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Blackburn et al.

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[45] Date of Patent: *Aug. 25, 1998

[54] **SYSTEM FOR INCREASING THE AERODYNAMIC AND HYDRODYNAMIC EFFICIENCY OF A VEHICLE IN MOTION**

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[*] Notice: The term of this patent shall not extend beyond the expiration date of Pat. No. 5,791,599.

[21] Appl. No.: **625,914**

[22] Filed: **Apr. 1, 1996**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 504,056, Jul. 18, 1995.

[51] **Int. Cl.**[6] **B64C 1/38**

[52] **U.S. Cl.** .... **244/130**; 322/2 A; 244/204; 244/205

[58] **Field of Search** .... 244/158 R, 130, 244/134 R, 134 D, 204, 205, 158 A, 163, 160; 60/39.07; 219/764, 748, 749; 322/2 A, 2 R

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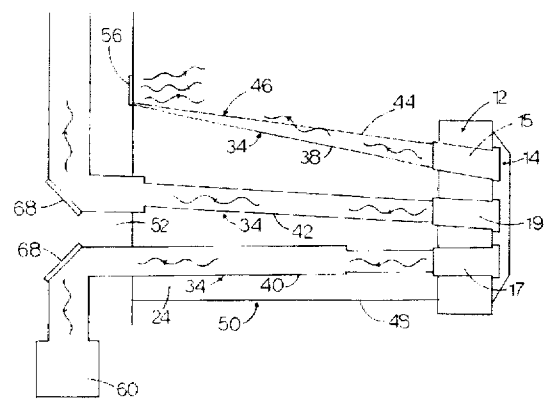
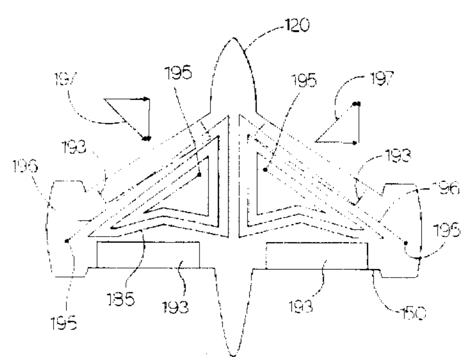
Primary Examiner—Andres Kashnikow
Assistant Examiner—Tien Dinh
Attorney, Agent, or Firm—Chris Papageorge

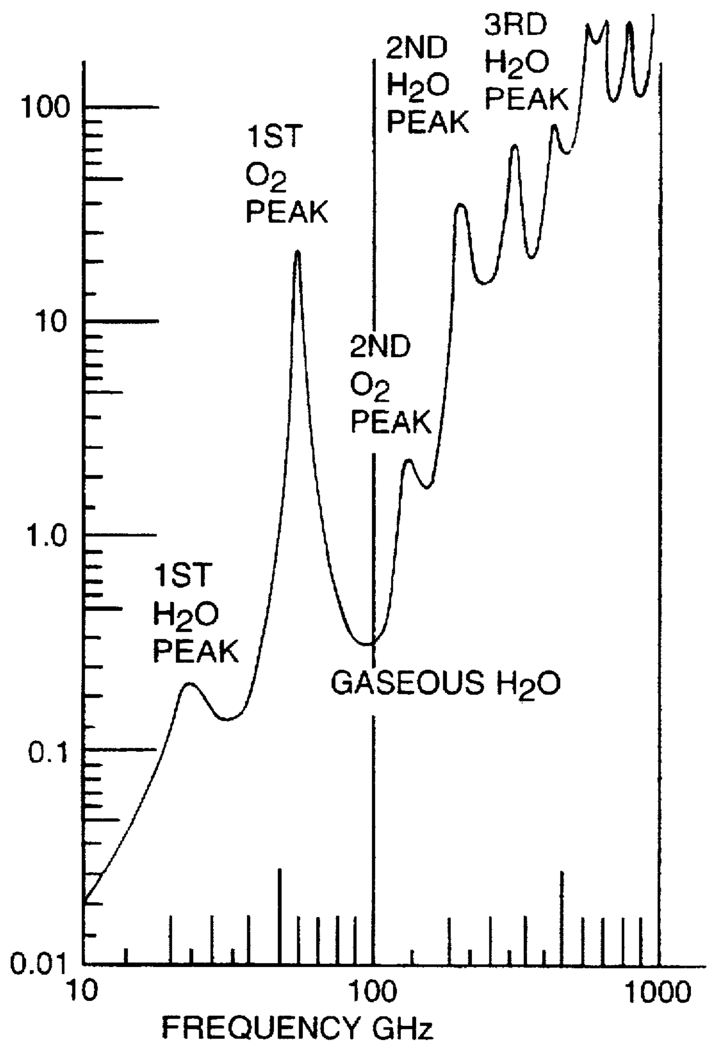
[57] **ABSTRACT**

The system includes radiation generation and transmission components which radiate tuned microwave electromagnetic energy outwardly from a vehicle through an antenna into a fluid medium through which the vehicle is moving. The microwave radiation is at the frequency of harmonic resonance electromagnetic excitation of the molecules of the medium which produces efficient heating and ionizing of the fluid resulting in a reduction of the mass density thereof. This reduction decreases the drag forces acting on the vehicle resulting in a greatly enhanced aerodynamic and/or hydrodynamic efficiency and also decreases the intensity of the shock waves (which often lead to sonic booms). An aircraft's dramatically higher speed in the surrounding rarefied medium can make it appear to be travelling at "supersonic" speeds. The system also includes a set of coiled wires and magnetic plates producing magnetic fields proximal to the vehicle and oriented to deflect heated molecules (ionized by the microwave heating) away from the vehicle thereby preventing or reducing contact of the heated molecules with the vehicle's outer surfaces and heating thereof.

29 Claims, 14 Drawing Sheets



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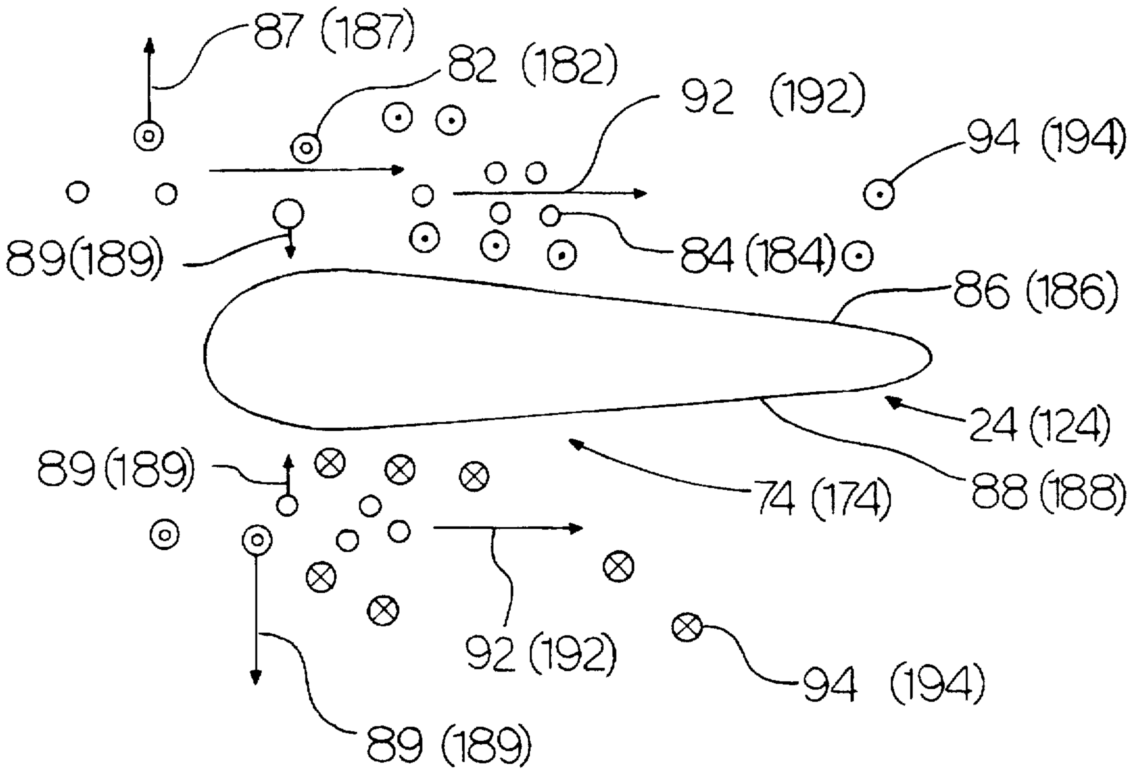
10
1.0
0.1
0.01
10
100
1000
FREQUENCY GHz
1ST H_2O PEAK
1ST O_2 PEAK
2ND O_2 PEAK
2ND H_2O PEAK
3RD H_2O PEAK
GASEOUS H_2O

FIG. 1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82 (182)
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84 (184)
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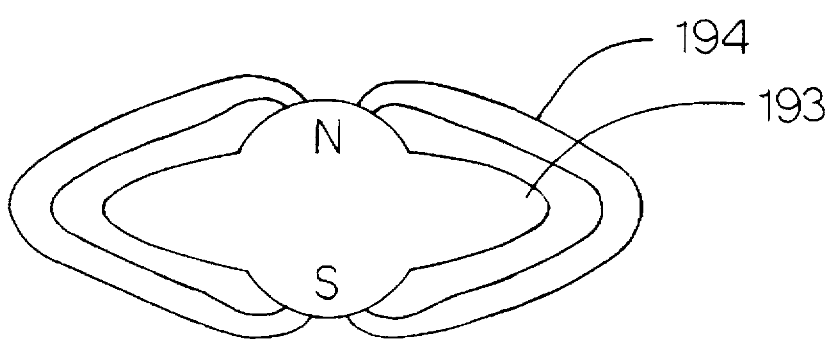
89 (189)

FIG. 2

FIG. 3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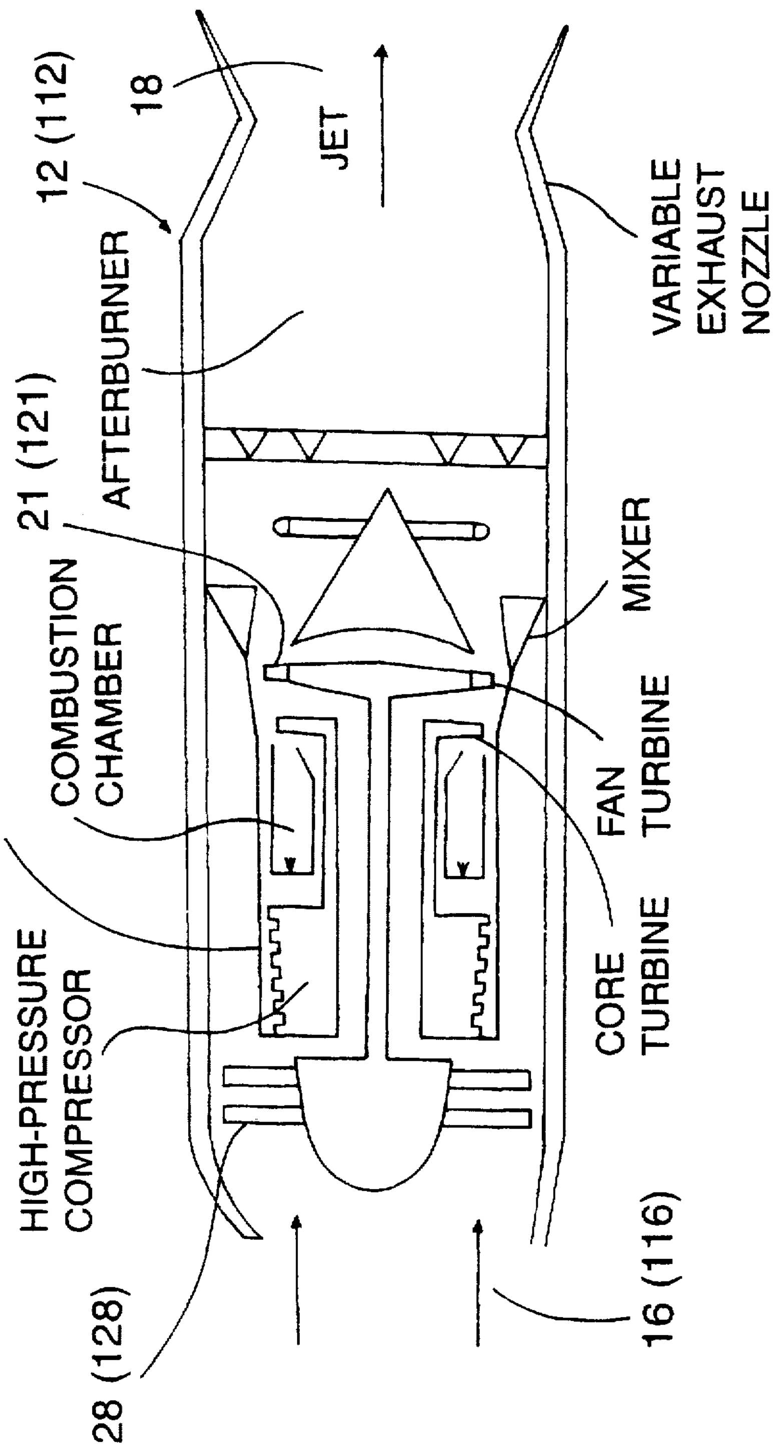
12 (112)
18
JET
VARIABLE
EXHAUST
NOZZLE
AFTERBURNER
21 (121)
MIXER
COMBUSTION
CHAMBER
25 (125)
FAN
TURBINE
CORE
TURBINE
HIGH-PRESSURE
COMPRESSOR
16 (116)
28 (128)

FIG. 4

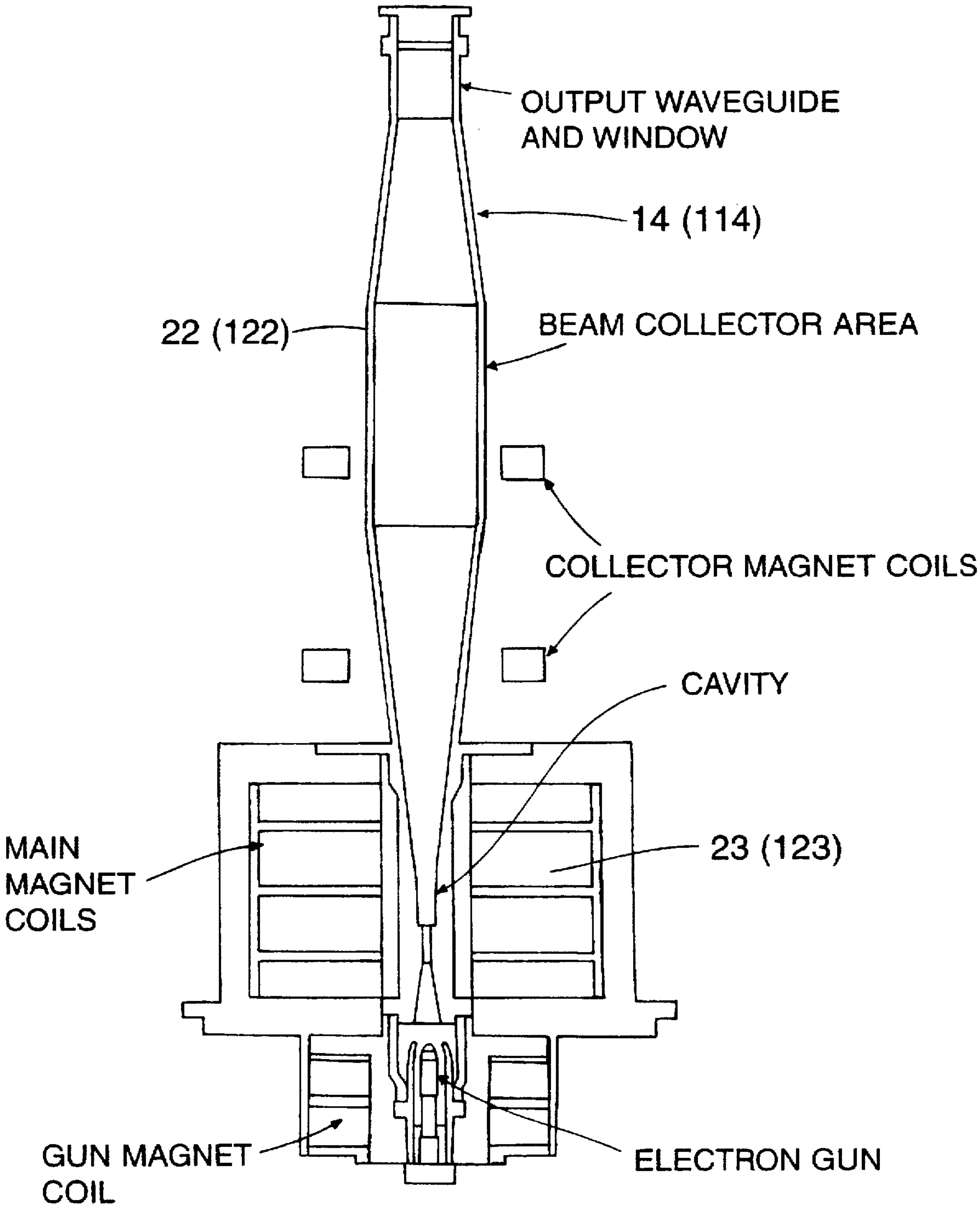
OUTPUT WAVEGUIDE AND WINDOW
14 (114)
22 (122)
BEAM COLLECTOR AREA
COLLECTOR MAGNET COILS
CAVITY
MAIN MAGNET COILS
23 (123)
GUN MAGNET COIL
ELECTRON GUN

