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AUXILIARY IGNITER AND SUSTAINER

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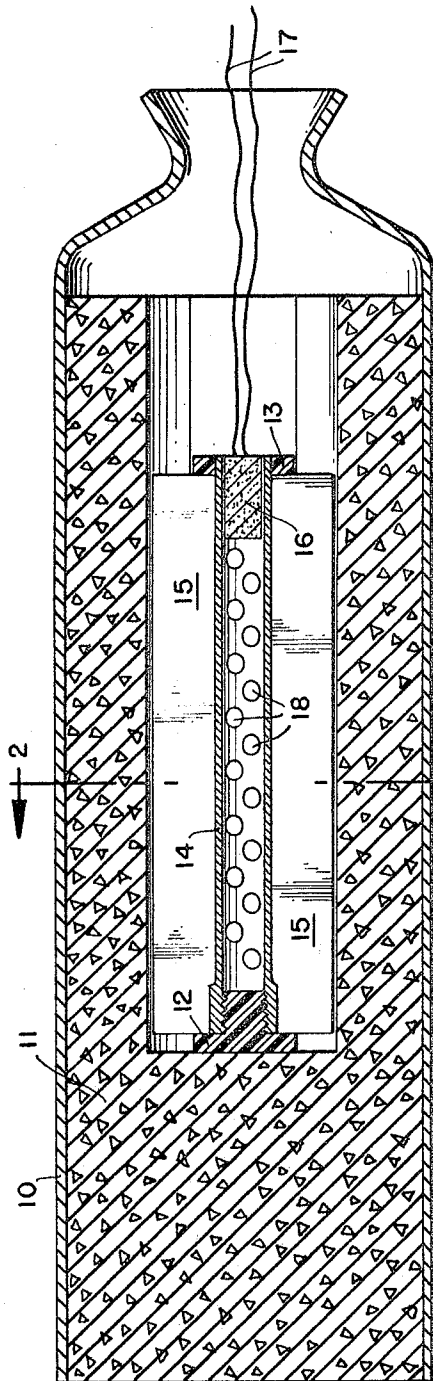


FIG. 1.

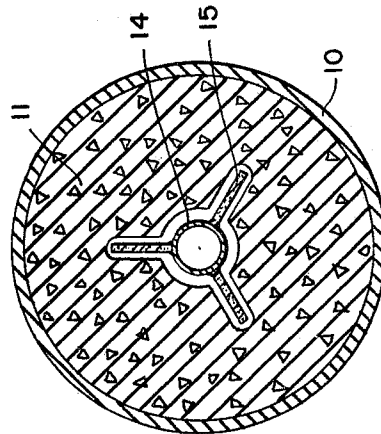


FIG. 2.

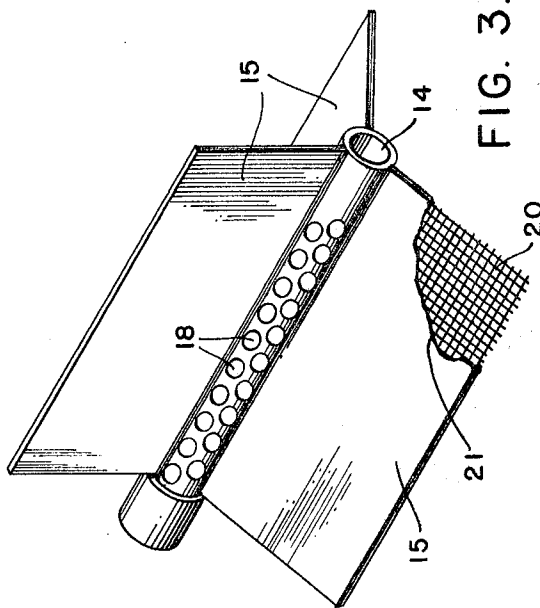


FIG. 3.

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AUXILIARY IGNITER AND SUSTAINER

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2 Claims. (Cl. 102—70)

The invention herein described may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention is directed to an igniter for rocket propellants; more specifically, it is directed to an igniter for solid propellant grains.

Prior igniters were made by placing a combustible material such as black powder, boron-potassium nitrate mixtures, and other metal-oxidizer mixtures in a suitable container such as a tube, a canister, or cloth bag and providing a suitable initiating device such as a squib in the container in close proximity to the combustible material.

Igniters so made were used by simply placing them in close proximity to the surface to be ignited where the propellant was subjected to hot gases and/or hot particles from the burning igniter material.

