Nov. 14, 1961 F. A. DEAN 3,008,667

RAMJET DIFFUSER

Filed March 27, 1953

FIG. 1.

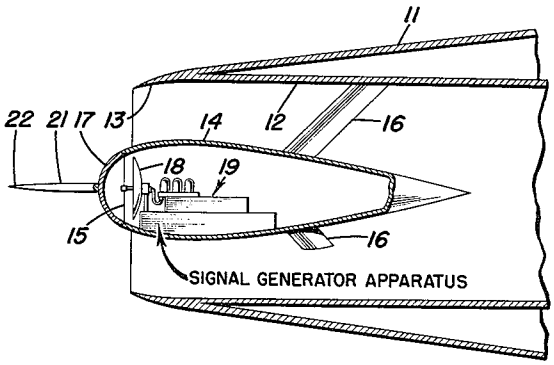


FIG. 2.

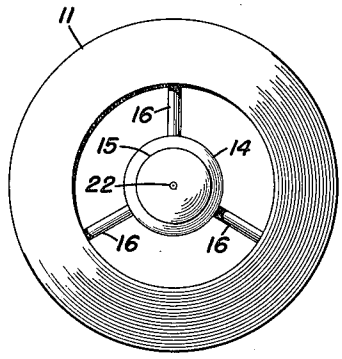


FIG. 3.

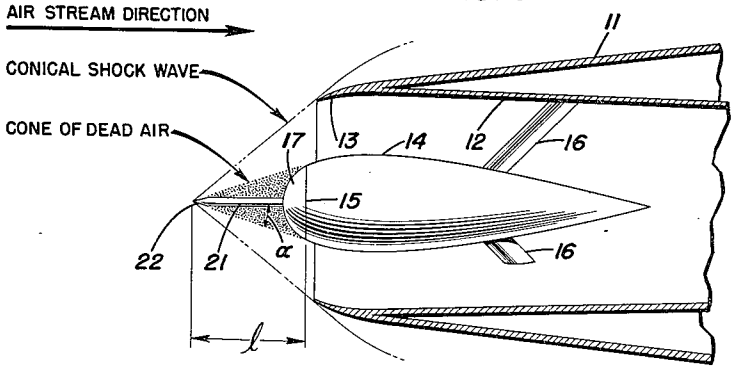
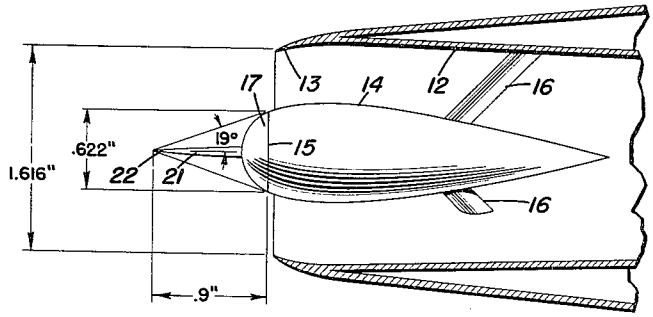


FIG. 4.



FRANK A. DEAN
INVENTOR.

BY O'Brien & Boxby & Warren
ATTORNEYS

United States Patent Office

3,008,667
Patented Nov. 14, 1961

3,008,667

RAMJET DIFFUSER

Frank A. Dean, Silver Spring, Md., assignor to the United States of America as represented by the Secretary of the Navy

Filed Mar. 27, 1953, Ser. No. 344,942
5 Claims. (Cl. 244—14)

This invention relates to diffusers for supersonic ramjet missiles and particularly to ramjet diffusers utilizing an oblique shock wave for pressure recovery in missles guided by dish radar homing systems.

The installation of a radar dish homing system in a ramjet missile is complicated by the necessity that the microwave radiating components of the system, e.g. the antenna and its radome, satisfy aerodynamic as well as optical requirements. For proper functioning, the radiating components of the homing system are situated in the foremost portions of the inner body of the missile. However, under these circumstances the solid, cone-like nose of the inner body, normally constituting a pressure recovery device in a ramjet diffuser, cannot be used without interfering with the transmission and reception of radar homing intelligence.

On the other hand, to eliminate the inner body nose is, of course, to eliminate its function as a pressure recovery device. To replace the inner body nose with a radome that is optically compatible with the distortion free transmission and reception of homing intelligence is to present to an oncoming airstream a blunt surface which cannot provide the required pressure recovery and which also increases the drag forces operating upon the missile.

The present invention is, therefore, intended to provide a device which is capable of functioning efficiently as a diffuser while at the same time permitting the freedom of operation of a radar dish homing system in a supersonic ramjet missile.

A further object of this invention is to provide a device which will furnish adequate pressure recovery to a supersonic ramjet missile without interfering with the transmission and reception of homing intelligence by a radar dish homing system carried in the missile.

A still further purpose of the invention is to provide a diffuser of simple but effective construction, for use in a supersonic ramjet missile and which will provide pressure recovery comparable to that attainable in prior diffusers.

