United States Patent

Lemmerman

[15] **3,684,054**

[45] **Aug. 15, 1972**

[54] **JET ENGINE EXHAUST AUGMENTATION UNIT**

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[52] **U.S. Cl.** .....**181/33 HC,** 60/39.5
[51] **Int. Cl.** **F01n 33/04,** B64d 33/06
[58] **Field of Search** ...60/264, 39.5, 310; 181/33 HC, 181/33 HB

[56] **References Cited**

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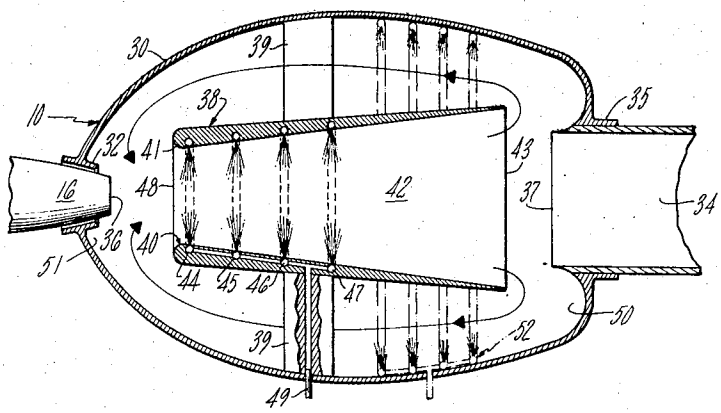
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Primary Examiner—Douglas Hart
Attorney—Prutzman, Hayes, Kalb & Chilton

[57] **ABSTRACT**

A turbojet engine exhaust augmentation unit comprising an elongated nozzle for receiving the turbojet engine exhaust, a water injection system for injecting water into the engine exhaust for cooling the exhaust, an enlarged rear discharge conduit for discharging the cooled engine exhaust from the augmentation unit and an elongated shroud having a forward collar for close coupling the augmentation unit to the turbojet engine tail pipe and operable for returning a portion of the nozzle exhaust from the nozzle outlet to the nozzle inlet for augmentation of the jet exhaust.

