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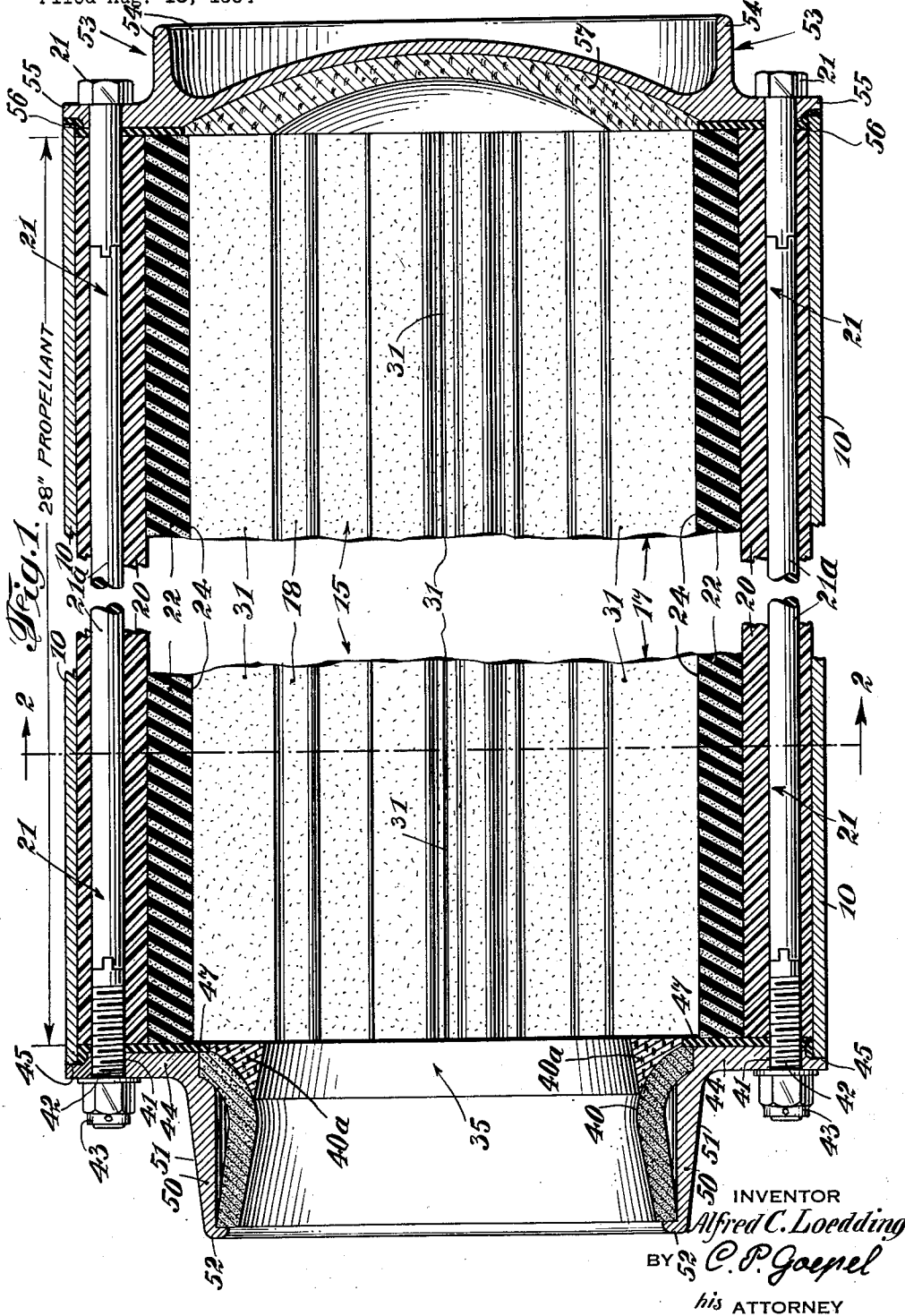
A. C. LOEDDING

