Feb. 17, 1953 B. H. SAGE ET AL 2,628,561

PROPELLANT POWDER GRAIN FOR ROCKET MOTORS

Filed March 17, 1943

FIG. 1.

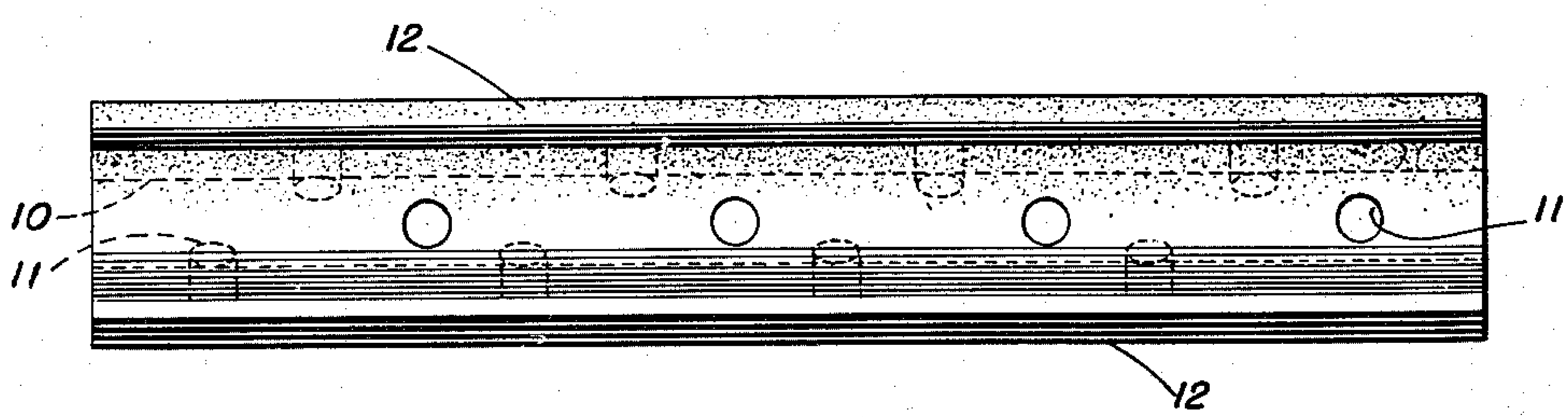
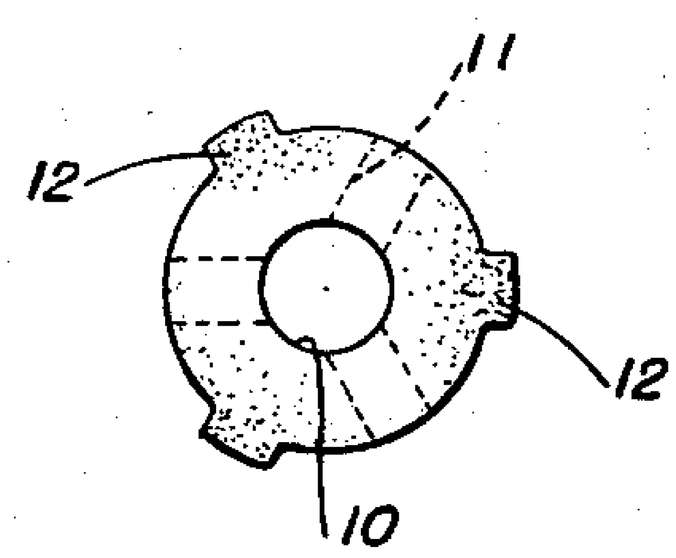


FIG. 2.