FIG. 5

FIG. 6

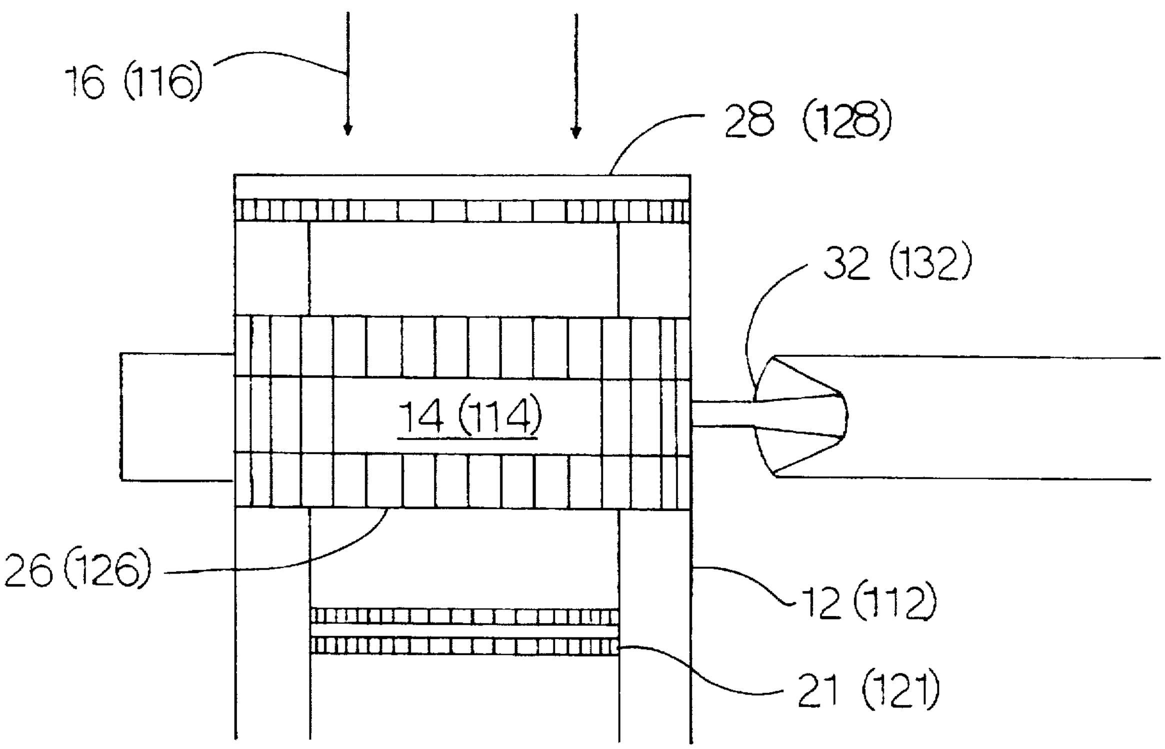

FIG. 7A

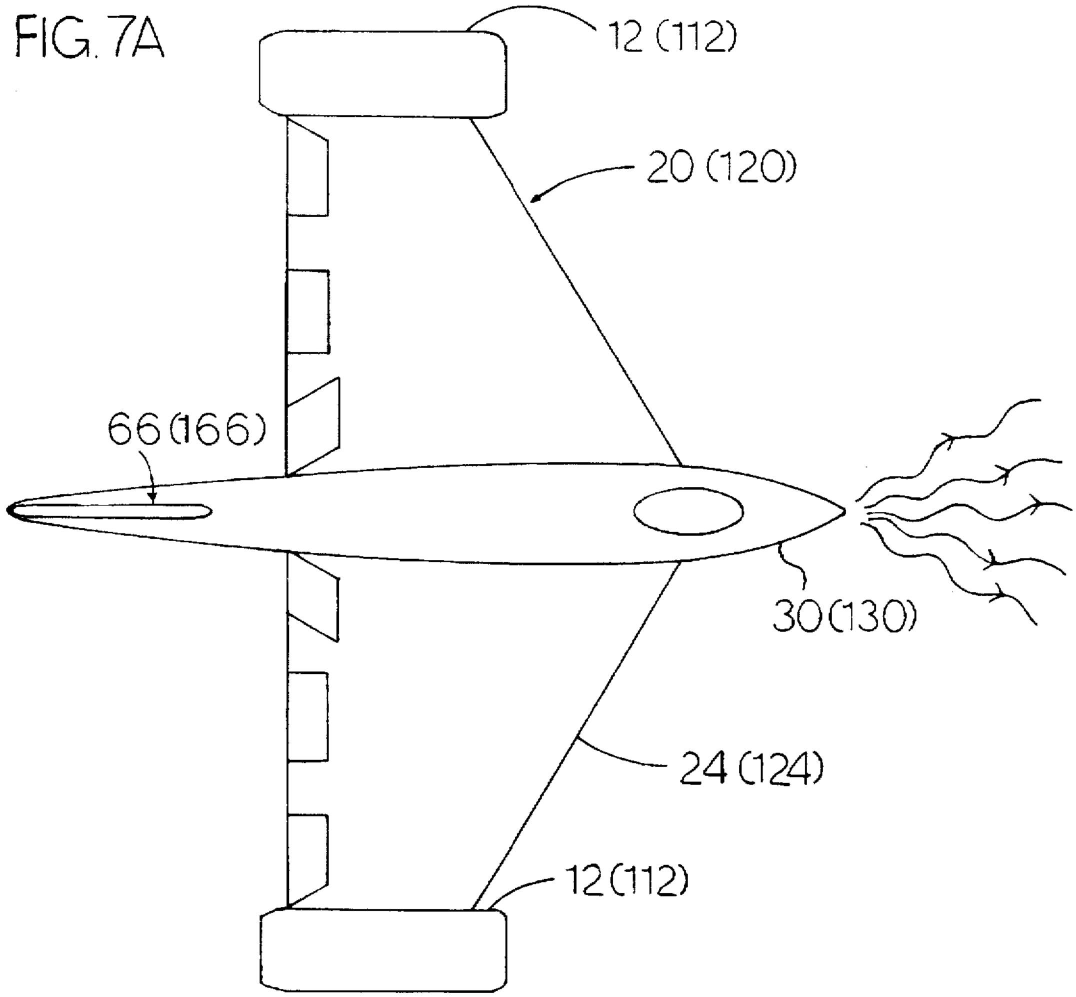
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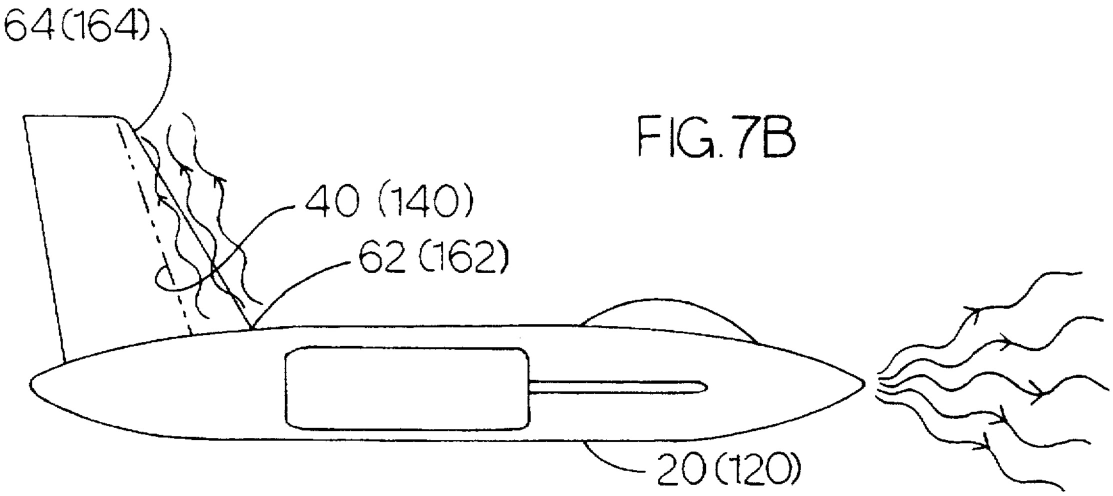
FIG. 7B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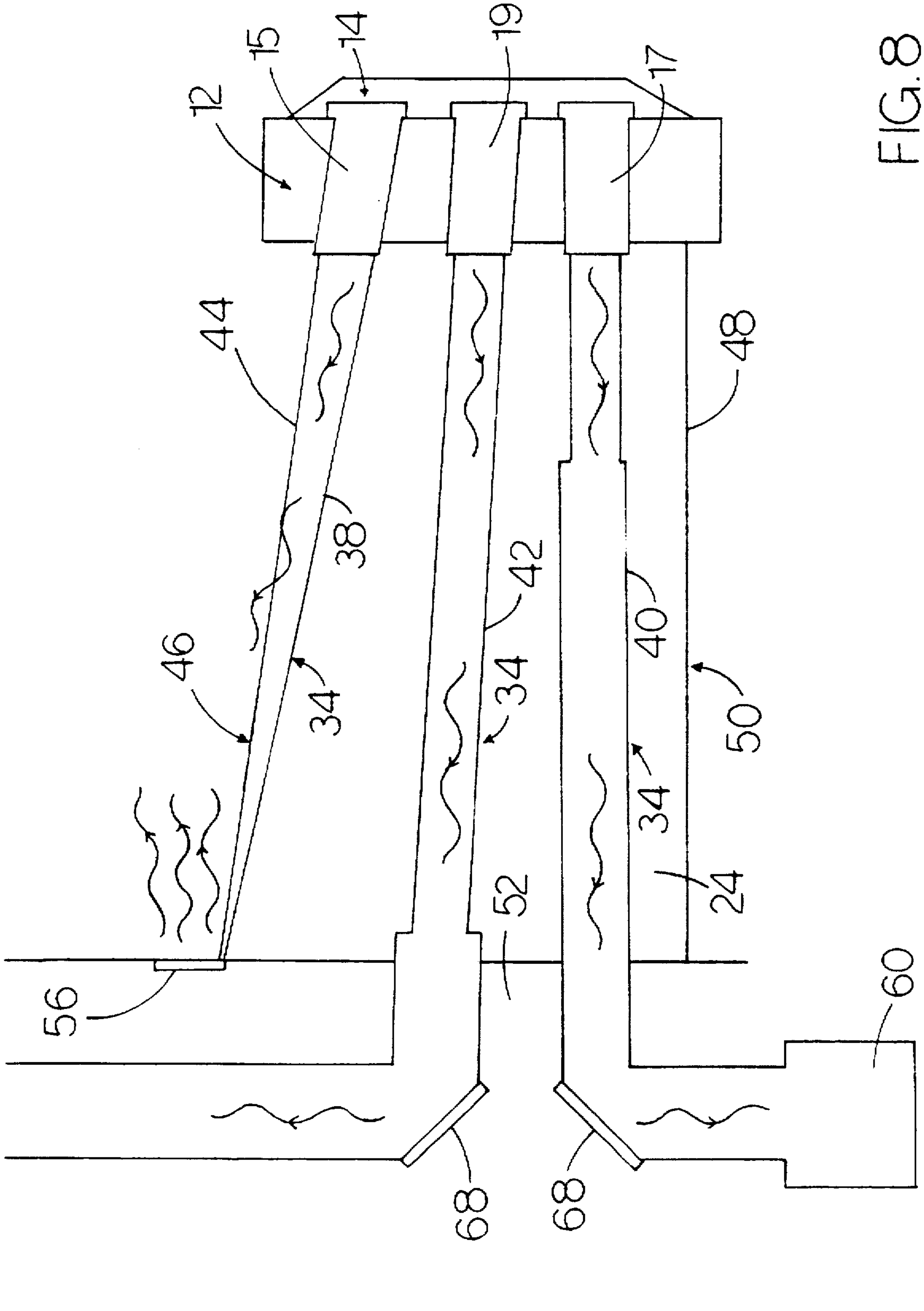


