Oct. 3, 1961 D. H. SLOAN 3,002,351

RAMJET DEVICE

Original Filed Jan. 26, 1951 3 Sheets-Sheet 1

FIG. 1

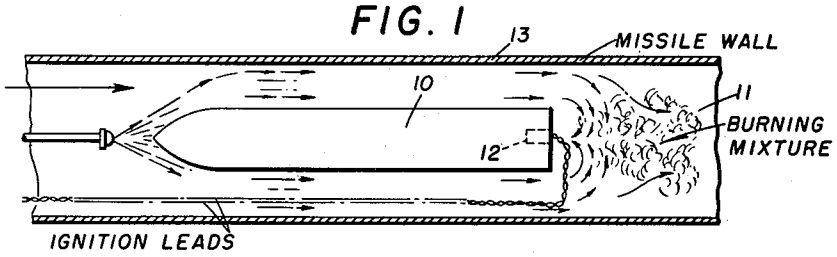

FIG. 2

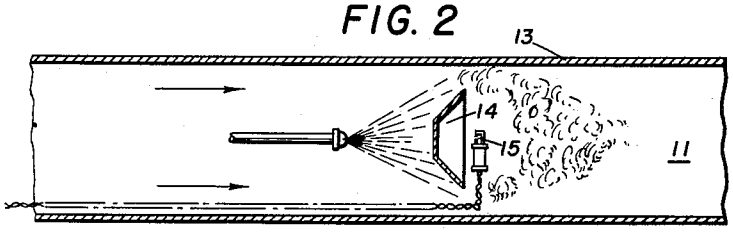

FIG. 3

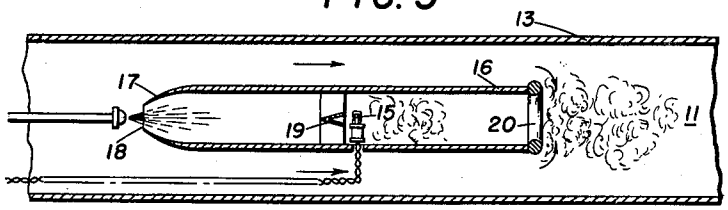

FIG. 4

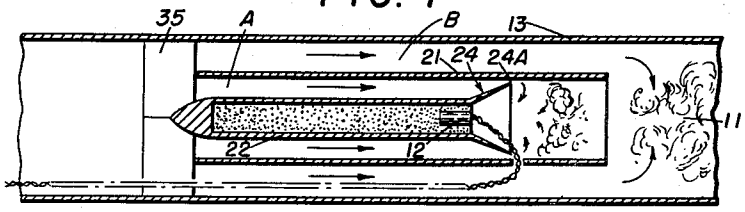

FIG. 5

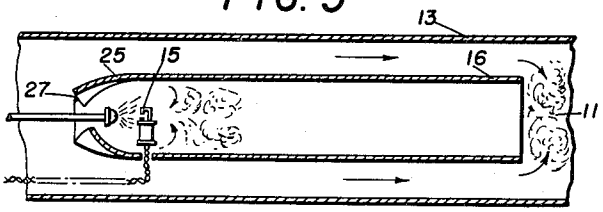

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FIG. 6

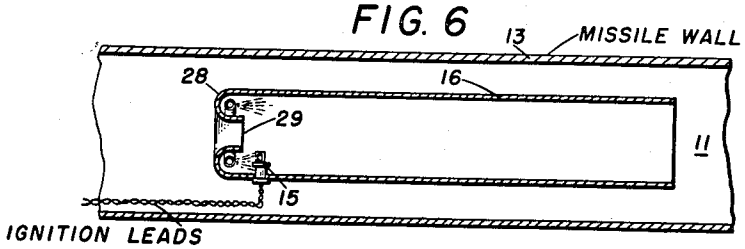
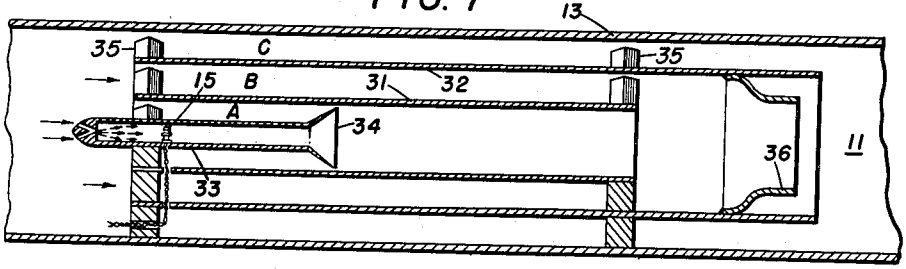


