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ROCKET PROPELLANT SPARK IGNITION SYSTEM

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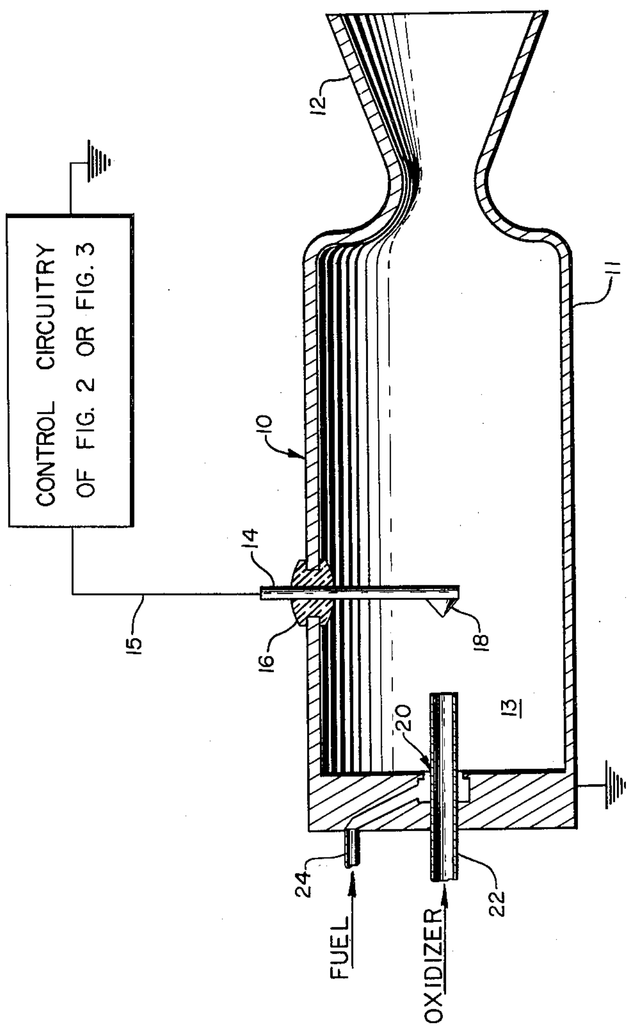

FIG-1

INVENTORS
CLARENCE L. LEINWEBER
HOWARD E. CORBITT
BY D. Gordon Angus
ATTORNEY

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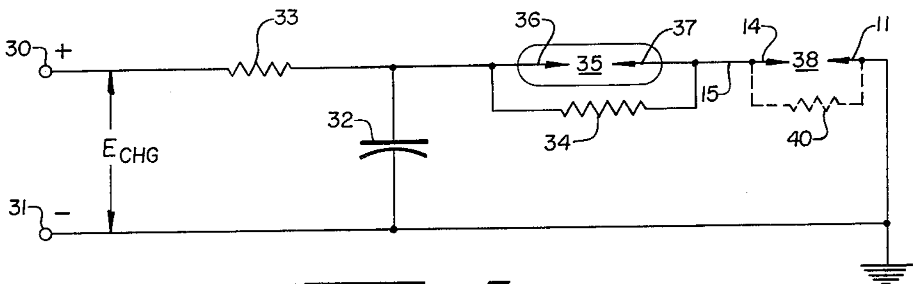

Fig. — 2

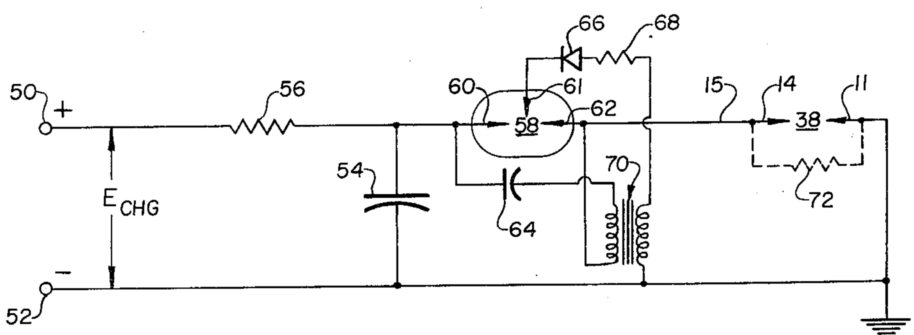

Fig. — 3

INVENTORS
CLARENCE L. LEINWEBER
HOWARD E. CORBITT
BY D. Gordon Angus
ATTORNEY

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ROCKET PROPELLANT SPARK IGNITION SYSTEM

