

Oct. 2, 1951

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2,569,996

SELF-ADJUSTING REACTION NOZZLE

Filed Aug. 20, 1945

3 Sheets-Sheet 1

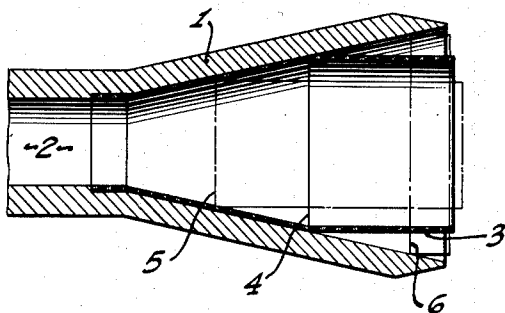


FIG. 1.

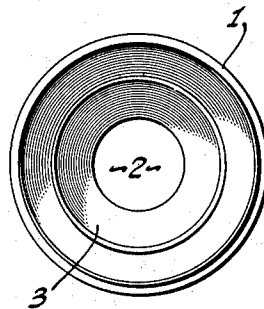


FIG. 2.

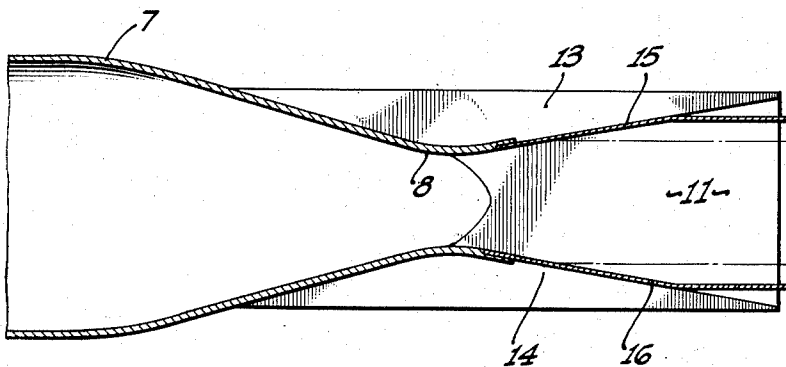


FIG. 3.

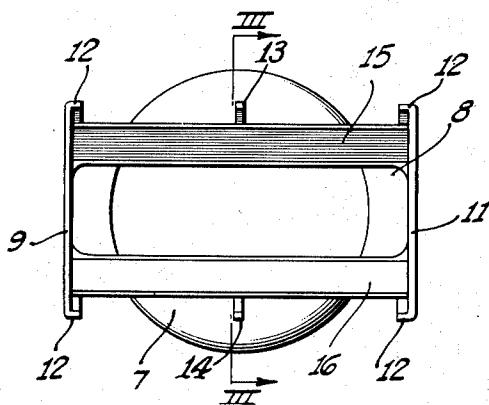


FIG. 4.

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3 Sheets-Sheet 2

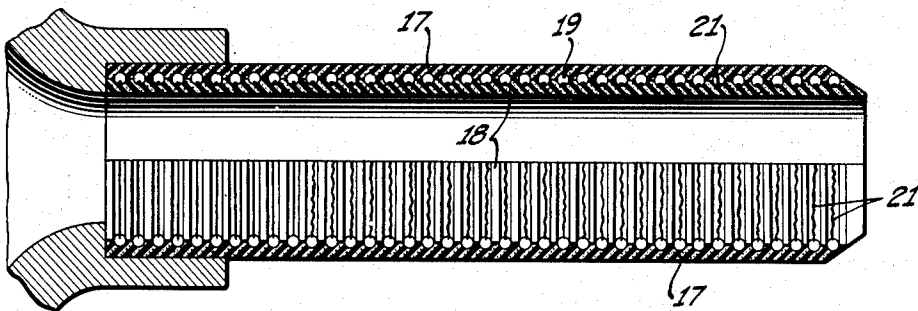


FIG. 5.

