Oct. 18, 1960 H. W. BURTON ET AL 2,956,403

IGNITER

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FIG. 1

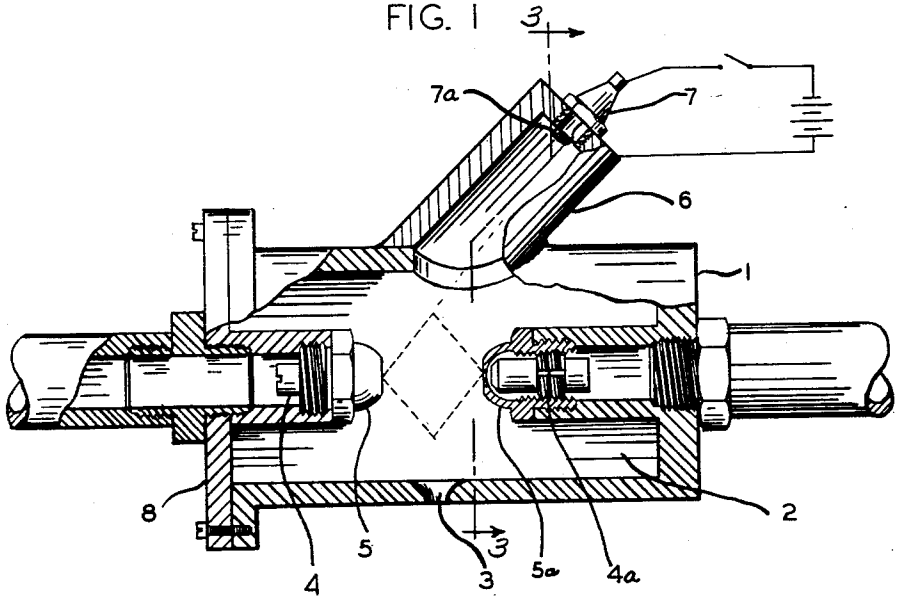
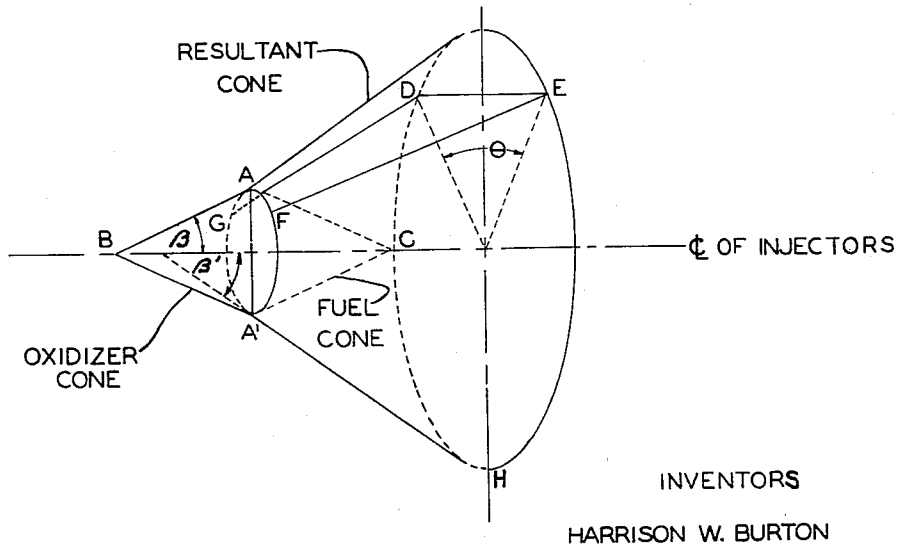