Such methods of ignition did not give sustained igniter action, did not properly direct the action of the products of igniter combustion onto the surfaces of the propellant grain, and did not always give rapid, reproducible ignition.

It is therefore an object of this invention to provide an igniter which will give sustained action on the propellant grain.

Another object is to provide an igniter which directs the flow of the hot gases and/or hot particles onto the propellant grain.

A final object is to provide an igniter which gives rapid reproducible ignition.

These objects are accomplished by employing a secondary or auxiliary igniter in addition to a primary igniter. The primary igniter is conventional, both in the construction of the mechanical parts and in the pyrotechnic mixtures employed therein, and its primary function is to ignite the secondary igniter, though it contributes directly to the ignition of the grain as well.

The secondary igniter is a sheet, screen, or the like which is coated with pyrotechnic material. The secondary igniter is positioned in very close proximity to or even in contact with the surface to be ignited and is also situated such that it will be readily ignited by the primary igniter.

The exact nature of this invention as well as other objects and advantages thereof will be readily apparent from consideration of the following specification relating to the annexed drawing in which:

FIG. 1 shows a longitudinal cross-sectional view of the rear portion of a rocket motor showing the grain and the igniter in place;

FIG. 2 illustrates a cross-sectional view taken along line 2—2 of the device illustrated in FIG. 1;

FIG. 3 is a perspective view of the present igniter minus squib and positioning disks, showing part of a fin cutaway.

Referring now to the drawings, wherein like reference characters designate like or corresponding parts throughout the several views, there is shown a motor tube 10 having a nozzle at one end, and a propellant grain 11 having a centrally located star-like well extending from the end nearest the nozzle into the grain in a longitudinal direction, the grain being attached to the motor tube.

Positioned inside the well with the aid of disks 12 and 13 which snugly fit the inner diameter of the well, disk 12 abutting the bottom of the well and attached thereto,

is the igniter having a tubular perforated body 14 which contains the primary igniter material and to which the aforementioned disks 12 and 13 are attached at the ends thereof. Perforations 18 are sealed with a rupturable material such as an epoxy resin, a thin metal sheet, or stiff paper. Fins 15 are longitudinally attached to the body 14 and project outwardly therefrom into the spaces which form the outer points of the star-like configuration of the grain, sometimes substantially filling up said spaces.

A squib 16 is snugly positioned in the end of the igniter body 14 nearest the nozzle, forming a closure for said end. Wires 17 are connected to the squib for its actuation.

Fins 15 are comprised of screens 20 which are coated with a pyrotechnic material 21.

The foregoing has described only one embodiment of the invention; there are as many embodiments as there are grain geometry designs.

The embodiment just described works very well with grains having star shaped perforations and it is obvious that the number of fins employed may vary depending upon how many points the star has.

Another embodiment for internal burning grains is a hollow, coated structure formed to the same cross-sectional configuration as the perforation but slightly smaller so as to be insertable into the perforation so that the pyrotechnic material is substantially in contact with the inner surface to be ignited.

External burning grains on the other hand should have a coated outer structure of the same cross-section as the grain but slightly longer so that the pyrotechnic material would be substantially in contact with the outer surface of the grain when the structure was slipped over the grain.

End burning grains require only a sheet of coated material held substantially in contact with the end of the grain to be ignited.

In addition, sheets and strips of coated material may be liberally applied to any surface to be ignited. There is no requirement that the total surface to be ignited have the secondary igniter material in close contact therewith.

The material upon which the pyrotechnic material is coated may be cloth, screen or sheet material, perforated or unperforated, and may be metal, natural fiber, or plastic, or the like. Common aluminum window screen is preferred however because of its cheapness, ready availability, and ease of forming.

The particular pyrotechnic material which is used to coat the screen, sheet or cloth, as well as the primary pyrotechnic material employed is a matter of the designer's choice. The materials may be chosen to give essentially gaseous or essentially solid products or any ratio of gas to solids in order to generate desired conditions of temperature and pressure for ignition of a wide variety of propellant formulations and grain configurations. Choice of pyrotechnic material also makes possible the control of ignition delay, functioning time, and rate of pressurization. More often than not the primary material and the secondary material are different.

The coating of pyrotechnic material should contain excess oxidizer to insure partial or complete combustion of the screen or sheet material upon which it is coated.

