Dec. 25, 1962 N. C. PRICE 3,069,842

VARIABLE GEOMETRY RAM INLET AND DIFFUSER

Filed Feb. 25, 1958 5 Sheets-Sheet 1

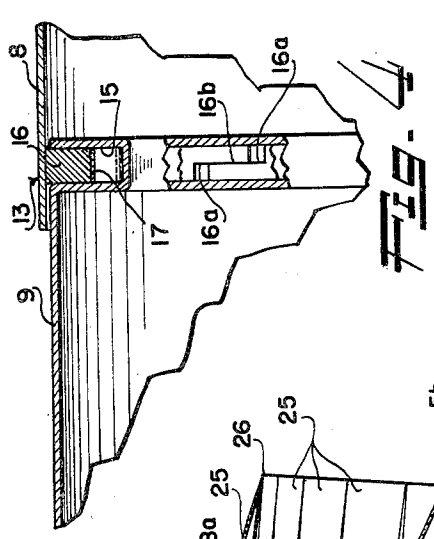


FIG. 4

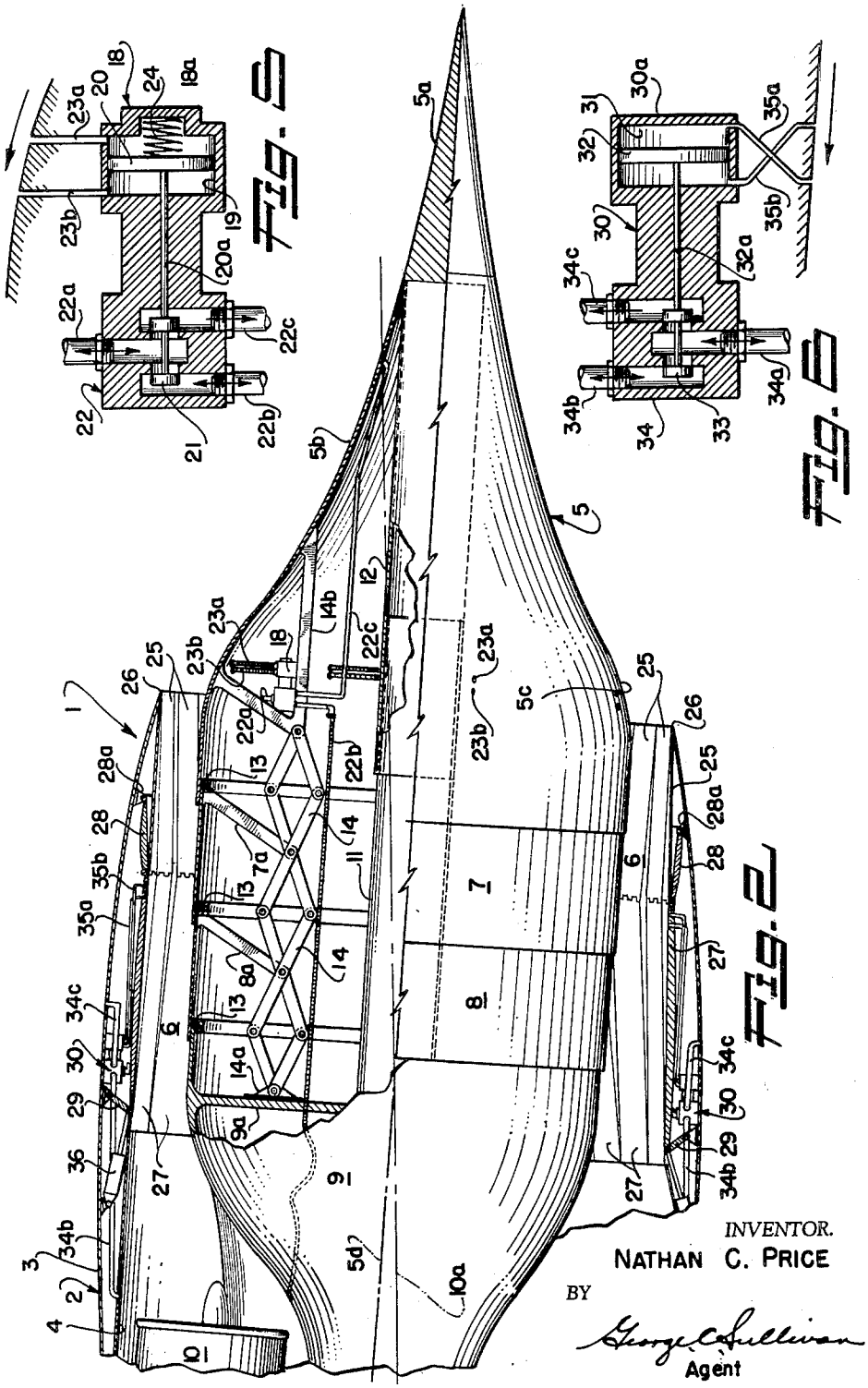
FIG. 1

INVENTOR.
NATHAN C. PRICE
BY
George C. Sullivan
Agent

Dec. 25, 1962 N. C. PRICE 3,069,842

VARIABLE GEOMETRY RAM INLET AND DIFFUSER

Filed Feb. 25, 1958 5 Sheets-Sheet 2

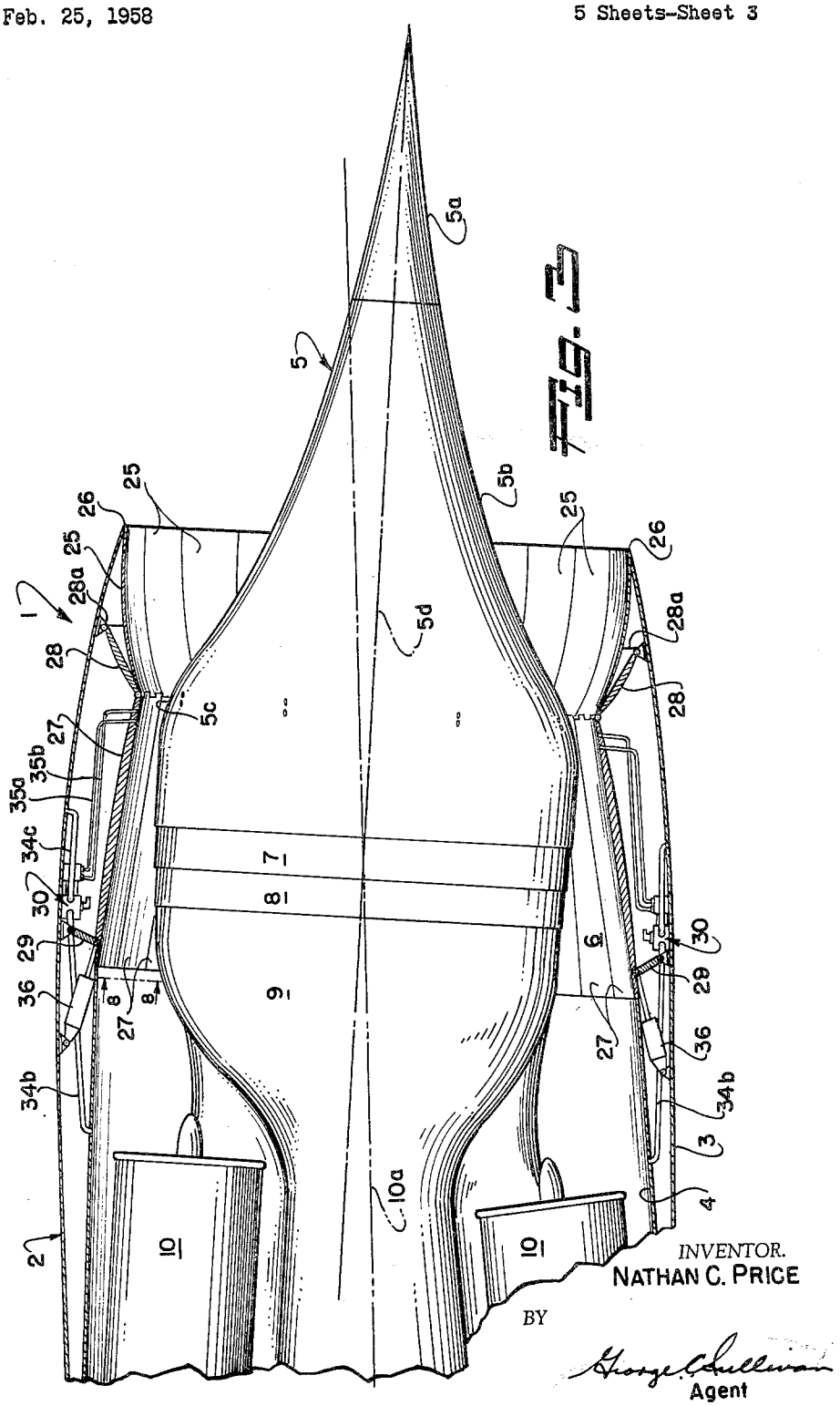


INVENTOR.
NATHAN C. PRICE
BY
George C. Sullivan
Agent

Dec. 25, 1962 N. C. PRICE 3,069,842

VARIABLE GEOMETRY RAM INLET AND DIFFUSER

Filed Feb. 25, 1958 5 Sheets-Sheet 3



Dec. 25, 1962 N. C. PRICE 3,069,842

VARIABLE GEOMETRY RAM INLET AND DIFFUSER

Filed Feb. 25, 1958 5 Sheets-Sheet 4

Fig. 7

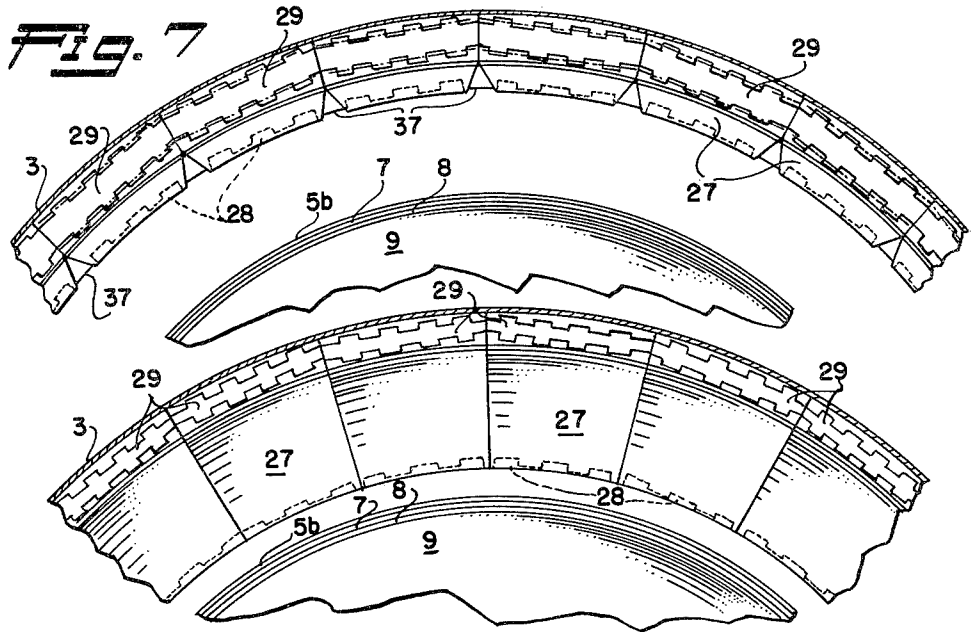


Fig. 8

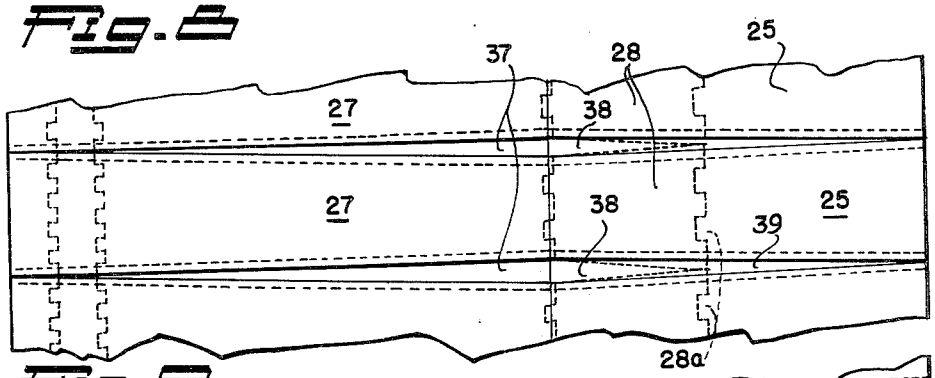


Fig. 9

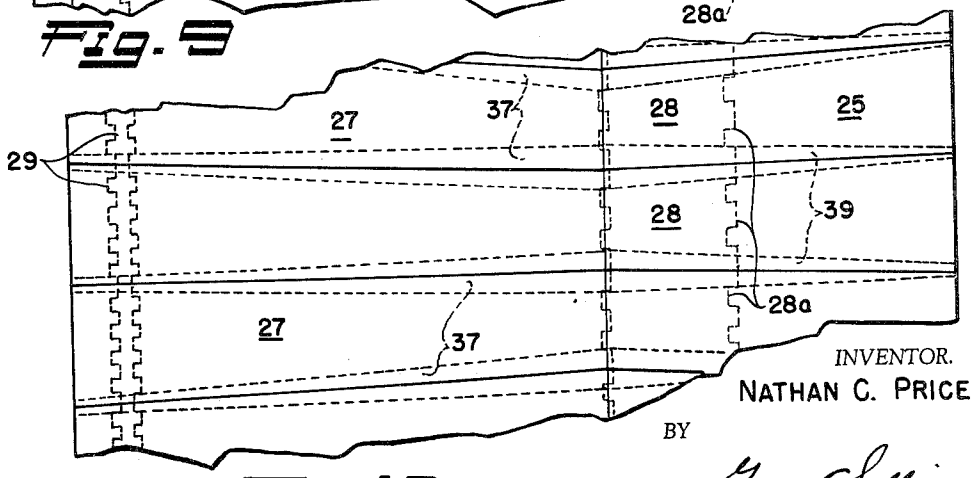


Fig. 10

INVENTOR.
NATHAN C. PRICE
BY
George C. Sullivan
Agent

Dec. 25, 1962 N. C. PRICE 3,069,842

VARIABLE GEOMETRY RAM INLET AND DIFFUSER

Filed Feb. 25, 1958 5 Sheets-Sheet 5

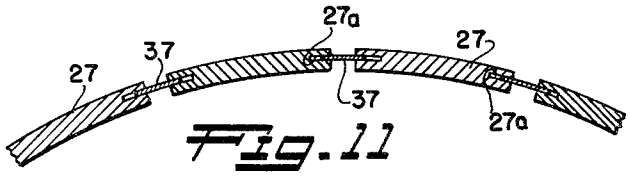


Fig. 11

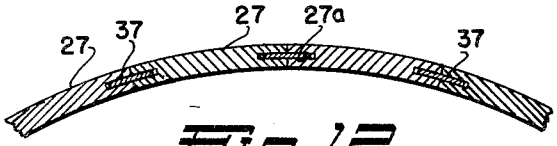


Fig. 12

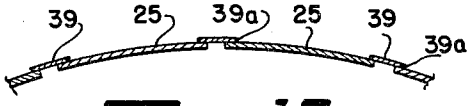


Fig. 13

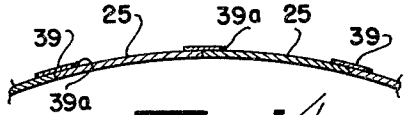


Fig. 14

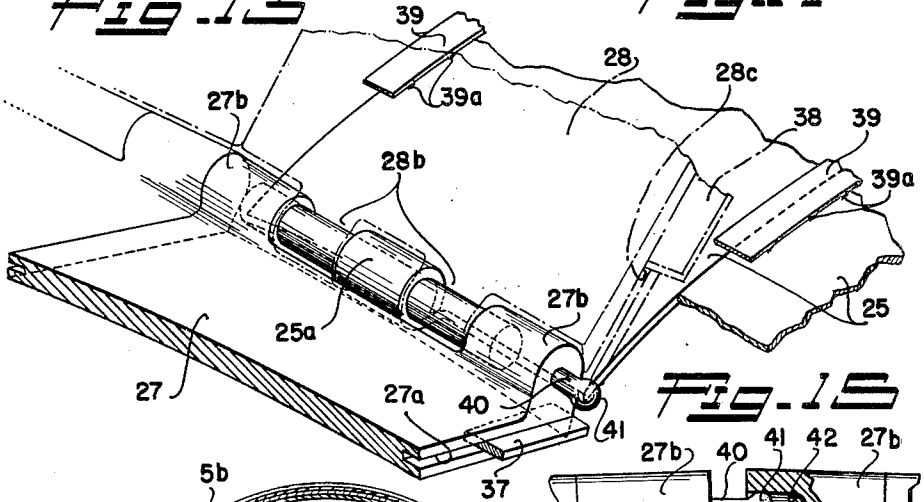


Fig. 15

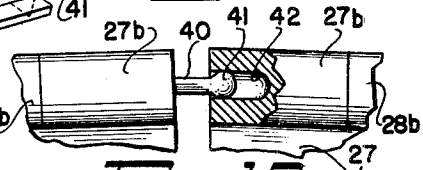


Fig. 16

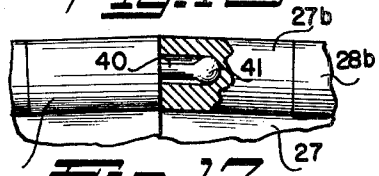


Fig. 17

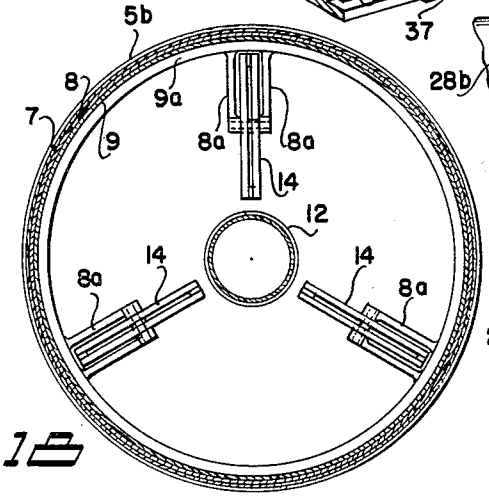


Fig. 18

INVENTOR.
NATHAN C. PRICE

BY

George C. Sullivan
Agent

United States Patent Office 3,069,842 Patented Dec. 25, 1962

3,069,842

VARIABLE GEOMETRY RAM INLET AND DIFFUSER

Nathan C. Price, Geneva, Switzerland
(424¼ Kelton Ave., Westwood, Calif.)

Filed Feb. 25, 1958, Ser. No. 717,427
13 Claims. (Cl. 60—35.6)

This invention relates to reactive propelled aircraft and athodyds, and more particularly to an improved variable geometry ram inlet and diffuser.

Efficiency of reactive propelled powerplant units, whether of the turbo-jet, ram-jet or pulse-jet type is in part directly proportional to the stagnation or static pressure recovery of the working fluid's ram kinetic energy, particularly when the relative velocity of the inlet through the working fluid is supersonic, i.e. at a velocity of Mach 1.0 or more. Stagnation or static pressure recovery is accomplished by the amount of diffusion of the air ingested by the inlet; such diffusion in turn being greatly increased by generating a plurality of oblique shocks or shock waves, then resulting in one weak normal shock being finally swallowed by the inlet rather than one severe normal shock. This more efficient diffusion with many oblique shocks is attainable since the velocity downstream of an oblique shock may