

Sept. 30, 1958

A. C. LOEDDING

2,853,946

ROCKETS

Filed Jan. 26, 1954

4 Sheets-Sheet 1

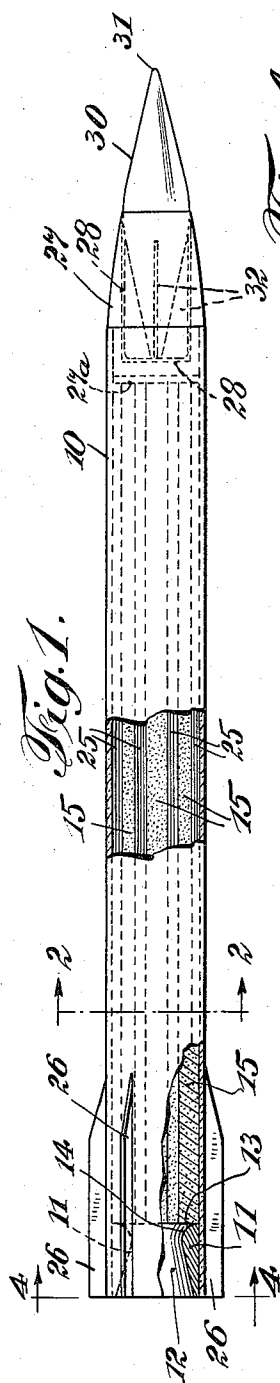


Fig. 1.

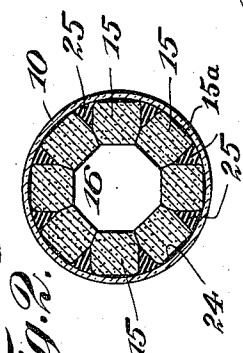


Fig. 2.

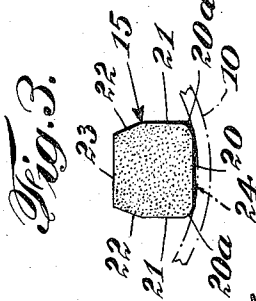


Fig. 3.

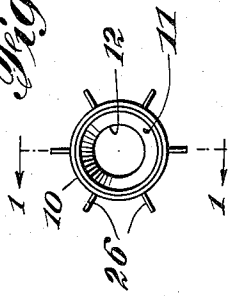


Fig. 4.

Fig. 5.



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Fig. 7.

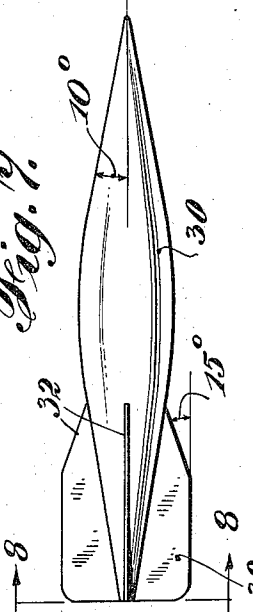


Fig. 6.

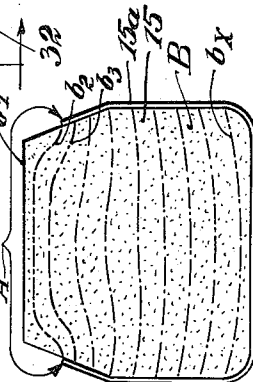
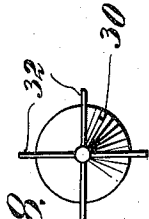


Fig. 8.



