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MANUFACTURE OF PROPELLANT CHARGES

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FIG. 1.

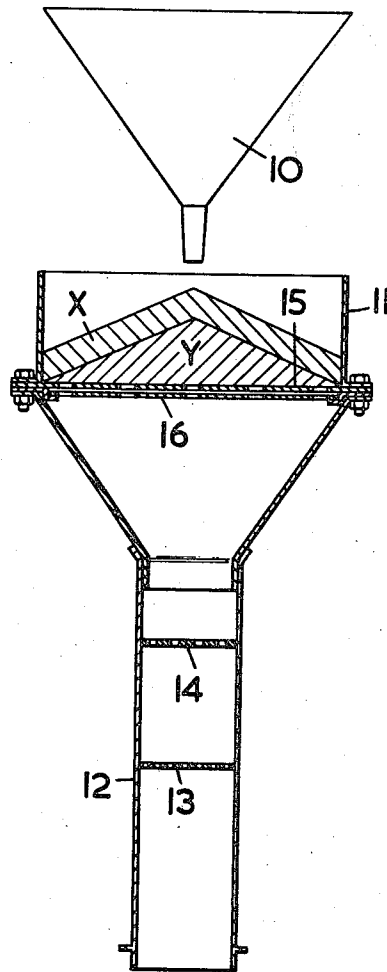
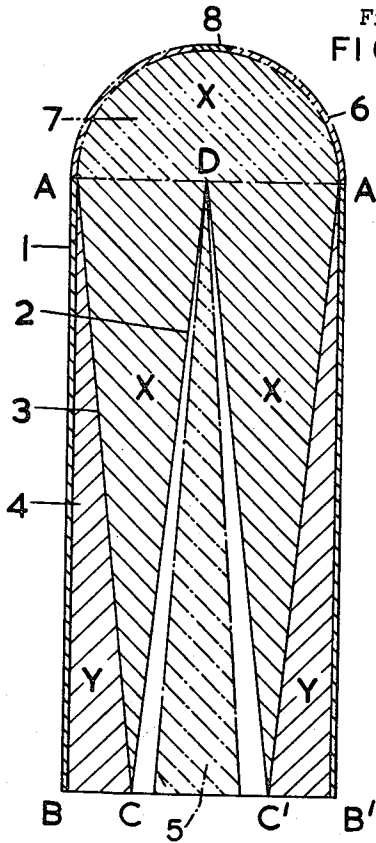


FIG. 2.

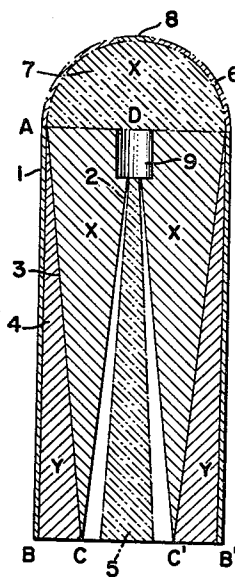


FIG. 3.

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MANUFACTURE OF PROPELLANT CHARGES

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This invention relates to the manufacture of gas producing propellant charges as used to propel rockets and for other gas pressure-operated devices. The invention refers particularly to the method of producing charges by the so-called cast double base technique, but it may also be applied to propellant charges produced by other methods.

Solid propellant charges for rockets and other low pressure mechanisms are usually designed to give a constant mass rate of discharge of the products of combustion. This is normally achieved by arranging the geometry of the charge so that as the propellant burns away, by successive layers parallel to the original burning surface, the total burning surface area remains constant. In addition certain propellant surfaces may be inhibited from burning by close adhesion to a layer of other material which is incombustible under the conditions prevailing. By this means the burning surfaces may be confined to an internal conduit or conduits. In a simple form such an internally-burning charge may consist of a cylinder inhibited from burning on the externally curved surface and possibly one or both ends. The conduit in which burning occurs may consist of a central hole extending along the axis of the charge, and of star cross-section with a perimeter approximately equal to the perimeter of the propellant charge.

The advantages of such a design as compared with non-inhibited externally burning grains, which may comprise a simple tube or set of tubes of propellant, are that the walls of the containing vessel are protected by the propellant itself from the weakening effect of the hot propellant gases, that the heat losses are reduced and consequently the useful energy of the system is increased and that the propellant receives mechanical support from the material inhibiting it. Disadvantages are that portions of the charge remain unburnt in the form of residual sliver, that sections of the charge may be mechanically weak, such as the portions of propellant projecting into a star conduit or surrounding the star points, and unable to withstand the stresses of temperature cycling or the forces imposed by the shock of ignition and discharge, which may include high angular and longitudinal accelerations. Further, when the conduit is of uniform cross-section there is a velocity gradient of gas from one end to the other. To obtain the greatest loading density and highest performance, the initial axial velocity of gas should be constant throughout the length of the conduit and only slightly less than that at which it passes through the throat of the vented vessel in which the charge is fired.