FIG. 8

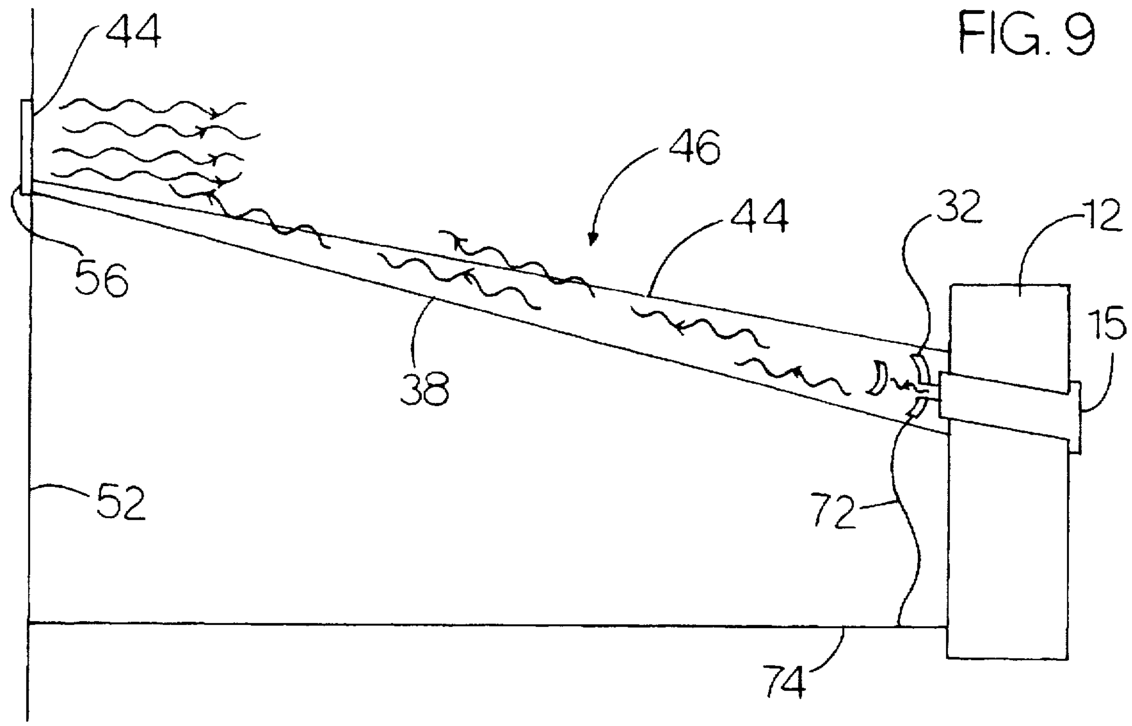


FIG. 9

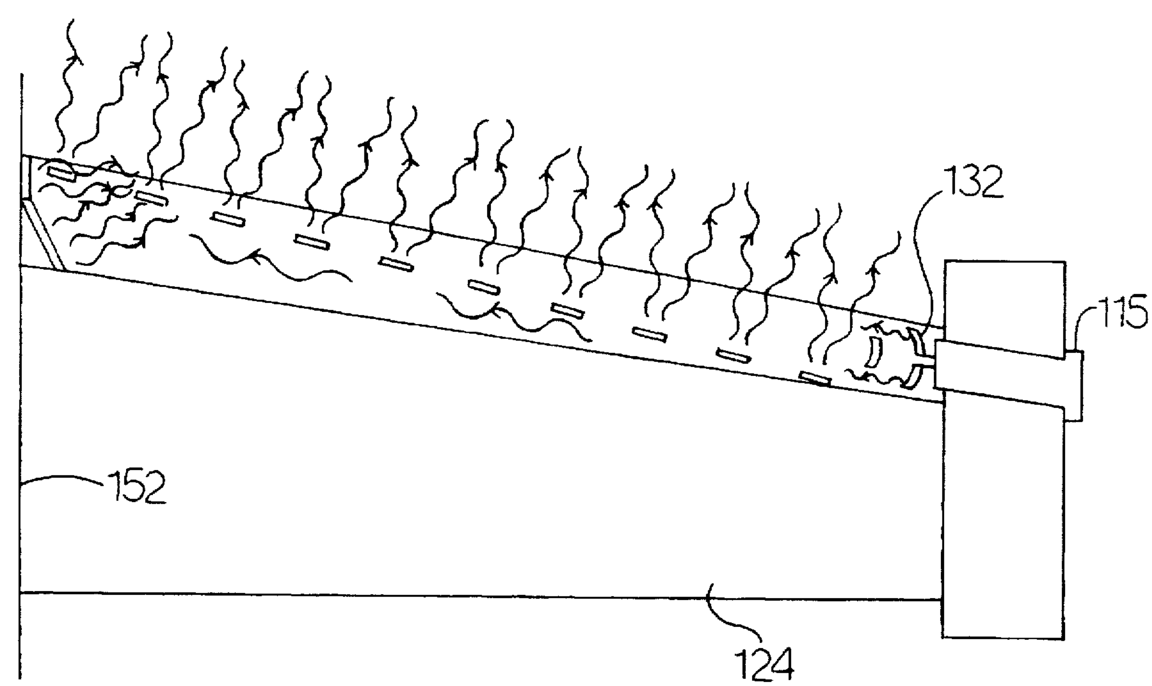


FIG. 15

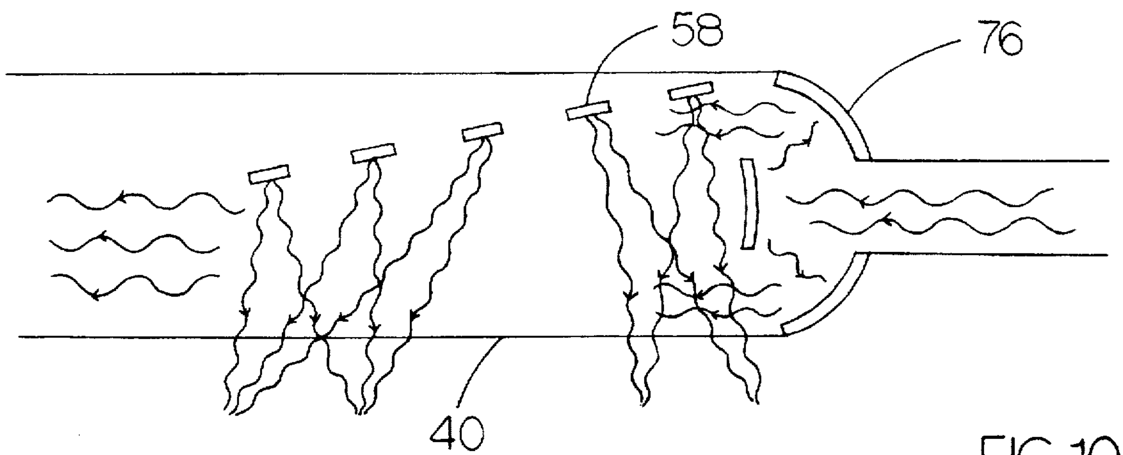


FIG.10

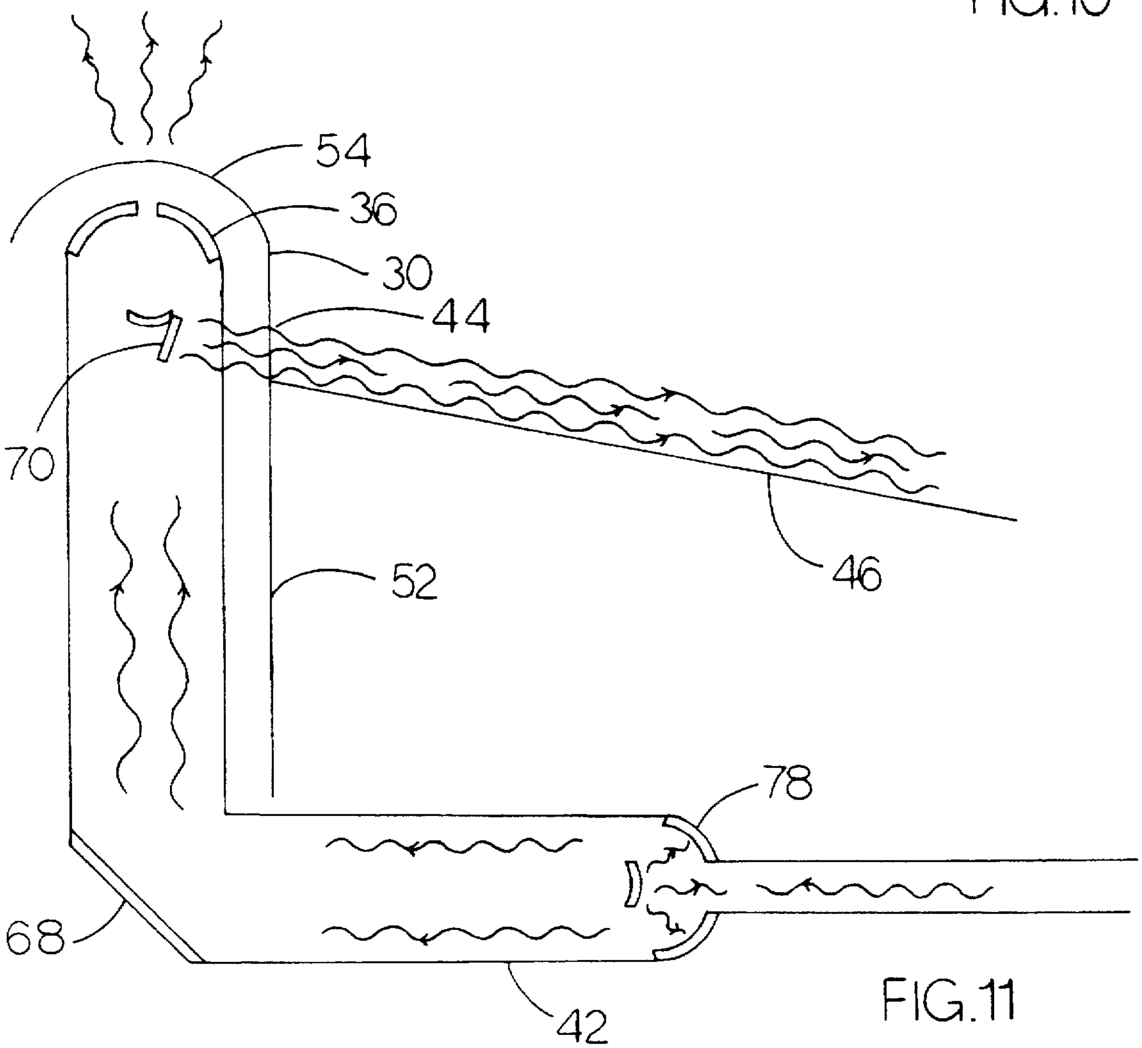
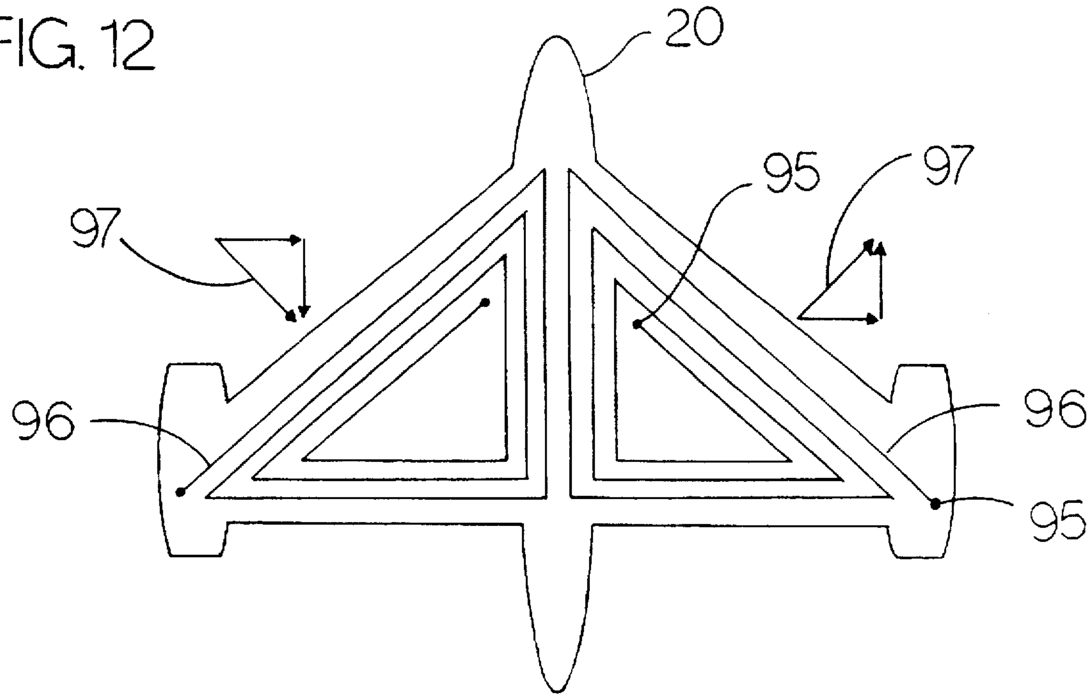


