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(71) Applicant: **Eaton Intelligent Power Limited**
Dublin 4 (IE)

(72) Inventors:
- **KUNTALIKA, Das**
  712409 Hooghly (IN)
- **SUBRATA, Sarkar**
  412207 Pune (IN)
- **ALAN, Massey**
  Southampton, SO316 (GB)

(74) Representative: **Schwan Schorer & Partner mbB**
Patentanwälte
Bauerstraße 22
80796 München (DE)

(54) **JET PUMP**

(57) A jet pump may include a body (102) that may include an inlet portion (104) having a motive port (108) and a first induce port (106), a throat (112), a tapered wall (120) connecting the inlet portion with the throat, a discharge port (110), and a diffuser (114) connecting the throat and the discharge port. The tapered wall may include a converging angle of about 5 degrees.

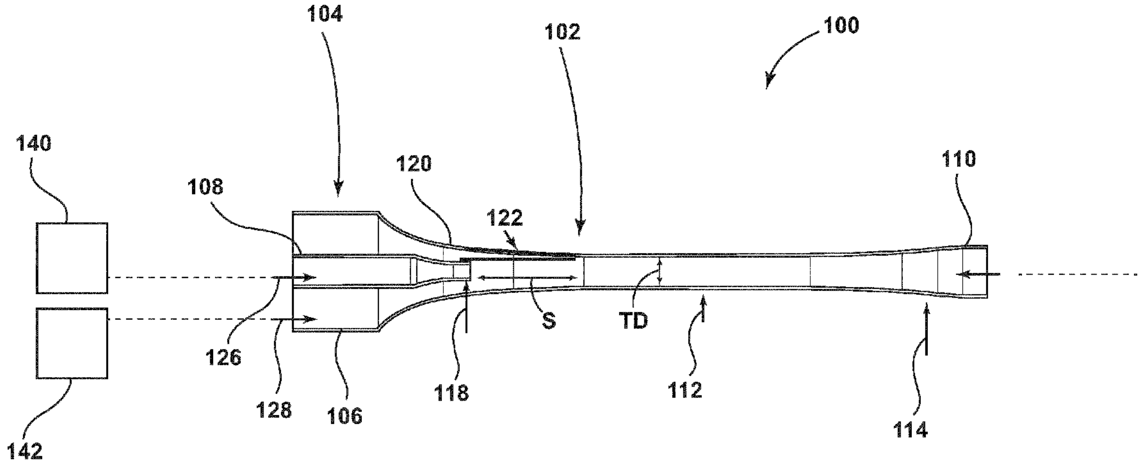


FIG. 1

EP 3 896 292 A1

Description

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of India Provisional Patent Application Serial No. 202011016130, filed on April 14, 2020, the disclosure of which is hereby incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] The present disclosure generally relates to jet pumps, including jet pumps that may be utilized in connection with aircraft fuel transfer/scavenge pumps, oil/gas pumps, water pumps, chemical injectors, thermal management systems, and/or nuclear reactor pumps, among others.

BACKGROUND

[0003] This background description is set forth below for the purpose of providing context only. Therefore, any aspect of this background description, to the extent that it does not otherwise qualify as prior art, is neither expressly nor impliedly admitted as prior art against the instant disclosure.

[0004] Some existing jet pump designs are not efficient and/or require large power inputs.

[0005] There is a desire for solutions/options that minimize or eliminate one or more challenges or shortcomings of jet pumps. The foregoing discussion is intended only to illustrate examples of the present field and is not a disavowal of scope.

BRIEF SUMMARY

[0006] In embodiments, a jet pump may include a body that may include an inlet portion having a motive port and a first induce port, a throat, a tapered wall connecting the inlet portion with the throat, a discharge port, and/or a diffuser connecting the throat and the discharge port. The tapered wall may, for example and without limitation, include a converging angle of about 5 degrees.

[0007] The foregoing and other potential aspects, features, details, utilities, and/or advantages of examples/embodiments of the present disclosure will be apparent from reading the following description, and from reviewing the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] While the claims are not limited to a specific illustration, an appreciation of various aspects may be gained through a discussion of various examples. The drawings are not necessarily to scale, and certain features may be exaggerated or hidden to better illustrate and explain an innovative aspect of an example. Further, the exemplary illustrations described herein are not exhaustive or otherwise limiting, and are not restricted to the precise form and configuration shown in the drawings or disclosed in the following detailed description. Exemplary illustrations are described in detail by referring to the drawings as follows:

FIG. 1 is a cross-sectional view generally illustrating an embodiment of a jet pump according to teachings of the present disclosure.

FIG. 2 is a cross-sectional view generally illustrating portions of an embodiment of a jet pump and the velocity of fluid therein according to teachings of the present disclosure.

FIG. 3 is a cross-sectional and graphical view generally illustrating fluid total pressure in a plurality of locations of an embodiment of a jet pump according to teachings of the present disclosure.

FIG. 4 is a graphical view of efficiency relative to a flow ratio of induced flow rate to motive flow rate associated with an embodiment of a jet pump according to teachings of the present disclosure.

FIG. 5 is a cross-sectional view generally illustrating an embodiment of a jet pump according to teachings of the present disclosure.

FIG. 6 is a cross-sectional view generally illustrating portions of an embodiment of a jet pump and the velocity of fluid therein according to teachings of the present disclosure.

FIG. 7 is a graphical view of efficiency relative to a flow ratio of induced flow rate to motive flow rate associated with an embodiment of a jet pump according to teachings of the present disclosure.

