

Nov. 29, 1949

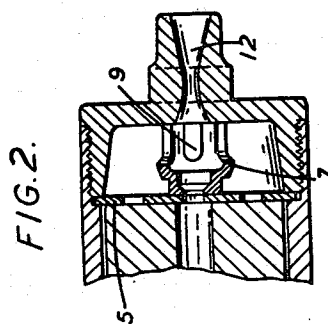
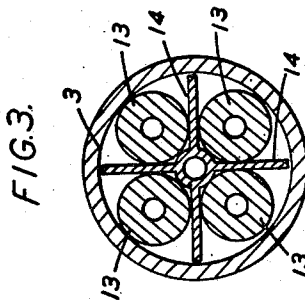
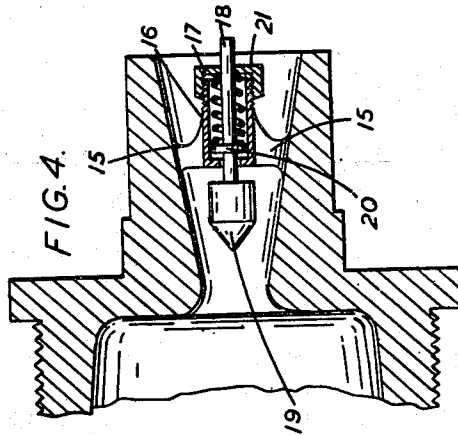
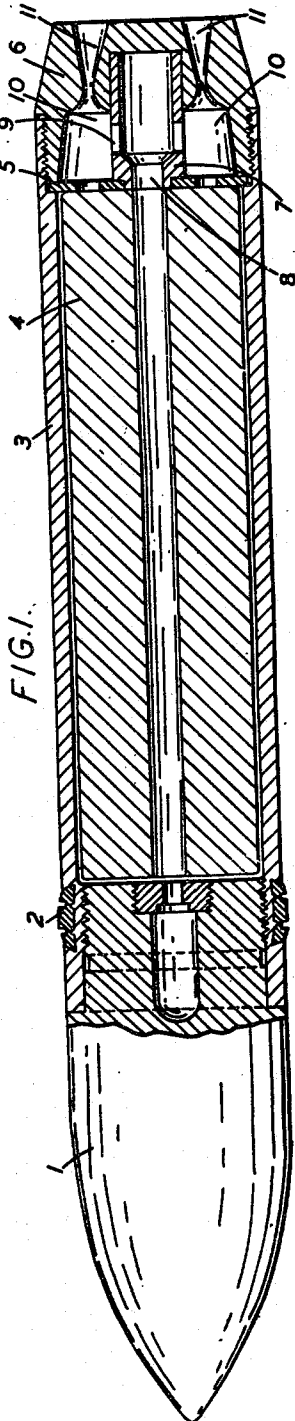
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2,489,953

PROJECTILES OPERATING WITH ROCKET PROPULSION

Filed Sept. 1, 1944

4 Sheets-Sheet 1



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PROJECTILES OPERATING WITH ROCKET PROPULSION

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4 Sheets-Sheet 2

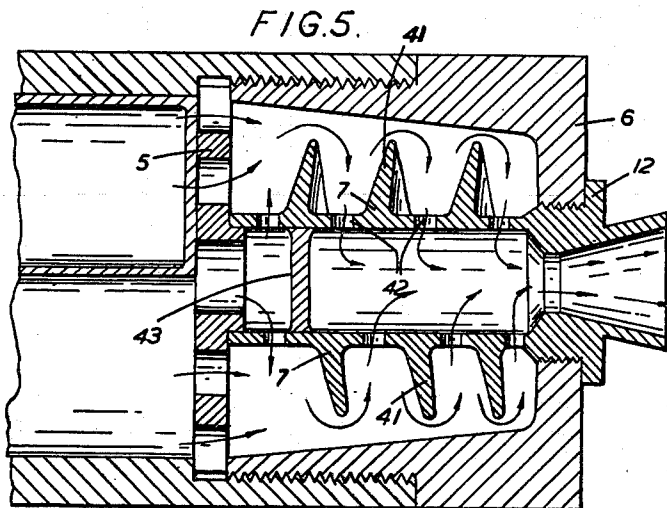


FIG. 8.

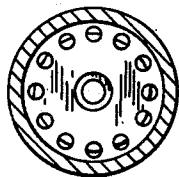


FIG. 9.

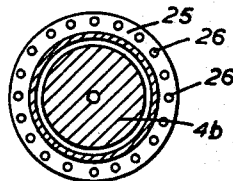


FIG. 10.

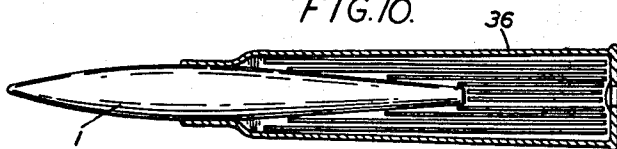


FIG. 13.

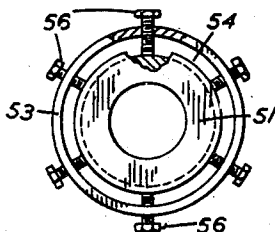
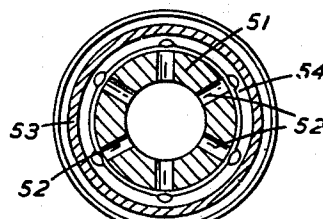


FIG. 14.



