June 27, 1961 H. COANDA ET AL 2,990,103

JET EXHAUSTER

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FIG.1

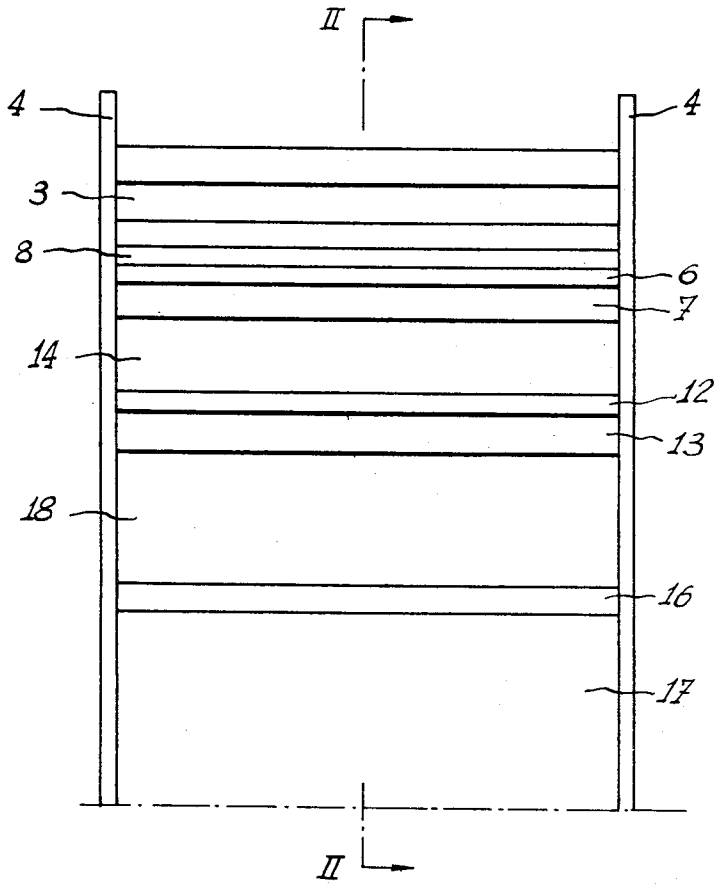

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FIG.2

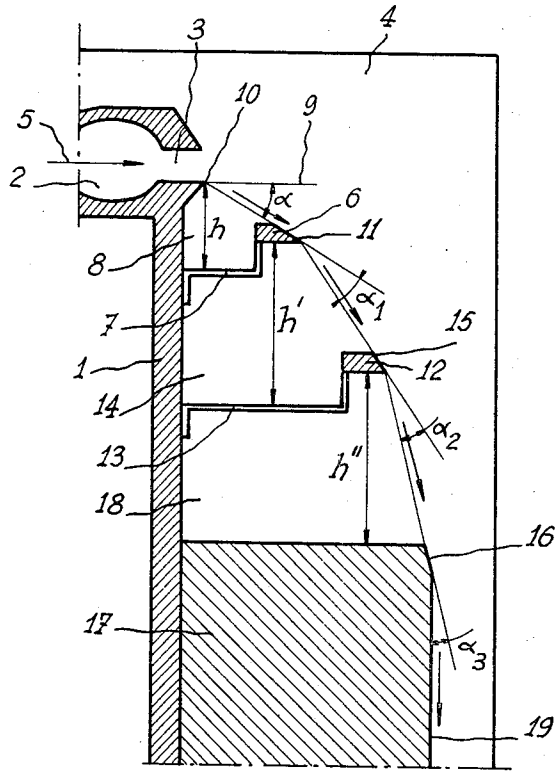