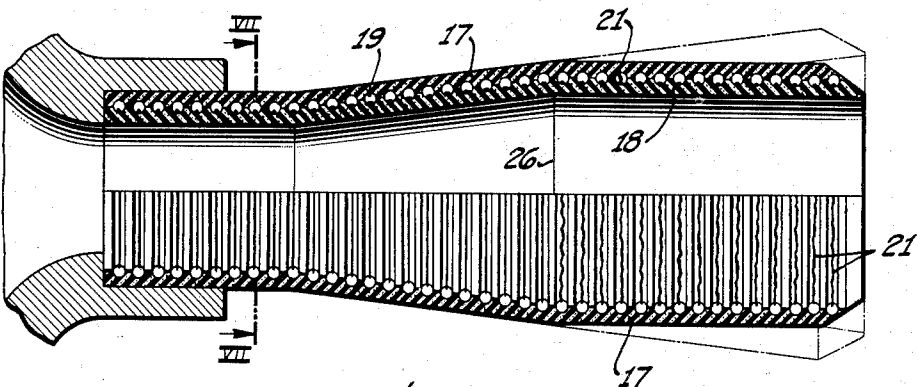


FIG. 6.

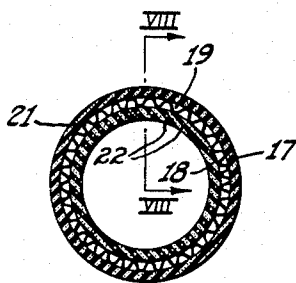


FIG. 7.

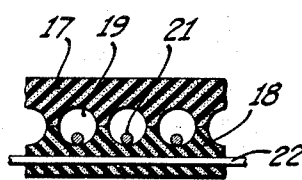


FIG. 8.

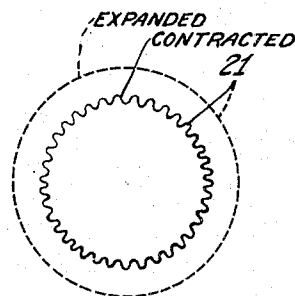


FIG. 9.

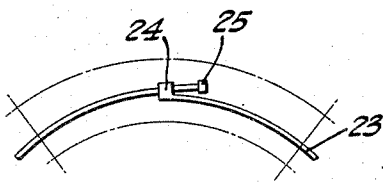


FIG. 10.

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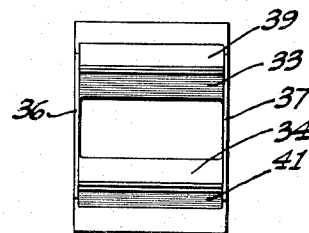
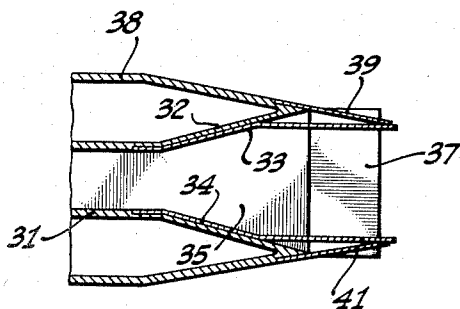
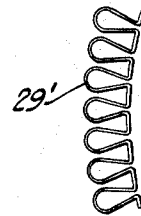
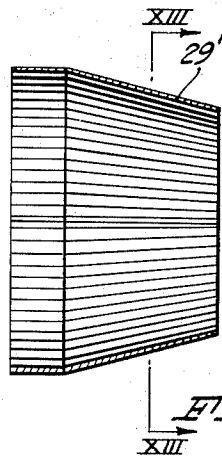
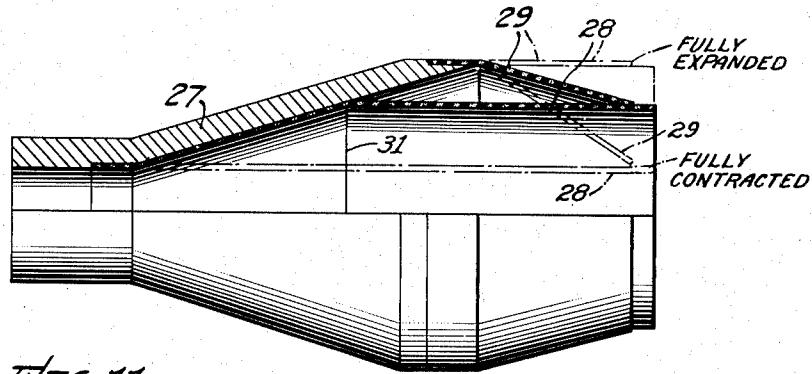
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SELF-ADJUSTING REACTION NOZZLE