16 Claims, No Drawings



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SHEET 1 OF 2

FIG. 1

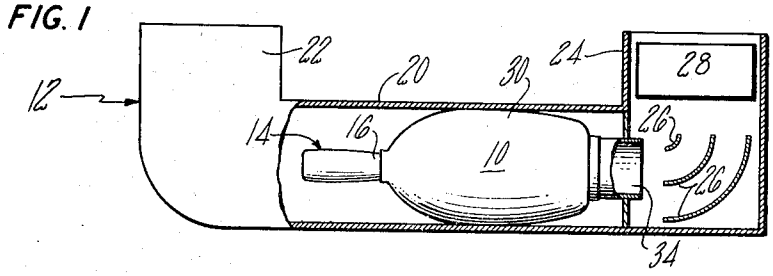


FIG. 2

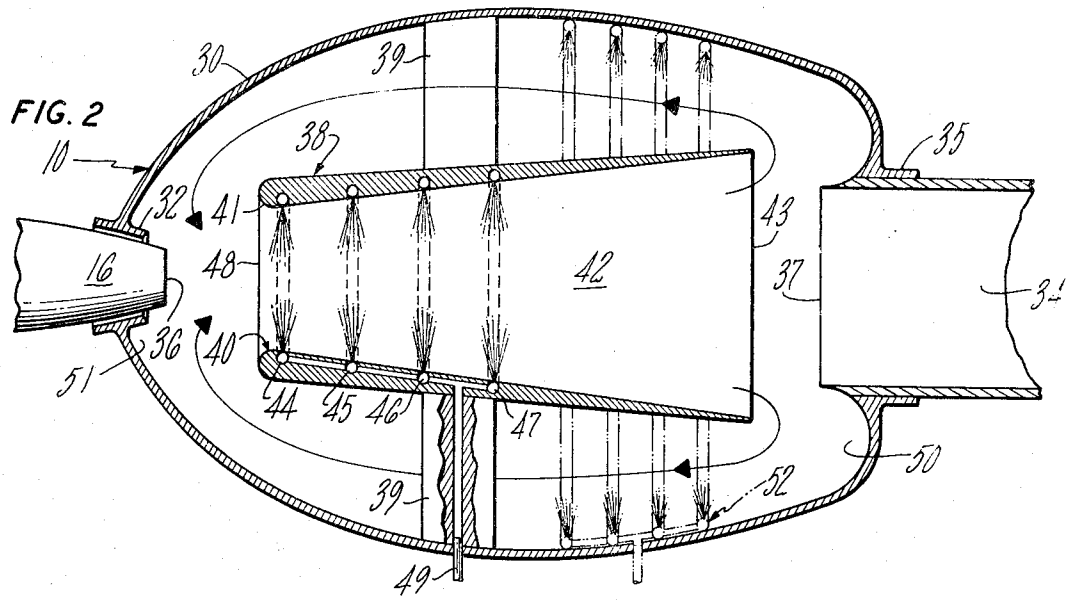
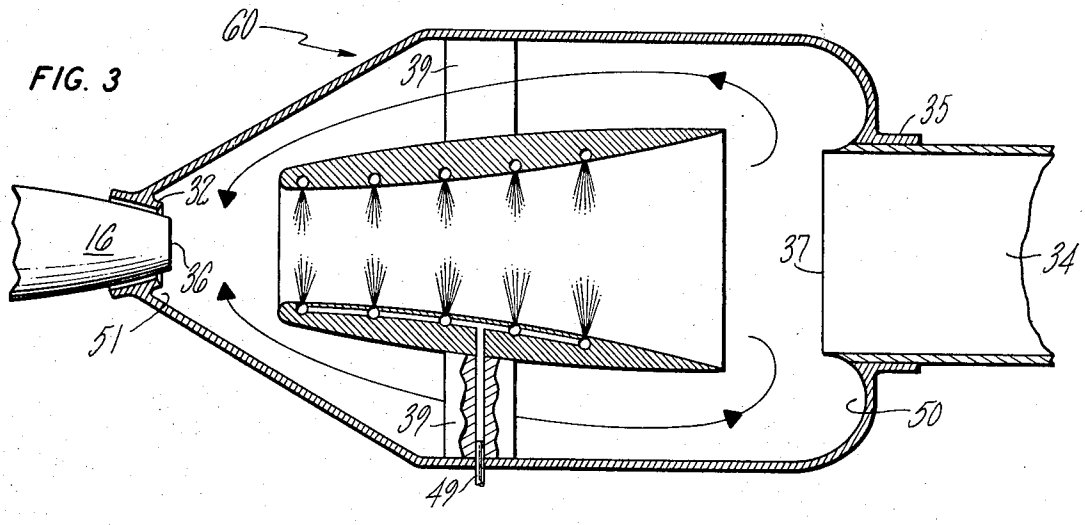