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4 Sheets-Sheet 3

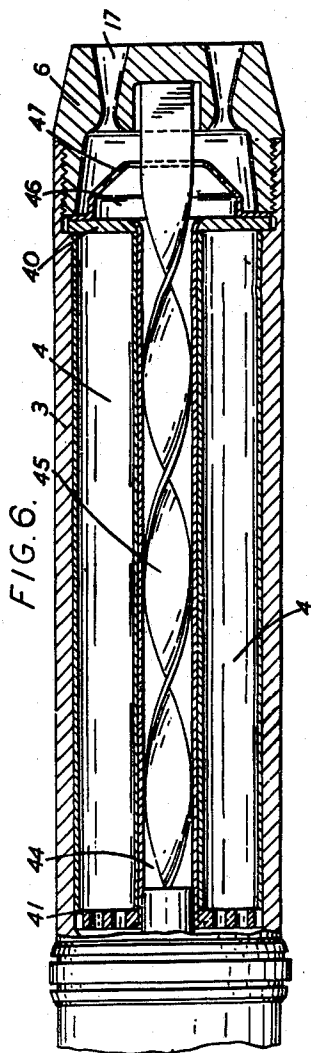
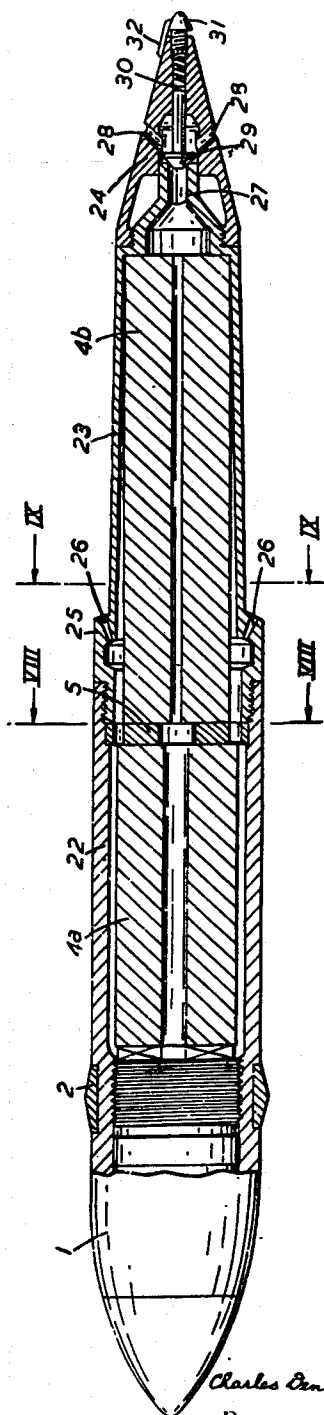


FIG. 7.



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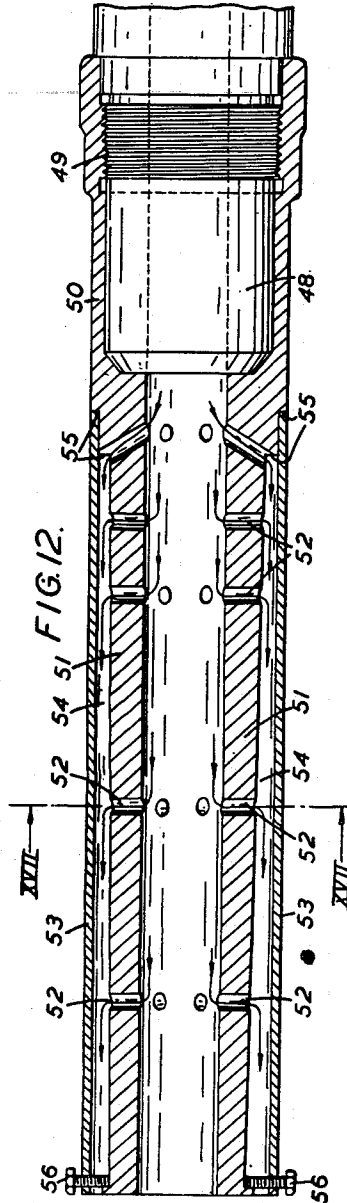
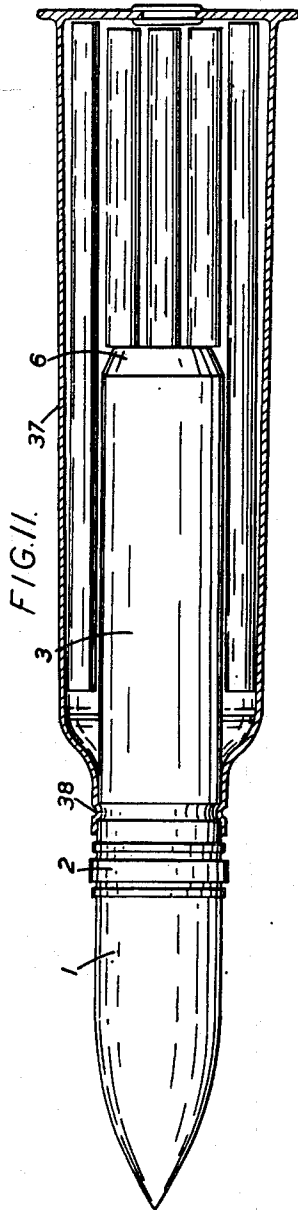
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PROJECTILES OPERATING WITH ROCKET PROPULSION

