Aug. 25, 1970 H. J. P. VON OHAIN ET AL 3,525,474

JET PUMP OR THRUST AUGMENTOR

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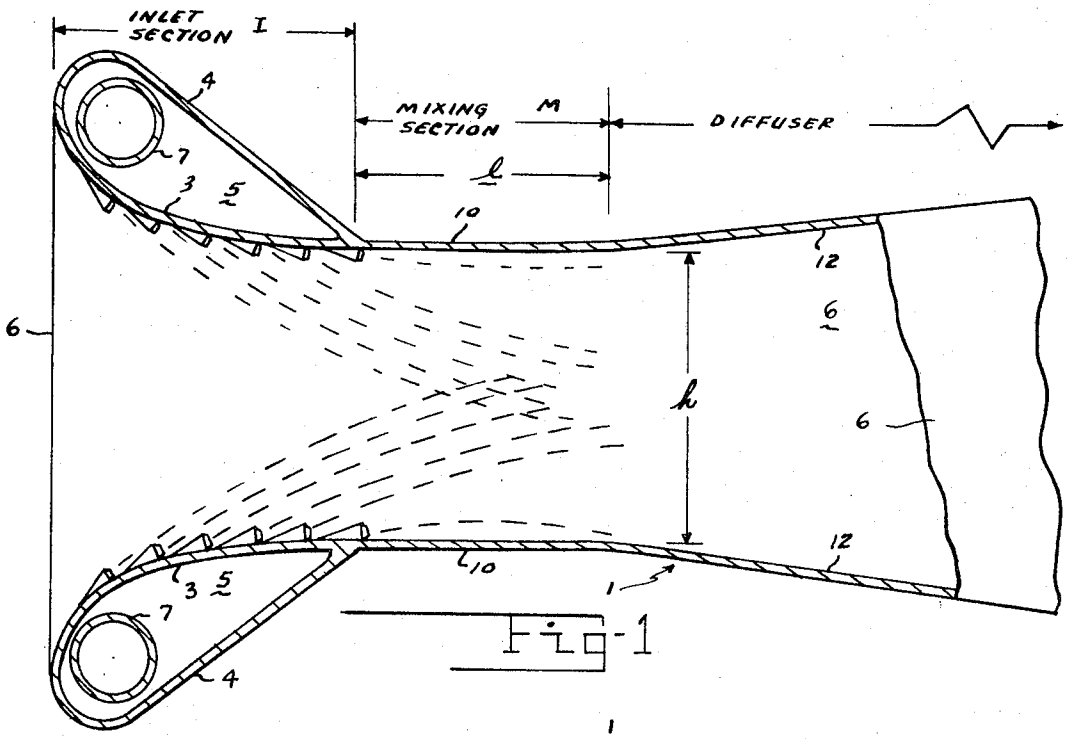


Fig-1

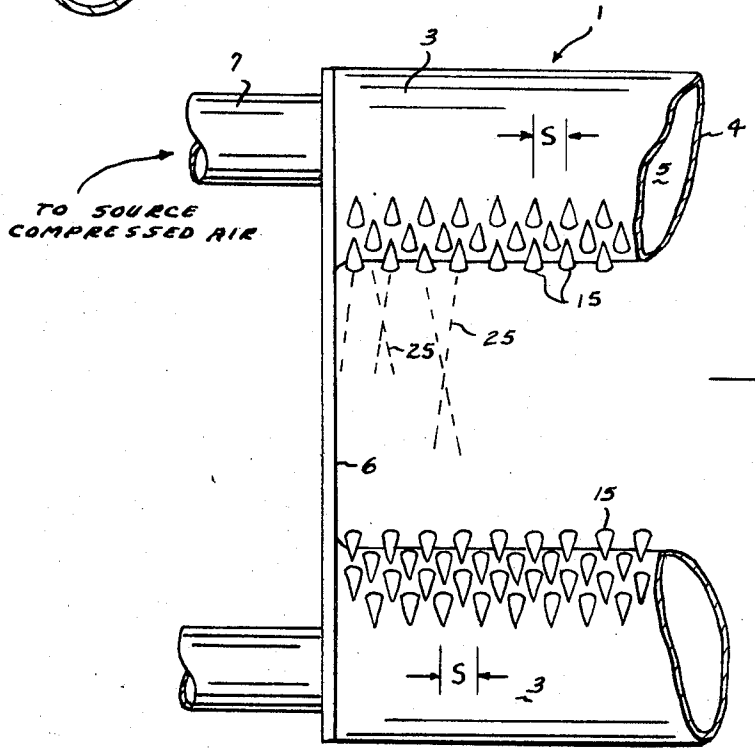


Fig-2

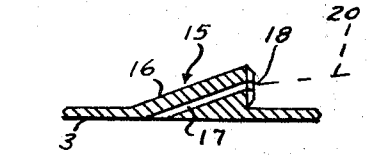


Fig-3

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JET PUMP OR THRUST AUGMENTOR

