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3,033,715

GAS PRODUCING CHARGE

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No Drawing. Filed Mar. 7, 1955, Ser. No. 492,801
18 Claims. (Cl. 149-96)

This invention relates to the production of smokeless powders and more particularly to the production of smokeless powders having peculiarly desirable ballistics for applications in jet-actuated devices.

It is well known that there is a definite and direct relationship between the pressure at which a smokeless powder propellant burns and its burning rate. This relationship may be mathematically expressed as $r=cP^n$ or as $\log r=n \log P + \log c$, where r is the burning rate, P is the pressure at which the burning rate is measured, and c and n are constants characteristic of a given propellant. Thus, when a plot of $\log r$ against $\log P$ is made for the conventional propellant, a straight line of slope n is obtained showing an increase in burning rate for each increase in pressure. Such a relationship is not disadvantageous in the conventional propellant and in fact is used to advantage in progressive powders where it is highly desirable to generate increased pressures after the projectile or shot charge has begun to move along the barrel. However, this relationship presents a serious problem in formulation of propellants for jet-actuated devices since once the desired operating pressure is reached, totally different considerations obtain.

It is highly desirable, once the operating pressure of a jet-actuated device is reached, that the pressure generated by the burning propellant be maintained as nearly constant as possible. Accordingly, if this result is to be attained, the slope n of the line representing the pressure-burning rate relationship of the particular propellant must desirably approach zero in the zone of useful rocket pressure. In the prior art rocket powders, in all of which the slope n has a value of 0.7 or over, any fracturing or slivering of the propellant charge leads to a pressure build-up because of an increase in linear burning rate resulting from the increase in pressure due to the increase in burning surface. The higher the n value of the particular powder, the higher will be the pressure rise encountered. Therefore, the results of such a fracturing or slivering vary from a highly undesirable thrust fluctuation, with consequent aberration in ballistics, to actual failure of the jet device if, with a propellant of high n value the pressure build-up is excessive. Even unusual roughness of the charge causes serious changes in burning pressure and burning rate in the presently available rocket propellants with the result that errors of 1% in the nozzle diameter have been found to build up to an aberration of 5% or more in ballistics. Consequently, with the propellants now available, there is very little allowable tolerance in manufacture of charges and nozzles for jet devices. A propellant having a very low n value within the range of useful rocket pressures, however, would allow for considerable tolerances without appreciable deviation from the specified ballistics.

A second serious problem confronting producers of propellants for jet-actuated devices is the diminution of the temperature coefficient of equilibrium pressure at the desired operating pressure or pressure range. The temperature coefficient of equilibrium pressure is a measure of the pressure variation to be expected on account of temperature variation alone, using a given propellant. It is obtained by firing identical samples of propellant under identical conditions except for changes in temperature and pressure. The coefficient may be expressed as

$$\frac{\Delta P}{P \Delta t}$$

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where ΔP is the experimental difference in pressure under

$$\frac{\Delta P}{P \Delta t}$$

conditions of equilibrium burning due to the temperature change Δt ; and $\bar{P}$ is the mean of the low-temperature and high-temperature pressures.

The advantage of having a low-temperature coefficient of equilibrium pressure is obvious. If the coefficient is low, the jet-actuated device may be designed for an unusually low range of service pressure over the wide temperature range ordinarily specified for such devices in field use. Since existing propellants generally have temperature coefficients of equilibrium pressure of about 0.8%/°C. or more, service pressure may change by 100% or more in going from the lowest expected temperature (about -60° C.) to the highest expected temperature (about 50° C.). It is therefore highly desirable to lower the temperature coefficient of equilibrium pressure below that of existing rocket propellants and thereby hold variation in service pressures due to temperature change to a minimum. If the coefficient could be lowered from 0.8%/°C. to 0.4%/°C. or less, service pressure variation would be diminished by at least one-half.