DETAILED DESCRIPTION

[0009] Reference will now be made in detail to embodiments of the present disclosure, examples of which are described herein and illustrated in the accompanying drawings. While the present disclosure will be described in conjunction with embodiments and/or examples, they do not limit the present disclosure to these embodiments and/or examples. On the contrary, the present disclosure covers alternatives, modifications, and equivalents.

[0010] In embodiments, such as generally illustrated in **FIG. 1,** a jet pump 100 may include a body 102 that may include a generally cylindrical and/or elongated configuration. The body 102 may include an inlet portion 104, an outlet/discharge port 110, a throat 112, and/or a diffuser 114. The inlet portion 104 may include a first induce port 106, a motive port 108, and/or a first nozzle 118. The throat 112 may be connected to an output of the inlet portion 104 and and/or an input of the diffuser 114. The diffuser 114 may be connected to an output of the throat 112 and/or an input of the discharge port 110. For example and without limitation, the body 102 may be configured for fluid to flow from the inlet portion 104 to the throat 112, from the throat 112 to the diffuser 114, and/or from the diffuser 114 to the discharge port 110.

[0011] With embodiments, a motive flow 126 (e.g., fluid, pressurized fuel, etc.) may be provided to the motive port 108, such as from a fluid source 140 (e.g., a fluid pump, tank, etc.). As the motive flow 126 moves through the motive port 108 and into the first nozzle 118, the motive flow 126 may speed up and the pressure of the motive flow 126 may decrease (e.g., the Venturi effect). The decrease in pressure may create a vacuum or reduced pressure area in the body 102, which may draw additional fluid (e.g., a first induced flow 128) into the first induce port 106, such as from a tank or reservoir 142. In embodiments, such as generally illustrated in **FIG. 2,** the first inducted flow 128 may flow around the outside of the first nozzle 118 toward a converging or tapered wall 120 of the body 102, where the first induced flow 128 may mix with the motive flow 126. The tapered wall 120 may, for example, at least partially define a mixing chamber for the motive flow 126 and the first induced flow 128. The tapered wall 120 may include a converging angle 122. The converging angle 122 may be configured to maximize a contact area between the motive flow 126 and the first induced flow 128, which may facilitate effective mixing. As generally illustrated in **FIG. 3,** in an example, a total pressure drop may, for example and without limitation, be about 14.7 percent up to plane 6, which may indicate a low expansion loss associated with an embodiment of a jet pump 100. The converging angle 122 may, for example and without limitation, be about 0 degrees to about 10 degrees, such as about 5 degrees and/or about 5.3 degrees.

[0012] With embodiments, an end/outlet of the first nozzle 118 may be at least partially aligned with the tapered wall 120 such that the motive flow 126 from the motive port 108 out of the first nozzle 118 mixes with the first induced flow 128 from the first induce port 106 proximate the tapered wall 120.

[0013] In embodiments, an efficiency of a jet pump 100 may correspond to the product of a flow ratio and a pressure ratio. The flow ratio may correspond to an induced flow rate divided by motive flow rate. The pressure ratio may correspond to a difference between a discharge total pressure and an induced total pressure divided by a difference between a motive total pressure and discharge total pressure.

[0014] Embodiments of a jet pump 100 may limit flow mixing losses, friction losses, and/or jet losses, which may provide embodiments of a jet pump 100 with improved performance relative to other designs.

[0015] With embodiments of a jet pump 100, a distance between an end of the first nozzle 118 and the start of the throat 112 and a throat diameter may be configured to optimize efficiency. For example and without limitation, the distance may be about two to four times greater than the throat diameter.

[0016] In embodiments of a jet pump 100, the tapered wall 120 may be curved. The curvature of the tapered wall 120 may be relative smooth such that a radius of curvature divided by the throat diameter may be about 60 to 80, such as about 73. Providing a relatively smooth curvature may limit sudden contraction loss and/or the Coanda effect.

[0017] With embodiments of a jet pump 100, a ratio of the nozzle area to the throat area may be configured to optimize efficiency. For example and without limitation, the ratio may be about 0.24 to about 0.25, such as about 0.246.

[0018] In embodiments, the throat 112 may be configured to optimize flow mixing, which may include the length of the throat 112 being longer than a diameter of the throat 112. For example and without limitation, the length of the throat 112 maybe at least about 7 times greater (e.g., 7.58 times greater) than the diameter of the throat 112. The diameter of the throat 112 may be substantially constant and/or the throat 112 may be substantially straight.

[0019] With embodiments, the diffuser 114 may be connected to an end of the throat 112 and may be configured for static pressure recovery. The diameter of the diffuser 114 may increase from the throat 112 toward the discharge port 110.

[0020] In embodiments, such as generally illustrated in **FIG. 5,** a body 102 of a jet pump 100 may include a motive port 108, a first induce port 106, a second induce port 116, a first nozzle 118, and/or a second nozzle 124. The motive port 108, the first induce port 106, and/or the second induce port 116, the first nozzle 118, and/or the second nozzle 124 may be disposed substantially concentrically. The second induce port 116 may include a greater outer diameter than the first induce port 106, which may include a greater outer diameter than the motive port 108. The first nozzle 118 may be connected for fluid communication with the motive port 108. The second nozzle 124 may be connected for fluid communication with the first induce port 106. The first nozzle 118 may include a smaller minimum diameter than the motive port 108. The second nozzle 124 may include a smaller minimum diameter than the first induce port 106. The minimum diameters of the first nozzle 118 and the second nozzle 124 may, for example and without limitation, be substantially equal.