FIG. 3



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FIG. 4

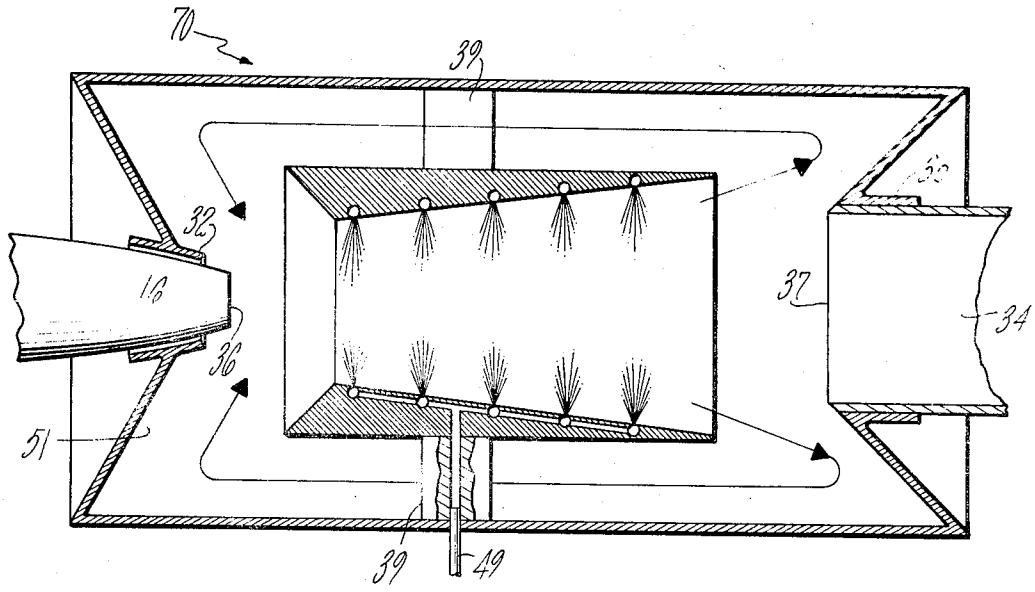
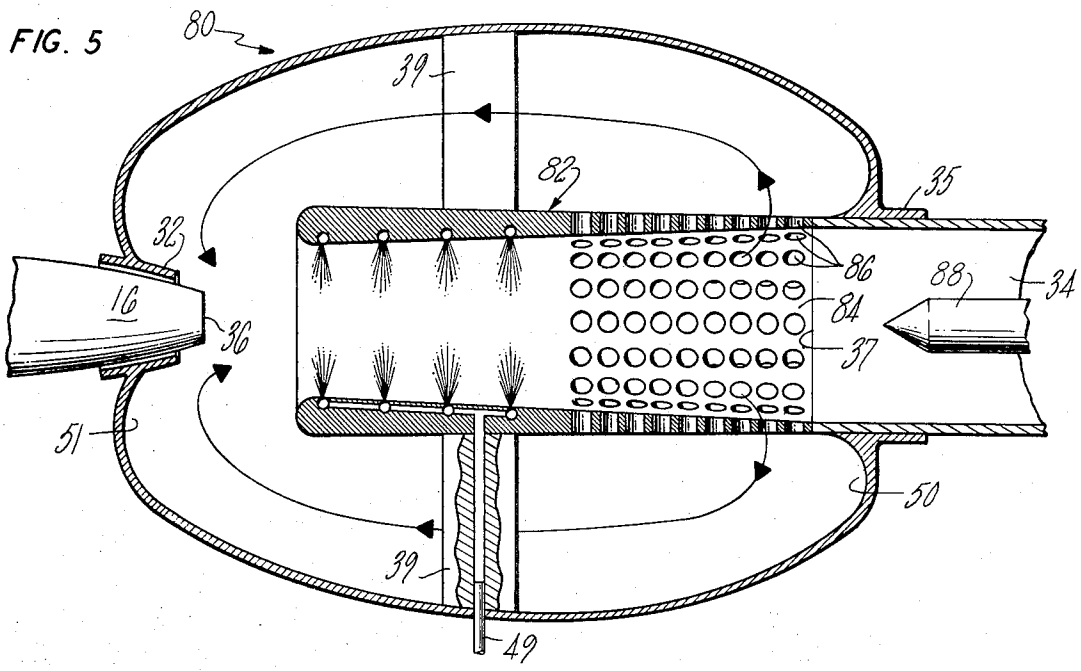

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FIG. 5


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JET ENGINE EXHAUST AUGMENTATION UNIT

BRIEF SUMMARY OF THE INVENTION

The present invention relates to a new and improved jet engine exhaust augmentation unit having notable utility in turbojet engine test cells for attenuating the engine exhaust temperature and noise.

Heretofore it has been the practice in the operation of turbojet engine test cells to provide for the aspiration of a large amount of secondary or augmentation air into the jet engine exhaust to reduce the engine exhaust temperature (from for example in excess of 1,250° F during normal military engine operation and in excess of 3,400° F during afterburner operation) to approximately 500° F to prevent damage to the engine test cell and the exhaust silencing system. In such prior augmentation systems it was customary to employ a mass flow rate of secondary air substantially greater than and in any event not less than the mass flow rate of the jet engine exhaust to avoid unstable engine operation and engine overheating. In accordance with the present invention the mass flow rate of secondary air is substantially reduced without causing unstable engine operation or engine overheating and the present invention therefore provides for substantially reducing the total mass flow rate through the engine test cell.

It is a primary aim of the present invention to provide a new and improved turbojet engine exhaust augmentation unit for substantially reducing the secondary air conventionally used for augmenting the engine exhaust and for thereby reducing the required capacity of the jet engine exhaust and intake air handling equipment.

