My invention relates to reaction-propelled missiles and particularly to reaction-propelled underwater missiles. The use of such type propulsion means for propelling missiles is now quite well known and has been developed to a more or less great degree. However, the form of underwater missiles having such propulsion means are of the conventional form, i.e., they have an ogive or a more or less pointed front portion, an elongated center portion, and a conical or pointed rear portion, said rear portion, containing the steering and propulsion members of the body moves through a medium such as water is inherently unstable, fins are provided on the rear portion of the body to provide stability and allow control of the body. In such an elongated body without fins, the "center of pressure" is forward of its center of gravity. The "center of pressure" on such a body is a point on the body where a single force will produce the same effect as the integrated product of the pressures on the body times the area of the body subjected to said pressures. It is this condition which makes such a body inherently unstable. However, attachment of fins to the rear of the body moves the center of pressure behind the center of gravity and when the body tends to pivot about its center of gravity, the resultant force at the new center of pressure produces a restoring moment to the body. The magnitude of this moment is defined by the magnitude of the forces involved and the distance between the center of pressure and the center of gravity. For this reason, it is desirable to have the center of gravity as far forward as possible and the center of pressure as far rearward as possible. Also, when such a body travels at a very high speed through a medium such as water, cavitation will take place at the front and fins and negative dynamic pressures exist at the fin or rear parts, thus upsetting the pressure distribution and stability condition.

This arrangement has proved entirely satisfactory at the present day relatively low speeds of propeller-driven missiles. However, as mentioned previously, this arrangement develops an undesirable characteristics at high speeds and is highly objectionable at extremely high speeds.

In accordance with the present invention, there is provided an underwater missile having a conic shape through substantially its entire forward portion. In the preferred embodiment, a low-thrust slow-burning reaction-type venting motor or equivalent gas producing means is mounted in the rear portion of the forward portion of the missile and a high-thrust quick-burning reaction-type propulsion motor is mounted rearwardly of the venting motor. These venting motor pass between the walls and completely fill the space between the outer surface of the propulsion motor and the wall of the bubble formed by the passage of the missile through the water, thus maintaining the pressure in the bubble at a value at least as high as static pressure during the majority of the travel of the missile. The length and diameter of the propulsion motor is preferably such that during regular travel a slight deviation of the missile will cause the periphery of said motor to strike the bubble wall and during non-vent travel only a small rear portion will be in contact with the bubble wall.

One object of my invention is to provide a missile which is stable and controllable at substantially all speeds, especially the higher speeds. Another object of my invention is to provide a missile having a degree of stability at high and extremely high speeds not heretofore attainable. Another object of my invention is to provide a missile that does not require stabilizing fins. Still another object of my invention is to provide a body that cooperates in a new and unique fashion with reaction-type propulsion means. Another object of my invention is to provide a high-speed underwater missile having a minimum of cavitation and a maximum of stability not heretofore attainable. Still another object of my invention is to provide an underwater missile having the propulsion motor means mounted such as to aid in maintaining the stability of the missile. Another object of my invention is to provide an underwater missile wherein the center of pressure is maintained rearwardly of the center of gravity without the use of stabilizing means. Still another object of my invention is to provide a reaction-propelled underwater missile that is substantially not subject to negative dynamic pressures.

Another object of my invention is to provide a high-speed missile that is peculiarly adapted for travel in a dense medium or for travel at supersonic speeds through a compressible medium of variable density.

These and other objects and advantages of my invention will be better understood by reference to the accompanying description and drawing wherein like numerals refer to like parts and in which: FIGURE 1 shows a graph of the pressure distribution in any one plane on the body having a slight amount of cusp forming the profile of a cone; FIGURE 2 shows a graph of the pressure distribution in any one plane on the body having an increased cusp; FIGURE 3 is a longitudinal view, partly in section, of my missile in its simplest form; FIGURE 4 is a longitudinal view, partially in section, of a preferred embodiment of my missile according to the present invention; FIGURE 5 is a fragmentary longitudinal view showing the preferred relation of the rear portion of the missile and the bubble wall during regular travel; and FIGURE 6 is a fragmentary longitudinal view showing the preferred relation of the rear portion of the missile and the bubble wall during non-vent travel.