2,816,418

SHAPED PROPELLANT CHARGES FOR SOLID-FUEL ROCKET TYPE MOTORS

Filed Aug. 18, 1954

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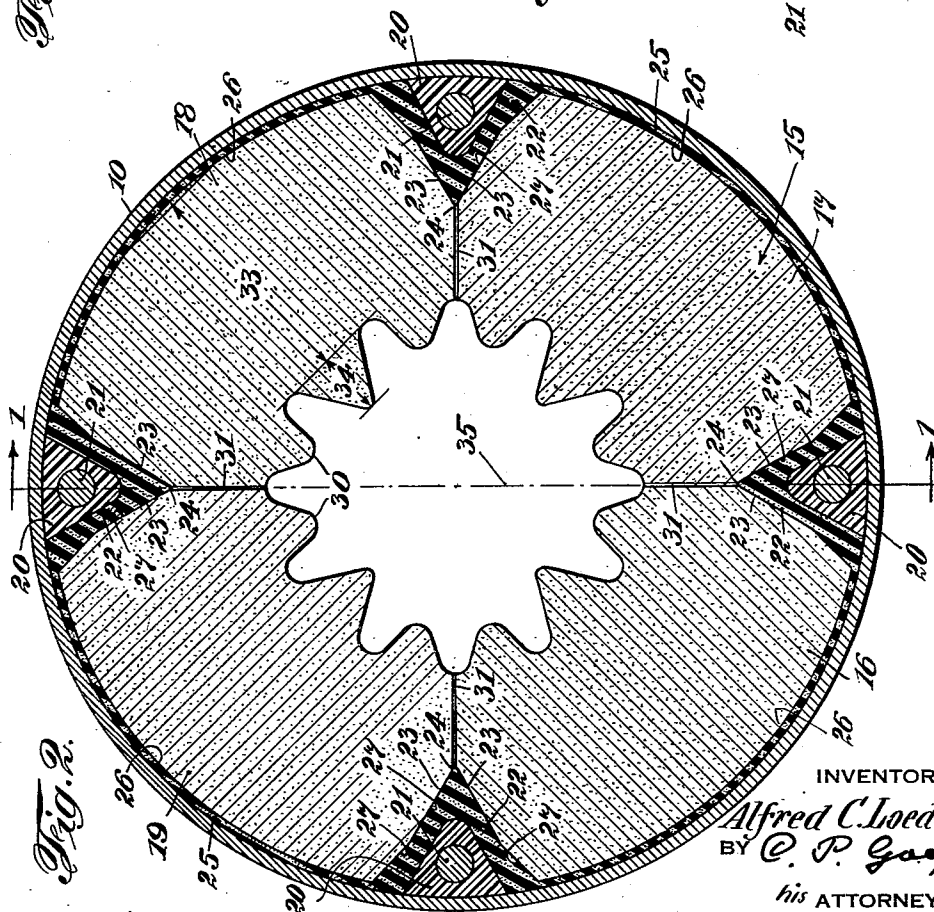
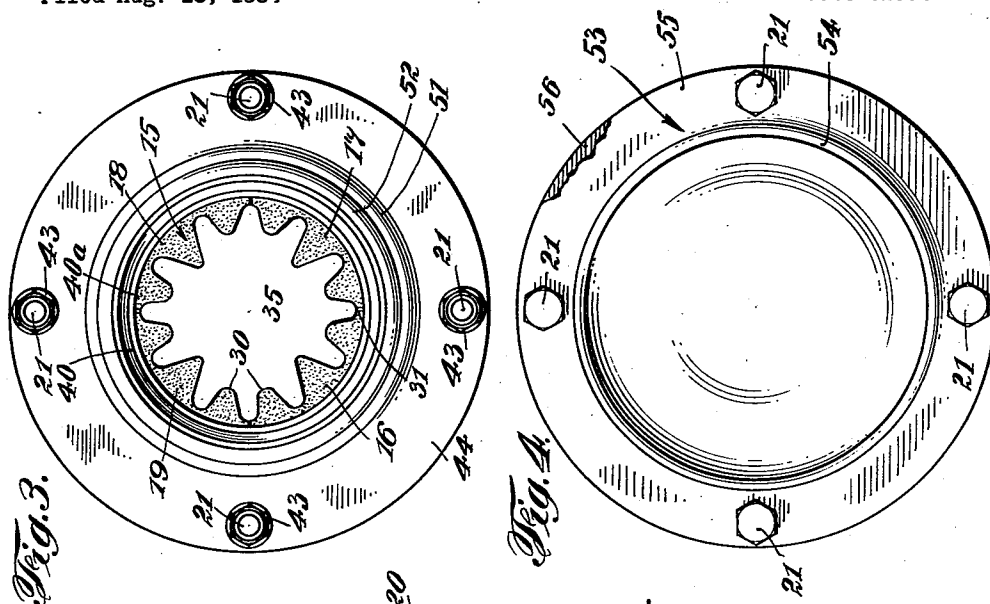