Other objects and advantages of this invention will become evident from the teachings of the following detailed description, made in conjunction with the accompanying drawings, in which:

FIG. 1 represents an axial section, partly in elevation, of the forward portion of a supersonic ramjet missile illustrating diffuser constituting this invention;

FIG. 2 is a front elevation of the missile forward portion of FIG. 1;

FIG. 3 is an axial detail section, partly in elevation, of a ramjet diffuser according to the invention; the flow conditions obtaining when the diffuser is in operation being shown schematically; and

FIG. 4 is an axial section, partly in elevation, of a ramjet diffuser similar to those shown in FIGS. 1 and 2, illustrating an exemplary embodiment of this invention.

A brief summary, now, of the functions of an oblique

shock of Ferri type diffuser in a supersonic missile will be instrumental to a clear understanding of this invention. Any diffuser, in effect, may be considered as an air compressor which increases the pressure of air in two stages, i.e. (1) by retarding the flow of the air upon passage through a shock wave and (2) by decreasing the velocity of the air upon passage through an expanding duct. The latter of these two stages does not concern the present invention and, therefore, is omitted from the following discussion.

A Ferri type diffuser comprises a solid cone mounted on the inner body at and projecting forward of the inlet of the ramjet duct. At supersonic Mach numbers a conical shock wave having its apex coincident with that of the solid cone is formed in front of said solid cone and a normal shock wave is formed on or proximate to the inlet lip. If the missile is operating at its design condition the conical and the normal shock waves are attached to the lip of the ramjet inlet.

As the oncoming air passes through the conical shock wave its initial Mach number is reduced and supersonic compression is accomplished. When the conical shock wave is properly attached to the lip of the inlet and the back pressure in the diffuser is sufficient to sustain the normal shock wave on the inlet, all of the air passing through the conical wave necessarily enters the duct and contributes to high pressure recovery in the missile. At other than design conditions the oblique shock wave and the normal shock wave may be at positions either away from the inlet lip altogether or within the missile duct. Either of these positions is undesirable from the standpoint of optimum diffuser operation. When the normal and oblique shock waves are at any other position than on the inlet lip, the drag of the inlet is increased and the pressure recovery decreases.

Referring now to FIGS. 1 and 2, a forward portion of a ramjet missile is shown comprising a main body **11** having a central duct **12** formed with an inlet **13** and a streamlined inner body **14** having a plane frontal area **15**, said inner body being largely contained within said duct but partially projecting forward therefrom. The inner body **14** is secured to the main body **11** by struts **16** and supports a dielectric radome **17** on its frontal area **15**. Behind the radome **17** is situated a radar dish antenna **18** of the conventional type constituting a component of a dish homing system, the component parts of which are contained within the inner body **14**. A signal generating apparatus **19** mounted in the inner body **14** energizes the dish antenna **18**.

A tapered dielectric rod **21** of predetermined length, to be explained more fully hereinafter, and having a tip **22**, is mounted, axial to the missile, on the forward end of the radome **17** and projects forward of the main body **11**.

The operation of the diffuser will be appreciated more readily with reference to FIG. 3 which, similar to FIG. 1, illustrates a forward fragment of a supersonic ramjet missile. The structures depicted in both FIGS. 1 and 3 are the same, with like reference characters designating like elements. When the missile is subjected to a supersonic airstream, incurred in actual flight or artificially in a wind tunnel, with the rod **21** of proper length alined in the direction of flow, the high pressures which occur in front of the radome **17** are transmitted upstream through the subsonic boundary layer on said rod. These trans-

mitted pressures cause the boundary layer to separate from the rod and define a cone of relatively dead air, which cone modifies the flow outside the boundary layer.

This modified flow resembles that which would be obtained if an identically shaped solid cone were substituted for the cone of dead air. In addition, the pressure in the relatively dead air space within the conical, separated boundary layer is found to approximate the pressure on the surface of a substituted solid cone. Further pressure measurements throughout the region of flow reveal agreement with similar measurements if the cone of dead air were replaced with an identically shaped solid cone.

It is significant to point out that the half angle of the cone of dead air, i.e. the separation angle α, for a given inlet configuration remains approximately the same for all rod lengths beyond a critical length, hereinafter called the maximum effective length. Furthermore, the separation angle α has been found to change but slightly over a wide range of Mach numbers.

The maximum effective length is the length beyond which unstable and inefficient operation occurs. This length may be determined from the separation angle α and the inner body configuration and is to be distinguished from the true length. In defining the maximum effective length reference is made to FIG. 3 where the dead air region describes a cone having a half angle equal to the separation angle and a plane base defined by the line of tangency of the outer boundary of said cone with the surface of the inner body. The maximum effective length *l*, then is the altitude of this cone. The true length of the rod **21**, as shown in FIG. 2, is measured by the axial distance from the radome **17** to the apex of the cone described by the relatively dead air region.

As an illustration of how the maximum effective length is determined, the following typical example is given with reference to FIG. 4, wherein there is shown a ramjet diffuser similar in construction to the diffusers shown in FIGS. 1 and 2, with like reference characters designating like elements. The inlet **13** to the duct **12** is circular in cross-section having a diameter of 1.616 inches. It has been found that when an airstream of Mach number 1.8 is directed axially of the rod **21**, a cone of relatively dead air having a half angle or separation angle of approximately 19 degrees forms with its apex at the tip **22** of said rod. The plane base of the cone of dead air, as defined by the line of tangency of the outer boundary of said cone with the surface of the inner body **14**, is circular having a diameter of 0.622 inch. The altitude of this cone, i.e. the maximum effective length, is therefore .9 inch.