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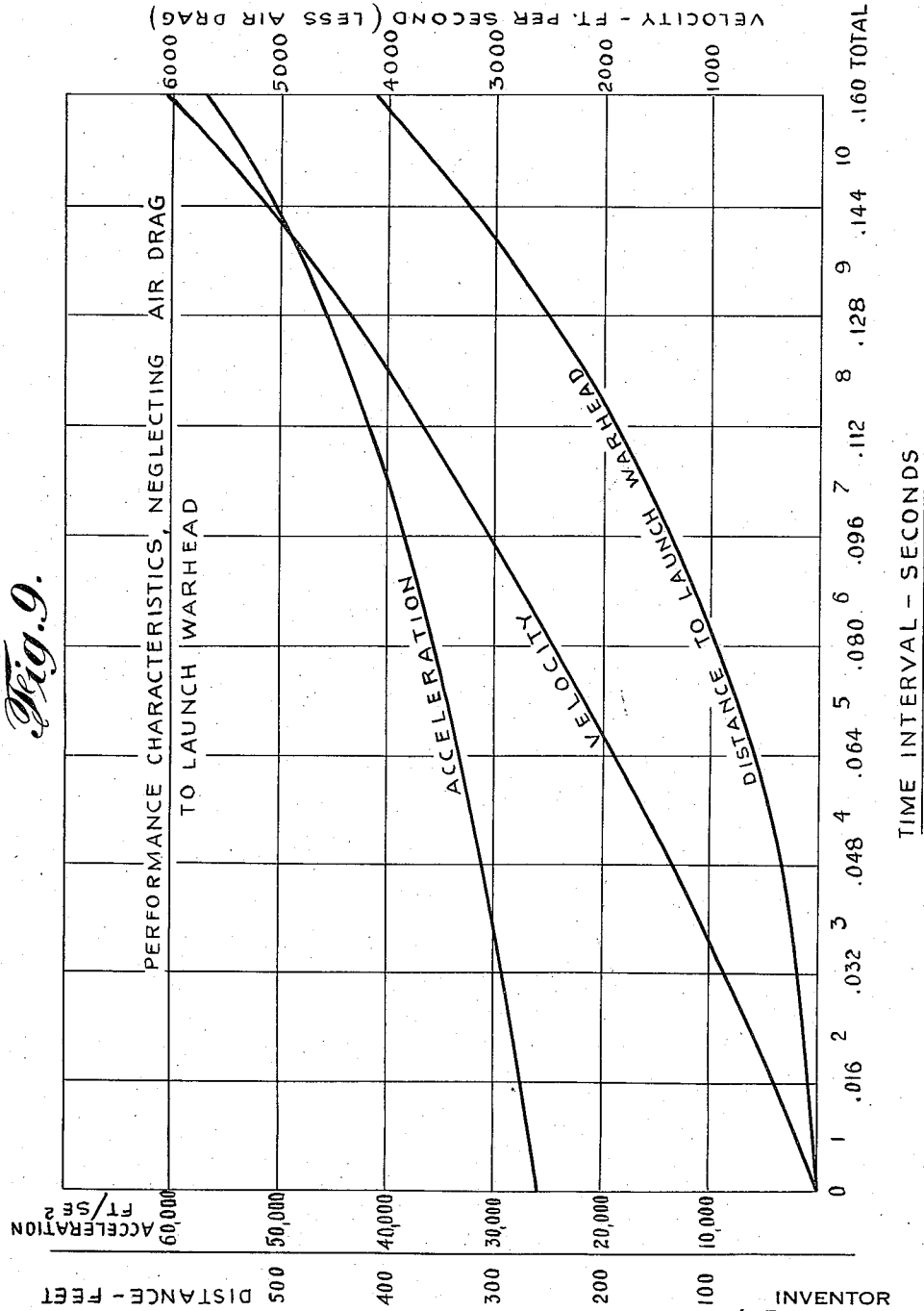
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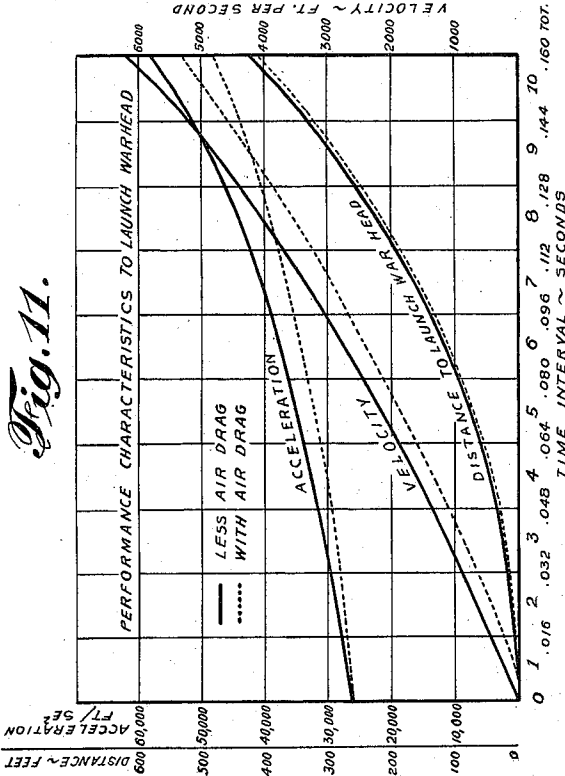
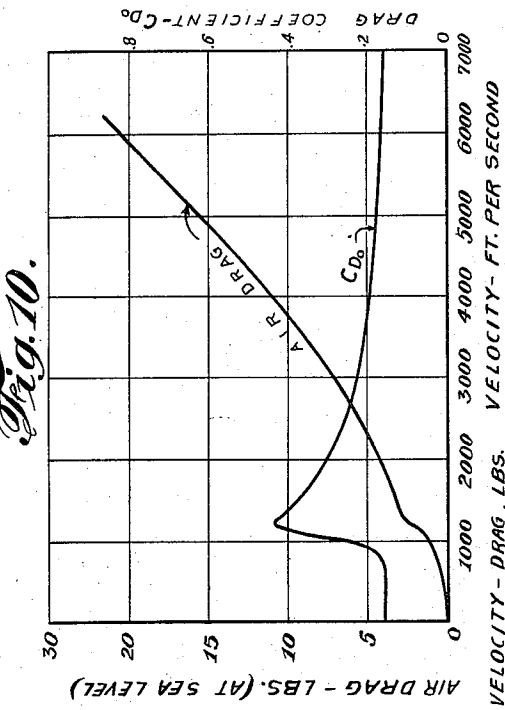
A. C. LOEDDING