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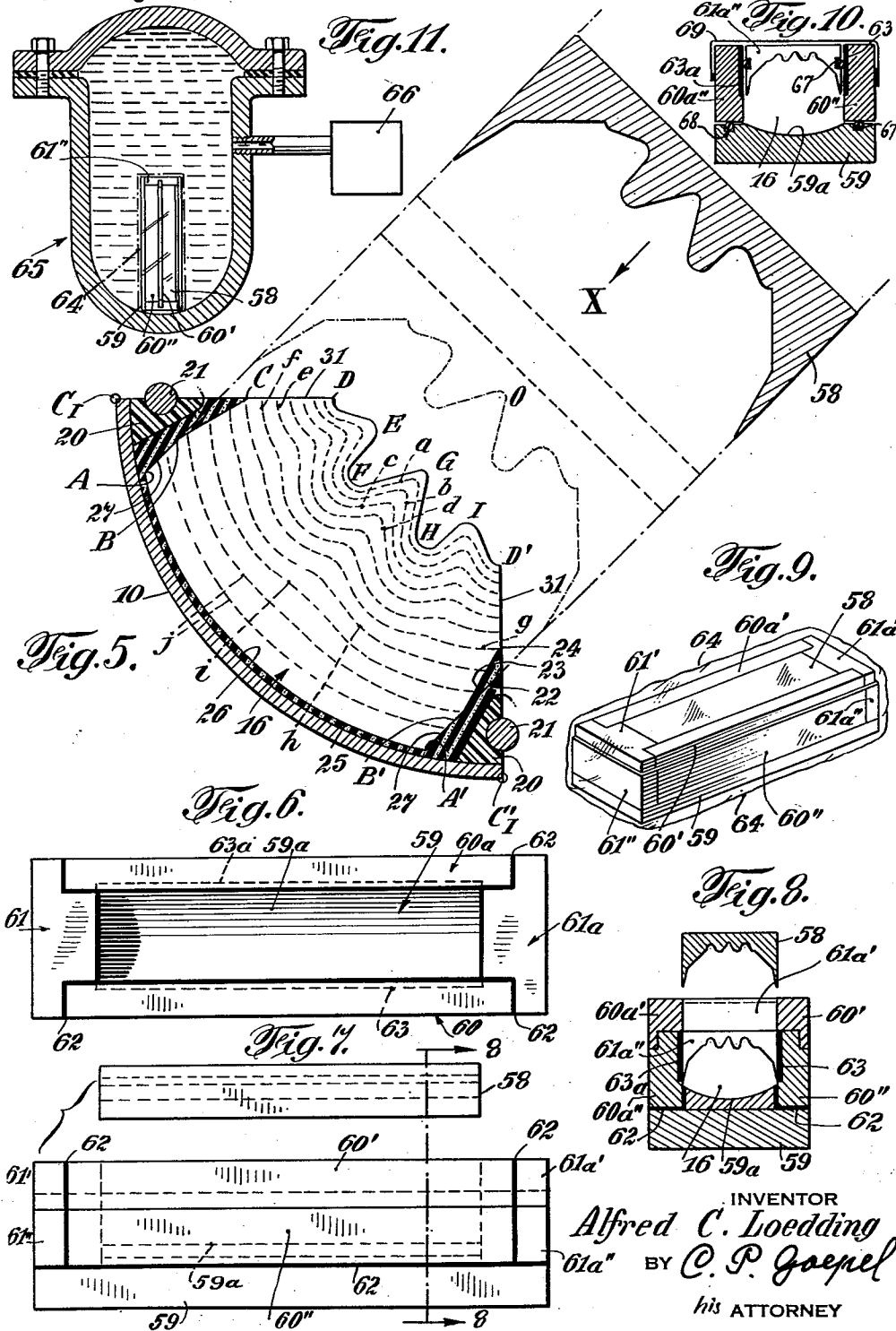
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SHAPED PROPELLANT CHARGES FOR SOLID-FUEL ROCKET TYPE MOTORS

