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GAS GENERATING CHARGE

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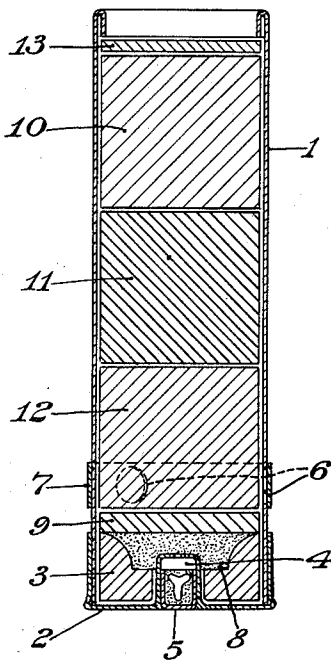


FIG. 1

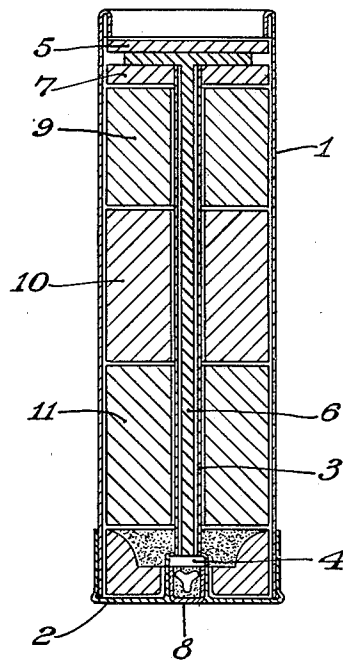


FIG. 2

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GAS-GENERATING CHARGE

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This invention relates to charges or cartridges for the generation of gases under pressure and to compositions and charge elements suitable for use in the said charges or cartridges. The invention relates in particular to cartridges or charges adapted for the operation of many mechanical devices usually worked by hydraulic or other means, e. g. for the operation of jacks or for the tilting of carriers of motor lorries, or for operating fire extinguishers and compressed air motors. The invention relates moreover, to the production of composite solid charges or charge elements of self-combustible materials which are suitable for use in cartridges of the kind described and which are adapted on ignition to burn without detonation and without producing an unduly rapid rise in pressure but with the production of a large output of gaseous products and with little or no solid residue or ash.

Typical ashless propellant charges of the hitherto known kind are adapted to develop their maximum pressure in a fraction of the extremely short space of time during which the projectile remains within the barrel and are characterized by so rapid a development of pressure, that they are not suited for the development of any considerable pressure for industrial purposes of the above kind. When fired in a confined space the development of any substantial final pressure is attended by the rapid development of intermediate pressures which may be excessively high. The materials which have hitherto been proposed for such purposes have usually consisted of heavily loaded compositions yielding relatively little gas and a considerable ash or solid residue, both of which features are obviously undesirable in compositions for use in mechanical devices of the kind described.

We have now discovered however that by suitable arrangement of charge elements each capable of yielding a high volume of permanent gas in relation to its weight and little or no solid residue or ash, but of differing ignition and combustion characteristics, there may be obtained a composite charge having the desirable properties which are required for the successful production of even high pressures in such devices. The charges of the present invention are adapted to develop a slowly rising pressure, thereby differing widely from typical ashless propellant charges, and are adapted, when fired under suitable conditions, to develop high pressures unaccompanied by the intermediate development

of any pressure very greatly in excess of the final pressure.

According to the present invention, a substantially ashless charge capable of burning without developing a maximum pressure greatly in excess of the final pressure comprises a charge element capable of self-propagating combustion at a slow rate when ignited at substantially atmospheric pressure, and in ignition contact therewith, a further charge element which is capable of self-propagating combustion when ignited at a pressure considerably in excess of atmospheric, e. g. the pressure generated by the combustion of the first mentioned charge element and the ignition means, but which is incapable of self-propagating combustion at substantially atmospheric pressure. The charge may also comprise one or more additional charge elements in successive ignition contact, each element being capable of self-propagating combustion at a pressure which is higher than that necessary to permit the self-propagating combustion of the preceding charge element but which is not higher than the total pressure produced by the combustion of the preceding elements. Each charge element is substantially ashless and yields a serviceably high permanent gas volume on combustion without detonating.