The present invention has for its object the production of an improved design of charge which eliminates the mechanically weak sections frequently associated heretofore with internally-burning charges and secondly by maintaining a constant gas velocity along a central conduit during the initial stages of burning and eliminating sliver at the end of burning the improved design of charge enables greater effective loading density and higher performance to be obtained.

This object is achieved according to the invention by providing a gas producing charge having a variable total burning area during firing comprising at least two propellants of different predetermined rates of burning apportioned in a predetermined manner throughout the charge

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such that during firing the mass rate of discharge of the gases of combustion is maintained substantially constant.

The charge may be cylindrical in shape and may contain a hollow truncated conical septum of equal height as the charge and having a base common with one end of the cylindrical charge and may contain an axial conduit in the form of a cone having an apex at the same said end of the cylinder and having a base in the plane of the other end of the said cylinder. The portion of the charge between the septum and the outer cylindrical wall of the charge may contain one propellant of a known predetermined rate of burning and the portion of the charge between the septum and the axial conduit may contain a second propellant of a predetermined different rate of burning such that during firing the mass rate of discharge of the gases of combustion is maintained substantially constant.

Alternatively the charge may enclose an axial conduit and comprise at least two propellants of different predetermined rates of burning which are dual blended in horizontal strata such that during firing the mass rate of discharge of the gases of combustion is maintained substantially constant.

The invention will be described by way of example with reference to the accompanying drawings in which:

FIG. 1 shows a sectional elevation of a so-called "double cone" propellant charge according to the invention.

FIG. 2 is a sectional elevation of an apparatus for filling a "dual-blended" charge with powder.

FIG. 3 shows a modification of the propellant charge illustrated in FIG. 1.

As shown in FIG. 1 the propellant charge is arranged within a cylindrical sleeve 1 of material such that it will inhibit the charge from burning on its cylindrical surface. A central conical cavity 2 in the charge forms the conduit. The propellant is built up of two coaxial masses X and Y of which the inner part X is formed as an inverted truncated cone 3 with the axial conduit 2, and the part Y is formed as an annulus 4 of tapered cross-section surrounding the cone 3 within the said sleeve. The portion X of the charge is constituted by propellant material which burns at a rate x and the portion Y of material which burns at a rate y , and the rate x is more rapid than the rate y .

It can be shown that if the rates x and y are correctly chosen, a nearly constant mass rate of discharge can be achieved. This is, however, somewhat lower at the beginning and end of burning and the uniformity can be improved by various devices. One of these illustrated in FIG. 1 is to add an additional cone 5 of propellant as shown and to maintain it in place by a grid (not shown) secured over the end BB' of the charge. This raises the mass rate of discharge at the beginning of burning, and also improves the loading density, except in the case of charges with a very high length/diameter ratio, where the open end of the conduit 2 is only just large enough to take away the gases at the start of burning at the maximum designed velocity and the additional cone 5 cannot be used. In practice the apex of the cone would be omitted to allow space to house the igniter 9, as illustrated in FIG. 3.

There are advantages in strength and lightness of case in using a containing vessel (not shown) with a hemispherical head end, into which the charge fits. This hemispherical portion 7 of propellant X contained within the boundary 6 of inhibitor may also be formed as part of the charge with advantage. The progressive nature of its burning reduces the slight fall off in pressure at the end of burning and further improves the uniformity of ballistics. When the cast double base process of manu-

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facture is used, a hole at 8 is left in the inhibiting coating 6 during casting, to assist the flow of casting liquid through the powder bed. It is subsequently filled with a disc of inhibitor cemented into position.

It has been found convenient in practice to choose a ratio of $x/y=2$, in which case the ratio of the diameter of the charge to the diameter of the mouth of the conduit

$$\frac{BB^1}{CC^1} = 2$$

In this example the volume of the conduit is $\frac{1}{12}$ the volume of the cylindrical portion of the charge giving a loading density of 91.6 percent. This is further raised by adding the cone 5 of propellant Y and again by adding the hemispherical end 7 of propellant X.