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3 Sheets-Sheet 3



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SELF-ADJUSTING REACTION NOZZLE

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Application August 20, 1945, Serial No. 611,631

7 Claims. (Cl. 299-133)

1

This invention relates to nozzles for converting pressure energy of a gas into kinetic energy, and is particularly applicable to nozzles or rockets and jet engines, nozzles for turbines operated by steam of variable pressure, and other uses where jets of a compressible fluid are discharged into a space within which the pressure varies, it being understood that the uses must be compatible with the physical characteristics of the structural materials of a nozzle, particularly the resistance of heat.

One object of the invention is a provision of a nozzle for converting pressure energy of a gas into kinetic energy in which the nozzle walls automatically assume a position providing the substantially maximum delivery of kinetic energy.

Another object of the invention is a provision of a nozzle for converting the pressure energy of a gas into kinetic energy in which the walls of the nozzle are automatically movable substantially to balance the internal and external pressures thereon to secure substantially the maximum delivered kinetic energy in the discharged gas.

Another object of the invention is a provision of a nozzle in accordance with the preceding objects in which the maximum divergence of the nozzle walls is controlled.

Another object of the invention is the provision of a nozzle in accordance with the preceding objects in which a provision is made for streamlining the variable nozzle exit to facilitate its movement through a gas.

Other objects and features of the invention will be readily apparent to those skilled in the art from the specification and appended drawing illustrating certain preferred embodiments in which:

Figure 1 is a sectional view through a nozzle according to the present invention.

Figure 2 is an end view of the nozzle of Figure 1.

Figure 3 is a sectional view of a modified form of a nozzle.

Figure 4 is an end view of the nozzle of Figure 3.

Figure 5 is a sectional view of a further modified form of nozzle.

Figure 6 is a view of the nozzle of Figure 5 showing the shape of the nozzle with gas passing therethrough.

Figure 7 is a sectional view on the line VII-VII of Figure 6.

Figure 8 is an enlarged detail sectional view through the wall of the nozzle of Figures 5 and 6.

2

Figure 9 is a detail showing the contracted and expanded positions of an interior element limiting the divergence of the nozzle wall.

Figure 10 is a modified partial view of a divergence limiter.

Figure 11 is a view partly in section and partly an elevation of a modified form of nozzle including streamlining of the variable outlet opening.

Figure 12 is a sectional view of a modified form of nozzle wall element particularly adapted for use in curved surface nozzles according to present invention.

Figure 13 is an enlarged transverse sectional detail of the wall of Figure 12.

Figure 14 is a sectional view of a further modified form of nozzle.

Figure 15 is an end view of the nozzle of Figure 14.

In the form of the invention illustrated in Figures 1 and 2, there is provided a rigid nozzle portion 1 into which gas flowing from the tube 2 is discharged to effect conversion of the pressure energy of the gas into kinetic energy. If the pressure differential between the nozzle inlet and outlet for a given gas condition is too great, the energy conversion is not effected throughout the entire length of the nozzle but is incomplete and at the outer portion of the nozzle the gas simply expands to lower its remaining velocity and kinetic energy. After the pressure energy of the gas has been converted into kinetic energy it is desired that there be no further divergence of the nozzle chamber walls so that the gas will continue its movement through a passage of constant width. To effect this change in the surface of the walls defining the nozzle opening there is provided within the rigid nozzle portion 1 a resilient member 3 which is readily flexible in a transverse direction but with its longitudinal length maintained substantially constant. The walls of the interior member 3 will assume a position where the interior gas pressure is not less than the exterior pressure. As indicated in full lines in Figure 1, the pressure differential between the inlet and outlet of the nozzle is such as to effect the conversion of the pressure energy of the gas into kinetic energy along the tapered nozzle wall only to the plane 4. At this point the interior gas pressure is substantially equal to the exterior pressure assuming the tendency of the member 3 to expand or contract by itself is nonexistent or negligible and the walls of the member 3 beyond plane 4 form a cylinder of substantially constant diameter with substantially maximum delivery of kinetic energy of the gas. The

3

rigid nozzle portion 1 determines the angle of divergence of the walls of the member 3 in operation regardless of the pressure difference between the interior and exterior of the nozzle to insure contact of the gas with the nozzle surfaces.