As a result of the advantages set forth above for a propellant having a low n value and a low temperature coefficient of equilibrium pressure, the combination of those two ballistic characteristics would allow additionally for important economies in the inert weight of jet-actuated devices. This is clearly seen if the equation is examined which relates the ratio between the mass of propellant (m) and the mass of the jet device without propellant (M), the gas velocity of the burning propellant (V), and the highest theoretically obtainable velocity of the jet device ($V_{\max.}$) as follows:

$$V_{\max.} = 2.303V \log_{10} \left(1 + \frac{m}{M} \right)$$

With propellants now available, the highest ratio of

$$\frac{m}{M}$$

has been about 1, where mass of propellant and mass of jet device are about equal. If it is possible, by use of a new propellant which will not build up excessive pressures, to decrease M by 10% and increase the amount of propellant to give the same total initial weight, $V_{\max.}$ would be increased by a factor

$$\frac{\log_{10} \left(1 + \frac{1.1}{0.9} \right)}{\log_{10} \left(1 + \frac{1}{1} \right)}$$

of about 1.15. This would be a 15% improvement.

Therefore, an object of the present invention is the production of propellants for jet-actuated devices which are characterized by such a burning rate-pressure relationship that substantially constant or more nearly constant burning rates are maintained throughout a wide pressure region within the range of useful rocket pressures.

It is a further object of this invention to produce a propellant for jet-actuated devices which is characterized by a lower temperature coefficient of equilibrium pressure which will minimize variation of service pressure due to temperature.

Generally described, the present invention comprises gas-producing compositions which comprise a smokeless powder having uniformly incorporated therein and intimately admixed therewith within every particle thereof not more than 10% of at least one aromatic compound of lead. The smokeless powders to which these ballistic modifiers are added may be of either single or multiple base. If the smokeless powder to which one or more of

the ballistic modifiers is added is a single-base powder, it should preferably comprise from 85 to 95% nitrocellulose and from 5 to 15% plasticizer. If the propellant used is a multiple-base formula, it should preferably comprise from 40 to 85% nitrocellulose, from 10 to 35% of explosive liquid ester, and from 5 to 30% of a substantially nonvolatile nonexplosive plasticizer. Propellants prepared according to this invention, which contain a minor amount of the above-listed modifiers will be characterized by a pressure-burning rate relationship having a substantially lower n value and a substantially lower temperature coefficient of equilibrium pressure. Moreover, in accordance with the invention disclosed and claimed in copending application Serial No. 492,802, filed March 7, 1955, it has been discovered that by addition of finely divided carbon to the compositions of the present invention, the burning rate of the composition can be desirably increased in the pressure region of low

n value. In fact, and as will be demonstrated, some of the aromatic lead compounds actually produce a negative n value. It has been found that up to 10% of the various operable additives may be employed without adversely affecting the ballistics of the gas-producing compositions of the invention. However, it is preferred to employ only sufficient of the additive to effect the desired modification in ballistics. In most cases it has been found that not more than about 4% of the various additives, based on the weight of the smokeless powder employed is usually ample.

Having now generally described the invention, the following examples are given to illustrate specific formulations in accordance with the invention and to compare such powders to similar formulations which do not include the aromatic lead compound. Unless otherwise indicated, the powder compositions of the examples were prepared by the solvent process hereinafter described.