[0021] With embodiments, the first induce port 106 and the second induce port 116 may be configured such that upon a reduction of fluid pressure in the body 102 (e.g., at the motive flow 126 speeds up), a first induced flow 128 may move into the first induce port 106 and a second induced flow 130 may move into the second induce port 116. The first induced flow 128 may move around the first nozzle 118 to mix with the motive flow 126. The second induced flow 130 may move around the second nozzle 124 to mix with the motive flow 126 and/or the first induced flow 128. With embodiments, a junction 134 between the inlet portion 104 and the throat 112 may be smooth and/or rounded, such as to minimize losses.

[0022] In embodiments, the second nozzle 124 (and/or an end thereof) may be offset from the first nozzle in an axial direction. With such a configuration, the first induced flow 128 may mix with the motive flow 126 in a first mixing area 136 upstream and/or before the second induced flow 130 mixes with the motive flow 126 in a second mixing area 138 (e.g., stepped mixing). Stepped mixing may facilitate effective mixing and/or lower mixing losses.

[0023] With embodiments, the ratio of the area of the first nozzle 118 to the area of the second nozzle 124 may be optimized for efficiency. For example and without limitation, the ratio may be about 0.35 to about 0.45, such as about 0.41. In embodiments, the distance between the first nozzle 118 and the second nozzle 124 (e.g., in an axial direction) may be optimized. For example and without limitation, a ratio of the distance between the first nozzle 118 and the second nozzle 124 relative to the diameter of the first nozzle 118 may be about 2.0 to about 4.0, such as about 2.4 to 3.3.

[0024] In embodiments, an inner surface of the second nozzle 124 may function as a mixing wall for the motive flow 126 and the first induced flow 128. The inner surface of the second nozzle 124 may be tapered and/or curved, and may, for example and without limitation, include a second converging angle 132 of about 8 degrees to about 9 degrees, such as about 8.4 degrees, which may maximize efficiency, at least in some circumstances. The tapered wall 120 may function as a mixing wall for the mixed motive flow 126 and first induced flow 128 mixing with the second induced flow 130. The converging angle 122 may, for example and without limitation, be about 18 degrees to about 19 degrees, such as about 18.5 degrees, which may maximize efficiency, at least in some circumstances.

[0025] With embodiments, a distance between the second nozzle 124 and the throat 112 and/or the throat diameter may be optimized for efficiency. For example and without limitation, a ratio of the distance between the second nozzle 124 and the start of the throat 112 relative to the throat diameter may be about 1 to about 2, such as about 1.4.

[0026] In embodiments, an area of the first nozzle 118 and/or an area of the throat 112 may be optimized for efficiency. For example and without limitation, a ratio of the area of the first nozzle 118 to the area of the throat 112 may be about 0.26 to about 0.27, such as about 0.263.

[0027] With embodiments, the throat length and/or the throat diameter may be optimized for efficiency. For example and without limitation, a ratio of the throat length relative to the throat diameter may be at least about 5, such as at least about 5.3.

[0028] With embodiments, a jet pump 100 may provide an efficiency of about 34 percent, which may be about 12-14 percent more efficient than other designs that may provide an efficiency of about 20-20 percent. Efficiency of embodiments of a jet pump 100 (e.g., with a single-induce port configuration of FIG. 1) may, for example and without limitation, be maximized when a ratio of induced flow rate to motive flow rate is about 1 to about 1.4, such as about 1.2 (see, e.g., **FIG. 4).** Additionally or alternatively, efficiency of embodiments of a jet pump 100 (e.g., with a dual-induce port configuration of **FIG. 5)** may, for example and without limitation, be maximized when a ratio of induced flow rate to motive flow rate is about 0.9 to about 1.1, such as about 0.95 (see, e.g., **FIG. 7).** Embodiments of a jet pump 100 may be configured for use with a wide range of fluids, including liquids and gasses. In contrast, ejectors may be configured only for gasses/air.

[0029] In embodiments, a jet pump 100 may, for example and without limitation, be manufactured via additive manufacturing (e.g., 3D printing).

[0030] Various examples/embodiments are described herein for various apparatuses, systems, and/or methods. Numerous specific details are set forth to provide a thorough understanding of the overall structure, function, manufacture, and use of the examples/embodiments as described in the specification and illustrated in the accompanying drawings. It will be understood by those skilled in the art, however, that the examples/embodiments may be practiced without such specific details. In other instances, well-known operations, components, and elements have not been described in detail so as not to obscure the examples/embodiments described in the specification. Those of ordinary skill in the art will understand that the examples/embodiments described and illustrated herein are non-limiting examples, and thus it can be appreciated that the specific structural and functional details disclosed herein may be representative and do not necessarily limit the scope of the embodiments.

[0031] Reference throughout the specification to "examples, "in examples," "with examples," "various embodiments," "with embodiments," "in embodiments," or "an embodiment," or the like, means that a particular feature, structure, or characteristic described in connection with the example/embodiment is included in at least one embodiment. Thus, appearances of the phrases "examples, "in examples," "with examples," "in various embodiments," "with embodiments," "in embodiments," or "an embodiment," or the like, in places throughout the specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner in one or more examples/embodiments. Thus, the particular features, structures, or characteristics illustrated or described in connection with one embodiment/example may be combined, in whole or in part, with the features, structures, functions, and/or characteristics of one or more other embodiments/examples without limitation given that such combination is not illogical or non-functional. Moreover, many modifications may be made to adapt a particular situation or material to the teachings of the present disclosure without departing from the scope thereof.