The charge elements which are required according to the invention are distinguished from typical ashless propellant charges by their considerably slower burning speeds, and they are necessarily adapted to burn without detonation at the pressures which they are required to generate. Usually they will be compact, and may comprise for example, one or more combustible organic substances and if necessary an oxidizing agent, the composition being such as to contain sufficient oxygen to avoid the deposition of carbon.

The cartridges of the present invention comprise a plurality of charge elements contained in a case of metal, cardboard or the like suitable material adapted to vent the products of combustion of the charge as they are formed, together with suitable means for igniting the charge, and it will be understood that a housing for the cartridge and actuating means for bringing about the initiation of the ignition means are associated with the mechanical device. The ignition means may be adapted for mechanical or electrical actuation, and may include a train of igniting compositions to convey the ignition to the first charge element of the composite charge, the ignition being conveyed to the suc-

ceeding charge elements by the combustion of the first charge element, and so successively if more than two charge elements are present.

By way of illustration ashless propellant charges may be prepared according to the present invention, which when initiated in a closed space at a sufficient loading density to yield a final pressure of the order of 500 to 1200 lbs. per sq. inch when the gas has cooled to atmospheric temperature, develop the maximum pressure in a period which is not less than about 5 seconds and which may be not less than about 10, 20 or even 30 seconds. The maximum pressure moreover does not exceed about three times the final pressure and may not exceed about twice and may even be less than twice the final pressure. The development of final pressures of the above order by typical ashless propellant charges would involve the production of maximum intermediate pressures very much higher and/or in very much shorter periods of time.

Preferably the amount and nature of the charge elements are such that the pressure which is required to permit the self-propagating combustion of each element after the first approximates to that which is developed by the elements up to and including the one which precedes it, including the ignition means. As the pressure developed by the combustion of a charge element increases, that element will tend to burn at an increasing rate, and in order to prevent undue acceleration and thus minimize the excess of the maximum pressure over the final pressure, it may be desirable to employ a graded series consisting of more than one or even more than two charge elements each of comparatively small dimensions in building up the pressure at which the last charge element commences to ignite. This is particularly the case when pressures above about 1000 lbs. per sq. inch are required, since it may be difficult to obtain a suitable charge element requiring a higher minimum pressure for its self supporting combustion than about 500 to 600 lbs. per sq. inch. In such a case it is particularly desirable that the pressure which is required for the combustion of the last elements of the charge should be developed as slowly and regularly as can be arranged.

The initiating means used for the purpose of igniting the first charge element, which is fundamentally of a slowly burning nature, will ordinarily comprise a certain quantity of some considerably more fiercely burning material, and it will be understood that for certainty of ignition it is inadvisable to use too small a quantity of such material. On the other hand, since the type of material which is convenient for use as igniting means, for instance a train constituting a fusehead or percussion cap, loose propellant powder, and cordite, is likely to burn fiercely with the development of a markedly higher maximum than final value even at moderately low pressure, it is not advisable to use too much.

By way of illustration we have satisfactorily ignited the first charge element of a cartridge developing 400-1200 lbs. per sq. inch with a train consisting of percussion cap, a small charge of shotgun powder and a plate of cordite in contact with the first charge element which igniting means gave a hot pressure amounting to about 120 lbs. per sq. inch, the corresponding cold pressure being about half this value. It may be said that the igniting means are likely to produce a maximum hot pressure about 100-150 lbs. per sq. inch.

From the foregoing it will have been appreciated that the minimum pressure at which the second charge element should be capable of ignition so as to support its combustion will normally be somewhat in excess of 10 atmospheres, and we often find it convenient to arrange that this minimum hot pressure should be about 200-250 lbs. per sq. inch, while the minimum pressure at which the first charge element can be ignited to support its combustion must necessarily be below that generated by the igniting means.

The first charge element may for instance be capable of supporting its combustion at atmospheric pressure at a slow rate when ignited by playing a gas flame or igniting a cordite disc upon one portion of a test piece. Thus a cylinder of the composition having a diameter of $17\frac{1}{2}$ mm. set upright and ignited by means of a 1 gm. disc of cordite resting on the top should not burn at a rate exceeding 30 seconds per cm. The composition may burn at a rate down to about 150 or more secs. per cm. or may just fail to support its combustion at atmospheric pressure, but usually a composition which just fails to be selfsupporting would show evidence of a tendency to combustion while it remains in contact with a gas flame. It will be understood that the second charge element adapted for ignition at increased pressure will have a lower rate of combustion than the first element if tested under equivalent conditions and similarly with successive charge elements.