FIGURE 1 shows a graph of the pressure distribution in any one plane over one-half of a body with a small amount of cusp forming the profile of a cone. The ordinates represent the length of the body, the rear being at the extreme left and the front at the extreme right, and the abscissa represents dynamic pressure in pounds per square foot, shown on the graph as the pressure coefficient. FIGURE 2 shows a graph of the pressure distribution in any one plane over one-half of a body with increased cusp. The ordinates and abscissa for FIGURE 2 are identical with those of FIGURE 1. The dynamic pressure for both cases may be found by the formula:

\[ P = 0.5 \times P_0 \times V^2 \]

where "P" is the dynamic pressure, "P_0" is the pressure coefficient, and "V" is the velocity of the body in feet per second.
Zero, or "P", is static or reference pressure, i.e., the pressure on the body determined by the depth of the body in the water. It will be noted that in FIGURE 1 and FIGURE 2, the pressure line does not extend to the right-hand limit of the graph. This is due to the fact that the pressure on the nose is dependent on the bluntness of the nose and for a more blunt nose, the line will rise higher, and vice versa. With reference to FIGURE 1, it should be noted that for a body having a slight degree of cusping and approaching the profile of a cone, the pressure drops off in a rearward direction until just forward of the rear edge where it drops off rapidly to zero or static pressure. However, as shown in FIGURE 2, it will be noted that with increased cusping the pressure on the nose section is decreased and that it increases as one moves rearward and reaches a value greater than that shown in FIGURE 1. This effect is just the reverse of that for a cone and is due to the decreased cone angle at the nose and the increased angle of the surface of the rear portion of the body to the medium with respect to the longitudinal axis of the body. This effect is the basis for bowing adjustment of the location of the center of pressure, the determination of which will be more fully explained hereinafter. With reference to FIGURE 2, it will also be noticed that as the rear edge is approached, the pressure drops off to a negative pressure with respect to the reference or static pressure. This phenomenon is due to the cavity or bubble that is formed behind such body as it moves through the medium. When the effect of the bubble has been properly compensated for, as is more fully explained later herein, the pressure curve at the rear will take the form of the broken line with the indicated increases in pressure, and negative pressures will be eliminated as is not possible on present day torpedoes.

The station of center of pressure of my body equivalent to that previously described for conventional bodies, may be located by integrating the area enclosed by the pressure graph. It may also be located by using the formula:

\[ S_{lep} = \frac{L}{4} \left( \frac{1}{2} \pi - \frac{1}{2} \ln \left( \frac{L}{d} \right) \right) \]

where \( S_{lep} \) is the distance from the rear of the missile as shown in FIGURE 3, in a forwardly direction at the end of which is located the station of the center of pressure of the body, \( L \) is the length of the body in FIGURE 3, \( d \) is the largest or rear diameter of said body, and \( h \) is the greatest perpendicular distance between a point on the surface of said body and a straight line drawn from the periphery of the rear edge of said body and the position on or from a plane parallel to the periphery of said body, at which it is desired to only approximately locate the station of center of pressure.

Thus, the formula:

\[ S_{lep} = \frac{L}{4} \left( 1 - \frac{8}{3} \pi \sqrt{h/d} \right) \]

may be used where \( S_{lep} = "L", \ "h", \ and \ "d", \) are the same as defined above. For convenience, the station of center of pressure is written as: \( S_{lep} \) so that it is defined as a fraction of the total length of the body as shown in FIGURE 3.

It is to be noted that the particular operating parameters of a missile incorporating the present invention may vary within wide limits and will substantially determine the various critical dimensions of the body as indicated above; it not being impossible to specify such with any degree of accuracy. Further, the utilization and procedure for the application of operating parameters to the design of a missile after the principles of design and the design parameters are understood is quite well known to those experienced in the art and is not considered pertinent to my invention.