FIG.11

FIG. 12



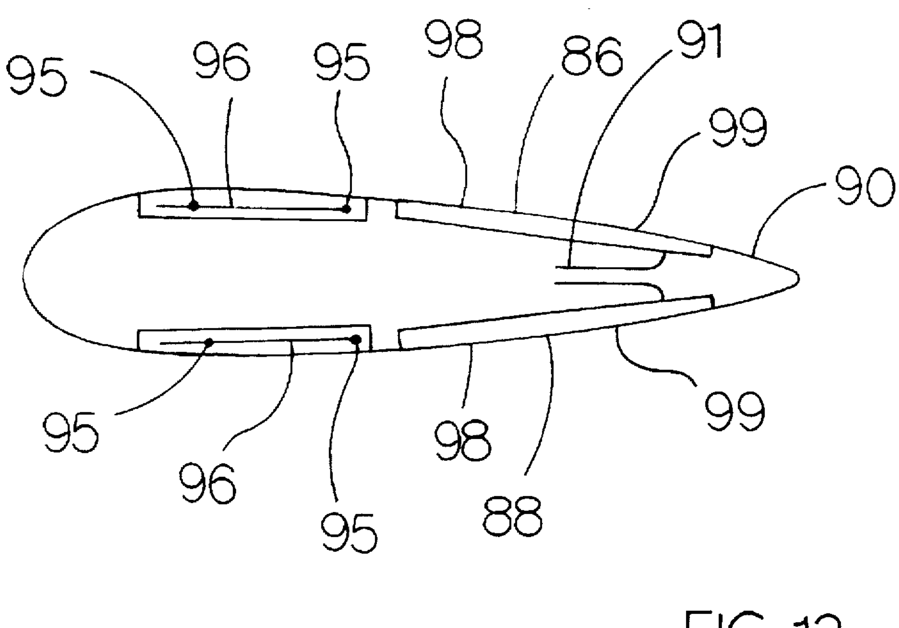


FIG. 13

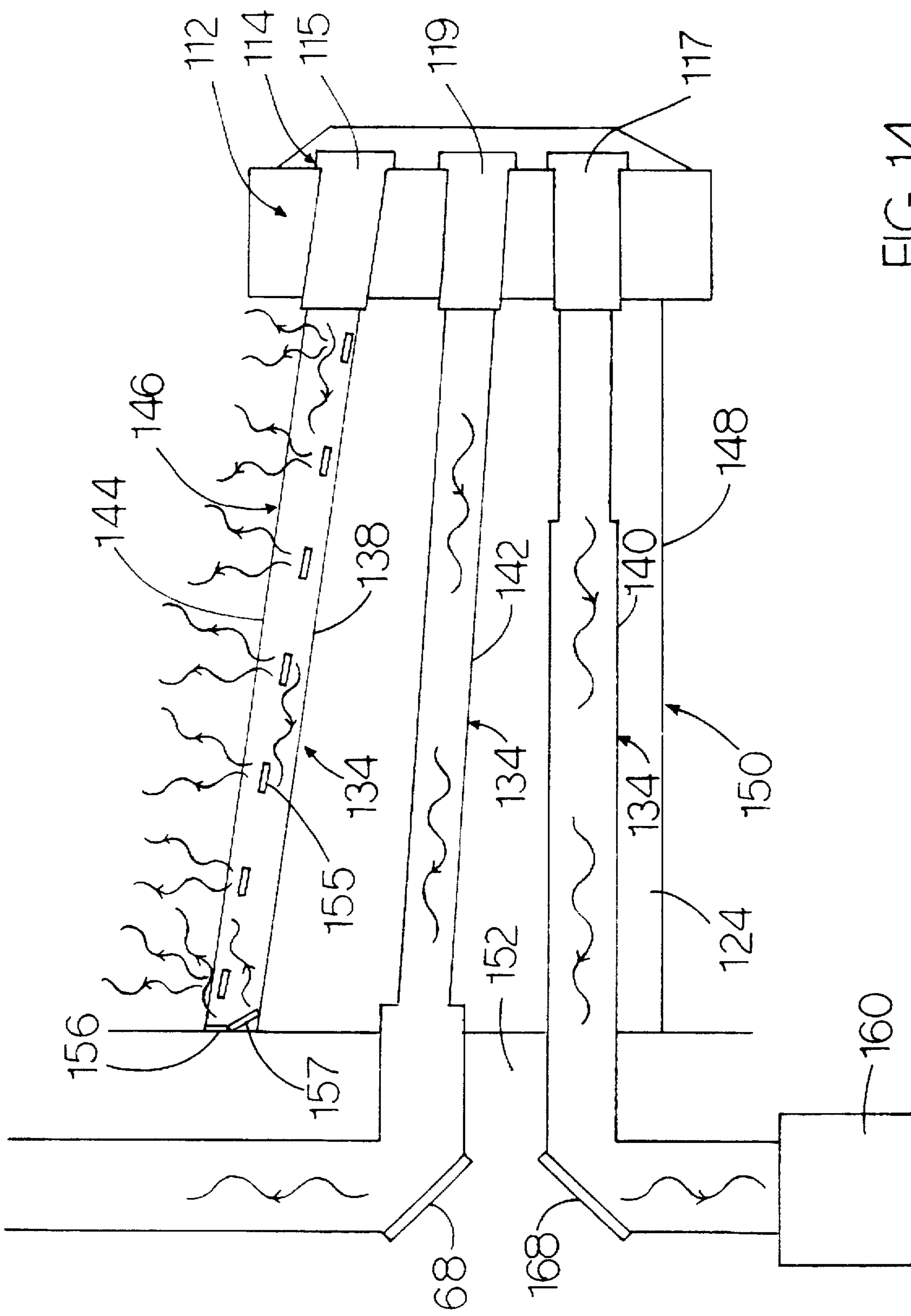

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FIG. 14

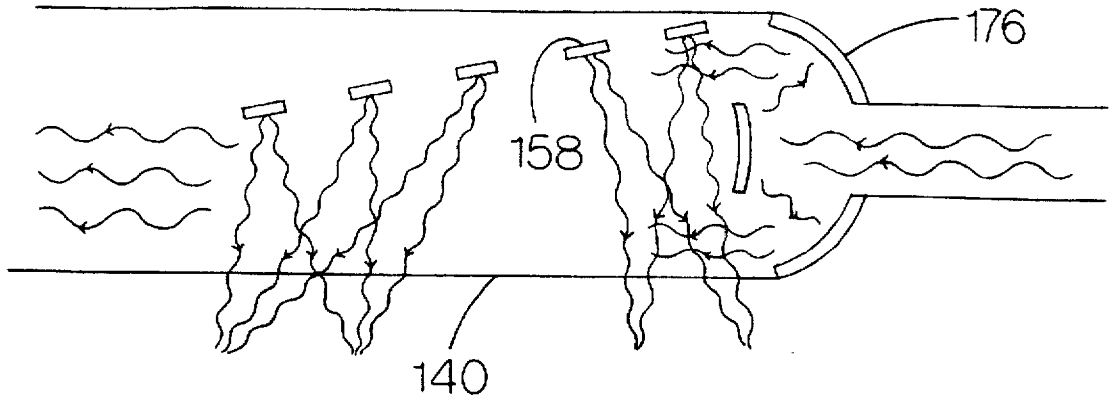


FIG. 16

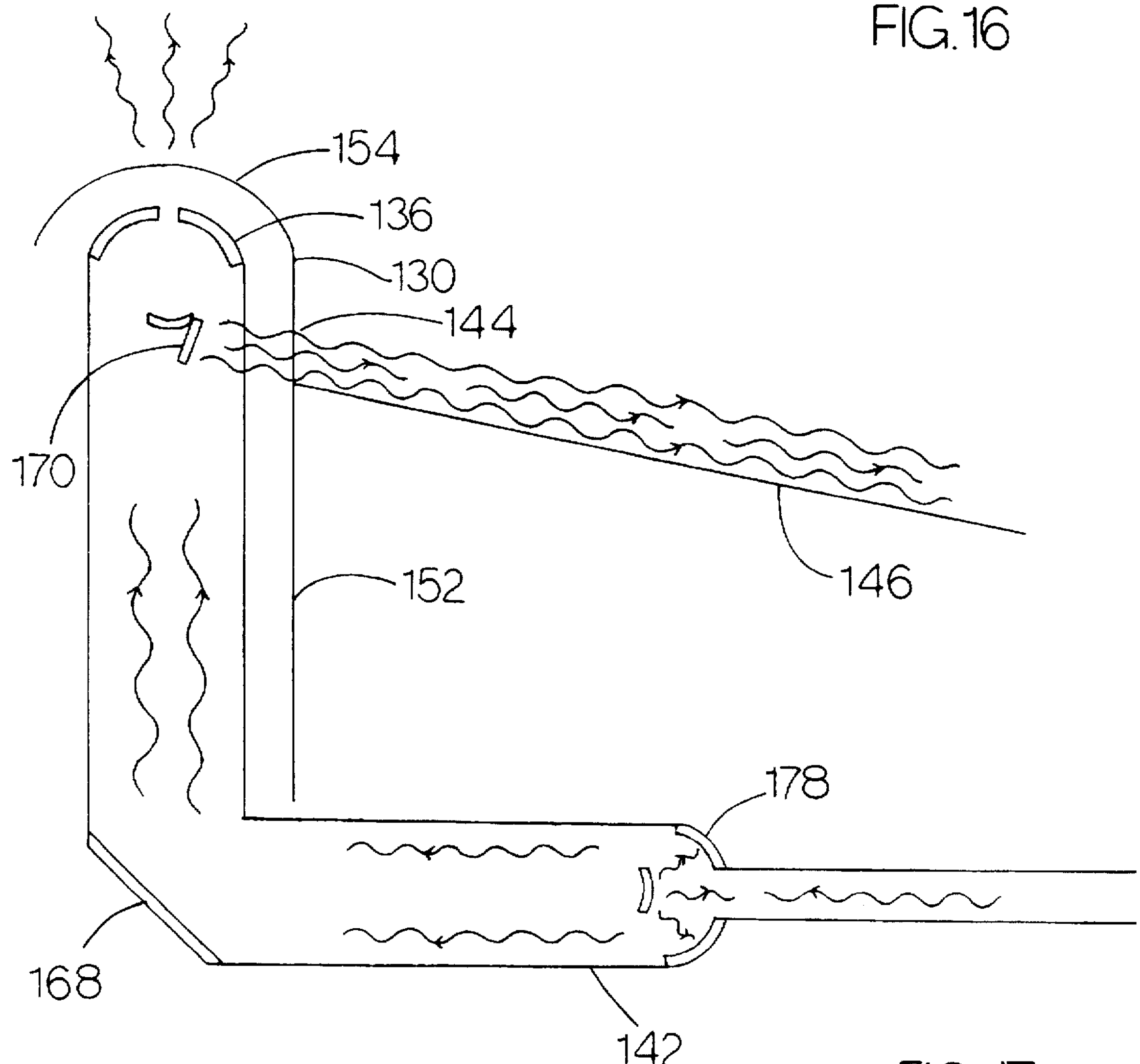


FIG. 17

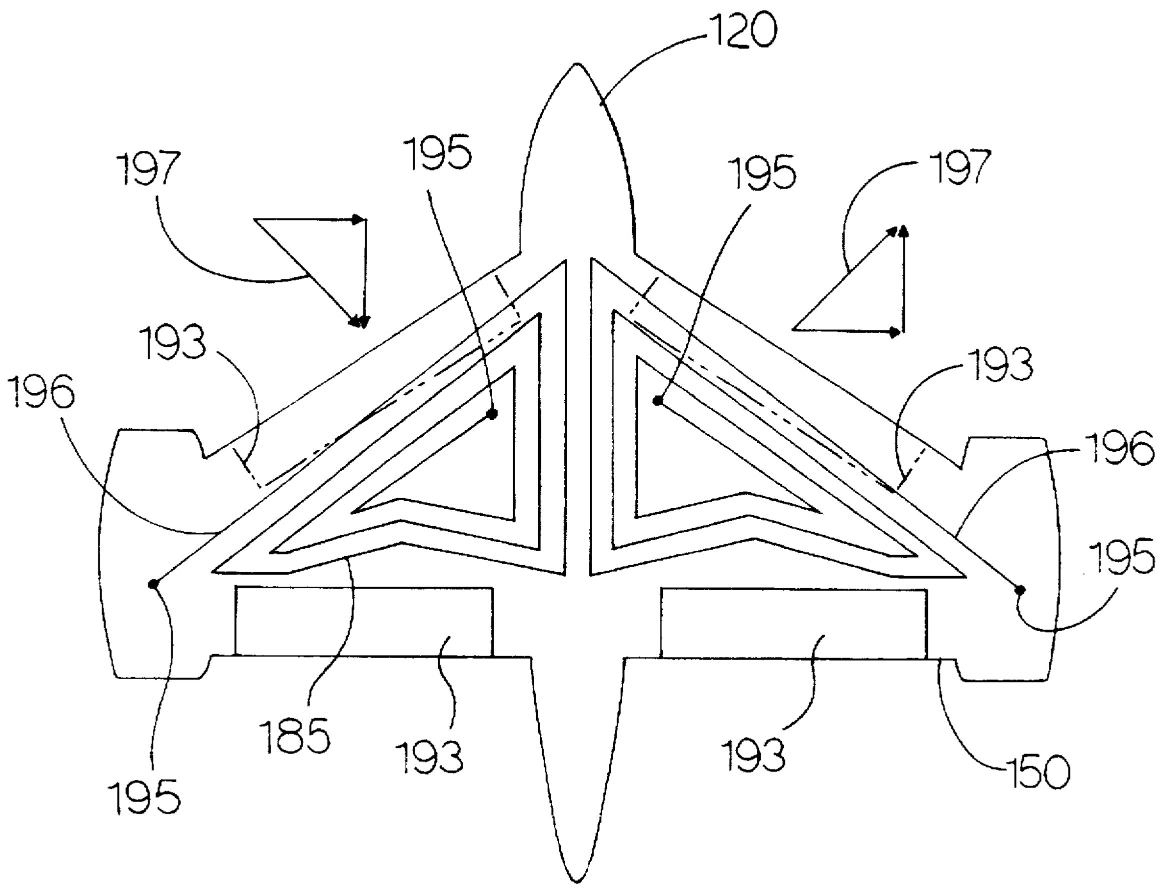


FIG. 18

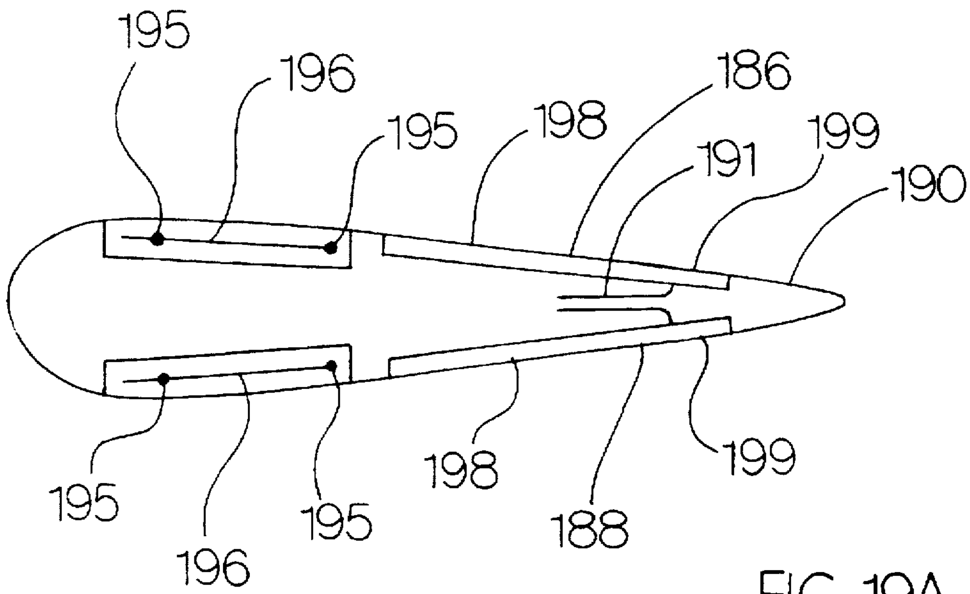
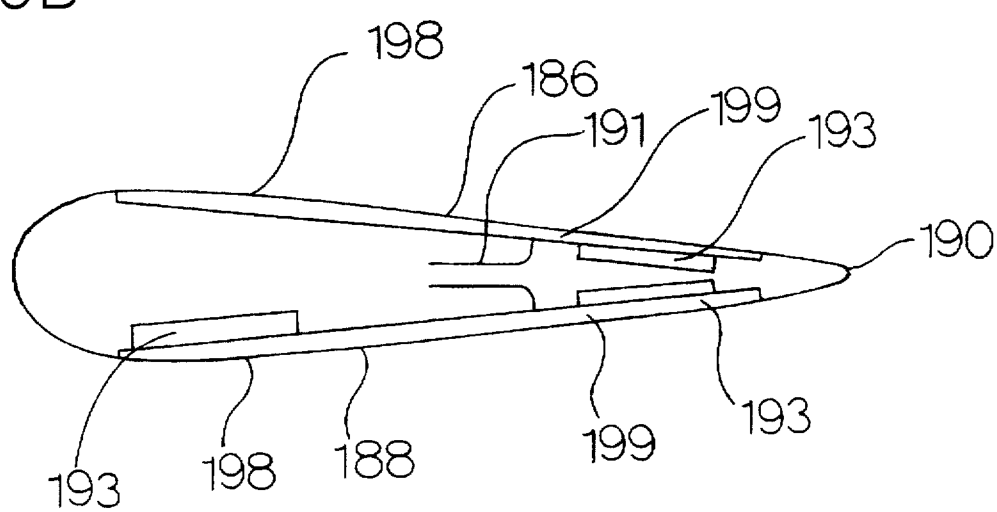


FIG. 19A

FIG. 19B



SYSTEM FOR INCREASING THE AERODYNAMIC AND HYDRODYNAMIC EFFICIENCY OF A VEHICLE IN MOTION

This application is a continuation-in-part of patent application Ser. No. 08/504,056 entitled "A System for Increasing the Aerodynamic and Hydrodynamic Efficiency of a Vehicle in Motion" filed Jul. 18, 1995 by applicants herein, Ronald F. Blackburn and Barry M. Warmkessel.

BACKGROUND OF THE INVENTION

The invention relates generally to systems for facilitating the motion of a vehicle through a fluid medium and, more particularly, to systems for facilitating the motion of aircraft through the atmosphere in order to significantly reduce the amount of energy required to propel the aircraft, signficantly increase the maximum speed of the aircraft and substantially reduce the intensity and incidence of shock waves associated with the motion.

The well known sonic boom is a significant problem presented by aircraft capable of flying at supersonic speeds. The sonic boom is so annoying and so often damaging to homes, buildings and other property that military aircraft have been required to attain supersonic speeds over large bodies of water or sparsely populated areas in order to minimize these undesired effects. With the increasing prevalence and viability of commercial supersonic flight resulting from government research and development efforts and the increasing viability of commercial aircraft designed for speeds well in excess of supersonic speeds, the sonic boom effects have become more problematic.

The sonic waves generated by supersonic flight are also detrimental to the practicality of such supersonic flight because they result in an aerodynamic drag effect which retards the velocity of the aircraft thereby requiring more energy to propel it. For this reason and because frictional forces resisting movement of an aircraft increase with the square of the aircraft's velocity, high velocity aircraft as well as other types of high velocity vehicles typically entail higher fuel expenditures and concomitantly produce higher levels of pollution as well as high consumption of fuel often made from nonrenewable natural resources. This high pollution and high fuel consumption is a serious economic and environmental problem. Solutions to this problem have been sought by designing engines that have higher fuel efficiencies and lower pollutant emissions. These design efforts have successfully produced engines that are very efficient. Unfortunately, the proliferation of motorized vehicles of many sorts has nevertheless resulted in an increase in global pollution and higher energy consumption. In addition, the pollution reduction and energy efficiency augmentation systems for conventional engines have become so effective that further improvements on systems used on conventional engines is not likely to produce substantial improvements. Consequently, many engineers have sought to reduce pollution and increase the energy efficiency of conventional vehicles by seeking to make modifications in other areas.

Ships and submarines are notoriously slow moving. Increases in the cruising speeds of surface ships are probibitively expensive to attain, and this is the reason most commercial shipping operates at a relatively slow speed of approximately twenty knots. Submarines, lacking the bow wave common to surface ships can travel faster, but substantial power sources are needed for a modest advantage over the speeds of surface ships. What's worse, there is tremendous acoustical vibration associated with these high speeds, which causes the submarine to lose its stealthy advantage normally afforded by the ocean's depths. Torpedoes can move faster than submarines, but they consume tremendous amounts of the limited non-nuclear fuels available along with the disadvantage of the accompanying warning from their acoustical signature that the weapon has been fired.

Many have sought solutions to the aerodynamic applications of these problems by developing systems which reduce the mass density of the medium through which a vehicle is moving and thereby reduce the drag forces acting on the vehicle while it is in motion. Some of these systems have specifically sought to reduce the mass density of the atmosphere through which aircraft are traveling and thereby reduce aerodynamic drag acting on the aircraft. This desired goal would not only provide increased fuel efficiency but also enable the aircraft to achieve higher maximum attainable speeds. As an additional benefit, the intensity and incidence of shock waves associated with the aircraft would be reduced resulting in elimination of or reduction of the intensity of a sonic boom otherwise produced when the aircraft attains supersonic speeds.

Some prior art methods and devices for reducing the mass density of the atmosphere through which an aircraft is flying have utilized incendiary compounds to heat the air and thereby reduce the mass density thereof. Two examples of such methods are disclosed in U.S. Pat. No. 4,917,335 to Tidman and U.S. Pat. No. 3,620,484 to Schoppe. The Tidman method essentially generates and maintains combustion of a flammable compound which is ejected from the aircraft directly into the atmosphere immediately in front of the aircraft. The Schoppe method utilizes a mechanical flame thrower to also produce combustion directly in front of the aircraft but additionally uses a blunt nosed body to compress the air prior to the combustion for enhanced efficiency thereof. Thus, in both of these methods, the aircraft consequently travels through a fireball of reduced mass density which reduces aerodynamic drag and the incidence and severity of sonic boom. However, a primary disadvantage of such methods is that the chemical reaction as well as the ejection of the combustible mass may not be fast enough to rarefy the atmosphere in front of an aircraft traveling at supersonic speeds. Another important disadvantage of such methods is that the fireball through which the aircraft is moving transfers a substantial amount of heat directly to the aircraft surfaces resulting in excessive heating of the aircraft; this undesired heating of the aircraft can result in melting, weakening, failure or malfunction under stress of structural components as well as of electronic or other heat sensitive components of the aircraft. In addition, the required speed of combustion may result in generally incomplete combustion and thereby wasting of fuel and production of inordinate amounts of pollutants. Moreover, the requirement of a blunt body precludes the Schoppe system from being used to reduce the density of the atmosphere in front of the entire aircraft or, more specifically, in front of wing leading edges as well as other portions thereof.

Other prior art systems designed to reduce aerodynamic drag and sonic waves rarefy the atmosphere in front of the aircraft by moving air molecules rearwardly from the leading edges of the aircraft. An example of such a system is disclosed in U.S. Pat. No. 3,446,464 to Donald. The Donald apparatus utilizes electrodes placed both at the leading edges and rearward of the leading edges. Different electrical potentials applied to the electrodes produce an electrical field which moves the air molecules rearwardly from the leading edges thereby reducing the buildup of air pressure in front of the leading edges. However, a primary shortcoming of the Donald apparatus is that it does not directly move air molecules which are in front of the leading edges and thus is of limited effectiveness in reducing aerodynamic drag and sonic boom.

