Aug. 7, 1962 W. E. HOWALD ETAL 3,048,376

FLUID MIXING APPARATUS

Filed April 9, 1958 3 Sheets-Sheet 1

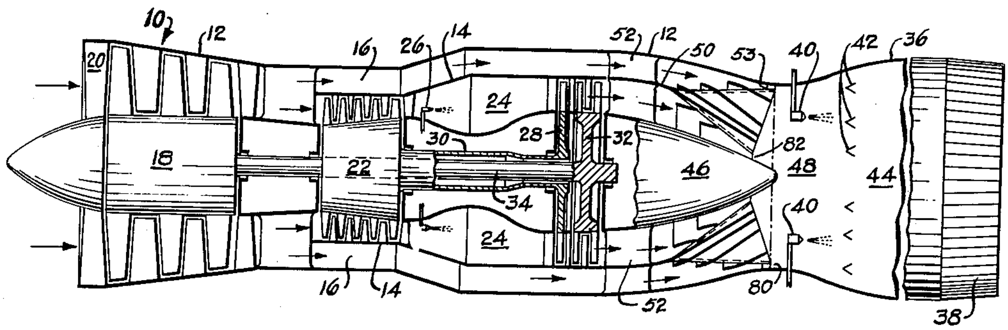

Fig-1

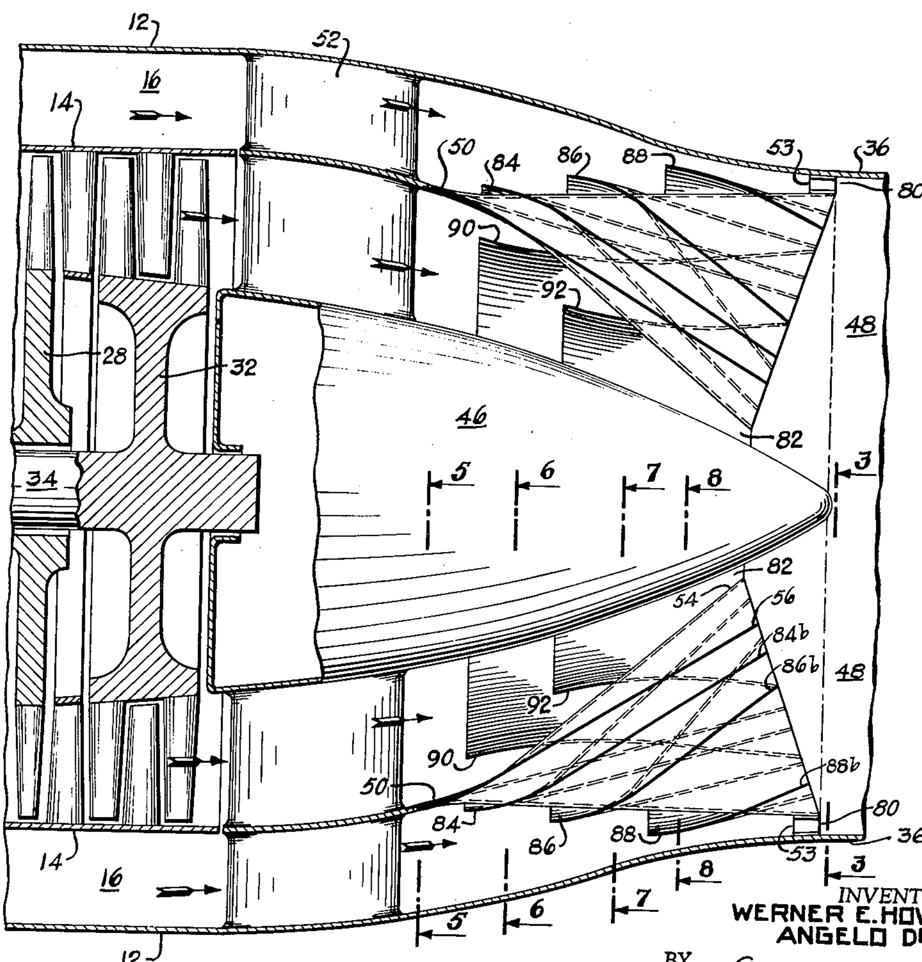

Fig-2

INVENTORS
WERNER E. HOWALD
ANGELO DEFEO

BY Victor D. Behn

ATTORNEY

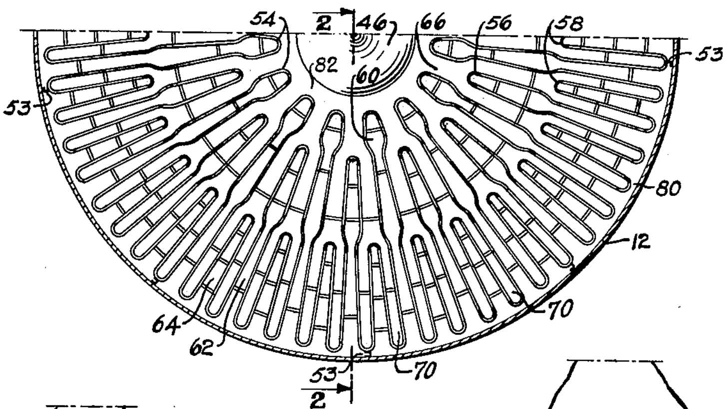

FIG. 3

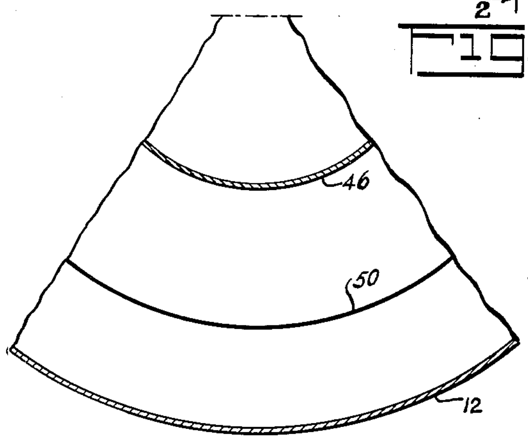

FIG. 5

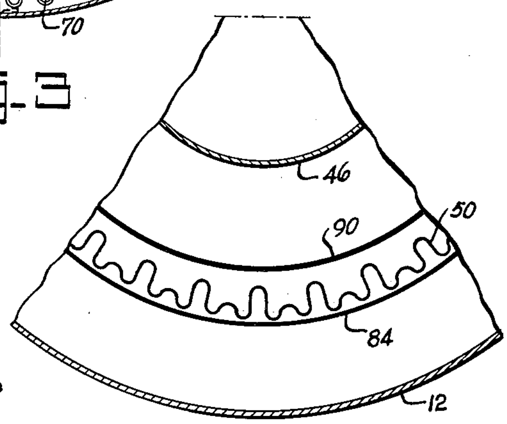

FIG. 6

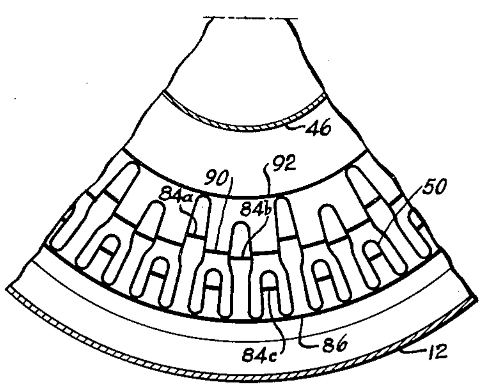

FIG. 7

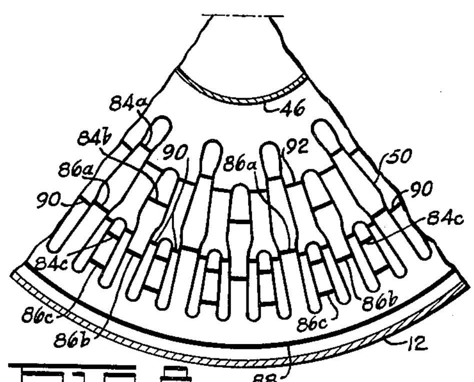

FIG. 8

INVENTORS
WERNER E. HOWALD
ANGELO DE FEO
BY
Victor D. Behn
ATTORNEY

Aug. 7, 1962 W. E. HOWALD ETAL 3,048,376

FLUID MIXING APPARATUS

Filed April 9, 1958 3 Sheets-Sheet 3

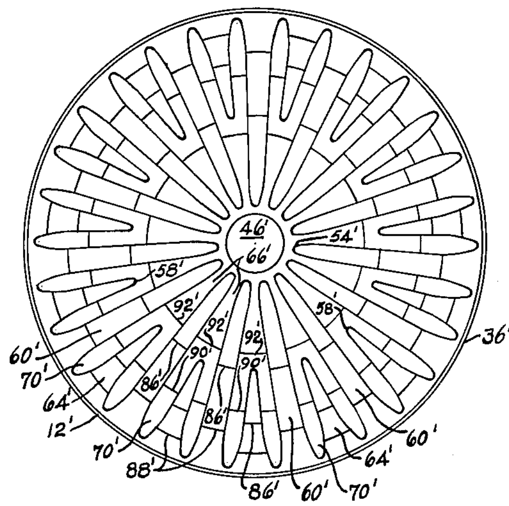

FIG-9

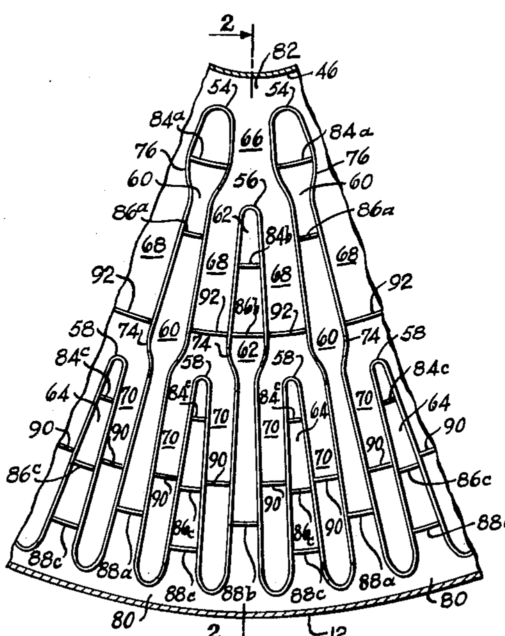

FIG-4

INVENTORS