Clarence L. Leinweber, Fort Worth, Tex., and Howard E. Corbitt, Arcadia, Calif., assignors to Aerojet-General Corporation, Azusa, Calif., a corporation of Ohio

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This invention relates to ignition systems generally and to systems for igniting liquid propellants in particular.

To insure reliable starting and continuous operation of a liquid propellant rocket motor or a gas generator, it is essential that ignition means be applied only when sufficient fuel and oxidizer are present in the rocket thrust or combustion chamber in the proper proportions. Should too large an amount of fuel be present, ignition of the mixture will result in explosion rather than burning characterized by rapid expansion of the gaseous products of combustion. Previous ignition systems have been known to utilize glow plugs of electrically heated wire. If electric energization is lost or removed, the residual heat of the mass of the glow plug and of the surrounding chamber structure may be sufficient to cause explosion of fuel which subsequently accumulates before it is possible to prevent further flow into the chamber. To minimize the possibility of explosion in such a situation it has heretofore been desirable to provide additional apparatus for purging the chamber, that is, to introduce a cold, noncombustible gas to cool the plug and chamber and sweep out all the combustible mixture.

Spark ignition of a liquid propellant mixture minimizes residual heat because of the transient nature of the spark, thereby increasing the safety of operation. Known spark ignition systems have been actuated by timers or at the will of an operator. Such operation affords application of ignition means irrespective of actual conditions within the ignition chamber and ignition could be premature or tardy, resulting in the disadvantages described above.

It is, therefore, the principal object of the present invention to provide an improved means for electric spark ignition of a liquid propellant fuel mixture.

Another object of this invention is to provide an improved means for automatically igniting rocket propellants in the liquid state.

Still another object of this invention is to provide a novel method of and improved means for igniting a liquid propellant when a proper quantity of fuel-oxidizer mixture in the proper ratio is present in the rocket thrust chamber.

And yet another object is to provide novel means for the prevention of accumulation of liquid propellant in explosive quantities in a rocket thrust chamber.

In its principal aspect, the present invention comprises a spark ignition system for the ignition of liquid propellants whereby ignition occurs when the optimum amount of fuel-oxidizer mixture is present within the chamber in the proper ratio. An electrode is arranged within the rocket thrust chamber, or combustion chamber in the case of a gas generator, to form an electric discharge or spark gap between the electrode and the chamber casing. The term "gas generator" as used hereinafter in the specification and the claims shall be understood to include rocket motors or any other device wherein ignition of combustible matter produces gaseous products of combustion. Liquid fuel and oxidizer, one of which is a good electrical conductor with respect to the other, are injected into the chamber thereby forming an electrically conductive path between the electrode and the casing. An electric potential or voltage placed across the gap causes

an electric discharge between the electrode and the casing when sufficient propellant in the proper ratio is within the chamber, thereby providing ignition of the fuel-oxidizer mixture at the optimum time. Although the instant of discharge may be determined by an external timer, in the preferred embodiment the discharge is made to occur automatically as external circuitry triggers the spark discharge when the necessary degree of completion of the electrical path within the chamber is provided by the injected fuel-oxidizer mixture. In this manner, any accumulation of unburned fuel is prevented.

These and other objects, aspects, features and conditions of the present invention will be apparent to those skilled in the art from the following more detailed descriptions taken in conjunction with the appended drawings, wherein:

FIGURE 1 is a cross-sectional view of a rocket motor incorporating the propellant injector and discharge electrode of the present invention;

FIGURE 2 is a circuit diagram of a typical spark gap trigger control circuit, employing as an integral part thereof a two-element sealed gap; and,

FIGURE 3 is an electrical circuit diagram of a typical spark gap trigger control circuit using a three-element sealed gap.