still be supersonic whereas the velocity downstream of a normal shock is limited to the sub-sonic range. Thus, diffusion accomplished by the generation of a plurality of oblique shocks (which are of weak intensity as compared to that of one normal shock) results in a greater percentage of static pressure recovery from the ram kinetic energy than with one normal shock, since the static pressure of stagnation or a compressible fluid increases as the Mach velocity decreases. By continually increasing the static pressure through a plurality of oblique shocks with decreasing the Mach velocity, there is a greater total static pressure recovery as the weak normal shock finally occurs in the diffuser passage; such weak normal shock occurring when the plane of the reflected shocks becomes perpendicular or normal to the axis of the inlet duct or flow passage, such normal shock being a considerably weaker shock wave as compared with only one severe normal shock generated from the original fluid velocity. This transmutation of the working fluid in the inlet and diffuser from kinetic energy to stagnation or static pressure at decreased velocity is also desirous for better combustion efficiency which is directly proportional to the available static pressure drop and inversely proportional to the working fluid velocity. Yet multiple weak shocks should be established without excessive turning of direction of the main body of ingested air and without creation of thick boundary layers, both of which would reduce the overall efficiency of the induction system. Furthermore, the diffuser must be capable of being contained in a relatively sharp airframe body to prevent external drag from being excessive. The induction system must prevent external air-spillage or internal choking.

Hence it is essential to perform supersonic diffusion at high Mach velocity of the aircraft, utilizing an inlet having dual confronting surfaces of variable configuration to generate multiple weak shocks.

Accordingly, it is an object of this invention to provide an efficient variable geometry ram air inlet and diffuser for obtaining efficient air inlet compression from sea level to extremely high altitudes at relative translational velocities of the inlet with the working fluid from zero to beyond at least Mach 3.5, the latter being a speed of high athodyd efficiency.

It is an object of this invention to provide a supersonic diffuser possessing improved controllability of internal flow areas, sufficient to eliminate external spilling of air

from the diffuser's inlet, and yet to minimize choking tendencies at all times.