Since the 1940's some designers of aircraft have sought to reduce aerodynamic drag by radioactive excitation of the air molecules proximal to or adjacent to the aircraft. Early designs have utilized radioactive coatings on the skins of the aircraft to ionize the air molecules at the boundary layer at the aircraft fluid-solid interface thereby inducing repelling or attractive forces on these ions and/or to induce a vibrational or rotational excited state in the air molecules thereby altering their viscosity. A technologically improved design utilizing such a concept is disclosed in U.S. Pat. No. 3,510,094 to Clark in which the magnitude and number of alpha and beta particle emissions from the radioactive layer on the aircraft skin are controlled. However, a primary disadvantage of these types of designs is that they do not have a high degree of energy efficiency in reducing the density of the air in front of the aircraft where it is most needed because the emissions radiate outwardly in all directions. Moreover, the radioactive emissions can interfere with aircraft computer, radio and radar systems as well as being potentially dangerous to personnel within the aircraft or in the vicinity of the aircraft.

Still other prior art systems utilize laser beam radiation to heat the air passing through the beam and thereby rarefy the air through which the aircraft is moving. An example of such a system is disclosed in U.S. Pat. No. 5,263,661 to Riley. The Riley device uses a laser radiating a beam along the leading edge of an aircraft wing to the tip. The air passing through the beam as the aircraft flies through the atmosphere is heated and rarified thereby compressing more slowly as a result of the aircraft's motion than it normally would and creating a lower mass density thereof which is less favorable to development of a sonic boom. However, a primary disadvantage of such a system is that it has a high power requirement because laser radiation does not efficiently produce a high degree of heat energy in the air molecules. Moreover, as with the Schoppe system, this system also may produce excessive heating of the skin of the aircraft resulting in malfunction or failure of components of the aircraft.

Consequently, what is needed is a system for reducing the mass density of the fluid medium in the path of flight or movement of the aircraft or other type of vehicle as well as adjacent to the skin surfaces thereof in order to maximize reduction of the forces of friction and other drag forces acting on the aircraft during flight or on another type of vehicle during movement through another type of fluid medium. What is also needed is a system for reducing the mass density of the air proximal the aircraft (or of another type of fluid medium proximal another type of vehicle) which is able to provide such reduction of mass density very quickly and with a relatively high degree of energy efficiency. What is also needed is such a system which does not produce excessive heating of the vehicle.

SUMMARY OF THE INVENTION

It is a principal object of the present invention to provide a system for reducing the mass density of the fluid medium in front of a vehicle moving through the medium in order to reduce drag forces and sonic waves produced by the motion.

It is also an object of the present invention to provide a system for reducing the mass density of the fluid medium adjacent to and proximal to lateral and rearward portions of a vehicle moving through a fluid medium in order to reduce drag forces and sonic waves produced by the motion.

It is also an object of the present invention to provide a system for reducing the mass density of the fluid medium through which a vehicle is moving which achieves the mass density reduction quickly and effectively.

It is also an object of the present invention to provide a system for reducing the mass density of the fluid medium through which a vehicle is moving which is relatively safe.

It is also an object of the present invention to provide a system for reducing the mass density of the fluid medium through which a vehicle is moving which is energy efficient.

It is also an object of the present invention to provide a system for reducing the mass density of the fluid medium through which a vehicle is moving which entails minimal interference with vehicle electronic components.

It is also another object of the present invention to provide a system for reducing the mass density of the fluid medium through which a vehicle is moving which is effective at both subsonic and supersonic speeds.

It is an object of the present invention to provide a system for reducing the mass density of the fluid medium through which a vehicle is moving which provides heat energy transfer with vehicle engine systems for enhanced energy and power efficiency.

It is an object of the present invention to provide a system for reducing the mass density of the fluid medium through which a vehicle is moving which provides a high degree of efficiency in producing a high degree of mass density reduction of the fluid medium.

It is an object of the present invention to provide a system for reducing the mass density of the fluid medium through which a vehicle is moving which does not produce excessive heating of the vehicle's outer surfaces.

Basically, the aerodynamic and hydrodynamic efficiency augmentation system of the present invention achieves its goal of reducing the mass density of the fluid medium through which a vehicle is moving by heating and ionizing the fluid medium proximal to the vehicle to a high temperature. The heating and ionizing is accomplished via radiation of tuned electromagnetic power outwardly from the vehicle into the fluid medium. The electromagnetic radiation is within the microwave range in order to maximize transfer of electromagnetic energy received by the fluid medium molecules into heat energy and to product the desired ion generation. In addition, the frequency of the electromagnetic radiation is at the harmonic resonance frequency of electromagnetic excitation of the particular type of molecules of which the medium is composed. Radiation at the harmonic resonance frequency maximizes the power transfer efficiency of the heating and ionizing of the fluid medium provided by the system of the invention.

The system of the present invention is particularly well suited for both subsonic and supersonic aircraft for which the effects of aerodynamic drag and sonic wave production are more pronounced. The system of the invention is also very suitable for Force Projection Vehicles type aircraft which utilize wing-in-ground effect airfoils generating almost double the normal lift capability because of a combination of ground effect and downwardly projecting airfoils (at the wing tips) that confine inrushing air. Force Projection Vehicles normally cruise twenty feet above the sea over which they are most efficient but can also fly above land although at a higher altitude. Their low altitude capability renders them very advantageous in military operations because they are relatively invisible to radar at such low altitude flight. However, Force Projection Vehicles, although also advantageous because effective and efficient in transport of large and heavy cargo, are currently limited to flight at relatively slow speeds. By substantially increasing maximum speed capability, the aerodynamic efficiency augmentation system can overcome this important shortcoming of Force Projection Vehicles. In addition, the system of the invention is also well suited for transatmospheric vehicles of many types. For these and similar types of applications in which the vehicle is moving through the atmosphere, the frequency of the electromagnetic radiation is preferably at the harmonic resonance frequency of electromagnetic excitation i.e., electromagnetic absorption peak, of oxygen. Oxygen (as well as water) has a substantial electric and magnetic dipole which can easily be excited by tuned microwave radiation. When ionized and heated, the oxygen molecules quickly transfer their heat energy to adjacent nitrogen and other component molecules of the medium resulting in quick and thorough heating and ionization of that portion of the atmosphere in the immediate path of the aircraft enabling the aircraft to fly in a thinner atmosphere resulting in reduced aerodynamic drag. Heating of the air decreases the pressure gradient at the front (and preferably also the rear) of the aircraft thereby destroying the coherency of the pressure fronts so that they do not add together coherently. This reduces the pressure gradients acting on the boundary layer between the ambient air and the aircraft because they are distributed over a larger region i.e., several meters rather than several centimeters. The system of the invention essentially produces a "hot air bubble" around the aircraft which reduces the expended power at true supersonic speeds because the coherent addition of pressure waves around the aircraft is degraded. This reduces or eliminates the energy transmitted to the shock cone i.e., the pressure field produced at supersonic speeds and located at the rear of the aircraft and extending therefrom in a widening cone, thereby preventing or reducing the build up of sonic waves and thus the reduction or elimination of a "sonic boom".

The system of the present invention can reduce the mass density of a fluid medium comprising either a liquid or gas and may even be utilized to reduce the mass density of a medium such as ice and thus increase the dynamic i.e., generally aerodynamic as well as hydrodynamic, efficiency of a vehicle moving through either air or water. Thus, the system may also be utilized for waterborne and underwater vehicles. For these types of vehicles the mass density of the water is reduced by irradiation at preferably the harmonic resonance frequency of electromagnetic excitation of water. As with aircraft, this enables the waterborne and underwater vehicles to move through the water with less inertial and/or viscous drag resisting their movement thereby allowing higher maximum speed and acceleration and reduced fuel consumption.

The torpedo seems to be the easiest application platform to which to apply this phenomena. The present invention could enable a torpedo to speed toward its target through an atmosphere of steam, stabilizing itself by a pair of fore and aft fins hydro-planing through the surrounding water. A submarine could enjoy the same advantage for a short period of time, unless some of the onrushing water were piped aboard for cooling purposes. Surface ships, of the sizeable displacement of current ocean going naval and commercial marine variety could ride a bubble of steam, effectively hydro-planing over the ocean's surface. The "steam bubble" would be the vehicle which would transmit the multi thousand tons of weight to the ocean's surface, replacing the conventional displacement of water which provides the buoyant force for these vessels.

For transatmospheric (reentry) vehicle applications, the rarefaction of the atmosphere in the path of the vehicle also results in reduced frictional heating of the nose cone or other portions of the vehicle prone to overheating and provides increased protection to internal computer, electronic or other components sensitive to heat which may otherwise be damaged by or malfunction due to such heat generation.

For aircraft applications, the dynamic efficiency augmentation system incorporates microwave radiation generators mounted in the engines of the aircraft. The microwave generators exchange heat with the airflow entering and exiting the engine resulting in improved energy efficiency of both the engines and the generators. The induction airflow provides cooling for the generators while the exhaust airflow is provided with increased heating and thereby increased expansion of the engine exhaust gases resulting in improved thrust.

The output of the microwave generator is fed to an antenna which transmits the radiation through the interior of the aircraft and outwardly therefrom into the atmosphere in order to heat and thereby rarefy the air in the path of the aircraft as well as preferably rearwardly thereof. Thus, the microwave energy is radiated outwardly from preferably both the leading and trailing edges of the aircraft. In addition to transmission directly into the air, radiation transmission over portions of the skin of the aircraft produces heating and rarefaction of the air adjacent to lateral surfaces of the aircraft which tends to cling to the aircraft skin and produce viscous drag. The net effect is the production of a hot bubble of rarefied air surrounding the aircraft while it is moving through the atmosphere reducing aerodynamic drag on the aircraft and sonic wave generation (which also adds to aerodynamic drag). As a result, this reduces the fuel expenditure required for the aircraft to reach a desired speed and to maintain a cruise speed and its maximum attainable speed is also increased. In addition, it may attain supersonic speeds without generation of a sonic boom or with generation of a sonic boom of reduced intensity.

Molecules of the fluid medium which are substantially heated by the system of the present invention may come into contact with outer surfaces of the vehicle as a result of being in close proximity thereto or because they are located in the direct path of the vehicle. Due to the high temperature of these fluid medium molecules, substantial heat transfer to these vehicle outer surfaces may occur and result in the temperature of these and other components of the vehicle exceeding their maximal tolerable limits resulting in malfunction or failure thereof. For many applications, the fluid medium in the path of or proximal to the vehicle is preferably heated to a temperature which is in excess of the melting point of most metals. Consequently, a magnetic field subsystem is utilized to propel these heated molecules away from the vehicle and thereby prevent or minimize contact thereof with the vehicle's outer surface so as to minimize heat transfer to the vehicle's outer surface. By propelling these molecules away from the vehicle, the magnetic field subsystem also produces further rarefaction of the fluid medium through which the vehicle is moving thereby enhancing the benefits afforded by such heating of the fluid medium.

Heating the fluid medium to very high temperatures results in ionization of at least some of the molecules of the fluid medium. Where the fluid medium is air, this ionization results especially when the radiation first enters the air where oxygen molecules are present. Although the resulting rarefaction process propels the air molecules away from each other in many directions, the velocity of the vehicle results in a direction of relative motion between the ions and the vehicle's outer surfaces which is approximately parallel to generally the lateral and horizontal portions of the vehicle's outer surfaces (which in the case of aircraft are the upper and lower surfaces of the wings, sides of the tail and sides of the fuselage). The magnetic field generated by the system of the invention is oriented so that its lines of force are perpendicular to both the direction of ion flow across the vehicle's outer surfaces as well as the vehicle outer surfaces. Interaction of these charged molecules or particles results in a force which propels the molecules or particles in a direction perpendicular to the direction of motion of the vehicle. Depending on whether the molecules or particles have a positive or negative charge and on the direction of the magnetic lines of force, the molecules or particles are propelled either toward or away from the vehicle's outer surfaces. Thus, in aircraft applications, the positively charged air molecules are forced away from the aircraft's wing and fuselage surfaces while the negatively charged electron particles (stripped from the ionized air molecules) are forced onto or toward the aircraft's wing and fuselage surfaces. The electrons collecting on the metallic outer surfaces of the aircraft will be conducted all over the exposed surfaces of the aircraft and attach themselves to air molecules adhering to these surfaces. These air molecules are the sources of viscous drag and, as such, retard the velocity of the aircraft in direct proportion to its velocity. By providing a negative charge to these adhering air molecules, they will be attracted to the positively charged ions generated by the RF radiation and located away from the aircraft's outer surfaces. Thus, these ions will attract and move toward each other with the result that the adhering air molecules which are combined with the electrons will be drawn off and away from the aircraft's wings and fuselage thereby reducing viscous drag on the aircraft's surface. These ions subsequently re-combine at locations distal from the aircraft's metallic components.

The calculations that follow provide a determination of the power needed as well as other parameters of the system components required to provide that power needed to heat the onrushing air from approximately zero degrees to 1800 degrees Centigrade for a typical fighter aircraft in flight where the wings of the aircraft are D meters wide and the aircraft velocity is v=1000 mph. In the calculations it is assumed that the column of onrushing air is ±y meters on either side of the wings. The mass of the air encountered by the wings (whose cold air density is 1.29 kgrams/meter^3) which must be heated every second is:

$$[2y \times D \times v \times 1.29] \times [273 \text{ degrees Kelvin}/2073 \text{ degrees Kelvin}].$$

Note that the factor [273 degrees Kelvin/2073 degrees Kelvin] is due to the expansion of a small amount of air whose volume will increase by this factor once it is heated to 1800 degrees Centigrade. This factor determines the ratio of the divergence of the radiated beam to the angle subtended by the column of heated air.

For a fighter aircraft flying at 1000 mph (or 514 meters/second) with wings 12 meters wide, the power needed to heat the air ±one meter above and below the wing's edge is:

$$2 \times 1 \times 12 \times 514 \times 1.29 \times 0.1317 = 2096 \text{ kgram/seconds.}$$

The change in the specific heat of the air when its temperature is increased from 100 degrees Centigrade (0.2404 cal/gram) to 1800 degrees Centigrade (0.2850 cal/gram) is 0.0446 cal/gram, and this leads to the following:

$$4.18 \text{ joules/cal.} \times 0.0466 \text{ cal/gram} = 0.1864 \text{ joules/gram} = 0.1864 \text{ kjoules/kgram.}$$

Thus, the power which must be transmitted into the air in front of the wings is:

$$0.1864 \text{ kjoules/kgram} \times 2096 \text{ kgram/sec} = 391 \text{ kjoules/sec} = 0.4 \text{ megawatt.}$$

To heat a column of air R meters in radius i.e., a size sufficient to permit the aircraft's fuselage and engine nacelles to pass therethrough, requires:

$$\pi \times R^2 \times v \times 1.29 \text{ (density of cold air)} \times 273 \text{ degrees Kelvin}/2073 \text{ degrees Kelvin.}$$

For an aircraft fuselage (and nacelles) 2 meters in radius requires:

$$\pi \times 4 \times 514 \times 1.29 \times 0.1317 = 1098 \text{ kgram/sec.}$$

Thus, the power which must be transmitted into the air is:

$$0.1864 \text{ kjoules/kgram} \times 1098 \text{ kgram/sec} = 205 \text{ kjoules/sec} = 0.2 \text{ megawatt.}$$

The total power required=0.4 megawatt+0.2 megawatt=0.6 megawatt.