The propellants X and Y may have normal positive pressure exponents, when the rate of burning increases exponentially with pressure, or they may be platonised, whereby with the addition of a ballistic modifier, such as a lead compound, the rate of burning can be made independent of pressure over a range of pressures, or even exhibit a negative pressure exponent. To obtain the best results the propellants should have plateaux which overlap as regards pressure range at the operating pressure of the charge, the rates of burning at this pressure being chosen to give the correct ratio of x/y .

The shape of charge described may be made by cementing or pressing together preformed sections of propellant, made by moulding or machining to shape. The design is, however, especially suitable for manufacture by the known cast double base process. The mould assembly may contain a conical former of the shape C.D.C.¹

A thin combustible hollow conical septum of shape outlined in section by ACC¹A¹ is fitted in position. This can be made by dipping a former in a solution of nitrocellulose, or casting powder, of suitable viscosity, 10 to 20 percent by weight in solvent, slowly withdrawing the former and drying the film. The process may be repeated until a film of the correct thickness is built up, say, 0.020 to 0.030 inch thick. The septum in the form of a hollow truncated conical surface of dried lacquer is then removed for use. Alternatively the septum may be made by rolling up and cementing together a sheet of celluloid or other suitable material of the correct shape. When the septum and a control former are in position the powder X is first filled through the top of the charge, which is then inverted to allow filling with powder Y. The assembly is closed and returned to its original position.

By way of example, if the ratio $x/y=2$ approximately and an operating pressure of approximately 1500 pounds per square inch at a charge temperature of 70° is required, the following formulations to give platonised propellants of the required properties may be used. Parts are by weight.

	Composition, Percent		
	Casting Powder to fill X	Casting Powder to fill Y	Casting Liquid
Nitrocellulose (cotton 12.6% N ₂)		88	
Nitrocellulose (paper wood 12.2% N ₂)	88		
Nitroglycerine	6.4		72
Diethylhexylphthalate		5	
Lead Stearate		5	
Lead 2-ethyl hexoate	2.3		
Lead Salicylate	2.3		
2-nitrodiphenylamine	1.0	2	1
Triacetin			27
Graphite glaze (added)	0.05	0.05	

A further development of this invention is the production of dual-blended charges. This relates only to methods of producing propellants by filling moulds with

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powder, such as the cast double base process, or the pressed charge process. It will be seen, on referring to FIG. 1, that there is no need to have the septum ACC¹A¹ if the propellants X and Y within the filled space are blended in horizontal strata, so that the rate of burning of the blend rises progressively from the lower end BC, C¹B¹ to the upper end ADA¹ from rate y to rate x.

If the charge does not include the hemispherical end 7, it is filled from the top ADA¹. If the hemispherical end is to be included, it is filled inverted, BCC¹B¹ being at the top. The powders may be blended in varying proportions by filling from two hoppers, each containing one powder, and opening or tilting these at different speeds by suitable mechanical means or by feeding with helical screw feeds driven by opposed conical pulleys and a common belt which traverses the length of the cones during filling.

Equipment for a simple gravity controlled method of filling is illustrated in FIG. 2. It consists of a funnel 10, a hopper 11 and a filling head 12. It makes use of the facts that a powder, unlike a liquid, when poured onto a horizontal surface, forms a cone which has a distinctive angle of repose for any particular powder, and the rate at which the powder flows through an orifice is independent of the head of powder above the orifice.

When using the equipment (FIG. 2) to fill the charge ABB¹A¹, the bottom of the filling head 12 is made of such diameter that it just fits into the mould assembly containing a cylindrical sleeve of inhibiting material and a central conical former. The filling head 12 carries two perforated plates 13 and 14. The plate 13 has a large number of evenly spaced small holes just sufficient in size to pass the powder if spread over it in a very thin layer. The plate 14 has evenly spaced larger holes just sufficient in diameter to pass the powder irrespective of the height of powder above it; the number is such that the rate of feed to plate 13 is just sufficient to prevent a build up of powder and cause clogging of the holes in plate 13.

The hopper 11 is divided by a plate 15 which is perforated with the same number and size of holes as plate 14 correctly spaced over its area. These holes can be exposed or closed by a perforated slide 16 or other device. The internal diameter of the cylindrical portion of the hopper 11 is made equal to the base of the cone of powder Y formed at its natural angle of repose, when the weight required for the charge is poured through funnel 10 on to plate 15.

The process of filling is as follows. The required weight of powder Y is poured through 10 into hopper 11, the slide 16 being closed. Next the required weight of powder X is poured through 10 on top of powder Y. The slide 16 is opened. At the start of filling pure powder Y pours into the charge; as filling continues, increasing amounts of powder X are blended with powder Y until at the end of a filling operation pure powder X is introduced.