Reference is made to FIGURE 1 which illustrates the present invention as incorporated in a conventional rocket motor **10** which basically comprises a chamber casing **11** within which a fuel-oxidizer mixture is burned to form hot gases which pass through an exhaust nozzle **12** to provide a propulsive force. When employed as a gas generator, the hot gases of combustion ejected from the exhaust nozzle **12** provide the force necessary to drive a turbine, not shown. The fuel and oxidizer are introduced into the chamber **13** by an injector **20** to form a stream of conducting propellant (oxidizer) surrounded by a stream of non-conducting propellant (fuel). A typical low conductivity fuel that may be used is kerosene, while suitable oxidizers include White Fuming Nitric Acid and Red Fuming Nitric Acid. Preferably the fluid propellant oxidizer is injected through the center conduit **22** which may, for example, be formed by extending a tube into the chamber **13**, or be an orifice. The fuel, therefore is injected into the chamber **13** from an annulus **24** formed around the conducting fluid tube **22**. Alternatively, the oxidizer could be injected through the center conduit **22** and the fuel through the outer annulus **24**; however, the arrangement described herein is preferred as it enables the fuel to vaporize more readily. Inserted into the chamber **13** in close proximity to the injector **20** is an electrode **14** which is introduced through a non-conducting pressure-tight seal **16** placed in one wall of the chamber casing **11**. The casing **11** is arranged at electrical ground potential while the electrode **14** is connected to external circuitry through an electrical lead **15**. A novel feature of the electrode **14** is the provision of a splash plate mixing device **18** to insure conversion of the fuel-oxidizer mixture stream into droplets dispersed throughout the chamber **13**. In operation, fuel and oxidizer are introduced into the chamber **13** through the injector **20**. Generally speaking, oxidizer fluids are relatively good electrical conductors relative to liquid fuels. Therefore, when sufficient oxidizer is introduced into the chamber **13**, the change in leakage resistance between the electrode **14** and chamber structure **11** can be sensed by external circuitry. The oxidizer and fuel are injected in predetermined ratio, thus presence of sufficient oxidizer also indicates presence of the proper quantity of fuel. The change in resistance brought about by the presence of optimum fuel-oxidizer mixture quantities within the chamber **13** therefore causes external circuitry, such as shown in FIGURES 2 or 3, to trigger a spark discharge between the electrode **14** and chamber casing **11**, thereby igniting the propellant mixture.

A typical circuit for automatic spark ignition of the mixture is shown in FIGURE 2. An external source of charging voltage is impressed across the first circuit input terminal **30** and the second circuit input terminal **31**. A current limiting resistance **33** is connected between the first input terminal **30** and one electrode **36** of a sealed spark gap **35**, the other electrode **37** of which is electrically connected by a lead **15** to the chamber ignition electrode **14**. A charging capacitor **32** is connected between the second circuit input terminal **31** and the point of connection between charging resistance **33** and the first gap electrode **36**. Additionally, a high value resistance **34** is connected in electrical parallel across the sealed spark gap **35**. The second circuit input terminal **31**, one terminal of the charging capacitor **32** and the rocket chamber casing **11** are all connected together and placed at ground potential.

