March 6, 1956 L. S. BILLMAN 2,737,019

VARIABLE AREA CONVERGENT-DIVERGENT DIFFUSER

Filed Aug. 14, 1953

FIG. 1

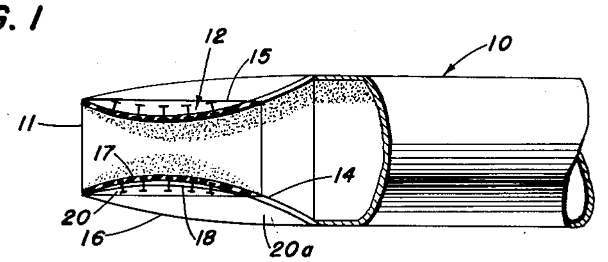


FIG. 2

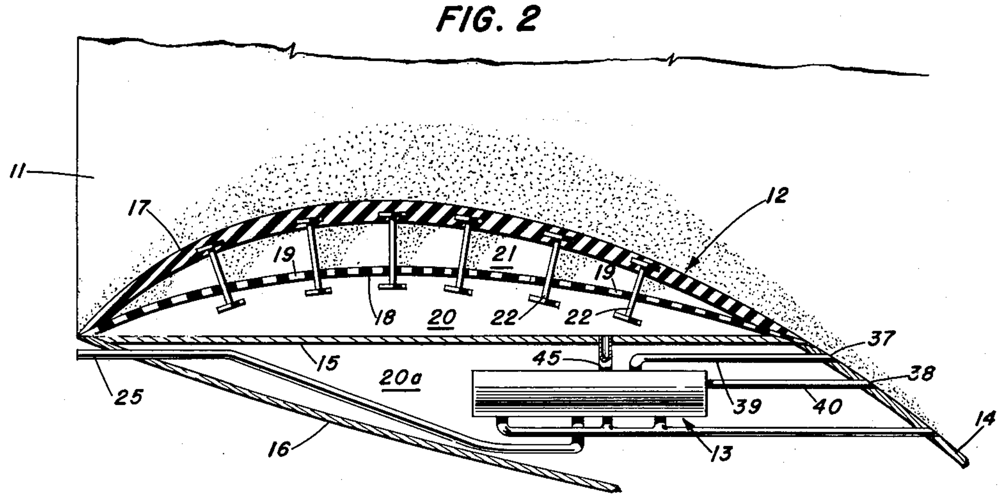


FIG. 3

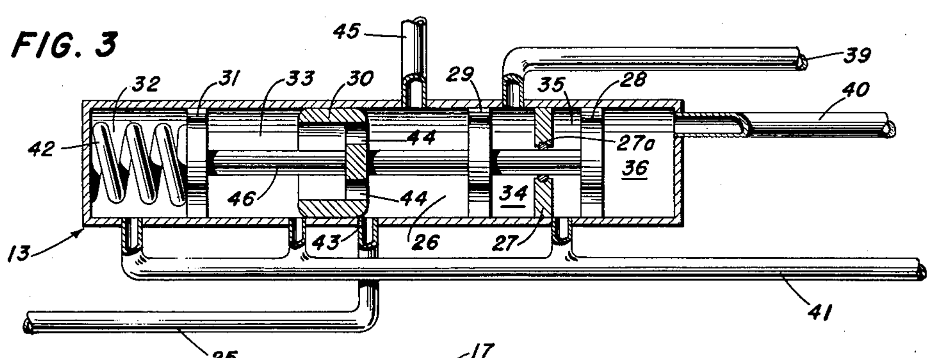
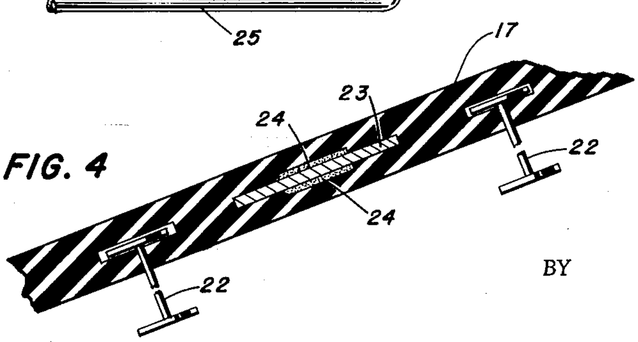


FIG. 4



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VARIABLE AREA CONVERGENT-DIVERGENT DIFFUSER

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4 Claims. (Cl. 60—39.29)

This invention relates to reactive propulsion power engines and more particularly to ram jet engines for the propulsion of high velocity missiles and aircraft.