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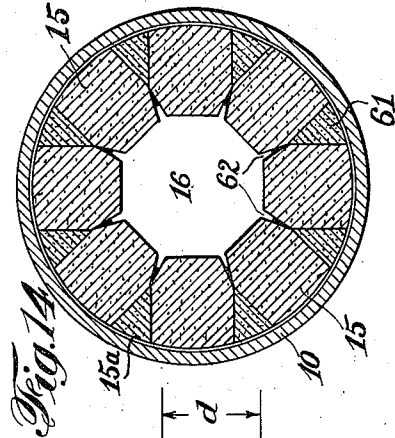
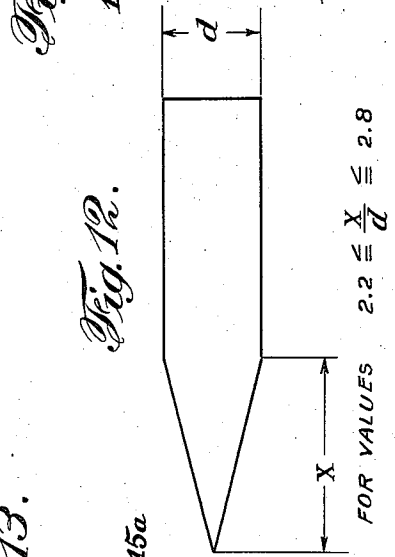
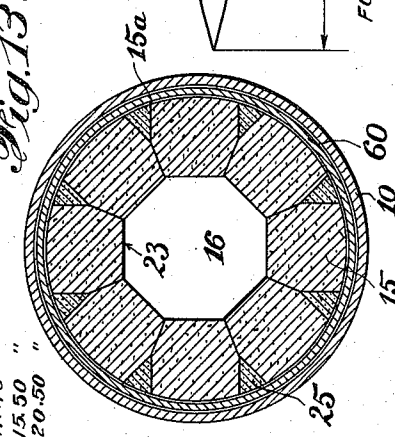
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4 Sheets-Sheet 3



VELOCITY - DRAG, LBS.