The absence of corrosive gases as well as a high yield of permanent gas from the products of combustion of the various charge elements constituting the charge is an obviously desirable feature, and, while other compositions fulfilling these requirements are available for use as one or other of the charge elements, we have found that particularly desirable compositions for preparing charge elements which are incapable of supporting their combustion at atmospheric pressure but are capable of supporting their combustion when ignited at pressures considerably in excess of atmospheric comprise compacted mixtures of non-explosive carbonaceous materials with sufficient ammonium nitrate to prevent the formation of carbon. The carbonaceous materials function as a fuel and although the proportion of ammonium nitrate to the fuel should be greater than that required for burning the carbon of the latter to carbon monoxide, it should not be greater than that required for complete combustion. For charge elements which are required to support their combustion only when ignited at very considerably higher pressures than atmospheric, the composition may consist entirely of the ammonium nitrate and the fuel, but a range of charge elements adapted to support their combustion when ignited at progressively rising pressures from atmospheric pressure upwards to the pressure at which the composition consisting of the ammonium nitrate and the fuel alone can be ignited, may be prepared by modifying such a composition with a progressively diminishing proportion of gelatinized nitrocellulose uniformly distributed through it, the proportion of ammonium nitrate being in any case greater than that which is required to burn the carbon of the carbonaceous ingredients to carbon monoxide, but not exceeding the amount required for complete combustion. A range of such modified compositions progressively arranged in order of increasing minimum self-propagating pressures

for use according to the invention may thus be prepared from a given ammonium nitrate-fuel mixture, and may or may not include as one of its charge elements the composition containing no nitrocellulose. The nitrocellulose may be introduced into the composition in the form of a solution in a volatile solvent, which is removed after incorporation of all the ingredients, or in the gelatinized form with the fuel itself, and the composition may be compacted by suitable means such as pressing it in a tube or die. In the case where a volatile solvent is used, the evaporation may advantageously be effected after compacting. When the fuel is a gelatinizer for nitrocellulose, the latter may be made into a homogeneous gelatinate or plastic by incorporating it with the gelatinizer, if desired or necessary at a raised temperature, after which the ammonium nitrate may also be incorporated at a high temperature, and the material may be moulded under pressure into a stick or other form. The amount of nitrocellulose may vary considerably and is so chosen as to render the material sufficiently self-propagating to serve as the initial charge element or as a succeeding charge element as the case may be. Nitrocelluloses of nitrogen content below 12.3% are quite suitable for the purpose.

The materials which may be used as fuel include hydrocarbons such as paraffin wax, mineral jelly, bitumen, waxes such as ceresine, bees wax, carnauba wax, fats such as stearine, palmitine, fatty acids such as stearic acid, and many other such substances containing a high proportion of carbon such for instance as camphor, terpineol, terpin, borneol and other terpene derivatives, nitrocompounds such as dinitrotoluene, dinitrobenzene, and mononitrotoluene, aromatic esters and ethers such as dibutyl phthalate, diamyl phthalate, dibenzyl phthalate, benzyl benzoate, dinaphthyl oxide, resins such as colophony and the copals, gums such as ester and damar gums, gelatinizers such as dimethyl diphenyl urea or diethyl diphenyl urea, and many other materials possessed of comparatively low degree of volatility, and in short almost any non-volatile non-explosive ashless organic fuel may be used.

It is not necessary that the fuel present in any one charge element containing gelatinized nitrocellulose should be the same fuel as that which is used in the other charge elements with which it is associated in the composite charge. When the fuel is not possessed of sufficient solvent properties for the nitrocellulose, the nitrocellulose may be gelatinized by means of volatile solvents and incorporated with the fuel and with the ammonium nitrate or a mixture previously prepared from the ammonium nitrate and the fuel. After incorporation of the ingredients by mechanical means and shaping, the remaining solvent may be evaporated at a convenient temperature. In the case of substances such as camphor, it is convenient to gelatinize the nitrocellulose in a mixture of camphor and solvent and incorporate the ammonium nitrate into the plastic mixture, it being unnecessary to use raised temperatures. Camphor is too volatile a fuel to use in the absence of nitrocellulose.