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Application August 18, 1954, Serial No. 450,714

2 Claims. (Cl. 60—35.6)

This invention relates to a solid-fuel rocket type motor assembly, and more particularly to a container having a resilient lining with several internal buttresses which divide the powder charge with the same number of sections; each of these sections has its exterior peripheral contour conforming to the internal curvature of the container and the assembled charge has an internal opening formed by a plurality of hills and valleys of different depths, the sections being separated by inhibited adjacent surfaces radially aligned with the peaks of the separating lining to achieve restricted internal burning of constant pressure.

The sections forming the propellant charge, which may be two, three, four or more than four in number, are composed of low pressure burning propellant of uniform burning capacity, made under an invention for which applications have been filed by me on March 10, 1951, under Serial No. 214,921, on January 18, 1954, under Serial No. 404,717, and on September 3, 1954, under Serial No. 454,209, from which it is possible to make charges of the peculiar shape shown.

The sections of the propellant charge of this invention are shaped by a novel method and in novel dies. This charge configuration assures restricted internal burning of constant pressure. This method and dies are claimed in a copending patent application filed by me under Serial No. 478,136, on December 28, 1954. The dies used for shaping my novel segmental charge are composite dies having a layer or a ring of resilient material between their adjoining walls so as to yield to the pressure of compressed charge when the hydraulic pressure in the vessel has been eased, and to prevent cracking of the expanding charge.

The invention will be further described hereinafter, embodiments thereof shown in the accompanying drawing, and the invention will be finally pointed out in the appended claims.

In the drawing:

Fig. 1 is a longitudinal central section of an assembly in accordance with this invention, taken on line 1—1 of Fig. 2;

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

Fig. 3 is a nozzle-end view of Fig. 1;

Fig. 4 is a front-end view of Fig. 1;

Fig. 5 is a detailed view illustrating one segment of the propellant charge showing the different stages of its restricted burning in dotted lines;

Fig. 6 is a top view illustrating the die used for the compression of a segmental charge according to this invention;

Fig. 7 is a side view of Fig. 6;

Fig. 8 is a section taken along line 8—8 of Fig. 7, as seen in the direction of arrows;

Fig. 9 is a perspective view of the assembled die in a liquid-proof bag;

Fig. 10 is a view illustrating in section another die

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which may be employed for shaping my segmental charges; and

Fig. 11 is a sectional view of a hydraulic press used in connection with the shaping of segmental charges according to this invention.

Similar characters of reference indicate similar parts throughout the various views shown in the drawing.

Referring now in more detail to the embodiments illustrated in the drawings, and more particularly to Fig. 2, the casing or container 10, made of light material so as to have as little weight as possible, has preferably a cylindrical contour.

Within the container 10, charge 15 is placed and in the embodiment of Fig. 2, said charge consists of four quadrants 16, 17, 18 and 19. Each of these quadrants has approximately the length of the container, and may further to be composed of two or more end-to-end abutting pieces.

Within the container, a number of triangular stringers 20 between the four quadrants forming the charge 15 are applied and are separated from the charge quadrants by sponge rubber liners or cork-rubber compositions 22. Each liner 22 has an angular outline as at 23, and a peak 24, and extends laterally in both directions between the charge quadrants and the inner wall of container 10 thus forming two thin liners 25 which connect each liner 22 with the adjoining left- and right-hand triangular portions 23. This arrangement is necessary to achieve constant burning area for internal burning. Thus, the liner is continuous along the inner surface of the shell 10, and gives protection against shock.

Each quadrant of the charge 15 has a circular outer contour 26 to closely adhere to the inner surface of the liner 25; and inclined portions 27 to fit against the angular portions 23 of liner 22. Each charge quadrant is further limited by two radial surfaces 31 from the tips 24 of liners 22 and inwardly toward the axis of the rocket, and finally has an undulating innermost surface 30. These quadrants 16, 17, 18, 19 when joined together along their radial surfaces 31 and inserted into the bore of the lining 25, form a central opening 35 having a continuous undulate contour, as shown in Figs. 2 and 3. The quadrants 16-19 contactingly abut each other at 31.

By way of example only, the radius of the internal curvature of the lining 25 may be about $4\frac{3}{4}$ inches, and the length of the web 33 of the quadrants about $2\frac{1}{2}$ inches, the hills 34 may be about $\frac{3}{4}$ inch in height with a $\frac{1}{16}$ inch radius. The other hills are arranged symmetrically.