FIG. 2



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FIG. 3

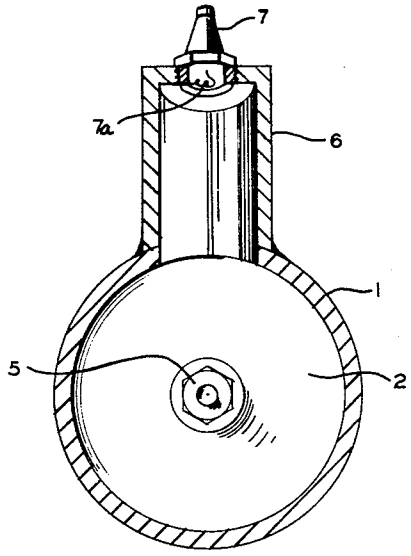


FIG. 4

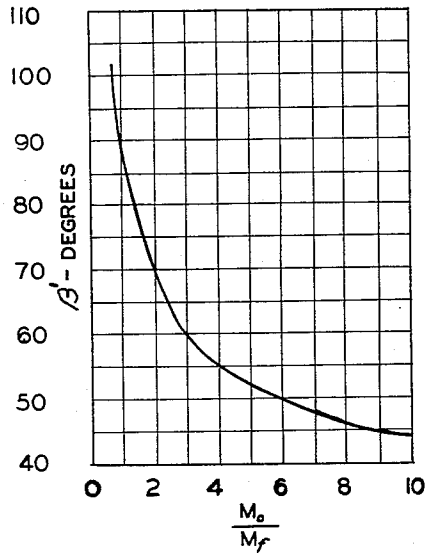
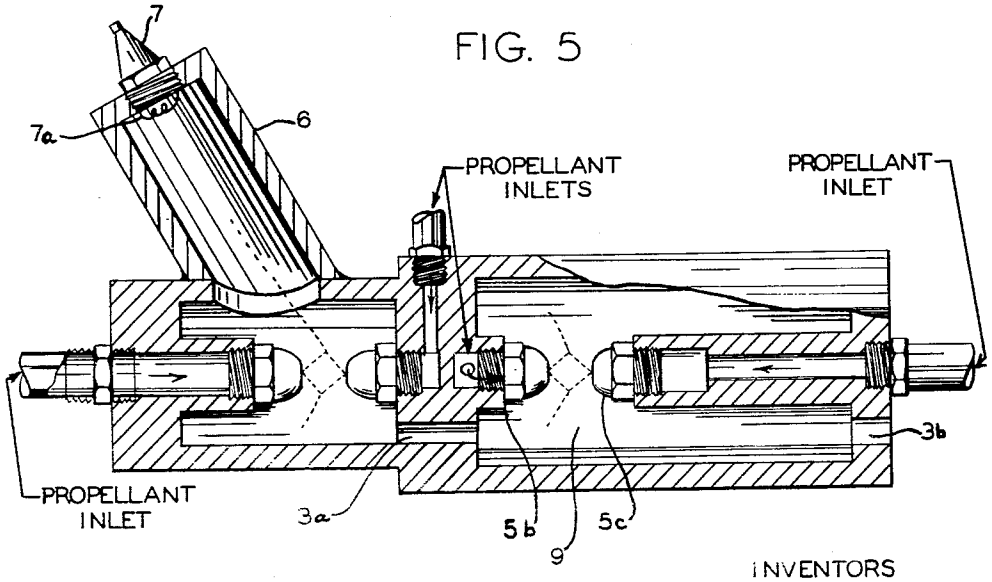


FIG. 5



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2,956,403

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4 Claims. (Cl. 60—39.46)

The present invention relates to devices for initiating combustion of a fuel, and is intended primarily for the ignition of a fuel within the combustion chamber of a rocket motor of the liquid propellant type where two propellants are used, one being a liquid fuel and the other a liquid oxidizer.

In the combustion chamber of a rocket motor of the liquid bi-propellant type, it is customary to burn a liquid fuel in the presence of an oxidizer, the oxidizer also being supplied as a liquid. Since the fuel is burned at a very rapid rate, once it is ignited, it is apparent that a considerable quantity of fuel must be continually admitted to the motor's combustion chamber to support steady combustion. Under such conditions, it has been found essential that a very strong flame be provided initially as a source of ignition so that the flame will not be extinguished prematurely and so that ignition is certain to occur. The production of such a flame without the use of heavy and complex devices or high energy electrical systems has been a difficult problem, the solution of which is an important factor in the usefulness of such engines, particularly when they are intended as propulsive power plants for aircraft where space and weight are at a premium and yet proper and adequate performance is absolutely essential.

In order that a strong and vigorous flame may be created for this purpose it has been found convenient to burn a considerable quantity of fuel in the presence of an oxidizer and to allow the flaming products of combustion to escape through an outlet of relatively small cross-sectional area. The flame is then directed into the combustion chamber of the rocket motor to act as an ignition source for fuel within the motor proper.