WERNER E. HOWALD
ANGELO DE FEO
BY Victor D. Behn
ATTORNEY

United States Patent Office

3,048,376

Patented Aug. 7, 1962

3,048,376
FLUID MIXING APPARATUS

Werner E. Howald, Ridgewood, and Angelo De Feo, Totowa Boro, N.J., assignors to Curtiss-Wright Corporation, a corporation of Delaware

Filed Apr. 9, 1958, Ser. No. 727,471
6 Claims. (Cl. 259—4)

This invention relates to fluid distributing apparatus and is particularly directed to apparatus for mixing the two fluid streams of a turbofan engine.

In a turbofan engine the turbine exhaust gases and the by-pass air are fed from co-axial annular paths into a common exhaust duct for mixing therein. Co-pending application Serial No. 563,479, filed February 6, 1956, now Patent No. 2,978,865, discloses fluid mixing apparatus for splitting each of said annular fluid paths into a plurality of circumferentially-spaced passages fitted between corresponding passages from the other path, each of said passages extending radially across and discharging into an annular exhaust duct. Splitting up each fluid path in this way greatly facilitates mixing of the two fluids in this exhaust duct. Since each of said passages extends radially across the annular exhaust duct, the circumferential width of said passages is greater at their radially outer ends. Hence the streams of the two fluids discharging from said passages into said duct will mix more quickly at the radially inner region of said duct than at its radially outer region. That is, said fluid streams will mix more quickly at the inner portions of said duct where their circumferential width is a minimum.