[0032] It should be understood that references to a single element are not necessarily so limited and may include one or more of such element. Any directional references (e.g., plus, minus, upper, lower, upward, downward, left, right, leftward, rightward, top, bottom, above, below, vertical, horizontal, clockwise, and counterclockwise) are only used for identification purposes to aid the reader's understanding of the present disclosure, and do not create limitations, particularly as to the position, orientation, or use of examples/embodiments.

[0033] Joinder references (e.g., attached, coupled, connected, and the like) are to be construed broadly and may include intermediate members between a connection of elements and relative movement between elements. As such, joinder references do not necessarily imply that two elements are directly connected/coupled and in fixed relation to each other. The use of "e.g." in the specification is to be construed broadly and is used to provide non-limiting examples of embodiments of the disclosure, and the disclosure is not limited to such examples. Uses of "and" and "or" are to be construed broadly (e.g., to be treated as "and/or"). For example and without limitation, uses of "and" do not necessarily require all elements or features listed, and uses of "or" are inclusive unless such a construction would be illogical.

[0034] While processes, systems, and methods may be described herein in connection with one or more steps in a particular sequence, it should be understood that such methods may be practiced with the steps in a different order, with certain steps performed simultaneously, with additional steps, and/or with certain described steps omitted.

[0035] All matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative only and not limiting. Changes in detail or structure may be made without departing from the present disclosure.

Claims

1. A jet pump, comprising:
   a body, including:

      an inlet portion including a motive port and a first induce port;
      a throat;
      a tapered wall connecting the inlet portion with the throat;
      a discharge port; and
      a diffuser connecting the throat and the discharge port.

2. The jet pump of claim 1, wherein the tapered wall includes a converging angle of about 5 degrees.

3. The jet pump of claim 1, wherein the inlet portion includes a first nozzle.

4. The jet pump of claim 3, wherein an outlet or end of the first nozzle is at least partially aligned with the tapered wall such that a motive flow flowing from the motive port out of the first nozzle mixes with an induced flow from the first induce port proximate the tapered wall.

5. The jet pump of claim 4, wherein the motive port and the first induce port are disposed substantially concentrically and the first induce port includes a greater outer diameter than the motive port.

6. The jet pump of claim 1, wherein the inlet portion includes a first nozzle, a second induce port and a second nozzle.

7. The jet pump of claim 6, wherein the motive port, the first induce port, and the second induce port are disposed substantially concentrically.

8. The jet pump of claim 7, wherein the second induce port includes a greater outer diameter than the motive port and the first induce port.

9. The jet pump of claim 8, wherein the first nozzle is offset in an axial direction from the second nozzle.

10. The jet pump of claim 6, wherein the tapered wall includes a converging angle and the second nozzle includes a second converging angle.