In broken lines in Figure 1 have been illustrated other conditions of operation of the nozzle. Assuming that the inlet and outlet pressure differential is lowered from the full line condition, conversion of energy will be effected only to the plane 5, and thereafter the member 3 assumes a cylindrical shape to the nozzle outlet. Similarly, should the pressure differential increase, the member 3 will conform to the surface of the rigid portion 1 to the plane 6, with its final exit portion cylindrical.

In the form of the invention of Figures 3 and 4 there is provided a rectangular nozzle having its cross-sectional variation produced by flexible metal wall portions. While shown as rectangular, the invention is not limited thereto as other metal wall shapes could obviously be used. As specifically shown in Figures 3 and 4, there is shown a discharge tube 7 formed into a rectangular shape at the portion 8. The top and bottom walls beyond the portion 8 are discontinued but the parallel side wall portions 9 and 11 are continued with substantially increasing height toward the outlet. The edges of the side walls 9 and 11 are inwardly directed at 12 to provide stops. Intermediate of the side walls 9 and 11 the tube 7 carries ribs 13 and 14 whose inner surfaces diverge and which again form stops. Connecting to the top and bottom walls of the portion 8 of the tube 7 are flexible metallic walls 15 and 16 forming the top and bottom surfaces of the discharge nozzle. The operation of the nozzle of Figures 3 and 4 is similar to that described for Figures 1 and 2. The flexible walls 15 and 16 are acted upon by the inside and the outside pressure. In the area within which the inside pressure is greater than the outside pressure the walls rest against the stops 12, 13 and 14. At the point of equal pressures and beyond this point the walls 15 and 16 continue substantially parallel thus providing a duct of substantially constant cross section. Energy conversion is thus being effected efficiently within the tapered portion and thereafter further expansion of the gas is avoided by maintaining the internal pressure substantially equal to the external pressure. The divergence of the walls 15 and 16 is determined by stops 12, 13 and 14. In view of the thin section of the side walls and ribs a substantial streamlining is effected.

In the form of the nozzle illustrated in Figures 5, 6 and 7, the nozzle is shown as circular in cross-section and comprised of a pair of concentric resilient tubes formed of a material such as rubber, indicated at 17 and 18. These tubes are joined together to form a plurality of circumferentially spaced pockets 19 in which are disposed contracted wires or cords 21 of progressively increasing expanded length from the inlet toward the outlet of the nozzle. The resilient material of the tubes 17 and 18 is prevented from expanding lengthwise by longitudinally extending wires 22 shown particularly in Figures 7 and 8.

Figure 9 illustrates the expanded and contracted positions of one of the circumferential elements 21.

Figure 10 illustrates a modified form of circumferential element formed of a wire 23 which slides through a hub 24 with a limiting stop 25.

The nozzle as shown in Figure 5 is in its normal position without gas flow therethrough. Figure

4

6 illustrates the position of the nozzle walls under certain operating conditions in which the gas pressure has been converted to kinetic energy and the internal and external pressures substantially equalized at the plane 26 assuming that the tendency of the nozzle to contract is negligible in relation to the internal pressure. The portion of the nozzle beyond the plane 26 is again cylindrical, as shown in full lines. The divergent angle between the inlet of the nozzle and the plane 26 is determined by the varying overall length of the expanding elements 21 and 23 in the chambers 19. The position of the nozzle of Figure 6 for full conversion through the entire nozzle length is indicated by the broken plane lines and again this maximum divergence is determined by the progressively increasing length of the expansible elements 21 and 23 from the inlet toward the outlet of the nozzle.