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4 Sheets-Sheet 4



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UNITED STATES PATENT OFFICE

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PROJECTILE OPERATING WITH ROCKET
PROPULSIONCharles Dennistoun Burney, Baynards Park,
near Cranleigh, EnglandApplication September 1, 1944, Serial No. 552,346
In Great Britain September 4, 1940Section 1, Public Law 690, August 8, 1946
Patent expires September 4, 1960

10 Claims. (Cl. 102—49)

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The present invention relates mainly to rocket projectiles, by which is meant projectiles whose velocity is increased after they leave the gun muzzle, by means of the thrust produced by the reaction on the air of gases discharged rearwardly from the projectile, said gases being developed by the combustion of a propellant charge within the body of the projectile. Such projectiles are necessarily of greater length than normal in relation to their calibre, so that they are of increased internal volume. Since the extra length of the projectile will increase its weight, the ballistic coefficient of the projectile will be increased, and thus when fired at the same velocity as an orthodox projectile its range will also be increased, apart from such advantages in performance as may be gained by the effective utilisation of the increased volume of the projectile for rocket propulsion.

Considerations of stability normally impose restrictions on the permissible length of a projectile in relation to its calibre, inasmuch as it is essential for stability to maintain the centre of gravity as close as possible to the centre of pressure, which is fixed for a given calibre of projectile by the frontal aspect of the projectile. On the other hand any increase in the length of a normally constructed projectile adds very materially to the weight of its rear portion, since its walls have to be sufficiently thick at all points along their length to carry the accelerating forces for the forward part of the projectile. Thus it is common practice in the design of ordinary shells for the thickness of the wall to be graded from a minimum at the nose end to a maximum at the base end, since the accelerating forces will gradually decrease from the base to the nose of the projectile.

The main object of the present invention is to provide an improved construction of rocket projectile of such increased length as to provide additional internal volume to carry a rocket propelling charge additional to the normal explosive charge, so that the advantages of rocket propulsion are not obtained at the expense of the tactical value of the projectile. In other words, it is desired to increase the volume of the projectile so that it can contain an adequate rocket charge without reduction of its stability.

According to the main feature of the invention the internal volume of a projectile is increased to provide accommodation for a self-propelling rocket charge by means of a casing extending rearwardly from the main body of the projectile, which is subject to balanced internal and ex-

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ternal pressures when the projectile is fired from the gun. Thus the propelling force of the explosion does not require to be transmitted to the main body of the projectile, through the walls of the casing, and the casing may therefore be made with relatively thin walls, which since they are subject to balanced internal and external pressures, are not liable to be crushed in by the force of the propelling explosion.

The equalisation of the internal and external pressures may be brought about by deriving the internal pressure from the chamber pressure outside the casing, or it may be built up within the casing by combustion of a suitable charge in the projectile. Thus, in the first case, one or more openings to the interior of the casing may be provided in rear of the driving band or gas check, which place it into communication with the chamber of the gun, so that on explosion the chamber pressure immediately becomes effective in the interior of the casing. The communication between the casing and the gun chamber may be provided by one or more of the nozzles provided for the escape of the gases developed by the rocket charge and used after the projectile has left the gun muzzle to produce propulsive reaction.

The main invention is therefore characterised by two important features, firstly, the weight of the projectile is graduated steeply from the driving band to the rear, so that the centre of gravity lies as far forward as possible, and secondly, the propulsive force of the explosion in the gun is applied, not to the rear end or base of the projectile, but to a plane intermediate along its length and as close to the driving band or gas check as possible, in consequence of which the forward part of the projectile is driven by the force of the explosion, whilst the rear part of the projectile is towed by the forward portion. Thus in constructing the projectile the walls of the forward portion or main body portion of the projectile may be graded or gradually reduced in thickness forwardly of the driving band in known manner, whilst the walls of the casing extending rearwardly from the driving band may not only be relatively thin but may even be graded, or gradually reduced in thickness in the rearward direction, thereby still further contributing towards a forward position of the centre of gravity of the projectile as a whole.

The rear portion of the projectile may be cylindrical in shape and of substantially the same diameter as the forward or main body portion, but in some cases it is preferably tapered in the

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rearward direction so as to be of substantially stream-line form.

In the case of rocket propelled projectiles, the production of a uniform reaction thrust is of great importance, and this depends to a great extent on the nature of the rocket charge and on factors which affect its rate of combustion. It is natural, for example, that the rate of development of gases will depend upon the burning area of the rocket charge, and when a solid combustible, such as cordite, is used, it is well-known that in order to produce uniformity in the burning area it is necessary to employ tubular cordite, which burns on both the inner and outer surfaces, so that the decrease in the outside burning area will be compensated by the increase in the internal burning area.

Furthermore, it has been found in the case of cordite, for example, that it is productive of gases at different rates depending upon the varying conditions of temperature and pressure to which it is subjected. If cordite is used as the rocket propellant in a rocket projectile, where it operates in a chamber which is closed except for the gas discharge nozzles, it is found that a small variation in the nozzle area makes a considerable difference in the internal pressure. If the pressure falls, the rate of burning of the charge falls, so that the pressure falls still further, and finally the pressure becomes so reduced that burning ceases. On the other hand if the pressure increases it continues to rise until a point is reached when the remaining rocket charge explodes instead of continuing to burn at a steady rate.