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FIG.3

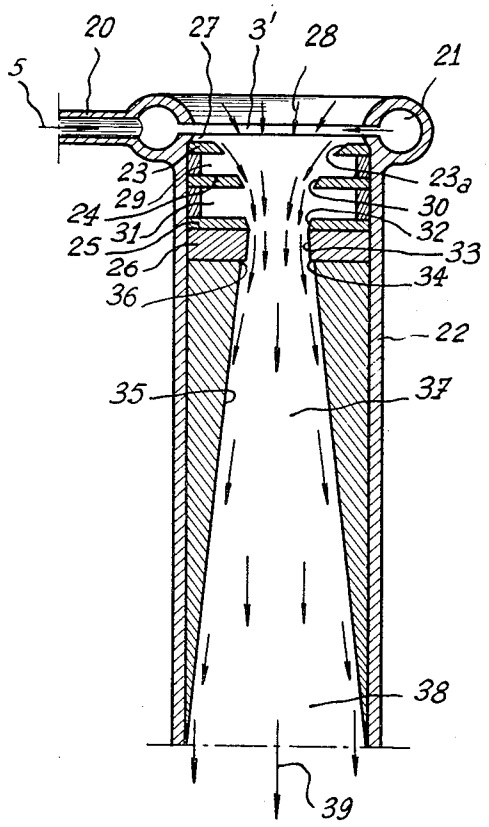

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FIG. 4

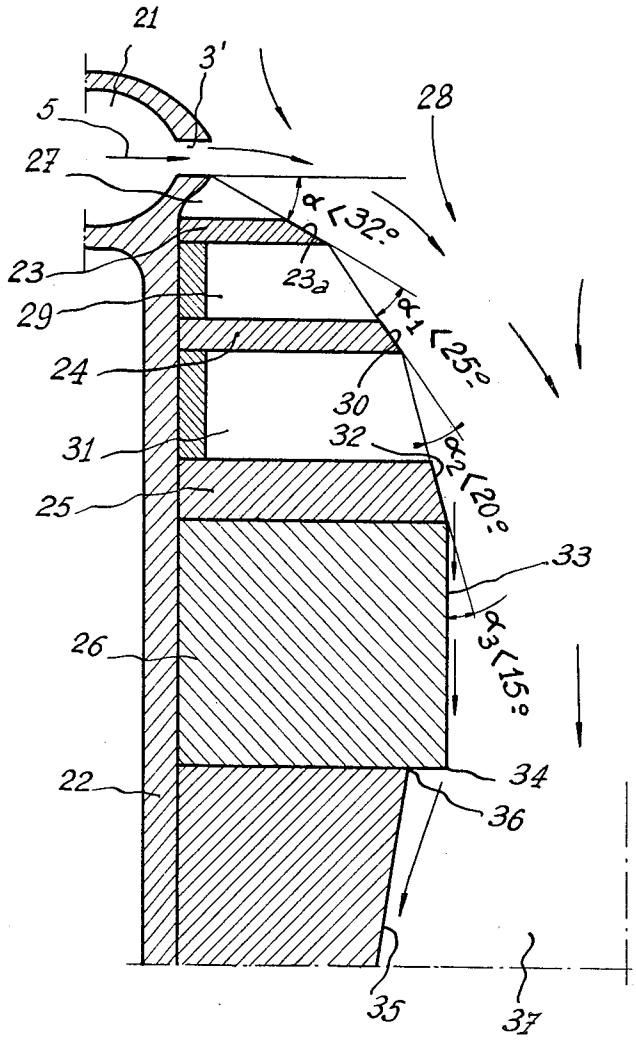

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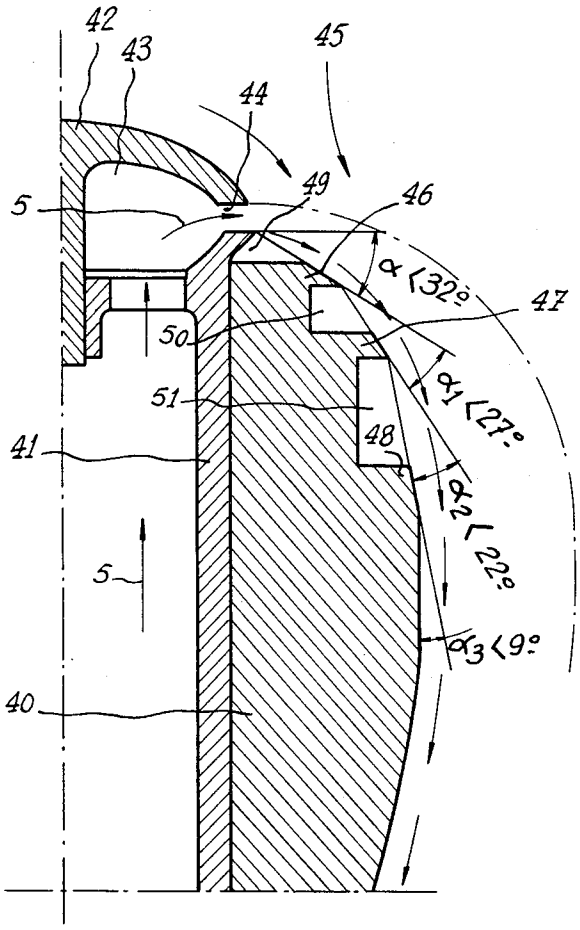
FIG.5



