May 13, 1952 E. B. BRADFORD ET AL 2,596,644

AUTOMATICALLY DETACHABLE FLASHLESS NOZZLE FOR ROCKETS

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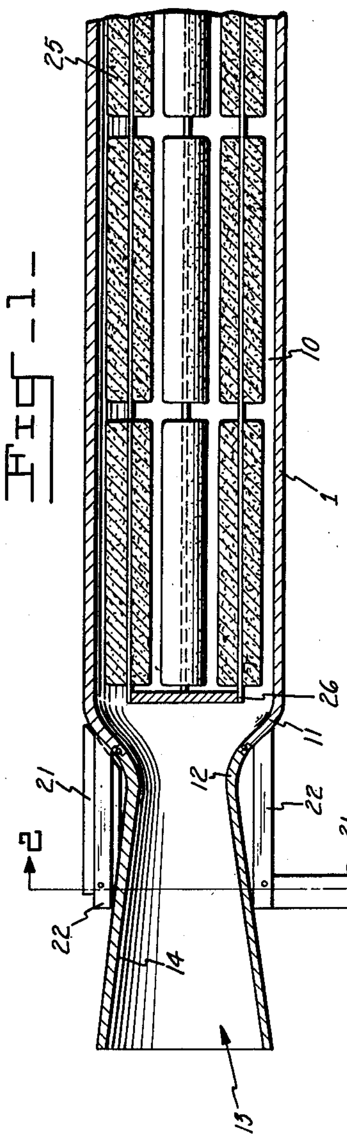

