60-253 CROSS REFERENCE SEARCH ROOM

Nov. 22, 1966 M. MILLER 3,286,462

GAS GENERATOR HAVING SLOW BURNING GRAIN FOR VARIABLE GAS FLOW

Filed Oct. 9, 1963 2 Sheets-Sheet 1

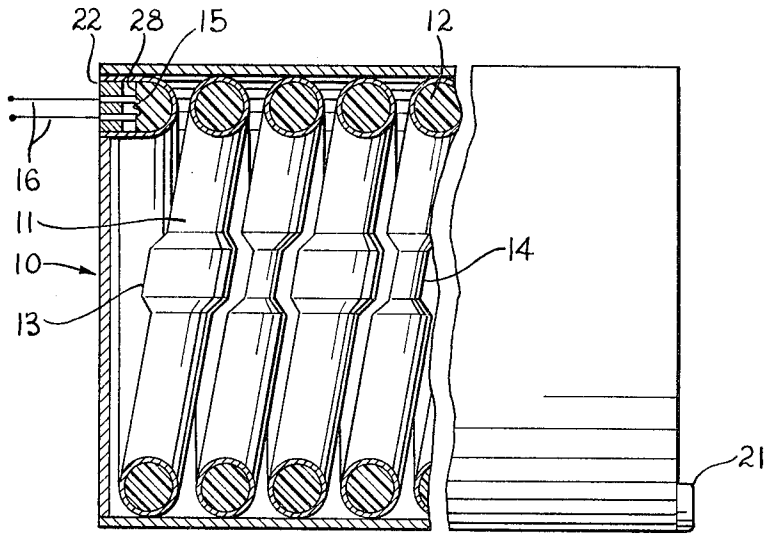


Fig. 1

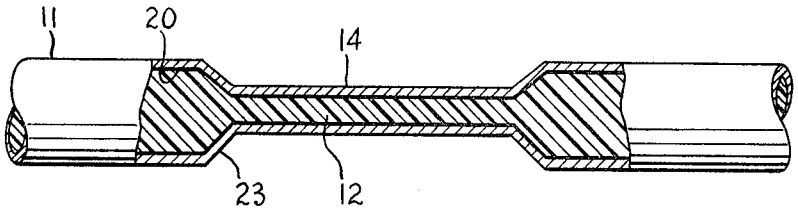


Fig. 2

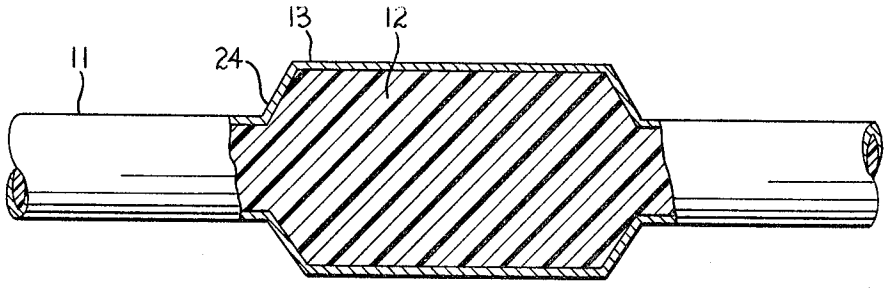


Fig. 3

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GAS GENERATOR HAVING SLOW BURNING GRAIN FOR VARIABLE GAS FLOW

Filed Oct. 9, 1963 2 Sheets-Sheet 2

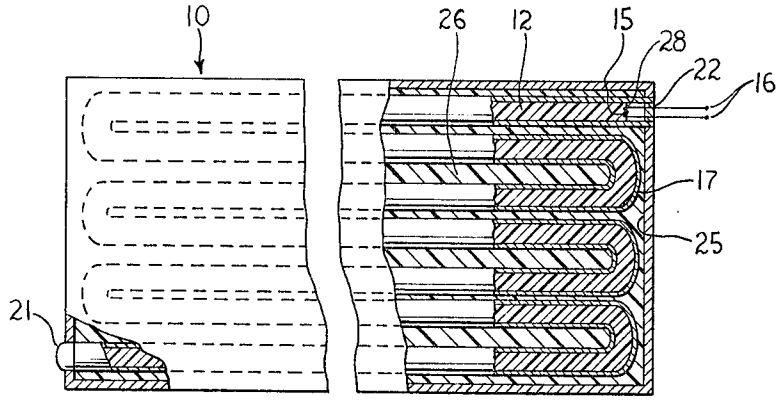


Fig. 4

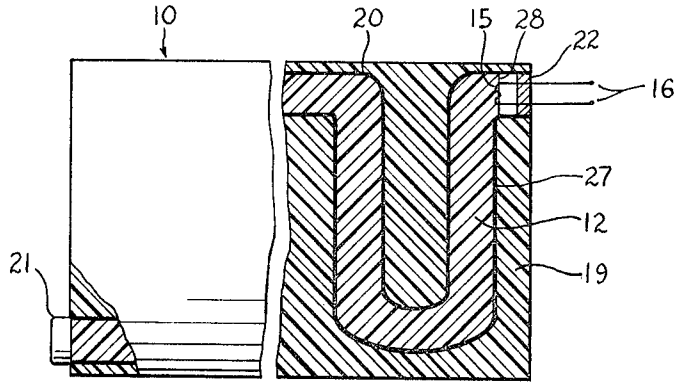


Fig. 5

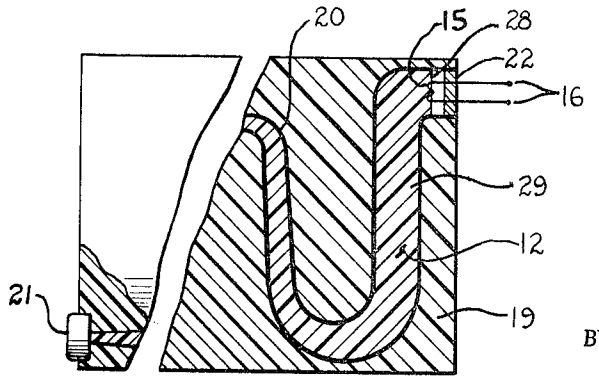


Fig. 6

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3,286,462

GAS GENERATOR HAVING SLOW BURNING GRAIN FOR VARIABLE GAS FLOW

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6 Claims. (Cl. 60—39.47)

This invention relates to gas generators, and more particularly to gas generators containing a charge of combustible material and means whereby variations in gas flow rate can be obtained upon ignition of the charge and subsequent burning thereof. Gas generators, even those operable from combustion products as herein contemplated, have had extensive use in the prior art. Uses have been mostly confined to applications in gas turbines, i.e., devices wherein a turbine is rotatively propelled by the gases derived from a burning solid propellant. In these devices, the solid propellant is most frequently a composite type of the end burning or "cigarette" configuration and may not be inhibited, i.e., include non-burning material within or around the charge to modify its burning rate. These solid propellant configurations are advantageous because of their low burning rates and relatively low flame temperatures. In additon, because of the very long burning times required for gas generator propellants, as in the case of the herein to be described invention, end burning type propellants are very useful.