It is another aim of the present invention to provide a new and improved jet engine exhaust augmentation unit which provides for assisting in abating the jet engine exhaust noise.

It is a further aim of the present invention to provide a new and improved jet engine exhaust augmentation unit which facilitates converting jet engine test cells for testing higher thrust jet engines.

It is another aim of the present invention to provide a new and improved jet engine exhaust augmentation unit which facilitates removing pollutants from the jet engine exhaust.

Other objects will be in part obvious and in part pointed out more in detail hereinafter.

A better understanding of the invention will be obtained from the following detailed description and the accompanying drawings of illustrative applications of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. **1** is a generally diagrammatic side elevation view, partly broken away and partly in section, of a turbojet engine test cell employing an embodiment of an exhaust augmentation unit incorporating the present invention;

FIG. **2** is an enlarged generally diagrammatic longitudinal section view, partly broken away and partly in section, showing the exhaust augmentation unit in more detail; and

FIGS. **3–5** are generally diagrammatic longitudinal section views, partly broken away and partly in section, similar to FIG. **2** and showing three additional embodiments of an exhaust augmentation unit incorporating the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings in detail wherein like numerals designate like parts throughout the several figures, and referring particularly to FIGS. **1** and **2**, an embodiment **10** of an exhaust augmentation unit incorporating the present invention is shown employed in a turbojet engine test cell **12** for augmentation of the jet engine exhaust of a turbojet engine **14**. In a conventional manner the test cell **12** comprises an elongated generally rectangular housing **20** for the turbojet engine **14** to be tested, a vertical air inlet stack **22**, and a vertical exhaust stack **24** having vanes **26** for directing the exhaust upwardly through a suitable scrubbing and sound treatment unit **28** provided for reducing noise and removing pollutants from the exhaust.

The exhaust augmentation unit **10** is shown comprising a housing with a generally bullet-shaped shroud **30** having a forward inwardly tapered generally conical collar or coupling **32** for receiving a turbojet engine tail pipe **16** and a rear cylindrical discharge conduit **34** secured to a rear flange **35** of the shroud **30** in alignment with the tail pipe outlet opening **36**. As seen in FIG. **2**, the forward inlet opening **37** of the discharge conduit **34** is substantially larger than the tail pipe outlet opening **36** (e.g., having a diameter more than twice the diameter of the tail pipe outlet opening **36**) and the collar **32** provides for close coupling the jet engine tail pipe **16** to the augmentation unit **10** with, however, suitable spacing between the tail pipe **16** and collar **32** to permit air flow between the collar **32** and tail pipe **16** to cool the tail pipe and provide a small amount of secondary air for augmenting the jet engine exhaust.

An elongated generally cylindrical tube or nozzle **38** is mounted within the housing **30** by vanes **39** intermediate of and coaxially with the jet engine **16** and discharge conduit **34**. The nozzle **38** has a forward throat **40** substantially larger than the tail pipe outlet opening **36**, a forward relatively short convergent nozzle section **41** and a rear relatively long divergent nozzle section **42** with a rear outlet opening **43** slightly larger than the forward inlet opening **37** of the discharge conduit **34**.

The nozzle **38** is provided with a plurality of axially spaced water injection rings or manifolds **44-47** along the divergent nozzle section **42**. Each water injection manifold has a plurality of equiangularly spaced nozzles (which may be formed by apertures in the manifolds) for injecting water into the gas stream passing through the nozzle. The water injection nozzles may be positioned to direct the water radially into the exhaust gas or rearwardly or forwardly thereof as found desirable in accordance with the requirements of each test cell installation. A suitable water conduit **49** (shown extending through one of the nozzle supporting vanes **39**) is provided for supplying water under pressure to the ring manifolds. The mass injection rate of water is preferably controlled to reduce the temperature of the engine exhaust and water mixture in the discharge conduit **34** to approximately 212° F and such that the water constituent in the discharged mixture may be formed in part by water droplets and/or be readily condensed into water droplets for reducing the total volumetric flow rate and for assisting in removing pollutants from the discharged mixture. Accordingly, suitable flow controls (not shown) are preferably pro-

vided for automatically controlling the water injection rate in accordance with the power setting of the jet engine.