A further object of this invention is to provide means for controlling the automatically positionable and adjustable variable geometry members of a radially adjustable outer duct wall and an axially adjustable inlet needle to obtain efficient working fluid compression in the inlet and diffuser at various altitudes and velocities.

A further object of this invention is to provide a supersonic diffuser which may be contained in an airframe body having a minimum external wedge angle, whereby external wave drag of the body will be held to a minimum.

It is a further object of this invention to provide a device and means whereby good static pressure recoveries may be accomplished at a substantial range of relative Mach flows or velocities of the inlet with a free body of working fluid.

It is a still further object of this invention to provide a device permitting unobstructed working fluid flows through the inlet at translational velocities of the inlet relative with a free body of working fluid below that in which a critical area is involved and yet maintain the efficiencies of the inlet and diffuser at the high Mach velocities.

Still another object of the invention is to provide a supersonic diffuser having variable-configuration opposing, dual walls arranged to prevent localized build-up of low-energy boundary layers which would reduce efficiency of diffusion.

A still further object of this invention is to provide a device for allowing a sufficient flow of air for combustion sustentation in the powerplant's combustion sections when there is insufficient translational velocity of the inlet through the air or insufficient ram kinetic energy of the working fluid to positively force a combustion sustaining airflow.

Another object of this invention is to provide a device and means for automatically controlling the position of the inlet normal shock wave and the throat area simultaneously or concurrently.

It is still a further object of this invention to provide a ram inlet and diffuser device that is relatively simple and inexpensive to manufacture, while containing few working parts.

Another object of this invention is to provide a supersonic diffuser which will withstand high aerodynamic temperatures without damage.

A still further object of this invention is to provide a ram inlet and diffuser device that is a compact unit with high efficiency and containing a minimum of parts and projections capable of producing aerodynamic drag in a free air or working fluid stream or the inlet air or fluid stream.

It is a still further object of this invention to provide a variable configuration supersonic diffuser for the formation of a maximum number of weak compressive shock waves, directing the air flow's main course in a single uniform direction to avoid subsequent wasteful turning losses in the subsonic region of the diffuser.