Nitrocellulose has itself sufficient oxygen to prevent the formation of carbon by its combustion and insufficient for complete combustion of its carbon to carbon dioxide, and the introduction of gelatinized nitrocellulose into a composition containing a fixed proportion of ammonium nitrate to fuel for the purpose of rendering

the composition capable of self-supporting combustion when initiated at a lower pressure will not usually necessitate any change in that proportion, so that a series of suitable charge elements may if desired be prepared from a single mix of ammonium nitrate and carbonaceous fuel by incorporating different amounts of nitrocellulose into different portions.

In the case of an organic fuel composed of carbon and hydrogen, the more closely the products of combustion approximate in composition to carbon monoxide and hydrogen instead of to the products of complete combustion, namely carbon dioxide and water, the lower will be its heat evolution and the higher the proportion of permanent gas in relation to the amount of water and the higher the absolute volume of permanent gas evolved by the combustion. The same rule holds good in general in the case of all carbonaceous substances, so that in order to further the objects of the invention it will be desirable to follow this principle so far as the circumstances and the nature of the particular fuel permit. However, it is not to be thought that the best results will necessarily be obtained by reducing the proportion of ammonium nitrate to fuel to the lowest value consistent with the theoretically formulated scheme for the oxidation of the fuel. For instance, in general the lower the proportion of ammonium nitrate in relation to the fuel, the lower will be the minimum pressure at which the composition will be able to support its combustion on initiation, although it may be possible to compensate for this by reduction in the proportion of nitrocellulose employed. With certain organic fuels, such for instance, as dinitrotoluene, it is found in practice that, to avoid the formation of carbon under certain conditions, the quantity of ammonium nitrate must be greater than is theoretically necessary to burn the carbon to carbon monoxide, so that it does not necessarily follow that the use of a more highly oxygenated fuel will necessarily reduce the amount of ammonium nitrate required. The nature of the cartridge case may also render it desirable to use a higher proportion of ammonium nitrate than would merely oxidize the carbon of the fuel to carbon monoxide, since it will usually be found that the cartridge case made of a carbonaceous material such as paper or cardboard is charred, and by increasing the proportion of ammonium nitrate towards the upper limit a considerable proportion of the case may be consumed.

Many of the substances suitable for use as fuels have themselves a waterproofing effect on ammonium nitrate, which can be taken advantage of to increase the resistance of the charges to climatic conditions. If desired the charges may be dipped in a solution of nitrocellulose or other waterproofing material, such as hot wax, to assist in waterproofing them, and since the material so applied will enter into the reaction its weight may be allowed for in calculating the quantity of ammonium nitrate to be used in the charge elements with which it is associated.

It will be appreciated therefore, that the optimum proportion of the ammonium nitrate in relation to the fuel may depend upon circumstances, but the amount used should not exceed that which is required for complete combustion of the charge, including any waterproofing material with which it is associated.

With further reference to the relative proportions of the components, it may be stated that

usually the proportion of ammonium nitrate will exceed 80% of the total amount of ammonium nitrate and fuel, excluding the nitrocellulose, and in the case of hydrocarbon fuels such as paraffin wax, mineral jelly, bitumen and higher fatty acid derivatives, ceresine wax and the like, 85-90% is a suitable proportion, and with paraffin wax, mineral jelly, bitumen and ceresine wax 85% is about the lowest amount which can be used without the deposition of carbon. In the case of 2-4 dinitrotoluene we have found that about 85% is required to avoid deposition of carbon in absence of nitrocellulose. The proportion of nitrocellulose included in the mixture may vary considerably but will not usually be less than about 7% for the first charge element to be initiated and may be as high as 20% or even more. Where sufficiently high pressures are required, the composition which is used for the final charge element may consist of a mixture of ammonium nitrate and fuel without nitrocellulose, but where more moderate pressures are required it will usually be necessary to employ a proportion of nitrocellulose even in the final element of the charge.

The employment in the cartridges and charges of the present invention of the ammonium nitrate fuel compositions described permits of the generation of a final gas pressure of a substantially high order without the production of an intermediate maximum pressure greatly exceeding the said final pressure. Thus propellant charges may be prepared according to the invention which, when initiated in a closed space at a loading density sufficient to generate a final cold gas pressure of the order of 500 to 1200 lbs. per sq. in., produce an intermediate maximum pressure not exceeding about 1.2 to 1.5 times the final pressure.