The secondary igniter material is coated on its supporting structure, which may or may not be attached to the primary igniter body, from a slurry of the material in a suitable solvent. The secondary igniter material usually contains solid ingredients which will not dissolve, so a solution of a binder such as nitrostarch, nitrocellulose, certain natural gums, certain synthetic resins or the like is prepared, the igniter material stirred in and the suspension simply spread on the surface, and allowed to dry.

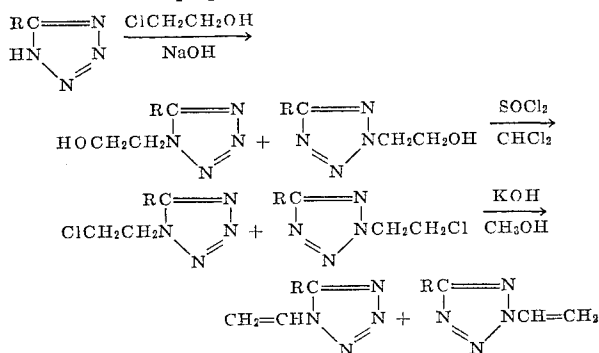
Excellent binders for insoluble pyrotechnic materials, particularly metal-oxidizer mixtures, are the vinyltetrazole

polymers. These polymers undergo sustained decomposition to their elements under pressure in the absence of oxidizers, are chemically inert, and possess good bonding characteristics with metals, glass, and other materials.

The polymers are unreported in the literature and are made as follows:

1- and 2-vinyltetrazoles

1- and 2-vinyltetrazoles, and 1- and 2-vinyl-5-aminotetrazoles are readily synthesized starting with tetrazole and 5-aminotetrazole as follows: Sodium tetrazole is alkylated with 2-chloroethanol to form a mixture of 1- and 2-(2-hydroxyethyl)tetrazoles which are in turn chlorinated with thionyl chloride. The chloro derivatives are converted to the vinyl compounds by dehydrohalogenation. The 1- and 2-vinyltetrazoles are isolated by distillation at reduced pressure. 1- and 2-vinyl-5-aminotetrazoles can be synthesized by the same procedure, starting with sodium 5-aminotetrazole. The following equations illustrate the above preparation:



where R is H or amino.

1- and 2-(2-hydroxyethyl)tetrazoles

A suspension of 140 g. (2.0 moles) of tetrazole in 300 ml. of distilled water, contained in a 2-liter, 2-necked round bottomed flask with a reflux condenser, was neutralized to a phenolphthalein endpoint with a solution of 82.5 g. (2.0 moles) of 97% sodium hydroxide in 300 ml. of water. The solution of sodium tetrazole was heated to reflux and 201 g. (2.0 moles) of 2-chloroethanol was added from an additional funnel over a 15 minute period. The resulting solution was refluxed for 18 hours and then concentrated in vacuo on a steam bath to a syrupy mixture of products and sodium chloride.

The hydroxyethylated products were extracted from the sodium chloride with one 300 ml. and three 100 ml. portions of boiling acetone. Concentration of the acetone extracts in vacuo on a steam bath yielded 236 g. (theory 288 g.) of a mixture of 1- and 2-(2-hydroxyethyl)tetrazoles and other alkylated products. The two products can be separated by acetylation of the mixture with acetic anhydride and distillation of the acetates at reduced pressure.

1- and 2-(2-chloroethyl)tetrazoles

The mixture of 2-hydroxyethyltetrazoles (236 g.) from the preceding section was slurried with 250 ml. of chloroform in a 2-liter, 3-necked flask equipped with a reflux condenser, "true-bore" stirrer and an addition funnel. Thionyl chloride (300 g., 2.5 moles) was added dropwise with stirring while the temperature of the reaction mixture was maintained below 20° C. by immersing the flask in an ice bath. The cooling bath was then removed and the mixture was allowed to stir at room temperature for 24 hours. The reaction mixture became homogeneous during this time. The mixture was refluxed for two hours to drive off hydrogen chloride and sulfur dioxide and then concentrated to a syrup at reduced pressure on a steam bath. After cooling to 5° C., the syrup was treated with 100 g. of crushed ice, with stirring, to decompose any thionyl chloride complexed with the tetrazoles. After the

initial reaction was over the excess ice was melted by warming the mixture on a steam bath and the chloroethyltetrazoles were extracted with three 100 ml. portions of chloroform. Evaporation of the chloroform solution left 265 g. of 1- and 2-(2-chloroethyl)tetrazoles as a yellow viscous oil. Separations of the isomers was possible at this point by distillation. Distillation of the chloroethyltetrazoles from 3.8 moles of tetrazole yielded 154.3 g. (30.7%) of 2-(2-chloroethyl)tetrazole, B.P. 76° C. at 1 mm. The 1-(2-chloroethyl)tetrazole was not distilled, but could be, using molecular distillation techniques.