Other objects and advantages will become apparent from the following description taken in connection with the accompanying drawings in which:

FIGURE 1 is a partial cross-sectional view of the inlet with the adjustable outer duct wall fully retracted and the adjustable needle fully retracted;

FIGURE 2 is the same as FIGURE 1 except for the adjustable needle being shown in its most extended position;

FIGURE 3 is similar to FIGURES 1 and 2 and shows the adjustable outer duct wall in an extended position and the adjustable needle located between the fully retracted

position of FIGURE 1 and the fully extended position of FIGURE 2;

FIGURE 4 is a cross-sectional view showing the sealing arrangement between adjacent telescopic sections of the adjustable needle;

FIGURE 5 is a schematic showing of an air servo relay for controlling the position of the adjustable needle;

FIGURE 6 is a schematic showing of an air servo relay for controlling the position of the adjustable outer duct wall;

FIGURE 7 is a view taken along line 7—7 of FIGURE 1;

FIGURE 8 is a view taken along line 8—8 of FIGURE 3;

FIGURE 9 is a partial plan view of the adjustable outer duct wall as positioned in FIGURES 1, 2 and 7;

FIGURE 10 is a partial plan view of the adjustable outer duct wall when positioned as shown in FIGURES 2 and 8;

FIGURE 11 is a partial cross-sectional view taken along line 11—11 of FIGURE 1;

FIGURE 12 is the same as FIGURE 11 with the adjustable outer duct wall extended as shown in FIGURE 3;

FIGURE 13 is a view taken along line 13—13 of FIGURE 1;

FIGURE 14 is a view the same as FIGURE 13 with the adjustable outer duct wall extended as shown in FIGURE 3;

FIGURE 15 is a perspective view showing enlarged details of the center hinge and pivot point of the adjustable outer duct wall;

FIGURE 16 shows the connecting details between two adjacent outer duct wall segments at the center hinge or pivot point shown in FIGURE 15, when the adjustable outer duct wall is retracted as shown in FIGURES 1 and 2;

FIGURE 17 is similar to FIGURE 16 with the adjustable outer duct wall extended as shown in FIGURE 3; and

FIGURE 18 is a cross-sectional view of the adjustable needle taken along line 18—18 of FIGURE 1.

Generally stated, the invention is practiced by utilization of a radially adjustable outer duct wall in a ram inlet and diffuser in cooperation or conjunction with an axially adjustable or positionable needle forming the inner wall of the duct; the adjustability and shape of both the outer duct wall and the needle being such as to generate a plurality of weak oblique and reflected shocks culminating in a weak normal shock at or very close to the critical area of the inlet throat, at relative supersonic velocities of the inlet through a free air or working fluid body. These confronting walls generally possess concavity to generate a predetermined series of compressive oblique shocks. Air relay servo means serve to position both the outer duct wall and needle as a result of static pressure differentials at different locations in the inlet duct. Additional flexibility of the inlet and diffuser is presented by the air relay servo means completely retracting the needle to permit free passage of sufficient sucked air through the duct for sustentation of combustion in the combustion section when the translational or forward velocity of the inlet through the free air body is less than that required to provide sufficient ram kinetic energy to force sufficient combustion air therethrough. Also, by use of the needle positioning means, the complete retraction of the needle during high speed flight can be used as a safety feature, producing an effective braking of the forward velocity thereof while still being capable of being positioned for a highly efficient conversion of ram air kinetic energy to static pressure through diffusion.

Referring now more specifically to the drawings, in FIGURES 1, 2 and 3, the numeral 1 indicates a ram inlet assembly of the type indicated in my copending application, Serial Number 677,877, filed on August 13, 1957, and entitled, Wingless Supersonic Aircraft. In the embodiment illustrated, the inlet assembly 1 includes a tubular structure 2 comprising outer and inner tubular wall members 3 and 4 respectively. Coaxially mounted within tubular structure 2 is an axially adjustable diffuser spike or needle 5 whose largest circumferential surface is radially removed from tubular member 4 forming an annular duct 6 therebetween. Needle 5 comprises a sharp pointed forward tip 5*a* secured to a tubular or hollow wall 5*b* that is diverging in a downstream direction to shoulder portion 5*c*, from which hollow wall 5*b* extends downstream at a substantially constant diameter to extend in over-lapping engagement with needle telescopic sections 7 and 8, which in turn are telescopically mounted on stationary needle base or island 9 located within tubular structure 2. The outer surface of island 9 converges in a downstream direction and is shaped to transform the annular passage into four substantially quadrantal segments forming a diffuser section, each segment having a turbo-jet powerplant 10 positioned therein. Each of the four powerplant units 10 are positioned at angles relative to each other and to the longitudinal axis of the inlet duct 6. Likewise, the longitudinal axis 10*a* of the subsonic diffuser section is at an angle to the longitudinal axis 5*d* of needle 5, annular duct 6 and the outer wall of the annular duct; the relative relationship between the longitudinal axes being that the axis of the needle is directed forwardly and downwardly of the axis of the diffuser. Thus, for the wingless airplane type of installation covered by my copending application Serial Number 677,877, identified above, wherein the longitudinal axis of the diffuser section, being part of the airframe proper, will have some angle of attack component with the true direction of flight to produce aerodynamic lift, the longitudinal axis of the inlet duct will be parallel with the true direction of flight. It is to be understood that in an installation where the longitudinal axis of the diffuser section is parallel to the true direction of flight as in the instance of an aircraft having wings, the longitudinal axes of the diffuser section and inlet duct can be co-axial.

Each powerplant 10 is positioned in its quadrantal passage segment so as to provide an annular air path between the outer wall of the powerplant and the inner and outer walls of the diffuser passage. Although the present showing utilizes turbo-jet powerplants, other types may be used such as ram-jet units, as may the number of powerplants used be changed without departing from the true spirit and scope of this invention.

The interior of island 9 is closed by a wall or bulkhead 9*a* which is integral with the inner surface of island 9 and has a coaxial opening 9*b* extending therethrough. A stationary support shaft 11 extends forwardly through opening 9*b* for guiding and supporting the adjustable needle 5. A tubular guide 12 in adjustable needle 5 is mounted on support shaft 11 so as to slide thereon in an axial direction as needle 5 is moved in a retracting or extending direction, and thusly, needle 5 is supported and guided by support shaft 11 extending from the stationary island 9. The space inside of hollow wall 5*b* is substantially closed off by the stationary wall 9*a* and the seals 13 at the peripheral forward ends of island 9 and telescopic sections 7 and 8; such space being a variable volume chamber by the movement of needle 5 relative to stationary wall 9*a*. Needle 5 is connected to island 9 by three equally spaced pantograph linkages 14 which are secured to island wall 9*a* by a mounting bracket 14*a*, and to the hollow wall 5*b* of needle 5 through a mounting bracket 14*b* which is secured to the inner surface of hollow wall 5*b*. Telescopic sections 7 and 8 each have a mounting bar 7*a* and 8*a* respectively fixedly secured thereto and connected to pivots of pantograph linkage 14 intermediate the pivotal connections to mounting brackets 14*a* and 14*b*. Thus, there is a fixed relative relationship of movable members 5*b*, 7 and 8 with the fixed wall 9*a* of island 9, so that as needle 5 is extended in a forward direction away from fixed wall 9*a*, telescopic sections 7

and 8 are also moved forward in a direction away from stationary wall 9a. Retraction of needle 5 toward the fixed wall 9a results in the telescopic sections 7 and 8 to also retract toward stationary wall 9a so as to acheive a substantially nested position as shown in FIGURE 1.

The seals 13 between the relative movable members 5, 7, 8 and 9 are of the rubbing or sliding type whose specific details are more clearly shown in FIGURE 4. At the forward peripheral edge of island 9 there is a circumferential U-shaped seal ring groove 15 formed therein. Within the seal ring groove 15 there is a rubbing seal ring 16, composed of such material as carbon, ceramel, or ceramic, the rubbing surface of which extends slightly beyond the outermost radial portion of groove 15 so as to seat in sliding engagement with the inner wall of telescopic section 8, such engagement being maintained by radial pressure against seal ring 16 from a marcel type wave spring 17 inserted between the bottom of groove 15 and the innermost radial surface of seal ring 16. A leak-proof expandable end joint for seal ring 16 is accomplished by an undercut 16a on opposite sides at each end thereof which permit the ends of seal ring 16 to lie in overlapping engagement along line 16b. It is to be understood that the same type of seal structure is incorporated in seal ring grooves in the leading edges of telescopic sections 7 and 8, the seal ring in the groove in telescopic section 8 seating on the inner surface of telescopic section 7 and the seal ring in the groove in the forward edge of telescopic section 7 seating on the inner surface of hollow wall 5b.