INVENTORS
BRUCE H. SAGE and
WILLIAM N. LACEY
BY
ATTORNEY

Patented Feb. 17, 1953 **2,628,561**

UNITED STATES PATENT OFFICE

2,628,561

PROPELLANT POWDER GRAIN FOR ROCKET MOTORS

Bruce H. Sage and William N. Lacey, Altadena, Calif., assignors to the United States of America as represented by the Secretary of the Navy

Application March 17, 1943, Serial No. 479,538

3 Claims. (Cl. 102—98)

1

This invention relates to double-base powder grains and more particularly to a novel grain of this character which is resistant to fissuring and has improved burning qualities, and to a new method by which the grain may be made expeditiously at low cost. The powder grain of the invention has various uses but may be employed to particular advantage for purposes requiring relatively large grain sizes, as, for example, for the propellant charge in a jet propulsion rocket. Accordingly, for illustrative purposes the invention will be described and illustrated in the form of a rocket propellant charge, although it will be understood that the invention is not limited to this use.

Jet propulsion rockets have been employed heretofore in which the propellant charge is in the form of a single powder grain made from sheet stock of a double base powder, such as ballistite. In such rockets, it is desirable to use a powder grain having neutral or slightly regressive burning characteristics and which does not produce excessive pressures. However, we have found that grains made from ordinary ballistite sheet stock exhibit a marked fissuring and disintegration resulting in a substantial increase in burning rate and pressure as the reaction proceeds.

One object of the present invention, therefore, resides in the provision of a novel powder grain which is resistant to fissuring and disintegration during combustion and burns at a substantially uniform rate over its entire surface.

Another object of the invention is to provide a new method of making powder grains by extruding sheet stock which is treated prior to the extrusion to render the finished product resistant to fissuring.

A further object of the invention resides in the provision of a novel powder grain of generally cylindrical form which is extruded with integral, longitudinal ribs on its cylindrical surface for strengthening the grain and for providing external combustion spaces between the ribs when the grain is mounted in a rocket motor body.

These and other objects of the invention may be better understood from the following detailed description, in which reference is made to the accompanying drawing illustrating one form of the new powder grain. In the drawing

Fig. 1 is a side view of the powder grain, and

Fig. 2 is an end view of the powder grain shown in Fig. 1.

The powder grain, as shown, is generally cylindrical in form and has an axial passage 10 extending through the grain, and a set of radial openings 11 spaced along its length in a helix, as disclosed in a copending application of C. C. Lauritsen, Ser. No. 481,644, filed April 2, 1943, now Patent No. 2,464,181, issued March 8, 1949. Preferably, the grain is extruded from sheet stock of ballistite, or the like, and the die of the extrusion press is constructed so as to form the grain with integral, longitudinal ribs 12 on its outer cylindrical surface, the ribs being spaced circumferentially around the grain. The ribs 12 serve to strengthen the grain and also support it in the rocket motor body so as to provide external combustion spaces between the ribs, as disclosed in the above-identified application.

2

Powder grains extruded from ordinary sheet stock are translucent. Even though they appear from visual examination to be relatively homogeneous, they do not have uniform deflagrating characteristics, as evidenced by the fact that partially burned samples have substantial fissures resembling worm holes and show sharp edges, in contrast to the rounded contours inherent in grains which burn uniformly. As a result of the disintegration of these grains, they produce widely varying pressures and undergo progressive burning, which is undesirable in rocket motors and other applications. The conditions under which the grains are extruded appear to have little or no effect on their burning characteristics, and reextrusion of the grains results in very irregular reactions.

We have found that the formation of fissures or "worm holes" during combustion of the powder grains may be inhibited to a substantial degree by rendering the grains relatively opaque. The reason for the decrease in fissuring with an increase in the opacity of the grain is not certain, but the following is offered as a possible explanation, it being understood that the invention is not in any way limited thereby or dependent thereon.