An object of the invention comprises the provision of a novel and simple arrangement of such fluid mixing apparatus in which variations in the circumferential width of each such passage, such as occur in the apparatus of the aforementioned co-pending application, are minimized whereby the rate of mixing of the two fluids proceeds uniformly across the exhaust duct. With this construction complete mixing of said fluids can be attained more efficiently and in a shorter length of exhaust duct.

Other objects of the invention will become apparent upon reading the annexed detailed description in connection with the drawing in which:

FIG. 1 is an axial sectional view of a turbofan engine embodying the invention;

FIG. 2 is an enlarged view of the fluid mixing portion of FIG. 1 and taken along line 2—2 of FIGS. 3 and 4;

FIG. 3 is an end view taken along line 3—3 of FIG. 2;

FIG. 4 is an enlarged view of a portion of FIG. 3;

FIGS. 5, 6, 7, and 8 are sectional views taken along lines 5—5, 6—6, 7—7, and 8—8 respectively of FIG. 2; and

FIG. 9 is a view similar to FIG. 3 but illustrating a modification of the invention.

Referring first to FIG. 1 of the drawing, a turbofan engine 10 comprises an outer shell or housing 12 and an inner shell 14 concentrically supported within the housing 12 so as to leave an annular by-pass path 16 therebetween. A low pressure axial flow compressor 18 is journaled within the housing 12 forwardly of the inner shell 14. The compressor 18 receives air through the forwardly directed inlet 20 formed at the forward end of the housing 12. The compressor 18 delivers a portion of its air to the annular path 16 and the remaining portion to a high pressure axial flow compressor 22 journaled within the inner shell 14.

The high pressure compressor 22 supplies its air to an annular combustion chamber 24 where heat is added to said air by burning fuel therein, said fuel being supplied by burner apparatus schematically indicated at 26. From the combustion chamber 24 the hot combustion gases coact with the blades of a high pressure turbine 28 for

driving said turbine. A shaft 30 drivably connects the high pressure turbine 28 with the high pressure compressor 22. The gases exhausting from the high pressure turbine 28 co-act with the blades of a low pressure turbine 32 for driving said latter turbine. The low pressure turbine 32 is drivably connected to the low pressure compressor 18 by a shaft 34 extending co-axially through the shaft 30. The high pressure compressor 22, combustion chamber 24 and turbines 28 and 32 provide an annular fluid path co-axial with and surrounded by the annular by-pass fluid path 16. From the low pressure turbine 32 the hot gases discharge into an outlet duct 36 formed by a rearward extension of the housing 12 beyond the turbine assembly 28 and 32. The air supplied through the annular by-pass path 16 by the compressor 18 also discharges into the outlet duct 36. The outlet duct 36 has a rearwardly directed exhaust nozzle 38 at its rear end through which the air from the by-pass path 16 and the hot gases from the turbine assembly discharge into the surrounding atmosphere whereby the engine is provided with forward propulsive thrust.

For increasing the thrust output of the engine 10, provision is made for afterburning in the outlet duct 36. For this purpose fuel nozzles 40 are provided for introducing fuel into the exhaust duct 36 upstream of flameholder apparatus 42 in said duct for combustion therein downstream of said flameholder apparatus. Thus the portion of the space inside the duct 36 downstream of the flameholder apparatus 42 forms the afterburner combustion chamber 44.