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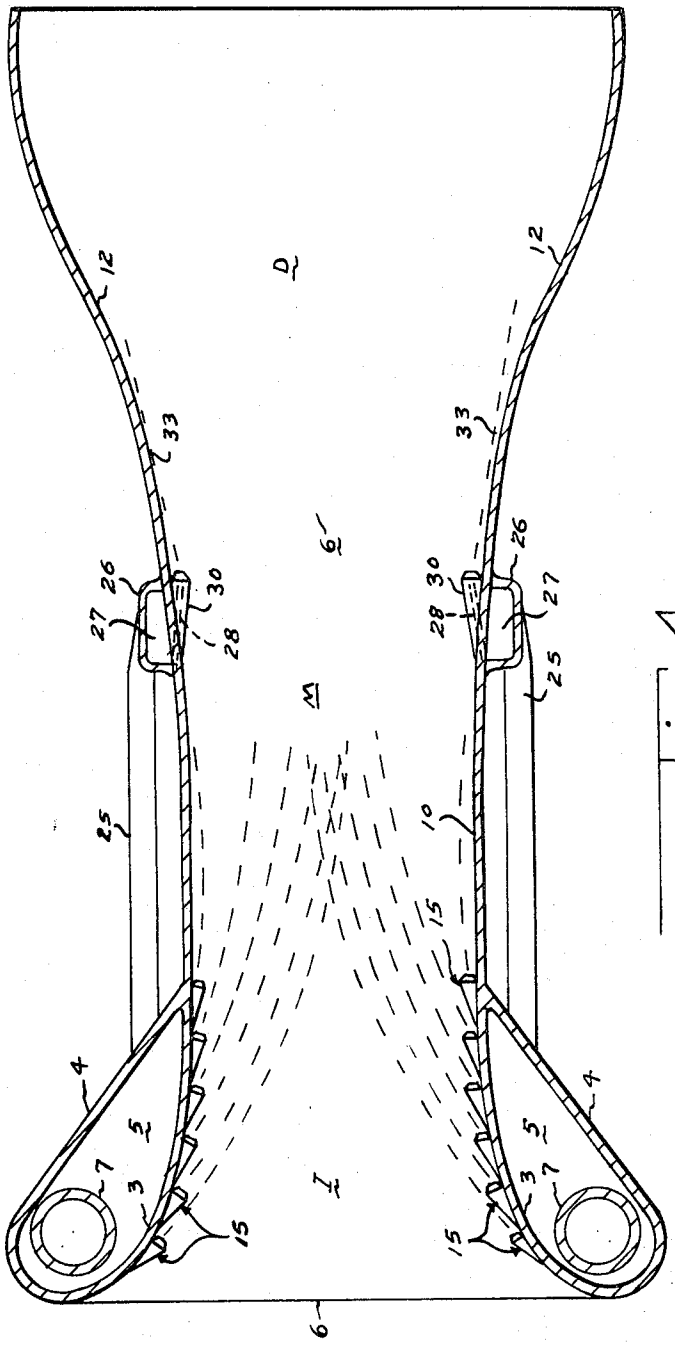


Fig-4

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JET PUMP OR THRUST AUGMENTOR

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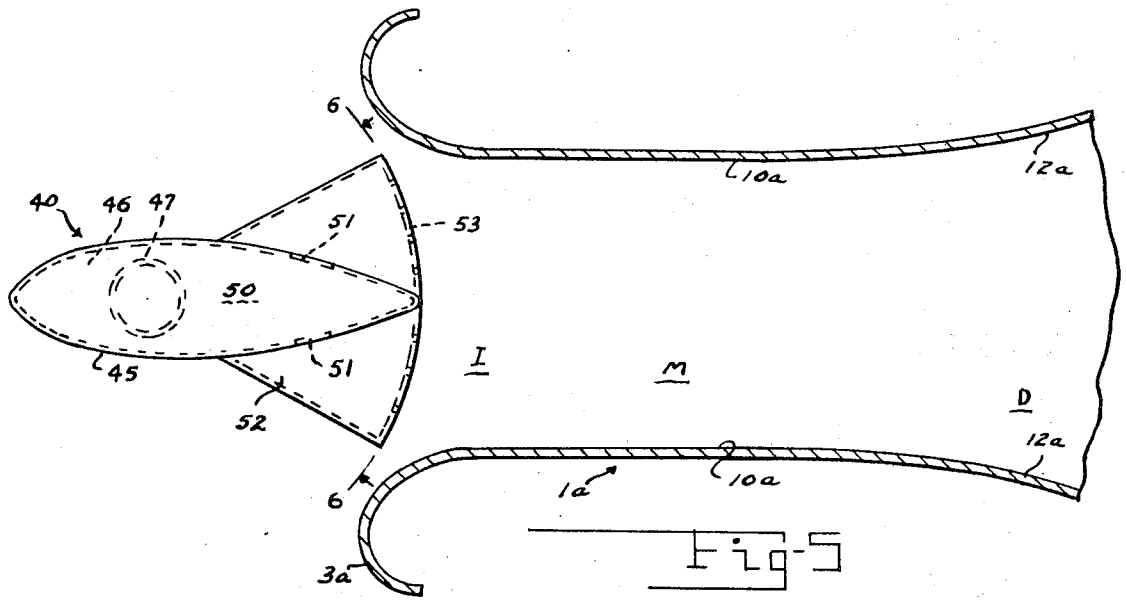


Fig-5

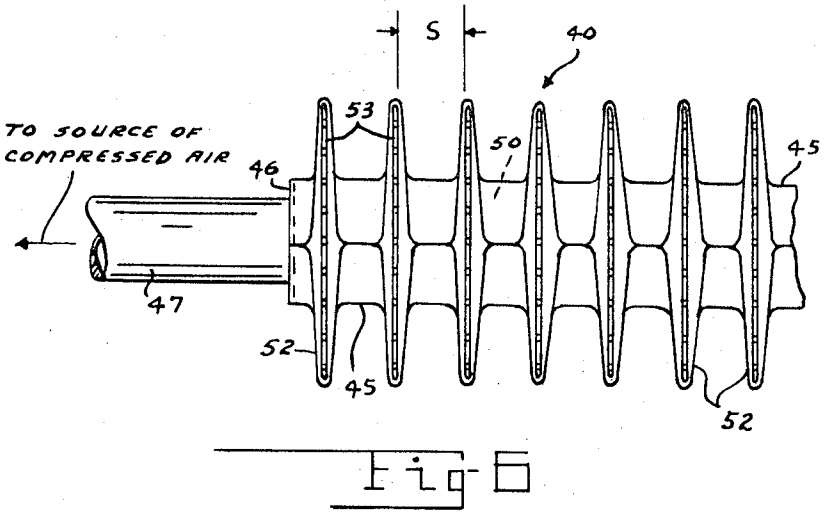


Fig-6

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JET PUMP OR THRUST AUGMENTOR