For accuracy of shooting with rocket propelled projectiles, it is of great importance to maintain a steady reaction thrust and to avoid extinction of the combustion on the one hand, and bursting of the rocket charge casing on the other hand. Consequently, although the effect of variations in temperature may generally be neglected it is highly important to provide means to maintain a constant internal pressure within the rocket charge casing, as has been heretofore proposed in connection with ordinary war rockets.

It has been proposed to obtain the desired result in the case of war rockets by discharging the gases through an annular nozzle having a wall which expands under increase of pressure so as to increase the nozzle area and maintain the area proportional to the pressures within the elastic limit of the wall. According to its invention, however, one or more of the gas discharge nozzles is or are fitted with an automatic valve which floats under spring control in the nozzle opening and regulates its effective size in accordance with the pressure of the gases in the rocket casing. The valve may consist, for example, of a conical valve body located in the throat of the nozzle and adapted to be moved against spring resistance to increase the effective nozzle opening, by the pressure acting on the valve. Alternatively, in the case of the gases discharging through a number of apertures or nozzles, one or more apertures or nozzles or an additional axial hole or nozzle may be fitted with a poppet valve which is opened by the gas pressure against spring resistance. If it is desired to make allowance for variation in temperature conditions, provision may be made for varying the initial compression of the control spring, as by providing an adjustable screw abutment for the end of the spring, the adjustment being made with reference to a scale calibrated in temperatures.

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When cordite is used as the rocket charge, if in long lengths it is liable to break up due to the acceleration forces arising from its own weight, with consequent increase of burning surface, too rapid evolution of gases, and possible bursting of the rocket casing. To avoid this source of uncertainty and irregularity of action, according to a further feature of the invention the cordite is sub-divided into lengths which are liable to stand the acceleration forces, perforated supporting plates or grids being interposed between the lengths.

Another important factor in obtaining uniformity of rocket thrust and the maintenance of such thrust for a predetermined period of time is the provision of satisfactory means for ensuring complete combustion of the rocket charge and the prevention of loss of rocket charge in the form of solid unburnt particles of charge carried away with the gases. Part of this invention resides in the provision of such means, and according to one feature of this part of the invention the gases pass to the discharge nozzles along an extended path so that solid particles are given time to ignite before reaching the nozzles. Preferably the direction of motion of the gases is reversed in passing to the nozzles so that the momentum of the solid particles stops their continued motion after the reversal point. According to another method the gases are caused to travel along a circular path so that they not only travel along an extended path but also become subject to the action of centrifugal force which throws the solid particles outwards and away from the direction of the continued travel of the gases.

In order that the invention may be more clearly understood and readily carried into practice, examples of projectiles embodying the various features of the invention will now be described by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a longitudinal section of one construction of rocket projectile according to the invention.

Figure 2 illustrates a modification of the nozzle system.

Figure 3 illustrates a modification in regard to the loading of the rocket charge in the projectile.

Figure 4 illustrates a pressure control valve applied to the nozzle system illustrated by Figure 2.

Figures 5 and 6 are sectional views of gas discharge nozzles embodying means for cleaning the gases from solid particles before discharge.

Figure 7 is a longitudinal section of another construction of rocket projectile according to the invention.

Figures 8 and 9 are cross-sectional views on the lines VIII—VIII and IX—IX of Figure 7.

Figures 10 and 11 are longitudinal sectional views of fixed ammunition for small arms and quick-firing field guns respectively, embodying the invention.

Figure 12 is a longitudinal section illustrating the application of a gun muzzle extension, to the muzzle of a gun to adapt it to fire self-propelled projectiles according to the invention, although this construction forms no part of the present invention.

Figure 13 is an end view of the extension, and Figure 14 is cross-section on line XVII—XVII of Figure 12.

The constructional example shown in Figure 1 is a shell having a normal main body portion 1, containing the usual explosive charge and fuze mechanism and fitted with a normal driving

band 2. Rearwardly from the driving band 2 extends a relatively thin walled casing 3 in which is contained a rocket charge 4 consisting of a tube of cordite, supported by a perforated plate 5 which is engaged against a shoulder in the casing 3. This perforated plate 5 serves not only to hold the cordite charge in place but also to prevent the passage of solid particles of the burning charge to the discharge nozzle. The plate 5 therefore acts in a measure as a gas cleaning device.

In the end of the casing 3 is screwed a hollow nozzle cap 6 comprising a central tubular member 7, which is shouldered to support the centre of the disc 5, and the bore of which communicates at 8 with the interior of casing 3. In the wall of member 7 are a number of radial holes 9 providing communication between the central tubular member 7 and the surrounding annular space 10. At the bottom of the annular space 10, and through the end wall of member 6, are formed an annular series of nozzles 11 of Venturi form, through which the gases evolved by the combustion of charge 4 escape into the atmosphere, and in doing so provide propulsive reaction for the projectile, which supplements the velocity imparted to the projectile by the gun from which it is fired. These nozzles 11 may discharge in directions parallel to the axis of the projectile but preferably they are all inclined at an angle to the axis of the projectile so as to give rise to a reaction having a tangential or peripheral component, whereby part of the energy of the gas reaction is utilised in spinning the projectile about its axis so as to maintain the necessary stabilising spin after the spin imparted by the rifling of the gun has ceased to be effective.