1000	2.50 "
2000	4.38 "
3000	7.23 "
4000	11.40 "
5000	15.50 "
6000	20.50 "



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4 Sheets-Sheet 4

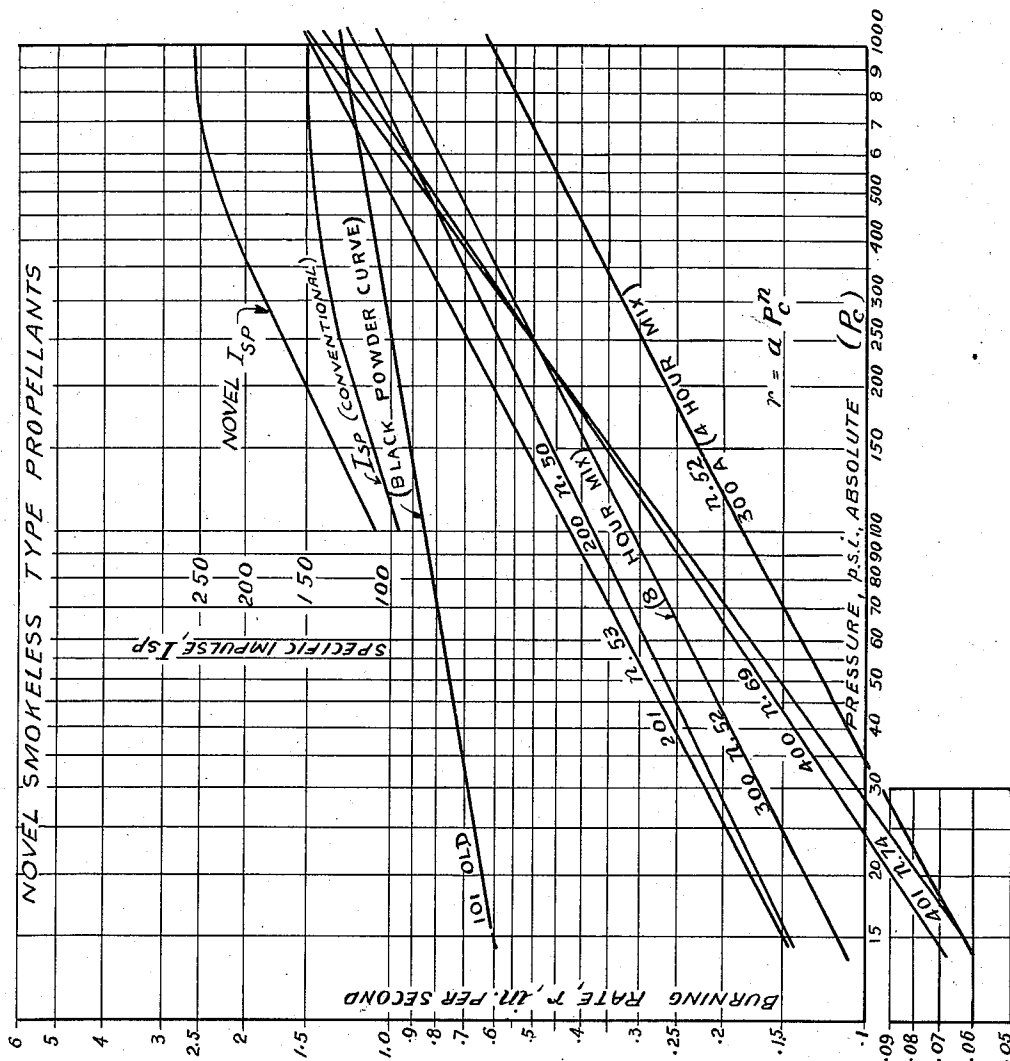


Fig. 15.

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2,853,946

ROCKETS

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Application January 26, 1954, Serial No. 406,103

3 Claims. (Cl. 102—49)

This invention relates to rockets.