Example	NC 12.6% N	NG	TA	EC	NDPA	Lead modifier	Percent modifier	CB	Low n	Pressure at low n p.s.i.	Temperature coefficient of equilibrium pressure, percent/° C.	Heat of explosion, cal./g.
1.....	58.5	22.5	8.5	8	12.5	None.....	1		.70	700-1,200	.80	700
2.....	58.5	22.5	8.5	8	12.5	Benzoate.....	1		.10	2,600-5,000	.5	680
3.....	50	43	4		1	do.....	2		.21	2,500-5,000	.67	1,160
4.....	50	47			1	do.....	2		.33	1,500-5,000	.60	1,280
5.....	35	62			1	do.....	2		.43	2,500-5,000	.56	1,400
6.....	30	67			1	do.....	2		.31	2,500-5,000	.57	1,450
7.....	39	60			1	do.....	2		.74		.50	1,252
8.....	58.5	34	3		2.5	None.....	2	.4	.44	250-1,500	.51	1,000
9.....	58.5	35.3	1.7		2.5	Benzoate.....	2		.46	400-1,800	.41	1,042
10.....	58.5	35.3	1.7		2.5	2-ethyl hexoate.....	2	.4	.45	400-1,500	.46	1,054
11.....	58.5	37			2.5	Salicylate.....	2		.38	350-1,300	.55	1,110
12.....	58.5	37			2.5	2-ethyl hexoate.....	2		.46	300-900	.62	1,107
13.....	58.5	37			2.5	Benzoate.....	2		.49	200-1,500	.37	1,122
14.....	58.5	36.3	1.7		2.5	2-ethyl hexoate.....	2	.2	.42	400-1,400	.46	1,051
15.....	58.5	35.3	1.7		2.5	Salicylate.....	2		.44	400-1,100	.41	1,062
16.....	58.5	33	4		2.5	Trimesate.....	2	.2	.39	200-1,200	.41	1,030
17.....	58.5	35.3	1.7		2.5	Salicylate.....	2		.47	350-1,300	.58	1,071
18.....	58.5	35.3	1.7		2.5	do.....	2		.36	400-1,400	.41	1,059
19.....	58.5	35.3	1.7		2.5	2-ethyl hexoate.....	1		.36	500-1,250	.60	1,090
20.....	58.5	35.3	1.7		2.5	Benzoate.....	1		.43	400-1,100	.51	1,104
21.....	58.5	31	6		2.5	2-ethyl hexoate.....	2		.38	300- 650	.46	972
22.....	58.5	31	6		2.5	Benzoate.....	2		.31	300- 900	.60	968
23.....	58.5	34	3		2.5	do.....	1		.10	400- 700	.41	1,018
24.....	58.5	31	6		2.5	2-ethyl hexoate.....	2		-.10	300- 700	.48	935
25.....	58.5	31	6		2.5	Benzoate.....	2		-.29	300- 700	.53	927
26.....	40	59			1	do.....	2		.36	700-1,800	.34	992
27.....	40	59			1	2-ethyl hexoate.....	2		.35	700-1,500	.60	1,032
28.....	58.5	29.5	7.5	2.5		Salicylate.....	1		-.20	1,500	.25	914
29.....	58.5	32.5		7		Salicylate.....	2		.36	1,000	.38	953
30.....	58.5	30	7.5		1	Acetyl salicylate.....	2		.00	1,050	.53	930
31.....	58.5	31	6	2.5		do.....	2		.00	1,050	-.18	958
32.....	58.5	31	6		1.5	do.....	3		-.02	1,100	-.34	983
33.....	58.5	30	7		1.5	do.....	2		.00	1,300	.00	952
34.....	58.5	31	7		1.5	do.....	2		.00	1,200	-.16	978
35.....	58.5	30	7		2.5	do.....	2		-.24	1,400	-.14	942
36.....	58.5	29	7		2.5	do.....	3		-.10	1,225	-.16	916
37.....	58.5	27	10		2.5	Pbthalate acetate.....	2		.00	700- 900	.3	827
38.....	58.5	27	10		2.5	Phthalate stearate.....	2		.00	1,100-1,300	.3	829
39.....	58.5	22.5	8.5	8	12.5	Tetraphenyl.....	1	.5	.5	1,350-1,700	.6	685
40.....	58.5	22.5	8.5	8	12.5	do.....	1		.00	1,000-1,450	.3	675
41.....	58.5	22.5	8.5	8	12.5	do.....	2		.00	1,000-1,400	.4	645
42.....	58.0	35	2		1	do.....	4		.40	200- 720	.6	1,093
43.....	58.5	27	10		2.5	o-Toluate.....	2		.20	1,300-2,300	.24	852
44.....	50	34.2	9.8		2	m-Aminobenzoate.....	2		.00	1,000-2,000	.25	851
45.....	50	34.2	9.8		2	Salicylate.....	2		.30	450-1,775	.32	853
46.....	58.5	27	10		2.5	Gentisate.....	2		.23	530-1,090	.16	847
47.....	58	35	2		1	Gallate.....	2		.47	200- 800	.70	1,108
48.....	58	27	10		2.5	Octyl salicylate.....	4		-.36	560- 800	.26	848
49.....	58	27	10		2.5	Tetrachloronaphthalate.....	2		-.05	520- 880	.33	855
50.....	58	27	10		2.5	n-Butylphthalate.....	2		-.27	580- 870	.30	852
51.....	58	27	10		2.5	Dichlorobenzoate.....	2		-.13	1,100-1,275	.50	850
52.....	58.5	27	10		2.5	2,4-dimethoxybenzoate.....	2		-.34	1,100-1,500	.12	846
53.....	58.5	27	10		2.5	4-ethoxy-2-hydroxy benzoate.....	2		.06	1,200-2,050	.06	851
54.....	58.5	27	10		2.5	1-hydroxy-2-naphthoate.....	2		.17	1,050-1,500	.50	856
55.....	58.5	27	10		2.5	Gallate.....	2		-.45	1,275-1,750	.14	849
56.....	58.5	27	10		2.5	Anthranilate.....	2		.15	1,500-2,550	.43	859
57.....						Pyromellitate.....	2					