As stated, the air in the annular path 16 for the by-pass air and the annular path for the turbine motive fluid exhaust both discharge into the outlet duct 36. A centerbody 46 extends downstream from the turbine 32 so that the upstream section 48 of the outlet duct 36 is annular. For efficient combustion in the afterburner combustion chamber 44, the by-pass air and turbine exhaust gases should be substantially completely mixed upstream of the flameholder apparatus 42. The apparatus for causing rapid mixing of these gases comprises a flow divider or distributor member 50 disposed between the downstream ends of said two annular fluid paths and the annular outlet duct 48.

The flow divider member 50 and the adjacent portion of the engine 10 are best seen in FIGS. 2–8 and reference is now made particularly to these figures. As already stated the inner cylindrical shell 14 separates the annular by-pass air path 16 from the annular flow path for the motive fluid of the turbine 32. The flow divider or distributor member 50 has a cylindrical upstream end co-axial with and having substantially the same diameter as the diameter of the adjacent portion of the inner shell 14. As illustrated, the upstream end of the flow dividing member 50 is supported by the struts 52 and the downstream end of the member 50 is supported from the duct 36 by supporting brackets 53.

The flow dividing member 50 has circumferentially-spaced corrugations which run axially from adjacent the upstream end of the member 50 to its downstream end, these corrugations progressively increasing in radial depth to the downstream end of the member 50 whereby the two annular streams of by-pass air and turbine exhaust undergo a gradual transition to a plurality of radial passages at the downstream end of the member 50. At said downstream end certain of the radially inward corrugations 54 have a radial depth such that they extend across substantially the entire radial width of the adacent annular outlet duct 48. Other radially inward corrugations 56 extend radially inwardly only part way across the radial width of the annular outlet 48 and still other radially inward corrugations 58 extend radially inwardly an even shorter radially distance than the corrugations 56 at the downstream end of the member 50, the corrugations 56 extending only about half way across said radial width. The radially outer portion of the corrugations in the flow dividing member 50 all have substantially the same diameter which, at the downstream end of said flow dividing member, is only slightly less than that of the outer boundary 12 of the adjacent portion of the annular outlet 48.

With this construction, the corrugated flow dividing member 50 divides the by-pass air from the annular path 16 into a plurality of circumferentially-spaced passages, those 60, formed by the corrugations 54, extend across substantially the entire radial width of the adjacent annular outlet 48 while others 62 and 64 formed by the corrugations 56 and 58 respectively extend only part way across said width. Similarly, the turbine exhaust flow is divided into a plurality of circumferentially-spaced passages 66. Each turbine exhaust passage 66 is bounded by an adjacent pair of the corrugations 54 and its radial outer portion is split into a pair of portions 68 by a corrugation 56 extending part way radially inwardly between said pair of corrugations 54. Likewise each turbine exhaust passage portion 68 has its radially outer portion further split into a pair of portions 70 by a short corrugation 58 extending radially therein.

This arrangement provides for more passages for both the by-pass air and the turbine exhaust at the radially outer portion of the annular outlet 48 than at the radially inner portion of said outlet. This makes it possible to divide up the annular outlet 48 into a plurality of streams 60, 62, and 64 of by-pass air and streams 66, 68, and 70 of turbine exhaust such that said streams more nearly have substantially the same circumferential width radially across the annular outlet 48. With this arrangement the rate of mixing of the by-pass air and turbine exhaust is more uniform radially across the annular outlet 48 than it would be, for example, if each corrugation in the member 50 extended across the annular outlet 48 to the same extent.

To further minimize differences in the circumferential width of the by-pass air and turbine exhaust passages radially across the annular outlet 48, each corrugation 54 and 56 widens slightly circumferentially just radially inwardly of the corrugations 58 as indicated by shoulders 74 and each corrugation 54 also widens slightly circumferentially just radially inwardly of the corrugations 56 as indicated by shoulders 76. Inwardly of the shoulders 74 and 76 the associated corrugations taper slightly in circumferential width toward their radially inner ends.