In the form of the invention illustrated in Figure 11, there is provided a nozzle adapted for movement through a gas in which there is provision for streamlining the variable nozzle outlet. As specifically shown, this form comprises a rigid nozzle portion 27 similar to the nozzle portion 1 of Figure 1 and within the nozzle there is disposed the resilient member 28 similar to the resilient member 3 of Figure 1 but of greater length, extending beyond the outer edge of the rigid portion 27. Exteriorly of the nozzle portion 27 there is provided a second flexible member 29 whose outer edge is adapted to contact member 28 adjacent to its end.

In the nozzle of Figure 11, the flexible portion 28 will again assume a position providing for the maximum gas kinetic energy. As specifically shown, the internal and external gas pressures are substantially equal at the plane 31 and beyond this plane member 28 assumes a substantially cylindrical form with a constant diameter it being understood that the elastic resistance of the members 28 and 29 to expansion is negligibly small in relation to the force exerted by the gas on the member 28 producing its deformation to the illustrated shape. The surface 29, whose outer edge follows the movement of the member 28, streamlines the ineffective nozzle portion to the flow of gas outside the nozzle. In the absence of the member 29, the ineffective portion of the nozzle between the member 28 and the edge of the rigid member 27 would cause a considerably greater gas drag to nozzle movement.

Figures 12 and 13 illustrate a form of metallic wall which may be substituted for the flexible members 3, 28, and 29 of Figures 1 and 11. This wall 29' is formed of a thin resilient metal, corrugated as indicated more particularly in Figure 13. The particular shape selected by way of example for the illustration of Figure 12, is that of the member 29 whose outer edge rests freely on the wall of the member 28 without being connected thereto.

Air is permitted to enter and escape from the space between the members 28 and 29 by appropriate vents, as are provided, for example, by the corrugations with which the member 29 rests on the member 28.

In the form of nozzle illustrated in Figures 14 and 15, there is again provided streamlined surfaces for the variable nozzle outlet but in a form utilizing resilient metal walls. There is here shown the gas discharge duct 31 terminating in a diverging rigid nozzle portion 32. The nozzle is illustrated as rectangular but it is understood that other structural shapes permitting the movement of the walls may be utilized. The top

and bottom interior walls of the nozzle are formed by flexible walls 33 and 34, which, as illustrated, conform to the interior surface of the rigid portion to the plane 35, at which point the internal and external pressures are substantially equal. The side walls of the nozzle are shown at 36 and 37. Exteriorly of the discharge duct and nozzle there is shown a streamlined surface 38 which may be a structural wall of a device in which the nozzle is located, for example, the surface of an airplane. The streamlining of the nozzle outlet is effected between flexible strips 39 and 41 whose outer edges follow the movement of the resilient walls 33 and 34 to provide streamline surfaces to eliminate the drag of the ineffective portion of the nozzle outlet.

While certain preferred embodiments of the invention have been specifically disclosed, it is understood that the invention is not limited thereto, as many variations will be readily apparent to those skilled in the art and the invention is to be given its broadest possible interpretation within the terms of the following claims:

What is claimed is:

1. In a nozzle for converting gas pressure energy into kinetic energy, the improvement which comprises, a flexible wall forming part of the gas passage through the nozzle, said wall being acted upon by the gas pressure on the interior side tending to flex the wall in a direction to increase the cross sectional area of the nozzle if the gas pressure on the interior side is greater than the pressure on the exterior side of the wall, and stop means for limiting the extent to which the wall may be flexed to a predetermined maximum angle of divergence of the nozzle passage towards the discharge end of the nozzle under predominant gas pressure on said interior side, the said wall due to its flexibility being capable of having its end portion, adjacent the discharge end of the nozzle, flexed into a position of substantially constant cross sectional nozzle area under condition of substantial equality of pressure on either side of the wall in which case said end portion, in longitudinal section, extends at an angle with respect to the divergent portion and is spaced from said stop means.