Efficient operation of the ram jet type of engine depends in large measure upon the ability of the unit to acclimate itself to the ever changing conditions encountered in flight particularly during supersonic flow rates. For example, at increased forward speeds of the engine the compressive effect of the ram action increases, thereby demanding a modified inlet, that is, one of decreased area; and conversely, as the forward speed decreases, the correspondingly decreased ram action will reduce the compressive effect thereby requiring an increase in the inlet area to produce an efficient compression of the air by ram action at the reduced supersonic range. Therefore, it is most desirable that the air inlet structure be capable of adjusting itself automatically to the variable flight requirements at supersonic speeds. One method of achieving such automatic air intake adjustment for a ram jet engine operating at supersonic flow rates is to so construct and control the rammed atmospheric air inlet that it will transform the kinetic energy of the compressible air into potential energy for use in the thermic cycle. With this object in view, the present invention provides a supersonic duct with a convergent portion and a divergent portion interconnected axially by a constricted throat portion, the zone within the convergent portion corresponding to a first compression zone wherein the translational velocity of the fluid diminishes until it equals substantially the speed of sound; this first stage being followed by a second stage of compression wherein a further damping of the velocity occurs.

Accordingly an object of this invention is to provide a ram jet engine with a variable area inlet means which will assure optimum operating compression for all velocities in the supersonic range.

Another object is to provide a variable area convergent-divergent diffuser capable of automatic control during changes in engine speed in the supersonic range.

A further object of this invention is to provide regulation of ram air compression by utilizing the pressure differential induced by shock wave action to vary the contour of the air intake passage in accordance with the ram jet speed.

Another object of this invention is to provide a flexible diffuser which will be responsive to variable pressure conditions encountered in ram jet flight.

Still another object of this invention is to provide a movable valve which will control the inlet ram air according to ram jet velocity.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

Fig. 1 is a fragmentary longitudinal sectional view of an embodiment of the present invention;

Fig. 2 is an enlarged partial sectional view of the for-

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ward ram jet section illustrating the flexible diffuser and the pressure regulator unit as applied to the inlet of the ram jet;

Fig. 3 is an enlarged longitudinal sectional view of the pressure regulator unit; and

Fig. 4 is a greatly enlarged sectional view of a portion of the flexible diffuser boot.

Referring to the drawings wherein the like numerals designate like parts, the invention may be said to comprise the combination of a ram jet duct **10** having a ram air inlet **11**, a variable convergent-divergent diffuser valve **12**, and an automatic control means designated as a pressure regulator **13**.

The ram jet **10** is an elongated tubular section designed aerodynamically to travel in a supersonic air stream with a minimum of air resistance. The interior of the duct **10** will accommodate a combustion unit in the downstream section and numerous other conventional components, which are not shown, depending upon the specific application to be made of the ram jet engine.

The ram air inlet **11** is of a supersonic type and is in the form of a convergent-divergent annular shell **14** surrounded by an intermediate cylindrical shell **15** and an outer conical shell **16**, constituting an extension of the main duct **10**, the contour of shell **14** being designed to conform to the air intake requirements for minimum air speed. The space between the flexible boot or valve member **17** and the cylindrical shell **15** is divided longitudinally by a supporting partition **18** having apertures **19** to allow flow of pressure fluid from the outer chamber **20** to the inner chamber **21** where the fluid pressure is exerted against the resilient flexible boot **17** of the annular diffuser shell **14**. The resilient boot diffuser **17** may be secured by any suitable means to the fore and aft positions on the porous supporting partition **18**. Affixed to the resilient valve member **17**, which may be made of rubber or other suitable material, is a series of spaced, guide and stop members **22** which will pass through the partition **18** to permit radial expansion and contraction of the flexible valve member **17** in accordance with the pressure exerted through the perforated partition **18** on the adjacent surface of the flexible member **17**. Stiffener ribs **23** spaced in the flexible member, as illustrated in Fig. 4, and made from any suitable material such as strip brass or laminated plastic strips provides the requisite rigidity for maintaining the desired contour of the flexible diffuser while permitting limited expansion and contraction under the influence of the pressure differential as between the chamber **21** and the ram air inlet **11**, the magnitude of which differential will vary with variations in the engine's speed. By modifying the length and spacing of the ribs **23**, as well as selective lamination of additional strips **24** of suitable material of varying thicknesses, and by resorting to other obvious modifying structures the flexible member may be flexed or stretched to attain the most suitable initial or basic contour for a particular condition of operation.