Figure 2 illustrates a modification in regard to the nozzle system, according to which instead of discharging through a ring of annular nozzles 11, the reaction gases discharge through a single axial nozzle 12. In this case the nozzle cap 6 again has a central tubular member 7, with lateral openings 9, which supports the perforated disc 5 holding the rocket charge 4 in position. For axially spinning this projectile by gas reaction, supplementary to the spin imparted by the rifling of the gun through the intermediary of driving band 2, an annular series of inclined nozzles may be provided just in rear of the driving band as described subsequently in connection with Figure 7.

In order to avoid the possibility of the projectile becoming unbalanced when the rocket charge is partially burnt, and is thus sufficiently reduced in diameter to take up an eccentric position in casing 3, the expedient illustrated by Figure 3 may be adopted. In this case the cordite charge is divided into four tubular sections 13, which are separated from one another by one or more metal separators 14 which are star-shaped in cross-section. As the sections 13 become burnt at equal rates and are maintained by the separator or separators 14 symmetrically in relation to the axis of the projectile, the balance of the projectile will remain unaltered as the rocket charge burns.

Figure 4 illustrates how a pressure regulating valve may be embodied in the example illustrated by Figure 2. Within the nozzle 12 is supported by spider arms 15, a tubular member 16 containing a compression spring 17 surrounding the rod 18 of a conically headed valve 19 which is located in the throat of the nozzle 12. The

rod 18 carries a collar 20 against which the inner end of spring 17 bears, and on the end of the tubular member 6 is a screw cap 21 against which the outer end of the spring bears, and by rotation of which the initial tension of the spring 17 can be adjusted. The outside of the tube 16 may be graduated so that the cap 21 can be adjusted to give an initial tension suited to the prevailing temperature conditions. As the gases issue from the nozzle 12 they exert pressure on the valve 19, which if too great overcomes the spring 17 and moves the valve 19 outwardly, thus increasing the annular space for the passage of the gases through the nozzle 12 and lowering the pressure inside the container 3. If, on the other hand, the pressure inside the container 3 falls below the desired value, the valve 19 will move forwardly into the throat of nozzle 12 and thus restrict the effective nozzle area, whereby the pressure in the container 3 will rise. In practice the valve 19 will float in a position maintaining substantially constant pressure within the container 3, so that the reaction thrust which propels the projectile remains substantially constant.

Figure 5 illustrates a construction of nozzle fitting embodying means additional to the perforated plate 5 for cleaning the gases more thoroughly from unburnt particles of combustible before discharge, as applied to a single axial nozzle, such as that of Figure 2. The internal tubular member 7 is formed with a helical vane or baffle 41 which does not extend quite to the wall of the nozzle fitting 6, whilst between the convolutions of the baffle 41 holes 42 are formed through the member 7. The gases are prevented from passing straight through the member 7 to the nozzle 12 by means of an internal cross-wall or partition 43, which forces the gases to pass round the convolutions of the helical baffle 41. This rotary motion of the gases gives rise to centrifugal force acting on the solid particles carried along by the gases, which throws them out radially against the wall of the nozzle fitting 6. At the same time the gases traverse a sinuous path which increases their time of passage to the nozzle 12 and gives more time for the solid particles to become burnt.

Figure 6 illustrates another method for cleaning the gases, according to which the rocket charge is supported at the rear end by a solid plate 40 which prevents direct access of the gases to the nozzles 17 and forces them to travel forwardly through the front perforated supporting plate 41 and thence into the central passage 44, along which is disposed a helically twisted strip of metal 45 which imparts a rotary motion to the gases as they pass along the passage, to the mixing chamber 46, formed by a perforated cage 47, which serves to hold back solid particles of combustible within the chamber 46.

Thus a proportion of the gases in passing to the nozzles 17 are forced to travel along an extended path and are reversed in their direction of motion after passing through perforated plate 41, whilst all of the gases are given a spiral rotary motion by the spiral strip 45, so that solid particles are thrown outwardly by centrifugal force and retained either in the central passage, or in the mixing chamber 46, until they have become ignited and converted into gas.

Figure 7 illustrates a modified construction for a rocket projectile which is required to contain a considerable quantity of propellant by reason of the high maximum velocity and range desired, and by reason of the small calibre of

the projectile it is necessary for the propellant space in the projectile to be very elongated. When the propellant is cordite it is found that definite limits are imposed on the permissible length of the cordite strands or tubes, having regard to the acceleration forces which they have to carry arising from their own weight, and accordingly as shown, the cordite is sub-divided in length into two charges 4a and 4b loaded one behind the other with an intermediate perforated supporting plate 5.

The rocket charge casing comprises a cylindrical section 22 into which is screwed a tapering section 23, the end of which supports the perforated plate 5, and on the other end of which is secured a conical nozzle member 24, so that the rear part of the projectile is substantially of streamline form.

The cylindrical casing 22 may have its wall graded or reduced in thickness rearwardly from the driving band 2, and the wall of the forward or main body portion of the projectile may be graded or reduced in thickness in the reverse direction, i. e. forwardly of the driving band 2, as is the common practice with shells.

As already explained the rocket charge is sub-divided into two parts 4a and 4b of suitable length contained respectively in the two cases 22 and 23. The forward part of rear casing 23 is externally shouldered at 25, and an annular series of nozzle openings 26 are formed therein, in an angular direction in relation to the axis of the projectile and facing rearwardly, so as to give rise not only to a propulsive thrust but also to a peripheral or spin imparting reaction. At the rear end of the casing 23 is an axial nozzle fitting 27, which is covered over by the conical tail piece 24, having outwardly inclined nozzle openings 28 producing an axial thrust and also if desired inclined to the axis to give a peripheral reaction productive of spin. The nozzle 27 is fitted with a pressure control valve 29 in the form of a poppet valve, the stem of which moves in a bore in the tail fitting 24 under the control of a spring 30, the initial tension of which may be adjusted to suit temperature conditions by a finger screw member 31, having a spring finger 32 co-operating with calibrated notches in the tail piece 24.