United States Patent Office 2,990,103 Patented June 27, 1961

2,990,103
JET EXHAUSTER

Henri Coanda, Paris, Marguerite Ribeyrolles, nee Gantillon, Clichy, and Michel Garnier, Paris, France, assignors to Sebac Nouvelle S.A., a corporation of Switzerland

Filed Sept. 1, 1959, Ser. No. 837,409
Claims priority, application France Sept. 8, 1958
5 Claims. (Cl. 230—95)

The present invention relates to an exhauster device for creating one or a number of zones of reduced pressure or partial vacuum by means of the flow of a flat fluid jet.

When a flat jet of fluid (gaseous or liquid) passes out of an orifice of rectangular section, which may be limited by walls or may be continuous, and passes into another fluid, and when a body is brought up to one of the larger sides of the rectangle which forms the jet, under certain conditions, surprising effects are obtained.

The first surprising effect consists in that, when the body which is brought up is connected to the chamber from which the jet issues, so that it creates a space isolated from the ambient fluid into which the jet discharges, it is found that on all sides except on the side of the jet, in the case of air under a certain pressure, when the angle α between the direction of the jet and the straight line drawn from the edge of the outlet orifice and passing tangentially to the body approaches 32°, there is created in the space a very high pressure drop or partial vacuum which has the unexpected characteristic of being attenuated when the angle α diminishes. This is true while the same pressure on the upstream side of the jet, the same outlet section and the same distance of the body from the outlet of the jet are maintained.

Still a more surprising effect is that which is produced in the jet itself, which is first of all turned or curved inwardly towards the body, accelerates its speed of flow and reduces its internal tension to a value substantially below the pressure obtaining in the ambient fluid. This has as its first result that the mass of the jet flowing through the same outlet section with a given upstream pressure is increased and secondly, the ambient fluid rushes into the zone of reduced pressure created in the jet, and re-establishes its pressure without reducing the speed of flow to any considerable extent, which has the result of substantially increasing the momentum per second of the jet.

As soon as the jet reaches the body, if another body is brought close to the jet it thus turned inwardly, and if the same conditions are observed, the phenomenon repeats itself and a new zone of reduced pressure is created between the first body and the second, and this second zone is smaller than the first, with the result that the speed is slightly reduced, but the jet continues to increase its mass by the ambient fluid which has flowed in to fill the new reduced pressure zone created in the jet. The stages of this flow can be continued in this way so as to obtain several stages of reduced pressure zones, while the momentum is continually increased.

The applications for an arrangement of this kind are very numerous. For example, as has been stated above, a large momentum can be produced without increasing the upstream pressure of the jet. Also, the spaces can be connected to chambers in which it is desired to maintain a reduced pressure. Further, it is possible to make use of these pressure drops for all kinds of other applications, such as the suction of liquid into the jet in order to produce a spray. The pressure drop or reduced pressure zones so created can also be employed to produce a lift effect by adapting it to an aircraft wing, etc.

The characteristic feature of the present invention resides in the method which consists in the use of a flat

fluid jet to create one or more reduced pressure zones by bringing up to one of the longer sides of the flat jet, of limited or continuous rectangular section, one or a number of bodies of appropriate shape. The first body is located at a pre-determined position with respect to the outlet orifice of the jet such that, for example in case of air, the angle between the direction of the jet and a straight line drawn from the orifice and passing tangentially to the first body is less than 32°, and such that the distance between the body and the orifice is less than twelve times the height of the jet and the ratio between the pressure on the upstream side of the jet and the ambient fluid is less than thirty. The second body of appropriate shape should be located in such manner with respect to the first body that the straight line drawn from the extreme point of the first body and passing tangentially to the second body forms an angle less than 30° with the extension of the tangent which starts from the outlet orifice to the first body, the distance being less than twelve times the thickness of the jet opposite the first body, and so on.