1- and 2-vinyltetrazole

The 265 g. (ca. 2.0 moles) of chloroethyltetrazoles from the preceding chlorination and 1 g. of hydroquinone were dissolved in 200 ml. of methanol in a 2-liter, 3-necked flask equipped with a reflux condenser, "true-bore" stirrer and addition funnel and the solution was heated to reflux.

A solution of 132 g. (2.0 moles) of 85% potassium hydroxide in 400 ml. of methanol was added dropwise with stirring over a one hour period. Precipitation of potassium chloride began immediately. Reflux was continued for 30 minutes after the addition was complete. The methanol was then distilled at atmospheric pressure; stirring was continued to prevent bumping. After cooling the residue of vinyl tetrazoles, water, and potassium chloride to room temperature, the vinyltetrazoles were extracted with three 100 ml. portions of methylene chloride. The methylene chloride solution was dried with anhydrous magnesium sulfate and an additional gram of hydroquinone was added to prevent polymerization. Distillation of the methylene chloride at atmospheric pressure left a residue of 1- and 2-vinyltetrazoles which was distilled at reduced pressure to yield: 38.6 g. (20.1% yield based on tetrazole) of 2-vinyltetrazole, B.P. 66°–68° C. at 60 mm., N_D^{20} 1.4850, D_4^{20} 1.131.

Analysis.—Calcd. for $C_3H_4N_4$: C, 37.49; H, 4.19; N, 58.31. Found: C, 37.62; H, 4.60; N, 57.82 and 70.6 g. (36.8% yield based on tetrazole) of 1-vinyltetrazole, B.P. 94° C. at 1 mm., N_D^{20} 1.500, D_4^{20} 1.179.

Analysis.—Calcd. for $C_3H_4N_4$: C, 37.49; H, 4.19. Found: C, 37.73; H, 4.54.

Dehydrohalogenation of 154.3 g. (1.17 moles) of distilled 2-chloroethyltetrazole by the same procedure yielded 78.0 g. (70%) of 2-vinyltetrazole.

1- AND 2-VINYL-5-AMINOTETRAZOLES

1- and 2-hydroxyethyl-5-aminotetrazole

A solution of 2 moles of the sodium of 5-aminotetrazole was made in a 2-liter, 2-necked flask by neutralizing a suspension of 206 g. (2.0 moles) of 5-aminotetrazole monohydrate in 200 ml. of water to a phenolphthalein endpoint with a solution of 82.5 g. (2.0 moles) of 97% sodium hydroxide in 200 ml. of water. The solution was heated to reflux and 180 g. (2.2 moles) of 2-chloroethanol was added over a 15 minute period. The resulting solution was refluxed over night and then stripped to dryness in vacuo on a steam bath. The syrupy residue of products and sodium chloride was extracted with two 200 ml. portions of boiling acetone. The combined acetone extracts were cooled to 5° C. and 61.2 g. (23.7%) of 1-(2-hydroxyethyl)-5-aminotetrazole were removed by filtration. An additional 12.6 g. of product were obtained by evaporation of the acetone filtrate to dryness, redissolving the residue in 400 ml. of boiling absolute ethanol and chilling the ethanol solution for 48 hours at 5° C. The total of 73.8 g. represents a 28.58% yield of 1-(2-hydroxyethyl)-5-aminotetrazole. Recrystallization from 600 ml. of boiling ethanol gave 61.2 g. (23.7%) of pure product M.P. 159°–161° C.

Analysis.—Calcd. for $C_3H_7ON_5$: C, 27.90; H, 5.47; N, 54.24. Found: C, 27.97; 28.21; H, 5.14, 5.30; N, 53.87, 54.09.

Evaporation of the ethanol filtrates (including the recrystallization mother liquors of 1-isomer) in vacuo on a steam bath left 191 g. of oily residue which on standing, partially solidified. This residue was slurried with ice cold absolute ethanol and filtered, yielding 96.8 g. (37.4%) of 2-(2-hydroxyethyl)-5-aminotetrazole. Recrystallization from ethyl acetate yielded 60.0 g. (23.2%) of pure product, M.P. 86.5°–88.5° C.