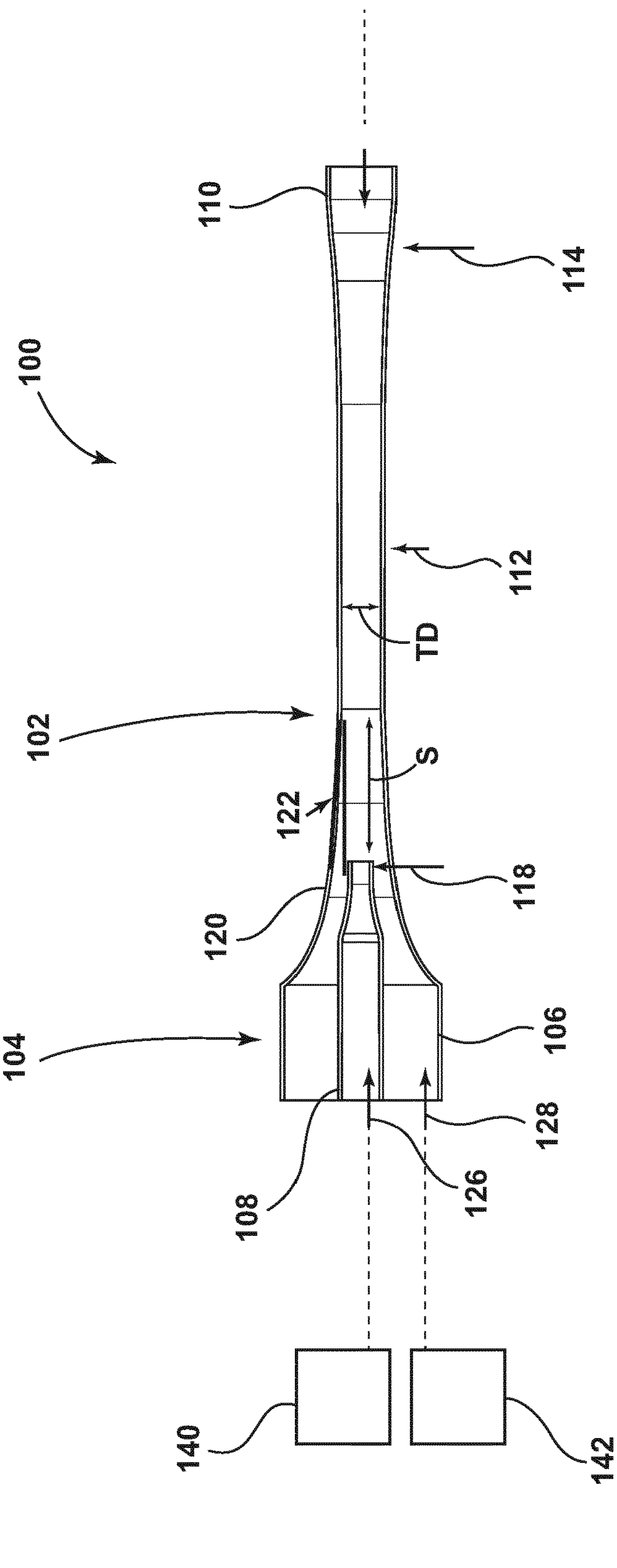
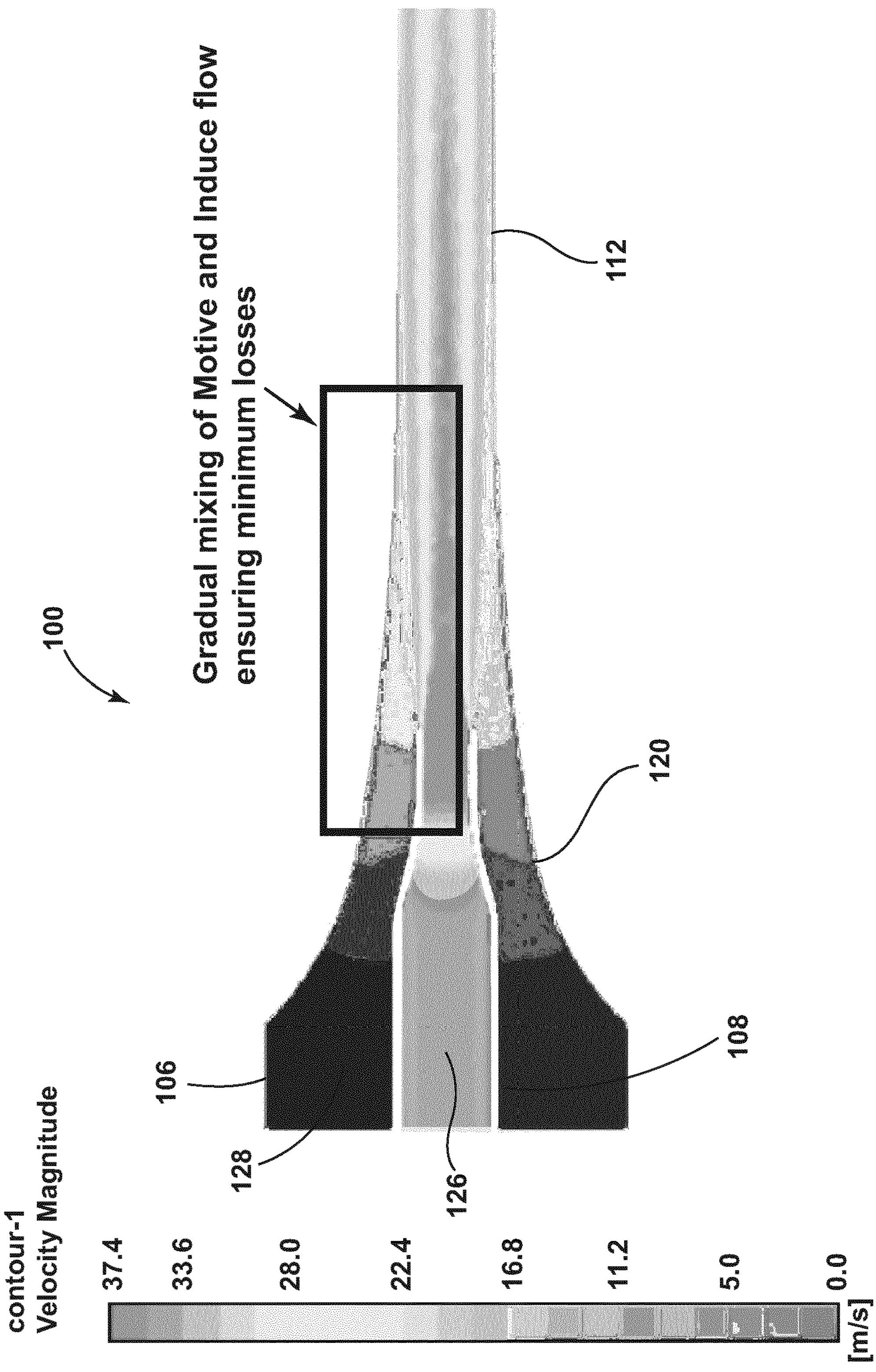
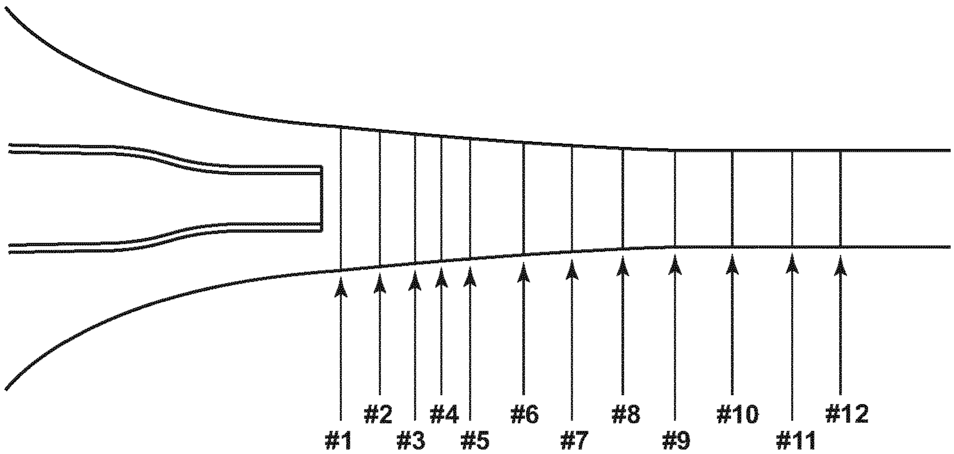