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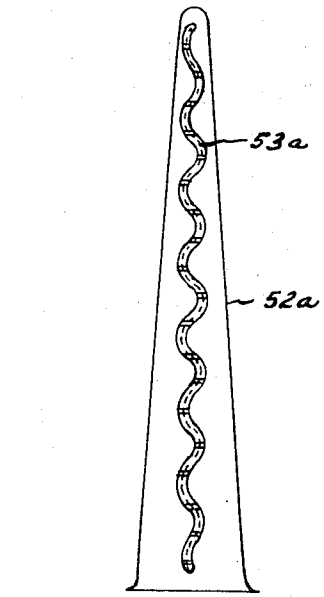


Fig-7

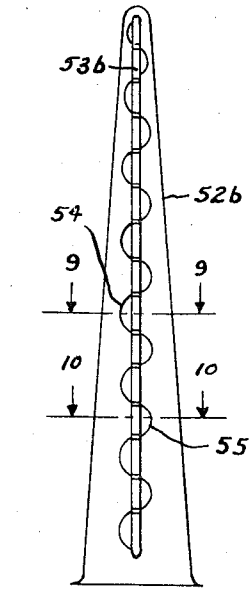


Fig-8

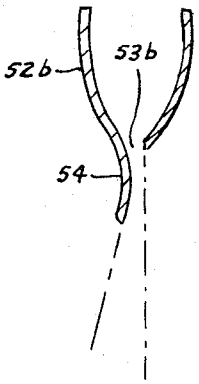


Fig-9

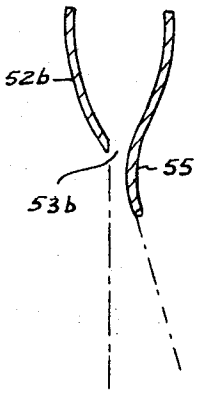


Fig-10

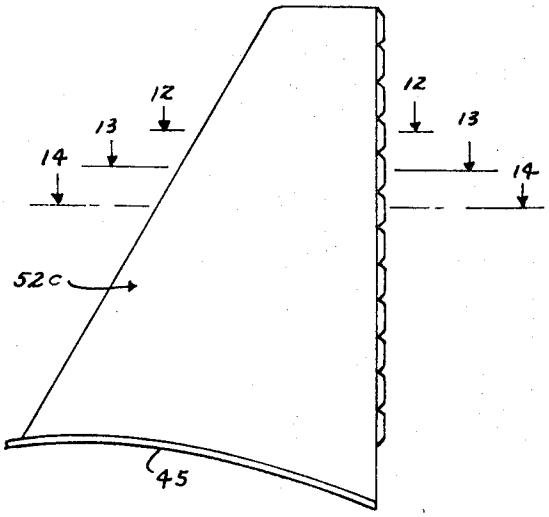


Fig-11

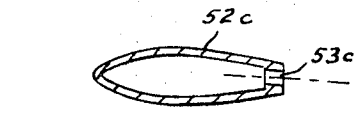


Fig-12

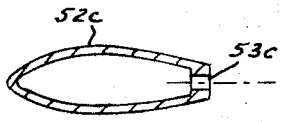


Fig-13

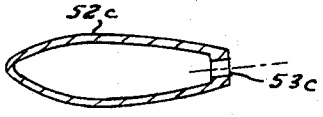


Fig-14

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JET PUMP OR THRUST AUGMENTOR