However, the prior art devices, especially those of the solid propellant type generally have the disadvantage of being unable to operate under variable flow rate output conditions, since constant gas flow rate is an inherent characteristic of end burning grains.

It is therefore an object of this invention to provide a solid propellant gas generator having the ability to produce variable gas flow rates.

It is another object of this invention to provide a solid propellant gas generator wherein volumetric gas flow rates are varied by means of a novel, simply constructed device incorporated into the generator structure comprising the invention.

It is still another object of this invention to provide a solid propellant grain or configuration together with its structural environment, wherein the above referred to variations in volumertic gas flow rates are achieved, and used in devices to perform a sequence of programmed functions.

It is a further object of this invention to provide a solid propellant gas generator of the type referred to wherein the variation in gas flow is continuous and at a predetermined rate.

Other objects and advantages will be apparent to one skilled in the art upon reading this specification and studying the accompanying drawings in which:

FIGURE 1 is an elevational view, partially in section, of one form of the invention;

FIGURE 2 is a view, partially in section, of a portion of the solid propellant casing of the invention;

FIGURE 3 is a view, similar to FIGURE 2, showing another portion of the solid propellant casing of the invention;

FIGURE 4 is a view, partially in section, of another embodiment of the gas generator of the invention, and

FIGURE 5 is a view similar to the FIGURE 4 showing still another embodiment of the invention;

FIGURE 6 is a view similar to FIGURE 5 of still another embodiment of the invention.