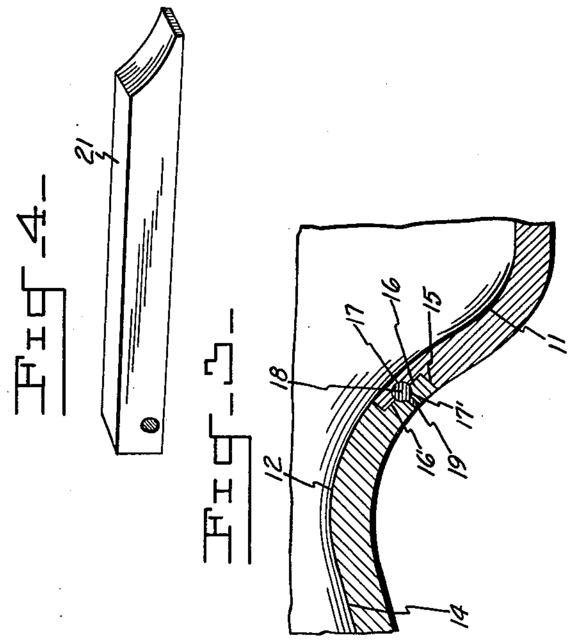

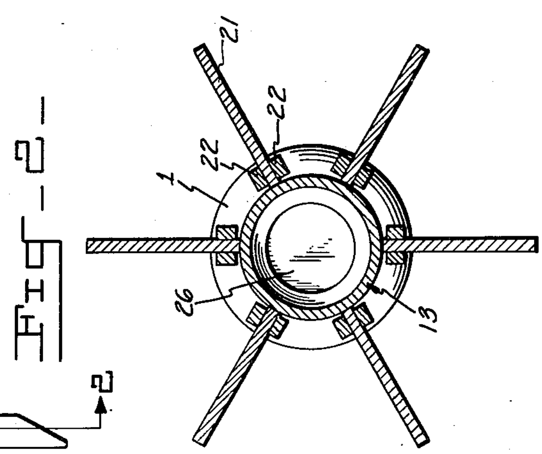

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Fig-5-

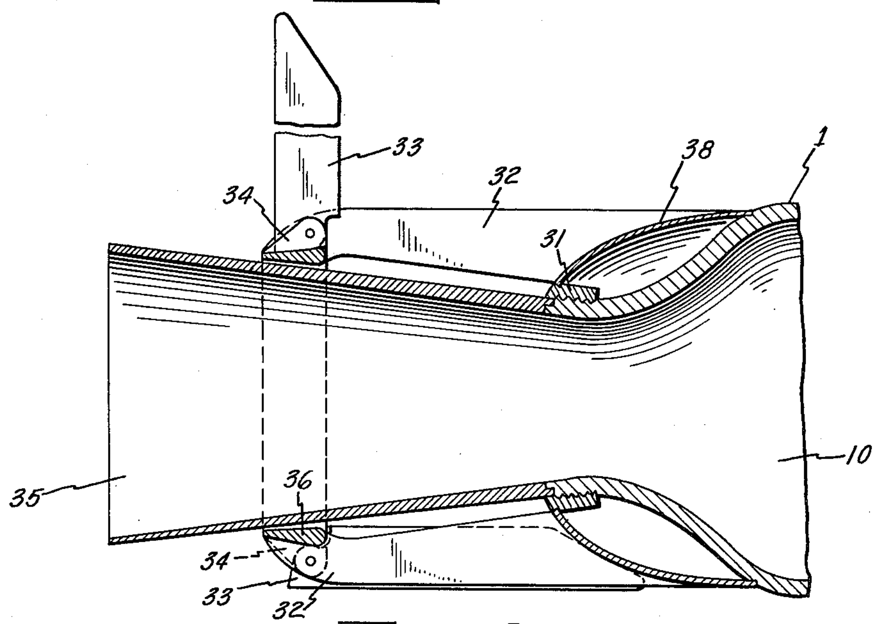

Fig-6-

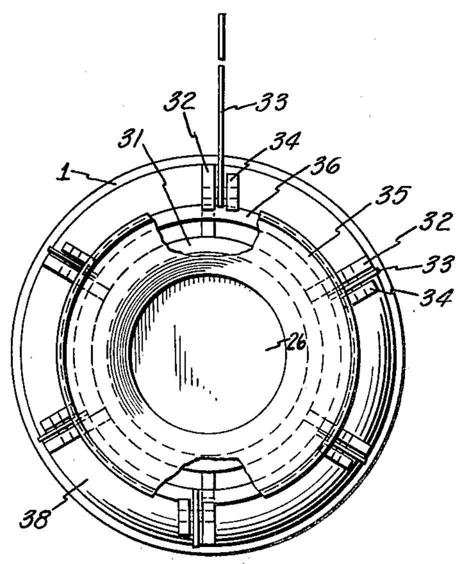

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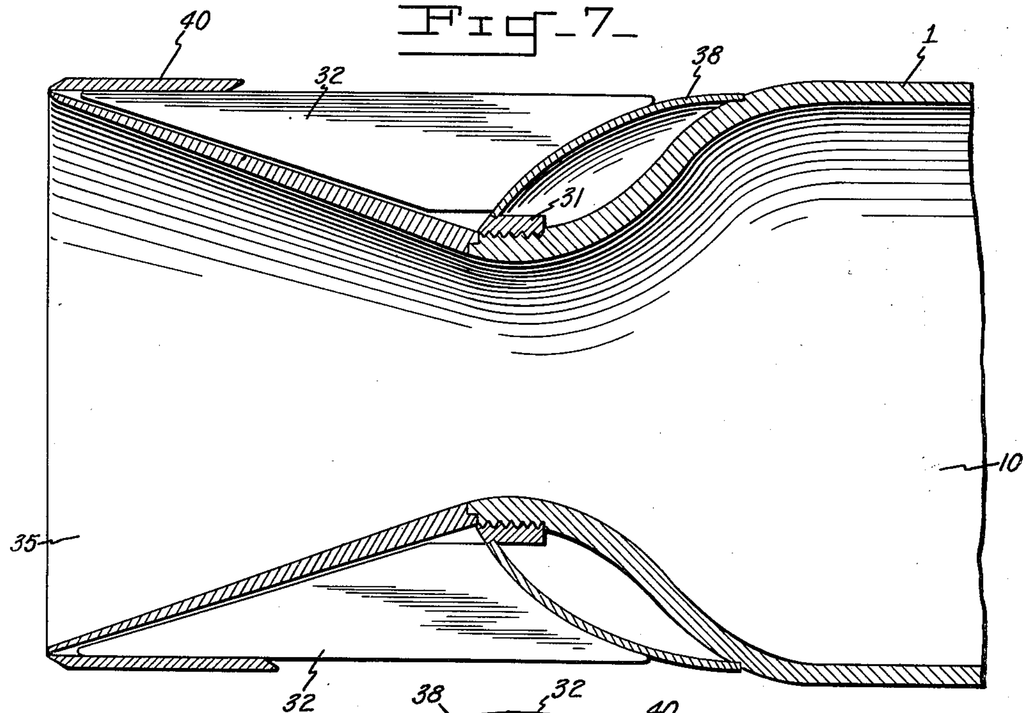
Fig. 7