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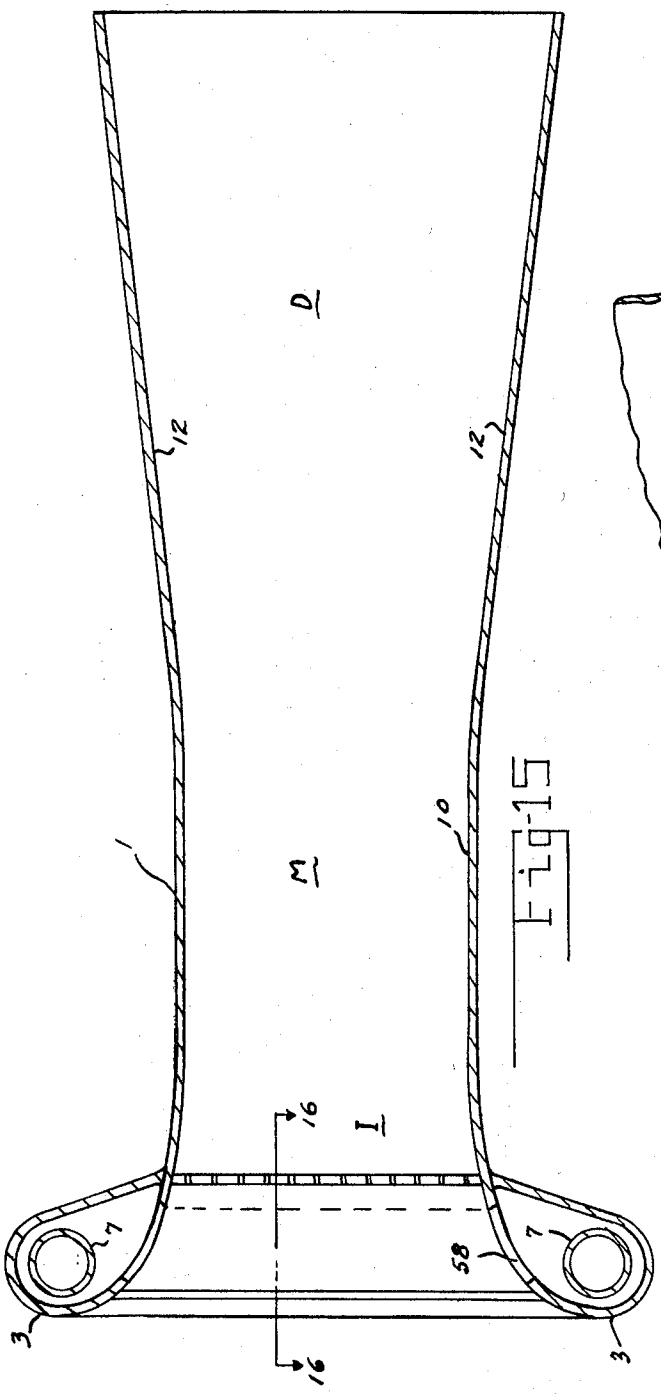


Fig-15

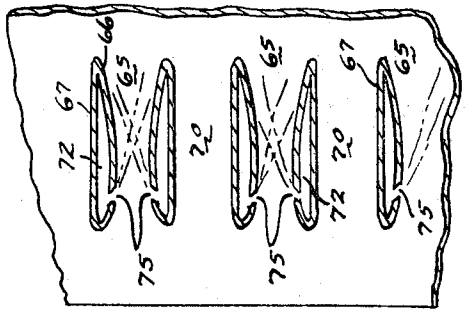


Fig-17

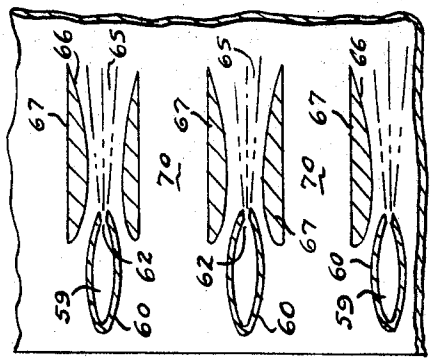


Fig-16

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3,525,474

JET PUMP OR THRUST AUGMENTOR

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Int. Cl. B64c 15/10
U.S. Cl. 239—265.17 10 Claims

ABSTRACT OF THE DISCLOSURE

The present invention relates to improvements in devices generally known as eductors, jet pumps or thrust augmentors. The eductor in the form of a duct has a convergent inlet section, a mixing section and a divergent diffuser section with nozzles injecting high velocity primary jets of fluid into the inlet section and by aspirator action inducing a secondary flow into the inlet. The improvements primarily lie in the overall design wherein the mixing section is preferably of constant cross section with a length less than the hydraulic diameter thereof. A large number of small diameter primary injection nozzles are employed with the total cross-sectional area of the nozzles being of the order of ten percent of the mixing section cross-sectional area. The primary injection nozzles are of such a number and are arranged so that a nearly uniform injection pattern is produced across the inlet to the mixing section, with the injection axis of each nozzle divergent with respect to the longitudinal axis of the duct. Further, the jets have a criss-cross pattern to improve mixing, the nozzle jets adjacent the duct walls being arranged so that the jets wash off the boundary layer on the exist of the mixing section walls. The invention contemplates special nozzle configurations and arrangements to achieve a minimum blockage of the duct inlet, uniform velocity distribution across the mixing section exit and intimate mixing between the primary and secondary fluid flow.

BACKGROUND OF THE INVENTION

Field of the invention

The invention relates broadly to devices known as eductors or jet pumps which, however, are also suitable for use as aircraft propulsion devices for increasing or augmenting the thrust of a high velocity primary fluid flow by causing the primary flow to entrain a secondary flow and exchange energy therewith with the mixed flow passing through a diffuser to increase its pressure and reduce its velocity.

Description of the prior art

So-called eductor devices or jet pumps per se are very old and proposals to employ the same in aircraft propulsion date back to World War I. Note Gas Turbines and Jet Propulsion for Aircraft by G. Geoffrey Smith, fourth edition 1946, published by Aircraft Books, Inc., pages 34 through 37 inclusive. An up-to-date resume of the state of the art is contained in U.S. Army Material Laboratories Technical Report 66–18 by Peter R. Payne, Defense Documentation Center No. AD632126 (unclassified), March 1966. In the prior art devices, the cross-sectional area of the primary flow nozzle or nozzles was generally large, greater than twenty-five percent of the cross-sectional area of the duct where mixing occurred. Further, no attention was given to reduction of blockage of the duct inlet, to velocity distribution or to the injection pattern across the duct mixing section. The applicants' design has made a material advancement over the known state of the art.