Referring to FIGURE 1 there is seen in the sectional portion, a casing in the form of a pipe or tube **11** completely enclosed in a container comprised of an outer envelope **10**. Casing **11** is completely filled with solid

propellant **12** which normally is one of the class generally known as "composite propellants." These propellants are comprised of a mixture of finely ground oxidizer, for example, sodium nitrate, potassium nitrate, potassium perchlorate, ammonium perchlorate, or lithium perchlorate in a matrix of plastic, resinous or elastomeric material. The matrix provides fuel for the combustion reaction to create hot gases and serves to bind the particles of oxidized into a solid structure. The amount of fuel or fuel binder (matrix) varies from about 15 to 20% by weight and can be composed of either thermosetting or thermoplastic substances. A typical composite solid propellant composition is one composed of 75.0% ammonium perchlorate, 20% resin binder and the remainder additives of various kinds; i.e., accelerators, coloring or darkening agents, etc. A second composite propellant composition is composed of 80% ammonium nitrate, 18% elastomeric binder and the remainder additives as in the previous example. In the invention herein any composite propellant is useable, it being sufficient that it be an end burning type of relatively low flame temperature and burning rate. Other types of propellants such as double base propellants, though relatively littel useable in this applications, can, when combined with special additives, also be useful.

Again refering to FIGURE 1 solid propellant **12** has an igniter **15** embedded in its surface **28** and connected to an electrical power source (not shown) by electrical conductors or leads **16**. Gas delivery port **22** is provided and its construction is such that gas flowing therefrom can be controlled. For instance, as will be evident to one skilled in the art, orifice devices, nozzles etc., can easily be attached thereto in any well known manner. Casing **11** includes along its coiled length a number of contractions **14** and enlargements **13**. The contractions **14** and enlargements **13** illustrated in FIGS. 2 and 3, are the core of the invention, and provide changes in cross sectional area of casing. Transitional portions or entrances **23** and **24** in contraction **14** and enlargement **13** respectively are provided to link casing **11** therewith. This invention thus contemplates the inclusion of one or more cross sectional area change spaced along the length of casing **11** within envelope **10** at judicious intervals determined by the application chosen therefor as will be indicated in what follows.

FIGURES 4 and 5 are illustrative of additional modifications of the invention. In FIG. 4, tubular casing **17** is coiled in a different manner and for convenience in illustration the enlargements **13** and contractions **14** of FIG. 1 are not shown. However, the invention set forth therein is understood to contain similar means to provide cross sectional area change in casing **17** and for the same purpose. In FIG. 4 tubing or casing **17** is heat insulated from the internal walls **25** of container **10** being immersed therein. For example, this space (between tubing or casing **17** and internal walls **25**) is filled with insulation such as rock wool, glass fiber, glass wool, vermiculite or other well known silicious substances. The choice of insulation is not a material part of this invention as almost any insulation will serve the purposes herein set forth and countless examples of such materials are available in the art. As an additional, and preferred insulation, any of the foamed plastics now finding wide use in the art of heat insulation and becoming increasingly available is contemplated for use herein. Such a foamed plastic is illustrated in FIG. 4 wherein the voids between the tubing **17** and internal walls **25** are filled with polyurethane plastic foam **26**. In FIG. 5, tubing or casing **11** of FIG. 1 (or **17** of FIG. 4) is replaced with a hollow, circuitous passage **27**. Passage **27** is preferably lined with an inhibitor **20** of inert plastic material commonly used with solid propellants, to insulate the hot gas derived

from the burning propellant from its surroundings. It should also be noted at this point that container **10**, in which passage **27** is formed, is fashioned from a plastic material **19**, preferably foamed polyurethane. However, any lightweight, highly insulative plastic material capable of withstanding the temperatures involved (of which many are available) can be used. In both FIGURES 4 and 5, the propellant **12** has igniter **15** as in the invention of FIGURE 1 although other igniter means known to those skilled in the art to which the invention pertains are useable.