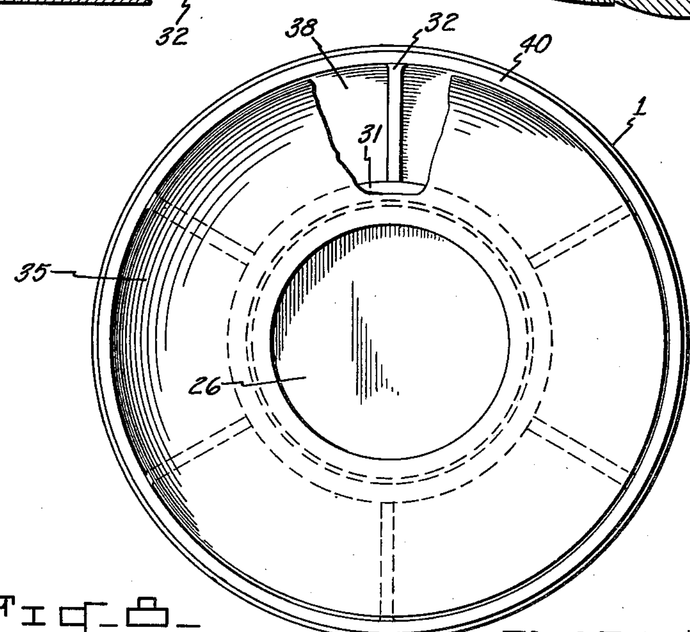


Fig. 8

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AUTOMATICALLY DETACHABLE FLASHLESS NOZZLE FOR ROCKETS

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20 Claims. (Cl. 60—35.6)

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This invention relates to jet reaction devices, particularly to jet reaction devices of the rocket projectile type useful especially for military purposes.

The jet reaction device of this invention consists mainly of a cylindrical housing forming a a motor combustion chamber and containing within its interior a propellent material such as a double-base powder composed of nitroglycerin and nitrocellulose. This propellent material is combustible to generate a hot propellent fluid under pressure. There is secured to the motor chamber, preferably at its rear end, a nozzle which provides for a high velocity exit of the propellent fluid.

The rockets of this invention are also characterized by the fact that their free-flight burning time is but a small fraction of the total time of free flight. As a consequence, it has been impracticable prior to this invention to provide a large nozzle for expanding the gases to obtain a maximum propulsion efficiency, because the increase in velocity obtained by the increase in expansion is more than offset by the increase in air resistance drag produced by the large nozzle. Consequently, in prior designs it has been the practice to utilize a nozzle which is more or less of a compromise between propulsion and aerodynamic efficiency.