The characteristic values given above correspond to air, and vary according to the fluid considered.

The determination of the value of the reduced pressure zones is effected either by reducing the dimensions of the angles α, or by acting on the pressure on the upstream side of the jet, or by acting on the ratio between the distances existing between the element carrying the jet and the bodies, and also by acting on the height of the jet. This determination can be made either by each of the above means taken separately, or by employing any combination of these means.

Several forms of construction of devices according to the invention are described below by way of simple example, reference being made to the accompanying drawings, in which:

FIG. 1 is a front view of a first device according to the invention having a limited rectangular section;

FIG. 2 is a cross-section taken along the line II—II of FIG. 1;

FIG. 3 is a cross-section of a hollow discharge nozzle device provided with bodies of revolution;

FIG. 4 is a fragmentary view of the same device on an enlarged scale; and

FIG. 5 is a cross-section of an alternative form, in which the discharge nozzle, provided with bodies of revolution, discharges towards the exterior.

The device shown in FIGS. 1 and 2 comprises a member **1** in which is formed a chamber **2** having an outlet orifice formed by a slot **3** of rectangular section. The slot is limited at its two extremities by walls **4** to which the member **1** is attached and which prevent ambient fluid from acting at the sides of a gaseous jet **5** discharged under pressure from the chamber **2** through the slot **3**. The walls **4** form and define an intake for an ambient fluid to be moved by the gaseous fluid under pressure discharged from the chamber **2** as a jet.

A body **6**, attached by a support **7** to the member **1** and the walls **4**, creates a space **8** which is isolated from the ambient fluid.

When the angle α existing between a plane **9** corresponding to the direction of the outlet of the jet **5** and a straight line which connects a portion **10** of the slot **3** to the body **6**, to which it is tangential at a surface **11**, is less than 32°, the jet **5** can be seen to curve inwardly and pass in contact with the surface **11** of the body **6**, while a substantial pressure drop is observed in the space **8**.

After having passed over the surface **11** of the body **6**, the jet again curves inwardly through an angle α_1, less than 25°, towards a second body **12** which is attached

like the body **6** by a support **13** to the member **1** and to the walls **4**. In the space **14** created by the second body **12**, a pressure drop is also produced. The jet which has been deflected from the surface **11** of the body **6**, now passes over a surface **15** of the body **12**, after which it is again curved through an angle α_2, less than 20° and is then directed towards a surface **16** drawn by the action of a third body **17**, while creating a new space **18** in which a pressure drop is also produced.

Finally, the jet passes along a surface **19** and leaves the surface of the body **17**, with which is makes an angle α_3 which is less than 15°.

In the above device, the value of the reduced pressures in the spaces **8**, **14** and **18** can be reduced by reducing the heights h, h' and h'' of the spaces respectively.

In the device shown in FIGS. 3 and 4, the operation is similar to that of the device shown in FIGS. 1 and 2, but there are no longer any lateral walls and the slot is continuous.

In this device, a gas **5** under pressure enters through a pipe **20** and is distributed in a circular chamber **21** from which it issues as a jet through a circular slot **3'**.

The circular chamber **21** is formed above a cylindrical body **22**, in which are mounted, one above the other, a plurality of annular bodies **23**, **24**, **25** and **26** which act on the jet.

The air passing out of the slot **3'** is drawn towards the first annular body **23** and passes over a surface **23***a*, thus producing a very high pressure drop in the annular space **27**. The jet of air is accelerated and its internal tension is less than that which obtains in ambient air denoted by the arrows **28**. This air rushes into the jet and the whole mixture is then drawn towards the second annular body **24** and produces a reduced pressure in the annular space **29**.