FIG. 1



100
Gradual mixing of Motive and Induce flow ensuring minimum losses
112
120
106
108
128
126
contour-1
Velocity Magnitude
37.4
33.6
28.0
22.4
16.8
11.2
5.0
0.0
[m/s]

FIG. 2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#2
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#6
#7
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#9
#10
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#12

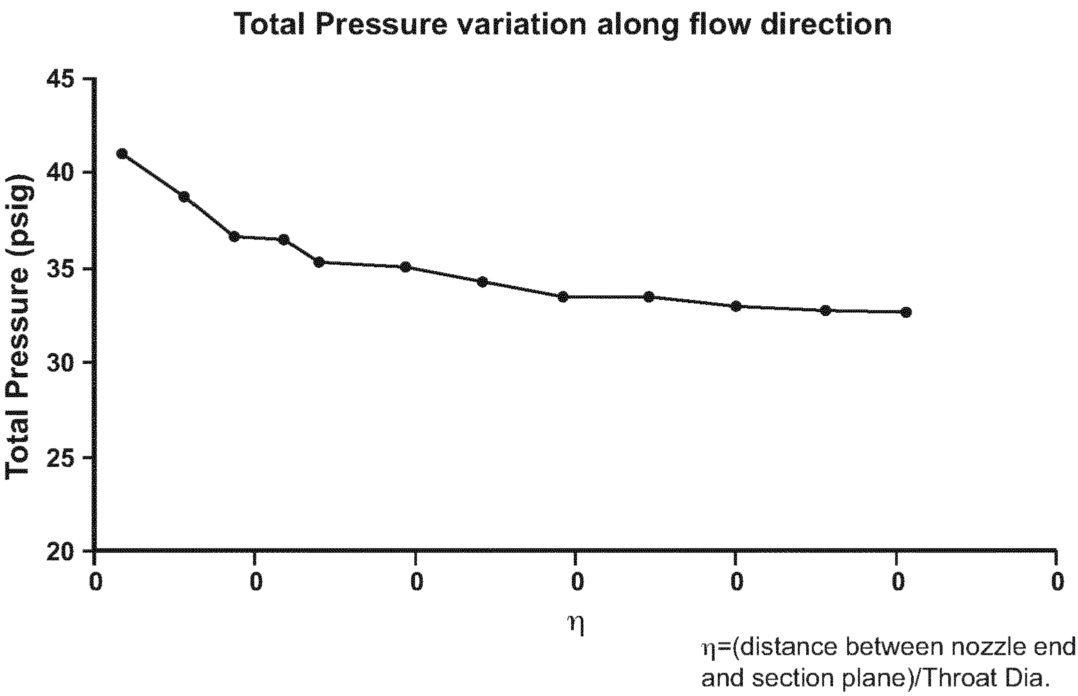
Total Pressure variation along flow direction
Total Pressure (psig)
45
40
35
30
25
20
0
0
0
0
0
0
0
η
η=(distance between nozzle end and section plane)/Throat Dia.

FIG. 3

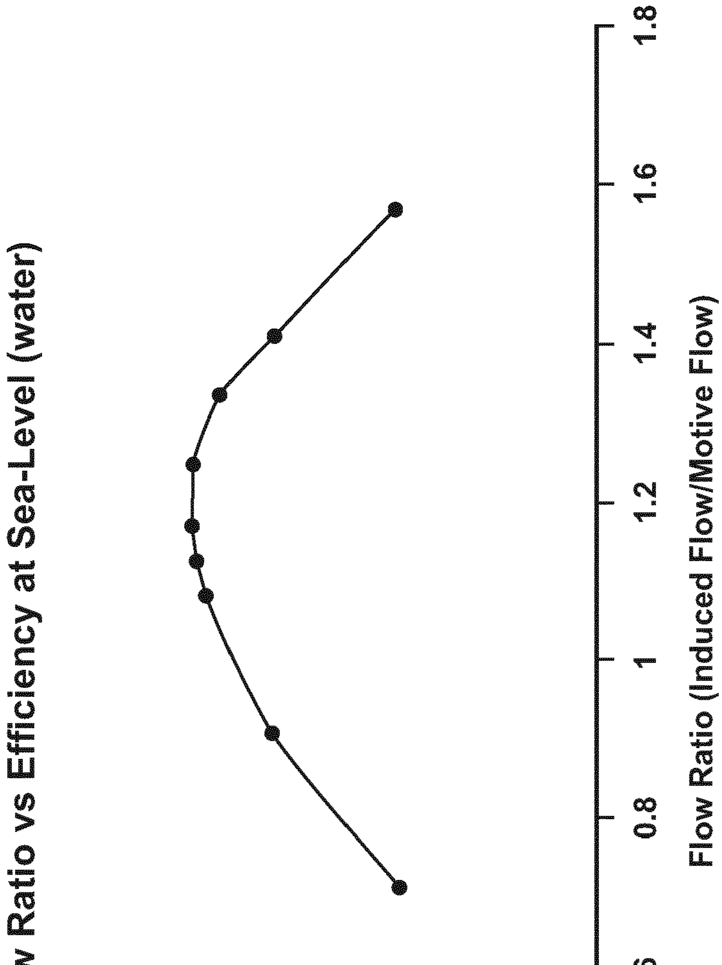
Flow Ratio vs Efficiency at Sea-Level (water)
Efficiency
36
34
32
30
28
26
24
22
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
Flow Ratio (Induced Flow/Motive Flow)