The charge 15 which in the embodiment shown in the drawings consists of four quadrants, is easily made and inserted, the innermost surfaces of the quadrants form a hole or opening 35 for the escape of gases toward the nozzle on the consumption of the charge made up of such quadrants. Instead of four, three, six or any other suitable number of charge sections may be utilized. Further, the whole charge may also be made of a single piece, in which case a rod must be inserted into the die to obtain the hole 35 for escape of gases.

The nozzle supporting plate 44 in the shell 10, shown in more detail in Fig. 1, consists of an aluminum alloy (1.14#) which has openings 41 for the passage of bolts 21, to which a screwthread 42 is applied at their extended ends, and the nozzle portion is held down by a nut 43 or the like.

This nozzle support is a radially disposed plate having said openings 41, and a shoulder 45 at its circumferential end. Shell 10 abuts rigidly the nozzle and wall shoulder 45. A flat rubber seal ring 47 is arranged in parallelism with plate 44 and spaced between said plate 44 and the ends of liner 25, members 20, 22 and charge 15, the radius of the seal ring 47 being about equal to the radius

of plate 44. Shell 10, as mentioned above, abuts shoulder 45.

Plate 44 has an outwardly extending flange 50, with a converging inclination 51, and at its end a shoulder 52 which engages the end of nozzle 40. The nozzle 40 may be of hard carbon (Dixon Crucible #821) or of Carborundum (a trade name for an abrasive of silicon carbide). A cork 40a is within the nozzle 40 to streamline the gas flow initially and to prevent the shock of the charge. On burning of the charge 15, cork 40a is consumed.

The front end of container 10 is closed by an end wall 53, shown in cross-section in Fig. 1 and in plan view in Fig. 4. This end wall or cap 53 has a reinforcing rib 54 extending somewhat beyond the outwardly curved central portion of the cap and is intended to protect the same. Bolts 21, four of them being shown in the embodiment illustrated in the drawings, are closely adjacent the reinforcing rib 54 and are only partly threaded, their middle portions 21a being of a lightweight material to decrease the weight of the entire structure. The circumference of cap 53 has a reduced portion 55 to receive the front end of container or shell 10. The end wall of cap 53 is made of a plastic glass composition or of an aluminum alloy, such as 61SO. A gasket of rubber-like material is indicated at 56 between the cap 53 and shell 10, said gasket being intended to tightly seal the front end of the rocket when the bolts 21 are screwed tight. Also, a pad 57 of cork-like elastic material fills partly or completely the space between the front ends of charge units 16-19 and the outwardly curved central portion of cap 53. After bolts 21 have been tightened, the reduced portion 55 of end wall 53 abuts the end of shell 10 and compresses the rubber disc 56 in the manner shown at the nozzle end. This prevents any looseness, due to the cold flow or shrinkage of rubber as a result of aging.

In certain structures, parts 20 and 21 could be eliminated. Also, the spaces 31 could be filled with a substance such as ammonium nitrate in a rubber-like matrix, which acts as an inhibitor coating, but will burn when the powder charge is burning, giving excellent ballistic characteristics and contributing to the thrust. The substances of elements 20, 21 and 22 could be substituted by similar inhibited materials, burning only with the main charge. This substitute material would act as a booster giving a secondary impulse at the end of the run. This substitution could also be omitted completely, but the bore configuration should then be changed accordingly to increase the peripheral length thereof (by increasing the number of hills and valleys) to maintain a constant thrust. This elimination and substitution will increase the burning area which has to be changed to correspond to the surface length of 30.

The novel configuration of the elements of the charge is made possible by the use of a low pressure, evenly burning powder for which I have made three applications for Letters Patent identified hereinabove.

In shaping the charge quadrants 16-19, the powdered propellant is filled into a container or die whose bottom has a shape corresponding to the finished outer contour 26 between points A and A' of the quadrant, reference being had to Fig. 5 of the drawing. The container walls are parallel between points A-B and A'-B', as shown at 27. The ram which is hydraulically operated, compresses the charge in the direction indicated by arrow X. The profile of the ram 58 has a contour corresponding to the line obtained by connecting points B, C, D, E, F, G, H, I, D', C' and B' of Fig. 5. It will be noted that the surfaces between points B-C, C-D, D-E, F-G and H-I always form an angle with the surface between A-B; and the surfaces between B'-C', C'-D', D'-I, H-G, and F-E also always form an angle with surface between A'-B', this being necessary in order to easily remove the ram 58 after the charge has been shaped. When the ram compresses the charge in the direction of arrow X, thereby giving the inner surface of the quadrant

the characteristic hill and valley shape, as shown between points D and D', it obviously compresses the charge more below each valley shown at D, F, H and D', and leaves the charge below crests E, G and I less compressed, i. e. more porous. This is important to obtain a constant burning rate, as will be described in more detail hereinafter.