One effective embodiment of means for providing the described automatic control for the flexible diffuser is shown in detail in Fig. 3, where it takes the form of a pressure regulating cylinder **13** securely mounted within the annular chamber **20***a* defined by the shell **16** and the intermediate cylindrical shell **15**. This pressure regulator **13** is adapted to apply fluid pressure to the member **17** by way of the impact pressure line **45** leading from the central chamber **26** of the pressure regulator to the above-described pressure chamber **20**. Operating pressure is admitted to regulator central chamber **26** by way of an impact tube **25** interconnecting the chamber **26** with the outer atmosphere; preferably, the impact tube is located at a suitable position adjacent the ram air inlet **11**. The regulator cylinder **13** houses a fixed partition **27** intermediate its ends and a piston assembly consisting of pistons 28, 29, 31 and slide valve 30, serving to divide the cylinder into chambers 32, 33, 26, 34, 35 and 36.

Pressure taps 37 and 38 are located in the divergent section of the diffuser at spaced intervals to receive and convey the static pressures obtained at the respective ports through the lines 39 and 40 leading to the chambers 34 and 35, respectively, of the regulator. A vent line 41 with branch lines projecting into the regulator vents the regulator chambers 32, 33 and 35. Fixed partition 27 is equipped with a sealing ring 27*a* and serves to segregate the chamber 35 from chamber 34. A compression spring 42 is inserted into chamber 32 and provides a counterbalancing effect upon piston 31 to maintain a state of equilibrium between the forces acting on the pistons 28 and 29 through the pressure lines 39 and 40, and thereby maintains the slide valve 30 in the desired position with respect to the impact pressure port 43. Ports 44 in slide valve 30 transmit the impact pressure from the impact line 25 through the ports 44 and exert a pressure against one face of piston 31. An equal and opposite force from that exerted by the fluid medium on the face of piston 31 is also exerted against the opposed face of piston 29. Therefore, it is readily apparent that the slide valve 30 will be sensitive to every slight pressure differential reflected through pressure taps 37 and 38, and tending to disturb the equilibrium maintained by spring 42 which, under normal operating conditions, in the subsonic zone, will act upon piston 31 and rod 46 to hold slide valve 30 in a position where it closes the inlet port 43. During supersonic flight operations pressure differentials induced by shock waves impinging within the divergent area will overcome the spring compression thereby uncovering, partially or wholly, the inlet opening 43 by shifting valve 30 to the position designed for in the zone of supersonic operation, as shown by the open position in Fig. 3. Fluid pressure from the pressure chamber 26 of regulator 13 will flow through the pressure line 45 to the outer chamber 20 to act upon the valve member 17 through the perforated supporting partition 18.

The static pickups or taps 37 and 38 for controlling the slide valve position in the pressure regulator are positioned to either side of the desired shock wave position in the divergent section of the inlet and the movement of the shock wave toward either static pressure tap position will vary according to the speed of the ram jet and the diffuser inlet and throat configuration. When the pressure increment is of sufficient magnitude to overcome the state of equilibrium maintained by the spring 42, the overbalancing pressure exerted on pistons 28 and 29 will permit limited axial displacement of the slide valve 30 to throttle the pressure from the impact pressure tube 25 by sliding over the pressure port 43. Therefore, by overcoming the force of the spring 42 the slide valve 30 will throttle and control the pressure to the pressure chamber 20. The resulting pressure within the inner pressure chamber 21 will vary in accordance with the impact pressure which is directly related to the engine speed and the pressure differential exerted on pistons 28 and 29 by the shock wave intensity and position within the divergent section of the diffuser as transmitted to the pressure regulator from pressure taps 37 and 38.