With reference to FIGURE 3, which is a representation of my body in its simplest form, the body comprises a front portion 10 which is substantially a point, a rear surface 11 which is substantially circular in shape, the periphery 13 of which is substantially perpendicular to the longitudinal axis of the body, and a surface 12 connecting the front 10 and the periphery 13 which increases in steepness concavely as it approaches the rear surface 11 whereby a cusp-shaped body of revolution is formed. A forward compartment 14 comprises the majority of the length of the body and is adapted to carry the load or explosive charge which preferably should also constitute the majority of the weight of the body so that the center of gravity of the body lies as far forward as possible in order to secure the maximum distance between the center of gravity and its station of the center of pressure.

An area 15 is formed at the rear portion of the body along the longitudinal axis and adapted to receive a propulsion motor of the reaction type and its associated parts. Said motor may be either a conventional solid fuel type or a liquid or gas fuel type. Obviously the diameter and length of area 15 will be dependent on the size and type of reaction motor that is used and whether cooling for the motor is considered necessary or not. A liquid fuel type motor is indicated schematically with a section broken away where the numeral 16 indicates a combustion chamber and the numeral 17 indicates an exhaust nozzle through which the combustion gases are exhausted in the conventional manner to form a thrust on the body. The injection means, the ignition means, and the like are not shown, since they may be of any conventional type and are not essential to the invention. Area 15 is surrounded by an annular area 19 and pressure is applied to the cavity or bubble that is formed by the missile such as, for example depth controls, test instruments, detection gear, control means, and the like. The dimensions of area 19 are dependent on the size and type of propulsion motor used and the type of instrumentation and controls, if any, that is desired to carry in the missile. No limitation with respect to the content of area 19 is intended other than that it is preferable that such not cause the center of gravity of the body to lie rearwardly of the center of pressure of the body.

A space 18 is located between the forward portion 14 and the motor area 15 for the storage of fuel and as shown in FIGURE 3, space 18 is adapted for the storage of a liquid or gaseous fuel. However, as mentioned previously herein, a solid fuel type motor may be used if desired and where such is the case, space 18 may be omitted as the circumstances may require. Further, if my missile is to be of the simple straight-nosed type as shown in FIGURE 1, the space 19 for the location of equipment, controls or the like in said area may be modified as desired and used for the storage of fuel and the like. Appropriate controlling mechanisms (not shown) may be associated with the body to control its movement over the surface of the water as desired. I have found that if a short length of the front portion of the missile is made movable such will provide a quick response and a large turning radius. If control means other than the control of the front portion of the missile is used, it is preferable that it be of the oscillatory type so that no obstructions are presented to and disturb the flow of water around and past the body when it is traveling in the desired direction. An example of control means would be a plurality of transversely movable spoiler plates or a circular ring mounted flush with surface 12 at or near periphery 13 and normally in a withdrawn or flush position and activated by or from means associated with the propulsion motor. If it is desired to change the normal direction of movement of the missile it would then only be necessary to cause the appropriate spoiler plate to be forced out into the water and then withdrawn to its normal position when the new direction or bearing has been attained. A ring type spoiler plate would operate in substantially the same manner except that it would be eccentrially driven.

A body constructed as I have indicated above will produce a stable high-speed missile having a minimum of
cavitation and a maximum of stability without the use of fins or the like to render it stable. FIGURE 4 shows an improved version of my body and a method and means for reducing to a minimum the negative dynamic pressures and the disadvantages inherent in the cavity or bubble mentioned previously. The numeral 30 indicates the main or front body portion of the missile having a point or front 31, a rear edge 32 circular in shape and concentric about the longitudinal axis of the body, and a surface 33 connecting the front 31 and the rear edge 32 which increases in steepness convexly in a rearward direction with regard to the longitudinal axis whereby a cusp is generated. The outside surface 33 of main body 30 delineates a cusp-shaped body of revolution as distinguished from a cone. The length of the main body, the degree of cusping, and the rear diameter of said body are dependent on design factors which may be determined from the formula:

\[ S_{rg} = L / A = 4 / 3 \left[ \frac{1}{4} - \sqrt{1 + \left( \frac{L}{d} \right)^2} \times 25 \times h / L \right] \]

which was explained previously herein. Broadly, the length of the main body portion and its rear diameter and degree of cusping are dependent on the desired location of the center of gravity of a particular missile incorporating the present invention. The load or charge-carrying portion of said missile 34 and occupies the majority of the length of the main body. As mentioned previously, this should constitute the majority of the weight and volume of the body in order that the center of gravity will lie as far forward as is possible. The fuel storage area 35 for the venting motor 49 should preferably be located immediately to the rear of area 34. Extending inwardly and forwardly from rear surface 36 is a circular venturi wall 37 having its rearward portion convex in shape and its forward portion concave in shape, said forward portion being spaced away from wall 36 whereby the inner surface of said rearward portion and the outer surface of said wall 46 form a ring venturi or throat 56. Rigidly connected to the forward end of venturi wall 37 and extending forwardly and concentrically about the longitudinal axis of the body is a cylindrical wall 38. Connected to the forward end of cylindrical wall 38 is a transverse wall 39. Venturi wall 37, cylindrical wall 38, annular wall 39, and surface 33 form an instrumentation space 41 wherein such instruments, controls, indicating equipment or the like as may be desired may be carried in the missile. Motor section 42 is comprised of a forward venting motor portion 43 and a rearward propulsion motor portion 44. The venting motor portion 43 is preferably comprised of a plenum chamber 45 formed by walls 46, 54 and venting motor area 47 forward of chamber 45 adopted to receive a reaction type venting motor gas producing means of the low-thrust long-burning type. The venting motor area 47 is preferably enclosed by a cylindrical forward extension 48 of the plenum chamber wall 46, said extension 48 being adapted for rigid connection to cylindrical wall 38 whereby the motor section 42 may be rigidly and securely connected to the missile body.

My venturi construction is preferable for exhausting the venting gases into the bubble and, as is obvious, such a construction requires that wall 46, wall 48, and venturi wall 37 be of such construction as to provide sufficient rigidity of motor portion 42 with regard to the main body portion 30. However, it is to be understood that departures may be made from this preferred construction with regard to exhausting the venting gases and mounting of the motor portion that will still effect substantially the same result as my venting means described herein.

Extension 48 may be connected to wall 38 in any suitable manner whereby sufficient rigidity is attained and heat transmission from area 47 to area 41 is kept to a minimum.

If desired, the inside surface of extension 48 and wall 39 may be lined with a ceramic material or the like having a high heat transfer time constant to aid in insulating the areas surrounding area 47 from the heat generated by venting motor 49 when in use.

The above is given only by way of an example and other equally efficient means and methods will readily occur to those experienced in the art for application to the requirements of my missile.

Venting motor 49 is comprised of a combustion chamber 51 and exhaust nozzle 52. Exhaust nozzle 52 may be connected to the combustion chamber 51 in any conventional manner and concentrically joined to the forward inside periphery of wall 46 at point 53. Plenum chamber 45 is closed by circular wall 54, said wall being suitably adapted to receive and diffuse the exhaust gases from venting motor 49. Slots or holes 55 are preferably formed in the forward portion of the plenum chamber wall 46, the area of each slot or hole being of about the same order of magnitude as the area of the throat 56 formed by walls 37, 46. The total area of slots 55 is not considered critical, it only being necessary that said total area be sufficient that an excessive back pressure on motor 49 is not developed.