FIG. 7



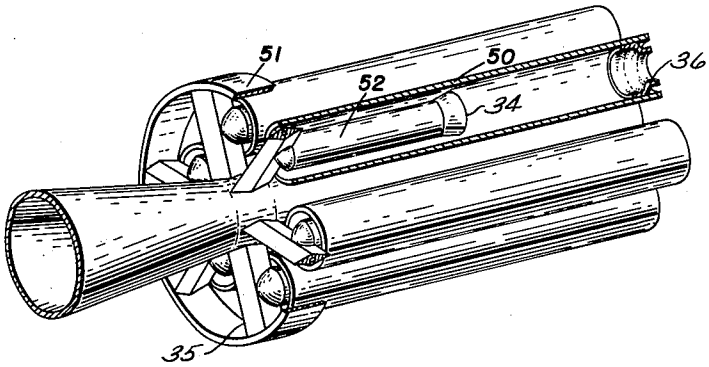


FIG. 8

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RAMJET DEVICE

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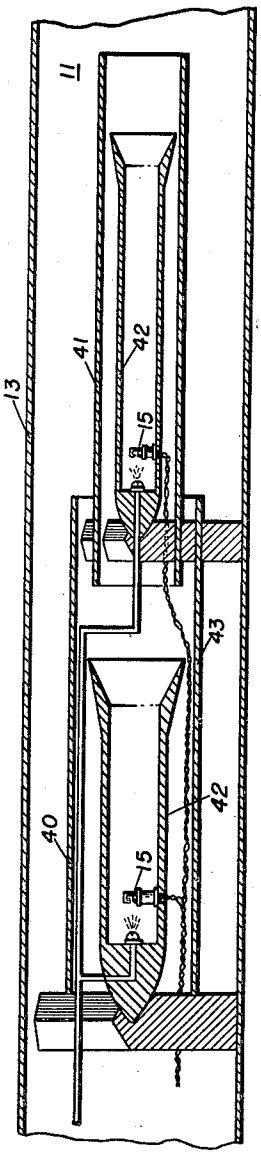

FIG. 9

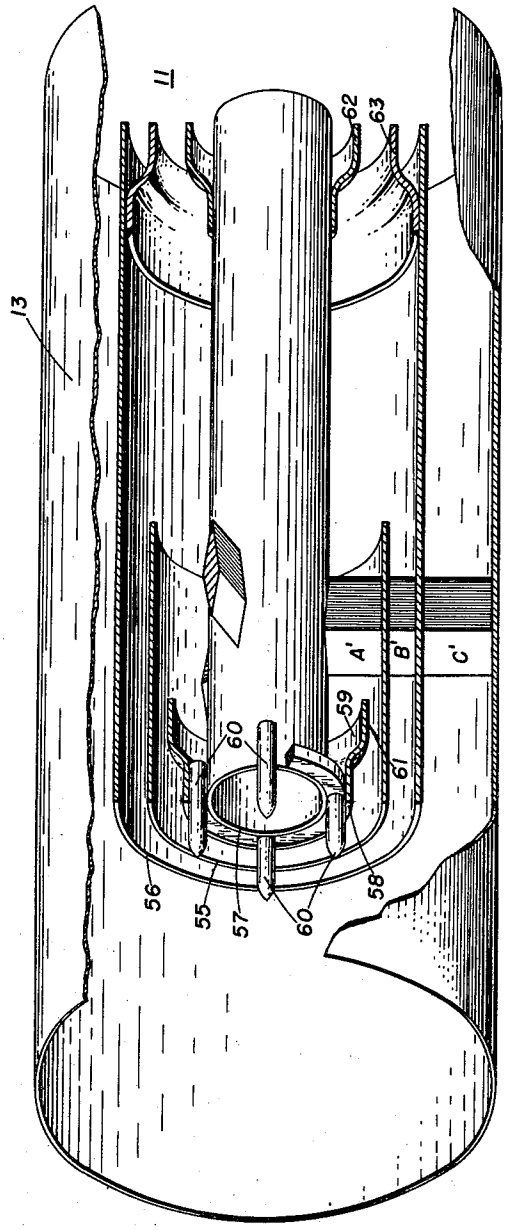

FIG. 10

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RAMJET DEVICE

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Original application Jan. 26, 1951, Ser. No. 207,948. Divided and this application Jan. 29, 1957, Ser. No. 648,985

2 Claims. (Cl. 60—39.72)

The present invention relates generally to a ramjet device, and more particularly to a ducted combustion system for maintaining burning in the combustion chamber of a ramjet missile.

The present invention relates to an improved burning system for use in ramjet guided missiles of the general type disclosed in U.S. patent application, Serial Number 659,188, filed April 3, 1946, D. H. Sloan and W. A. Goss, inventors. This application is a division of copending U.S. patent application, Serial No. 207,948, filed January 26, 1951, by the same inventor.