In operation, a source of direct current impressed across the circuit input terminals **30**, **31** charges the storage capacitor **32**. The length of time required for the capacitor **32** to reach the breakdown voltage of the gap **35** is determined in part by the values of the limiting resistance **33** and the capacitor **32**. The voltage charge of the capacitor **32** is impressed across the series circuit of the sealed gap **35** and ignition gap **38**, the latter including the ignition electrode **14** and the chamber casing **11**. Both these gaps normally have a sufficiently high resistance to preclude an electrical discharge therethrough by application of voltages of the magnitude of the charging voltage. The resistance of the ignition gap **38** is represented in FIGURE 1 by a dashed resistor **40**. When a sufficient amount of conducting fluid is injected into the ignition gap **38** by virtue of the injector **20** of FIGURE 1, the leakage resistance **40** across the ignition gap **38** changes to low value. In effect, the voltage of the storage capacitor **32** is thereby imposed across the terminals of the sealed gap **35**, sharply increasing the potential gradient therein and causing an electrical discharge. This discharge in the sealed gap **35** will thereby place the circuit voltage across the terminals **14**, **11** of the ignition gap **38** and similarly cause a spark therein. The high tension spark within ignition gap **38** travels in the interface between the stream composed of conducting oxidizer and nonconducting fuel. The resulting electrical energy is transformed to heat and kinetic energy, heating and atomizing a portion of the fuel and oxidizer at their interface, that is, the region where the stream of oxidizer is in contact with the encompassing stream of fuel. Ignition is then propagated to the remainder of the propellant mixture within the chamber **13** which has been broken into droplets by impingement upon the electrode splash plate **18**. When the capacitor **32** is discharged below the breakdown voltage of the sealed gap **35**, it will cease to conduct, thereby halting the electrical discharge in the ignition gap **38**. The capacitor **32** will then recharge and, when a voltage of sufficient magnitude is reached to cause a discharge across the sealed gap **35**, another spark discharge will subsequently take place within the ignition gap **38**. The system thus described is a repetitive spark system as long as the conducting fluid bridges the ignition gap **38**.

FIGURE 3 illustrates in schematic diagram a typical spark gap trigger control circuit of the non-repetitive or "single shot" type. The external source of charging voltage is impressed across the first circuit input terminal **50** and the second circuit input terminal **52**. A current limiting resistance **56** is connected between the first input terminal **50** and the first electrode **60** of a three-element sealed spark gap **58**. A storage capacitor **54** is connected between the first electrode **60** and ground. A blocking capacitor **64** ties the first gap electrode **60** to a second gap electrode **62** through the primary winding of a pulse

transformer **70**. One side of the secondary winding of the pulse transformer **70** is connected to ground. The other side is connected to a third or trigger electrode **61** within the sealed gap **58** through a current limiting resistor **68** and a unilateral current conducting device **66** which, in the present embodiment, is a semi-conductor diode. The second gap electrode **62** is electrically connected by a lead **15** to the ignition electrode **14** located within the ignition gap **38**, the other electrode or casing **11** of which is at electrical ground potential. The resistance between the ignition electrode **14** and the casing **11** is represented by the dashed resistance **72**. Under normal conditions, no current flows through the blocking capacitor **64**. When a mixture containing the electrically conductive oxidizer is injected into the ignition gap **38**, the resistance **72** between the electrodes **14**, **11** is suddenly decreased, thereby causing a transient current discharge from the capacitor **64** through the primary winding of the pulse transformer **70** and the fluid-bridged ignition gap to ground. A voltage pulse is thereby induced in the secondary winding of the transformer **70** which is applied through the limiting resistor **68** and diode **66** to the trigger electrode **61** of the sealed gap **58**, increasing the potential gradient therein. As in the embodiment described with FIGURE 1, the sealed gap **58** "breaks down," as the voltage of the storage capacitor **54** is applied thereto, consequentially causing an electrical discharge in the ignition gap **38**, hence ignition of the propellant mixture takes place.

The system described herein need not be confined to a device utilizing a liquid propellant mixture composed of fuel and oxidizer. It will perform in an equally satisfactory manner with a monopropellant fuel, so long as the electrical conductivity of the fluid fuel is substantially better than that of air. Similarly, the control circuits illustrated are by way of example only, and numerous variations may be employed.

It is to be understood that the form of the invention herewith shown and described is to be taken as a preferred example of the same and that various changes in the shape, size and arrangement of the parts may be resorted to without departing from the spirit of the invention and the scope of the subjoined claims.