FIG. 4

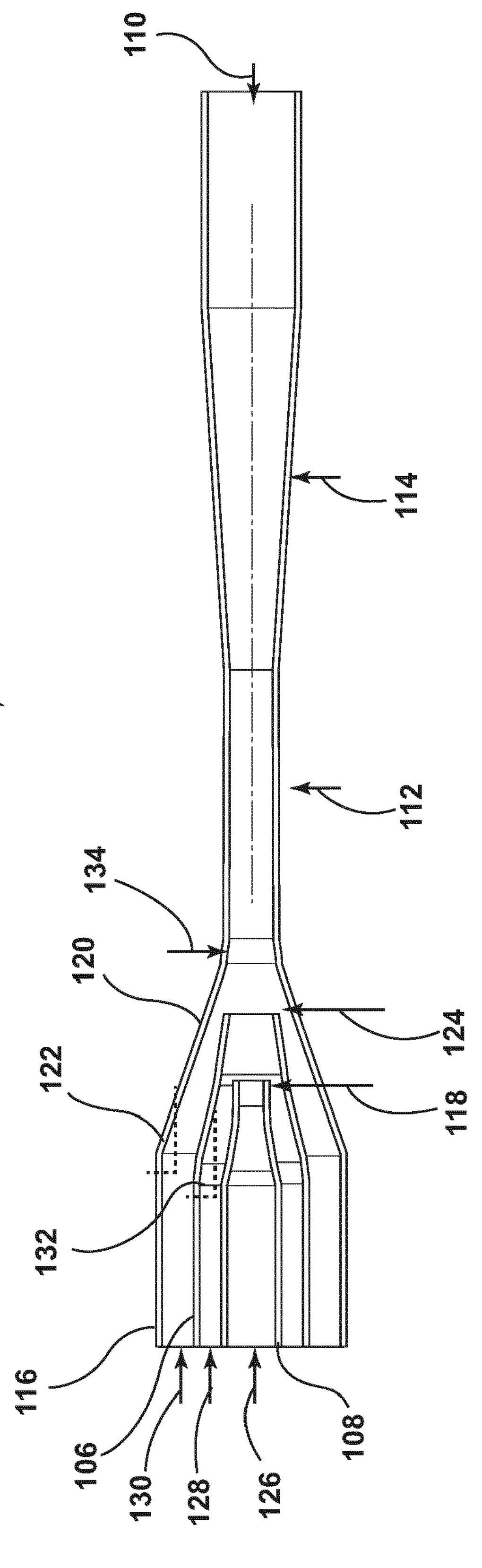

FIG. 5

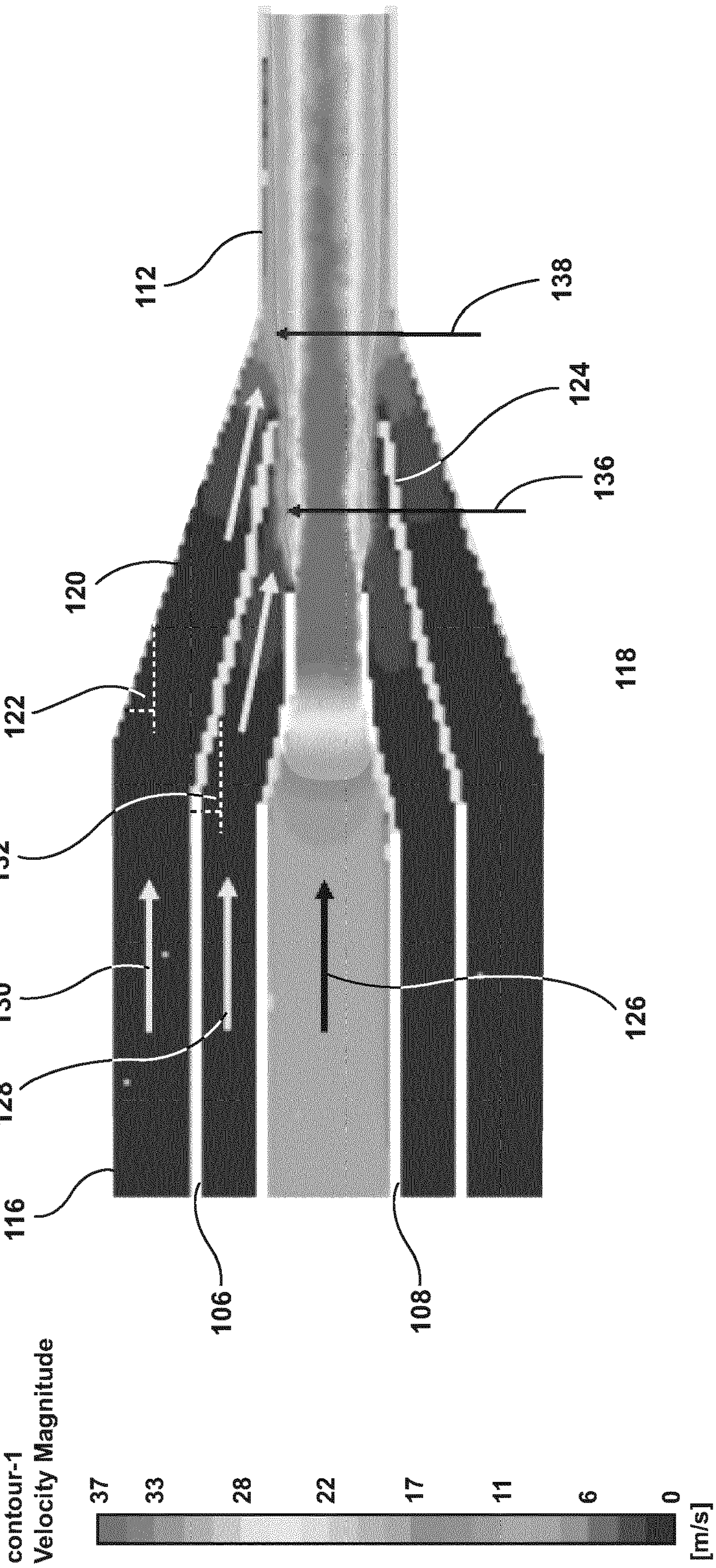
100
112
138
124
136
120
118
122
132
130
126
128
116
106
108
contour-1
Velocity Magnitude
37
33
28
22
17
11
6
0
[m/s]