The injected water provides for assisting in decreasing the velocity and abating the noise of the jet engine exhaust and the divergent nozzle section **42** is preferably designed for expanding the combined jet exhaust and water vapor (formed by the vaporization of the injected water) with minimum turbulence for assisting in attenuating the exhaust velocity and noise.

The augmentation unit **10** provides for augmentation of the jet engine exhaust by providing for drawing a large volume of secondary fluid into the nozzle inlet opening **48**. The secondary fluid consists of a relatively high percentage (e.g., 95 percent) of the fluid mixture from the rear nozzle outlet opening **43** and a relatively small percentage (e.g., 5percent) of secondary air drawn through the forward coupling **32**. For this purpose the rear nozzle outlet opening **43** is made slightly larger than the discharge conduit inlet opening **37** and the rear end of the shroud **30** is formed to provide a concave annular section or baffle **50** surrounding the discharge conduit **34** for returning a portion of the mixed jet exhaust and water constituents from the rear nozzle outlet opening **43** to the forward nozzle inlet opening. Also the shroud **30** is preferably formed to provide a forward annular baffle **51** forward of the tail pipe outlet opening **36** and contoured to direct the returned jet exhaust and water mixture rearwardly and inwardly for facilitating aspiration of the mixture into the jet exhaust. It is preferred that a sufficient portion of the jet exhaust and water mixture is returned to the nozzle inlet to provide that the total mass flow rate of secondary fluid (including the secondary air) approximately equals and in any event is no less than the mass flow rate of the jet engine exhaust.

An additional or substitute water injection system **52** (shown in broken lines in FIG. **2**) may be provided in the shroud for injecting water into the annular return passage surrounding the nozzle **38** and for thereby adding water to the fluid being recycled to the forward nozzle inlet opening, in which case the recycled fluid would preferably be cooled by the injected water to a temperature at or below **212**°F and with a major portion of the injected water remaining in the liquid state (in the form of water droplets) for subsequent rapid cooling of the jet engine exhaust within the nozzle.

The augmentation unit **10** therefore provides for attenuating the jet engine exhaust temperature and noise without the addition of a substantial amount of secondary air as heretofore believed essential. Accordingly, the mass flow rate through the discharge conduit **34**, exclusive of the injected water which is or may be readily condensed, is substantially less than and no more than approximately half the mass flow rate previously believed to be necessary. The required capacity of the exhaust handling equipment may therefore be substantially less than what was previously required.

Three alternative embodiments **60**, **70**, and **80** of an augmentation unit incorporating the present invention are shown in FIGS. **3–5** respectively. In each of these embodiments a portion of the jet engine exhaust and water mixture is returned from the rear nozzle outlet to the forward nozzle inlet in generally the same manner as the embodiment of FIG. **2**, and the embodiments of FIGS. **3–5** are shown to illustrate alternative shroud and nozzle configurations. In each of these embodiments the nozzle is shown provided with an enlarged forward throat, a relatively long rear divergent nozzle section and a relatively short forward convergent nozzle section and the water injection system is shown provided for injecting water into the divergent section of the nozzle. In FIG. **5** the outlet of the nozzle **82** is provided by a rear outlet opening **84** having the same diameter as the inlet opening **37** of the discharge conduit **34** and a plurality of radial outlet openings **86** provided for returning a portion of the exhaust and water mixture to the forward nozzle inlet opening. Also, a deflector **88** is coaxially mounted within the discharge conduit **34** for assisting in diverting a portion of the exhaust and water mixture out through the nozzle outlet openings **86**.

As will be apparent to persons skilled in the art, various modifications, adaptations and variations of the foregoing specific disclosure can be made without departing from the teachings of the present invention.

I claim:

1. A jet engine exhaust augmentation unit comprising a longitudinally extending augmentation tube having an inlet for receiving the exhaust from a jet engine and an outlet, recycling means for returning a portion of the exhaust from the augmentation tube outlet for reintroduction into the inlet thereof for combination with the jet engine exhaust, and a water injection system for injecting water into the jet engine exhaust for lowering the temperature of the exhaust out of the augmentation tube outlet.

2. A jet engine exhaust augmentation unit according to claim **1** wherein the recycling means comprises a return shroud having a forward coupling for close coupling a jet engine thereto in alignment with the augmentation tube.