Having passed over a surface **30** of the body **24**, the jet is again curved inwardly by the pull of the body **25**, creating a reduced pressure zone in a space **31**. After passing over a surface **32** of the body **25** and a surface **33** of the body **26**, the mixture of the jet and the ambient air **28** which it has carried along, reaches the level of a throat **34**. At this point, under the drawing-in action of the wall **35**, it creates at **36** a last reduced pressure zone which imparts a final acceleration to the mixture.

Subsequently, in accordance with Bernouilli's law, the mixture of the air of the jet and the ambient air slows down its movement in the divergent section **37** and transforms its kinetic energy to potential energy up to an outlet zone **38**, where it leaves the entire device, which in this case acts as an ejector-injector at **39**.

In the embodiment shown in FIG. 5, the bodies which define the spaces or zones in which a reduced pressure is created and affect the form and course of the jet constitute a single block of revolution **40** external to and fitting over a central tubular member **41**.

A cap **42** forms an annular chamber **43** with the tubular member **41**. This chamber opens into the ambient, fluid denoted by the arrow **45**, through a circular slot **44**.

The fluid under pressure, illustrated by the arrow **5**, passes out of the slot **44** and the jet is subjected to the successive attractions of the projections **46**, **47** and **48** formed at the periphery of the outer block **40** and defining spaces **49**, **50** and **51** in which a reduced pressure is created.

The operation of this device is the same as in the devices previously described.

The devices described above have been assumed to be traversed by air, but it is clear that the invention can just as well be applied to all other devices intended for all other liquid or gaseous fluids, by modifying the dimensions and characteristics of some of their members.

If, for example, it is desired to apply the devices to a fluid which is heavier than air, for example water, the reasoning which has enabled the values for air to be determined in the examples previously described, should be completed as follows:

It is considered that the adhesion of a fluid stream to a pre-determined point is due to an imbalance produced between the ambient pressure, acting on one side of the flat jet, and the vacuum produced on the opposite side of the jet.

On the other hand, the detachment of the jet is caused by centrifugal force applied to the jet and which, for the above reason, prevents the cavity in which the reduced pressure is created from being made fluid-tight at a certain moment.

This centrifugal force is equal to

$$\frac{mV^2}{r}$$

in which m is the fluid mass, V is its speed at the moment when the jet touches the desired point, and r is the radius of curvature, the arc of which represents the line which makes an angle with the original direction of the jet.

The speed due to an isentropic flow for air is given by:

$$V=44.818\sqrt{T_1-T_0}$$

or again by the equation of condition:

$$PW=RgT,\ P_1W_1=RgT_1\ \ldots$$

and we have

$$\frac{PW}{Rg}=\frac{P}{dR}=T,\ \frac{P_1W_1}{Rg}=\frac{P_1}{d_1R}=T_1,\ \text{etc.}$$

in which W is the volume, P the pressure, g the weight, d the density and R the constant of the gases.

In the case of air, the speed of flow can therefore be written as follows:

$$V_a=44.818\sqrt{\frac{1}{R}\frac{P_1}{d_1}-\frac{P_0}{d_0}} \qquad (1)$$

In the case of water, the speed of flow is:

$$V_e=\sqrt{2gH}$$

and therefore

$$V_e=44.4\sqrt{\frac{P_1-P_0}{P_0}} \qquad (2)$$

since in the case of water,

$$H=10\left(\frac{P_1-P_0}{P_0}\right)$$

from (1) and (2) it may be deduced that the ratio between the speed or air and the speed of water for the same pressures, will be approximately as follows, to within 1%:

$$\frac{V_a}{V_e}=\sqrt{\frac{1}{R}\left(\frac{P_1}{d_1}-\frac{P_0}{d_0}\right)\frac{P_0}{P_1-P_0}}$$

Assuming that $P_0=10{,}000$ (which is not quite accurate, since in the case of water we are about one meter below the level) the above can give in round figures an order of magnitude, for infrasonic speeds of air especially:

$$\frac{V_a}{V_e}=100\sqrt{\frac{P_1-P_0\frac{d_1}{d_0}}{Rd_1(P_1-P_0)}}$$

in which d_1 is the density of the air just on the upstream side of the outlet of the slot, and

$$\frac{d_1}{d_0}$$

is the relative density of the air.