What is claimed is:

1. In a gas generator, an ignition system comprising, a chamber, an ignition electrode arranged within said chamber, said chamber and electrode together forming a spark gap, an energy storage capacitor, a second spark gap, said capacitor being in series electrical connection with said first and second spark gaps, means injecting an electrically conductive fluid stream concentrically surrounded by an electrically non-conductive fluid stream within said chamber, and means mounted on said ignition electrode within said chamber for converting said fluid streams to a plurality of droplets, whereby said capacitor discharges electrical energy into said first and second spark gaps causing spark discharges therein.

2. In a gas generator, an ignition system comprising, a chamber, an ignition electrode arranged within said chamber and electrically insulated therefrom, said chamber and electrode together forming a first electric discharge device, an electric energy storage device, a second electric discharge device, said energy storage device being in electrical series circuit connection with said first and second discharge device, and means for injecting within said chamber in a predetermined ratio fuel and oxidizer in concentric streams, at least one component of which is electrically conductive, said fuel and oxidizer streams being intermixed within said chamber.

3. A system for igniting a liquid rocket propellant comprising, an electrically conductive structure containing a combustion chamber, an ignition electrode arranged within said combustion chamber and electrically insulated from said structure, a first resistor, a two-electrode spark gap of sealed construction having a first electrode which

connects to said first resistor and a second electrode which connects to said ignition electrode, a second resistor in electrical parallel connection across the electrodes of said spark gap, a capacitor connected between said first electrode and said conductive structure, means connecting a two-terminal source of direct current between said first resistor and said structure, and means injecting an electrically conductive liquid propellant within said chamber.

4. A fuel ignition system comprising, a combustion chamber casing fabricated of electrically conductive material and at ground potential, an ignition electrode arranged within said chamber to form an electric discharge gap therewith, a unidirectional source of electrical current one terminal of which is at ground potential, a first current limiting device, a spark gap of sealed construction, a second current limiting device connected in electrical parallel with said sealed spark gap, means serially connecting in the order named, said current source, said first limiting device, said sealed gap, and said ignition electrode, an energy storage device arranged in electrical connection between ground and the junction between said first current limiting device and said sealed gap, and means for injecting an electrically conductive propellant in the fluid state into said chamber, whereby said propellant is ignited by an electric discharge between said ignition electrode and said combustion chamber casing when the proper quantity of propellant is within said chamber.

5. A system for igniting liquid propellant comprising, an electrically conductive structure containing a combustion chamber, an ignition electrode arranged within said combustion chamber and electrically insulated from said conductive structure, a first resistor, a spark gap of sealed construction containing first, second and third electrodes, said first resistor being connected to said first electrode, a storage capacitor connected between said first electrode and ground, a blocking capacitor connecting to said first

electrode a pulse transformer having primary and secondary windings, the primary winding of said pulse transformer connecting between said blocking capacitor and said second electrode, a unilateral current conducting device, a second resistor, the secondary winding of said transformer connecting between ground and said second resistor, said unilateral current conducting device connecting said third electrode and said second resistor, means connecting said second gap electrode to said ignition electrode, means connecting said conductive structure to ground, and means injecting within said chamber a propellant which is electrically conductive.

References Cited in the file of this patent

UNITED STATES PATENTS

1,960,685	Thompson et al.	May 29, 1934
2,090,039	Goddard	Aug. 17, 1937
2,194,081	Block	Mar. 19, 1940
2,493,073	Kinneen	Jan. 3, 1950
2,549,806	Hall	Apr. 24, 1951
2,572,209	Smits	Oct. 23, 1951
2,643,284	Putnam	June 23, 1953
2,655,617	Laird	Oct. 13, 1953
2,789,632	Smits	Apr. 23, 1957
2,826,721	Smits	Mar. 11, 1958

FOREIGN PATENTS

655,121	Great Britain	July 11, 1951
747,593	Great Britain	Aug. 11, 1956

OTHER REFERENCES

"Ignition Systems Must Keep Up With Engine Performance," by K. R. Stehling, Aviation Age, September 1957, vol. 28, No. 3, pp. 56–61.

"A Mechanical Igniter for Liquid Rocket Engines," by Stehling and Freeland, Jet Propulsion, August 1957, pp. 896 and 897.