The propulsion motor portion 44 is preferably rigidly connected to motor portion 43 although it may be integral if desired. Said propulsion motor portion 44 comprises a propulsion motor area 57 similar to venting motor area 47 having located therein a combustion chamber 58, and exhaust nozzle 59, plumbing, ignition means, and the like (not shown) necessary for operation of the propulsion motor, and a fuel storage area 61 surrounding said propulsion motor. Cylindrical wall 62 encloses area 57 and may form the inner wall of fuel storage area 61, the forward portion of said wall 62 being suitably joined to wall 54 and the rear portion being suitably joined to rear wall 63 wherein fluid and/or gas may be retained without danger of leakage. Area 61 must, of course, be suitably insulated from the heat generated by the propulsion motor and the type and amount of insulation will be proportional to and dependent on the size and type of propulsion motor used. As mentioned previously, various conventional methods and means for the insulation of reaction type motors is now quite well known in the art and are readily adaptable to my missile. Rear wall 63 preferably is a flat circular wall having a diameter equal to or greater than the diameter of ring 36 for reasons that will more fully explained later herein. The propulsion motor must be located concentrically along the longitudinal axis of the missile as is venting motor 49. As mentioned previously, the propulsion motor may be of either the conventional solid fuel or the liquid fuel type. However, the propulsion motor is distinguished from the venting motor in that it must be a high-thrust quick-burning type whereas the venting motor must be of the low-thrust low-burning type.

The precise relation between the length and diameter of a so-called "cavitation" bubble is complex and is fully discussed in Office of Naval Research Report and Transactions Number 766, October 1947; H. Reichardt "The Laws of Cavitation Bubbles At Axially Symmetrical Bodies in a Flow."

The relation between the length and diameter of the cavitation bubble is dependent upon the cavitation coefficient

\[ \sigma = \frac{P_2 - P_0}{1/2 \rho V^2} \]

where "\sigma" is the cavitation coefficient, "P_0" is the ambient static pressure, "P_2" is the pressure in the bubble, "\rho" is the density of the water, and "V" is the velocity of the body.

For a bubble length "l" and a rear diameter "d" of wall 63, d/l should equal about 0.02 to 0.8 for a \sigma of about 0.02 for regular travel and a \sigma of about 0.3 for non-
vented travel. As used herein, "non-vented" travel means travel of the missile after the propulsion and venting motors have ceased operation and "regular" travel means travel when at least the venting motor is operating. It should now be obvious that when a e has been prescribed and achieved by sufficient venting, the relation between the front cone angle and the rearward thrust of the exhaust gases through exhaust nozzle 59 causes the missile to move forward through the water at preferably a high rate of speed. As previously explained, a cavity is formed behind the missile, beginning substantially at edge 32 and extending rearwardly past rear wall 63 of the propulsion motor portion. Due to the cusp shape of main body 30, the forward portion of the wall of the cavity is formed entirely of wall and past the rearwardly extending cavity portion 44, said forward portion being substantially circular convex in form. The diameter of rear wall 63 being preferably of such diameter that the periphery thereof is immediately adjacent to the surface of cavity wall 65, the exhaust gases of the venting motor completely fill the space between the cavity wall 65 and the periphery of propulsion motor portion 44. The gases generated in combustion chamber 51 of venting motor 49 are exhausted into chamber 45 through exhaust nozzle 52. Said gases expand and impinge on the rear wall 54 of chamber 45, thus reducing their velocity and completely filling said chamber 45. As the pressure in said chamber builds up, the gases in turn are forced out through slots or ports 55 and further expand into cavity 64. Due to the location and angle of said slots 55, the gases impinge on the concave section of the cavity 64 and are directed in a forwardly direction, thus filling said cavity and further reducing their velocity. When cavity 64 becomes filled, the exhaust gases are in turn forced out through throat 56 of the ring venturi. It is to be noted that for this embodiment the final exit velocity of the exhaust gases of the venting motor is below the initial velocity of said gases and do not materially aid in the propulsion of the missile. It may be further noted that if the initial velocity of the gases through exhaust nozzle 52 may be exhausted at a sufficiently low velocity, cavity 64 may be eliminated and slots 55 or the like relocated such that the gases passing therethrough will be directed directly into throat 56. The venting motor should preferably continue to operate after the thrust motor has stopped in order to keep the remaining cavity filled to substantially static pressure and negate the undesirable effects of an unfilled cavity. As the exhaust gases of the venting motor leave the ring venturi, they further expand and completely fill the space between the wall of cavity 65 and the periphery of propulsion motor portion 44. As long as the pressure exerted on the surface of the water forming the cavity is at least static pressure, substantially no undesirable effects, such as for example, negative dynamic pressures, will be created by the cavity. As said gases pass over the periphery of said rear wall 63, they combine with the exhaust gases of the thrust motor to fill the balance of the cavity. Since the front 31 is substantially a point, little or no cavitation occurs there as the body passes through the water. Further due to the cusp-shaped smooth surface 33 a positive pressure is always present on said surface and substantially no cavitation occurs along the entire length of the main body 30 as it moves through the water. Still further, no cavitation is present on the propulsion motor portion 44 during regular travel due to the fact that it is entirely contained within the bubble or cavity and little or no cavitation occurs during non-vented travel due to the fact that all but a small portion is contained within the now charged bubble or cavity. It may now be obvious that little or no cavitation occurs on the missile due to disturb its stability characteristics, and the missile remains stable, said stability being independent of velocity and the velocity being substantially limited only by the thrust that the propulsion motor can develop.