See footnotes at end of table.

Example	NC 12.6% N	NG	TA	EC	NDPA	Lead modifier	Percent modifier	CB	Low <i>n</i>	Pressure at low <i>n</i> p.s.i.	Temper- ature coefficient of equilib- rium pressure, percent/° C.	Heat of explosion, cal./g.
57.....	58.5	27	10	-----	2.5	Aminosalicylate.....	2	-----	.10	1,770-3,000	.50	850
58.....	58.5	27	10	-----	2.5	Citrazinate.....	2	-----	.16	1,520-3,500	.29	883
59.....	58.5	27	8	-----	2.5	3-hydroxy-2-naphthoate.....	2	-----	.10	1,880-3,050	.28	858
60.....	58.5	27	8	-----	2.5	β -Resorcyate.....	2	-----	-----	1,270-1,910	.24	859
61.....	95	-----	-----	-----	1	Salicylate.....	2	-----	-.40	-----	.5	860
						p-Hydroxybenzoate.....	2	-----	-----	-----	-----	-----
						β -Resorcyate.....	2	-----	-.45	-----	-----	-----
						Acetyl salicylate.....	2	-----	-----	-----	-----	-----

¹ Dinitrotoluene substituted for nitrodiphenylamine.

² Pentaerythritol trinitrate substituted for nitroglycerin.

³ Diethylphthalate substituted for triacetin.

NOTE.—NC=nitrocellulose, NG=nitroglycerin, TA=triacetin, EC=ethyl centralite, NDPA=nitrodiphenylamine, CB=carbon black.

From the foregoing examples it is evident that although all of the ballistic modifiers disclosed are operable, some are more effective than others in lowering the *n* value or the temperature coefficient of equilibrium pressure of a given propellant. This fact allows for a wide choice of modifier based on economic considerations as well as the ballistics desired for a particular application. From the combined viewpoints of effectiveness and economy, lead 2,4-dihydroxy benzoate, lead salicylate and lead acetyl salicylate are preferred.

In copending application Serial No. 492,802, filed March 7, 1955, it is disclosed that lowered *n* values and coefficients of equilibrium pressure can also be obtained by incorporating lead, inorganic lead compounds or aliphatic lead compound in smokeless powder compositions having a heat of explosion not exceeding about 900 calories per gram. As illustrated in the examples, it may be desirable to employ a mixture of an aromatic lead compound and lead or nonaromatic lead compound. The use of mixtures of aromatic lead compounds with lead 2-ethyl hexoate are particularly desirable since lead 2-ethyl hexoate is a liquid and assists in obtaining the necessary uniform admixture of modifier throughout the composition. It has been noted, moreover, that especially where the heat of explosion of the composition does not exceed 900 calories per gram, the incorporation of lead or nonaromatic lead compound with the aromatic lead compound will often extend the pressure range of low *n* value in the low pressure direction. No more than 10% by weight of the mixture may be used.

The compositions of the invention may be prepared by solventless extrusion. In the conventional solventless process, water-wet nitrocellulose and the other ingredients are admixed in a Schrader bowl with water. The resulting slurry or paste is dried to ten percent water and is colloided and dried between hot colloiding rolls which may be even speed or differential speed rolls as desired. The resulting colloided, dry sheets are then cut into disks or convolutedly rolled into "carpet rolls." The disks or carpet rolls are then extruded to desired grain size. Flake powder may be formed by suitably shredding the sheet. The resulting grains are normally glazed, usually with graphite, to lower static generation and to improve flowing characteristics.