Although the ammonium nitrate fuel compositions described are preferred for use in the cartridges and charges of the invention, other compositions may be used provided that they are substantially ashless and capable of undergoing a non-detonating self-propagating gas-evolving decomposition when suitably initiated. Thus for example there may be used a compacted mixture of guanidine nitrate with 10% of its weight of gelatinized nitrocellulose, conveniently prepared with the aid of a volatile solvent.

The burning speed of a 17½ mm. cylinder of the composition is about 60 sec. per cm., and the composition has a permanent gas yield above 700 cc. per gm. By reducing the amount of nitrocellulose or omitting it, suitable charge elements capable of self-propagation when ignited only at higher pressures can be obtained.

Furthermore, the sensitized ammonium nitrate compositions described and claimed in pending application No. 7601/35, may be used in the cartridges and charges of the present invention, although it is to be understood that we make no claim to such compositions themselves in the present application.

The charges of the present invention may be contained in a suitable case provided with means of ignition, for instance a percussion cap advantageously containing less than the usual charge of cap composition employed for propellant cartridges, together with an appropriate priming train, for instance a small charge of fine grain blackpowder or quick burning nitrocellulose powder followed by a disc of cordite or quickmatch fuse in contact with the end of the first and most sensitive section of the charge. The

cartridge may if desired be closed at the far end and provided with vent holes in the vicinity of the cap, and if desired also along the length of the cartridge at intervals. It is sometimes convenient that the cartridge should be contained in a cage.

In order to disclose my invention more clearly, reference is made to the accompanying drawing wherein Figure 1 is a sectional elevation of a cartridge wherein the gases are vented near the base thereof; while Figure 2 is a vertical elevation of a cartridge wherein the gases are vented from the turnover end of the cartridge.

Referring to the accompanying drawing which represents a longitudinal section of a cartridge suitable for the purpose of the invention, the paper shell 1 and the metal base 2, the recessed cardboard base wad 3 and the cap chamber 4 containing the cap 5 are of the normal type used for 12 bore sporting cartridges, the charge of priming cap composition, however, being reduced to 0.2 of a grain, and the shell 1 being provided with three equidistant venting holes 6 around its circumference near the base. These are temporarily closed by means of a strip of thin gummed paper 7. Within the recess of the wad 3 there is placed a charge 8 of 0.15 gm. of quick burning nitrocellulose powder, and on top of that a disc 9 of cordite size 60 weighing about 1 gm. The main charge of the cartridge consists of three cylinders 10, 11 and 12 placed alongside each other, and corresponding to the compositions hereinafter described in Example 1 and containing respectively, 5, 10 and 15 parts of gelatinized nitrocellulose in association with every 100 parts of the ammonium nitrate-paraffin wax mixture.

The cartridge is closed by a disc 13 in the usual manner, and may be fired by percussion. It is conveniently located in an open metal cylinder not shown provided with holes near the base to correspond with the holes 6 and a further succession of holes along its length to permit escape of the gases and retain the ash of the cartridge shell, this being located in a portion of the space within which it is desired to generate the gas pressure.

The cartridge described above is adapted for venting through the side of the case near the base, but suitable cartridges may also be prepared in which the products of combustion are vented from the turnover end of the case in the normal manner employed in shotgun cartridges, the entire charge however remaining inside the case during its combustion instead of being ejected.

Fig. 2 represents a longitudinal section of a cartridge of this type. In Fig. 2 the paper shell 1 and the metal base 2 have the same significance as in Fig. 1. A central hollow metal flash tube 3 forms a continuation of the cap chamber 4 and extends to within a few mm. of the celluloid closure disc 5; this flash tube contains a piece of quickmatch fuse 6 which communicates the ignition from the cap to the cordite igniter 7. To prevent the ejection of the quickmatch fuse the cap 8 contains a smaller charge than is normally employed in shotgun cartridge caps, and the quickmatch is firmly secured at the end of the flash tube by being pressed between the closure disc and the cordite ignitor.