SUMMARY OF THE INVENTION

A theoretical study of the performance of the prior art eductor devices by the applicants led to the conclusions that if the performance were to be bettered, the following were the areas for improvement. The inlet section of the duct would have to be designed so that the injection means would offer a minimum of obstruction to reduce friction losses. The primary flow injection nozzles must each be small in diameter and the total nozzle cross-sectional area should be of the order of ten percent of the cross-sectional area of the mixing section of the duct. A mixing section must be employed between the inlet section of the duct and the diffuser, with a length less than the hydraulic diameter of the mixing section and with the mixing section preferably having a constant cross-sectional area throughout its length. For improved mixing between the primary jets and the secondary flow, the primary jets must be very small in diameter, i.e., one-fourth inch or less, and very large in number, for example, ten to twenty jets or more per square foot of cross-sectional area of the mixing section, with the jet streams intersecting at a small angle to provide penetration normal to as well as along the streamlines to improve mixing. It was also necessary to have the primary jets adjacent the mixing section walls to be inclined so as to accelerate the boundary layer at the entrance to the diffuser section and to have a nearly uniform velocity distribution across the entrance to the duct diffuser section with a small excess velocity adjacent the diffuser entrance walls.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates in longitudinal section a preferred form of the invention.

FIG. 2 is a front elevation of the propulsion duct of FIG. 1.

FIG. 3 is a longitudinal sectional view of a typical primary injection nozzle of the device of FIG. 1.

FIG. 4 is a longitudinal sectional view of a device similar to FIG. 1 provided with supplementary injection nozzles to remove the boundary layer from the walls of the entrance to the diffuser section.

FIG. 5 is a view of an augmentor device similar to the device of FIG. 1 in which the injection nozzle structure is constructed so as to create a minimum of blockage of the inlet section.

FIG. 6 is a view taken on line **6—6** of FIG. 5 illustrating the injection nozzle structure of the device of FIG. 5.

FIG. 7 is an end view of a primary nozzle structure suitable for use in the device of FIG. 5 and giving improved mixing.

FIG. 8 is a view similar to FIG. 7 of a further improved primary nozzle structure.

FIG. 9 is an enlarged horizontal sectional view of the nozzle of FIG. 8 taken on line **9—9** of FIG. 8.

FIG. 10 is an enlarged sectional view similar to FIG. 9, taken on line **10—10** of FIG. 8.

FIG. 11 is a view of a further streamlined nozzle structure capable of use with a device of the type of FIG. 5.

FIG. 12 is a sectional view taken on line **12—12** of FIG. 11.

FIG. 13 is a sectional view taken on line **13—13** of FIG. 11.

FIG. 14 is a view taken on line **14—14** of FIG. 11.

FIG. 15 is a longitudinal sectional view of a thrust augmenting duct involving internal plural staging.

FIG. 16 is a sectional view of the nozzle structure taken on line **16—16** of FIG. 15.

FIG. 17 is a view similar to FIG. 16 showing a modified primary injection means.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIGS. 1 and 2, the reference numeral **1** generally indicates an eductor, jet pump or thrust augmentor in the form of a duct preferably of rectangular cross section. The duct **1** includes an inlet section indicated by the reference character I, a mixing section indicated by reference character M, and a diffuser section indicated by reference character D. The inlet section I, mixing section M and diffuser section D are arranged in series to form a continuous flow channel.

The inlet section I is provided with curved convergent inner walls **3** which connect to the inlet of the mixing section M. The inlet section M is also provided with rearward and inwardly directed wall members **4** which join with the ends of wall members **3** to form internal laterally extending chambers **5**. The duct **1** is provided at each end with vertical end walls **6** which also form closures for the chambers **5**. Conduits **7** connect to one end of each respective chamber **5** as indicated in FIG. 2. The conduits **7** are adapted to be connected to a source of primary air (not shown) under pressure of as much as three atmospheres gage pressure.

As seen in FIG. 1, the convergent walls **3** of the inlet section I join the walls **10** of the mixing section M, which together with end walls **6** form a duct of rectangular cross section having a constant vertical dimension *h*. The mixing section M preferably is of constant cross section and has a length *l* which is made less than the hydraulic diameter of the mixing section.

The mixing section M as seen in FIG. 1, joins the diffuser section D, which has end walls formed by the walls **6** and divergent top and bottom walls **12**. The divergence angle of the walls **12** should not be greater than seven degrees.

The convergent walls **3** of the inlet section **I**, as seen in FIG. 1 and FIG. 2, is provided with a series of primary injection nozzles generally indicated by reference numeral **15** which, as seen in FIG. 3, includes a streamlined body **16** extending above the respective wall **3**. The body **16** is provided with a passage **17** adapted to communicate with the chamber **5** so as to allow the passage of air udner pressure from the chamber through the nozzle. A counterbore **18** connecting with passage **17** forms the nozzle proper and may be drilled so that the orientation of the stream issuing therefrom, such as indicated at **20**, will have a desired inclination both in the vertical and horizontal planes. The nozzles **15** may be arranged in staggered rows as indicated in FIG. 2 and the number of nozzles in each row is not necessarily the same and may be in some predetermined ratio such as 1:3:5, etc. The nozzles **15** may have the orifices **18** thereof drilled so as to selectively orient the jet streams of compressed air therefrom. The jet streams must have penetration normal to the streamlines as well as along the streamlines of flow of the secondary or induced flow. This results in a criss-cross pattern of flow lines, as indicated at **25** in FIG. 2, and is essential in order to obtain good mixing and a maximum transfer of energy from the primary jets to the induced secondary flow. Further, it is essential that some of the jets have their discharge oriented to blow off the boundary layer adjacent the entrance portion of the diffuser section and to result with a slight excess of velocity adjacent the diffuser entrance walls. The number of individual nozzles is greatly in excess of the number employed in known prior art devices. For example, the number of nozzles or individual primary fluid streams may be twenty or more nozzles or streams per square foot of mixing section cross-sectional area. The diameter of the nozzle bore or orifice **18** (FIG. 3) may vary from about five thirty-seconds of an inch to a maximum of about a quarter of an inch. In any event, the total cross-sectional area of the nozzle orifices should be from about five percent to more than fifteen percent of the cross-sectional area of the mixing section with the lateral spacing S between nozzles of the order of one twentieth to one fourtieth of the effective length of the mixing chamber. The large number of small diameter primary fluid streams intersecting within the mixing section, with the streams distributed nearly uniformly over the mixing section cross section, produces a maximum transfer of kinetic energy from the primary jet streams to the secondary induced flow into the duct inlet. Further, the velocity distribution at the entrance to the diffuser is more nearly constant, a requirement for low diffuser losses.