The corrugations of the flow dividing member 50 do not extend entirely to the radially inner and outer boundaries of the annular outlet 48. This leaves a thin annular layer 80 of relatively cool by-pass air at the radially outer wall of the annular outlet 48 to help cool said wall. In addition a core 82 of the relatively hot turbine exhaust gases is left at the center of the annular outlet 48 and the outlet duct 36. This core of relatively hot gas helps to promote ignition in the afterburner 44.

A plurality of guide vanes 84, 86, and 88 are provided to distribute the by-pass air flow substantially uniformly radially across the annular outlet 48. As illustrated, the upstream ends of these guide vanes are annular and their downstream ends have finger-like extensions disposed in the by-pass air passages 60, 62, and 64 to distribute the air flow radially across these passages. Said finger-like guide vane extensions in the by-pass air passages 60, 62, and 64 are designated by the same reference numerals as their respective guide vanes but with a subscript *a* for the passages 60, a subscript *b* for the passages 62 and a subscript *c* for the passages 64. For the purpose of properyl distributing the by-pass air flow radially across the passages 60, 62, and 64, the radial positions of each of the guide vane finger-like extensions varies in accordance with the radial depth of said passages. For example, of the finger-like extensions 84*a*, 84*b*, and 84*c* of the guide vane 84, the extensions 84*a* bend radially inwardly to the greatest extent while the extensions 84*c* bend radially inwardly the least.

The guide vanes 84, 86, and 88 and their finger-like extensions are secured, as by brazing to the walls of the corrugations 54, 56, and 58 defining the by-pass air passages 60, 62, and 64 respectively. In this way said guide vanes also add to the rigidity of the flow dividing member 50.

A similar plurality of guide vanes 90 and 92 are provided to distribute the turbine exhaust gases substantially uniformly radially across the annular outlet 48. As in the case of the by-pass air guide vanes, the guide vanes 90 and 92 have finger-like extensions disposed in the portions 68 and 70 of the turbine exhaust passages 66. Unlike the by-pass air passages, the turbine exhaust passages 66 all have the same radial depth so that the finger-like extensions of the guide vane 90 all bend radially outwardly to the same extent as do the extensions of the guide vane 92.

In FIGS. 2–8, the flow dividing member 50 has three types of radially inward corrugations 54, 56, and 58 of different radial depth so as to minimize variations in the circumferential width of the by-pass air and turbine exhaust streams radially across the outlet 48. Such variations could be further minimized by increasing the number of different radially inward corrugations. Also the rate of mixing of the two streams downstream of the flow divider member can be increased by increasing the number of corrugations in the flow divider member so as to decrease the circumferential width of the individual by-pass air and turbine exhaust streams. However, any such increase in the complexity of the flow divider member increases its frictional resistance to flow therethrough. A less complex flow-divider embodying the invention and having but two types of radially-inward corrugations is illustrated in FIG. 9.

For ease of understanding the parts of FIG. 9 have been designated by the same but primed reference numerals as the corresponding parts of FIGS. 2–8.

In FIG. 9, the flow divider member 50′ is illustrated as having corrugations 54′ extending radially inwardly across substantially the entire radial width of the adjacent annular portion of the outlet duct 36′ and having shorter corrugations 58′ which extend radially inwardly only about half way across said radial width. The intermediate radial depth corrugations 56 of FIGS. 2–8 have been eliminated in FIG. 9. The structure of FIG. 9 is also simplified to the extent that its corrugations 54′ do not have a stepped or shouldered construction as do the corrugations 54 of FIGS. 2–8. As in FIGS. 2–8, guide vanes 86′, 88′, 90′, and 92′ are provided to properly distribute the by-pass air and turbine exhaust radially across their respective passages.

While we have described our invention in detail in its present preferred embodiment, it will be obvious to those skilled in the art, after understanding our invention, that various changes and modifications may be made therein without departing from the spirit or scope thereof. We aim in the appended claims to cover all such modifications.