Since the mass m may be written reciprocally:

$$\tfrac{1}{8}S_aV_a \text{ for air, and } 102S_eV_e \text{ for water}$$

S_a and S_e being the cross section of the jets of air and of water, respectively,

if $S_a=S_e$, it is found that:

$$\frac{m_a}{m_e}=\frac{1}{816}\cdot\frac{V_a}{V_e}=0.123\sqrt{\frac{1}{R}\frac{P_1-P_0\frac{d_1}{d_0}}{d_1(P_1-P_0)}}$$

and therefore the ratio which will give the radius of curvature will be:

$$\frac{m_aV_a^2}{r_a}\cdot\frac{r_e}{m_eV_e^2}=1230\left[\frac{P_1-P_0\frac{d_1}{d_0}}{Rd_1(P_1-P_0)}\right]^{1.5}\frac{r_e}{r_a}$$

from which can be found the value of the arc, its length, etc. for the same vacuum created on one side of the jet.

It can therefore be seen that by a simple calculation it is possible to determine the angles and therefore the shapes.

It should also be observed that in view of the partial vacuum created behind the jet of water, there will be produced in this reduced pressure zone an evaporation of the water which will partly fill this zone.

What we claim is:

1. A device for creating at least one reduced pressure zone by the flow of a substantially flat fluid jet comprising, means defining a chamber supplied with fluid under pressure and having two spaced, elongated lips defining a narrow elongated slot of continuous uniform substantially rectangular section formed communicating with said chamber for discharging a flat jet of said pressure fluid therefrom in a given initial direction, means defining a wall fast with said means defining said chamber and extending perpendicularly to a plane disposed in a direction corresponding to the longitudinal dimension of said slot and corresponding to an exit axis of said slot which corresponds to the initial direction of fluid flow through said slot, a first member mounted on said wall extending therefrom and spaced axially from and in close relation to the nearer of said lips defining said slot and having a sloping outermost face spaced from said wall to deflect the jet from its direction of flow and forming in conjunction with said jet and the wall a fluid-tight space, said first member sloping face being so formed and axially spaced from said slot that an angle included between said plane corresponding with the initial direction of flow of the jet and a straight line tangential to the outermost tip of said nearer lip of said slot and passing tangentially to said outermost sloping face on said first member has a predetermined value dependent on the nature of said fluid, and a plurality of other members mounted axially spaced on said wall extending therefrom and axially spaced from said first member, and each of said other members being formed with an outermost sloped face spaced axially from the outer sloped face of a preceding member which is disposed in a direction toward said slot relative to a next succeeding other member so that respective angles included between intersecting straight lines each disposed tangentially to the outermost tip of the sloped face of a preceding member and disposed tangentially to the outer sloping face of the next succeeding member progressively diminish in value relative to each other, and means on said device forming and defining an intake for ambient fluid and directing it in a downstream direction toward said elongated slot to be moved by said jet of fluid under pressure, said intake defining means being disposed on said device upstream of said slot.

2. A device for creating at least one reduced pressure zone by the flow of a substantially flat fluid jet comprising, means defining a chamber supplied with fluid under pressure and having two spaced, elongated lips defining a narrow elongated slot of continuous uniform substantially rectangular section formed communicating with said chamber for discharging a flat jet of said pressure fluid therefrom in a given initial direction, means defining a wall fast with said means defining said chamber and extending perpendicularly to a plane disposed in a direction corresponding to the longitudinal dimension of said slot and corresponding to an exit axis of said slot which corresponds to the initial direction of fluid flow through said slot, a first member mounted on said wall extending therefrom and spaced axially from and in close relation to the nearer of said lips defining said slot and having a sloping outermost face spaced from said wall to deflect the jet from its direction of flow and forming in conjunction with said jet and the wall a fluid-tight space, said first member sloping face being so formed and axially spaced from said slot that an angle included between said plane corresponding with the initial direction of flow of the jet and a straight line tangential to the outermost tip of said nearer lip of said slot and passing tangentially to said outermost sloping face on said first member has a predetermined value dependent on the nature of said fluid, and a plurality of other members mounted axially spaced on said wall extending therefrom and axially spaced from said first member, and each of said other members being formed with an outermost sloped face spaced axially from the outer sloped face of a preceding member which is disposed in a direction toward said slot relative to a next succeeding other member so that respective angles included between intersecting straight lines disposed tangentially to the outermost tip of the sloped face of a preceding member and disposed tangentially to the outer sloping face of the next succeeding member progressively diminish in value relative to each other, and said means defining said chamber forming and defining an intake for an ambient fluid to be moved by said fluid under pressure.