The invention has for its object to provide a lightweight rocket, to achieve a low empty weight (less fuel) which is one of the most important parameters in rocket performance, and low cost, so that such an improved rocket may have wide utility. The great striking force of the improved rocket, due to its high velocity and small size, also renders it useful as an infantry weapon against ground targets.

The improved rocket employs preferably a plurality of bars of suitably packed propellant. The bars are arranged in a circle, one adjacent to the other, to form a central bore with the inner sides thereof, and having radial side walls adjacent each other, the outer surfaces of the charge bars being peripherally spaced with widening spaces therebetween filled with some lightweight structural material or special fuel to fill said spaces, and to enable an adhesive to hold said bars in place, which is necessary due to high accelerating forces during flight and in order to protect against high shock loads and vibrations due to rough handling of the rockets during shipment. The charge bars are provided with an outer inhibiting coating along their outer sides that are tangential to the bore of the enveloping container. Longitudinally the bars may be single units or made of a multiplicity of short members.

The bars extend almost the entire length of the rocket, save for a nozzle held by the container at its rear end, and for a headcap at its front end to support a replaceable warhead, provided with explosives.

The charge configuration permits controlled internal burning resulting in a constant thrust and constant pressure during the combustion thereof, which is highly desirable.

The nature of the propellant is such that the ratio of the burning area to the nozzle throat area may remain low. This ratio symbol is commonly designated as K_N .

The nature of the propellant having low K_N and low chamber pressure allows the improved configuration of the bars which configuration permits proper burning of the charge (uniform burning area of a constant character throughout the depth of the bars). This arrangement does not require a large ratio of burning area to throat area. In case of composite charge bars consisting of a plurality of units of short length, instead of a single bar, the abutting ends of the short units are completely inhibited, which however will not change the constant burning area of the uninhibited ignition surfaces of the bars, the remaining parts of the bars being provided with a coating to inhibit or restrict burning to the constant factor of the ignition surfaces of the bars.

The configuration and the constituency of the propellant makes possible a charge which is self-sustaining circumferentially, to be insertable into a lightweight container of either plastic material, light steel, or an aluminum alloy. The low container weight is primarily the result of the low operating pressure of the propellant, i. e. 500 to 700 lbs. per square inch. The container must

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support the charge to some degree and should therefore be structurally sound and rigid to protect the same.

Suitable fins are provided on the container at the rear end thereof, and a warhead at the front end thereof. Due to the novel configuration of the charge bars, the burning area remains constant from the top (innermost bore end) to the bottom thereof (in contact with the container).

The invention will be more fully described hereinafter, embodiments thereof shown in the drawings, and the invention will be finally pointed out in the claims.

In the accompanying drawing,

Fig. 1 is a side elevational view, partly in section, of the improved rocket, taken on line 1—1 of Fig. 4;

Fig. 2 is a transverse section taken on line 2—2 of Fig. 1;

Fig. 3 is an enlarged transverse section of one of the charge bars shown in Fig. 2;

Fig. 3a is a diagrammatic view showing the evenness of the burning or burning surface propagation on ignition of a rod or charge pellet;

Fig. 4 is an end view of Fig. 1, seen from line 4—4 of Fig. 1;

Fig. 5 is a side view of a warhead;

Fig. 6 is an end view of Fig. 5, seen from line 6—6 in Fig. 5;

Fig. 7 is a side view of another warhead;

Fig. 8 is an end view of Fig. 7, seen from line 8—8 in Fig. 7;

Fig. 9 is a diagram chart showing curves indicating performance characteristics, such as acceleration, velocity and distance to launch warhead;

Fig. 10 is a diagram showing the drag and drag coefficient characteristics, as to transonic and supersonic regions;

Fig. 11 is a diagram showing the performance characteristics to launch warhead;

Fig. 12 is a diagram for air drag coefficient values;

Fig. 13 is a section illustrating a modified form of charge bars arranged in the elongated cylindrical casing;

Fig. 14 is a section similar to that of Fig. 13, illustrating a further preferred form of said charge bars; and

Fig. 15 is a burning rate-pressure diagram of the propellants usable with this invention.

Similar characters of reference indicate corresponding parts throughout the drawing.