The nozzle which is described above and which is utilized in this invention is essentially a steady-flow device in which there results an exchange in the form of energy of the flowing fluid, from internal pressure energy to kinetic energy. It has been demonstrated by theoretical analysis and confirmed by experiment that the angle of exit flare of the nozzle is not particularly critical between 8° and 32° total included angle, and in practice we have preferred to remain substantially within these limitations. Consequently, if the flare angle is small the length of the nozzle must be considerably increased over prior designs if a sufficient volume is to be provided for the gases to attain the desired expansion. Furthermore, since it is frequently desirable to fire these rockets from a projector tube, the maximum diameter of the nozzle is limited to the over-all diameter of the rocket. There is, therefore, a limit in the amount the gases may be expanded.

The rockets of this invention must also be stabilized in free flight. It has been the practice prior to this invention to utilize folding fins and to secure these fins to the nozzle at its end. This folding fin assembly of prior constructions further limited the maximum nozzle diameter and the

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amount of expansion. In the fin assembly of this invention the nozzle is extended beyond the fins.

In order to improve the propulsion and aerodynamic efficiencies of rockets, this invention provides means by which the advantages of large nozzles, that is, those having terminal diameters approaching the diameter of the motor chamber or even equaling it, could be utilized without lessening the areodynamic efficiency of the rocket in free flight. In accordance with this invention this objective is attained by providing a rocket motor in which the nozzle thereof is so constructed and attached to the main body of the projectile that after the burning of the rocket propellent has been completed, the nozzle will automatically separate from the rocket body. This dropping away of the nozzle materially reduces the drag of the rocket and improves its aerodynamic efficiency in free flight towards its objective. By virtue of this construction it is possible to utilize a large nozzle for expanding the gases to a higher degree than was practical heretofore to obtain better propulsion efficiencies. The inherent areodynamic disadvantages of such large nozzles are avoided in this invention by the construction which permits release of the nozzle during the portion of the rocket trajectory wherein it serves no useful purpose.

It has also been discovered, in accordance with this invention, that when these improved nozzles are utilized to expand the gases to a temperature and pressure much lower than has been possible heretofore, that a substantially flashless jet can be obtained by utilizing flash reducing agents in the propellent in such fashion that the discharged gases emitted from the open end of the nozzle do not ignite upon contact with the atmosphere. Accordingly, the flash and luminous flame heretofore inherent in the operation of such rockets is substantially eliminated.

The prior art is replete with so-called flashless propellants, many of them contain as the flash inhibitor metallic salts such as potassium nitrate, barium nitrate, etc., while others may contain hydrocellulose, abietates, etc. Most of these added ingredients have some effect on reducing flash when the propellant is used in guns, but their effect is hardly discernible in jet propelled devices where burning continues to take place after the projectile has left the confines of its projector tube. We have discovered, however, that when the nozzle has a relatively large diameter at its rear end, preferably a diameter not less than 80% of the over-all diameter of the motor chamber, the flash reducing constituents of the propellant become much more effective. If the flash reducing constituent is potassium nitrate, which is a preferred constituent, it is believed that the potassium nitrate serves as an oxidizing agent and provides the oxygen necessary to complete the combustion of the gases in their expansion in the nozzle. It is believed that this accounts for the fact that the application of this invention provides a nearly flashless jet reaction device, but we do not wish to be bound by the theory presented herein.

Accordingly, it is an object of this invention to provide an improved rocket projectile having outstanding advantages for military applications.

A further object of this invention is to provide a rocket projectile having a nozzle permitting a high degree of expansion of the propellent fluid but whose ballistic properties are not detrimentally affected by such nozzle.

Another object of this invention is to provide an improved nozzle construction for a rocket projectile characterized by the fact that such nozzle is automatically detachable from the projectile upon completion of flow of propellent fluid therethrough.

A particular object of this invention is to provide a substantially flashless jet reaction device.