In FIG. 6 is illustrated another embodiment of the invention, which, though similar to that set forth in FIG. 5, differs in that passage **29** (corresponding to passage **27** of FIG. 5) while also circuitous is of continuously decreasing cross sectional area. As will be hereinafter explained, the manner in which gas is evolved from burning propellant **12** in passage **29**, permits a significantly improved rocket motor driven missile to be designed and operated than was heretofore possible.

By properly selecting the material of casing **11** (or **17**) it is now possible to achieve burning times of durations significantly longer than formerly possible during which gas can be generated to perform useful work. Casing **11** material selection is limited only by the ability thereof to withstand the temperature and pressure produced by the burning propellant. It is therefore considered wisest in most instances to select a composite solid propellant having oxidizer and fuel mixtures which will produce gas of temperatures and pressures consistant with the application at hand. Depending then on the application, it is apparent that casing **11** (or **17**) can be prepared from copper, aluminum, steel, titanium and the like. For inhibitor **20**, materials such as asbestos, plastic and fuel binder as shown in FIGURE 2 and again in FIGURE 5, are useable.

To prepare the propellant grain and fabricate the entire invention is a relatively simple matter in that uncured propellant in liquified or plastic (pourable) state is flowed into casing **11** at one end and continued until flowthrough is achieved at the other, whereupon the propellant is allowed to cure in place and system closed off at both ends. For example, in FIGURE 1 at the lower right hand, end cap **21** is shown secured in place. Cap **21** is secured by any well known means, i.e., a threaded fitting or force fit plug. The opposite end is sealed by any other well known means (not shown) for instance a plastic covering in exit **22** which is later blown out of position upon ignition of propellant **12**. Obviously many other methods to accomplish this will occur to one skilled in this art.

In operation of the invention reference is had to FIG. 1. For gas flow when desired as for supplying the nozzle of a gas operated turbine, igniter **15** in propellant surface **28** is energized to ignite propellant **12** in exhaust port **22**. As propellant **12** burns, gas evolution begins and gas is expelled from port **22**. Because propellant **12** is of the end burning type and the cross sectional area of casing **11** is constant in this portion thereof, gas flow rate (and generation rate) is also constant through port **22**. As gas continues to be generated, the flame front adjacent surface **28** moves back in casing **11** as propellant is consumed. Gas flow continues at a constant rate until the first contraction **14** (FIG. 2) is encountered, whereupon a decrease occurs which is proportional to the decrease in cross sectional area in transitional portion or entrance **23** of contraction **14**. Gas flow rate continues to decrease in entrance **23** until the minimal area is reached in contraction **14**, whereupon a lower, but constant, flow rate is achieved and maintained until the flame front (burning surface) reaches a changed area, (right hand part of FIG. 2). At this part of casing **11** the cross sectional area thereof becomes larger and gas flow rate increases. Thus, it is seen that gas generation from burning propellant **12** proceeds at a constant rate changing only when a change in area of casing **11** occurs.

In the FIGURE 3 illustration, a similar phenomenon takes place except in reverse order. As the gas or flame front at surface **28** approaches enlargement **13** through transitional portion or entrance **24**, gas generation and flow rate increases until a maximum rate is achieved in the casing **11** maximum area portion **13**. Gas flow continues to be generated at this maximum rate until all of propellant **12** in enlargement **13** is consumed. Following this a decrease to the former rate occurs.

In operation of the FIG. 6 embodiment, solid propellant **12** is ignited by electrically energizing igniter **15** as described above. Gas evolution, due to the cross sectional area of passage **29** being at its maximum in and near outlet **22**, commences at the maximum rate. In use, the gases generated are conducted to a turbine nozzle (not shown) for rotation thereof to pump liquid propellants to a liquid propellant rocket motor (or the gases are conducted directly to liquid propellant supply tanks for pressurization thereof). In this manner propellants are supplied to the motor and combusted therein to produce thrust upon the expulsion of the resulting gases. As the solid propellant **12** in passage **29** continues to burn, the burning area therein continuously decreases which results in a continuously decreasing rate of gas evolution from outlet **22**. This in turn causes a decrease in rotational speed in the turbine above mentioned (or in pressure in the engine propellant supply tank) and a corresponding decrease in thrust output of the engine.