The device of FIG. 1 operates in the following manner: Air under pressure from a suitable source (not shown) enters the conduits **7** and from thence flows to the chambers **5** from which it enters the passages **17** of each respective nozzle assembly **15** (FIG. 3). The air issues from the nozzle orifices **18** (FIG. 3) as high velocity, small diameter jets and because of the high velocity, the jet streams are at sub-atmospheric pressure. The jet streams cause secondary air at atmospheric pressures to flow into the inlet I of the duct assembly and mix with the primary jet streams. If the number of primary jets is very large and of small diameter, contact with secondary air is greatly enhanced and an exchange of energy takes place from the primary to the secondary flow so that by the time the stream flow reaches the inlet to the diffuser D (FIG. 1), the mixing process is complete. The velocity distribution across the mixed flow at the entrance to the diffuser, section D (FIG. 1), should be constant with a slight excess adjacent the duct walls. The mixed flow then enters the diffuser D and expands to substantially decrease the velocity and increase the pressure to the mass flow the diffuser exit which is large compared to the mass of the primary air. Because of the increased mass flow, there is a considerable thrust developed which is a multiple of the thrust produced by the primary jets alone if discharging in the atmosphere without a duct. Tests of devices constructed in accordance with the applicants' invention have shown very substantial improvements over the performance of prior art devices.

Where it is desired to use a thrust augmenting duct with a diffuser section of short overall length, a modified version of the device of FIG. 1 is employed, as illustrated in FIG. 4. In the device of FIG. 4 the structure generally is the same as that of FIG. 1, with the exception that supplemental primary injection nozzles are employed to remove the boundary layer from the diffuser walls particularly at the entrance thereof. The removal of the boundary layer tends to prevent flow breakdown and permits the use of a short diffuser.

In the device of FIG. 4 the respective air reservoir pressure chambers **5** are each connected by conduits **25** to an inverted U-shaped channel **26**, the hollow interior of which forms a chamber **27** connected by passages **28** to individual supplemental injection nozzles **30** distribuated in a row laterally across the walls **10** of the mixing section at the entrance to the diffuser section D. The nozzles **30** inject streams of primary air along the walls of the diffuser D, as indicated by the reference numeral **33**, to continuously remove the boundary layer and pre-

vent flow breakdown. This provision makes it possible to make the overall length of the diffuser section D less than would otherwise be possible and still obtain a high efficiency.

The form of the invention disclosed in FIGS. 5 and 6 includes a thrust augmenting duct of the same form as disclosed in FIG. 1, with the exception that the corresponding parts are identified by the same reference numeral with the subscription *a*. The structure differs from that of FIG. 1 in that the primary injection nozzle assembly is made so as to create a minimum of inlet section blockage. The duct generally indicated by the reference numeral **1***a* has an inlet section I, mixing section M and a diffuser section D of the same type as disclosed in FIG. 1. The inlet section I has the primary injection apparatus generally indicated by the reference character **40** positioned forward of the inlet section I with the nozzles thereof positioned within the bell mouthed walls **3***a* thereof. The injection apparatus **40** includes a hollow streamlined housing **45** having end walls **46** through which a conduit **47** extends. The conduit **47** is adapted to be connected to a source of compressed air (not shown) and conducts the compressed air into the chamber **50** formed by the interior of the housing **45**. The chamber **50** is provided with a series of internal ports **51** communicating with respective hollow streamlined vanes **52** secured to the housing **45** by welding or the like. The entire trailing edge of each vane, as seen in FIG. 6, is provided with narrow interrupted slots **53**, which serve as nozzles or orifices for the discharge of primary air from the interior of the vanes **52**. The width of the slot orifices **53** may be of the order of one sixteenth of an inch and the spacing S (FIG. 6) between vanes may be of the order of one and one-half to three inches. Where the vane discharge slot is made very narrow, it may be made continuous. The operation of the device of FIGS. 5 and 6 is similar to the operation of the device of FIG. 1 with the exception that due to streamlined construction physical blockage to the inlet flow of secondary air is reduced to a minimum.

FIG. 7 illustrates a modified form of streamlined vane injection apparatus suitable for use in apparatus of the type disclosed in FIGS. 5 and 6. In FIG. 7 only, the upper half of the vane structure indicated by the reference character **52***a* is shown. The vane **52***a* has its trailing edge deformed in a wave-like manner with curved orifice slots **53***a* formed therein. The curved orifice slots **53***a* serve to discharge high velocity jets of air in the form of sheets having an alternating lateral pattern which will cause the jets from adjacent vanes **52***a* to ultimately cross and intimately mix with the ambient secondary air flow.