Referring now in more detail to the drawing, an example of a supersonic barrage rocket, such as "air to air," is shown in Figs. 1 and 2.

An elongated hollow cylindrical container or shell 10 made of glass, plastic or the like, for example fibre glass cloth, flock or filaments suitably incorporated in a tubular plastic or vulcanized fibre structure, is of a thinness to render said container as light as possible, but to withstand necessary bursting stresses. At one end of said container, a nozzle 11 having an open bore 12 is inserted and frictionally held therein, aided by a suitable adhesive and/or mechanical means. The contour of the nozzle 11 is such that it conforms with standard practice, that is, it gradually increases in depth from its extreme outlet end to its peak, and then suddenly decreases in depth at 14, as shown by the curved portion 13, the end of which is formed as an abutment against the rear ends of the charge bars. Within the shell 10, there is longitudinally distributed and circumferentially disposed a plurality of bars 15 of a specific cross-sectional area, the bars 15 being so placed as to form a central bore 16, as shown in Fig. 2. The propellant bars of this shape are practical to manufacture, easy to install, may be quickly ignited, and quickly consumed in a controlled manner to form gases within the bore 16, which gases exhaust through the nozzle 11 under constant,

equal, relatively low pressure. The length of bars 15 almost equals the length of shell 10, and thus the bars provide expulsion gases until they are uniformly consumed. As stated, said bars 15 abut against the abutment end 13 of the nozzle 11.

The propellant bar 15, shown in Fig. 3, has a base portion 20, with rounded corners 20a, and two parallel side walls 21, two slightly inclined walls 22 in continuation of the side walls 21, and a top wall 23.

When a plurality of bars is assembled in a shell, e. g. eight in number the corners 20a tangentially contact with the bore 24 of the shell (Fig. 2), and each bar has its inclined walls 22 in faying parallel relationship with the corresponding inclined walls of the adjacent bars, whereby the top walls 23 form a bore 16 of angular shape. This intimate connection of a multiplicity of bars 15 provides a unitary self-sustaining structure of generally cylindrical contour with a desirable bore for the emission of gases. The spaces between the bars 15 and the bore 24 of the container 10 are filled with an adhesive 25 to hold the bars securely in position in their arrangement shown in Fig. 2.

The rear end of shell 10 is provided with fins 26, preferably six in number. These fins may be of the retractible type and may be reduced in number to 3 or 4 of different configuration.

The front end of shell 10 is provided with a head cap 27 secured to and within said shell 10. Cap 27 has a bore 28 for a warhead 30 seated therein. The bars 15 with their foremost ends abut against the base of headcap 27.

Warhead 30 has a pointed nose 31 at its front end, and four fins 32. It is filled with suitable explosives of known composition, according to the uses intended. Figs. 5 and 6 show one type of such warhead, and Figs. 7 and 8 demonstrate another embodiment thereof.

In Fig. 5, the nose of the warhead is inclined about 12° to the horizontal, and in Fig. 7 the inclination of the nose is about 10°. The warhead is either securely or loosely placed into the head cap 27; in the latter case, in flight, the warhead may soar onward when the shell 10 drags away.

Fig. 3a shows diagrammatically, the cross section of a bar 15, surrounded by a layer of cement 15a, the bar being indicated by the character B. Each dot-dash section $b_1, b_2, b_3 \dots b_x$ represents an equal burning surface of the charge bar B on progressive combustion thereof from b_1 (corresponding to surface 23 in Fig. 3) toward b_x (in the proximity of surface 20 in Fig. 3). This is to show the evenness of burning across the cross-sections of individual bars as the powder charge is being consumed. The coating terminates at A, leaving an exposed surface b_1 to start the burning of the charge bar.

The factors of acceleration, velocity, distance to launch warhead, are shown in Fig. 9 with the nomenclature explained hereinbelow. This Fig. 9 shows a diagram in which the abscissa is the time interval in seconds. The ordinate is the distance in feet and also acceleration which is measured in feet per second per second; the right-hand ordinate indicates the velocity, measured in feet per second. The curves shown are both theoretical, and actual (calculated) where air drag is involved.