Analysis.—Calcd. for $C_3H_7ON_5$: C, 27.90; H, 5.47; N, 54.24. Found: C, 28.24; H, 5.41; N, 53.65.

1-(2-chloroethyl)-5-aminotetrazole

Thionyl chloride (150 ml.) was placed in a 500 ml. flask and cooled to 5° C. in an ice bath. 1-(2-hydroxyethyl)-5-aminotetrazole (45.4 g., 0.352 mole) was added portionwise with shaking and cooling to maintain the temperature below 20° C. The mixture was then heated to reflux for four hours. Hydrogen chloride and sulfur dioxide were evolved and the mixture became homogeneous. The excess thionyl chloride was then removed in vacuo on a steam bath and the residue was treated (after cooling to room temperature) with 50 ml. of 95% ethanol to decompose any complexed thionyl chloride. When the exothermic reaction had subsided, 50 ml. of water was added and the mixture was stripped to dryness at reduced pressure on a steam bath. The solid residue was dissolved in 250 ml. of boiling water, decolorized with charcoal and the solution was cooled to 5° C. overnight. The yield of 1-(2-chloroethyl)-5-aminotetrazole amounted to 39.24 g. (75.7% yield based on 1-(2-hydroxyethyl)-5-aminotetrazole), M.P. 150°–151.5° C.

Analysis.—Calcd. for $C_3H_6N_5Cl$: N, 47.46; Cl, 24.03. Found: N, 48.4; Cl, 24.40.

2-(2-chloroethyl)-5-aminotetrazole

The chlorination of 78.5 g. (0.609 mole) of 2-(2-hydroxyethyl)-5-aminotetrazole was accomplished in the same manner as that described for the 1-isomer. Recrystallization of the crude product from benzene yielded 55.4 g. (61.8% yield) of pure 2-(2-chloroethyl)-5-aminotetrazole, M.P. 51°–52.5° C.

Analysis.—Calcd. for $C_3H_6N_5Cl$: N, 47.46; Cl, 24.03. Found: N, 48.6; Cl, 24.0.

1-vinyl-5-aminotetrazole

A solution of 39.79 g. (0.27 mole) of 1-(2-chloroethyl)-5-aminotetrazole and 0.1 g. of hydroquinone in 150 ml. of methanol, contained in a 1-liter flask equipped with a reflux condenser, "true-bore" stirrer and an addition funnel, was heated to reflux. A solution of 18 g. (0.27 mole) of 85% potassium hydroxide in 100 ml. of methanol was then added dropwise with stirring over a period of 30 minutes. The reaction was refluxed for one hour after the addition was complete and then cooled to 20° C. After the precipitated potassium chloride was removed by filtration the solution was concentrated to dryness at reduced pressure on a steam bath. The residue of impure 1-vinyl-5-aminotetrazole was dissolved in a minimum of hot water and cooled, yielding 22.75 g. (0.247 mole) of 1-vinyl-5-aminotetrazole, M.P. 157°–158° C. An additional 2.30 g. was recovered by concentrating and cooling the mother liquors. The total of 26.05 g. represents an 86.8% yield based on 1-(2-chloroethyl)-5-aminotetrazole.

Analysis.—Calcd. for $C_3H_5N_5$: C, 32.42; H, 4.54; N, 63.04. Found: C, 32.5; H, 4.72; N, 64.0.

2-vinyl-5-aminotetrazole

The dehydrohalogenation of 40.47 g. (0.274 mole) of 2-(2-chloroethyl)-aminotetrazole with potassium hydroxide in methanol was accomplished in the same manner as for the 1-isomer. The crude product was obtained as an oil (30 g.) which was distilled at reduced pressure to yield 23.39 g. (77.7% yield based on the starting chloro compound), B.P. 75°–77° C. at 0.8 mm., M.P. 47°–49° C. after recrystallization from carbon tetra-

chloride. The melting point of a sample, purified for analysis by sublimation at reduced pressure, was unchanged.

Analysis.—Calcd. for $C_3H_5N_5$: C, 32.42; H, 4.54; N, 63.04. Found: C, 33.00; H, 4.44; N, 61.50.