3. A device as claimed in claim 2, in which said fluid under pressure is air, the angle included between the first-mentioned plane and the plane disposed tangentially to said first member sloped face has a value less than 32°, the distance between the first member and said nearer lip being less than twelve times a thickness dimension of the jet in the vicinity of said slot, and the ratio of the fluid under pressure at said slot to the pressure of the ambient fluid is less than 30.

4. A device for creating at least one reduced pressure zone by the flow of a substantially flat fluid jet comprising, means defining a chamber supplied with fluid under pressure and having two spaced, circular lips defining a narrow, circular slot of continuous uniform substantially rectangular section formed communicating with said chamber for discharging a flat jet of said pressure fluid therefrom in a given initial direction, circular means defining a wall fast with said means defining said chamber and extending perpendicularly to a plane disposed in a direction corresponding to the length of said slot and corresponding to an exit axis of said slot which corresponds to the initial direction of fluid flow through said slot, a first member mounted on said wall extending therefrom and spaced axially from and in close relation to the nearer of said lips defining said slot and having a sloping outermost face spaced from said wall to deflect the jet from its direction of flow and forming in conjunction with said jet and the wall a fluid-tight space, said first member sloping face being so formed and axially spaced from said slot that an angle included between said plane corresponding with the initial direction of flow of the jet and a straight line tangential to the outermost tip of said nearer lip of said slot and passing tangentially to said outermost sloping face on said first member has a predetermined value dependent on the nature of said fluid, and a plurality of other members mounted axially spaced on said wall extending therefrom and axially spaced from said first member, and each of said other members being formed with an outermost sloped face spaced axially from the outer sloped face of a preceding member which is disposed in a direction toward said slot relative to a next succeeding other member so that respective angles included between intersecting straight lines disposed tangentially to the outermost tip of the sloped face of a

preceding member and disposed tangentially to the outer sloping face of the next succeeding member progressively diminish in value relative to each other, and said means defining said chamber being annular in shape forming and defining an intake for an ambient fluid to be moved by said fluid under pressure.

5. A device for creating at least one reduced pressure zone by the flow of a substantially flat fluid jet comprising, means defining a chamber supplied with fluid under pressure and having two spaced lips defining a narrow slot of continuous uniform substantially rectangular section formed communicating with said chamber for discharging a flat jet of said pressure fluid therefrom in a given initial direction, means defining a wall fast with said means defining said chamber and extending perpendicularly to a plane disposed in a direction corresponding to the longitudinal dimension of said slot and corresponding to an exit axis of said slot which corresponds to the initial direction of fluid flow through said slot, a first member mounted on said wall extending therefrom and spaced axially from and in close relation to the nearer of said lips defining said slot and having a sloping outermost face spaced from said wall to deflect the jet from its direction of flow and forming in conjunction with said jet and the wall a fluid-tight space, said first member sloping face being so formed and axially spaced from said slot that an angle included between said plane corresponding with the initial direction of flow of the jet and a straight line tangential to the outermost tip of said nearer lip of said slot and passing tangentially to said outermost sloping face on said first member has a predetermined value dependent on the nature of said fluid, and a plurality of other members mounted axially spaced on said wall extending therefrom and axially spaced from said first member, and each of said other members being formed with an outermost sloped face spaced axially from the outer sloped face of a preceding member which is disposed in a direction toward said slot relative to a next succeeding other member so that respective angles included between intersecting straight lines each disposed tangentially to the outermost tip of the sloped face of a preceding member and disposed tangentially to the outer sloping face of the next succeeding member progressively diminish in value relative to each other and means on said device forming and defining an intake for ambient fluid and directing it in a downstream direction toward said elongated slot to be moved by said jet of fluid under pressure, said intake defining means being disposed on said device upstream of said slot.

No references cited.