The charge used consists of three charge elements 9, 10 and 11 as described in the opening sentences of Example 4 in the proportions 1:1:2. These elements are moulded into the form of cylindrical pellets provided with a central hole

just sufficiently wide to enable them to be loaded into the case over the flash tube on to the cardboard base wad, the element 11 nearest the base being free from nitrocellulose, and that nearest the cordite igniter disc containing the greatest proportion of nitrocellulose. The ignition is thus conveyed from the turnover end of the cartridge backwards.

The invention is further illustrated by the following examples of charges made according to the invention:—

Example 1

Each section of the charge contains a mixture of ammonium nitrate, and paraffin wax melting at 50–60° C. 87½ parts hot ammonium nitrate in powder form is mixed into 12½ parts molten paraffin wax at 60° C. in heated incorporator until evenly moistened. The mixture is allowed to cool while being sufficiently agitated to prevent caking.

(a) With one portion of the charge (100 parts) there is mixed in at room temperature a solution of 15 parts nitrocotton of nitrogen content 12.0% in 20 parts of acetone, after which the material is moulded under a pressure of 200 lbs. per sq. in. into stick form, of 17½ mm. diameter and the required length. The units are then dried off in an oven at 40° C. rising to 50° C. for 2 to 3 days. A permanent gas volume of about 727 ccs. is obtained from each gm. of this composition. When ignited by means of a 1 gm. cordite disc placed on top of an upright cylinder of 17½ mm. diameter made as above this composition burned at a rate of 70 secs. per cm.

(b) Another portion of the mixture is incorporated with a solution of 10 parts of the same nitrocellulose in 15 parts of acetone, and after moulding is dried off at a temperature rising from 40° C. to 50° C. When ignited under similar conditions to those mentioned above at atmospheric pressure this composition just supports its own combustion at a rate of about 135 secs. per cm. giving a permanent gas volume nearly as great as that of composition (a).

(c) A third portion is likewise incorporated with a solution of 5 parts nitrocotton in 12–15 parts of acetone and after moulding is dried off as before. The resulting composition does not support its combustion when ignited at atmospheric pressure.

A composite charge made up from charge elements consisting of compositions (a), (b) and (c) in the ratio 5:3.5:4 in a paper cartridge case was fired in an apparatus with the employment of an igniter, which igniter develops a pressure of about 120 lbs. per sq. in. The final pressure was about 1000 lbs. per sq. in. and the maximum pressure of about 1.3 times this amount was developed in about 14 secs. This charge can also be fired in a zinc cartridge case, giving a somewhat lower final pressure. In one modification of this example the charge element of composition (a) may be omitted since in this case the charge element of composition (b) is itself just capable of supporting its combustion when ignited at atmospheric pressure, and there may be juxtaposed to the charge element of composition (c) a charge element consisting of ammonium nitrate and paraffin wax alone in the ratio 87.5:12.5. Such a composition may be moulded into shape when hot.

In a further modification of the example there may be employed one or more additional charge elements each having less than 10 parts of nitrocellulose to each 100 parts of the original am-

monium nitrate-paraffin wax mixture and each element being juxtaposed between charge elements having higher and lower nitrocellulose contents.

Example 2

The first element of the charge, which is ignitable and burns readily at ordinary pressure, is made from 90 parts ammonium nitrate, 10 parts bitumen softening at about 60° C. and 20 parts nitrocellulose gelatinized by means of acetone. The bitumen had a softening temperature of 66°–71° C. (determined by the A. S. T. M. ball and ring method) and gave a penetrometer test of 20/30 at 25° C. The ammonium nitrate and bitumen are incorporated at a temperature of about 70° C., and the acetone gelatinized nitrocellulose is incorporated into the cooled and stirred mixture, which is next moulded and dried out. Only sufficient of this element is used to ignite the second element of the charge, which is made as follows:—3 parts nitrocellulose (12% nitrogen) and 15 parts 2-4 dinitrotoluol are gelatinized together by incorporation at a temperature of 75–80° C. until a clear plastic is obtained. Into the hot material there are introduced 85 parts ammonium nitrate at a similar temperature. After thoroughly mixing the mass it is moulded into shape. This material does not burn at ordinary pressure, but can be ignited and will burn once a pressure of several atmospheres has been built up by the combustion of the first unit. This charge is advantageously fired in a paper cartridge case.