In addition to the numerous advantages of the present invention previously enumerated, it may now be further obvious that even for the case of a simple straight-running missile as herein described, said missile provides substantial practical and tactical advantages over present-day torpedoes, i.e., it can be fired from substantially large distances and, due to its stability and high speeds, reach...
its target before being detected or substantial evasive action can be taken to avoid it. Still further, I have found that with certain modifications a missile incorporating the present invention is highly useful as a missile designed to be fired out of the earth's atmosphere and to re-enter the atmosphere at some point. Conventional missiles having main control surfaces are not entirely satisfactory in that said surfaces are burned off, seriously damaged, or incapacitated due to the heat generated therein during re-entry into the atmosphere. Since my missile requires no such stabilizing surfaces this problem is completely eliminated, the missile remaining stable at substantially all times during supersonic travel.

For purposes of re-entry into the earth's atmosphere, if the front surface of the main body is modified to be or become a relatively flat or blunt circular disc, such as for example by making the extreme front portion removable or by forming it of a material or materials that will be burned away by friction only until a relatively flat front surface having the necessary diameter is secured, the resulting front surface will cause the initial shock wave to be shifted away from the body. Under these conditions substantial heating will occur only at the periphery of the flat or blunt front surface; hence only the periphery of the front surface need be cooled or made of a ceramic material or the like sufficient to withstand the heat generated at this point. Due to the cusp shape of the main body portion and the resulting positive pressures on the body additional substantial heating will occur only at the rear edge or periphery of the main body portion. The detrimental effects of heating at this point may be alleviated by forming said rear periphery of a suitable ceramic material similar to or the same as that used at the front periphery of the missile and modifying the venting motor and the means for exhausting the exhaust gases of the venting motor whereby the exhaust gases will be exhausted at a velocity sufficient to shift the trailing shock wave away from the rear periphery of the main body portion. If the exhaust is a coolant, additional benefits may be derived.

This invention is not limited to the particular details of construction, materials, and processes described, as many equivalents will suggest themselves to those skilled in the art. It is accordingly desired that the appended claims be given a broad interpretation commensurate with the scope of the invention within the art.