These curves are calculated values obtained from well established formulae and indicate the performance of the rocket in definite fractional time intervals of the total duration of the thrust.

In Fig. 10, a theoretical curve shows the variation of the drag coefficient against the velocity, and also the air drag against velocity.

Drag is calculated as follows:

$$\text{Drag} = C_{D0} \times A \times V^2 = \text{lbs.}$$

wherein C_{D0} is the drag coefficient, A is the cross-section

tional area in square feet, and V is the velocity in feet per second.

The density factor, of course, must be considered, which is $\frac{1}{2}\rho$ for sea level conditions.

The above is well established formula for the air drag calculation of aerodynamic bodies.

In Fig. 11, the legends make the diagram self-explanatory.

In Fig. 15, the numbers of the curves correspond to test numbers of various propellants. The curve for old black powder is marked 101. The $n_{.50}$ curve is marked 200, and the $n_{.53}$ curve by 201. The $n_{.52}$ curve is numbered 300, this propellant having been obtained by an 8 hours' tumbling; the propellant having the same constituents with only 4 hours' tumbling is marked 300A. Numeral 400 indicates the $n_{.69}$ curve, and the $n_{.74}$ curve is indicated by numeral 401. The symbol I_{sp} indicates the specific impulse curve.

The established generation of low pressure gases under desirable conditions is clearly indicated.

The diagram of Fig. 15 shows the variation of propellant performance against the chamber pressure and justifies the use of a relatively low chamber pressure, i. e. about 500 lbs. per square inch, which produces a better than average value of the specific impulse. The low pressure of about 500 lbs. per square inch obviously will result in a much lighter chamber construction, as compared to other rockets in which the propellants must operate at pressures of approximately 1,500 lbs. per square inch.

Fig. 13 shows possible use of an intermediate tube 60, of plastic or thin metal, between the charges and the container.

Another way of assembling the charges is to have a flat layer provided with spaced triangles, and then to install the bars and roll said layer to form a circular ring, the needed amount of triangles and bars being determined to make a charge, and then to insert said charge ring into the container.

In Fig. 14 a larger triangle 61 is shown, and the bars 15 are radially spaced at their bore end, as shown by the triangular spaces 62.

The following calculation is given by way of an example to show unusually high performance of the novel rocket:

The initial acceleration equals 812 g. Final acceleration is 1780 g. Average acceleration is 1450 g. (approximately 46,700 ft. per second per second).

The launching velocity V_L (neglecting air drag) is equal 32.2 (g.) times I_{sp} (specific impulse) times I_n

$$\left(1 + \frac{W_p}{W_0}\right)$$

where W_p is the propellant weight, W_0 is total weight less propellant, and I_n is natural log.

This typical case gives a velocity of 6070 feet per second. The distance to attain the theoretical V_L equals 415 feet. Similar calculations, using the best known propellants other than used here, will show reduced performance by at least 25 percent because of the increased weight due to higher pressures necessary to burn conventional propellants.

The following dimensions are in inches and are given for a complete understanding of the inventive concept, without being limited thereto:

The overall length from nozzle to warhead nose tip equals 9½ inches.

The distance from nozzle tip to the base of head cap equals 7½ inches.

The length of fins at the rear end of shell is 1¾ inches, including the inclined portion, whose length is ½ inch.

The outer diameter of the shell is ¾ inch. The height of the charge bar is .150 inch, and the base width thereof is .150 inch. The height of the parallel sides of the

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charge is .093 inch. The distance from top to top of the diametrically opposed bars is $1\frac{1}{2}$ inch.

The height of the fin from the shell is $\frac{5}{32}$ inch, and its thickness is $\frac{1}{4}$ inch. The diametrical distance from tip of fin to tip of fin is $1\frac{1}{16}$ inches.