Example 3

The first element of the charge is made from 8 parts nitrocellulose gelatinized with 15 parts 2-4 dinitrotoluol and 85 parts ammonium nitrate in the manner described in Example 2. The second element is similarly made but contains only 4 parts nitrocellulose instead of 8 parts, while the third element contains no nitrocellulose at all, the proportion of ammonium nitrate to 2-4 dinitrotoluol being the same as for the first unit. These elements may be used in approximately the ratio 1:2:2 in a paper cartridge case to build up a final pressure of the order of 800 lbs. per sq. in., the maximum pressure being attained more than 12 seconds from the start. The yield of permanent gas from the charge is about 425 ccs. per gm. respectively, but by the use of the paper cartridge case the gas volumes are considerably increased.

Example 4

The charge consists of three elements of which the first contains ammonium nitrate, paraffin wax and gelatinized nitrocellulose in the ratio of 90:10:20; the second contains these ingredients in the ratio of 90:10:5, and the third contains ammonium nitrate and paraffin wax in the ratio 90:10 without any nitrocellulose. These elements are used in the proportions 1:1:2, and are juxtaposed in that order in a paper cartridge case with ignition train, which contributes a maximum pressure of about 120 lbs. per sq. in. The first element when ignited in the form of a cylinder of 17½ mm. diameter by means of a 1 gm. cordite disc placed on top of it burns at atmospheric pressure at a rate of about 45 seconds per cm. and yields about 600 ccs. of permanent gas per gm. The second section fails to support its own combustion when ignited at atmospheric pressure or when ignited by the

above ignition train under a pressure of less than 150 lbs. per sq. inch, while the third section requires a pressure of about 400 lbs. per sq. inch before it will support its combustion when so ignited. A charge element may also be inserted containing ammonium nitrate, paraffin wax and gelatinized nitrocellulose in the proportions 90:10:2½ and this will be found to require a pressure of about 300 lbs. per sq. inch to support its combustion when so initiated. Mixtures of the ingredients in the proportions 90:10:20 or 90:10:10 will only require the pressure developed by the igniter. By so regulating the proportion of nitrocellulose and the quantity of the charge elements so that each element ignites at only slightly below the maximum pressure developed by the preceding one, a very slow and regular development of pressure may be attained. When fired in a paper case the quantities of gas developed from the above mixtures are considerably greater than those which would be expected from the composition of the charge element alone, since the cartridge case takes part in the reaction and is partly converted into carbon monoxide, and in practice it will be found that almost as high permanent gas volumes may be expected from those mixtures in which the ammonium nitrate content is approaching the maximum as from those in which it is nearing its minimum—easily over 700 ccs. per gm.

Example 5

The charge elements used had respectively the compositions:—ammonium nitrate:ester gum:nitrocellulose—88:12:7.5; 88:12:2.5; 88:12:0, and were used in the proportions 3.6:5.0 and 3.5. A final pressure of 836 lbs. per sq. in. was developed the maximum pressure 905 lbs. per sq. inch being developed in 18 secs. Charges composed of equal weights of charge elements containing these ingredients in the ratios 91:9:8; 91:9:4 and 91:9:0 burned to give a final pressure of 712 lbs. per sq. in. and yielded a maximum pressure of 960 lbs. per sq. in. which was attained in about 10 secs. A redistribution of the charge in favour of the most difficultly burning element was brought about by replacing the portion of intermediate composition by its weight of the nitrocellulose free composition, with the result that the gas volumes slightly increased and the ratio of maximum pressure to final pressure was diminished to less than 1.1:1, while the time taken to attain the maximum pressure was increased to over 30 secs.

55 I claim:

1. A composite gas-generating charge within a container capable of retaining relatively high pressures developed therein, said composite charge comprising a series of at least two juxtaposed individual charges and ignition means for the first of said individual charges, said first charge being capable of self-sustained combustion upon ignition by said means, and each subsequent charge being incapable of self-sustained combustion at substantially atmospheric pressure but being capable of sustaining propagation of the combustion when ignited by the preceding charge under the super-atmospheric pressure then prevailing within the container.

2. A composite charge of claim 1, wherein the individual charges are substantially ashless.

3. A cartridge suitable for the actuation of pressure-operated mechanical devices, which comprises a series of juxtaposed substantially ashless charge elements, and ignition means ad-

jacent to the first charge element, said first element being capable of self-sustained combustion upon initiation by said ignition means, and each further element in said series being capable of self-sustained combustion only at pressures considerably in excess of atmospheric.