It will be understood that in the constructions of projectile described, the rocket charge 4, or 4a and 4b, will be ignited by the flash of the explosion in the chamber of the gun, and that the nature of the rocket charge and its rate of burning will be chosen according to the desired magnitude and duration of the rocket thrust. It will also be understood that if the nozzle openings communicating with the chamber space are insufficient in area to allow immediate equalisation of the pressure inside and outside the casing 3 (22, 23) on explosion of the gun charge, a part of the normal rocket charge will be replaced by a charge having the same rate of burning and pressure development as the gun charge, so that an internal pressure develops in the casing which balances the external chamber pressure on the casing.

Figure 10 illustrates the application of the invention to small arm ammunition, the projectile or bullet 1 being constructed of streamline shape, and with its tail portion containing a rocket charge of cordite or the like corresponding to the charge 4 of Fig. 1. This self-propelled bullet is fitted in the usual way in a cartridge case 36, which contains the propelling charge fired in the

gun. If a cartridge case of normal size is employed the propelling charge will be reduced in volume and thus the muzzle velocity will be reduced. The recoil will also be reduced, so that if the small arm is of automatic or machine gun type the recoil mechanism and the mounting may be of lighter than normal construction. If, however, it is desired to obtain the normal muzzle velocity the cartridge case 36 must be enlarged in diameter, or length, or both, to compensate for the space occupied within the cartridge by the rear end extension of the bullet, carrying the rocket charge into the casing, and to allow also for the extra weight of the projectile.

If, however, it is only desired to obtain a maximum velocity equal to the normal maximum velocity, i. e. the normal muzzle velocity, and to rely for greater range on the improved ballistic coefficient of the bullet due to its extra weight, the increase in the volume of the cartridge case will be somewhat less, and will depend upon the proportions of the maximum velocity to be attributed respectively to the gun and to the rocket charge. Since the rocket tail of the projectile will occupy a substantial proportion of the cartridge space available for the propellant charge, the volume of the cartridge case must be increased if the normal muzzle velocity is to be attained, either by increasing its diameter or its length, or both. If, however, it is desired to operate with a sub-normal chamber pressure it may be possible to use a cartridge case of normal size.

A fixed type of ammunition, suitable for use with a light quick-firing field gun is illustrated by Figure 11. The construction is similar to that of Figure 10, but the projectile 1 itself is shown of the type illustrated by Figure 1, and the mouth of the cartridge casing 37 is crimped at 38 to engage in a groove round the projectile in rear of the driving band 2. As in the case of small arm ammunition a cartridge case 37 of normal size will result in a sub-normal muzzle velocity due to the reduced space available for the propellant charge in order to accommodate the rocket charge casing 3, and therefore to obtain the normal muzzle velocity the volume of the cartridge case 37 will require to be suitably increased.

Since normal guns cannot be used for firing rocket or other projectiles according to this invention, in order that this specification may be sufficient to enable the invention to be carried into practice, certain novel features of construction, or modifications in the construction of guns are necessary, which, however, form no part of the present invention, will now be described. It should be noted that owing to the increased weight of the projectile due to the added propellant charge, and to the limitations imposed on the chamber pressure, the acceleration of the projectile will be slower and therefore a slower burning propellant charge may be used in the gun.

In the first place the rifling pitch normal to a gun of given calibre will not be suited to projectiles of the extended length forming the subject matter of this invention, and in consequence, with normal muzzle velocity, it becomes necessary to increase the pitch of the rifling in order to increase the rate of spin imparted by the gun to the projectile to produce stability immediately the projectile leaves the gun muzzle. Thus a measure of overspin is given in comparison with normal practice.

Further the volume, and thus the dimensions of the gun chamber, will require modification in comparison with standard practice, depending upon the tactical performance required of the gun. Assuming for the moment that it is required simply to increase the maximum velocity of the projectile to give greater range and/or penetration powers, whilst retaining the normal muzzle velocity, then the rearward extension of the projectile into the chamber of the gun will reduce the space normally available for the propelling charge, in consequence of which the chamber will require to be increased in volume, if the same propelling charge is to be used, by the volume which the propellant casing of the projectile occupies in the chamber when the projectile is in firing position. Standard guns of calibre appropriate to the projectile may be modified to increase the chamber volume by removing or eliminating a suitable length of the rifling of the barrel towards the chamber so that the driving band seating is shifted so far forwardly that the rocket charge casing is wholly or partly accommodated in the bore of the gun. In other words the combustion chamber volume is enlarged by including in it a portion of the barrel volume. If the rocket charge casing is of less diameter than the bore the surrounding annular space should be regarded as part of the chamber volume, so that in that case a volume of the casing may be left within the chamber equal to the volume of said annular space. Consequently, the rocket charge casing may project only partly into the chamber proper. If, however, the rocket charge casing is a close fit in the bore of the gun, the whole of its length must be accommodated in the bore of the gun so that it does not reduce the effective chamber volume.