The compositions of the invention may also be made by the solvent process. In the usual solvent process, the water in hydrated nitrocellulose is first replaced, for example, by treatment with ethyl alcohol. A colloiding solvent such as ether or acetone is then added to the dehydrated nitrocellulose along with additional ingredients and a doughy mass is formed in a suitable mixer such as Sigma blade mixer. This dough is then formed into green grains usually by extrusion into cords and cutting the cords to the desired length. The green grains are then subjected to solvent removal steps. The greater portion of the solvent is normally removed by passing a warm

20 inert gaseous medium such as air or flue gas over the grains. The remainder of the solvent which can be practically removed is then usually leached out by a water treatment. Water is then removed by an air dry step and the dry grains are normally given a glaze, usually of graphite, to lower static generation and to improve flowing characteristics.

As is well known to the art, colloiding solvent can be removed from powder grains of large diameter and web only with extreme difficulty. This difficulty increases as the web thickness is increased. It is therefore desirable to prepare grains of multiple-base formulations of this invention by solventless extrusion or by a suitable casting process. It is preferred to extrude grains up to about 5 or 6 inches in diameter and to cast all larger grains. Casting of the larger grains is preferred because the cost and massive nature of extrusion presses large enough to produce grains of over 5 or 6 inches in diameter become prohibitive.

In the usual casting process, tiny single- or double-base powder grains, prepared by either the solvent or solventless techniques, are introduced into a mold together with suitable plasticizers. The plasticizers cause the grains to coalesce into a unitary mass of plastic composition. The preferred casting process is that disclosed in the copending application of Gordon W. McCurdy, Serial No. 28,218, filed May 20, 1948.

The single-base formulations given in the examples are preferably made by a conventional solvent process, extruded and cut to the desired granulation. Such a process limits the possible size of the single-base grains to a diameter or web thickness which will allow sufficient removal of the colloiding solvent. Grains of solvent-colloided powder having large diameter and web are of course operable and addition of the disclosed modifiers according to this invention will effect the desired modification in ballistics. It is of course well known that the change in ballistics during storage caused by gradual migration and evaporation of the colloiding solvent is the reason why large grains of solvent-colloided powder are not manufactured. As improved processes and means for solvent removal are developed, it will perhaps be possible to produce correspondingly larger grains of solvent-colloided powder which are ballistically stable.

It is not preferred to produce single-base grains by solventless extrusion or by casting because, in order to keep the powder in the single-base category, the plasticizer employed to bring about colloiding and/or consolidation must be of lower potential than the nitrocellulose. The necessary amount of plasticizer, therefore, so lowers the potential that such powders have only a limited application. Nevertheless, incorporation of the disclosed modifiers in single-base grains prepared by solventless extrusion or by casting still results in a low *n* value and a low-temperature coefficient of equilibrium pressure.

If the gas-producing charges of this invention are made

by solventless extrusion, the ballistic modifier or modifiers are preferably added at some time prior to dehydration of the water slurry and the additive system is mixed to a state of homogeneity. The slurry is then dehydrated, the moist mass is rolled into colloided sheets, the sheets are made into rolls and the rolls are extruded in the conventional manner. However, it is often found advantageous to add the ballistic modifiers during the rolling operation, rather than to the water slurry. The modifiers are then intimately admixed throughout the composition by action of the rolls. If the well known Schrader process is employed, the modifiers may be added to the hydrated nitrocellulose in the mixing bowl in any preferred order. A portion of the water is evaporated prior to rolling. The Schrader process is preferred when water-soluble plasticizers are employed.

If the charges of this invention are prepared by solvent extrusion, the ballistic modifier or modifiers are preferably added to the dehydrated nitrocellulose after it has been broken up in a mixer. The modifiers may be introduced with the plasticizer or plasticizers or may be added before or after introduction of the plasticizer as may be desired in the particular formulation.

If the grains are made by casting, the ballistic modifier is homogeneously incorporated during the preparation of the casting powder as above described.