What I claim is:
1. In an elongated missile the combination comprising: a front surface that is substantially a point; a rear surface having an opening therein concentric about the longitudinal axis of the missile, said rear surface having a diameter greater than said front surface and concentric therewith; a surface connecting said front surface and said rear surface, said connecting surface having a continuous ceratoid cusp shape and a length considerably greater than its largest diameter; a reaction motor, said motor being mounted forward of said opening and concentric about the longitudinal axis of said missile and adapted to propel said missile in a forwardly direction; a first closed compartment surrounding and separated from said reaction motor; and a second compartment comprising the majority of the forward length of the missile having located therein the majority of the weight of said missile whereby the center of gravity of said missile is located in a forwardly direction, the cusing of said connecting surface being such that the center of pressure of said missile lies rearwardly of said center of gravity.
2. The combination as defined in claim 1 wherein the reaction motor is of the liquid fuel type and a fuel storage compartment is provided between said first and second compartments.
3. In a missile the combination comprising: a main body portion, said main body portion being comprised of a front portion, an annular rear surface having a diameter greater than said front portion and concentric therewith, a surface connecting said front portion and said rear surface, said connecting surface having in general a ceratoid cusp shape and a length considerably greater than its largest diameter, a first compartment comprising the majority of the length of said main body portion having located therein a substantial portion of the weight of said missile and a reaction motor mounted rearwardly of said first compartment and concentric about the longitudinal axis of the missile, and a second compartment surrounding and separated from said first reaction motor; a rear motor portion; means rigidly connecting said rear motor portion and said main body portion and adapted to receive and exhaust the gases of said first reaction motor around and past said rear motor portion; and a second reaction motor, said second reaction motor being mounted in said rear motor portion concentric about the longitudinal axis of said missile and adapted to propel said missile in a forwardly direction.
4. In a missile the combination comprising: a main body portion, said main body portion being comprised of a front portion, an annular rear edge having a diameter greater than said front portion and concentric therewith, a surface connecting said front portion and said rear edge, said connecting surface having in general a ceratoid cusp shape and a length considerably greater than its largest diameter, a first compartment comprising the majority of the length of said main body portion having located therein a majority of the weight of said missile, a first reaction motor mounted rearwardly of said first compartment and concentric about the longitudinal axis of the missile, and a second compartment surrounding and separated from said first reaction motor; a rear motor portion; means rigidly connecting said rear motor portion and main body portion and adapted to receive and exhaust the gases of said first reaction motor around and past said rear motor portion; and a second reaction motor, said second motor being mounted in said rear motor portion concentric about the longitudinal axis of said missile and adapted to propel said missile in a forwardly direction, the cusing of said connecting surface being such that the center of pressure of said missile lies rearwardly of the center of gravity of said missile.
5. In a missile the combination comprising: a main body portion, said main body portion being comprised of a front portion, an annular rear edge having a diameter greater than said front portion and concentric therewith, a surface connecting said front portion and said rear edge, said connecting surface having in general a ceratoid cusp shape and a length considerably greater than its largest diameter, a first compartment comprising the majority of the length of said main body portion having located therein a substantial portion of the weight of said missile whereby the center of gravity of said missile lies forwardly of the otherwise normal location of the center of gravity, a first reaction motor mounted rearwardly of said first compartment and concentric about the longitudinal axis of the missile, and a second compartment surrounding and separated from said first reaction motor; a rear motor portion, said rear motor portion having a forward taper; means rigidly connecting said rear motor portion and said main body portion and adapted to receive and exhaust the gases of said first reaction motor around and past said rear motor portion; and a second reaction motor, said second motor being mounted in said rear motor portion concentric about the longitudinal axis of said missile and adapted to propel said missile in a forwardly direction, the cusing of said connecting surface being such that the center of pressure of said missile lies rearwardly of the center of gravity of said missile.
6. In a missile the combination comprising: a main body portion, said main body portion being comprised of a front portion, an annular rear edge having a diameter greater than said front portion and concentric therewith,
a surface connecting said front portion and said rear edge, said connecting surface having in general a cusp shape and a length considerably greater than its largest diameter, a first compartment comprising the majority of the length of said main body portion having located therein a substantial portion of the weight of said missile where the center of gravity of said missile lies forwardly of the otherwise normal location of the center of gravity, a first reaction motor mounted rearwardly of said first compartment and concentric about the longitudinal axis of the missile, and a second compartment surrounding and separated from said first reaction motor; a rear motor portion having a second front portion and a rear portion, said rear portion being larger than said second front portion; a second reaction motor, said second motor being mounted in said rear motor portion concentric about the longitudinal axis of said missile and adapted to propel said missile in a forwardly direction; and means rigidly connecting said rear motor portion and said main body portion and adapted to receive and exhaust the gases of said first reaction motor around and past said rear motor portion, the cupping of said connecting surface being such that the center of pressure of said missile lies rearwardly of the center of gravity of said missile.