New guns may be constructed with an advanced band seating, but, since the effective length of the barrel is reduced by accommodating the projectile wholly or partly in the barrel before firing, new guns are preferably constructed so that the effective length of barrel is not reduced, specifically for use with rocket propelled projectiles. The band seating will be located where the rifling meets the chamber, and the increased chamber volume required to compensate for the presence of the rocket charge casing within the chamber will be provided by increasing the diameter and/or length of chamber volume required to compensate for the presence of the rocket charge casing within the chamber will be provided by increasing the diameter and/or length of the chamber proper. Since the chamber pressure will thus be maintained of normal value the strength and thickness of the chamber walls will not require to be increased. Consequently the weight of the gun will not require to be substantially increased, since only a relatively small increase of weight will follow from the increased diameter and/or length of chamber.

Thus whereas in the case of a standard gun of given calibre the chamber volume bears a definite relation to the volume of the propelling charge to be fired therein for maximum range, in guns for firing projectiles according to this invention, the chamber volume will be increased in relation to the normal ratio by an amount equal to the volume of the chamber space occupied by the propellant charge casing of the projectile, when in firing position in the gun.

Assuming a propellant cartridge charge equal

to 40% of the gross chamber volume, and a rocket propellant charge carried by the projectile of equal weight and volume to that fired in the gun and wholly accommodated before firing in the chamber, then, in order to maintain the same effective or net chamber volume, the gross chamber volume will require to be increased by some 40%, so that the gun propellant charge will only then occupy 28.5% of the gross chamber volume, or conversely, instead of the gross chamber volume being $2\frac{1}{2}$ times the volume of the propellant charge, it will be $3\frac{1}{2}$ times the volume of the propellant charge.

In applying the invention to fixed ammunition for quick firing guns the cartridge case will be treated as the equivalent of the gun chamber. In other words, its diameter or length will be increased in order that the case may receive the rocket propellant casing of the projectile without decrease of the volume normally provided for the explosive propellant charge contained in the case. The gun chamber will of course have to be correspondingly increased in diameter or length to receive the enlarged cartridge case.

Similar considerations will apply when for tactical reasons no increase of maximum velocity is required to give greater range and/or penetration powers, the advantages of lightness of gun construction, increased mobility, and reduction of barrel wear being the desiderata. In this case the reduction of the gun propellant volume arising from the occupation of part of the chamber space by the rocket charge casing, may only require to be made good to a partial extent, by increase of the chamber volume. In this connection allowance will have to be made for the increased weight of the projectile necessitating a larger charge for a given muzzle velocity than for a projectile of the same calibre but normal length, and allowance must also be made for the fact that the rocket charge will operate with less efficiency than that of the gun chamber propellant in producing velocity.

As hereinbefore briefly indicated it has been found in practice that long projectiles, such as projectiles according to this invention, are subject to fortuitous inaccuracies which appear to be due to the muzzle blast of the gun acting on the base of the projectile immediately after it has left the muzzle and before the blast has had time to dissipate. Any slight axial deviation of the projectile on leaving the muzzle produces, owing to the great length of the projectile, a relatively large angular cant of the base of the projectile, with the result that the muzzle blast acting on the canted base is liable to give the projectile a powerful lateral thrust which magnifies the deviation to an undesirable extent. To overcome this difficulty, the expedient illustrated by Figures 12-14 may be adopted. These figures illustrate a means for reducing muzzle blast applicable to existing guns, according to which the muzzle end of the gun 48 is reduced and threaded externally at 49 to receive the socket end 50 of a barrel extension 51. This extension 51 is of the same diameter as the bore of the gun barrel across the lands, but has no rifling, and at intervals along its length it has rings of gas vents 52, which allow the escape of the explosion gases as soon as the base of the projectile passes them, so that by the time the base of the projectile leaves the mouth of the muzzle extension 51, the force or blast of the gases issuing from the bore itself is reduced to a value which is not ad-

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verse in its effect on the base of the projectile in the manner described above.

Preferably the muzzle extension 51 is enclosed by a tubular casing 53 spaced from the muzzle extension 51 to provide an annular space 54 for the passage of the gases as indicated by the arrows, which will produce a tubular blast surrounding the base of the projectile and tending to resist any lateral deviation of its base end, a direct blast on the base of the projectile being mainly or wholly eliminated. In order to provide for the fitting of the tubular casing 53, the extension 51 has a double shouldering at 55, the outer one of which receives the end of the casing 53, and the inner one produces the annular space 54. At its forward end the casing 53 is supported from the mouth end of the muzzle extension 51 by a number of radial screw bolts 56. Whilst Figures 12-14 show an attachment suitable for application to existing guns modified in a suitable manner, it will be understood that new guns may, if desired, be constructed in a corresponding manner, the muzzle extension 51 being made integral with the normal gun barrel and the socket 50 being eliminated.

It should be understood that the improved projectiles may be desired for use not only with heavy ordnance, such as artillery and naval guns of all calibres, but also for use with small arms such as rifles, machine guns, and anti-tank guns.

Further, although several constructions of projectile and constructional modifications have been described, it should be understood that many of the constructional details are interchangeable so that the invention should not be regarded as restricted to the constructional examples shown, many other modifications and constructional forms being included within the scope of the invention.

What I claim is:

1. A self-propelling projectile of the type adapted to be fired from the chamber of a gun by an explosive propellant charge including in combination with the body proper of the projectile, a thin walled casing extending from the base end of said body, a self-propelling rocket charge contained in said casing, means associated with said casing for providing communication between its interior and the propellant-charge chamber from which it is fired, said last named means being constructed to provide, upon firing, a substantial equalization of the pressure internally of said casing with the chamber pressure acting externally thereon, and means associated with said casing whereby solid unburnt particles are separated from the gases arising from combustion of the rocket charge.