4. The cartridge of claim 1 wherein each of the charge elements is characterized by a slow rate of combustion, said rate decreasing in successive elements.

5. A cartridge suitable for the actuation of pressure-operated mechanical devices, which comprises a series of juxtaposed substantially ashless charge elements, and ignition means adjacent to the first charge element, said first element being capable of self-sustained combustion at atmospheric pressure upon initiation by said ignition means, and each further element in said series being capable of self-sustained combustion only at pressures considerably in excess of atmospheric.

6. A cartridge suitable for the actuation of pressure-operated mechanical devices, which comprises a series of juxtaposed substantially ashless charge elements and ignition means adjacent to the first charge element, said first element being capable of self-sustained combustion at the pressure generated by said ignition means, and each further element in said series being capable of self-sustained combustion only at pressures considerably in excess of that generated by said ignition means.

7. A cartridge suitable for the actuation of pressure-operated mechanical devices, which comprises a series of juxtaposed substantially ashless charge elements, and ignition means adjacent to the first charge element, said first element being capable of self-sustained combustion upon initiation by said ignition means, and each further element in said series being capable of self-sustained combustion at pressures progressively generated by the combustion of the elements and ignition means preceding said element, but incapable of self-sustained combustion at the minimum pressure required to insure self-sustained combustion in the immediately preceding element.

8. A cartridge of claim 7 wherein the charge elements comprise compositions in varying proportions of non-explosive carbonaceous fuel, and ammonium nitrate sufficient substantially to prevent the deposition of carbon from said fuel upon combustion but insufficient to oxidize said carbon completely to carbon dioxide.

9. A cartridge of claim 7 wherein each charge element includes a portion of gelatinized nitrocellulose sufficient to render the composition capable of self-sustaining combustion upon ignition at a predetermined pressure.

10. A cartridge of claim 7 wherein the charge elements comprise compositions including 80 to 90% ammonium nitrate.

11. A cartridge of claim 7 wherein each charge element includes 7 to 20% nitrocellulose.

12. A cartridge of claim 7 wherein each charge element comprises guanidine nitrate and gelatinized nitrocellulose.

13. The cartridge of claim 7 wherein the series of charges is capable of developing a final pressure of 500 to 1200 pounds per square inch after the gas generated on combustion has cooled to atmospheric temperature, the maximum pressure being reached in a period of at least 5 seconds.

14. The cartridge of claim 7 wherein the series of charges is capable of developing a maximum

pressure which fails to exceed three times the final pressure.

15. A cartridge suitable for the actuation of pressure-operated mechanical devices, which comprises a series of juxtaposed substantially ashless charge elements, and ignition means adjacent to the first charge element, said first element being capable of self-sustained combustion upon initiation by said ignition means, each further element in said series being capable of self-sustained combustion only at pressures progressively generated by the combustion of the elements and ignition means preceding said element, but incapable of self-sustained combustion at the minimum pressure required to insure self-sustained combustion in the immediately preceding element, and venting means adapted to permit the escape of the generated gases at a locus adjacent to said ignition means.

16. A cartridge of claim 15 wherein the venting means comprise a sleeve provided with base venting apertures.

17. A cartridge of claim 7 wherein the charge

elements comprise ammonium nitrate and a hydrocarbon.

18. A cartridge suitable for the actuation of pressure-operated mechanical devices, which comprises a series of juxtaposed substantially ashless charge elements, and ignition means adjacent to the first charge element, said elements being so selected that the pressure required to permit the self-sustained combustion of each element after the first approximates that developed by the combustion of the elements up to and including the one which precedes it, including said ignition means.

19. A cartridge of claim 7 wherein the charge elements comprise compositions in varying proportions of non-explosive carbonaceous fuel, and ammonium nitrate sufficient substantially to prevent the deposition of carbon from said fuel upon combustion but insufficient to oxidize said carbon completely to carbon dioxide, said compositions being in compact form.

JOHN MACFIE HOLM.

CERTIFICATE OF CORRECTION.

Patent No. 2,090,608.

August 17, 1937.

JOHN MACFIE HOLM.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 3, first column, line 62, for the article "a" read as; page 4, second column, line 11, for "vertical" read sectional; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 25th day of January, A. D. 1938.

(Seal)

Henry Van Arsdale,
Acting Commissioner of Patents.