In order to produce the "plateau" type ballistics of the invention, the modifiers must be uniformly incorporated with the other ingredients of the composition; that is, the modifier must be intimately admixed with the other ingredients within each particle of the composition whether the charge is a loose charge of individual grains or consists of a single grain of any desired size. The glazing or coating of a single grain or a plurality of grains in a loose charge will not produce the desired modification in the pressure-burning rate relationships. Thus, powder grains coated or glazed with a lead compound to render them free-flowing are not operable in the invention.

The heat of explosion of an explosive composition may be experimentally determined in the known manner by actually exploding a sample of the substance in a bomb calorimeter under conditions which insure complete combustion of the constituents of the composition, and measuring the heat liberated. However, in the case of smokeless powder compositions which contain at most only small portions of inorganic material, it is usually desirable to determine the heat of explosion by calculation. The calculation of heats of explosion is especially desirable in order to predetermine the calorific value of a proposed composition prior to its formulation. In this calculation, use is made of a simple relation; namely, the heat of explosion per gram of powder is equivalent to the sum of the products of the weight fraction of a given constituent by the contribution to the heat of explosion of the constituent. This contribution of the constituent is for convenience termed the "partial calorific potential" or the "partial heat of explosion," and is usually designated as " K_i ." Thus, the heat of explosion of the composition is derived by the equation:

$$\text{Heat of explosion} = \sum X_i K_i$$

where X_i is the weight fraction of the powder component i .

For compositions consisting principally of carbon, hydrogen, oxygen and nitrogen, K_i is quickly and accurately determined according to the following equations:

$$K_i = 67,392O_i - 40,702C_i - \Delta E_{f_i}$$

$$\Delta E_{f_i} = H.C. - 94,030C_i - 33,715H_i$$

where O_i is the number of gram-atoms of oxygen per gram of the powder component i , C_i is the number of gram-atoms of carbon per gram of the powder component i , H_i is the number of gram-atoms of hydrogen per gram of the powder component i , H.C. is the heat of combustion at 25° C. and constant volume, and

ΔE_{f_i} is the heat of formation per gram of the powder component i from its elements.

"Partial heats of explosion" for inorganic substances such as the ballistic modifiers of the invention are not quite so easily calculated by may be determined according to methods disclosed by De Pauw in *Z.f.ges. Schiess- und Sprengstoffwesen*, 32, 11, 36, 60 (1937); or by Hirschfelder and Sherman in "Simple Calculation of Thermochemical Properties for Use in Ballistics," O.S.R.D. Report No. 1300, declassified and issued as PB27421S.

Actually, it is unnecessary to experimentally determine the K_i values for the various constituents of the smokeless powders in accordance with the invention since tables of the "partial heats of explosion" for these materials are available as published data. The following is a listing of the K_i values of the normally used smokeless powder components and many of the operable ballistic modifiers in accordance with the invention.

Substance (i):	Partial heat of explosion (cal./g.)
Acetone	-1938
Carbon black	-3330
Diamylphthalate	-2190
Dibutylphthalate	-2055
Diethanol nitramine dinitrate	+1294
Diethylene glycol dinitrate	+1030
Diethylphthalate	-1746
Nitrotoluene	-140
Diphenylamine	-2684
Diphenylurea	-2227
Diphenylurethane	-2739
Ethyl alcohol	-1749
Ethyl centralite	-2398
Ethyl urethane	-1639
Graphite	-3377
Lead	0
Lead acetate	-282
Lead phthalate acetate	-462
Lead diacetylacetate	-868
Lead anthranilate	-864
Lead azide	+365
Lead benzoate	-950
Lead m-aminobenzoate	-796
Lead dichlorobenzoate	-736
Lead 2,4-dimethoxybenzoate	-766
Lead 2-ethylhexoate	-1336
Lead 4-ethoxy-2-hydroxybenzoate	-870
Lead p-hydroxybenzoate	-826
Lead bromide	-137
Lead carbonate (basic)	-471
Lead chloride	-151
Lead chromate	+977
Lead citrazinate	-752
Lead tetraethyl	-1725
Lead fluoride	-127
Lead gallate	-573
Lead gentisate	-674
Lead hydroxide	-189
Lead iodide	-91
Lead linoleate	-1982
Lead pyromellitate	-250
Lead trimesate	-460
Lead molybdate	+403
Lead tetrachloronaphthalate	-534
Lead naphthenate	-2048
Lead 1-hydroxy-2-naphthoate	-1117
Lead 3-hydroxy-2-naphthoate	-1117
Lead oleate	-2010
Lead oxalate	+58
Lead oxide (PbO)	+67
Lead oxide (Pb ₃ O ₄)	+139
Lead oxide (PbO ₂)	+302
Lead n-butylphthalate	-974
Lead β -resorcylate	-704