The specific nature of this invention as well as other objects and advantages thereof will clearly appear from a description of a preferred embodiment as shown in the accompanying drawings in which:

Fig. 1 is a fragmentary elevational view in a longitudinal section of a rocket motor combustion chamber and nozzle assembly;

Fig. 2 is a cross-sectional view taken along line 2—2 of Fig. 1;

Fig. 3 is an enlarged partial view of Fig. 1 showing the method of securing the nozzle to the combustion chamber;

Fig. 4 is an enlarged view of the fin supporting arm of Fig. 1;

Fig. 5 is an elevational view in section of a preferred modification of the structure shown in Fig. 1;

Fig. 6 is an end view of Fig. 5;

Fig. 7 is a longitudinal view in section of a modification employing fixed fins; and

Fig. 8 is an end view of Fig. 7.

Referring now to the drawings, and more particularly to Fig. 1, the rocket comprises a generally cylindrical body member 1 defining a combustion chamber 10 and having a rearwardly inwardly flared entrance 11 leading to a constricted throat 12 of a nozzle 13. The nozzle 13 is actually formed of two parts, a separately formed rearwardly, outwardly flared exit 14 and the constricted throat 12 integrally formed with the combustion chamber. It should be understood, however, that the term "nozzle" utilized includes that portion of the steady-flow device which expands the gases without necessarily excluding the throat portion. In other words, it is contemplated that the nozzle may be secured to the motor combustion chamber at any one of a number of points. In any event, that portion of the nozzle which is permitted to fall free of the rocket motor may or may not include the throat.

As illustrated in Fig. 1, the interior surface of the motor chamber at the end to which the nozzle flare 14 is secured is undercut to provide a shoulder 15 and a flat contact surface 16 (Fig. 3). The throat end of the nozzle is cut away in a complementary manner and the wide contact surfaces 16 and 16' of the motor and nozzle respectively may be machined to insure accurate line-up of the two parts. Surfaces 16 and 16' each have a groove 17 and 17' cut therein, as shown in Fig. 3, to provide a recess into which a low melting point metal 18 may be flowed when the two parts are assembled for the purpose of holding the parts firmly together. Drilled openings 19 are provided in the nozzle leading to groove 17' to facilitate filling such groove with the low melting point metal 18.

A plurality of pairs of radially projecting, rearwardly extending arms 22 are welded in spaced relationship to the periphery of the rocket motor combustion chamber as shown in Fig. 2, so that fins 21 may be pivoted between these arms. Suitable strengthening or reinforcing may be employed, consistent with good practice and design, to further strengthen and support arms 22; and the construction must, of course, be such as to maintain fins 21 open in the position shown at the bottom of Fig. 1 while in free flight, but as these details are well known in the art and form no part of our invention, they are not shown in the drawing, which is purely schematic as regards the fin assembly. The advantage of the construction shown in Figs. 1 and 2 is that the arms 22 protect the fins from being bent or otherwise damaged in shipment or rough handling. These arms also give an added fin surface area which aids in stabilizing the flight of the rocket and finally the arms provide lateral support for nozzle 13. By virtue of this construction, it is possible to extend the nozzle past the fin assembly to provide for a maximum nozzle diameter.

A suitable double-base propellant 25 is mounted within combustion chamber 10 and retained therein by a cage trap 26. Propellant 25 preferably consists of cylindrical grains formed of nitroglycerin, nitrocellulose, and a flash reducing agent such as potassium nitrate. The cylindrical grains are provided with a single axial and concentric perforation by which the grains are mounted on the cage trap 26.