As is well known in missile and rocket technology the acceleration of a rocket powered vehicle is proportional to the thrust of its engine and inversely proportional to its mass. A vehicle's maximum acceleration is therefore at the instant of engine burnout since the mass (due to propellant consumption) is at its minimum at that point (thrust is usually held constant throughout the flight). It is therefore apparent that the maximum acceleration that a vehicle can withstand is a limiting factor on the thrust produced therein, since the vehicle must be designed to operate so that its acceleration at burnout is within the limits of the structural capability of the vehicle to withstand it.

Use of the invention herein, specifically the configuration of FIG. 6, provides a means whereby the problem of burnout acceleration and its effect on missile operation is obviated or mitigated. Since the gaseous products evolved and emanating from outlet **22** (FIG. 6) vary from a maximum at ignition to a minimum at burnout, the thrust of the missile motor will also be maximum at start or lift-off and minimum at burnout. Hence, thrust can be caused to vary in direct proportion to the instantaneous mass of the vehicle to culminate at burnout in a missile acceleration well within the bounds of its structural capabilities. In the final analysis the missile is thereby operating throughout its powered flight at the best possible efficiency.

By properly selecting and/or combining contractions **14** and enlargements **13** in casing **11**, it is apparent that what is provided is a hot gas generation system which is capable of performing many functions in many applications. In addition, in FIGS. 2 and 3, by appropriate design of contraction **14** entrance **23**, and enlargement **13** entrance **24**, various rate changes are made possible. These changes can be abrupt or very gradual, depending on the application of the invention.

Other uses to which the invention herein finds application are; hot gas control systems, wherein valves or similar devices must be opened or closed by gases in accordance with a command or in a timed sequential process; gas turbines, as stated above, wherein timed or programmed variable power output is required; and missile or high altitude aircraft attitude control systems wherein gas is supplied to control nozzles and ejected therefrom

to provide jet thrust control of the machine's attitude in flight.

Having described the invention in its many embodiments and since many other embodiments of the invention can be foreseen without departing from its scope, it is to be understood that all matter herein set forth or shown in the accompanying drawings is to be interpreted as illustrative and not as unduly limiting the invention except as set forth in the subtended claims.

What is claimed is:

1. A variable output gas generator comprising, a casing in the form of a coiled tube having portions thereof varying in cross sectional area spaced along its length, combustible material in the casing for generation of gases upon ignition and combustion thereof, and means in said generator for ignition of said combustible material.

2. The gas generator of claim 1 wherein the tube variations in cross sectional area proceed uniformly from a maximum at one end to a minimum at the other end.

3. A variable output gas generator for supplying varying amounts of gas to a gas operated control system and the like comprising, a container, a coiled tubular casing in the container, said casing heat insulated from the inner surfaces of said container, solid propellant in the casing for generation of gas upon combustion thereof, means in said generator for igniting said propellant, and at least one enlargement and one contraction in said casing spaced along its length whereby the rate of gas generation is increased in said enlargement and decreased in said contraction.

4. A variable flow rate gas generator for supplying varying rates of gas comprising, a polyurethane container, having a continuous hollow circuitous passage therein, said passage filled with solid propellant for generation of gas upon combustion thereof and having at least one enlarged cross sectional area portion and at least one diminished cross sectional area portion, for generation of increasing and decreasing rates of gas respectively, and ignition means in said solid propellant to initiate combustion thereof.

5. A variable output gas generator for supplying varying amounts of gas to a gas operated control system and the like comprising an envelope having inner and outer surfaces, a tubular casing arranged in a continuous coil configuration within the envelope, said casing heat insulated from said envelope interior surface, solid propellant completely filling said casing for generation of gas upon combustion thereof, means in said solid propellant for initiating combustion of said propellant, and a plurality of enlargements and contractions spaced along said casing length in accordance with a programmed pattern so as to produce a programmed mode of variation in volumetric gas flow rate emanating from said casing during the course of the combustion of the propellant contained therein.

6. A gas generator for supplying varying amounts of gas from a combustible solid propellant comprising, a continuously coiled casing in tubular form for containing the propellant, a container enclosing the casing, means for heat insulating the casing from the inner portions of the container and supporting said casing therein, said casing having one of its ends capped and its other end adapted to receive a propellant ignition means thereat, said casing ignition means receiving end being the portion of maximum cross-sectional area of said casing, said capped end being the portion of minimum cross-sectional area of said casing, and said casing being uniformly varying in crosssection all along its length between said ends.

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