There are, however, in a liquid bi-propellant igniter of the aforementioned type, two principal requirements. These are as follows:

(1) Thorough intermingling of the fuel and oxidizer.

(2) Ignition of the large quantity of fuel required with a minimum of energy input.

The present invention answers the first of these problems by means of a novel arrangement of propellant inlet nozzles which effectively intermingle the fuel and oxidizer. The second problem has been uniquely solved in the present invention by utilization of a structural arrangement which allows only a small portion of the fuel, intermingled with oxidizer, to be ignited initially, thus saving the energy input otherwise required to raise the whole quantity of fuel to the ignition temperature. If the initial ignition source is electrical in nature, such as a glow plug or spark plug, the saving in electrical energy results in simplification of the associated electrical system and its current supply source. Since rocket engines are most useful as propulsive devices for vehicles, particularly aircraft, or missiles, any saving in complexity of the required electrical system is important both from the standpoint of decrease in weight and that of increase in dependability.

It is, therefore, an object of the present invention to

provide an igniter for a reaction motor, in which igniter liquid fuel and oxidizer are effectively intermingled in two opposing sprays, and then a portion of the resultant spray of the intermingled propellants is initially ignited by exposure to an ignition source.

It is also an object of the present invention to provide a reaction motor igniter wherein a more substantial and less easily extinguished flame is produced for a given input of electric current to its electrical ignition source than has been heretofore possible.

It is also an object of the present invention to provide an igniter for a reaction motor, in which igniter a larger quantity of fuel can be ignited with the same input of electric current as would otherwise be needed to ignite a small quantity of fuel, with the result that a more substantial and less easily extinguished flame is made to emanate from the igniter.

It is another object of the present invention to provide a reaction motor igniter of the foregoing type having two or more combustion chambers or stages whereby the size and strength of the flame produced is further increased for a given input of electrical energy to the electrical ignition source in the first stage.

It is also an object of the present invention to provide an igniter of the foregoing type wherein the source of initial ignition is protected from the direct heat of the combustion within the igniter's combustion chamber.

Other objects and advantages of the present invention will be apparent from the detailed description of the device and its operation which follows:

In the drawings:

Figure 1 is a cross sectional side view of a single-stage igniter.

Figure 2 is a diagrammatic three-dimensional view of the view of the path of flow of the injected propellants showing the opposed intersecting cones of injected liquid and the frusto-conical resultant path of the liquid propellants after they have been intermingled.

Figure 3 is a transverse cross sectional view of the igniter shown in Figure 1 and taken on section line 3—3.

Figure 4 is a chart of a typical curve showing the angular setting of the ignition tube relative to the longitudinal central axis of the igniter combustion chamber for various values of the ratio of oxidizer input to fuel input.

Figure 5 is a cross sectional side view of a two-stage igniter. While the present invention is well adapted to operation with white fumming nitric acid as an oxidizer and kerosene fuel as the other propellant, it is to be understood that other liquid or liquified propellants may be used as well if desired.

The unique arrangement and operation of the present invention will be apparent from the detailed description which follows.

A cross sectional view of the igniter is shown in Figure 1, in which it will be seen that an igniter housing 1 encloses combustion chamber 2 and has an outlet 3 in its wall. An oxidizer injector or spray nozzle 5 and a fuel injector or spray nozzle 5*a* are located within chamber 2 opposing and facing one another and substantially in axial alignment with one another. These nozzles are of the common divergent hollow cone type and may be of the type shown having internal fluid-directing plugs 4 and fluid passages 4*a*. Nozzles of this sort create hollow conical divergent fluid sprays each of which have an included divergence angle of less than 180 degrees. It is preferable that this angle be within the range of from 30 to 90 degrees, since such spray nozzles are commonly available, and that both nozzles should be of the same divergence angle for best efficiency,

although this is not absolutely essential to operation of the device.

It is essential that spray nozzles **5** and **5***a* be far enough apart that each can form a fully developed hollow cone of liquid. They must not, however, be so far apart as to cause the divergent hollow cone liquid sprays to break up into some other pattern or to form droplets, for the spray resulting from the intersection of the two sprays under such conditions would follow an indefinite path and would be a poor mixture of fuel and oxidizer.