The compression of charge quadrants is preferably made in two steps and Fig. 5 shows in dotted lines the original level of powdered propellant before first compression, and the dot-dash line represents the powder level after the first or preliminary compression. The reason for this stepwise compression is that the overall size of the die is substantially reduced when such die is placed into the hydraulic press for final compression.

When the propellant charge has been ignited, it burns outwardly, toward lining 25, i. e. from the surface between D and D' toward the surface between A and A'. As stated above, the propellant is somewhat porous at E, G and I and therefore burns faster than the propellant below D, F, H and D'. Due to the uniformity of the radial pressure from the core to the shell, the propellant quadrant inherently will burn from an irregular surface toward a regular concave surface and will thus conform to the inner surface of the shell 10.

Hence, as the burning of the quadrant progresses, the crests become lower and the valleys shallower, this being indicated by lines a-j in quadrant 16 of Fig. 5. The length of undulate line between D-D' is substantially the same as that of undulate lines a-h, inclusive, and as that of lines i, j and line between A-A', these latter lines i, j and A-A' not being undulate but having the same curvature as the container wall, since the wall A-B and A'-B' are parallel, as above stated.

In other words, the hill and valley configuration of the inner surface of each propellant charge enables each charge quadrant to burn at a constant rate and is completely consumed when the burning surface reaches any one of points between A and A'.

In certain cases it is desired to completely eliminate members 20, 21 and 22. Then the hill and valley contour of the inner surface of each quadrant must be changed accordingly, i. e. the number of hills and valleys increased or the depth of the valleys increased, since the facets A-B, B-C and A'-B', B'-C' will be omitted, and the two radial sides of each quadrant will be formed each by a single facet C-D and C'-D' with the difference that C and C' will be moved radially outwardly toward the imaginary points C₁ and C'₁. Accordingly, the lines indicating the intermediate burning surfaces will be undulate up to the, or almost up to the points C₁ and C'₁, the length of these intermediate burning surface lines always being substantially equal to the line connecting C₁ and C'₁.

The method of compressing the powdered charge into above-described configurations and preferred dies for use with this method will be described in connection with Figs. 6 to 10, showing two different dies, and in connection with Fig. 11 illustrating a hydraulic press. The structure of Figs. 6-11 and the method disclosed hereinbelow are not claimed by me in this application and are disclosed to facilitate the understanding of this case only.

Fig. 6 shows the die in plan view, with the ram 58 removed to reveal the concave bottom 59a in bottom wall or plate 59, with a curvature corresponding to that of container 10. Side walls 60, 60a and end walls 61, 61a enclose the space receiving the loose propellant powder. A layer of rubber-like elastic material 62 is provided between the adjoining surfaces of bottom 59, side walls 60, 60a and end walls 61, 61a to (a) tightly seal the die, and (b) to permit gradual expansion of the compressed charge during the gradual reduction of hydraulic pressure applied to the walls of the die and to the ram 58, whereby the cracking of compressed segmental charge is prevented.

Fig. 7 is a side view of Fig. 6, showing the ram 58 above the die before compression of the powdered charge. It

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may be seen that side walls 60, 60a and end walls 61, 61a are preferably made as composite walls consisting of two portions 60', 60''—60a', 60a''—61', 61''—61a', 61a''. The upper portions 60', 60a', 61', 61a' are removed after the preliminary compression of the powdered charge in order to reduce the overall size of the die when the same is placed into the hydraulic press. In this manner the press may receive a number of dies at the same time and the whole process is more economical.

Fig. 8 is a section along line 8—8 in Fig. 7, as viewed in the direction of arrows. Two layers 63, 63a of a lining such as nylon or the like are shown on the inside of the lower portions 60'' of side wall 60, and 60a'' of wall 60a. This lining is intended to smoothen the surface of the die which is in contact with ram 58 and is replaceable when damaged, whereby the life of the die is substantially increased.