When a rod longer than is consonant with the maximum effective length is used a cone of dead air is formed by the separation of the subsonic boundary layer from the rod. As the back pressure within the central duct increases sufficiently to expel the normal shock wave the separation point, i.e. the apex of the cone of dead air, moves forward along the rod until the base of the cone corresponds to the total inlet area. This decreases the air flow through the duct and the back pressure decreases until the cone of dead air collapses and the separation point moves backward along the rod to its initial position. Air flow through the duct then increases and the back pressure rises to cause the separation point again to move forward along the rod. Successive repetition of this cycle results in the unstable and inefficient operation of the diffuser, since the normal and oblique shock waves are never attached to the lip of the inlet for any appreciable duration of the operation.

If the rod **21** is shorter than is consistent with the maximum effective length, the dead air region that is formed has an apex at the tip **22** but has a configuration which is no longer conical. Under these circumstances the optimum flow pattern is changed and the operation of the diffuser is stable although not as efficient as when the rod is consistent with the maximum effective length.

Therefore, the optimum operation, i.e. the most stable and efficient operation, of the diffuser is obtained when the rod is consistent with the maximum effective length because the oblique and normal shock waves are attached to the inlet lip substantially throughout the diffuser operation. Less than optimum, although stable, operation is obtained with a rod of shorter length than is consistent with the maximum effective length and unstable and inefficient operation is obtained when the rod is longer than is consistent with the maximum effective length.

A rod of proper length mounted on and projecting forward of an inner body which is supported at the inlet of a diffuser appears to function as efficiently as a solid cone in producing an oblique shock wave and in attaining a high pressure recovery. Furthermore, a rod causes very little interference to the transmission and/or reception of intelligence signals by a radar antenna mounted behind it. Thus, a slender rod of proper length satisfies both the aerodynamic requirements of a diffuser and the optical requirements of a radar homing system mounted in the forward portions of a missile.

Obviously many other modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described

What is claimed is:

1. A diffuser for a supersonic ramjet comprising, a central duct having an inlet at one end, an inner body having a face including a spherical cap mounted coaxially in the inlet of said duct, and a rod mounted coaxially on the face of said inner body external thereto and extending beyond said inlet, said rod being of critical length determined by constructing an imaginary cone of revolution coaxial with said duct and having a half angle equal to the separation angle of the subsonic boundary layer of air on said rod and a plane base defined by the line of tangency of the outer boundary of said cone of revolution with said inner body, the length of said rod being the minimum distance between said inner body and the apex of said cone.

2. A diffuser for a supersonic ramjet comprising, a central duct having an inlet at one end, an inner body mounted coaxially in the inlet of said duct, a radome mounted upon the forward end of said inner body, a radar dish antenna and radar signal generating apparatus mounted in said inner body behind said radome, and a rod coaxially mounted on said radome external thereto and extending beyond said inlet, said rod being of critical length determined by constructing an imaginary cone of revolution coaxially of said duct and having a half angle equal to the separation angle of the subsonic boundary layer of air on said rod and a plane base defined by the line of tangency of the outer boundary of said cone with said inner body, the length of said rod being the minimum distance from the radome to the apex of said cone.

3. A diffuser for a supersonic ramjet engine comprising, a main body having a central duct, a lip at the forward end of said main body defining the inlet to said duct, an inner body having a face consisting of a spherical cap, said inner body being mounted coaxially in said duct with said face extending forward beyond said lip, and a rod externally mounted on said face and extending forward coaxially with said duct.

4. A diffuser for a supersonic ramjet engine comprising, a tubular main body having a lip at the forward end and a central duct, an inner body mounted coaxially in said duct, said inner body having a forward portion formed of dielectric material suitably shaped to minimize aberration of electromagnetic waves transmitted therethrough, means carried within said inner body for the transmission and reception of electromagnetic waves, and a dielectric rod mounted centrally on said forward por-

tion of said inner body and extending along the axis of said duct beyond said lip.

5. A diffuser for a supersonic ramjet engine comprising, a main body having a central duct, an inner body having the forward portion thereof formed of a dielectric suitable for the transmission of high frequency radio waves, means carried within said inner body for the transmission and reception of high frequency radio waves, and a dielectric rod having a tip and a base, said base being mounted on said forward portion of said inner body and said tip projecting forward along the longitiudinal axis of said duct beyond its forward end, said rod being so constructed and arranged as to cause the formation of a conical shock wave flowing off the tip of said rod and a cone of dead air included within said conical shock wave and having its apex positioned at said tip.

References Cited in the file of this patent

UNITED STATES PATENTS

2,540,594	Price	Feb. 6, 1951
2,638,738	Salter	May 19, 1953

FOREIGN PATENTS

439,805	Great Britain	Dec. 6, 1935