Figure 1 also shows an ignition tube **6** which extends outward from combustion chamber **2** and communicates with its interior in the manner shown. In the outer closed end of ignition tube **6** is an electrical glow plug **7** which is threaded in place in a suitable hole located at the closed end of ignition tube **6**, either in the head or side of ignition tube **6** as may be desirable for practical installation purposes. Although a glow plug is to be preferred a spark plug can be used as the ignition source. Ignition tube **6** is of sufficient cross section to admit only a portion of the total amount of the injected propellants. This fraction of intermingled fuel and oxidizer then impinges upon or strikes near the heated element **7***a* of glow plug **7**. The length of ignition tube **6** and thus the position of the glow plug element is dependent upon the diameter of the intersecting cones of injected propellant since it is undesirable to have the glow plug element closely exposed to the high temperature of the combustion which will take place in igniter chamber **2**. In order to prevent damage to the glow plug from overheating in this manner, it is preferable that it be located so that its element is within the confines of ignition tube **6** and not within combustion chamber **2**. In this position outside of the combustion chamber, it will be less exposed to the high heat of combustion within combustion chamber **2**.

In operation, liquid fuel is fed to spray nozzle **5***a* under pressure and liquid oxidizer is fed under pressure to spray nozzle **5**. The two liquids are thus injected into chamber **2** as two hollow divergent cones of liquid which are substantially axially aligned and intersect in a circular locus shown in Figure 2 as GAFA'. As they intersect, a resultant spray of hollow frusto-conical form is created. This entire spray pattern is shown diagrammatically in Figure 2, wherein the fuel and oxidizer cones are designated as those having apices C and B respectively and a common base GAFA' on the plane of intersection, and the resultant path of flow of intermingled propellants is designated as the substantially frusto-cone having GAFA' as its smaller diameter base and HDE as its larger diameter base. Base HDE is not actually sharply defined in practice, however, since the fluids strike upon the interior of the igniter.

Since the fuel and oxidizer may be of different specific gravities even though their velocities of injection may be identical, the resultant spray of intermingled fuel and oxidizer will assume a resultant angle with the longitudinal axis of the spray nozzles, which angle has been designated in Figure 2 by the Greek letter β' and which is dependent upon the ratio of the momentums of the two fluids. A curve chart is shown in Figure 3 as a typical indication of the angular direction of the spray path resulting from the intersection of two liquid propellants injected at a momentum ratio falling within those values shown as the abscissa. The particular curve shown is that of the path angle β' resulting from injection through spray nozzles having a β equal to 40 degrees (included divergence angle of 80 degrees). In order to plot such a curve to determine angle β' for nozzles of other divergence angles, the following procedure can be followed.

The momentum ratio of the propellant is found by means of the mathematical relationship:

$$\text{Momentum ratio}=\frac{M_o}{M_f}=\frac{Q_o}{Q_f}\left[\frac{(\text{Specific Gravity}_f)}{(\text{Specific Gravity}_o)}\cdot\frac{p_o}{p_f}\right]^{1/2}$$

where

M_o=momentum of oxidizer
M_f=momentum of fuel
Q_o=quantity of oxidizer flowing=pounds per second
Q_f=quantity of fuel flowing=pounds per second
Specific gravity$_o$=Specific gravity of oxidizer
Specific gravity$_f$=Specific gravity of fuel
Δp_o=Oxidizer pressure drop
Δp_f=Fuel pressure drop

Using this relationship for any two liquid propellants injected through, for instance, 80° divergent hollow cone nozzles at equal velocities, it is possible to quickly determine

$$\frac{M_o}{M_f}$$

and then enter the curve shown in Figure 4 to determine angle β' of the resultant spray of intermingled propellants. If injection nozzles having included divergence angles other than 40 degrees are used, similar curves can be easily plotted in the same manner as was this one, i.e., by calculation of

$$\frac{M_o}{M_f}$$

for a particular set of propellants for

$$\frac{Q_o}{Q_f}$$

ratios from, say, 1 to 10, graphical layout of these values vectors having the direction of each of their respective injected propellants, and measurement of the angle β' which their resultant makes with the longitudinal axis of the spray nozzles. It is possible from this to determine angle β' for a variety of liquid propellants, and for various nozzle divergence angles, provided that the propellants are made to intersect in the manner shown in this specification.