Assuming that the air is heated by first ionizing the oxygen molecules to their first ionization state, then this energy is shared by mutual excitation (rotation) of the nitrogen molecules so that the nearby air molecules eventually rise to as high as a temperature of about 1800 degrees Centigrade. A triangular (in cross-section) beam ±A° wide at the front edge or tip portion of the aircraft fuselage (and engine nacelle) and extending b meters from it must be formed to heat this column of air. It will be assumed that all the oxygen molecules in this region will be ionized every time the 60 GHz beam produced by the microwave generator fires, and the duty cycle of this transmission is 0.0012. The first ionization potential, I_p is 4.8844×10^4 kjoule/kgram. It is believed that air exists in an ionized state out to at least b (6 meters). The instantaneous mass of oxygen excited by the 60 GHz radio frequency beam=I and is provided by:

$$I = \pi \times D \times \tfrac{1}{2} b \times (2 \times b \tan A) \times 0.2 \text{ (air: 20\% oxygen)} \times 1.29 \text{ kgram/m}^3 \text{ (cold air density)}$$

$$I = 3.1416 \times 30 \times 6\ m \text{ (assumed extent of ionization)} \times 6 \times \tan 1.24° \times 0.2 \times 1.29$$

$$I = 18.9519 \text{ kgram.}$$

The average ionization power expended P_i is:

$$P_i = I_p \times I \times \text{transmission duty cycle} = 4.8844 \times 10^4 \text{ kioule/kgram} \times 18.95 \text{ kgram} \times 0.0012.$$

Thus, the ionization power expended is:

$$P_i = 1.1 \text{ megajoules per second} = \text{approximately 1 megawatt.}$$

The half beam-width required to ionize a column of air r meters (1 meter) in radius a distance b meters (6 meters) in front of the aircraft's fuselage is given by:

$$A° = \tan^{-1} (r/b) = \tan^{-1} (1/6) \backslash 19°/2.$$

The microwave beam is preferably radiated outwardly from the aircraft into the column of air by means of a forward refocusing cassagrain antenna. The size z of the aperture which is the focus of the secondary antenna of the forward refocusing cassagrain antenna (assuming 60 GHz power) to generate a beam 2×A° wide is:

$$z=65°\times 0.5\ \text{cm.(wavelength for 60 GHz } RF)/(2\times A°)=65°\times 0.5\ \text{cm.}/(19°)$$

$$z=1.7\ \text{cm.}$$

The size d of the cassagrain primary needed to form a beam 2.5° wide is:

$$d=65°\times 0.5\ \text{cm.}/(A°)=65°\times 0.5\ \text{cm.}/(2.5°)=13\ \text{cm.}$$

The magnetic field propelling the ions away from the outer surfaces of the vehicle is provided by a set of electric coils or looped wires in one embodiment and by a set of magnetic slabs in another embodiment. For the electric coil embodiment providing an electromagnet, the magnetic flux density in the vicinity of an aircraft's fuselage or wing outer surfaces required to propel the ionized molecules a desired distance therefrom may be determined from the following equations in which the electric loops are configured so that they are in the shape of a sphere. Utilizing a cylindrical coordinate system, the magnetic field H in the region outside the sphere is given by:

$$H=(m/4\ \pi r^3)\times(i_r 2\cos\theta+i_\theta \sin\theta)$$

$$H=m/2\ \pi R^3 i_z$$

$$m=4\ \pi R^3 K_o/3$$

where the cylindrical coordinates are the standard r, θ and z; R=radius of the sphere; r>R; m=magnetic moment; K_o=current density.

The magnetic flux density B is given by:

$$B=\mu_o H=(1/4\ \pi r^3)\times(4\ \pi R^3 K_o/3)\times\sin\theta$$

Assuming ions approximately 15 centimeters from the aircraft's outer surfaces must be effected by the magnetic field and θ=45°, the resulting value for B is given by:

$$B=3.04\times10^{-7}\times K_o$$

Assuming the wire needed for the coils is approximately ⅛ inch in thickness, a single layer of 312 wires per meter is sufficient. The Gyrotron utilized in the aircraft requires approximately 3×10^5 watts to drive it. Assuming a generator providing 400 volts is powering it, then the electric coils must be supplied with at least 750 amperes (and possibly twice this value) per Gyrotron. The value of the current density of the coils is

$$K_o=750\times312=\text{approximately } 2.25\times10^5\ \text{amperes per meter}$$

The numerical value for B becomes:

$$B=3.04\times10^{-7}\times K_o=7\times10^{-2}\ \text{webers per meter}$$

The force on an ion is:

$$F=qv_oB=1.6\times10^{-19}\times500\ \text{meters per second}\times7\ \text{webers per square meter}$$

$$F=5.7\times10^{-18}\ \text{newtons}$$

But, since F=MΔv/Δt and assuming that the force is applied over approximately one-half of a meter of the wing surface (as the aircraft moves forward), then $\Delta t=10^{-4}$ seconds.

$$\text{Since } F=M\Delta v/\Delta t,\ \text{then } \Delta v=F\times\Delta t/M$$

where M=32 grams/Avogadro's number=$32/6.03\times10^{-26}$ kilograms

The acceleration imparted to the ion is given by:

$$\Delta v=F\times\Delta t/M=(5.7\times10^{-18}\ \text{newtons}/5.3\times10^{-26}\ \text{kilograms})\times10^{-4}\ \text{seconds}$$

$\Delta v=10^5$ meters per second.

Since this velocity Δv is perpendicular to the aircraft's outer surfaces and is applied for 10^{-4} seconds, the positively charged ions are propelled away from the aircraft's outer surface a distance of approximately one meter by this magnetic field.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a graphical representation showing the atmospheric attenuation of microwave radiation by oxygen and water molecules thereof and illustrating their absorption peaks.

FIG. **2** is a side cross-sectional view of an aircraft wing depicting the ion flow across the upper and lower surfaces thereof and also the lines of force of the magnetic field produced by the magnetic field subsystem of the invention and showing the direction of the forces acting on the ions.

FIG. **3** is a sectional view of a representative magnet utilized in the magnetic field subsystem of the invention and illustrating the shape of the magnetic field lines which are ultimately formed by the magnetic field subsystem which is shaped to provide the laterally elongated lines of force configuration shown.

FIG. **4** is a plan view of a typical turbofan jet engine suitable for use with the aerodynamic efficiency augmentation system of the present invention.

FIG. **5** is a plan view of a continuous wave gyrotron type of microwave radiation generator component of the aerodynamic efficiency system of the invention.

FIG. **6** is a plan view of the gyrotron mounted in an aircraft jet engine and positioned for heat exchange therebetween and also showing the antenna therefor.

FIG. **7A** is a top plan view of the aerodynamic efficiency augmentation system of the invention mounted in an aircraft and showing the microwave beams radiated into the atmosphere in front of the aircraft.

FIG. **7B** is a side plan view of the aerodynamic efficiency augmentation system of the invention mounted in an aircraft and showing the microwave beams radiated into the atmosphere in front of the aircraft.

FIG. **8** is a diagram of components of a first embodiment of the invention showing microwave beams radiated through a wing and fuselage portion of an aircraft and radiated into the atmosphere in front of the leading edge of the wing and in the rear of the trailing edge of the wing.

FIG. **9** is a diagram of components of the first embodiment of the invention shown in FIG. **8** for the radiation beams directed into the atmosphere in front of the leading edge of the wing and illustrating the beam, the mirrors and antenna and the orientation and placement thereof.

FIG. **10** is a diagram of components of the first embodiment of the invention shown in FIG. **8** for the radiation beams directed into the atmosphere rearward of the trailing edge of the wing and illustrating the beam, the mirrors and antenna and the orientation and placement thereof.

FIG. **11** is a diagram of components of the first embodiment of the invention shown in FIGS. **8**, **9** and **10** and additionally showing components utilized to radiate the microwave beam from the fuselage of the aircraft outwardly into the atmosphere both in front of the fuselage and along the leading edge of the wing.

FIG. **12** is a top plan view of components of the magnetic field subsystem of the first embodiment showing the electromagnet producing coiled wires thereof mounted in the wings of the aircraft.

FIG. **13** is a side cross-sectional view of a representative one of the wings of the aircraft showing the coiled wire components of the magnetic field subsystem in addition to components of the electric power recovery subsystem utilized to obtain electrical power from the ion flow in the aircraft wing.

FIG. **14** is a diagram of components of a second embodiment of the invention showing microwave beams radiated through a wing portion of the aircraft and radiated outwardly into the atmosphere in front of the leading edge of the wing and in the rear of the trailing edge of the wing.

FIG. **15** is a diagram of the components of the second embodiment of the invention shown in FIG. **14** and specifically showing in more detail components utilized to radiate the microwave beam through the wing portion of the aircraft and radiated into the atmosphere in front of the leading edge of the wing.

FIG. **16** is a diagram of the components of the second embodiment of the invention shown in FIG. **14** and specifically showing in more detail components utilized to radiate the microwave beam through a wing portion of the aircraft and radiated into the atmosphere rearward of the trailing edge of the wing.

FIG. **17** is a diagram of the components of the second embodiment of the invention shown in FIGS. **14**, **15** and **16** and specifically showing in more detail components utilized to radiate the microwave beam from the fuselage of the aircraft outwardly into the atmosphere both in front of the fuselage and along the leading edge of the wing.

FIG. **18** is a top plan view of components of the magnetic field subsystem of the second embodiment showing the electromagnet producing coiled wires and the magnetic slabs thereof mounted in the wings of the aircraft.

FIG. **19**A is a side cross-sectional view of a representative one of the wings of the aircraft showing the coiled wire components of the magnetic field subsystem in addition to components of the electric power recovery subsystem utilized to obtain electrical power from the ion flow in the aircraft wing.

FIG. **19**B is a side cross-sectional view of a representative one of the wings of the aircraft showing the magnetic slab components of the magnetic field subsystem in addition to components of the electric power recovery subsystem utilized to obtain electrical power from the ion flow in the aircraft wing.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Basically, the aerodynamic efficiency system of the invention utilizes the microwave frequency selective absorption peaks of oxygen to provide effective and efficient heating of portions of the atmosphere in the path of a vehicle moving therethrough. Water and oxygen have electric and magnetic dipoles which enable them to more readily vibrate in response to microwave radiation. The microwave absorption peaks shown in FIG. **1** are the microwave frequencies at which harmonic resonance excitation of these types of molecules occur which maximizes heat produced in response thereto. As shown in FIG. **1**, maximum attenuation of radiation occurs at the first oxygen peak of approximately sixty GHz and this is therefore the frequency deemed optimum for energy efficient heating of the atmosphere. However, nitrogen molecules do not have significant dipole properties and therefore cannot efficiently be heated by microwave radiation. Consequently, the nitrogen molecules in the atmosphere (as well as other types of molecules therein) are instead indirectly heated by direct physical transfer of the thermal motion from oxygen molecules which are proximal thereto thereby producing rapid heating of an entire desired portion of the atmosphere. As is also evident from FIG. **1**, microwave radiation can also be used to heat a medium composed partly or entirely of water thereby allowing a vehicle to move with less friction through a "tunnel" or "channel" of rarefied steer (e.g., steam) in the path of the vehicle.

Two preferred means of applying the concept of the present invention to a jet aircraft are described in a first embodiment and a second embodiment generally designated by the numerals **10** and **110**, respectively. The first and second embodiments differ only in how the RF energy used to heat the air is fed in front of the wing assembly. The first embodiment **10** radiates a beam along the front edge of the wing. Part of the beam is initially contained within the wing assembly and diverges from this containment as it radiates along the front edge of the wing. A component structure of the first embodiment **10** permits passage of this beam both within and without the wing's forward edge surface. Some attenuation of the beam by the component structure can be expected, but it is not immediately quantifiable. For the second embodiment **110**, the entire beam is initially contained within the wing assemblies as it radiates from its source. However, component structures of the second embodiment **110** intercept parts of this beam and radiate it outward through the forward edge of the wing.

FIGS. **4**, **5** and **6** depict components of the invention common to both embodiments and used in essentially the same way. FIG. **4** shows a typical jet engine **12** (**112**) between the low pressure fan **28** (**128**) and the compressure turbine fans **21** (**121**) thereof which is suitable for use with the concept of the present invention, and FIG. **5** depicts a microwave electromagnetic radiation generator **14** (**114**) and FIG. **6** shows the generator **14** (**114**) positioned in such an engine **12** (**112**) for heat transfer between the induction and exhaust airflows **16** (**116**), **18** (**118**) and the generator **14** (**114**). The microwave generator **14** (**114**) is preferably a gyrotron tube **14** (**114**) although other suitable types of microwave generators may also be utilized. The gyrotron tube **14** (**114**) is thus attached to the engine **12** (**112**) before the compressor **25** (**125**) and the compressor turbine fan **21** (**121**) and arranged so that it is in the path of the dense flow of air after the bypass fan **28** (**128**) of a low or high bypass jet engine **12** (**112**) but before the compressor of the engine **12** (**112**), as shown in FIG. **4** and with reference to FIG. **2**. The gyrotron tube **14** (**114**) is also preferably oriented so that it is approximately transverse to the axis of the jet engine **12** (**112**), as shown in FIGS. **4**, **6**, **7**, **10** and **11**. The gyrotron tube **14** (**114**) has an electron collector **22** (**122**) which is the major source of heat due to the relative high density and high velocity of the electron beam and super conducting magnets **23** (**123**) which must be kept cool to provide maximum power efficiency in maintaining magnetic field strength. The electron collector **22** (**122**) is conventional in structure and function and is preferably cooled with water (although liquid sodium may also be suitable) as with conventional gyrotron designs preferably via a conventional radiator subsystem suitably positioned in the path of the airflow **16 (116)**, while the super-conducting magnets are located at outermost portions of the engine **12 (112)** and wings **24 (124)** of the aircraft **20 (120)** thereby obtaining the required cooling directly from the atmosphere. The electron gun of the gyrotron **14 (114)** forms an electron beam which is accelerated through the focusing field of the magnets **23 (123)** to the electron collector **22 (122)**. The electrons of the beam interact with radio-frequency electric fields perpendicular to the magnetic focusing field. The rotation of the electrons in the field and the alternation of the fields in synchronism therewith produce a cumulative interaction resulting in an oscillation. The interaction between the electrons and the fields causes the electrons to bunch in an elongate configuration parallel to the axis of the electron trajectories enabling extraction of energy from the electrons and by utilizing the resonance nature of the interaction producing the desired high frequency output. As shown in FIG. **6**, the coolant vanes **26 (126)** of the gyrotron tube **14 (114)** are preferably mounted inside the engine **12 (112)** for heat exchange with the induction airflow passing through the engine **12 (112)**. The vanes **26 (126)** are preferably curved to conform with the laminar flow of the air generated by the bypass fans **28 (128)** of the engine **12 (112)**, but they are depicted as straight for simplicity of illustration. The heat from the electron collector **22 (122)** is transferred to the airflow **16 (116)** passing into the low pressure fan **28 (128)** used to generate compressed cold air which is mixed with the engine's gas turbine hot exhaust **18 (118)**. The temperature of the exhaust airflow **18 (118)** is thereby increased providing increased engine thrust while the electron collector **22 (122)** is cooled without necessitating the energy burden of a cooling subsystem specifically for cooling the collector. Thus, the efficiency of both the generator **14 (114)** and the engine **12 (112)** are improved. This heat exchange could be used in a high bypass jet engine as well as a low bypass turbofan jet engine the latter of which would be more effective because a two or three stage low pressure fan is used to generate compressed cold air (a high pressure compressor feeds the jet engine's fuel/air mixture).

The first embodiment **10** of the invention is shown generally in FIGS. 7A and 7B and more specifically in FIGS. **8**, **9**, **10**, **11**, **12** and **13**. The first embodiment includes the generators **14** and the components thereof which are mounted in the engines **12** of the aircraft **20**, as described generally above. The generators **14** preferably include a pair of continuous wave gyrotrons **15** and **17** and a pulse gyrotron **19** mounted in each of the engines **12**. The pulse gyrotron **19** provides pulsed radiation which is emitted from preferably the front portion of the fuselage **30** of the aircraft **20** in order to allow radar and continuous wave (cw) communication subsystems to be used in the aircraft. High speed interruption of the low frequency audio rates employed on a single channel VHF or UHF (cw) radio transmitter is tolerable for such transmissions where the gyrotron **19** operates with a pulse repetition interval of four-hundred microseconds (2500 pulses per second) and would also permit a thirty mile weather or engagement radar subsystem to operate effectively. The gyrotron **19** preferably operates with a fifty percent duty factor, on for four-hundred microseconds and off for four-hundred microseconds. It is believed that pulsed gyrotrons produce greater ionization of the medium into which they emit their radiation.

All of the gyrotrons **15**, **17** and **19** utilize antennas to radiate the microwave energy both directly outwardly of the aircraft **20** into the atmosphere and into and through inner structures of the aircraft **20** to locations where the energy may be radiated directly into the atmosphere. Sets of preferably cassagrain types of output antennas **32**, **76** and **78** are mounted at the output of each of the gyrotrons **15**, **17** and **19** to emit the radiation into and through conduits which are preferably nitrogen filled waveguides **34** (or simply nitrogen filled passageways) located within the wing **24** of the aircraft **20**, as shown in FIG. **11**. However, other types of microwave radiation waveguides or conductors may also be utilized if desired and as appropriate for the particular application. Preferably an inverse cassagrain type of antenna **36** is mounted at appropriate fuselage portions of the aircraft **20** for receiving the transmitted through the waveguides **34** and emission of the radiation directly into the atmosphere. The waveguides **34** preferably include a first set of waveguides **38**, a second set of waveguides **40** and a third set of waveguides **42**. The first set of waveguides **36** are preferably mounted within the wing **24** and positioned at the output of the gyrotrons **15** (and antennas **32**) in order to receive the radiation output therefrom and transmit and direct it to a first set of (preferably contoured) radomes **44** at leading edges **46** of the wing **24**. The second set of waveguides **40** are preferably also mounted within the wing **24** and positioned at the output of the gyrotrons **17** (and antennas **76**) in order to receive the radiation output therefrom and transmit and direct it to a second set of radomes **48** at trailing edges **50** of the wing **24**. The third set of waveguides **42** are preferably mounted within the wing **24** and the fuselage **52** and positioned at the output of the gyrotrons **19** (and antennas **78**) in order to receive the radiation output therefrom and transmit and direct it to a third set of radomes **54** at the front portion (or tip) **30** of the fuselage **58**. The sets of radomes **44**, **48** and **54** are preferably composed of sintered aluminum oxide to provide heat and oxidation resistance while also allowing the microwave radiation to pass therethrough into the atmosphere. The sets of radomes **44**, **48** and **54** are also positioned at surface portions of the aircraft **20** in the path of the microwave radiation beams exiting the aircraft **20** and emitted into the atmosphere.