In order to extend needle 5, the variable volume sealed chamber inside of hollow wall 5b is connected to a source of pressurized air or working fluid which is in the embodiment shown, the diffuser section, through an air relay servo control means 18, the schematic details of which are shown in FIGURE 5. Control means 18 includes a casing 18a having a cylinder 19 adjacent one end thereof with a piston 20 therein. Extending from one side of the piston 20 is a rod or shaft 20a which in turn is connected to a two-land servo-valve piston 21 whereby axial movement of piston 20 in cylinder 19 is translated to servo-valve piston 21, for controlling the entrance or exhaust of fluid pressure into the interior of hollow needle 5. The air relay means 22 comprises conduit passages 22a, 22b and 22c; passage 22a connects the interior of air relay 22 with the hollow interior of needle 5, with passage 22b connected to a suitable source of fluid pressure, such as the subsonic diffuser section of the inlet, and passage 22c being connected to an atmospheric vent or exhaust. Position of the servo-valve piston 21 in air relay 22 is controlled by the static pressure differential between two points along the shoulder 5c of needle 5. Pressure tap 23a transmits the most upstream static pressure signal from the exterior surface of shoulder 5c to the forward portion of cylinder 19 to react upon one surface of piston 20, while pressure tap 23b conducts the static pressure from a point on the exterior surface of shoulder 5c that is located downstream from pressure tap 23a to another portion of cylinder 19 to react upon the opposite side of piston 20. Piston 20 is biased in one direction by a coil spring 24. When needle 5 is in the proper axial position for the forward translational speed of the inlet through the free air stream, there will be a static pressure differential, straddling a normal shock, between the location of pressure taps 23a and 23b on shoulder 5c of needle 5. This static pressure differential will be substantially the same as the bias force of spring 24 on piston 20. Since the static pressure at the point of pressure tap 23b is higher than that at tap 23a, increase of the static pressure differential will cause piston 20 to move against the combined force of static pressure from tap 23a and spring 24 so as to open conduit 22c and allow a reduction in the air pressure in the interior of needle 5 so that the pressure of the free air stream at the forward end of needle 5 will cause it to move backward in a retracting direction. Should the static pressure differential pressure be too small or if the normal shock tends to move upstream from tap 23a the pressure from tap 23a combined with the bias force of spring 24 will cause actuation of piston 20 so that air relay means 22 will put conduit 22b in communication with conduit 22a and thereby increasing the pressure level in the hollow interior of needle 5 so as to force the needle forward in an extending direction by reaction of the increased pressurization against the fixed wall 9a of island 9.

Referring back to FIGURES 1, 2 and 3, the outer wall of duct 6 consists of a plurality of flexible strips 25 rigidly secured to the outer tubular wall 3 at the leading edge by welding or other appropriate means of joining at joint 26. The other end of each flexible strip 25 is pivotally hinged to a duct wall segment 27 and a forward trapezoidal link 28 which in turn is pivotally connected to a bracket on the interior of outer tubular wall 3 at a point upstream or forward of the plane of pivot connections of links 28 with flexible strips 25, as indicated at 28a. Outer duct wall segments 27 are pivotally connected to a second set of trapezoidal links 29 at their rearward or downstream ends, the trapezoidal links 29 in turn being pivotally connected to the inner surface of outer tubular wall 3 at a point upstream of the plane or pivot point connections of links 29 with segments 27 similar to that of pivot connections 28a for the flexible strips 25.

Since the outer tubular wall 3 is one continuous tubular or ring-like member and the outer wall of duct 6 comprises a plurality of adjustable or movable parts composed of flexible strips 25 and segments 27 pivoted at forward and rearward ends, these movable members can be adjusted or repositioned relative to outer tubular walls 3 by subjecting the variable volume annular space between the outer wall of duct 6 and inner surface of outer tubular wall 3 to a fluid pressure thereby causing the diameter of the outer wall of duct 6 be changed at the point of pivotal connection between flexible links 25 and segments 27.

Control of the pressure level in the annular space between outer tubular wall 3 and the segments 27, which form the outer wall of duct 6, is maintained by an air relay servo control means 30 located within the annular space, and which is similar in construction and operation to air relay servo control means 18 discussed above. Referring to FIGURE 6, air relay servo control means 30 comprises a casing 30a having a cylinder 31 adjacent one end thereof. A piston 32 is located within cylinder 31, and has extending from one side thereof a shaft or rod 32a which is connected to a two-land servo-piston 33 located in air relay means or mechanism 34 adjacent the other end of the casing 30a. Air relay means 34 likewise has three passages or conduits connected thereto and indicated as 34a, 34b and 34c. Conduit 34a is in communication with the variable volume annular space between outer tubular wall 3 and the adjustable segments 27 for introducing or bleeding air pressure to or from the annular space for causing a change in the volume thereof and the resultant change in diameter of the outer wall of duct 6. Passage 34b is connected to a suitable source of air or fluid pressure, which in the embodiment shown is the subsonic diffuser section similar to passage 22b, as shown in FIGURES 1, 2 and 3. Control of piston 33 is accomplished by the position of piston 22 which in turn is controlled by static pressure differentials in inlet duct 6 reacting against the opposite sides of piston 32 through pressure taps 35a and 35b, which are located in outer wall segments 27 just downstream of their pivotal connection with flexible strips 25. The position of the outer duct wall adjustable members, and thus the diameter of the outer wall of duct 6, is accomplished by locating the plane of the inlet normal shock from the reflected shock waves of both the needle 5 and the flexible strips 25 between the pressure taps 35a and 35b, similar to the method of controlling the position of the axial adjustable needle in U.S. Letters Patent No. 2,540,594, issued on February

6, 1951, and assigned to the Lockheed Aircraft Corporation.

During relative velocities of the inlet through a free air stream the unbalanced servo-piston **33** will be positioned to the left causing communication of passage **34***a* with the diffuser static pressure through passage **34***b* which is caused by the piston **32** being positioned toward the left side of cylinder **31** because of the higher static pressure from pressure tap **35***a* than in pressure tap **35***b*; pressure tap **35***a* being at a location axially downstream from pressure tap **35***b*. As the velocity of the inlet through the free air stream approaches Mach 2.0, for example, the static pressure level in the subsonic diffuser becomes sufficiently large to overcome the resistance of the somewhat lower static pressure level of the high Mach velocity flow through the duct **6** and thus the volume of the annular space between outer tubular wall **3** and the outer duct wall segments **27** is increased, causing the diameter of the outer wall of duct **6** to decrease at the pivot point between flexible strips **25** and segments **27**. As the Mach velocity of fluid flow through the inlet duct **6** increases, there is a resulting lesser static pressure level therein, which in turn permits the diffuser static pressure to further decrease the diameter of the annular duct outer wall. As the Mach velocity of the air flow in the duct decreases there is a resulting increase in the static pressure level of the airflow in the annular duct **6** which results in a lower pressure differential between pressure taps **35***a* and **35***b*, and with the assistance of the static pressure in passage **34***b* reacting by pressing against the exposed end surface of servo-piston **33**, servo-piston **33** is shifted to the right allowing communication between passages **34***a* and **34***c*, which in turn exhausts air from the annular space between outer tubular wall **3** and outer duct wall segments **27**, such space thus being reduced in volume and the diameter of the outer duct wall at the pivot point connection between flexible strips **25** and segments **27** being increased. Thus it can be seen that the diameter of the outer wall of duct **6** will not be decreased below a predetermined static pressure differential between the static pressure in the annular duct **6** and the diffuser whereupon once the predetermined pressure differential is achieved, the diameter of the outer wall duct **6** will be automatically reduced accordingly. To avoid oscillations or hunting of the new position by segments **27**, hydraulic dash pot dampening means **36** are incorporated and connected to trapezoidal links **29**.

In the accompanying figures the pressure taps for the outer diffuser wall, and for the needle, are provided in multiple, say at 60° intervals circumferentially, and each pair of associated pressure taps is connected to a control air relay. Thus local variations of pressure due to slightly off-design angles of airplane incidence in flight can be "averaged out," and the possible failure of a single relay will be offset by the action of the remaining relays. On the other hand, if preferred, the pressure taps of like category can be interconnected by piezo-meter rings so that one relay will suffice for the needle, and one for the outer wall.

In order to prevent air leakage radially through the outer wall of duct **6** between the elongate sides of segments **27**, there is an elongate slot **27***a* formed in both elongate sides of each segment **27** as is most clearly shown in FIGURES 11 and 12. There is a strip of sealing material **37** partly inserted into each of the two channels **27***a* facing each other on adjacent segments **27**. When the outer wall of duct **6** is in a retracted position so that this diameter is at a maximum, as in FIGURES 1 and 2, the tapered side edges of segments **27** are circumferentially spaced apart as shown in FIGURES 7, 9 and 11, while when the outer wall of duct **6** is positioned such that the diameter is at a minimum, the tapered sides of segments **27** are contiguous to each other with the sealing strips **37** completely enclosed within the channels **27***a* as shown in FIGURES 8, 10 and 12.