Substance (i):	Partial heat of explosion (cal./g.)
Lead tetraphenyl -----	-1725
Lead salicylate -----	-752
Lead acetylsalicylate -----	-857
Lead aminosalicylate -----	-746
Lead thiosalicylate -----	-874
Lead stearate -----	-2800
Lead phthalate stearate -----	-1543
Lead sulfate -----	-150
Lead sulfide -----	-222
Lead tartrate -----	-172
Lead o-toluate -----	-1057
Nitrocellulose	
13.25% N -----	+1041
13.15% N -----	+1027
13.00% N -----	+1007
12.60% N -----	+951
12.20% N -----	+895
12.00% N -----	+867
11.50% N -----	+797
Nitroglycerin -----	+1785
Nitroguanidine -----	+720
Triacetin -----	-1284
Water -----	-5

The advantages of the gas-producing compositions of this invention over presently available formulations are readily apparent. The compositions of this invention are characterized by distinguishing properties which have heretofore been found highly desirable but unobtainable, namely, a very low temperature coefficient of equilibrium pressure and a substantially constant burning rate over a wide pressure range within the zone of useful rocket pressures. Additional safety and rocket motor design possibilities are present in the compositions where a 0.0 n value or a negative n value is obtained. Although particular emphasis has been placed on the desirability and advantages of the compositions of this invention when applied to jet-actuated devices, it is to be understood that these compositions have a general utility in applications where gas-producing charges are desired. They are especially advantageous where substantially constant pressures are desired and where any rapid increase in pressure would be highly undesirable.

This application is a continuation-in-part of my co-pending application Serial No. 102,427, filed June 30, 1949, now abandoned.

What I claim and desire to protect by Letters Patent is:

1. A gas-producing composition consisting essentially of a smokeless powder having uniformly incorporated therein and intimately admixed therewith within each particle thereof an amount not exceeding 10% of at least one aromatic compound of lead and said composition having a value of less than 0.7 for the slope n of the line representing the pressure-burning rate relationship.

2. A gas-producing composition consisting essentially of a smokeless powder having uniformly incorporated therein and intimately admixed therewith within each particle thereof an amount not exceeding 10% of lead 2,4-dihydroxy benzoate and said composition having a value of less than 0.7 for the slope n of the line representing the pressure-burning rate relationship.

3. A gas-producing composition consisting essentially of a smokeless powder having uniformly incorporated therein and intimately admixed therewith within each particle thereof an amount not exceeding 10% of lead salicylate and said composition having a value of less than 0.7 for the slope n of the line representing the pressure-burning rate relationship.

4. A gas-producing composition consisting essentially of a smokeless powder having uniformly incorporated therein and intimately admixed therewith within each particle thereof an amount not exceeding 10% of lead acetyl salicylate and said composition having a value of

less than 0.7 for the slope n of the line representing the pressure-burning rate relationship.

5. A gas-producing composition consisting essentially of a smokeless powder having uniformly incorporated therein and intimately admixed therewith within each particle thereof an amount not exceeding 10% of a mixture of lead salicylate and lead 2-ethyl hexoate and said composition having a value of less than 0.7 for the slope n of the line representing the pressure-burning rate relationship.

6. A gas-producing composition consisting essentially of a smokeless powder having uniformly incorporated therein and intimately admixed therewith within each particle thereof an amount not exceeding 10% of a mixture of lead acetyl salicylate and lead 2-ethyl hexoate and said composition having a value of less than 0.7 for the slope n of the line representing the pressure-burning rate relationship.