In the double cone charge (without the cone 5 and hemispherical end 7) the volumes of propellant X and propellant Y are equal. When a dual-blended charge is filled, it will be found that the propellant made by blending the two powders will have a higher rate of burning than calculated by simple proportion from the amounts of powder X and Y and their respective rates of burning x and y . The blend at various levels in the charge and hence the internal ballistics, can be adjusted as required by suitable positioning of the holes in hopper 11 and adjusting the weights of X and Y. Alternatively the disposition of the piles of powder X and Y can be altered in the hopper 11. For example powder Y may be poured in through funnel 10 having a narrow orifice and powder X be more widely distributed through a funnel replacing that illustrated, which has a wide annular exit.

Allowance must be made in calculating the diameter

of hopper 11 for powder left on the perforated plates and any additional length to be formed at the bottom of the charge and subsequently trimmed away. Powder can be prevented from remaining on the perforated plates 13, 14, 15 by making these sufficiently thick and counter-sinking the holes at the tops of the plates, so that the top of each plate consists of a number of completely intersecting conical surfaces with no horizontal surfaces.

I claim:

1. A method of casting shaped gas producing charges having a variable total burning area during firing which includes so apportioning at least two propellants of different predetermined rates of burning in a predetermined manner throughout the charge that during firing the mass rate of discharge of the gases of combustion is maintained substantially constant, said apportionment being attained by the steps of placing a mass of gas-generating powder over a closed screen to form a cone of said powder formed at its natural angle of repose, covering said cone with a given thickness of gas generating powder of a different gas generating rate than said first mentioned powder, and opening said closed screen to allow gravity flow into a mold, whereby the said two powders are filled into said mold in constantly varying proportions.

2. A method of making shaped gas producing charges having a variable total burning area and a constant rate of gas generation during firing, said method comprising forming a hollow conical septum of thin combustible material, placing said septum about an inner control former and positioning said assembled septum and former centrally in a casing, filling the open side of said septum with relatively fast burning propellant, and then inverting said casing and filling the space between the septum and the casing with a relatively slower burning propellant.

3. A cylindrical gas producing charge having a variable total burning area during firing, a hollow truncated septum of equal height as said charge and being enclosed by said charge, the base of said septum being the same size and in the same plane as one end of the cylindrical charge, an axial conduit in the form of a cone having its apex at the same end of the cylinder as the base of said septum and having a base in the plane of the other end of said cylinder the same size as the other end of said septum, said other end of said septum being substantially one-half the diameter of said charge, said axial conical conduit being arranged within said septum, the portion of the said charge between the septum and the outer cylindrical wall of the charge containing one propellant of a predetermined rate of burning, and the portion of the charge between the septum and the conical axial conduit containing a second propellant of a predetermined faster rate of burning, the two said propellants being so dual blended in horizontal strata that during firing the mass

rate of discharge of the gases of combustion from the burning of said propellants is maintained substantially constant.

4. A gas producing charge as set forth in claim 3 wherein the axial conical conduit is provided with an enlarged apex portion for housing a charge igniter.

5. A gas producing charge as set forth in claim 4 wherein the end of the charge which houses said charge igniter is provided with a hemispherical head of propellant.

6. A cylindrical gas producing charge having a variable total burning area during firing, a hollow truncated conical septum of equal height as said charge and being enclosed by said charge, the base of said septum being the same size and in the same plane as one end of the cylindrical charge, an axial conduit in the form of a cone having its apex at the same end of the cylinder as the base of said septum and having a base in the plane of the other end of said cylinder the same size as the other end of said septum, said other end of said septum being substantially one-half the diameter of said charge, said axial conical conduit being arranged within said septum, an axial conical charge of propellant of a predetermined rate of burning in the form of a cone having its apex at the same end of said cylinder as the apex of said axial conical conduit and having its base in the plane of the other end of said cylinder, said axial conical charge being arranged within and spaced from the sides of said axial conical conduit, the portion of the charge between the septum and the outer cylindrical wall of the charge containing one propellant of a predetermined rate of burning and the portion of the charge between the septum and the conical axial conduit containing a second propellant of a predetermined faster rate of burning, the said propellants being so blended in horizontal strata that during firing the mass rate of discharge of the gases of combustion from the burning of said propellants is maintained substantially constant.

7. A device as in claim 3 wherein said one propellant has a burning rate of one-half that of said second propellant.

8. A device as in claim 6 wherein said one propellant has a burning rate substantially one-half that of said second propellant.

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