In order to prevent axial leakage from the annular variable volume chamber of the air pressure that positions the adjustable outer wall of duct **6**, there is a similar type of sealing arrangement between adjacent trapezoidal links **28**, the details of which are shown more specifically in FIGURE 15. In this figure is shown the pivotal hinge details of connection between the downstream end of flexible strips **25** and the upstream end of segments **27**, with the trapezoidal link **28** being shown in phantom. Each of the trapezoidal links **28** has side channels **28***c* on each side thereof similar to the channels **27***a* in the segments **27**. Sealing strips **38** are disposed with their sides inserted into the two juxtaposed channels **28***c* of adjacent trapezoidal links **28**. It is also to be noted that the sides of links **28** are tapered similar to those of segments **27** so that when the outer wall of duct **6** is extended or positioned so that the inlet diameter is at a minimum the sides of the downstream portions of links **28** are contiguous but when the outer wall of duct **6** is positioned so that the inlet diameter is at a maximum, the sides of the downstream portions of links **28** are circumferentially spaced with sealing strips **38** bridging such spacing.

Because of the very slightly arcuate transverse shape of the flexible links **25** and segments **27** the centerline of the piano hinge pivot connection between flexible strips **25** and segments **27** may be placed so that it is slightly more radially spaced from the inner surface of segments **27** at the sides of the segments than at the center. This permits a hinge or pivotal center being in a straight line notwithstanding the arcuate shape of the members being connected and is accomplished by the end hinge tangs **27***b* being more radially offset from the arcuate surfaces of flexible strips **25** and segments **27** than the hinge tangs **25***a* of flexible strips **25** and **28***b* of links **28**. However as an alternative, since there are numerous links **25**, these links may be flat, if desired, the resulting cross-sectional polygon closely approaching a truly circular cross-section.

There is a sealing arrangement between trapezoidal links **29** the same as the sealing arrangement between adjacent trapezoidal links **28** as shown in FIGURE 15, which in effect makes an annular chamber of variable volume generated or enclosed by the inner surface of outer tubular wall **3**, trapezoidal links **28**, segments **27** and trapezoidal links **29**.

In order to accomplish the necessary circumferential relational differentiations in the surface generated by flexible strips **25** at the connecting point with segments **27** and links **28**, I provide a plurality of elongate sealing strips **39** in overlapping engagement with the tapered edges of adjacent flexible strips **25**, which is more clearly shown in FIGURES 13, 14 and 15. The strips **39** are suitably secured to one of two adjacent flexible strips **25** for instance by an electric resistane weld **39***a* extending along one side of strip **39**. The other side of strip **39** is left free to slide over the outer surface of the flexible strip **25** adjacent to the flexible strip **25** that the seal **39** is welded to. FIGURE 13 shows the sealing strips **39** bridging the circumferential space between the longitudinal sides of adjacent flexible strips **25** when the outer wall of duct **6** is in a retracted position as shown in FIGURES 1 and 2 while FIGURES 14 and 15 show the relationships when the outer wall of duct **6** is extended as shown in FIGURE 3.

Connections between adjacent segments **27** at the forward pivotal hinge line is accomplished by a pintle **40** extending circumferentially from the side of mounting tang **27***b* of segment **27** and having a ball end **41** as shown in FIGURES 16 and 17. When assembled the ball end **41** of pintle **40** fits into a cylindrical opening **42** in the hinge tang **27***b* of the adjacent segment **27**. The centerline of the pintle **40** and cylindrical passage **42** on each segment **27** are coaxial with the pivotal hinge line for that segment. As the outer wall of duct

6 is adjusted, the circumferential relationship between longitudinal sides of adjacent segments 27 will change in that when the outer wall of duct 6 is at its maximum diameter the longitudinal sides of adjacent segments 27 will be circumferentially spaced apart as indicated in FIGURE 16. When the diameter of the outer wall of duct 6 is at a minimum, the longitudinal sides of adjacent segments 27 will have moved together so that they are juxtaposed as shown in FIGURE 17. The relative circumferential adjustment of the hinge tangs 27*b* and longitudinal sides of adjacent segments 27 is accomplished by the free sliding of the ball end 41 of pintle 40 sliding in cylindrical passage 42.

In operation, when the turbo-jet powerplants are started up the needle 5 is fully retracted as is the outer wall of annular duct 6 as both are shown in FIGURE 1, and with no forward or translational velocity of the inlet through a free airstream, the airflow through annular duct 6, which is at its largest area when both the needle and duct wall are fully retracted, is in essence sucked in by the pumping effect of the jet engine compressors. This maximum duct area at little or no translational velocity of the inlet through a free air stream is of importance when the application of this type of inlet is in a vertical rising type of aircraft as disclosed in my copending application Serial Number 677,877, identified above. As the inlet starts moving forward in a free air stream whereby the ram pressure increases the subsonic diffuser total pressure to more than the stream pressure in the forward part of the duct, the needle 5 becomes fully extended as shown in FIGURE 2 as the increase in the diffuser static pressure passes to the interior of the needle hollow wall 5*b* through passage 22*b*, air relay means 22, and passage 22*a*; passages 22*a* and 22*b* being in communication with each other through air relay means 22 because of the forcing of piston 20 to the left as viewed in FIGURE 5 by the bias of spring 24 because of the lack of sufficient pressure differential in pressure taps 23*a* and 23*b* on shoulder 5*c* of needle 5, and thus causing needle 5 to become fully extended as shown in FIGURE 2. As the needle 5 moves forward it is securely guided by the tubular guide 12 sliding on stationary guide shaft 11 extending from stationary island 9 through stationary wall 9*a*. As the needle 5 moves forward, there is also some forward movement of telescopic sections 7 and 8 which serve to bridge the axial distance between the downstream end of hollow wall 5*b* and the upstream portion of stationary island 9, such movement of 7 and 8 being transmitted thereto by the pantograph linkages 14 and mounting bars 7*a* and 8*a*. The pressure level in the interior of the needle is maintained by annular seals 13 at the forward edge of each circular member having another circular member telescoping thereover. The use of telescopic members reduces the total required overall length of the diffuser region thereby substantially reducing the amount of destructive air boundary layer formed therein.

Full extension of needle 5 is maintained up to translational velocity of slightly more than Mach 1.0 at which time a normal shock is generated in the forward portion of the inlet, the location of the normal shock on the outer surface of hollow wall 5*b* being axially located between pressure taps 23*a* and 23*b* whereby the static pressure at tap 23*b* being higher as it is downstream of the shock wave, serves to actuate piston 20 against the combined forces of the static pressure in pressure tap 23*a* and bias of spring 24 and opening the pressurized interior of the needle to the atmosphere by communicating passages 22*a* and 22*c*; such reduction of the pressure in the hollow needle resulting in the needle 5 to be repositioned in a retracting direction by the ram air force reacting against the exterior of the needle 5. As the forward translational speed increases the normal shock in the inlet duct 6 travels downstream resulting in a continual retraction of needle 5 as the forward speed increases. As the forward translational speed increases there is a greater pressure level in the annular chamber between outer tubular wall 3 and the outer wall of duct 6 which results from a higher static pressure level in the diffuser section being transmitted through conduit 34*b* to air relay 34 and from thence into the annular space through conduit 34*a*, conduits 34*a* and 34*b* being in communication in view of piston 32 being biased to the left as shown in FIGURE 6 by the higher static pressure in pressure tap 35*a* than that in pressure tap 35*b*, pressure tap 35*a* being downstream from pressure tap 35*b* and thus being subjected to a higher pressure. Continuation of the increasing diffuser section static pressure level results in the outer wall of duct 6 to extend resulting in the diameter of the outer wall of duct 6 to be diminished. This in turn causes the forward flexible strips 25 to assume an arcuate shape as shown in FIGURE 3 and acts as a means for reflecting the oblique shock waves generated by needle 5 in addition to generating oblique shocks itself which are reflected off the outer surface of needle 5, the combined shapes of the reflecting surfaces of flexible strips 35 and needle 5 culminating in a weak normal shock wave being positioned at the point of minimum inlet area which is at the pivotal hinge connecting point between segments 27 and flexible strips 25 and trapezoidal links 28, such transverse plane being located in reference to the outer needle surface between the pressure taps 23*a* and 23*b*.