2. A self-propelling projectile of the type adapted to be fired from the chamber of a gun by an explosive propellant charge including in combination with the body proper of the projectile, a thin walled casing extending from the base end of said body, a self-propelling rocket charge contained in said casing, means associated with said casing for providing communication between its interior and the propellant-charge chamber from which it is fired, said last named means being constructed to provide, upon firing, a substantial equalization of the pressure internally of said casing with the chamber pressure acting externally thereon and including at least one expansion nozzle through which the gases produced by the continued burning of said rocket charge are discharged rearwardly to produce a propelling reaction on said projectile, and at least one

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perforated plate disposed between said rocket charge and said nozzle.

3. A self-propelling projectile of the type adapted to be fired from the chamber of a gun by an explosive propellant charge including in combination with the body proper of the projectile, a thin walled casing extending from the base end of said body, a self-propelling rocket charge contained in said casing, means associated with said casing for providing communication between its interior and the propellant-charge chamber from which it is fired, said last named means being constructed to provide, upon firing, a substantial equalization of the pressure internally of said casing with the chamber pressure acting externally thereon, and means associated with said casing whereby solid unburnt particles are separated from the gases arising from combustion of the rocket charge and including means for reversing the direction of motion of said gases.

4. A self-propelling projectile of the type adapted to be fired from the chamber of a gun by an explosive propellant charge including in combination with the body proper of the projectile, a thin walled casing extending from the base end of said body, a self-propelling rocket charge contained in said casing, means associated with said casing for providing communication between its interior and the propellant-charge chamber from which it is fired, said last named means being constructed to provide, upon firing, a substantial equalization of the pressure internally of said casing with the chamber pressure acting externally thereon, and means associated with said casing whereby solid unburnt particles are separated from the gases arising from combustion of the rocket charge and including means for imparting a rotary motion to said gases.

5. A self-propelling projectile of the type adapted to be fired from the chamber of a gun by an explosive propellant charge including in combination with the body proper of the projectile, a thin walled casing extending from the base end of said body, a self-propelling rocket charge contained in said casing, means associated with said casing for providing communication between its interior and the propellant-charge chamber from which it is fired, said last named means being constructed to provide, upon firing, a substantial equalization of the pressure internally of said casing with the chamber pressure acting externally thereon, and means associated with said casing whereby solid unburnt particles are separated from the gases arising from combustion of the rocket charge and including means forming a helical path along which at least some of said gases must flow.

6. A self-propelling projectile of the type adapted to be fired from the chamber of a gun by an explosive propellant charge including in combination with the body proper of the projectile, a thin walled casing extending from the base end of said body, a self-propelling rocket charge contained in said casing, and means associated with said casing for providing communication between its interior and the propellant-charge chamber from which it is fired, said last named means being constructed to provide, upon firing, a substantial equalization of the pressure internally of said casing with the chamber pressure acting externally thereon and said rocket charge comprising a plurality of cylindrical sections disposed symmetrically in said casing.

7. A self-propelling projectile of the type adapted to be fired from the chamber of a gun by an explosive propellant charge including in combination with the body proper of the projectile, a thin walled casing extending from the base end of said body, a self-propelling rocket charge contained in said casing, means associated with said casing for providing communication between its interior and the propellant-charge chamber from which it is fired, said last named means being constructed to provide, upon firing, a substantial equalization of the pressure internally of said casing with the chamber pressure acting externally thereon, and means associated with said last named means for maintaining a substantially constant pressure in said casing.

8. A self-propelling projectile of the type adapted to be fired from the chamber of a gun by an explosive propellant charge including in combination with the body proper of the projectile, a thin walled casing extending from the base end of said body, a self-propelling rocket charge contained in said casing, means associated with said casing for providing communication between its interior and the propellant-charge chamber from which it is fired, said last named means being constructed to provide, upon firing, a substantial equalization of the pressure internally of said casing with the chamber pressure acting externally thereon, and means associated with said last named means for maintaining a substantially constant pressure in said casing, said last named means including a valve for closing an aperture through which flow the gases arising from the combustion of said rocket charge and a spring for urging said valve in a direction to restrict said aperture upon decrease of gas pressure in said casing.

9. A self-propelling projectile of the type adapted to be fired from the chamber of a gun by an explosive propellant charge including in combination with the body proper of the projectile, a thin walled casing extending from the base end of said body, a self-propelling rocket charge contained in said casing, means associated with said casing for providing communication between its interior and the propellant-charge chamber from which it is fired, said last

named means being constructed to provide, upon firing, a substantial equalization of the pressure internally of said casing with the chamber pressure acting externally thereon, said rocket charge being subdivided in the direction of the length of the projectile, and means separately supporting said subdivisions.

10. In a rocket-propelled device having a propelling rocket charge and a casing surrounding said charge, said casing having an open end through which the gases resulting from the burning of the charge exhaust to the atmosphere, concentric outer and inner elements disposed within said open end and being contoured to form an open Venturi passage therebetween in all positions of said elements, for said gases, said inner element being movable axially of the outer element to vary the size of said passage, and means for maintaining said inner element in predetermined position, and providing the said open Venturi passage at normal and sub-normal pressures developed within said casing and being operative in response to abnormal pressures within said casing to permit said inner element to enlarge said passage.

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