The warhead is $2\frac{1}{4}$ inches long with the sides having a radius of 1 inch. The fins are $\frac{7}{8}$ inch, the head end flat inclination is $\frac{7}{8}$ inch flat. The tip offset is $\frac{1}{32}$ inch with a $\frac{1}{4}$ inch radius, the angle of inclination being 12 degrees. The fin has a $\frac{1}{16}$ inch radius, and the end of the warhead tip is $\frac{1}{16}$ inch in diameter. From tip to tip of the fins, transversely, the distance is $3\frac{1}{4}$ inch; and the diameter of the warhead is $\frac{1}{2}$ inch. The length of the fins is $\frac{7}{8}$ inch.

The rocket could be made to spin by modifying the fins.

The rocket can be ignited from its nozzle and launched from a manifold type base permitting only one or a large number of rockets, say 1,000, to be fired at the same time. A very fast burning strip of gauze impregnated with the same type of powder as used in the main propellant charge has been found satisfactory. This gauze strip extends from the nozzle to the forward end of charge and can be inclosed in a light paper or aluminum foil tube to cause the ignition to take place in the forward end of the charge. This will cause the entire inner surface of the charge to be properly ignited due to the fact that the hot gases, in order to escape, must flash rearwardly toward the nozzle opening.

The alternate warhead has a length of $2\frac{1}{4}$ inches with a 2-inch radius at its central portion, with front flat inclined $\frac{5}{8}$ inch at 10 degrees; the distance from its center to its tip is $1\frac{1}{4}$ inches; the length of fins is $\frac{1}{2}$ inch; the inclination of the fin front is 15 degrees; diametrical length of fin edge is $\frac{1}{2}$ inch; and the diameter of warhead is $\frac{3}{8}$ inch.

The weight in lbs. is as follows:

Shell.....	.0235
Head cap.....	.0116
Nozzle.....	.0043
Fins (6).....	.0011
Warhead.....	.0313

Total empty weight, W_e equals... .0730 (without propellant W_p) 45

Fuel or propellant weight equals... .0870 lbs.

Loaded (fuel)..... .1600 (Total weight W_T)

One of the essentials is to have a very light-weight shell, with an outer diameter of $\frac{3}{4}$ inch and an internal diameter of $1\frac{1}{16}$ inch, weighing .025 lb. or less. Due to the low weight and high thrust, high acceleration is obtained. The charge does not crumble because of the unique installation of the propellant charges. The maximum air drag is calculated to be only 20 lbs. 50

The propellant weight (W_p equals .087 lbs.; it is of

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smokeless type, and the charge arrangement provides internal burning which is restricted for constant thrust (130 lbs.), P_c (500 lbs. per square inch), I_{sp} (240), duration (160 seconds). The weight of the empty rocket equals .073 lb. Total weight of the rocket (propellant charge plus shell) thus equals .160 lb. (W_T).

The foregoing configuration and contour of the charge, and disposition of the same, whereby a light-weight container is obtained, is made possible by the novel powder utilized, which combines low pressure combustion and even propagation of the burning area to assure constant thrust. I have heretofore filed applications Serial Nos. 404,717 and 454,209, filed January 18, 1954, and September 3, 1954, respectively to which reference is made.

I have described several forms of my invention, but obviously various changes may be made in the details disclosed without departing from the spirit of the invention as set out in the appended claims.

I claim:

1. In a rocket having a shell of light-weight material, said shell having a bore, a nozzle at one extremity of said shell and a warhead at the other extremity of said shell, in combination: a plurality of elongated propellant charges each having a substantially polygonal transverse cross-section and operating at pressures of up to approximately 500 p. s. i., said propellant charges being adjacent each other in circular sequence, forming a composite charge, and defining a relatively large internal bore, the surfaces of said propellant charges which define said internal bore being uninhibited for quick ignition thereof, an elastic inhibitor, filling the spaces between said propellant charges and said shell, said inhibitor forming with said propellant charges a solid unit in said shell, said composite charge with said inhibitor having a high degree of elasticity. 30

2. The structure of claim 1, wherein the adjacent pairs of said propellant charges define with said shell substantially triangular areas and said inhibitor in said triangular areas is an elastic adhesive. 35

3. The combination of claim 1, wherein said composite charge is a self-sustaining unit. 40

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