Ignition tube **6** is ordinarily set approximately at the angle determined as above and as previously mentioned is so proportioned that the heatable element, or electrical resistance element of the glow plug is remote from the combustion chamber **2** to help protect it from damage due to the high heat of combustion therein, yet is sufficiently close to the combustion chamber that the intermingled fuel and oxidizer which reach it are substantially in liquid form.

As this extreme outer portion of the intermingled propellants designated for example in Figure 2 as that portion included in arc DE subtended by central angle θ, impinges upon or comes in close proximity to the heated element **7***a* of glow plug **7**, the fuel ignites and the flame spreads rapidly to the remainder of the fuel in ignition tube **6** and combustion chamber **2**. With all the fuel burning in the presence of an oxidizer, a very hot flame is produced, and a large quantity of combustion gas is created. A high velocity is thus imparted to the gases as they leave chamber **2** through its relatively small outlet **3**, and the resultant flame is a strong and vigorous one which is very suitable for igniting the fuel within a rocket motor combustion chamber.

In Figure 5 is shown a two-stage version of the igniter wherein a second combustion chamber **9** of larger volume than the first is included as a part of housing **1** and is in communication with the first by means of outlet or conduit **3***a*. Spray nozzles **5***b* and **5***c* are included in chamber **9** to supply additional propellants to that chamber. An outlet **3***b* is provided for chamber **9** to allow the flame of combustion to extend outward therethrough.

The use of a second combustion chamber makes it possible to burn a greater quantity of fuel in the second chamber to provide a still larger and more vigorous flame than that provided by a single chamber. With this arrangement, as with that in Figure 1, fuel and oxidizer are separately admitted to combustion chamber **9** through

nozzles 5*b* and 5*c* in the form of divergent hollow cone liquid sprays which intersect and form a resultant spray of intermingled fuel and oxidizer. A portion of this resultant spray comes in contact with the flame from the first combustion chamber and the fuel is ignited thereby. This combustion spreads rapidly until the entire quantity has been ignited. Since the initial flame is so great in intensity it is apparent that a considerable quantity of fuel can be burned in this chamber and the flame emanating therefrom through outlet 3*b* will be a very hot and vigorous one.

While there have been shown and described and pointed out the fundamental novel features of this invention as applied to a single modification, it will be understood that various omissions and substitutions and changes in the form and details of the device illustrated and in its operation may be made by those skilled in the art without departing from the spirit of the invention. It is the intention, therefore, to be limited only as indicated by the scope of the following claims.

What is claimed is:

1. An igniter for a reaction motor comprising an enclosed combustion chamber, an outlet for said combustion chamber, nozzle means for separately injecting fuel and oxidizer into said chamber in two opposed intersecting hollow divergent cone liquid sprays each having a substantially constant velocity, a hollow ignition tube communicating with said chamber and so extending outwardly therefrom that its longitudinal axis is substantially in alignment with an element of the path of the liquid spray resulting from impingement of the two opposed hollow cones of moving liquid, the direction of said element being determined by the momentum ratio of the entering liquids and the divergence angles of the said nozzle means, and a heated element located within the ignition tube exposed to a portion of said resultant liquid spray.

2. The invention set forth in claim 1 with the heated element located substantially on the longitudinal axis of the ignition tube.

3. The invention set forth in claim 1 with the heated element comprising an electrically energized electrical resistance.

4. An igniter for a reaction motor comprising an enclosed combustion chamber, an outlet for said combustion chamber, nozzle means for separately injecting fuel and oxidizer into said chamber in two opposed intersecting hollow divergent cone liquid sprays each having a substantially constant velocity, a hollow ignition tube extending outwardly from said chamber and communicating therewith, the longitudintl axis of said ignition tube being substantially in alignment with an element of the path of the liquid spray resulting from impingement of the two hollow cones of moving liquid, the direction of said element being determined by the momentum ratio of the entering liquids and the divergence angles of the said nozzle means, an ignition source within said ignition tube but outside of said combustion chamber and directly impinged upon by an extreme outer portion of the spray resulting from impingement of the two hollow cones of moving liquid.

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