Thus, as the forward translational speed of the inlet through the free air stream progressively increases beyond Mach 1, the normal shock wave generated in the inlet duct 6 tends to move downstream resulting in progressive retraction of the needle 5, but the normal shock wave is prevented from passing rearwardly beyond the tape 35*a* by the progressive extension of the outer duct wall, so maintaining the reflected normal shock in the inlet duct 6 essentially at point of smallest annular passage area.

In the type of installation as shown in my above identified copending application, Serial Number 677,877, a braking effect on the forward translational velocity of the vehicle can be arbitrarily affected by venting the interior of hollow needle 5 to the atmosphere so that the ram kinetic energy causes the needle 5 to be fully retracted, which in turn will cause the outer wall of duct 6 to become retracted also so that its diameter is at a maximum, the braking effect being achieved by air spilling over from the forward edge of the inlet due to the decreased consumption of ingested air. During this state of condition the turbo-jet power plants 10 are still operating although the ram recovery efficiency of the diffuser is greatly lowered so as to cause the braking effect on the vehicle.

Thus it can be seen that by this invention combining a radially adjustable outer duct wall and an axially adjustable needle, a higher static pressure recovery from ram kinetic energy of a free air body is accomplished over a wider range of relative velocities between the inlet and a free air body than that which can be accomplished if only one of the adjustable devices were used solely by itself. On the other hand, a single variable configuration wall would require greatly turning the direction of flow of the main body of air to accomplish supersonic diffusion at very high airplane speeds which would involve three main disadvantages: firstly, a relatively blunt airplane nose producing large external drag to physically contain the air passages, secondly a thick internal boundary layer caused by longer internal surfaces, and thirdly, the necessity to provide turning vanes, or the like, to redirect the air toward the engine's inlets. These and other disadvantages of conventional ram inlets are overcome by the invention.

It is, of course, intended to cover by the appended

claims all such modifications and equivalents as fall within the true spirit and scope of this invention.

I claim:

1. A variable geometry ram inlet and diffuser comprising a tubular wall that is radially adjustable, and a conical wall having its entire conic section axially adjustable, said conical wall located coaxially within the tubular wall forming an annular duct therebetween whereby the area of said annular duct is variable by adjustment of either or both of the walls.

2. A variable geometry ram inlet and diffuser comprising a radially adjustable tubular wall, an axially adjustable second wall located coaxially within said tubular wall and forming an annular variable area duct therebetween, and a diffuser section connected to the downstream portion of said duct, the longitudinal axis of the duct at an angle to the longitudinal axis of the diffuser section so that the longitudinal axis of the inlet duct is sloping downwardly and forwardly relative to the longitudinal axis of the diffuser section.

3. A variable geometry ram inlet and diffuser comprising a radially adjustable outer duct wall, an axially adjustable hollow needle, said hollow needle located coaxially within said outer duct wall and forming a variable area converging-diverging annular duct therebetween, a stationary wall transverse to the longitudinal axis of said needle, means connecting the needle to said stationary transverse wall, said means cooperating with the stationary wall and needle interior to form a variable volume closed chamber, first control means for effecting the radial adjustment of the outer duct wall, and second control means for effective axial adjustment of the needle by increasing or decreasing the pressure level in said variable volume closed chamber whereby the needle may be extended away from the stationary wall by an increase in pressure level and retracted toward the wall by a decrease in pressure level, said axially adjustable needle and radially adjustable wall cooperating to control both the location of shock waves within the inlet and the inlet throat area.

4. A variable geometry ram inlet and diffuser comprising a radially adjustable outer duct wall, an axially adjustable inner duct wall of fixed longitudinal cross-sectional area, said inner duct wall coaxial within said outer duct wall and forming a variable area converging-diverging annular duct therebetween, and a variable volume closed annular chamber, said chamber extending coaxially around said annular duct and separated therefrom by the radially adjustable outer duct wall whereby a decrease in the effective area of the duct is accomplished by a volume increase in the variable annular chamber and an increase in the effective area of the duct is accomplished by a volume decrease in the variable annular chamber, said axially and radially adjustable walls cooperating to control both the location of shock waves within the inlet and the inlet throat area.

5. A variable geometry ram inlet and diffuser comprising a radially adjustable outer duct wall, an axially adjustable inner duct wall, said inner duct wall coaxial with said outer duct wall and forming a variable area converging-diverging annular duct therebetween, said outer duct wall comprising a plurality of longitudinal segments, a tubular member coaxial with and radially spaced from said segments, a first and second plurality of segmental links pivotally connecting the fore and aft ends of the segments to said tubular member, sealing means between each pair of adjacent segments and each pair of adjacent links thereby forming an annular variable volume closed chamber between the tubular member and segmental outer duct wall, first control means for axially adjusting the inner duct wall, and second control means for varying the pressure level in said annular variable volume chamber whereby the area of the duct is reduced by an increase in the pressure level and the effective area of the duct is increased upon a decrease in the pressure level.

6. A variable geometry ram inlet and diffuser comprising a radially adjustable outer duct wall, an axially adjustable inner duct wall, said inner duct wall coaxial within said outer duct wall and forming a variable area converging-diverging annular duct therebetween, said outer duct wall comprising a plurality of longitudinal segments and a plurality of longitudinal flexible strips, the aft end of said strips pivotally connected to the fore end of said longitudinal segments, a tubular member coaxial with and radially spaced from said segments and strips, said tubular member and forward end of the strips fixedly connected together to form the lip of the inlet, a first and second plurality of segmental links pivotally connecting the fore and aft ends of the segments to said tubular member, sealing means between each pair of adjacent segments and each pair of adjacent links thereby forming an annular variable volume closed chamber between the tubular member and segmental outer duct wall, first control means for axially adjusting the inner duct wall, and second control means for varying the pressure level in said annular variable volume chamber whereby the area of the duct is reduced as the divergency of the inlet is increased by the arcuate bowing of the strips by an increase in the pressure level and the area of the duct is increased as the divergency of the inlet is decreased by straightening of the strips by a decrease in the pressure level.

7. A variable geometry ram inlet and diffuser comprising a radially adjustable outer duct wall, an axially adjustable inner duct wall, said inner duct wall coaxial within said outer duct wall and forming a variable area converging-diverging annular duct therebetween, said outer duct wall comprising a plurality of longitudinal segments and a plurality of longitudinal flexible strips, the aft end of said strips pivotally connected to the fore end of said longitudinal segments, a tubular member coaxial with and radially spaced from said segments and strips, said tubular member and forward end of the strips fixedly connected together to form the lip of the inlet, a first and second plurality of segmental links pivotally connecting the fore and aft ends of the segments to said tubular member, a lateral extending pintle from a forward side of each of the segments, a lateral passage extending into the opposite forward side of each of the segments, said pintles slidable within said passages of adjacent segments to connect the forward ends of the segments in circumferential seriatim, sealing means between each pair of adjacent segments and each pair of adjacent links thereby forming an annular variable volume closed chamber between the tubular member and segmental outer duct wall, first control means for axially adjusting the inner duct wall, and second control means for varying the pressure level in said annular variable volume chamber whereby the area of the duct is reduced as the divergency of the inlet is increased by the arcuate bowing of the strips by an increase in the pressure level and the area of the duct is increased as the divergency of the inlet is decreased by straightening of the strips by a decrease in pressure level, said connection of adjacent segments in seriatim allowing a variable connection between adjacent segments while maintaining all segments relative radially as the circumferential relative relations change.

8. A variable geometry ram inlet and diffuser comprising a radially adjustable outer duct wall, an axially adjustable hollow needle, said needle located coaxially within said outer duct wall and forming a variable area converging-diverging annular duct therebetween, a stationary wall transverse to the longitudinal axis of said needle, means connecting the needle to said stationary transverse wall, said connecting means cooperating with the stationary wall and needle interior to form a variable volume closed chamber, said outer duct wall comprising a plurality of longitudinal segments, a tubular member

coaxial with and radially spaced from said segments, a first and second plurality of segmental links pivotally connecting the fore and aft ends of the segments to said tubular member, and sealing means between each pair of adjacent segments and each pair of adjacent links thereby forming a variable volume closed chamber between the tubular member and segmental outer duct wall, said adjustable inner and outer duct walls cooperating whereby the effective area of the annular duct is variable by changing the volumes of said variable volume closed chambers.