We claim as our invention:

1. Apparatus for mixing two fluids; said apparatus comprising first and second annular fluid passageways having a common cylindrical wall structure separating the two passageways; a third annular fluid passageway co-axial with said first and second annular passageways and into which fluid from said first and second passageways is to discharge and mix; flow dividing means disposed between said first and second passageways and said third passageway; said flow dividing means comprising an annular wall member having a cylindrical upstream end forming a continuation of said common cylindrical wall structure, said annular wall member having a plurality of circumferentially-spaced corrugations running axially from adjacent its upstream end to its downstream end with the radial depth of said corrugations progressively increasing to-

ward the downstream end of said wall member, certain of the radially-inward corrugations having a radial depth which is substantially less than that of other radially inward corrugations.

2. The combination recited in claim 1 in which all of said corrugations terminate short of the adjacent inner and outer walls of said third annular passageway at the downstream end of said member.

3. Apparatus for mixing two fluids; said apparatus comprising first and second annular fluid passageways having a common cylindrical wall structure separating the two passageways; a third annular fluid passageway co-axial with said first and second annular passageways and into which fluid from said first and second passageways is to discharge and mix; flow dividing means disposed between said first and second passageways and said third passageway; said flow dividing means comprising an annular wall member having a cylindrical upstream end forming a continuation of said common cylindrical wall structure, said annular wall member having a plurality of circumferentially-spaced corrugations running axially from adjacent its upstream end to its downstream end with the radial depth of said corrugations progressively increasing toward the downstream end of said wall member, at the downstream end of said member certain of the radially-inward corrugations extending radially inwardly only approximately half the radial width of said third passageway while other of said radially-inward corrugations extend radially inwardly substantially across said radial width.

4. Apparatus for mixing two fluids; said apparatus comprising first and second annular fluid passageways having a common cylindrical wall structure separating the two passageways; a third annular fluid passageway coaxial with said first and second annular passageways and into which fluid from said first and second passageways is to discharge and mix; flow dividing means disposed between said first and second passageways and said third passageway; said flow dividing means comprising an annular wall member having a cylindrical upstream end forming a continuation of said common cylindrical wall structure, said annular wall member having a plurality of circumferentially-spaced corrugations running axially from adjacent its upstream end to its downstream end with the radial depth of said corrugations progressively increasing toward the downstream end of said wall member, at the downstream end of said member certain of the radially-inward corrugations extending radially inwardly only approximately half the radial width of said third passageway while other of said radially-inward corrugations extend radially inwardly substantially across said radial width and still other of said corrugations extend radially inwardly an intermediate distance.

5. The combination recited in claim 1 and including at least one guide vane member for each of said first and second passageways for distributing their respective fluids radially across the passages formed for each said fluid by said corrugations, each said guide vane member having an annular upstream portion disposed in the flow path of its passageway and having finger-like extensions extending downstream from said annular portion into its associated passages formed by said corrugations.

6. The combination recited in claim 1 and including at least one guide vane member for each of said first and second passageways for distributing their respective fluids radially across the passages formed for each said fluid by said corrugations, each said guide vane member having an annular upstream portion disposed in the flow path of its passageway and having finger-like extensions extending downstream from said annular portion into its associated passages formed by said corrugations, the downstream ends of the finger-like extensions extending into the passages formed by the radially inward corrugations of relatively short radial depth being disposed radially outwardly of the ends of the finger-like extensions from the same guide member but extending into the passages formed by radially inward corrugations of relatively long radial depth.

References Cited in the file of this patent

UNITED STATES PATENTS

1,767,305	Musall	June 24, 1930
2,588,532	Johnson	Mar. 11, 1952
2,647,369	Leduc	Aug. 4, 1953
2,674,264	Nicholas	Apr. 6, 1954
2,704,440	Nicholson	Mar. 22, 1955
2,794,447	Spitz	June 4, 1957
2,875,576	Endres	Mar. 3, 1959

FOREIGN PATENTS

997,262	France	Sept. 12, 1951

OTHER REFERENCES

Flight (British Periodical), vol. 72, p. 567, October 11, 1957.