In the manufacture of solventless double base powders, a mixture of nitrocellulose and nitroglycerin is subjected to a colloiding action, usually with the aid of a blending agent, such as a "gelatinizer" or a "gelatinizing accelerator," which remains in the finished powder. A suitable stabilizer may also be added, such as diphenylamine, to take up nitrogen oxides which may form in the powder. The emulsion then undergoes a drying operation, as by pressing or centrifuging, and the mass is rolled, molded or otherwise formed into blocks, sheets, strips, etc. While many improvements have been made in the art of colloiding nitrocellulose and nitroglycerin mixture, it is practically impossible to obtain commercially a perfectly uniform colloid. As a result, the finished powder includes minute particles which are more sensitive to combustion than the other parts, and these more sensitive particles are dispersed throughout any grain which is extruded from the powder. When the grain is ignited, it burns first on its exposed surfaces, and since the grain is translucent the resulting radiation penetrates the interior of the grain and initiates combustion of the more sensitive particles inside the grain, whereby the fissures or "worm holes" are formed, the burning area is substantially increased, and the adverse results of progressive burning are obtained.

A powder grain made in accordance with the present invention is characterized by the fact that the normal translucency of the powder is reduced to the point where the grain is opaque or substantially opaque. We have found that a grain of this character is extremely resistant to fissuring and disintegration, exhibits neutral or slightly regressive burning qualities, and burns uniformly without widely varying pressures, apparently for the reason that the opacity of the grain inhibits radiation of light to the more sensitive particles within the grain during combustion.

In accordance with the method of the invention, the powder is subjected to a darkening operation to obtain the desired opacity. In one form of the new method, the powder is rendered substantially opaque by exposing sheet stock of the powder to the action of light radiation of the shorter wave lengths, as by subjecting the sheet for a substantial period of time to sunlight, which is contrary to the usual practice in powder manufacture. The irradiation causes a rapid darkening and discoloring of the sheet stock, apparently due to chemical decomposition resulting in the liberation of one or more of the oxides of nitrogen and in their possible recombination with the stabilizer in the powder. Preferably, the darkening process is continued until the light which the sheet transmits is reduced to substantially 15% of the light initially transmitted by the sheet. Such darkening may be obtained by placing the sheet in bright sunlight for a period of ten minutes or more, exposing first one side of the sheet and then the other side. The time required to darken the sheet may vary, depending upon the intensity of the light, the composition of the powder and the initial color of the sheet. After the sheet has been darkened, it is placed in an extrusion press and extruded into a grain of the desired size. It will be understood that while we prefer to darken the powder stock before it is extruded, the stock may be extruded first and then darkened.

As one example of the practice of our invention, powder grains having the desired burning characteristics have been made from sheet stock of solventless ballistite of .025 inch thickness and of the following composition expressed as percentages of the total weight: nitrocellulose, 51.42; nitroglycerin, 43.02; diethylphthalate, 3.49; potassium nitrate, 1.41; diphenylamine, .66. The untreated sheet was light yellow in color and translucent, yielding a straw-colored grain when extruded, and the grain burned progressively with an irregular reaction in which a large number of fissures, crevices and indentations developed. When a sheet of the powder stock, prior to extrusion, was placed in sunlight, the exposed surface appeared oily in the first few minutes, and after exposure for a period of approximately 30 minutes, the stock darkened perceptibly and yielded a black extruded grain which appeared slightly more homogeneous than the grain extruded from the untreated stock. A tubular powder grain having an outside diameter of 1.7 inches and an inside diameter of .6 of an inch was extruded from the darkened stock and burned smoothly at a substantially uniform rate over its entire surface, even to the point where the remaining web was less than .1 of an inch in thickness.

In the darkening of the sheet stock, it appears that radiation of wave lengths shorter than approximately 4500 A. causes most of the discoloration and that the amount of darkening is proportional to the time of exposure. No lower limit to the effective wave length has been found, but it is probable that as the wave length is decreased a minimum in effectiveness is reached. In connection with the chemical decomposition which presumably produces the darkening of the irradiated stock, it should be noted that exposure to radiation of relatively high frequency has been found to cause spontaneous decomposition of nitrocellulose explosives, especially those containing nitroglycerin, and it appears that double-base powder when exposed to radiation of a short wave length undergoes an accelerated decomposition.