In operation, the passage of the hot gases of combustion through the nozzle liquefy the solder or low melting point metal 18 after a time interval which is determined by the design of the joint. In some designs this metal which serves to hold the two parts of the nozzle together may be melted before the burning of the propellant has been completed. This will not adversely affect the operation of the rocket however, because the reaction of the expanding high velocity gases upon the flared surfaces 14 will force the nozzle up tight against the tubular body member so that the nozzle will not be dropped clear of the tubular body member until after the burning has been completed and the flow of propellent gases stopped. As soon as the burning is completed, the rearwardly directed forces produced by the air-drag offered by the nozzle exceed the now-spent reaction forces of the propellent gases, so that the nozzle will be pulled free of its connection with the combustion chamber. The deceleration of the nozzle will be greater than the deceleration of the rocket motor per se and as a result the nozzle will fall behind the rocket motor in free flight. Thus the ballistic properties of the projectile during its free flight will not be adversely affected by the large diameter nozzle. Furthermore, the combination of the large diameter nozzle plus the potassium nitrate flash inhibitor produce a burning of the propellant which is substantially free from flash.

In Figs. 5 and 6 there is shown a modified construction of the nozzle assembly wherein a ring 31 is threaded to the exterior of the constricted portion of the tubular member 1 defining motor combustion chamber 10 for supporting a flared hemispherical member 38 and fin supporting arms 32. The hemispherical member 38 tends to streamline the air flow past the rear portion of the projectile and is instrumental in materially reducing the drag caused by that portion of the combustion chamber which is inwardly flared to form the nozzle throat. A ring 36 of streamlined cross-section is secured to the rear ends of arms 32 and folding fins 33 are pivotally mounted to the end portions of arms 32. These folding fins are preferably mounted between the respective arms 32 and a parallel bracket member 34 which is suitably secured to ring 36. The nozzle cone 35 is secured to the combustion chamber 10 by being soft soldered at its forward end to the rear end of the tubular member 1.

One of the advantages of the construction of Figs. 5 and 6 is that the flaring of the hemispherical end member 38 not only reduces the drag offered by the rocket but streamlines the air flow so as to make effective use of the fin area of arms 32 whereby greater stability in flight is obtained. Operation is identical to that described in connection with the arrangement shown in Fig. 1, the nozzle cone 35 being dropped at the end of the propellent fluid flow. The propellant utilized in this modification is the same as that provided in the modification of Fig. 1 and preferably contains potassium nitrate as a flash inhibitor. It should be noted that the arms 32 and ring 36 provide lateral support for nozzle cone 35.

The modification disclosed in Figs. 7 and 8 differs from that of Figs. 5 and 6 in that a ring type fin 40 is substituted for the pivoted fins 33 and the ring 36. Ring fin 40 is suitably secured, as by spot welding, to the rear ends of arms 32. The propellant utilized in this modification is the same as that provided in the modification of Fig. 1 and preferably contains potassium nitrate as a flash inhibitor. It should be noted that arms 32 and fin ring 40 provide lateral support for nozzle cone 35.

The modification of Figs. 7 and 8 is particularly well adapted for use on rockets designed to complete their burning within the projector tube, because with the design here disclosed, if the burning continued while the rocket was in free flight, the active fin area would be insufficient to stabilize the rocket and the pocketed effect formed between the ring fin 40 and the nozzle cone 35 would produce considerable drag.

It should be understood in all modifications disclosed that the nozzle may be dropped away by any other method and the invention is not limited to that disclosed.

We claim:

1. In a jet propelled device the combination including a tubular member defining a cylindrical combustion chamber containing a material combustible to generate a hot propellent fluid under pressure, said tubular member having an inwardly flared passage leading to a constricted exit orifice at the rear end thereof, a separately formed Venturi-like nozzle having an outwardly flared exit passage extending from the constricted portion thereof, and means for securing said nozzle to said tubular member at said exit orifice to expand said propellent fluid flowing through said orifice to a lower temperature and pressure, said nozzle being extended a distance sufficient to substantially reduce the flash occurring on secondary ignition of said fluid upon discharge from said nozzle, said securing means including a metal having a relatively low melting point operative in response to combustion of said material for releasing said nozzle from said tubular member.