7. In a missile adapted for travel in water the combination comprising: a forward body of revolution having in general a cusp shape, said body having a front surface that is substantially a point, an annular rear surface having a diameter greater than said front surface and concentric therewith, a first compartment comprising the majority of the length of said body having located therein a substantial portion of the weight of said missile, a first reaction motor mounted rearwardly of said first compartment and concentric about the longitudinal axis of the missile, and a second compartment surrounding and separated from said first reaction motor; a rear motor portion, said rear motor portion having a rearward diameter greater than its forward diameter; means rigidly connecting said rear motor portion and said main body portion and adapted to receive an exhaust the gases of said first reaction motor around and past said rear motor portion; and a second reaction motor, said second motor being mounted in said rear motor portion concentric about the longitudinal axis of said missile and adapted to propel said missile in a forwardly direction.

8. In a missile adapted for travel in water the combination comprising: a forward relatively slender body of revolution having in general a cusp shape, said body having a front surface that is substantially a point, an annular rear surface having a diameter greater than said front surface and concentric therewith, a surface connecting said front surface and said rear surface having a length greater than its greatest diameter, a first compartment comprising the majority of the length of said body having located therein a substantial portion of the weight of said missile, a first low-thrust reaction motor mounted rearwardly of said first compartment and concentric about the longitudinal axis of the missile, and a second compartment surrounding and separated from said first reaction motor; a rear motor portion disposed rearwardly of said annular rear bearing having a front portion and a rear portion, said rear portion having a diameter such that a small deflection of the missile during regular travel will cause said rear portion to touch the wall of the bubble; a second high-thrust reaction motor, said second motor being mounted in said rear portion concentric about the longitudinal axis of said missile and adapted to propel said missile in a forwardly direction; and means rigidly connecting said rear motor portion and said forward body adapted to receive and exhaust the gases of said first reaction motor around and past said rear motor portion comprising a plenum chamber adapted to receive the exhaust gases of said first reaction motor and disposed inwardly from said second chamber rear wall and adapted to form the inside surface of a ring venturi, said plenum chamber having a plurality of openings whereby said gases may be exhausted through said ring venturi, the cupping of said body being such that the center of pressure of said body lies rearwardly of the center of gravity of said body.

9. In a missile adapted for travel in water the combination comprising: a forward relatively slender body of revolution having in general a cusp shape, said body having a front surface that is substantially a point, an annular rear surface having a diameter greater than said front surface and concentric therewith, a surface connecting said front surface and said rear surface having a length considerably greater than its greatest diameter, a first compartment comprising the majority of the length of said body having located therein a substantial portion of the weight of said missile, a first low-thrust reaction motor mounted rearwardly of said first compartment and concentric about the longitudinal axis of the missile, a second compartment surrounding and separated from said first reaction motor, said second compartment having a rear wall extending inwardly and forwardly and forming the outside surface of a ring venturi; a rear motor portion disposed rearwardly of said annular rear bearing having a front portion and a rear portion, said rear portion having a diameter such that a small deflection of the missile during regular travel will cause said rear portion to touch the wall of the bubble; a second high-thrust reaction motor, said second motor being mounted in said rear portion concentric about the longitudinal axis of said missile and adapted to propel said missile in a forwardly direction; and means rigidly connecting said rear motor portion and said forward body adapted to receive and exhaust the gases of said first reaction motor around and past said rear motor portion comprising a plenum chamber adapted to receive the exhaust gases of said first reaction motor and disposed inwardly from said second chamber rear wall and adapted to form the inside surface of a ring venturi, said plenum chamber having a plurality of openings whereby said gases may be exhausted through said ring venturi, the cupping of said body being such that the center of pressure of said body lies rearwardly of the center of gravity of said body.

10. The combination as defined in claim 9 wherein said second compartment is adapted to contain means for controlling the missile and additionally including a third compartment surrounding and separated from said second reaction motor.

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