Fig. 9 illustrates the die after final compression in the hydraulic press of Fig. 11. A tightly sealed plastic bag 64 surrounds the die when the same is placed into the press in order to prevent the access of liquid into the powdered propellant charge 16. Instead of bag 64, a diaphragm 69 may be used to seal the die, as shown in Fig. 10. Such a diaphragm is sealed to one side of the die wall 60, and when the ram has sufficiently descended after the preliminary compression, the diaphragm 69 is sealed to walls 60a, 61 and 61a of the die before its insertion into the hydraulic press. After final compression, the seal which may be a suitable adhesive, is removed from walls 60a, 61 and 61a so as to permit removal of ram 58 and of compressed segmental shaped charge, and the die is ready for reception of powder for the next compression.

In Fig. 11, which represents a hydraulic press 65 operable from a hydraulic pump 66 or the like, the die is shown inserted into the plastic bag 64 before the final compression. The press is preferably of elongated shape for well-known pressure-economy reasons.

When the pressure from pump 66 is supplied to press 65, the liquid compresses all sides of the die and ram 58 equally, whereby the ram descends into the die and gives the propellant charge quadrant 16 its characteristic hill and valley shape. The elastic hinging 62 yields when the pressure in the press is gradually reduced and permits charge 16 to expand in all directions, thus preventing it from concentrating pressure which could cause cracks therein. The elastic material 62 also facilitates removal of charge 16 from the die upon removal from the hydraulic press.

Fig. 10 shows another die wherein only a rubber or other resilient ring 67 is inserted into suitable recesses 68 provided in one of two adjoining walls to seal the die and prevent access of liquid in the hydraulic press.

A unique feature of the improved charge configuration is the fact that it permits the use of a somewhat brittle propellant for internal type of burning. The separate sections are free to move outwardly and are restrained only by the shell or motor tube 10 which prevents breakage of the charge during combustion or at the moment of ignition when there is a pressure shock. There are other charge shapes having irregular or "star" shaped holes for internal burning. The improved configuration assures constant burning area and adequate flexibility to permit the utilization of the improved brittle propellant which has the advantage of burning well at low pressures. The development of the special inhibitor coating which is flexible at all temperatures allows the use of such sections with safety in spite of the great additional surface that must be inhibited due to this configuration. The general

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practice is to reduce to a minimum the exposed surface that must be inhibited because of the difficulty of obtaining a good, reliable inhibiting coating that will meet all the rigid requirements. Without this configuration and the ability to inhibit to gain the restricted burning and the flexibility indicated, one could not use the improved propellant or any such propellant for booster or artillery rocket applications, because they would not withstand the great acceleration forces and sudden internal pressures due to combustion.

The invention is applicable to an Ato motor, as well as to a Jato motor, which words are frequently interchanged.

I have described herein the invention in the light of the embodiments thereof, but changes may be made without departing from the spirit and scope of the invention as defined in the appended claims.

I claim:

1. In a solid fuel type power plant, the combination of a substantially cylindrical container, a first end wall at one end of said container, a second end wall at the other end of said container, said first and said second end wall each having a plurality of openings adjacent to the peripheral portions thereof, a nozzle supported in said second end wall, an annularly disposed charge between said end walls in said container, said charge having an axial opening of hill and valley shape for regulating the burning characteristics of said charge radially outwardly, the gases developing on the burning of said charge emanating from said charge opening into and through said nozzle, and fastening means consisting of a plurality of elongated at least partially threaded members and means at both extremities of said members for preventing axial displacement of said end walls, said elongated members passing through said openings in said end walls, and rubber-like elongated lining for enclosing said elongated members substantially between said end walls, said lining being disposed between said propellant charge and the inner wall of said container.

2. In a solid-fuel type power plant, the combination of a tubular container, two end walls for closing the respective ends of said container, a nozzle in one of said end walls, an annularly disposed composite charge of adjacent radially abutting propellant sectors extending between said end walls inwardly from said container and defining an axial bore, the surfaces of said sectors surrounding said bore defining a plurality of hills and valleys with an overall area substantially equal to that of said propellant charge adjacent to said container, the density of said sectors in the radial direction from said bore toward said container being greater below said valleys than below said hills whereby, upon ignition and burning of said propellant charge in radial directions from said bore toward said container the combustion of areas below said hills is more rapid than the combustion below said valleys, the gases developing by the burning of said propellant charge emanating from said bore and passing into and through said nozzle.

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