Powder grains extruded from irradiated stock in accordance with our invention have physical properties comparable to those of grains extruded from nonirradiated stock. More particularly, the tensile strength, hardness, and spontaneous ignition temperature are not substantially affected by the irradiation treatment, and the conditions required for extrusion remain substantially the same, except that a considerably greater pressure is required to obtain the same extrusion rates with the nonirradiated stock. With respect to the burning characteristics, however, it has been established by test that while grains extruded from the irradiated material yield uniformly good results, the results with grains made from nonirradiated material are almost as uniformly poor.

It is to be understood that the darkening of the powder grains may be effected by means other than irradiation, as, for example, by the addition of carbon black to the powder stock prior to extrusion of the grains. When the desired opacity is to be obtained by adding a darkening agent to the stock, the amount of the darkening agent should be such as to cause a reduction in the light transmission capacity of the finished grain comparable to that obtained by irradiating the stock, as described heretofore.

We have found that the size and positioning of the radial openings 11 affect the combustion characteristics of the grain. More particularly, the desired combustion characteristics for rocket use are obtained by spacing each opening 11 from the adjacent opening a distance equal substantially to twice the diameter of the axial passage 10, and making each opening of a diameter equal substantially to half the web thickness of the grain, that is, to substantially one-half the difference between the internal and external diameters of the grain. With this construction, the radial openings 11 in the grain tend to improve its combustion characteristics, providing more uniform burning and more constant pressure.

We claim:

1. A propellant for rocket motors, which comprises a generally cylindrical powder grain of

ballistite having an axial passage and radial openings extending through the grain from said passage and each having a diameter equal to substantially one half the web thickness of the grain, the openings being spaced along the length of the grain and each opening being spaced from the adjacent opening a distance equal substantially to twice the diameter of said passage.

2. A propellant for rocket motors, which comprises a generally cylindrical powder grain of ballistite having an axial passage and radial openings extending through the grain from said passage and each having a diameter equal substantially to one-half the web thickness of the grain, the openings being spaced along the length of the grain in a generally helical series and each opening being spaced from the adjacent opening a distance equal substantially to twice the diameter of said passage.

3. A propellant for rocket motors, comprising a generally cylindrical powder grain which is darkened to render the grain substantially opaque and thereby inhibit the transmission of radiant energy into the interior of the grain during deflagration thereof, said grain having an axial passage and radial openings extending through the grain from said passage, the openings being spaced along the length of the grain and each opening being spaced from the adjacent opening a distance equal substantially to twice the diameter of said passage.

BRUCE H. SAGE.
WILLIAM N. LACEY.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
175,735	Nobel	Apr. 4, 1876
273,209	Wiard	Feb. 27, 1883
440,921	Mindeleff	Aug. 19, 1890
677,528	Maxim	July 2, 1901
726,901	Gathmann	May 5, 1903
778,788	Maxim	Dec. 27, 1904
1,397,915	Bacon	Nov. 22, 1921
2,267,261	Allison	Dec. 23, 1941
2,408,252	Ganahl	Sept. 24, 1946

OTHER REFERENCES

Berthelot et al. in "Comptes Rendus" (1911), vol. 153, pp. 1220 and 1223.

Goddard, "Method of Reaching Extreme Altitudes," Smithsonian Miscellaneous Collections, vol. 71, pp. 13 and 14, circa 1919, as reprinted by American Rocket Society, 1946, under the title "Rockets" by R. H. Goddard.

Sanger, "Raketenflugtechnik," Oldenbourg, Munich and Berlin, 1933, pp. 54–67.

Ellis, "Chemical Action of Ultra-Violet Rays," Reinhold, New York, 1941, Revised Edit. pp. 461–463.

Chem. and Met. Engineering, May 1943, pp. 206, 208.