1- AND 2-METHYL-5-VINYLTETRAZOLES

5-hydroxyethyltetrazole

A mixture of 213 g. (3.0 moles) of hydracrylonitrile, 214.8 g. (3.3 moles) of sodium azide, 176.7 g. (3.3 moles) of ammonium chloride and 1500 ml. of dimethylformamide, recovered from a previous synthesis, is heated at 123°–127° C. with stirring for 24 hours. The dimethylformamide is then removed at 100° C. under reduced pressure (ca. 20 mm.). Care should be taken to remove the dimethylformamide in this operation as completely as possible. The residue of sodium chloride and 5-hydroxyethyltetrazole is then dissolved in 250 ml. of water and made basic with a solution of 140 g. (3.5 moles) of sodium hydroxide in 250 ml. of water. The temperature should be maintained at ca. 25° C. during this step to prevent excessive foaming. The solution is then stripped to about half volume at reduced pressure on a steam bath. The pH of the solution at this time should be nine or higher. If the pH is lower than nine, additional base should be added and the evaporation continued until the pH remains at nine or higher. The solution is then cooled to room temperature and acidified to about pH 2 with 300 ml. of concentrated hydrochloric acid (or more if additional base had been used). It is advantageous at this point to cool the solution to 5° C. and remove the precipitated sodium chloride by filtration. The filter cake is washed with 95% ethanol and the filtrate combined with the product solution. The acidified product solution and alcohol washings are then stripped of solvents at 100° C. under reduced pressure. The 5-hydroxyethyltetrazole is then extracted from the residue with one 500 ml., one 250 ml. and one 125 ml. portions of cold 95% ethanol and neutralized to a phenolphthalein endpoint by the addition of a solution of 197.4 g. (3.0 moles) of 85% potassium hydroxide in 625 ml. of 95% ethanol with stirring and cooling.

1- and 2-methyl-5-(2-hydroxyethyl)tetrazoles

The 3.0 moles of potassium 5-hydroxyethyltetrazole in 1500 ml. of 95% ethanol from the previous reaction is placed in a 3-liter, 3-necked flask.

Potassium bicarbonate (30 g., 0.3 mole) is added and 417 g. (3.3 moles) of dimethyl sulfate is added dropwise with stirring over a 30 minute period. The temperature of the solution is maintained at 28°–33° C. during the addition and for an additional 30 minutes and then raised to 40°–45° C. for 30 minutes. The solution is then cooled to 5° C. The precipitate of potassium methylsulfate is removed by filtration and the filter cake is washed with several portions of 95% ethanol. The combined ethanol filtrates are evaporated to dryness at reduced pressure on a steam bath.

The 1- and 2-methyl-5-(2-hydroxyethyl) tetrazoles are extracted from the residue with a total of 350 ml. of chloroform and the chloroform solution is dried for one hour with magnesium sulfate, or alternatively by azeotropic distillation of part of the chloroform. (If the vacuum stripping of the ethanol and water in the previous step is through, the chloroform solution should be essentially dry. Care should be taken that the chloroform solution is dry before the chlorination reaction.)

1- and 2-methyl-5-(2-chloroethyl)tetrazoles

The solution of 1- and 2-methyl-5-(2-hydroxyethyl) tetrazoles in 350 ml. of chloroform from the preceding methylation reaction is cooled to 5° C. and 330 ml., 537 g. (4.5 moles) of thionyl chloride is added with stirring at a rate such that the reaction temperature does not rise above 25° C. the solution is then heated to reflux for four

hours, or longer if necessary, to complete the evolution of hydrochloric acid and sulfur dioxide. The chloroform and excess thionyl chloride are then removed at reduced pressure on a steam bath. The heating at reduced pressure should be thorough to ensure complete removal of any thionyl chloride, but it is also essential that there be excess thionyl chloride at the end of the reflux period. The residue of products is then cooled to room temperature and dissolved in 300 ml. of chloroform. Water (200 ml.) is added and the mixture is stirred and cooled to 5° C. Solid sodium bicarbonate is then added, with stirring and cooling in sufficient quantity (0.2–0.3 mole/mole) to bring the pH of the mixture to 6–7. The chloroform layer is then separated and the water layer is extracted with an additional 100 ml. portion of chloroform. The combined chloroform solutions are dried with magnesium sulfate and stripped to dryness at reduced pressure on a steam bath. The residue of mixed 1- and 2-methyl-5-(2-chloroethyl)tetrazoles is then heated to 100° C. at 10–20 mm. and stripped of the low boiling impurities present. 2-methyl-5-(2-chloroethyl)tetrazole is then removed from the mixture of chlorocompounds by high vacuum distillation.