During subsonic operation the spring 42 will keep the slide valve 30 over the entrance of the port 43 of the impact tube 25 and as supersonic speeds are reached the pressure from the shock waves impinging proximate the static pressure taps 37 and 38 will overcome the resistance offered by the spring 42 to move the slide valve 30 from the closed position and open the port 43 thereby passing the increased pressure through the impact tube 25 into the inner pressure chamber 21 which will in turn cause the flexible member 17 to assume a more contracted contour, the degree of contraction being proportional to the internal pressure within the inner pressure chamber 21.

Operation of the regulator will commence as soon as the ram jet attains a translational velocity of sufficient magnitude to create a shock wave which will exert a pressure through the pressure taps 37 and 38 to overcome the counteracting pressure exerted by the spring 42 on the pistons 28 and 29. As the spring force against piston 31 is exceeded by the pressure applied against pistons 28 and 29 the slide valve 30 will open the impact pressure opening 43 into the regulator 13 to increase the pressure within the pressure chamber 21. The resilient member 17 is sufficiently sensitive to the various pressure changes encountered within the chamber 21, and that pass through the perforated supporting partition 18 to assume a contour commensurate with the pressure range in the chamber 21. Preselection of the optimum diffuser contours with the most suitable throat constriction for the range of supersonic operation will enable the resilient member, with the proper supporting rib structure, as shown in Fig. 4, to assume the selected contour corresponding to the pressure applied from the pressure regulator.

The present invention has been described as applying to a variable area inlet convergent-divergent diffuser, however, with minor modifications which will be readily apparent to one skilled in the art, a diffuser of similar structural features may be employed at the discharge section of a ram jet.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A variable area convergent-divergent diffuser for a reactive propulsion engine adapted to be moved at supersonic speeds comprising; a movable valve member defining a throat area and enclosing a pressure chamber, a perforated support positioned in said chamber, stop members carried by said valve member and extending inwardly into said chamber through the perforations in said support and cooperating therewith to limit the movement of said valve member in response to pressure in said chamber, a pressure regulator cooperating to control the pressure in said chamber and hence the throat constriction defined by said valve member, and static pressure taps controlling said regulator positioned to either side of the desired shock wave position whereby movement of the shock wave position toward either tap position accordingly varies the pressure differential between said taps to control said regulator to throttle the pressure in said chamber and hence the throat constriction to return the shock wave position to the desired position between said two taps.

2. A variable area convergent-divergent diffuser for a reactive propulsion engine adapted to be moved at supersonic speeds comprising; a duct having a longitudinal ram air passage therethrough, a flexible valve member forming the convergent section and throat area of the diffuser, a perforated pressure chamber conforming to a convergent-divergent configuration within said duct enclosed by said valve member, and a pressure regulator within said duct to vary the valve member contour in response to pressure differentials induced by the speed of the engine.

3. A variable area convergent-divergent diffuser for a reactive propulsion engine adapted to be moved at supersonic speeds comprising; a duct having a longitudinal ram air passage therethrough, a flexible valve member forming the throat area, a perforated pressure chamber conforming to a convergent-divergent configuration within said duct, said flexible valve member enclosing the perforations in the inlet section of said pressure chamber, and a pressure regulator to transmit suitable pressure increments to said chamber to vary the resilient member contour consonant with the requirements of the engine combustion cycle.

4. A variable area convergent-divergent diffuser for a reactive propulsion engine adapted to be moved at super-

sonic speeds comprising; a duct having a longitudinal ram air passage therethrough, a flexible valve member forming the convergent section and throat area of the diffuser, a perforated pressure chamber conforming to a convergent-divergent configuration within said duct enclosed by said flexible valve member, a pressure regulator within said duct to vary the valve member contours in response to pressure differentials induced by the speed of the engine, an impact pressure inlet facing the inlet ram air mounted on said duct leading to the regulator, and static pressure taps suitably located in the diffuser for controlling the regulator pressure whereby movement of the shock position will accordingly vary the pressure differential at the pressure taps thereby controlling said regulator to throttle the impact pressure to said pressure chamber and hence vary the convergent section and throat area formed by the flexible valve member.

References Cited in the file of this patent

UNITED STATES PATENTS

2,570,129	Johnson	Oct. 2, 1951
2,590,215	Sausa	Mar. 25, 1952
2,596,435	Robert	May 13, 1952
2,632,295	Price	Mar. 24, 1953
2,638,738	Solter	May 19, 1953
2,648,195	Wilde et al.	Aug. 11, 1953