3. A jet engine exhaust augmentation unit according to claim **2** wherein the forward coupling provides for introducing secondary augmentation air around the jet engine into the inlet of the augmentation tube.

4. A jet engine exhaust augmentation unit according to claim **1** further comprising secondary air inlet means for introducing secondary air into the inlet of the augmentation tube for combination with the jet engine exhaust.

5. A jet engine exhaust augmentation unit according to claim **4** wherein the total mass flow rate of the additional fluid introduced into the augmentation tube inlet is no less than the mass flow rate of the jet engine exhaust.

6. A jet engine exhaust augmentation unit according to claim **1** further comprising a rear discharge conduit having a forward inlet opening in alignment with the augmentation tube for discharging from the augmentation unit the remainder of the exhaust from the augmentation tube outlet.

7. A jet engine exhaust augmentation unit according to claim **6** wherein the augmentation tube comprises a rear divergent nozzle section with a rear outlet opening in alignment with the discharge conduit inlet opening.

8. A jet engine exhaust augmentation unit according to claim **7** wherein the rear outlet opening of the divergent nozzle section is larger than and is spaced forwardly of the forward inlet opening of the discharge conduit.

9. A jet engine exhaust augmentation unit according to claim 8 wherein the recycling means comprises an annular concave deflector for substantially reversing the flow of said returned portion of the exhaust from the augmentation tube outlet.

10. A jet engine exhaust augmentation unit according to claim 1 wherein the water injection system provides for injecting sufficient water to reduce the temperature of the jet engine exhaust out the augmentation tube outlet to approximately 212° F.

11. A jet engine exhaust augmentation unit according to claim 1 wherein the water injection system provides for injecting water into the augmentation tube for lowering the temperature of the jet engine exhaust.

12. A jet engine exhaust augmentation unit according to claim 1 wherein the water injection system provides for injecting water into said returned portion of the exhaust as it is returned for reintroduction to the tube inlet.

13. A jet engine exhaust augmentation unit according to claim 1 wherein the augmentation tube outlet comprises a plurality of generally radial openings in a rear portion of the augmentation tube.

14. A turbojet engine exhaust augmentation unit for a turbojet engine test cell comprising a housing with an elongated shroud having a forward opening for receiving a turbojet engine and a rear discharge conduit with a forward inlet opening substantially larger than and in alignment with the rear exhaust opening of the turbojet engine, an elongated augmentation nozzle mounted within the shroud intermediate of and in alignment with the turbojet engine and discharge conduit and having a forward inlet opening for receiving the turbojet engine exhaust and a rear divergent nozzle section with a rear outlet opening in alignment with and forwardly of the discharge conduit inlet opening, the augmentation nozzle forming with the elongated shroud a substantially annular recirculating passage around the nozzle for returning a portion of the exhaust from the rear outlet opening of the nozzle to its forward inlet opening, and water injection means for injecting water into the engine exhaust for lowering the temperature of the exhaust out the rear nozzle outlet opening, the augmentation nozzle being dimensioned so that the engine exhaust flow through the nozzle provides for drawing said returned exhaust portion into the nozzle inlet opening for augmentation of the engine exhaust.

15. A method of augmenting jet engine exhaust in a jet engine test cell for reducing the exhaust temperature and noise, comprising the steps of returning a portion of the jet exhaust from a relative downstream point for aspiration into the jet engine exhaust at a relative upstream point for augmentation of the exhaust, and injecting water into the jet exhaust to form an exhaust and water mixture for cooling the exhaust and vaporizing the water at least in part and such that a jet exhaust and water mixture is aspirated into the jet exhaust at said relative upstream point.

16. A method of augmenting jet engine exhaust in a jet engine test cell according to claim 15 further comprising the step of aspirating secondary air into the jet engine exhaust at a mass flow rate substantially less than the mass flow rate of the exhaust and water mixture aspirated into the jet engine exhaust.

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Notice of Adverse Decision in Interference

In Interference No. 98,414 involving Patent No. 3,684,054, R. D. Lemmerman, JET ENGINE EXHAUST AUGMENTATION UNIT, final judgment adverse to the patentee was rendered July 18, 1974, as to claim 3.

[*Official Gazette November 12, 1974.*]

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