A first set of mirrors **56** are also included and positioned at preferably the distal end of the first set of waveguides **38** for receiving the radiation beam transmitted through the set of waveguides **38** and reflecting the beam generally backward into and through the first set of radomes **44** and outward into the atmosphere in front of the wing's **24** leading edge **46**. The reflected beam is preferably angled relative to the leading edge **46** so that it is nearly parallel thereto and more preferably at an angle of approximately fifteen degrees relative thereto, as shown in FIGS. **8** and **9**. Thus, the beam is oriented such that although it is projected so that it is directly in front of the entire length of leading edge **46** it is not positioned at an excessive distance from any portion of the leading edge **46** and therefore does not heat a portion of the atmosphere an excessive distance from the leading edge **46**.

The output of the continuous wave gyrotron **15** is fed into the first set of cassagrain output antennas **32** which are oriented so that they emit the radiation directly into the first set of waveguides **38** as well as into and through the first set of radomes **44**, as shown in FIG. **9**. Thus, a portion of the beam emitted from the output antenna **32** is transmitted into the first set of waveguides **38** while another portion of the beam emitted therefrom is transmitted into the first set of radomes. The portion of the radiation beam transmitted through the first set of radomes **44** directly from the output antenna **32** is emitted into the atmosphere directly in front of the leading edge **46** and approximately parallel thereto. The beams reflected into the atmosphere in front of the leading edge **46** from the mirrors **56** and directly from the output antenna **32** are directed generally towards each other.

The output of the continuous wave gyrotron **17** is fed into another set of cassagrain output antennas **76** which radiate the microwave beam into and through the second set of waveguides **40**. A second set of mirrors **58** positioned in the second set of waveguides **40** reflects and directs the beam into and through the second set of radomes **48** into the atmosphere directly rearward of the trailing edges **50**. More specifically, the radiation beam is radiated through the second set of waveguides **40** onto a second set of mirrors **58**, located at approximately midwing, which direct the beam rearwardly. The second set of radomes **48** at the trailing edges are wider than the first set of radomes **44** at the leading edge and consequently a larger region of aft wing heats the air leaving the wing's surface.

A portion of the microwave beam transmitted through the second set of waveguides **40** is directed onto a third set of mirrors **60** located in the fuselage **52** which reflect the beam toward a fourth set of radomes **62** located at the vertical leading edge **64** of the tail stabilizer **66**. More specifically, a third set of mirrors **60** located at a bend in the waveguide (preferably in the fuselage **52**) reflects the beam rearwardly through the waveguide **40** and the fuselage **52** to another of the third set of mirrors **60** located proximal the tail stabilizer **66** which reflects the beam into and through the fourth set of radomes **62** and outwardly into the atmosphere directly in front of the tail stabilizer **66** leading edge **64**. The beam emitted into the atmosphere from the fourth set of radomes **62** is oriented so that it is generally parallel to the tail stabilizer's **66** leading edge **64**, as is the beam emitted from the antenna **32** directly into the atmosphere in front of the leading edge **46** of the wing **24**, as described above.

The output of the pulsed gyrotron **19** is fed to the third set of the cassagrain antennas **78** which radiate it into and through the third set of waveguides **42** and through the third set of radomes **54** into the atmosphere directly in front of the front portion **30** of the fuselage **52**. As shown in FIGS. **8** and **11**, a fourth set of mirrors **68** located in the fuselage and at a bend in the third set of waveguides **42** reflects the beam forwardly through the fuselage **52** into one of the inverse cassagrain antennas **36** which emits the radiation beam into and through the third set of radomes **54**. As with the other of the inverse cassagrain antennas **36**, this inverse cassagrain antenna **36** emits a broadened beam of radiation into the atmosphere directly in front of the front portion **30** of the fuselage **52**. In addition, there is also a seventh mirror or set of mirrors **70** mounted in the fuselage **52** which receives, reflects and directs a portion of the pulsed radiation beam transmitted through the fuselage **52** into and through the first set of radomes **44** and outwardly into the atmosphere directly in front of the leading edge **46**. As described above, the radiation emitted from the fuselage **52** is pulsed in order to allow both radar and continuous wave communications signals to be transmitted and received while the aerodynamic efficiency augmentation system of the present invention is in operation.

Since the heat energy of the air molecules proximal to the aircraft **20** may be readily transferred to the outer surfaces of the aircraft **20** due to proximity or due to direct contact therewith resulting from motion of the aircraft **20** through the rarefied atmosphere, it is necessary that these hot air molecules be prevented from getting too close to the outer surfaces of the aircraft **20**. Consequently, a magnetic field subsystem **80** is provided to direct and propel the air molecules away from the aircraft **20** when the molecules get within the effective range of the magnetic field produced by the subsystem **80**.

FIG. **2** shows the orientation of the magnetic field produced by the subsystem **80**. Since the ionized air molecules **82** and electrons **84** flow over the aircraft's outer surfaces or skin **74** (which are also specifically depicted as the upper and lower surfaces **86** and **88** of the wing **24** shown in FIG. **2**) in a direction of flow **92** which is generally parallel to these surfaces **74**, the lines of force **94** are oriented so that they are generally perpendicular to this direction of flow **92**. The magnetic field and lines of force **94** thereof are also oriented so that the interaction of the lines of force **94** with the charged molecules or particles **82** and **84** produces a force acting thereon which propels them in a direction perpendicular to the outer surfaces **74** and perpendicular to the lines of force **94**. The ions **82** and **84** flowing over the upper surfaces **86** interact with the lines of force **94** which are directed out of the illustration of FIG. **2** so that the positive ions **82** are propelled vertically away from the upper surfaces **86** by the force **87** acting thereon while the negative ions **84** are propelled vertically toward the upper surfaces **86** by the force **89** acting thereon. The positively charged air molecules **82** which contribute mass densities greater than the negatively charged ions i.e., the electrons, **84** thus contribute higher quantities of heat energy. Thus, propelling these positively charged ions **82** away from the aircraft **20** producing less likelihood of contact therewith and heat transfer thereto minimizes the likelihood that the system's radiation heating of the atmosphere will result in excessive heating of the aircraft **20**. This reduces the need to utilize heat shields, exotic metals or interior insulation to protect the aircraft components, instruments, etc. This also further rarefies the atmosphere proximal to the aircraft **20** thereby enhancing the increased dynamic efficiency afforded by the system **10**.

The magnetic field subsystem **80** preferably utilizes a set of coiled wires **96** preferably mounted in the wings **24** preferably at the upper and lower portions thereof, as shown in FIGS. **12** and **13**. The sets of coiled wires **96** are fed electrical current via current distributors **95**. The set of coiled wires **96** are preferably wound horizontally around the core or center of each wing **24** so that the coils of each set **96** lie in the same plane and have the same approximate center and are proximal the periphery of the wing. Each set of coiled wires thus produces an electromagnet which is vertically oriented so that its poles are in vertical alignment. The set of coiled wires **96** thus produce a magnetic field whose lines of force **94** extend laterally over the upper and lower surfaces **86** and **88** of the wings **24**, as illustrated in FIG. **2**. The set of coiled wires **96** thus also produce a magnetic field whose magnetic flux density vectors **97** point toward the fuselage **52** on one side thereof and point away from the fuselage **52** on the other side thereof. The lines of force **94** are thus oriented generally horizontally and generally perpendicular to the direction of ion flow across the outer surfaces **74** providing the desired deflection of the ions in a direction perpendicular to the upper and lower surfaces **86** and **88** (and perpendicular to the direction of motion of the aircraft **20**). However, other lines of force **94** provided by the set of coiled wires **96** will not have this particular desired orientation. Other lines of force located at the center line of the aircraft **20** are generally parallel to the direction of flow **92** of the ions and would thus not affect the direction of motion of the ions. Still other lines of force may have different orientations which may instead propel the ions in other directions. Nevertheless, since the lines of force **94** with the described desired orientation are located immediately rearward of the radomes **44** at the leading edges **46** of the wings **90**, they will produce the desired deflection of the ions as soon as the ions enter the space directly above or below the wings **24**, whereas the lines of force which have a more vertical orientation are located more rearward of the leading edges of the wings **24** at which location there are relatively few ions close enough to the outer surfaces **74** to result in the undesired heat transfer thereto. Consequently, at least most of the ions that can result in the undesired heat transfer are removed from proximity to the outer surfaces **74** of the aircraft **20** by the subsystem **80**.

The negatively charged ions **84** are directed toward and onto the outer surfaces **74** of the wing **24** (as well as the fuselage, tail, etc.). The electrons **84** collecting on these outer surfaces **74** will be conducted all over the exposed surface of the aircraft and attach themselves to air molecules adhering to these surfaces thereby transferring a negative charge to these air molecules. These air molecules are the sources of viscous drag and, as such, retard the velocity of the aircraft in direct proportion to its velocity. But, once these air molecules acquire the negative charge, they are attracted to the positively charged air molecules **82** more distal of these outer surfaces **74**. These positively charged air molecules **82** are produced by the radiation generated by the system **10**. The mutual attraction between these ions draws these molecules adhering to the outer surfaces **74** off and away from the surfaces **74** thereby reducing viscous drag acting on these outer surfaces **74**.

Additionally, air molecules adhering to the outer surfaces **74** may be drawn from other portions thereof at which the magnetic subsystem **80** is not adequately effective in removing the adhering air molecules by heating these portions of the outer surfaces **74**. In order to provide this heating of the outer surfaces **74**, some of the remaining microwave radiation is fed directly from the output antenna **32** to the electromagnetically conducting skin **74** (preferably portions thereof from which the magnetic subsystem **80** is not adequately effective in removing adhering air molecules) of the wing **24** by means of an electric conductor (or waveguide) **72**, as shown in FIG. **9**. The microwave radiation is thus allowed to be transmitted directly through the outer surface **74** of the wing **24** (and other parts of the aircraft **20** such as the fuselage **52**, if desired). This radiation being conducted through the outer surfaces **74** heats the air adjacent thereto resulting in reduced viscous drag for these portions of the aircraft **20**.

The presence of the negatively charged ions **84** produced by the radiation heating of the atmosphere proximal to the aircraft **20** and the propelling of the negatively charged ions **84** toward and onto the aircraft **20** result in a high relative concentration of negatively charged ions **84** at the outer surfaces **74**. The presence of these ions **84** in combination with the forward motion of the aircraft through this ionized air plasma results in backward flow of negatively charged ions over the aircraft **20**. The backward flow of negatively charged ions (electrons) **84** over the outer surfaces **74** induces an electrical current in the outer surfaces **74** which also flows backward. In order to extract this current flow and allow it to be utilized to power electrical units of the aircraft **20**, the panels **98** (shown in FIG. **13**) of the upper outer surfaces **86** have to be electrically isolated from the lower outer surfaces **88** in order to prevent merging and neutralization of these currents at the trailing edges **50** of the wing **24** via insulator panels **90**. Ion collector plates **99** are also provided and positioned directly underneath the panels **98** of the upper surfaces **86** and directly above the panels **98** of the lower surfaces **88** in order to collect the electrical current flowing through surfaces **86** and **88**. A set of electrical wires **91** connected to the ion collector plates **99** receive the electrical current therefrom and allow it to be used to provide electrical power to other subsystems and electrical units of the aircraft **20**.

FIGS. **14**, **15**, **16**, **17**, **18**, **19A** and **19B** show the second embodiment of the invention **110** which is essentially identical to the first embodiment **10** except that the microwave beams are radiated outwardly in front of the leading edges **146** in a direction generally parallel to the direction of motion of the aircraft **120** rather than at a small angle (or nearly parallel) to the leading edge **46** i.e., approximately perpendicular to the direction of motion, as in the design of embodiment **10** and that the magnetic field subsystem **180** additionally includes permanently magnetized slabs **181**. The rays of the radiation beam emitted from the leading edges **146** are also divergent from each other, as shown in FIG. **14**. In the embodiment **110**, a fifth set of mirrors **155** is provided which receive the radiation beam emitted from the first set of cassagrain output antennas **132**. The fifth set of mirrors **155** are located in the first set of waveguides **138** at locations along the length thereof behind the leading edges **146** of the wings **124**, as shown in FIG. **14**. The fifth set of mirrors **155** are oriented so that they reflect and direct the radiation beam into and through a first set of radomes **144** mounted at the surface portions of the leading edges **146** and into the atmosphere directly in front of the leading edges **146**. The remainder of the radiation beam transmitted through the first set of waveguides **138** which is not emitted through the first set of radomes **144** via reflection from the fifth set of mirrors **155** is reflected off a first and sixth set of mirrors **156** and **157** located at the inner end portion of the first set of waveguides **138** at or proximal to the fuselage **152** and directed to the first set of radomes **144** at the leading edge **146** of the wing for emission into the atmosphere in front of the leading edge **146**. The radiation beam emitted from the first set of mirrors **156** through the first set of radomes **144** is oriented such that it is preferably angled relative to the leading edge **146** so that it is nearly parallel thereto and more preferably at an angle of approximately fifteen degrees relative thereto, as shown in FIG. **14** and similar to the angle produced by the first set of mirrors **56** of embodiment **10**. The sixth set of mirrors **157** is oriented so that it is more nearly perpendicular to the direction of transmission of the radiation beam through the first set of waveguides **138** and thus reflects and directs the radiation beam through the first set of radomes **144** in a direction laterally outward from the aircraft **120** and in front of the leading edge **146**. The sixth set of mirrors **157** is oriented so that the angle of the radiation beam reflected therefrom is more obtuse than that of the beam reflected from the first set of mirrors **156** and this angle is preferably approximately 30 degrees. Thus, each of the beams is oriented such that although it is projected so that it is directly in front of the entire length of leading edge **146** it is not positioned at an excessive distance from any portion of the leading edge **146** and therefore does not heat a portion of the atmosphere an excessive distance from the leading edge **146**.

As shown in detail in FIG. **16**, the output of the continuous wave gyrotron **117** is fed into a second set of cassagrain output antennas **176** which radiate the microwave beam into and through the second set of waveguides **140**. A second set of mirrors **158** positioned in the second set of waveguides **140** reflects and directs the beam into and through the second set of radomes **148** into the atmosphere directly rearward of the trailing edges **150**. The emission of the radiation beam from the trailing edges **150** is accomplished using structures which are identical to and function the same as correspondingly numbered components described above with respect to embodiment **10**. The radiation beam is radiated through the second set of waveguides **140** onto a second set of mirrors **158**, located at approximately midwing, which direct the beam rearwardly into an inverse cassagrain antenna **136** which emits the radiation beam into and through the second set of radomes **148** outwardly and rearwardly into the atmosphere rearward of the trailing edges **150**. As with the corresponding structures of embodiment **10**, the second set of radomes **148** at the trailing edges **150** are wider than the first set of radomes **144** at the leading edge and consequently a larger region of aft wing heats the air leaving the wing's surface.

A portion of the microwave beam transmitted through the second set of waveguides **140** is directed onto a third set of mirrors **160** located in the fuselage **152** which reflect the beam toward a fourth set of radomes **162** located at the vertical leading edge **164** of the tail stabilizer **166**. As with the correspondingly numbered components of embodiment **10**, the third set of mirrors **160** reflects the beam rearwardly through the waveguide **140** and the fuselage **152** to another of the third set of mirrors **160** located proximal the tail stabilizer **166** which reflects the beam into and through the fourth set of radomes **162** and outwardly into the atmosphere directly in front of the tail stabilizer **166** and leading edge **164** thereof and generally parallel to the leading edge **164**.