7. A gas-producing composition consisting essentially of a smokeless powder containing 85% to 95% of nitrocellulose and having uniformly incorporated therein and intimately admixed therewith within each particle thereof not more than 10% of at least one aromatic compound of lead and said composition having a value of less than 0.7 for the slope n of the line representing the pressure-burning rate relationship.

8. A gas-producing composition consisting essentially of a smokeless powder containing 85% to 95% of nitrocellulose and having uniformly incorporated therein and intimately admixed therewith within each particle thereof not more than 10% of lead 2,4-dihydroxy benzoate and said composition having a value of less than 0.7 for the slope n of the line representing the pressure-burning rate relationship.

9. A gas-producing composition consisting essentially of a smokeless powder containing 85% to 95% of nitrocellulose and having uniformly incorporated therein and intimately admixed therewith within each particle thereof not more than 10% of lead acetyl salicylate and said composition having a value of less than 0.7 for the slope n of the line representing the pressure-burning rate relationship.

10. A gas-producing composition consisting essentially of a smokeless powder containing 85% to 95% of nitrocellulose and having uniformly incorporated therein and intimately admixed therewith within each particle thereof not more than 10% of lead acetyl salicylate and said composition having a value of less than 0.7 for the slope n of the line representing the pressure-burning rate relationship.

11. A gas-producing composition consisting essentially of a smokeless powder containing 85% to 95% of nitrocellulose and having uniformly incorporated therein and intimately admixed therewith within each particle thereof not more than 10% of a mixture of lead salicylate and lead 2-ethyl hexoate and said composition having a value of less than 0.7 for the slope n of the line representing the pressure-burning rate relationship.

12. A gas-producing composition consisting essentially of a smokeless powder containing 85% to 95% of nitrocellulose and having uniformly incorporated therein and intimately admixed therewith within each particle thereof not more than 10% of a mixture of lead acetyl salicylate and lead 2-ethyl hexoate and said composition having a value of less than 0.7 for the slope n of the line representing the pressure-burning rate relationship.

13. A gas-producing composition consisting essentially of a smokeless powder containing nitrocellulose and at least one explosive nitric ester and having uniformly incorporated therein and intimately admixed therewith not more than 10% of an aromatic compound of lead and said composition having a value of less than 0.7 for the slope n of the line representing the pressure-burning rate relationship.

14. A gas-producing composition consisting essentially of a smokeless powder containing nitrocellulose and at

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least one explosive nitric ester and having uniformly incorporated therein and intimately admixed therewith not more than 10% of lead 2,4-dihydroxy benzoate and said composition having a value of less than 0.7 for the slope n of the line representing the pressure-burning rate relationship.

15. A gas-producing composition consisting essentially of a smokeless powder containing nitrocellulose and at least one explosive nitric ester and having uniformly incorporated therein and intimately admixed therewith not more than 10% of lead salicylate and said composition having a value of less than 0.7 for the slope n of the line representing the pressure-burning rate relationship.

16. A gas-producing composition consisting essentially of a smokeless powder containing nitrocellulose and at least one explosive nitric ester and having uniformly incorporated therein and intimately admixed therewith not more than 10% of lead acetyl salicylate and said composition having a value of less than 0.7 for the slope n of the line representing the pressure-burning rate relationship.

17. A gas-producing composition consisting essentially of a smokeless powder containing nitrocellulose and at least one explosive nitric ester and having uniformly in-

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corporated therein and intimately admixed therewith not more than 10% of a mixture of lead salicylate and lead 2-ethyl hexoate and said composition having a value of less than 0.7 for the slope n of the line representing the pressure-burning rate relationship.

18. A gas-producing composition consisting essentially of a smokeless powder containing nitrocellulose and at least one explosive nitric ester and having uniformly incorporated therein and intimately admixed therewith not more than 10% of a mixture of lead acetyl salicylate and lead 2-ethyl hexoate and said composition having a value of less than 0.7 for the slope n of the line representing the pressure-burning rate relationship.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,033,715

May 8, 1962

Ralph F. Preckel

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 5, line 34, for "compound" read -- compounds --;
column 8, line 5, for "by" read -- but --; column 10, line 39, for
"thon" read -- than --; same line 39, strike out "acetyl".

Signed and sealed this 4th day of September 1962.

(SEAL)

Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents