DETONATION REACTION ENGINE

Filed Dec. 6, 1965 4 Sheets-Sheet 1

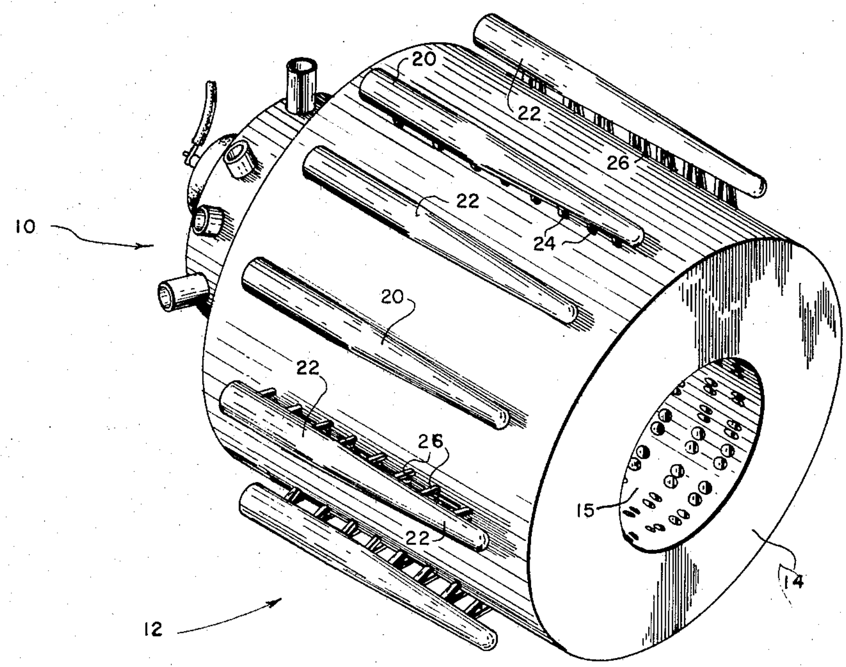

FIG. I

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DETONATION REACTION ENGINE

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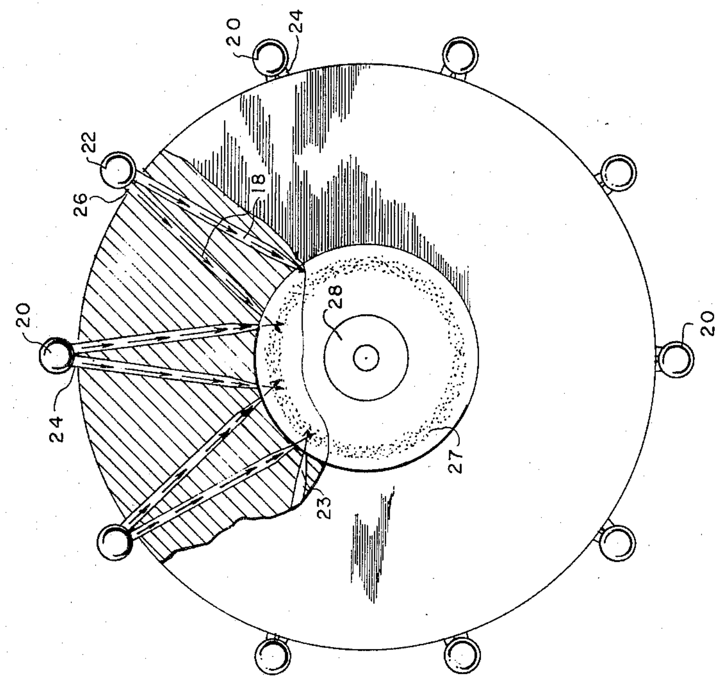

FIG. 3

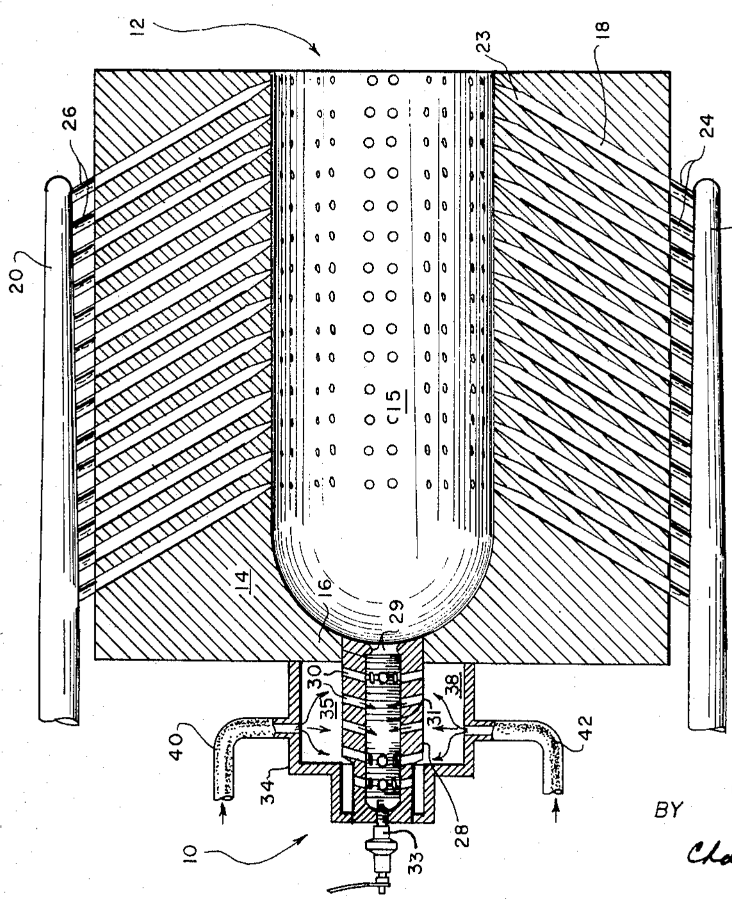

FIG. 2

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DETONATION REACTION ENGINE

Filed Dec. 6, 1965 4 Sheets-Sheet 3

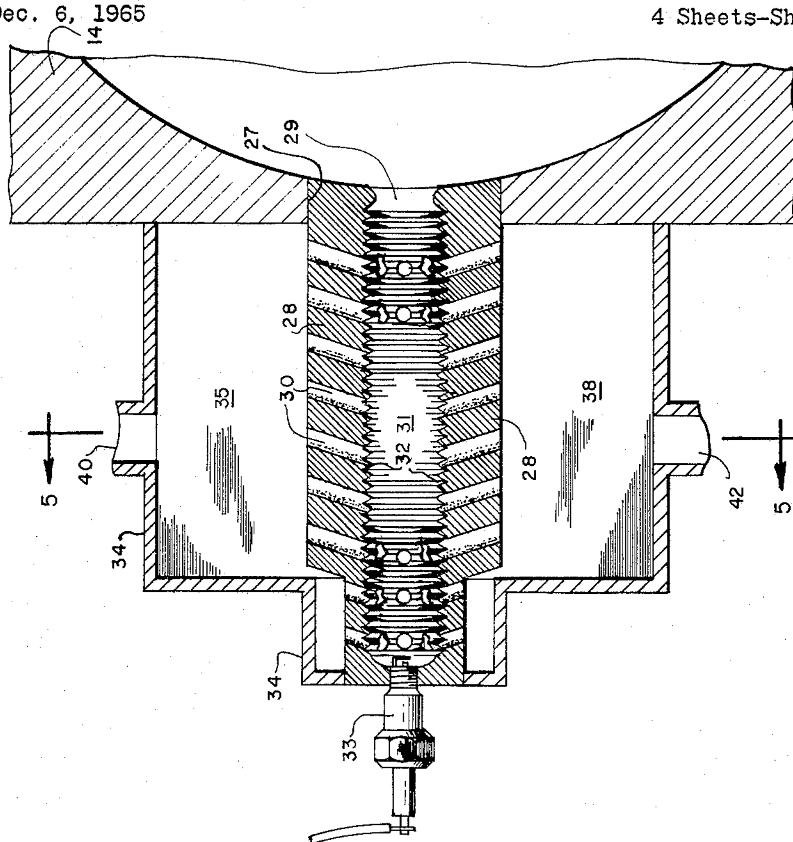

FIG. 4

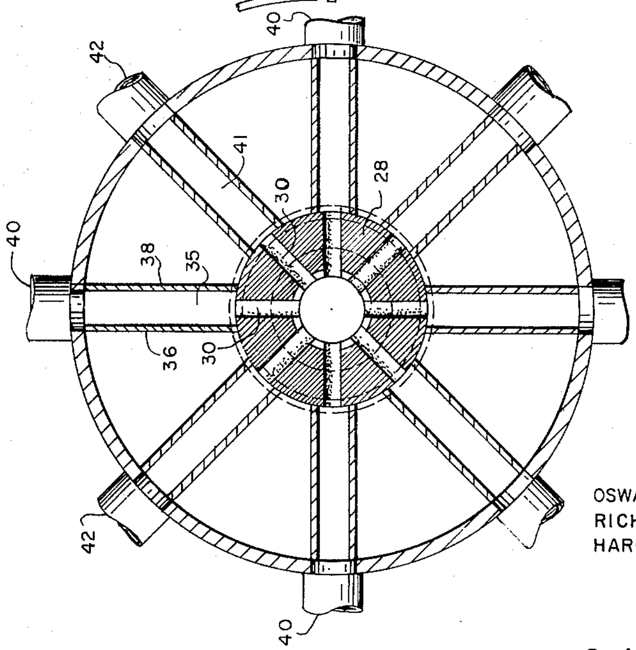

FIG. 5

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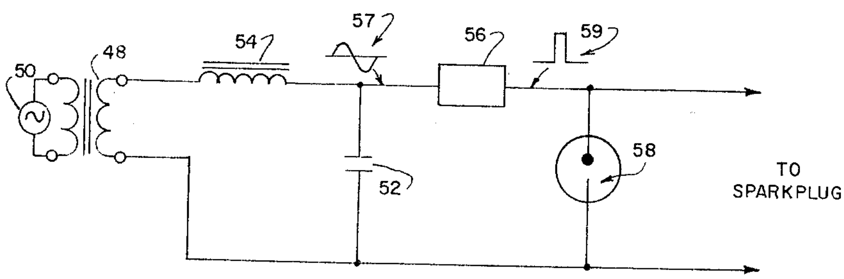

FIG. 6

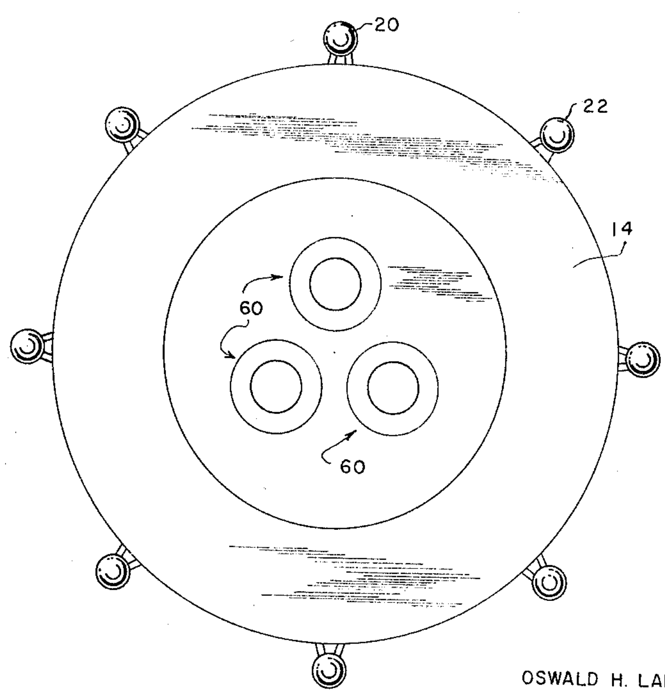

FIG. 7

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3,263,418

DETONATION REACTION ENGINE

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9 Claims. (Cl. 60—35.6)

The invention described herein 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.

The invention relates in general to reaction type engines wherein force or thrust is generated by the expulsion of gaseous products of combustion from an engine. More particularly this invention relates to a reaction type motor wherein the gaseous products expelled to produce thrust are generated by condensed detonation rather than by a burning as in a conventional type reaction engine.

Reaction type motors in use heretofore on space vehicles and capable of producing a large amount of thrust have employed a controlled burning of propellants in the combustion or thrust chamber of the motor. The propellants utilized have usually consisted of a liquid fuel and oxidizer or a solid fuel and oxidizer. In any event the propellants are burned in the thrust chamber of the motor to produce gaseous combustion products therein which are at a high temperature and pressure. The gases in the thrust chamber have high potential energy and when expanded and ejected through a De Laval nozzle, or as it is more commonly termed a rocket nozzle, the potential energy is converted to kinetic energy. The velocity of the gases are greatly increased by expansion through the nozzle and the pressure thereof is decreased. A force is required to accelerate the gases to their increased velocity and the reaction to this force produces thrust.

The development of conventional reaction type engines has progressed to a very sophisticated level and a point has been reached where it is very difficult to obtain any significant increase in thrust from an engine without resorting to increasing the size of the engine. This is true even though very potent and high energy content fuels have been developed as well as very efficient engines for converting the energy content of the propellants into thrust.

The temperature and pressure at which rocket propellants are burned in the thrust chamber of an engine directly effects the exit velocity of the combustion products from the rocket engine. To date the materials available for fabrication of rocket engines and the operating characteristics of such engines has limited the temperatures and pressures that such engines can operate at and thus the exhaust velocities which can be obtained have also been limited.

The present invention provides a reaction engine operating on the principles of controlled condensed detonation rather than on the principle of gas expansion. This results in reaction products that are expelled at a much higher velocity than are the gaseous products resulting from a controlled burning. Higher exit velocities are attainable in an engine constructed in accordance with this invention since a shock wave formed by the initial reaction, and the condensed detonation products resulting from the condensed detonation are vectored in a symmetrical pattern and are co-directional. Thus, the exit velocity of the reaction products approaches the velocity of the shock wave.

This is accomplished by providing an engine constructed of two basic sections consisting of: (1) a detonation wave generator section and (2) a condensed detonation reaction section. A controlled shock wave is generated in the wave generator section and this shock wave is directed into the detonation reaction section where a condensed detonation is initiated that results in high density directional reaction products which are expelled from the engine to produce thrust. Each section includes a cylindrical casing that defines a chamber into which a fuel and oxidizer are injected.

Liquid hydrogen and oxygen or any other suitable liquid oxidizer/fuel combination, are sprayed into a wave generator chamber formed in the wave generator section through injector ports and the vapor mixture thus introduced therein is exploded by an electric spark generated by an appropriate ignition device mounted on one end of the wave generator section. Through creation of turbulent flow conditions in the wave generator chamber, as will be discussed more fully hereafter, and by wave reflection and enforcement, a shock wave is produced within the wave generator chamber. This shock wave is directed into a detonation reaction chamber formed in the detonation reaction section of the engine where it triggers a condensed detonation of the propellant mixture which has been injected into the detonation reaction chamber.

A manifold arrangement is provided for each of the two chambers that provides the wave generator chamber with a vaporized fuel and oxidizer mixture and the condensed reaction chamber with a flow of liquid oxidizer and fuel. These manifolds are in communication with propellant passageways which open through sized injector ports into the wave generator chamber and the detonation reaction chamber. The propellant passageways and injector ports through which propellant is introduced into the detonation reaction chamber are oval in shape and canted so that an elongated annular impingement zone of liquid fuel and oxidizer is formed within the detonation reaction chamber. The fuel and oxidizer mixture in the annular impingement zone is detonated by the shock wave from the detonation wave generator chamber passing the impingement points as it travels along the length of the detonation reaction chamber. The injection angle of the fuel and oxidizer being introduced into the detonation reaction chamber, and the shape of the shock wave from the detonation wave generator chamber, is such that a condensed detonation reaction in the detonation reaction chamber is produced which is similar to the reaction created by detonation of a conventional shaped charge. In other words, the gaseous products that result from the detonation of the liquid fuel and oxidizer in the annular impingement zone are squeezed or confined to the area of this annular zone. The temperature, pressure and velocity of gases obtainable from such a reaction are considerably larger than that obtainable from the controlled burning in a conventional reaction engine.

Inasmuch as the specific impulse, a measure of the force of thrust generated by an engine, is directly proportional to the exhaust or exit velocities of the gaseous products formed by a reaction engine, it is readily apparent that the greatly increased exhaust velocities obtained by using an engine constructed in accordance with this invention will greatly increase the thrust output of such an engine.

It is therefore a principal object of this invention to provide a reaction type engine whose thrust or specific impulse is greatly increased when compared to conventional reaction type engines of the same weight and volumetric size.

It is another object of this invention to provide a reaction engine capable of utilizing the energy generated in a condensed detonation reaction to produce thrust.

A yet further object of this invention is to provide a detonation reaction engine capable of generating a condensed detonation reaction wherein the shock wave and gaseous products resulting therefrom are condensed and co-directional.

Other objects and attendant advantages of the present invention will become more apparent when considering the following detailed description in conjunction with the attached drawings wherein:

FIGURE 1 is a pictorial view of a detonation reaction engine constructed in accordance with the principles of this invention.

FIGURE 2 is a cross-sectional view which illustrates the inner details of the detonation reaction engine.

FIGURE 3 is an end view, partly in section, looking into the open end of FIGURE 1 that illustrates the flow of oxidizer and fuel into the detonation reaction chamber.

FIGURE 4 is an enlarged sectional view of the detonation wave generator section similar to that shown in FIGURE 2.

FIGURE 5 is a view of the detonation reaction chamber taken along lines 5—5 of FIGURE 4.

FIGURE 6 is a circuit diagram of one electrical system suitable for triggering or actuating the ignition device mounted in the detonation wave generator chamber.

FIGURE 7 is a schematic view of an alternate embodiment of the invention wherein an engine employing a plurality of wave generator sections opening into a single detonation reaction chamber is used to provide directional control of a vehicle being propelled.

Referring now to the drawings, particularly FIGURES 1 and 2 thereof, a detonation reaction engine is shown consisting of two basic cylindrical sections which are in axial alignment and comprise a detonation wave generator section **10**, and a detonation reaction section **12**.

The detonation reaction section **12** includes a casing **14** that defines a detonation reaction chamber **15** and takes the form of a cylinder having a closed end **16** and the other end open. Casing **14** has a plurality of canted propellant passageways **18** formed around the periphery thereof and along the longitudinal length thereof through which a stream of fuel and oxidizer is injected into chamber **15**. A plurality of manifolds **20** and **22** are mounted in a spaced alternate relation around the periphery of casing **14**. Manifolds **20** are connected into a fuel supply (not shown) and have a plurality of tubes **24** extending therefrom which are connected to the passageways formed in casing **14**. Manifolds **2** are connected into an oxidizer supply (not shown) and are also mounted around the periphery of casing **14**. Manifolds **2** are alternately spaced between fuel manifolds **22**. The oxidizer manifolds have a plurality of tubes **26** extending therefrom which are also connected into passageways **18** formed in casing **14**. The manifold tubes are secured to casing **14** by welding or brazing of the tubes to the casing. If desired, or deemed necessary, the manifolds **20** and **22** can be braced by a mounting bracket or other suitable supporting means (not shown) attached between the casing and the manifolds.

Passageways **18** are formed in paired rows in casing **14** and are canted (see FIG. 2) at an angle to the longitudinal axis of the engine such that sized outlet ends or injector ports **23** of the passageways are directed toward the discharge end of the engine. Also, as can be seen in FIGURE 3, each of the passageways and feeder tubes leading away from each manifold are directed at an angle to a transverse axis of the engine and the longitudinal axis of the manifold from which the feeder tube extends. There results, in the preferred embodiment shown, an annular zone **27** wherein the streams of fuel and oxidizer from the manifolds impinge upon one another to form a propellant mixture.

The impingement points of the streams of liquid fuel and oxidizer can be regulated by controlling the injection angle of the propellant passageways and the configuration of injector port or orifice **23**. When properly regulated, the impingement points will all lie within the annular zone **27** and away from the interior surface of casing **14**.

The detonation wave generating section of the engine consists of an annular casing **28** threaded into an opening **27** formed in end **16** of casing **14**. Casing **28** has a plurality of annular injection ports **30** formed around the periphery thereof through which fuel and oxidizer are sprayed into a detonation wave generator chamber **31** formed by casing **28**. The interior surface of casing **28** is threaded as indicated at **32**, so as to impart turbulence to the fuel and oxidizer injected thereinto and improve the detonation initiated therein. One end of casing **28** is closed and a spark plug **33** is threaded into an opening formed in this closed end. The other end of casing **28** is in communication with chamber **15** through an opening **29**. A pulsating current is applied to the spark plug by an electrical ignition system such as that disclosed in FIGURE 6 and discussed more fully hereafter. An annular manifold **34** is mounted around casing **28** and attached at one end to casing **14** and at the other end to casing **28**. Manifold **34** is divided into a plurality of fuel compartments **35** by partitions such as that indicated at **36** and **38**, see FIGURE 5, each of which are attached at one end to casing **28** and extend radially outward therefrom to a point where the partitions are attached to the inner surface of manifold **34**. A fuel is supplied to compartments **35** via fuel lines **40** connected to manifold **34**. Likewise an oxidizer is supplied to similar compartments **41** by oxidizer lines **42** connected to manifold **34**.

The detonation wave generator section **10** in which the detonation wave is initiated is one of the most critical components of a reaction engine of this type. The shock wave from the wave generator chamber must enter the condensed detonation reaction chamber at the precise moment that a fresh charge of fuel and oxidizer have been sprayed into the detonation reaction chamber and the gaseous reaction products from the previous detonation reaction have cleared the reaction chamber.

A preferred wave initiation and timing circuit capable of achieving the precise timing required in the operation of this engine is illustrated in FIGURE 6. This circuit includes a transformer **48** which steps up an A.C. voltage from source **50** to a high value. The stepped-up voltage is impressed across a resonant series combination of a capacitor **52** and a choke **54**. The A.C. voltage across capacitor **52**, which is very high, is passed through a pulse forming network **56**. Pulse forming network **56** converts the A.C. sine wave voltage, indicated at **57**, into a high D.C. voltage pulse indicated at **59**. The high voltage pulses are applied to a switch device **58** which is connected in parallel with spark plug **32**. Switch **58** is an ionized-gas device that is conductive and shorts out pulses **59** so long as it is in an ionized state. When switch **58** becomes deionized it is nonconducting and the high voltage pulses are then applied at full voltage to the spark plug and are of sufficient voltage to jump the spark plug gap and ignite the gaseous fuel and oxidized mixture in the wave generator chamber.

In this preferred embodiment switch device **58** is an ignitron, which is an electron tube device composed of a glass envelope containing an argon gas and two tungsten electrodes. An ignitron conducts when the argon gas contained therein is ionized and is nonconducting when the gas is deionized. For use with the engine described herein the ignitron is placed near the discharge or exit end of the condensed detonation reaction chamber and the argon gas within the ignitron is ionized by the radiation emitted during combustion of the gaseous fuels within the detonation reaction chamber. Thus, during the time when combustion is taking place within the detonation reaction chamber, the spark plug is shorted out and no new initiation can be started within the detonation wave generator chamber. Upon completion of the detonation reaction the gas in the ignitron quickly becomes deionized and the spark plug is again supplied with a voltage which will result in a spark being generated within the wave generator chamber to initiate a new detonation wave. While a preferred wave initiation and timing circuit has been shown in FIGURE 6 it should be understood that various other rapidly repetitive ignition devices, such as an exploding bridge wire, could be employed.

In operation, fuel is fed through fuel lines **40** into alternate compartments **35** of manifold **34** and oxidizer is fed through fuel lines **42** into compartments **41** of manifold **34**. Fine sprays of fuel and oxidizer are then introduced into the detonation wave generating chamber **31** through alternate injection ports **30**. This vaporized fuel and oxidizer form a gaseous explosive mixture in the wave generator chamber and this mixture is ignited by a spark from spark plug **33**. This resulting initial explosive reaction spreads in the direction of the detonation reaction chamber along the longitudinal axis of the engine. The threaded interior surface of casing **28** imparts turbulence to the fuel and oxidizer which results in shock waves being developed within the wave generator chambers that improves the explosive combustion therein. The shock wave thus created is directed out of the wave generator chamber along the longitudinal axis of the engine so as to pass through opening **29** and into the condensed detonation reaction chamber **15**. The shock wave which emerges from wave generator chamber **30** through opening **29** is symmetrical about the longitudinal axis of the engine and results in plane wave initiation at the closed end of the detonation reaction chamber. Fuel and oxidizer have been introduced into the detonation reaction chamber through the manifold and injection port arrangement and, due to the cant angle of the propellant passageways **18**, an annular zone of a fuel-oxidizer mixture is formed in the detonation reaction chamber. Detonation, with resultant reactive energy, is produced as the detonation wave emerges from the wave generator chamber through opening **29** and shoots down through the cylindrical zone of impinging fuel and oxidizer in the condensed detonation reaction chamber.

The shape of the condensed detonation reaction chamber as shown herein is cylindrical; however, the chamber could be convergent or divergent to produce a desired propulsive force. In the alternative, the chamber could be maintained cylindrical, but the linear feed rate of fuel and oxidizer along the line of propellant passageways **18** can be varied to alter the shape of the annular impingement zone of fuel and oxidizer and thus the shape of the condensed reaction in the condensed reaction chamber.

The discharge of the condensed detonation products from the detonation reaction chamber creates a suction effect which aids in drawing the propellants from the manifold through the ports and into the chamber. As the condensed detonation products discharge from the detonation reaction chamber the ignitron or other sensor device positioned adjacent to the discharge end of the engine becomes deionized and a voltage is applied to the sparkplug and results in another explosion initiated in the wave generator and the entire cycle is repeated.

Through the use of an alternate embodiment or modification, this type of engine can provide a valuable additional feature, namely, an alternative to the usual thrust vector control found in space vehicle engines wherein the engine is tilted in a gimbal mount. In this type of engine it is possible to employ off-centered initiation wave introduction into the condensed detonation reaction chamber. This distorts the detonation firing in the reaction chamber to emit a thrust whose direction vector is not parallel to or coaxial with the engine longitudinal axis. In this alternate embodiment (see FIGURE 7) three shock wave generator mechanisms **60** are mounted symmetrically on the closed end of the condensed detonation reaction chamber. The three shock wave generator mechanisms, which would all be alike and like that of

FIGURE 4, would, in this embodiment, be mounted on the closed end of the detonation reaction chamber in a circular pattern, equidistantly spaced from each other and with their axes parallel to the longitudinal axis of the engine. Vector directional thrust control can then be exercised by activating one (or two, if required) of the appropriate detonation wave generator mechanisms.

While the three wave-generators-system is an on-off control system, it will be apparent that other vector directional control systems alternatives are possible which provide on-off and/or continuous control. Such a dual on-off or continuous alternative would be a flow system wherein the pressures, and hence the flow rates, in appropriate zones of the fuel and oxidizer manifolds **20** and **22** could be cut on or off for on-off control or could simply be increased or decreased with respect to the flow rate in the remaining manifolds to provide a continuous vector direction deviation from the engine axis.

These alternative embodiments of a detonation reaction engine obviate the use of gimbal mounts for the engines in missile or space vehicle propulsion applications and less attendant hydraulic activating equipment is required. The engines are lighter, entail less operational complexity, and provide improved operational reliability over conventional rocket engines.

This completes the description of this invention. While a preferred exemplary embodiment has been described herein, with possible alterations and modifications thereto, it should be understood that there will be many additional changes and modifications which can be made to the invention by one skilled in the art without departing from the spirit and scope of the invention as defined by the claims appended hereto.

What is claimed is:

1. A detonation reaction engine comprising:

(a) a first casing forming a detonation reaction chamber having a discharge opening therein,

(b) a second casing mounted to said first casing and forming a shock wave generating chamber having an open end in communication with said reaction chamber,

(c) means connected to said second casing for injecting an explosive mixture into said wave generator chamber,

(d) means for repeatedly detonating the explosive mixture in said wave generator to thereby generate shock waves which travel into said reaction chamber,

(e) means connected to said second casing for supplying a propellant mixture to said reaction chamber that is detonated by the shock wave from said wave generator chamber to produce condensed detonation products that are expelled from the open end of the reaction chamber to generate thrust.

2. The detonation reaction engine recited in claim **1** wherein said means for supplying a propellant mixture to said reaction chamber includes:

(a) manifold means mounted on said first casing, and

(b) propellant passageways formed in said first casing that are in communication with said manifold means and said reaction chamber,

(c) said propellant passageways being disposed around the periphery of said second casing and along the longitudinal length thereof,

(d) said propellant passageways being canted at an angle with respect to the longitudinal and transverse axes of said reaction chamber so as to form an annular impingement zone of propellants within said reaction chamber that is in axial alignment with said reaction chamber.

3. The detonation reaction engine recited in claim **2** wherein said means for supplying an explosive mixture to said wave generator chamber includes:

(a) a second manifold means mounted on said second casing, and

(b) injector ports formed in said second casing that are in communication with said second manifold and said wave generator chamber.