2. In a jet propelled device, the combination including a tubular member defining a combustion chamber adapted to contain a material combustible to generate a propellent fluid under pressure, a separately formed nozzle for exchanging the energy form of the propellent fluid, bonding means securing said nozzle to said tubular member communicating with said chamber, said bonding means including a metal having a relatively low melting point for rendering said bonding means ineffective upon the application of heat at a temperature below that generated in the combustion chamber during normal operation thereof, whereby said nozzle is freed from said tubular member upon combustion thereof.

3. In a jet propelled device the combination including, a tubular member defining a combustion chamber adapted to contain a propellent material combustible to generate a hot propellent fluid under pressure, a separately formed nozzle, means securing said nozzle to said tubular member in communicating relation with said chamber to produce high velocity discharge of said fluid, and means including a normally solid, bonding material having a relatively low melting point responsive to the transfer of heat from said propellent fluid to said nozzle for rendering said securing means ineffective, whereby said nozzle will be free to drop clear of said tubular member.

4. In a jet propelled device the combination including, a tubular member defining a cylindrical combustion chamber, a propellent material in said chamber comprising a plurality of cylindrical grains of double-base powder having a flash inhibiting ingredient added thereto, said chamber having an inwardly tapered outlet for the gases liberated by the combustion of said propellent material, an outwardly tapered Venturi nozzle, and means for separably securing said nozzle to said tubular member with the small end thereof aligned with said tapered outlet for expending said gases, said nozzle being proportioned to expand said gases to a temperature and pressure such that said flash inhibiting ingredient will be effective in reducing the flash, said last mentioned means including metallic means having a low melting point for releasing said nozzle from said tubular member after combustion of said material has been completed.

5. A rocket projectile comprising, in combination, a tubular member defining a combustion chamber adapted to contain a material combustible to generate a hot propellent fluid under pressure, said tubular member having a rearwardly opening exhaust passage communicating with said combustion chamber, a plurality of arms secured in spaced relationship to the periphery of said tubular member and projecting rearwardly therefrom, air fin means secured to said arms, a nozzle for exchanging the energy force of the propellent fluid, and bonding means securing said nozzle to said tubular member in communicating relation with said exhaust passage, said arms cooperating with said nozzle in its secured position to provide lateral support

therefor, said bonding means being rendered ineffective upon the application of heat thereto, whereby said nozzle is freed from said tubular member upon the combustion of said material.

6. In a jet propelled device, a cylindrical member defining a combustion chamber and having a rearwardly, inwardly flared entrance portion, a nozzle having a constricted throat portion and a rearwardly, outwardly flared exit portion, a propellent charge mounted in said chamber, means for detachably securing the constricted throat portion of said nozzle to said entrance portion of said combustion chamber, said securing means including a low melting point metal for rendering ineffective said first-mentioned means upon application of heat of a predetermined temperature generated by combustion of said propellent charge.

7. In a jet propelled device, a cylindrical member defining a combustion chamber and including a rearwardly, inwardly flared entrance portion, a nozzle including a constricted throat portion and a rearwardly, outwardly flared exit portion, a propellent charge mounted in said chamber, means for detachably securing the constricted throat portion of said nozzle to the entrance portion of said combustion chamber, said securing means including complementary undercut portions on said entrance portion and on said constricted throat portion inclined to the axis of said cylindrical member, the undercut portion on said constricted throat portion being held against the undercut portion of said entrance portion by the pressure generated by combustion of said propellent charge and exerted on the flared exit portion of said nozzle, said securing means being rendered ineffective upon cessation of a predetermined pressure generated by combustion of said propellent charge.

8. In a jet propelled device, a cylindrical member defining a combustion chamber and including a rearwardly, inwardly flared entrance portion, a nozzle including a constricted throat portion and a rearwardly, outwardly flared exit portion, a propellent charge mounted in said chamber, means for detachably securing the constricted throat portion of said nozzle to the entrance portion of said chamber, said securing means including a metallic bonding means having a relatively low melting point for rendering ineffective said first-mentioned means only upon application of heat of a predetermined temperature and upon cessation of a predetermined pressure generated by combustion of said propellent charge.