FIG. 6

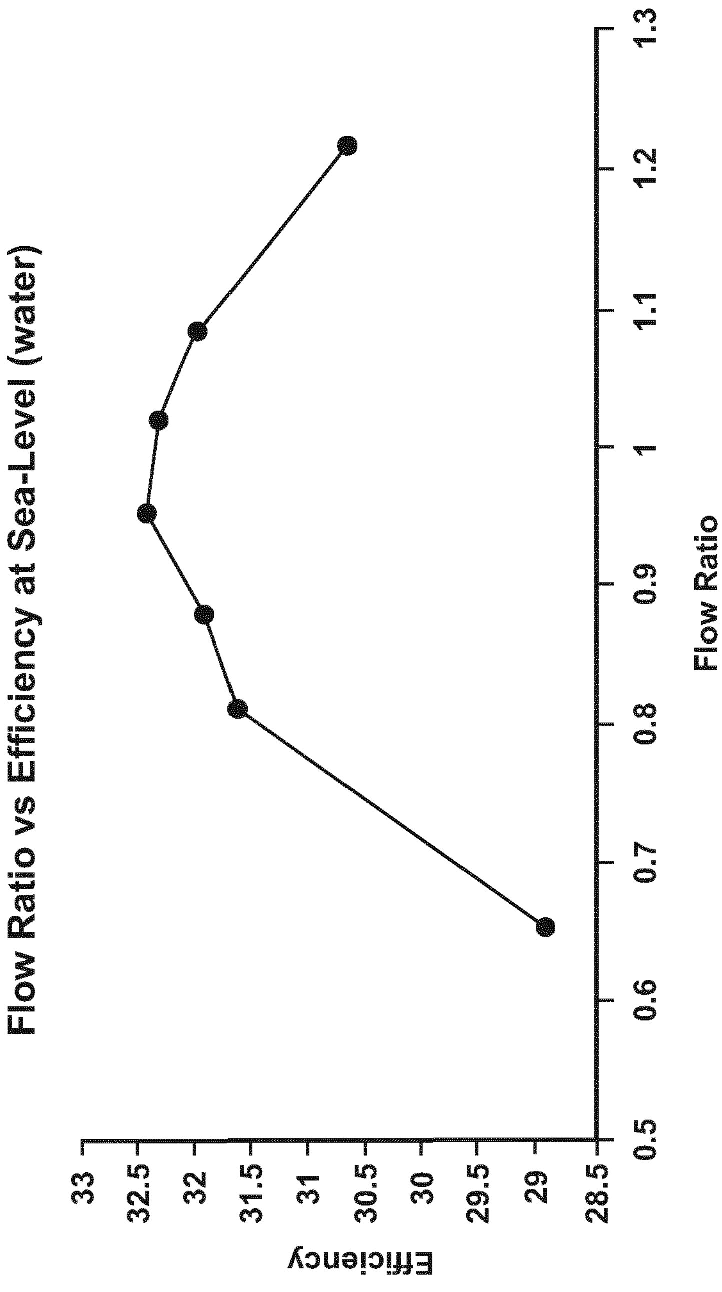
Flow Ratio vs Efficiency at Sea-Level (water)
Efficiency
33
32.5
32
31.5
31
30.5
30
29.5
29
28.5
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
Flow Ratio

FIG. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 21 16 8459

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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TECHNICAL FIELDS SEARCHED (IPC)

F04F

The present search report has been drawn up for all claims

3

Place of search	Date of completion of the search	Examiner
Munich	5 July 2021	Lange, Christian

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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REFERENCES CITED IN THE DESCRIPTION

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