2-methyl-5-vinyltetrazole

The 2-methyl-5-(2-chloroethyl)tetrazole from the preceding reaction is dissolved in 250 ml. of methanol and the solution is heated to reflux. A solution of approximately 98.5 g. (1.5 moles) of 85% potassium hydroxide in 500 ml. of methanol is then added dropwise with stirring over a period of one hour and the reaction is stirred and refluxed for an additional hour. The solution is then cooled to room temperature, neutralized to pH 6–7 with concentrated hydrochloric acid and one gram of hydroquinone is added. The methanol is removed by distillation at atmospheric pressure on a steam bath. The residue of salts and products is cooled to room temperature and the products are extracted with one 150 ml. and two 50 ml. portions of methylene chloride. The methylene chloride solution is dried with magnesium sulfate and the solvent is removed by distillation at atmospheric pressure on a steam bath. The 2-methyl-5-vinyltetrazole is removed from the mixture of crude products by distillation at 20 mm. pressure; B.P. ca. 80° C., N_D^{25} 1.4800.

1-methyl-5-vinyltetrazole

1-methyl-5-(2-chloroethyl)tetrazole separated from the residue of mixed 1- and 2-methyl-5-(2-chloroethyl)tetrazoles as outlined above was used in this example. A solution of 229 g. of undistilled but partially purified 1-

(N-methylmorpholine was chosen as the tertiary base for this dehydrohalogenation for several reasons: (1) The chloro compound is readily and completely miscible in this solvent. By way of contrast, the chloro compound is only poorly soluble in triethylamine. (2) The moderate boiling point of about 104° C. at 785 mm. permits easy removal of excess solvent from the monomer without overheating; furthermore, if the reaction becomes vigorous, the boiling of the excess amine will serve to moderate and maintain a reasonable temperature. (3) The hydrochloride separated from the reaction solution as coarse, easily filterable crystals with little or no tendency to gum.)

A very definite exothermic reaction was noted about one-half hour after heating commenced; the heating was discontinued for a few minutes until this vigorous reaction ceased. The solution was cooled to 5° C., diluted with 600 ml. of fresh diethyl ether, and recooled to 5° C. The precipitated N-methylmorpholine hydrochloride was removed by filtration and washed with two 100 ml. portions of diethyl ether. The combined extracts were evaporated under reduced pressure (15 mm.) and to a final pot temperature of 100° C. The yield was 156.6 g. An additional quantity of less pure material was obtained by extracting the cake of N-methylmorpholine hydrochloride with several portions of methylene chloride, and evaporating the methylene chloride.

(Although the pure 1-methyl-5-vinyltetrazole is only sparingly soluble in diethyl ether, this monomer is apparently reasonably soluble in the mixture of diethyl ether and the unreacted N-methylmorpholine. The monomer is much more soluble in methylene chloride; however, this solvent is not recommended since it also extracts any polymer and tars which are formed during the dehydrohalogenation; the crude monomer so obtained is more difficult to handle in the molecular still.

(The weight of dried N-methylmorpholine hydrochloride remaining after the methylene chloride extraction was 191.8 g., or 89.3% theory).

The crops of impure 1-methyl-5-vinyltetrazole were distilled separately in a falling-film, molecular-still at a pressure of about one micron and a jacket temperature of about 120° C. The total yield of canary yellow product was 151 g. (87.8%); N_D^{25} = 1.5046. Two additional distillations in a molecular still gave an almost water-white monomer (N_D^{25} = 1.5044) which crystallized between 15° and 20° C. when seeded. Analytical data for 1- and 2-methyl-5-vinyltetrazoles, some of the intermediate compounds and one polymer, disclosed above, are set forth in the following table.

Compound	Analysis					
	Carbon		Hydrogen		Nitrogen	
	Calcd.	Found	Calcd.	Found	Calcd.	Found
5-(2-hydroxyethyl)tetrazole.....	31.57	31.59	5.30	5.23	49.10	49.17
2-methyl-5-(2-hydroxyethyl)tetrazole.....	37.49	37.05	6.29	6.32	43.73	44.00
2-methyl-5-(2-chloroethyl)tetrazole.....	32.77	32.72	4.82	4.73	38.23	38.50
1-methyl-5-vinyltetrazole.....	43.62	43.81	5.49	5.70	50.89	51.34
2-methyl-5-vinyltetrazole.....	43.62	43.63	5.49	5.66	50.89	50.60
poly(2-methyl-5-vinyltetrazole).....	43.62	43.70	5.49	5.76	50.89	50.53

methyl-5-(2-chloroethyl)tetrazole in 275 ml. of dried, distilled N-methylmorpholine was heated under reflux on the steam bath for eight hours.