4. The detonation reaction engine recited in claim 3 wherein said means for detonating the explosive mixture in said wave generator includes:

(a) an igniter device mounted in said second casing and extending into said wave generator chamber, and

(b) means for sensing and absence of reaction products in said reaction chamber and actuating said igniter device in response thereto.

5. A detonation reaction engine comprising:

(a) a first housing defining a cylindrical detonation wave generator chamber, said wave generator chamber having one end thereof closed and the other end open,

(b) an igniter device mounted in the closed end of said wave generator chamber,

(c) a second housing mounted to said first housing and in axial alignment therewith, said second housing defining a cylindrical detonation reaction chamber having one end closed by the open end of said first housing and the other end thereof open,

(d) a first manifold means mounted on said first housing and in communication with a supply of an explosive mixture,

(e) injector ports formed in said first housing and positioned so as to provide a path for a flow of the explosive mixture from said manifold means to the wave generator chamber,

(f) means for actuating said igniter device to detonate the explosive mixture in said wave generator chamber and thus generate a shock wave that travels into said detonation reaction chamber,

(g) a second manifold means connected to said second housing and in communication with a propellant supply,

(h) propellant passageways formed in said second housing and connected to said second manifold means so as to provide a path for a flow of the propellant from said second manifold means to the detonation reaction chamber where it is detonated by the shock wave from said wave generator chamber; whereby, condensed detonation products will be formed that are expelled from the open end of said detonation reaction chamber to produce thrust.

6. The detonation reaction engine recited in claim 5 wherein:

(a) said injector ports in said first housing are arranged in a plurality of spaced and longitudinally extending rows about the periphery of said first housing, and

(b) said first manifold means mounted on said first housing is cylindrical and surrounds said first housing, and further, said first manifold means includes a plurality of spaced wall members that divides said first manifold means into compartments, each of which compartments are in communication with said wave generator chamber through a single row of said injector ports.

7. The detonation reaction engine recited in claim 5 wherein:

(a) said propellant passageways formed in said second housing are arranged in spaced and longitudinally extending paired rows about the periphery of said second housing, and

(b) said propellant passageways are inclined toward the open end of said second housing at an acute angle to the longitudinal axis of said second housing, and further,

(c) each row of propellant passageways in said paired rows are oppositely inclined to one another at an acute angle to a transverse axis of said second housing which extends radially from the center of said second housing to a point between each row of said pair of rows, whereby propellant passing through said propellant passageways are impinged together in said reaction chamber to form an annular zone of propellant that is detonated by a shock wave from said wave generator chamber.

8. The detonation reaction engine recited in claim 7 wherein:

(a) said second manifold means comprises a plurality of spaced, longitudinally extending tubular manifolds mounted on said second housing, each of said tubular manifolds being positioned on said second housing so as to closely parallel a paired row of passageways, and

(b) tubular members extending from each of said tubular manifolds to each of said propellant passageways for permitting propellant flow from said second manifold means to said reaction chamber.

9. A detonation reaction engine comprising:

(a) a first cylindrical housing having a centrally disposed inlet opening in one end thereof and the other end open so as to provide an outlet, said first housing defining a detonation reaction chamber,

(b) said first housing having a plurality of passageways disposed around the periphery of the housing and along the longitudinal length thereof,

(c) a second cylindrical housing mounted in the inlet opening of said first housing and positioned such that the longitudinal axes of said first and second housings are coincidental, said second housing defining a detonation wave generating chamber,

(d) said second housing having one closed end and one open end that provides a passageway between said wave generating chamber and said reaction chamber,

(e) said second housing having a plurality of passageways disposed around the periphery of the housing and along the longitudinal length thereof,

(f) a first manifold means mounted around said first housing and in communication with the passageways in said first housing for supplying a liquid propellant to said reaction chamber,

(g) a second manifold means mounted around said second housing and in communication with the passageways in said second housing for supplying a vaporized propellant to said wave generating chamber, and

(h) igniter means connected into the closed end of said second housing for repeatedly detonating the propellant supplied to said wave generator chamber whereby a shock wave is generated which travels into said reaction chamber to detonate the propellant therein and form detonation products which are expelled from the outlet of said reaction chamber to produce thrust.

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