The nozzle structure illustrated in FIGS. 8, 9 and 10 is intended for use in an assembly of the type disclosed in FIGS. 5 and 6 and the like vane structure of FIG. 7 gives rise to an improved mixing of primary and secondary air. The device of FIG. 8 as indicated by the reference character **52***b* is provided with an interrupted slot trailing edge with the slot orifices indicated by the reference character **53***b*. The flow of primary fluid under pressure from the interior of the hollow vane structure **52***b* is the same as in the corresponding vane structure of FIGS. 5 and 6. In the vane structure of FIG. 8, however, each alternate slot orifice **53***b* has a trailing edge on one side thereof extended in the form of a bent metal tongue **54** deflected for example in the manner as indicated in FIG. 9. Similarly, the remaining set of alternate orifices **53***b* is provided on one side of the orifice with a trailing edge extension in the form of a bent metal tongue **55** deflected in the opposite sense from the tongues **54** as illustrated in FIG. 10. The jets of primary fluid issuing from the slot orifices **53***b* are accordingly deflected laterally to the right and left as indicated by the dotted lines in FIGS. 9 and 10. The jet streams in contact with the alternating tongues **54** and **55** tend to adhere to the tongues and hence be deflected laterally in alternate opposite directions to give an improved mixing of primary and secondary flows.

The improved mixing function of the vanes of FIGS. 7 and 8 can also be accomplished with the vane structure of FIG. 11, when employed in an assembly of the type disclosed in FIGS. 5 and 6. The hollow streamlined vane **52***c* of FIG. 11 has a blunt trailing edge which is drilled with a number of orifices **53***c* communicating with the hollow interior of the vane **52***c* and adapted to discharge primary jets of air therefrom. The orifices **53***c* are preferably arranged seriatim so that the orifices as seen in FIG. 12 directs its discharge slightly to the right of the center line of the vane. The succeeding orifice **53***c* as seen in FIG. 13 directs its discharge in the plane of the center line of the vane **52***c* while in FIG. 14 the orifice discharge is to the left of the vane center line. This pattern is repeated in successive sets of three of the orifices. The changing lateral flow direction from the orifices **53***c* accomplishes the improved mixing of primary and secondary flows.

The device illustrated in FIGS. 15 and 16 relates to a so-called two stage thrust augmentor. As seen in these figures, the propulsion duct **1** with inlet I, mixing chamber M and diffuser D is identical with that disclosed in FIG. 1 and corresponding parts are identified by the same reference numerals as in the device of FIG. 1.

As seen in FIG. 16, the inlet chambers **5** supplied with compressed air from conduits **7**, as in the device of FIG. 1, communicate by means of ports **58** with the hollow interior **59** of vertical streamlined struts **60**. The struts **60** are laterally spaced across the width of the duct **1** as shown in FIG. 16 and the trailing edge of each strut is drilled with a large number of primary orifices or nozzles **62** which may be made in the form as described with respect to FIGS. 11 through 13 to obtain adequate mixing. The nozzles **62** of each vertical strut **60**, each discharge into the inlet portion of a venturi-shaped passage **65** formed by the curved inner walls **66** of vertical extending laterally spaced strut members **67**, the outer walls of which are flat and adjacent pairs of which form the constant cross section passages **70**. The operation of the device of FIGS. 15 and 16 is as follows: Air under pressure from conduits **7** flows into chambers **5** (FIG. 15) and by way of parts **58** flows into the interior space **59** of each vertical strut or housing **60**. The air under pressure in space **59** then flows in high velocity primary jets from the nozzle orifices **62** (FIG. 15) into the inlet section of the venturi-shaped passage **65**. The fall in pressure in the jets issuing from nozzles **62** by aspiration causes an inflow of secondary air from the inlet I of the propulsive duct (FIG. 15). This air flowing into the venturi-shaped passages **65** mixes with the primary air jets and picks up kinetic energy therefrom. The mixed flow moves through the mixing section of the venturi passages **65** which are designed in the same manner as the principal duct **1** to expand in the diffuser section. The mixed flow issuing from the venturi-shaped passages **65** is still at high velocity and low pressure so that other secondary air is drawn from the inlet of duct **1** to pass through the constant cross section passages **70** (see FIG. 16) where these streams of secondary air mix with the flow from the passages **65** in the mixing section M of the main duct **1**. The final increased mass flow further expands in the diffuser section D to exit therefrom and the two stage mixing of the primary air with secondary air produces a considerable increase in the thrust developed from that of a single stage device such as that of FIG. 1.

To eliminate blockage of the inlet to as great an extent as possible, the device of FIG. 15 may be modified by using the injection system disclosed in FIG. 17. In the system of FIG. 17, the hollow streamlined struts **60** are eliminated and each of the vertical struts **67** are made hollow in the form of shaped tubing each having a central passage **72** adapted to communicate with the chambers

5 of the device of the type shown in FIG. 15 by suitable ports (not shown) through the curved walls 3 of the main duct 1. Suitable injection orifices 75 in the form of a vertical row of holes are drilled through each venturi wall 66 adjacent its forward end. The primary jets of high velocity air issue from the holes 75 into the venturi-shaped passages 65 so that the device thereafter functions in the same manner as previously described with respect to FIGS. 15 and 16.

We claim:

1. In an augmentation device of the character described, a duct for fluid flow therethrough and having a convergent inlet section communicating with the ambient atmosphere, a mixing section and an outlet diffuser section, said sections being connected to each other in series, a plurality of nozzles each adapted to be connected to a primary source of fluid under pressure to discharge a high velocity primary fluid stream into said inlet section, said primary fluid streams inducing a secondary fluid flow through said inlet section to merge with said primary fluid streams, the said nozzles being arranged so that the jet discharge path therefrom forms a criss-cross pattern in both the vertical and horizontal plane whereby the primary fluted jets achieve a lateral as well as a longitudinal penetration of the ambient secondary fluid flow, the jet discharge pattern being arranged so as to wash the boundary layer from at least the entrance to the diffuser section and to cause a substantially uniform velocity distribution across the entrance to the diffuser section and the number of primary fluid jets being in excess of ten jets per square foot of cross-sectional area of the mixing section and the length of the mixing section being less than the hydraulic diameter thereof.

2. The structure as claimed in claim 1, in which the convergent inlet section of the duct is provided with curved walls on opposite sides of the longitudinal plane of symmetry, each nozzle of a group of said primary discharge nozzles forming a streamlined projection extending from the curved wall of the inlet section and the nozzles of each group being longitudinally spaced from each other along the curved inlet section wall with the angle of discharge with respect to the longitudinal axis of the duct inlet section decreasing for each nozzle in the group in the direction of downstream flow.

3. The structure as claimed in claim 2, in which the individual nozzles are laterally spaced across the width of the duct with a spacing between adjacent nozzles of the order of one-twentieth to one-fortieth of the effective length of the mixing section of the duct.

4. The structure as claimed in claim 1, in which each of the groups of primary discharge nozzles are housed in a streamlined vane positioned in the inlet section of the duct and the nozzles adapted to discharge downstream from the trailing edge of the streamlined vane.

5. In a thrust augmenting device of the character described, a duct having a convergent inlet section communicating with the ambient atmosphere, a mixing section and a divergent diffuser section, said sections being connected in series, a plurality of nozzles each adapted to be connected to a primary source of fluid under pressure to discharge a high velocity fluid stream into the said inlet section, said primary fluid streams inducing a secondary flow through said inlet section to merge with said primary fluid streams, said nozzles adapted to form a discharge sheet extending in a plane substantially normal to the longitudinal plane of symmetry of the inlet section of the duct, each nozzle assembly consisting of a streamlined vane type housing positioned in the inlet section of the duct and the interior of the housing adapted to communicate with said primary source of fluid under pressure, fluid discharge means coextensive with the trailing edge of said streamlined housing and adapted to discharge fluid into the inlet in the form of a thin sheet and means for causing minor undulations in the plane of the nozzle discharge sheet to thereby create a vigorous mixing with the ambient fluid induced into the inlet by the primary fluid flow therethrough.

6. The structure as claimed in claim 5, in which the fluid discharge means coextensive with the trailing edge of said streamlined housing comprises a narrow interrupted discharge slot extending the length of the trailing edge and said slot being curved to form a series of undulations extending on opposite sides of a plane of symmetry containing the theoretical trailing edge of the streamlined housing whereby portions of the discharge sheet are alternately deflected on opposite sides of said last-named plane of symmetry.

7. The structure as claimed in claim 5, in which the fluid discharge means coextensive with the trailing edge of said streamlined housing comprises three groups of orifices one group permitting discharge parallel with a plane of symmetry of said streamlined housing passing through the trailing edge thereof, a second group adapted to discharge slightly to the right from said last-named plane of symmetry and the third group discharging slightly to the left of the plane of discharge of the first group, the orifices of the first group each having an orifice of the second and third groups positioned on opposite sides thereof.

8. The structure as claimed in claim 5, in which the fluid discharge means coextensive with the trailing edge of said streamlined housing comprises a plurality of orifices adapted to discharge fluid in a common plane forming the longitudinal plane of symmetry of said streamlined housing, and means associated with each of said orifices to impart a lateral deflection to the discharge therefrom and the direction of lateral deflection alternating successively in proceeding from one orifice to the next in a row.

9. In a thrust augmenting device of the character described, a duct having a continuous flow channel therethrough and having a convergent inlet section communicating with the ambient atmosphere, a mixing section and a divergent diffuser section, said sections being arranged in series, a plurality of nozzles adapted to be connected to a source of primary fluid under pressure and discharging high velocity fluid jets adjacent the entrance of said inlet section and inducing a secondary flow into said inlet section to mix with the primary fluid jets, the total cross-sectional area of the nozzles being of the order of ten percent of the cross-sectional area of the duct mixing section, the length of the duct mixing section being less than the hydraulic diameter of the mixing section and the number of primary fluid jets being at least ten or more per square foot of mixing section cross-sectional area.

10. In a thrust augmentation device of the character described, a main duct having an inlet section, a mixing section and a diffuser section said sections being connected in series to form a flow section said sections being connected in series to form a flow channel therethrough, said inlet section communicating with the ambient atmosphere, a plurality of nozzles being adapted to be connected to a source of primary fluid under pressure and discharging high velocity fluid jets adjacent the entrance of said inlet section, secondary ducts within the inlet section of said main duct said secondary ducts each having a convergent inlet section communicating directly with the inlet section of the main duct, a central mixing section, and a divergent diffuser section communicating directly with the mixing section of said main duct, each of said secondary ducts having its inlet positioned to receive the jet discharge of primary fluid from at least one of said plurality of nozzles whereby the jet stream of primary fluid causes an induction of secondary fluid flow through the inlet of said main duct to said main duct mixing section and also into the inlet of each of said secondary ducts to mix with the primary jet fluid therein and the mixed fluid flow discharged from the diffuser section of each secondary duct flowing into the main

duct mixing section for further mixing with the flow of secondary induced fluid flow therein the final mixed flow in the mixing section of said main duct flowing into and expanding in said main duct diffuser section.

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