(The crude 1-methyl-5-(2-chloroethyl)tetrazole remaining after the 2-isomer has been removed by distillation is a dark brown, murky oil. Its appearance can be greatly improved by dissolving it in toluene (4.5 ml. per gram) at room temperature, stirring with decoloring charcoal, filtering and evaporating. The treatment with toluene precipitates much dark tar. The resulting chloro compound is clear and orange-yellow in color. The recovery from 260 g. of crude product was 229 g.

Another experiment on a smaller scale gave a yield of 86.7%.

The monomeric compounds prepared above may be polymerized by standard polymerization techniques, including bulk and emulsion polymerization techniques and others. The polymerization of the compounds is typified by the bulk and emulsion polymerization of 2-methyl-5-vinyltetrazole. Emulsion polymerization of this monomer was accomplished as follows: 11 g. (0.1 mole) of 2-methyl-5-vinyltetrazole was added with stirring to a solution of 15 drops of sorbitan trioleate in 80 ml. of distilled water. Nitrogen was bubbled through the water during the for-

mation of the emulsion and the duration of the polymerization. The emulsion was cooled to 0°–2° C. in an ice bath. One ml. of a solution of 0.03 g. of ferrous sulfate heptahydrate in 100 ml. of distilled water was added, followed by 0.025 g. of ammonium persulfate and 0.025 g. of sodium metabisulfite. The temperature was maintained at 1°–2° C. After 24 hours, the conversion to polymer was estimated at 30–50% and after 46 hours the conversion appeared reasonably complete, although some odor of monomer was still present. The polymer was a solid rubbery mass at this point. The product was kneaded under distilled water until free of soap and inorganic salts, cut into small pieces and dried. The dried polymer was dissolved in 250 ml. of ethylene dichloride and precipitated into 500 ml. of cyclohexane. The polymer was removed by filtration and dried. Intrinsic viscosities in chloroform at 25° C. for polymers from various batches prepared as above varied from 3.910 to 4.232 depending upon the batch.

Bulk polymerization of 2-methyl-5-vinyltetrazole was effected by the use of benzoyl peroxide or azobisisobutyronitrile as the catalyst. Intrinsic viscosities in chloroform at 25° C. for the polymer prepared by this method varied from 1.055 (60° C., 1 mole percent azobisisobutyronitrile) to 3.812 (40° C., 0.1 mole percent azobisisobutyronitrile). One polymer, from a bulk polymerization run for 48 hours at 50° C. (0.1 mole percent azobisisobutyronitrile), had an intrinsic viscosity in chloroform at 25° C. of 5.606. Precipitated poly 2-methyl-5-vinyltetrazole (purified polymer from a bulk polymerization run for five days at 40° C., 0.1 mole percent azobisisobutyronitrile) was vacuum pressed into pellets at 110° C. and 3000 p.s.i. The pellets were well consolidated and semitranslucent. Molecular weights estimated from intrinsic viscosity data varied in a range from 500,000 to several million.

Comparative tests performed using a finned igniter such as the embodiment pictured in the drawing wherein the secondary igniter composition was a mixture of about 28% aluminum powder, about 67% potassium perchlorate, and the remainder poly (2-methyl-5-vinyltetrazole) compared to a tube igniter employing a mixture of about 30% aluminum and about 70% potassium perchlorate without the fins showed that the use of the fins significantly reduced the ignition delay time and at the same time gave remarkably consistent ignition delay times.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the

scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. In a solid propellant grain rocket comprising a motor tube having a nozzle at one end, and a propellant grain having a centrally located star-like well extending from the end nearest the nozzle into the grain in a longitudinal direction, a primary igniter having a tubular perforated body disposed within the said star like well, and an auxiliary igniter comprising fins extending radially from said primary igniter and projecting into the spaces which form the outer points of the star-like configuration of the grain and substantially coextensive with the walls defining said spaces, and a squib positioned at the end of the primary igniter nearest the nozzle, whereby the squib ignites the primary igniter material which ignites the auxiliary igniter material which in turn directs hot combustion products upon the propellant grain surface to be ignited.
2. An auxiliary igniter structure for an internal burning star-perforation propellant grain consisting of a plurality of radially extending aluminum-wire screen fins coated with a pyrotechnic mixture and attached longitudinally to an oblong-cylindric primary igniter positioned centrally of the grain, said fins projecting outwardly and coextensive with the walls defining the internal perforation of the grain.

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