The output of the pulse gyrotron **119** is fed to a third set of the cassagrain antennas **178** which radiate it into and through the third set of waveguides **142** and through the third set of radomes **154** into the atmosphere directly in front of the front portion **130** of the fuselage **152**. The components utilized to accomplish this emission of radiation from the front portion **130** of the fuselage are structurally and functionally identical to the correspondingly numbered components of embodiment **10**. As shown in FIG. **17** and more generally in FIGS. **7A** and **7B**, a fourth set of mirrors **168** located in the fuselage and at a bend in the third set of waveguides **142** reflects the beam forwardly through the fuselage **152** into one of the inverse cassagrain antennas **136** which emits a preferably pulsed broadened beam of radiation into and through the third set of radomes **154**. There is also a seventh mirror or set of mirrors **170** mounted in the fuselage **152** which receives, reflects and directs a portion of the pulsed radiation beam transmitted through the fuselage **152** into and through the first set of radomes **144** and outwardly into the atmosphere directly in front of the wing's **124** leading edge **146**.

The cassagrain antennas **32**, **132**, **76**, **176**, **78** and **178** include a cassagrain primary aperture which is approximately thirteen centimeters in diameter in order to provide a radiation beam the rays of which are divergent at an angle of approximately 2.5 degrees. This divergence is required because the air heated to 1800 degrees Centigrade expands to encompass a nineteen degree sector at six meters thereby forming a plus or minus one meter high column of heated air for the wing to pass through. This beam is transmitted through the appropriate sets of waveguides **38**, **40** and **42** where it gradually expands as it passes therethrough. The inverse cassagrain antennas **36** and **136** include a cassagrain primary aperture which collects the radiation transmitted through the appropriate waveguide and reflects it through a smaller aperture. This effectively broadens the beam so that the rays thereof diverge from each other at an angle of approximately nineteen degrees in order to heat a region of air two meters wide six meters in front of the aircraft. As set forth in the calculations, the primary aperture is approximately in excess of thirteen centimeters in diameter while the secondary aperture is approximately 1.7 centimeters in diamter. However, the particular sizing of these components depends on the physical design of the aircraft, its flight envelope, etc. and will thus vary in accordance with the particular application.

FIG. **2** shows the orientation of the magnetic field produced by the subsystem **180**. As with embodiment **10**, the lines of force **194** are oriented so that they are generally perpendicular to the direction of flow **192** of the ions **182** and **184** over the upper and lower surfaces **186** and **188**. The magnetic field and lines of force **194** thereof are also oriented so that the interaction of the lines of force **194** with the charged molecules or particles **182** and **184** produces a force acting thereon which propels them in a direction perpendicular to the outer surfaces **174** and perpendicular to the lines of force **194**. The ions **182** and **184** flowing over the upper surfaces **186** interact with the lines of force **194** so that the positive ions **182** are propelled vertically away from the upper surfaces **186** by the force **187** acting thereon while the negative ions **184** are propelled vertically toward the upper surfaces **186** by the force **189** acting thereon.

The magnetic field subsystem **180** preferably utilizes a set of coiled wires **196** preferably mounted in the wings **124** preferably at the upper and lower portions thereof, as shown in FIGS. **18** and **19A**. The sets of coiled wires **196** are fed electrical current via current distributors **195**. The set of coiled wires **196** are preferably wound horizontally around the core or center of each wing **124** so that the coils of each set **196** lie in the same plane and have the same approximate center and are located at the periphery of the wing forming preferably a triangular configuration. Each set of coiled wires thus produces an electromagnet which is vertically oriented so that its poles are in vertical alignment. The set of coiled wires **196** thus produce a magnetic field whose lines of force **194** extend laterally over the upper and lower surfaces **186** and **188** of the wings **24**, as illustrated in FIG. **2**. The magnetic flux density vectors **197** of the generated magnetic field point toward the fuselage **152** on one side thereof and point away from the fuselage **152** on the other side thereof. The lines of force **194** are thus identical to those of embodiment **10** and produce the same results.

The negatively charged ions **184** are directed toward and onto the outer surfaces **174** of the wing **124** (as well as the fuselage, tail, etc.). The electrons **184** collecting on these outer surfaces **174** will be conducted all over the exposed surface of the aircraft and attach themselves to air molecules adhering to these surfaces thereby transferring a negative charge to these air molecules and result in drawing these molecules adhering to these surfaces off and away from the surfaces **174** thereby reducing viscous drag.

In order to extract and utilize the current flow in the conducting surfaces of the wings **124**, the panels **198** (shown in FIG. **19A**) of the upper outer surfaces **186** have to be electrically isolated from the lower outer surfaces **188** in order to prevent merging and neutralization of these currents at the trailing edges **150** of the wing **124** via insulator panels **190**. Ion collector plates **199** are also provided and positioned directly underneath the panels **198** of the upper surfaces **186** and directly above the panels **198** of the lower surfaces **188** in order to collect the electrical current flowing through surfaces **186** and **188**. A set of electrical wires **191** connected to the ion collector plates **199** receive the electrical current therefrom and allow it to be used to provide electrical power to other subsystems and electrical units of the aircraft **120**.

FIG. **19B** shows the magnetic slabs or plates **193** positioned inside and above the lower surface **188** of the wing

124 aft of the radome 144 (where heating effects might continue) and also positioned inside and below the upper surface 186 and inside and below the lower surface 188 but proximal to the trailing edge 150 of the wing 124. The magnetic plates 193 are preferably shaped to provide a laterally elongated magnetic field the lines of force 194 of which are generally parallel to the upper and lower surfaces 186 and 188 and thereby provide the desired force propelling the ions 182 and 184 in the desired directions, as described hereinabove with regard to embodiment 10. Although the panels 198 of the lower surfaces 188 which are under the magnetic plates 193 are electrically isolated, they are electrically connected to the panels 198 of the upper surfaces 186 which are above the magnetic plates 193 in order to merge the electron flow therein which is received by the set of electrical wires 191. Magnetic plates 193 are also preferably placed in the fuselage just behind the tip 130 thereof (where there is likely to be a high concentration of heat) to provide lines of force which are also oriented perpendicular to the direction of flow 192 of the ions 182 and 184. The magnetic plates 193 proximal the trailing edge 150 of the wing 124 direct the energized ions away from the bottom of the wing 124 but attract the (highly diluted and de-energized) ions to the trailing edge 150 of the upper surface 186. At the upper surface 186 the negatively charged ions 184 are attracted to the positively charged ions 182 in the fluid medium above the upper surface 186 of the wing 124 and will draw the ions viscously adhering to the outer surface 174 off and away. Thus, utilization of magnetic plates 193 in conjunction with the electromagnet producing sets of coiled wires 196 further enhances reduction of viscous drag on the outer surfaces 174 of the aircraft 120.

The set of coiled wires 196 have aft portions 185 located in front of the magnetic slabs 193 and extending in a zig-zag configuration proximal to and along the trailing edge 150 of the wing 124. The aft portions 185 are thus skewed (or angled) relative to the direction of ion flow across the outer surface 174, as shown in FIG. 18. This orientation of the aft portions 185 produces a magnetic field orientation which is angled relative to the direction of ion flow in order to draw diluted and de-energized ions to the collector plates 199.

Accordingly, there has been provided, in accordance with the invention, a system for increasing the aerodynamic efficiency of a vehicle in motion that fully satisfies the objectives set forth above. Although the invention has been described in regard to increasing the aerodynamic efficiency of an aircraft in flight, the system of the invention may also be applied to other types of vehicles or bodies in motion through other types of fluid media. It is to be understood that all terms used herein are descriptive rather than limiting. Although the invention has been described in conjunction with the specific embodiments set forth above, many alternative embodiments, modifications and variations will be apparent to those skilled in the art in light of the disclosure set forth herein. Accordingly, it is intended to include all such alternatives, embodiments, modifications and variations that fall within the spirit and scope of the invention set forth in the claims hereinbelow.

What is claimed is:

1. A system for increasing the dynamic efficiency of a vehicle in a fluid medium, comprising:

a source of electromagnetic radiation;

means for transmitting electromagnetic radiation from said source to desired surface portions of the vehicle, said surface portions including leading edges, said means for transmitting receiving the radiation from said source;

means for emitting a beam of the radiation outwardly and away from the desired surface portions, the leading edges and the vehicle in order to heat the fluid medium thereby reducing mass density of the fluid medium to reduce dynamic drag on the vehicle, said means for emitting receiving the radiation from said means for transmitting, said desired surface portions adjacent to areas of the fluid medium heated by the radiation;

means for producing a magnetic field proximal to the vehicle in order to provide a force for propelling molecules of the fluid medium in a direction generally perpendicular to the vehicle.

2. The system of claim 1 wherein frequency of the radiation is approximately a harmonic resonance frequency of electromagnetic excitation of molecules of the fluid to maximize heating thereof.

3. The system of claim 2 wherein the frequency is approximately sixty Gigahertz.

4. The system of claim 1 wherein said source of radiation includes a pulsed gyrotron to allow radar to be used on the vehicle and a continuous wave gyrotron, said pulsed and continuous wave gyrotrons located at engine of the vehicle and positioned for heat exchange between engine induction and exhaust flow and said gyrotron in order to enhance energy efficiency thereof, said pulsed and continuous wave gyrotrons producing ionization of the molecules of the fluid medium.

5. The system of claim 1 wherein said means for transmitting includes a set of waveguides interconnecting said source and the desired surface portions.

6. The system of claim 5 wherein said means for emitting includes an inverse cassagrain antenna for receiving radiation transmitted through said set of waveguides and emitting the radiation through the surface portions and into the fluid medium.

7. The system of claim 1 wherein said means for transmitting includes a mirror for deflecting and directing the beam to the desired surface portions.

8. The system of claim 1 wherein said means for transmitting, said means for emitting and said source are mounted within the vehicle.

9. The system of claim 1 wherein said source has sufficient power to provide the radiation at an energy density sufficient to heat the fluid medium to a temperature of approximately 1800 degrees Centigrade.

10. The system of claim 5 wherein said means for transmitting includes an output cassagrain antenna for directing a first portion of the radiation from said source into said waveguide and a second portion of the radiation from said source into a portion of the fluid medium proximal to the vehicle.

11. The system of claim 10 wherein said output antenna is connected to an outer surface of the vehicle for transmission of the radiation through the outer surface in order to heat an area of the fluid medium adjacent thereto.

12. The system of claim 1 wherein said means for producing includes:

a source of electrical current;

a set of coiled wires connected to said source and mounted in the vehicle, each of said set of coiled wires oriented and current flow therein directed to produce lines of force of the magnetic field oriented to propel the molecules of the fluid medium in a direction perpendicular to desired surfaces of the vehicle.

13. The system of claim 12 wherein said set of coiled wires are configured into loops.

14. The system of claim 1 wherein said means for producing includes a set of magnets mounted in said vehicle,

each of said set of magnets oriented to produce lines of force of the magnetic field oriented to propel the molecules of the fluid medium in a direction perpendicular to desired surfaces of the vehicle.

15. The system of claim 1 further including:

a means for collecting electron flow on surface portions of the vehicle;

a set of electrical wires connected to said means for collecting for receiving the electron flow therefrom in order to provide a flow of electrical current.

16. The system of claim 15 wherein said means for collecting includes a set of ion collector plates mounted adjacent the surfaces of the vehicle and insulated at edges thereof to prevent crossing over of the electron flow between vehicle surface portions in order to prevent neutralization of the electron flow.

17. The system of claim 1 wherein desired surface portions of the vehicle are composed of a material which is permeable to lines of force of the magnetic field.

18. A system for increasing the dynamic efficiency of a vehicle moving in a fluid medium, comprising:

a source of microwave electromagnetic radiation at a selected frequency of at least fifty Gigahertz;

means for transmitting said millimeter wavelength electromagnetic radiation from said source to desired surface portions of the vehicle, said means for transmitting receiving the radiation from said source;

means for emitting a beam of the radiation outwardly from the desired surface portions in order to heat and ionize the fluid medium thereby reducing mass density of the fluid medium to reduce dynamic drag on the vehicle, said means for emitting receiving the radiation from said means for transmitting;

means for producing a magnetic field proximal to the vehicle in order to provide a force for propelling ionized molecules of the fluid medium away from the vehicle.

19. The system of claim 18 wherein the radiation is at a frequency of approximately sixty Gigahertz for producing harmonic resonance electromagnetic excitation of oxygen molecules of the fluid medium to maximize heating thereof.

20. The system of claim 18 wherein said source of radiation includes a pulsed gyrotron to allow radar to be used in the vehicle and a continuous wave gyrotron, said pulsed and continuous wave gyrotrons located at engine of the vehicle and positioned for heat exchange between engine induction and exhaust flow and said gyrotron in order to enhance efficiency thereof.

21. The system of claim 18 wherein said means for transmitting includes a waveguide interconnecting said source and at least one of the desired surface portions.

22. The system of claim 18 wherein said means for emitting includes an inverse cassagrain antenna for receiving radiation transmitted through said means for transmitting and emitting the radiation through said at least one of the surface portions and into the fluid medium, said cassagrain antenna including a primary reflector having an aperture and a secondary reflector small relative to the primary reflector, said primary and secondary reflectors positioned so that the radiation is radiated through the aperture and reflected off the secondary reflector back into said primary reflector where it is reradiated into the fluid medium in a narrow beam the rays of which are divergent at an angle of approximately nineteen degrees.

23. The system of claim 18 wherein said means for transmitting includes a waveguide for propagating the radiation and a mirror mounted in said waveguide for deflecting and directing the beam to at least one of the desired surface portions without scattering thereof.

24. The system of claim 18 wherein said means for transmitting, said means for emitting and said source are mounted within the vehicle.

25. The system of claim 18 wherein said source has sufficient power to provide the radiation at a power density sufficient to continually heat the fluid to a temperature of approximately 1800 degrees Centigrade.

26. A system for increasing the dynamic efficiency of a vehicle moving in a fluid medium, comprising:

a source of electromagnetic radiation;

means for transmitting electromagnetic radiation from said source to desired surface portions of the vehicle, said means for transmitting receiving the radiation from said source;

means for emitting a beam of the radiation outwardly and away from the desired surface portions and away from the vehicle into the fluid medium so that the fluid medium absorbs substantially all the electromagnetic radiation energy thereof in order to heat the fluid medium thereby reducing mass density of the fluid medium to reduce dynamic drag on the vehicle, said means for emitting receiving the radiation from said means for transmitting, said surface portions adjacent to areas of the fluid medium heated by the radiation;

means for producing a magnetic field proximal to the vehicle in order to provide a force for propelling molecules of the fluid medium away from the vehicle.

27. A system for increasing the dynamic efficiency of a vehicle moving in a fluid medium, comprising:

a source of electromagnetic radiation at a frequency of approximately sixty Gigahertz;

means for transmitting electromagnetic radiation at the frequency of sixty Gigahertz from said source to desired surface portions of the vehicle, said means for transmitting receiving the radiation from said source;

means for emitting a beam of the radiation outwardly from the desired surface portions into the fluid medium in order to heat the fluid medium thereby reducing mass density of the fluid medium to reduce dynamic drag on the vehicle, said means for emitting receiving the radiation from said means for transmitting;

means for producing a magnetic field proximal to the vehicle in order to provide a force for propelling molecules of the fluid medium away from the vehicle.

28. A system for increasing the aerodynamic efficiency of an aircraft in flight and reducing the incidence and intensity of shock waves produced by the aircraft when flying at supersonic velocities, comprising:

a continuous wave gyrotron located in a jet engine of the aircraft and positioned for heat exchange between exhaust and intake flows of the engine and said gyrotron for enhanced energy efficiency thereof;

a pulsed gyrotron located in the jet engine of the aircraft and positioned for heat exchange between intake and exhaust flows of the engine and said pulsed gyrotron for enhanced energy efficiency thereof;

means for emitting a beam of the radiation outwardly from desired surface portions of the aircraft into the desired portions of the atmosphere proximal to the aircraft in order to heat the desired portions of the atmosphere thereby reducing mass density thereof to reduce dynamic drag on the aircraft, said means for emitting receiving the radiation from said continuous wave gyrotron and from said pulsed gyrotron;

means for producing a magnetic field proximal to the aircraft in order to provide a force for propelling molecules of the atmosphere away from the aircraft.

29. A system for increasing the dynamic efficiency of a vehicle moving in a fluid medium, comprising:

a source of millimeter wavelength electromagnetic radiation;

means for transmitting said millimeter wavelength electromagnetic radiation from said source to desired surface portions of the vehicle, said means for transmitting receiving the radiation from said source;

means for emitting a beam of the radiation outwardly and away from the desired surface portions in order to heat the fluid medium thereby reducing mass density of the fluid medium to reduce dynamic drag on the vehicle, said means for emitting receiving the radiation from said means for transmitting;

means for producing a magnetic field proximal to the vehicle in order to provide a force for propelling ionized molecules of the fluid medium away from the vehicle, the magnetic field having lines of force oriented generally perpendicular to the direction of ion flow over the desired surface portions and to the direction of motion of the vehicle relative to the fluid medium.

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