wherein the air is compressed in the compressor to a pressure of about 6 atmospheres, the weight of atmospheric air admitted to the mixing chamber is twice the weight of air supplied to the mixing chamber from the compressor through the Laval nozzle and the air fed from the mixing chamber to the pure fluid device is fed at a pressure in the range from 50 to 100 mm. of mercury.

3. A fluidic system for supplying compressed air to a fluidic device comprising lubricated compressor means, mixing chamber means located in said fluid device, first inlet passage means connecting said compressor means to said chamber means including a Laval nozzle, second inlet passage means connecting said chamber means to atmosphere for admitting atmospheric air into said chamber means and outlet means leading from said chamber means, said second inlet passage means being dimensioned to admit sufficient atmospheric air to mix with the lubricant contaminated compressed air to maintain the lubricant contaminant in suspension when fed through said outlet passage means.

4. A fluidic system as set forth in claim **3** wherein said compressor means is a lubricated reciprocating compressor.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,636,964 Dated January 25, 1972

Inventor(s) Arturo Colamussi and Pier Gabriele Molari

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

Page 1 (In the Heading)

Delete lines 4, 5 and 6 "Arturo Ferrara Colamussi, and Pier Gabriele Molari, both of Novafeltria, Italy, assignors to Consiglio Nazionale Delle Ricerche, Rome, Italy" and substitute therefor

--Arturo Colamussi of Ferrara, Italy and Pier Gabriele Molari of Novafeltria, Italy assignors to Consiglio Nazionale Delle Ricerche, Rome, Italy--.

Signed and sealed this 15th day of August 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

FORM PO-1050 (10-69)

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