2. An automatically adjustable nozzle for converting gas pressure energy into kinetic energy, the nozzle including an outer rigid housing, and a flexible wall within said housing forming at least a part of the gas passage through the nozzle within which the energy conversion takes place, said flexible wall being acted upon on the interior side by an internal pressure exerted by the gas flowing through the nozzle and on the exterior side by an external pressure, said flexible wall being free under condition of equal pressure on either side to assume a rest position in which the cross sectional area of the nozzle passage portion of which said wall forms a part is substantially constant, the wall being flexible in a direction to increase the cross sectional area of the nozzle passage towards the nozzle exit under condition of predominant internal gas pressure, said housing including a rigid wall for limiting the extent to which said wall may be flexed to a predetermined maximum angle of divergence of the passage towards the discharge end of the nozzle under action of predominant internal pressure, the flexible wall being sufficiently limp to have its end portion adjacent the discharge end of the nozzle flexed into a position of substantially

constant cross sectional nozzle area under the influence of substantially equal internal and the external pressure, said last named position being intermediate said rest position and the position of restraint by said rigid wall and lying at an angle, in longitudinal section, with respect to the position of restraint.

3. An automatic adjustable nozzle for converting gas pressure energy into kinetic energy by passage through a divergent passage, the nozzle including a flexible deformable wall portion leading to the nozzle discharge end, said wall portion normally providing a nozzle passage of substantially constant cross sectional area, the wall portion being deformable into a position in which it provides a divergent nozzle passage portion of progressively increasing cross sectional area of the passage towards the nozzle discharge end; provision for varying the length of the divergent passage portion in dependence on the difference in pressure between points inside the nozzle passage and the pressure outside the nozzle passage, the wall portion being capable due to its deformability to assume a position of substantially constant cross sectional passage area adjacent the nozzle discharge end under the compelling influence of the inside and outside pressure acting on the wall; and stop means for restraining said wall portion to a predetermined maximum angle of divergence of the passage portion under predominant interior pressure.

4. An automatically adjustable nozzle for converting gas pressure energy into kinetic energy comprising, an expansible tube; and a constraining outer rigid housing for said tube, the housing having an internal cavity of progressively increasing cross sectional area towards the nozzle exit, the tube being secured to said housing at an area of smaller cross section than that of the exit, the tube being expansible against the wall of the cavity under predominating pressure of a gas flowing through the nozzle.

5. An automatically adjustable nozzle for converting gas pressure energy into kinetic energy comprising an expansible tube of substantially cylindrical shape in non-expanded condition; and a constraining outer rigid housing for said tube, the housing having an internal cone-shaped cavity of progressively increasing diameter towards the nozzle exit, the tube being secured to said housing at the entrance portion of the housing, the tube being expansible against the conical wall of the cavity under predominating pressure of a gas flowing through the nozzle.

6. An adjustable nozzle comprising a rigid outer nozzle housing having a small diameter entrance portion and a large diameter body portion, a deformable member inside said nozzle housing secured to said housing with one end at the entrance portion, the said member providing, with its other end a nozzle discharge port of adjustable size depending on its state of deformation; and a deformable cover element secured with one end to said housing at said large diameter body portion and extending with its other end to said member adjacent the discharge port to provide an adjustable tapering wall from said body portion to said discharge port, said cover element having an inherent tension causing its other end to follow said deformable member towards a position of small nozzle size.

7. In a nozzle for converting gas pressure energy into kinetic energy, the improvement which comprises a flexible wall forming part of a gas passage through the nozzle, said wall being acted

upon by the gas pressure on one side tending to flex the wall in a direction to increase the cross sectional area of the nozzle if the gas pressure on said one side is greater than the pressure on the other side of the wall; stop means for limiting the freedom of adjustment of the said wall to a predetermined rate of divergence of the nozzle passage towards the nozzle exit provided by said wall in deflected position under predominant gas pressure on said one side, the said wall having freedom to adjust itself to a position of substantially constant cross sectional nozzle area under condition of substantial equality of pressure on either side of the wall; and a movable cover element secured with one end to said stop means and extending with its other end to said flexible wall adjacent the nozzle exit to provide a tapering surface from said stop means to said flexible wall adapted to reduce drag on the nozzle by an exterior flow of gas past the nozzle.

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