9. A variable geometry ram inlet and diffuser comprising a radially adjustable outer duct wall, an axially adjustable hollow needle, said needle located coaxially within said outer duct wall and forming a variable area converging-diverging annular duct therebetween, a stationary wall transverse to the longitudinal axis of said needle, means connecting the needle to said stationary transverse wall, said connecting means cooperating with the stationary wall and needle interior to form a variable volume closed chamber, first pneumatic control means for effecting axial adjustment of the needle by increasing or decreasing the pressure level in said variable volume chamber whereby the needle may be extended away from the stationary wall by an increase in pressure level and retracted toward the wall by a decrease in pressure level, said outer duct wall comprising a plurality of longitudinal segments, a first and second plurality of segmental links pivotally connecting the fore and aft ends of the segments to said tubular member, sealing means between each pair of adjacent segments and each pair of adjacent links thereby forming an annular variable volume closed chamber between the tubular member and segmental outer duct wall, and second pneumatic control means for varying the pressure level in said annular variable volume chamber whereby the diameter of the segmental outer duct wall is decreased by an increase in the pressure level in the annular variable volume chamber and the diameter increased by a decrease in the pressure level.

10. A variable geometry ram inlet and diffuser comprising a radially adjustable outer duct wall, an axially adjustable hollow needle, said needle located coaxially within said outer duct wall and forming a variable area converging-diverging annular duct therebetween, a diffuser section connected to the downstream portion of said duct, a stationary wall transverse to the longitudinal axis of said needle, means connecting the needle to said stationary transverse wall, said connecting means cooperating with the stationary wall and needle interior to form a variable volume closed chamber, a first air relay servo control located within the hollow needle, said air relay servo connecting the diffuser to the interior of the hollow needle for effecting axial adjustment of the needle by increasing or decreasing the pressure level in said variable volume chamber whereby the needle may be extended away from the stationary wall by an increase in pressure level introduced through the air relay servo control from the diffuser section and retracted toward the stationary wall by a decrease in pressure level by the bleed of air from the variable volume chamber to the atmosphere through the air relay servo control, said outer duct wall comprising a plurality of longitudinal segments, a tubular member coaxial with and radially spaced from said segments, a first and second plurality of segmental links pivotally connecting the fore and aft ends of the segments to said tubular member, sealing means between each pair of adjacent segments and each pair of adjacent links thereby forming an annular variable volume closed chamber between the tubular member and segmental outer duct wall, and a second air relay servo control within the annular variable volume chamber, said air relay servo control connecting the diffuser to the inlet of the annular variable volume chamber for varying the pressure level therein whereby the diameter of the segmental outer duct wall is decreased by an increase in pressure level in the annular variable volume chamber introduced through the air relay servo means from the diffuser section while the said diameter is increased by a decrease in the pressure level in the annular variable volume chamber by the bleed of air from the chamber to the atmosphere through the air relay servo control.

11. A variable geometry ram inlet and diffuser comprising a radially adjustable outer duct wall, an axially adjustable hollow needle, said needle located coaxially within said outer duct wall and forming a variable area converging-diverging annular duct therebetween, a stationary wall transverse of the longitudinal axis of said needle, means connecting the needle to said stationary transverse wall, said connecting means cooperating with the stationary wall and needle interior to form a variable volume closed chamber, a first air relay servo control, a first set of pressure taps located on the surface of said hollow needle in an upstream-downstream relative relation for controlling said first air relay servo control by the differential of static pressures between the upstream-downstream pressure taps, said first air relay servo means connecting a source of pressure to the interior of the hollow needle for effecting axial adjustment of the needle by increasing or decreasing the pressure level therein whereby the needle may be extended away from the stationary wall by an increase in pressure level introduced through the first air relay servo control and retracted toward the stationary wall by a decrease in pressure level by the bleed of air from the variable volume chamber to the atmosphere through the first air relay servo control, said outer duct wall comprising a plurality of longitudinal segments, a tubular member coaxial with and radially spaced from said segments, a first and second plurality of segmental links pivotally connecting the fore and aft ends of the segments to said tubular member, sealing means between each pair of adjacent segments and each pair of adjacent links thereby forming an annular variable volume chamber between the tubular member and segmental outer duct wall, a second air relay servo control, and a second set of pressure taps located on the surface of said outer duct wall segments in an upstream-downstream relative relation for controlling said second air relay servo control by the differential of static pressures between the upstream-downstream pressure taps, said second air relay servo control connecting a source of pressure to the interior of the annular variable volume chamber for varying the pressure level therein whereby the diameter of the segmental outer duct wall is reduced by an increase in pressure level in the annular variable volume chamber introduced through the second air relay servo control while the diameter is increased upon a decrease in the pressure level in the annular variable volume chamber by the bleed of air therefrom to the atmosphere through the second air relay servo control.

12. A variable geometry ram inlet and diffuser comprising a radially adjustable outer duct wall, an axially adjustable hollow needle, said needle located coaxially within said outer duct wall and forming a variable area converging-diverging annular duct therebetween, a diffuser section connected to the downstream portion of said duct, a stationary wall transverse to the longitudinal axis of said needle, means connecting the needle to said stationary transverse wall, said connecting means cooperating with the stationary wall and needle interior to form a variable volume closed chamber, a first control means for effecting axial adjustment of the needle by increasing or decreasing the pressure level in said variable volume chamber whereby the needle may be extended away from the stationary wall by an increase in pressure level therein and retracted toward the wall by a decrease in pressure level therein by the bleed of pressure from the variable volume chamber to the atmosphere through the first control means, said outer duct wall comprising a plurality of longitudinal segments,

a tubular member coaxial with and radially spaced from said segments, a first and second plurality of segmental links pivotally connecting the fore and aft ends of the segments to said tubular member, sealing means between each pair of adjacent segments and each pair of adjacent links thereby forming an annular variable volume closed chamber between the tubular member and segmental outer duct wall, and a second control means for varying the pressure level in said annular variable volume chamber whereby the diameter of the segmental outer duct wall is reduced by an increase in pressure level in the annular variable volume chamber introduced through the second control means while the said diameter is increased by a decrease in the pressure level in the annular variable volume annular chamber by the bleed of pressure therefrom to the atmosphere through the second control means, the longitudinal axes of the needle and duct being coextensive and at an angle to the longitudinal axis of the diffuser so that the longitudinal axes of the needle and duct slope downwardly and forwardly relative to the longitudinal axis of the diffuser section.

13. A variable geometry supersonic ram inlet and diffuser comprising a radially adjustable outer duct wall, an inlet spike coaxial with said outer duct wall having a forward portion of fixed cross-section, the entire forward portion of which is axially adjustable relative to the outer duct wall by extension or retraction thereof, first control means responsive to location of shock waves in the inlet during supersonic flow conditions for effecting the radial adjustment of the outer duct wall, and second control means responsive to location of shock waves in the inlet during supersonic flow condition for effecting the axial adjustment of the inlet spike, said adjustable inlet spike and outer duct wall and separate control means therefor all cooperating to form a variable area converging-diverging annular inlet duct controlling both the inlet area and normal shock wave location during supersonic flow conditions.

References Cited in the file of this patent

UNITED STATES PATENTS

294,887	Letton	Mar. 11, 1884
2,409,433	Hunter	Oct. 15, 1946
2,514,393	Hutchinson	July 11, 1950
2,540,594	Price	Feb. 6, 1951
2,737,019	Billman	Mar. 6, 1956
2,763,426	Erwin	Sept. 18, 1956
2,780,056	Colley	Feb. 5, 1957
2,828,603	Laucher	Apr. 1, 1958
2,864,236	Touré et al.	Dec. 16, 1958
2,932,945	Brandt	Apr. 19, 1960

FOREIGN PATENTS

749,767	Great Britain	May 30, 1956
	(Corresponding U.S. 2,864,236 Dec. 16, 1958)	
761,235	Great Britain	Nov. 14, 1956