9. In a jet propelled device, a cylindrical member defining a combustion chamber, a propellent charge mounted in said chamber, a nozzle, means for detachably securing said nozzle to said cylindrical member to provide for expansion of the high velocity gases produced by combustion of said propellent charge, said securing means including complementary undercut end-portions on said cylindrical member and on said nozzle and a low melting point material therebetween for rendering ineffective said first-mentioned means only upon substantial completion of the combustion of said propellent charge.

10. In a jet propelled device the combination of a cylindrical member defining a combustion chamber, a propellent charge mounted in said chamber, a nozzle, fin supporting structure affixed to said cylindrical member, means for detachably securing said nozzle to said cylindrical member to provide for expansion of the high velocity gases produced by the combustion of said propellent charge, said securing means comprising complementary undercut portions in said cylindrical member and in said nozzle at the point of their contact and a low melting point metal therebetween for rendering ineffective said first-mentioned means upon stoppage of flow of said high velocity gases after substantial completion of combustion of said propellent charge.

11. The apparatus according to claim 10 wherein said propellent charge includes a flash inhibitor of the group consisting of potassium nitrate, barium nitrate, hydrocellulose and abietates, and wherein said nozzle extends beyond said fin supporting structure whereby said flash inhibitor is rendered substantially more effective without adversely affecting the ballistic properties of said device during its free flight.

12. The apparatus according to claim 10 wherein a plurality of fin members are pivotably supported by said fin supporting structure.

13. The apparatus according to claim 10 wherein said fin supporting structure is streamlined.

14. In a jet propelled device the combination of a cylindrical member defining a combustion chamber and including a rearwardly, inwardly flared entrance portion, a nozzle including a constricted throat portion and a rearwardly, outwardly flared exit portion, a propellent charge including a flash inhibitor of the group consisting of potassium nitrate, barium nitrate, hydrocellulose and abietates mounted in said chamber to produce high velocity gases during combustion, a fin supporting structure fixedly attached to the entrance portion of said cylindrical member, means for detachably securing said nozzle to the rear end of said cylindrical member, said detachable means including material having a low melting point for rendering ineffective said first-mentioned means upon stoppage of flow of said high velocity gases after substantial completion of combustion of said propellent charge.

15. The apparatus according to claim 14 wherein the rearwardly, outwardly flared exit portion of said nozzle extends beyond said fin supporting structure whereby said flash inhibitor is rendered substantially more effective without adversely affecting the ballistic properties of said device during its free flight.

16. In a rocket component, a motor casing having a rearwardly-directed discharge orifice, a Venturi nozzle, means detachably securing said nozzle to said casing in cooperative relation with said orifice, said means including a low melting point metal for rendering ineffective said securing means to thereby release said nozzle from said casing in response to a predetermined temperature rise in said casing.

17. In a rocket motor component, a motor casing including a rearwardly directed Venturi nozzle comprising a first inwardly and rearwardly constricted throat portion terminating in a second outwardly and rearwardly flared nozzle portion, said portions being discrete, means releasably securing said portions together, and further means responsive to a predetermined temperature rise in said casing for releasing said second portion.

18. The apparatus according to claim 17, wherein said last-named means consists of an alloy of relatively low melting point.

19. In a jet propelled rocket the combination comprising a cylindrical member defining a combustion chamber having a rearwardly-directed

entrance portion forming a discharge orifice, a nozzle having a constricted throat portion, and means for detachably securing said constricted throat portion to said entrance portion, said entrance portion and said constricted throat portion each comprising a single, substantially Z-shaped undercut at the point of their respective juncture, said undercuts being complementary with respect to each other.

20. The apparatus according to claim 19 wherein the last-named means is rendered inoperable to release said nozzle from said member in response to a predetermined temperature rise in said combustion chamber.

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