In the construction and utilization of ramjet devices considerable difficulty has been experienced in obtaining proper burning of the fuel. In particular, difficulty has been encountered because of so-called rough burning which frequently terminates in flash-backs or blowouts. Also, in flame holders of the types heretofore used, optimum burning of the fuel has frequently not been accomplished. This is because of the fact that fuel flows through the combustion chamber too rapidly and may not become ignited or may be ignited for short explosive bursts of flame followed by intervals of "no flame."

This condition results from the fact that a simple baffle-like flame holder as heretofore used, while providing a protected region in which to stabilize or anchor a small flame as well as operating for spreading flame to the air-fuel mixture by disturbance of the flow pattern in its wake, constitutes at best only a compromise because the requirements for a satisfactory baffle are contradictory, i.e., optimum stability of burning and best mixing and spreading of the burning fuel mixture cannot be satisfactorily achieved by a simple baffle.

In accordance with the present invention, a duct has been placed in the air-fuel stream of the combustion chamber. This duct provides a plurality of separate fuel channels, and in at least one of these channels conditions are maintained such that burning of a small portion of the fuel is carried forward with a maximum degree of protection and resultant stability. To this end, there has been provided a restriction to produce a jet effect which, in turn, reduces the quantity of air-fuel mixture passing through the duct and causes the maintenance of an area of low velocity, high turbulent fuel mixture, and which ignites the fuel mixture within this low velocity, high turbulent area. The burning of the small quantity of fuel communicates itself to an air-fuel stream within the protected area so that substantially complete combustion of the fuel in the duct takes place. The combusted fuel issuing from the protected duct is mixed with the fuel flowing past the duct. Spreaders are utilized to insure rapid mixing of the combusted and uncombusted fuel mixtures at the inter-face between the two streams.

The burning within the duct further heats at least a portion of the burner above the ignition point of the mixture so that ignition of the fuel stream becomes spontaneous after a brief ignition interval. The burning within the duct heats the duct wall and communicates a large amount of heat to the fuel stream to provide material preheating of the fuel prior to the junction of the streams of combusted and non-combusted fuel downstream from the duct.

One of the foremost objects of the present invention,

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therefore, is to provide an improved ignition unit for ramjet missiles.

It is another object of the invention to provide a ducted ignition device which effects separation of the functions of burning stabilization and flame mixing and spreading.

A further object of the invention is to provide a unit securing progressive burning of the fuel in a ramjet device.

It is a further object of the invention to provide an ignition system in which stability is fostered in the combustion phase within the unit while mixing is accomplished by suitable mixing devices in the precise amount desired and at the most effective location, i.e., at the inter-face between the combusted stream issuing from the ignition unit and the main fuel stream or streams flowing past said unit.

Even another object of the invention is to provide, in a ramjet missile, an ignition unit which constitutes both a protected region in which to stabilize a flame as well as an agitating means for spreading the flame in the air-fuel mixture flowing past the unit by the disturbance of a fluid flow pattern arising in the wake of said unit in order to obtain optimum fuel combustion.

And another object of the invention is to provide a ducted combustion system having a plurality of progressively ignited fuel-carrying channels.

Still a further object of the invention is to provide a ducted combustion chamber in which portions of the fuel are sequentially ignited in progressively turbulent conditions.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

FIGURE 1 is a diagrammatic view of a section of a ramjet device utilizing as an ignition unit a conventional flare heretofore in general use in this type of device;

FIG. 2 is a view similar to FIG. 1 but showing the use of an ignition baffle as a flame stabilizing device;

FIG. 3 is a diagrammatic view of an improved ignition unit according to the present invention;

FIG. 4 is a similar diagrammatic view of a modification of the improved ignition unit;

FIG. 5 is a further diagrammatic view of another embodiment of the invention;

FIG. 6 is a diagrammatic view of a further modification to accomplish the objects of the invention;

FIG. 7 is a similar view showing the application of the device to a three-stage combustor;

FIG. 8 is a perspective view partially broken away of a modification of the invention for application to a larger type of ramjet device;

FIG. 9 is a similar view showing utilization of tandem type combustors; and

FIG. 10 is a perspective view, also partially broken away, of an annular type combustor according to the invention.

In the exemplary embodiments according to the present invention, FIG. 1 discloses a well known flare type of combustion initiator in which a pyrotechnic flare **10** is placed within the combustion chamber **11** in the fuel-air mixture stream. Flare **10** is ignited by any suitable means, usually by an electric igniter device **12**. The presence of the flare **10** produces a turbulence in the air-fuel mixture stream which causes at least a portion of the air-fuel mixture to trail behind the igniter unit so that the flare **10** communicates flame to the mixture and causes burning of the mixture flowing downstream from the flare **10**.

It has also been proposed to utilize a flame holding baffle **14** as shown in FIG. 2, the baffle being intended

to cause a low velocity area back of the baffle in which a fuel mixture can be ignited by suitable means, such as an electric spark **15** or a heated element.

As pointed out hereinbefore, these devices have not been entirely satisfactory in that the proper mixing of the burning gases with the main fuel stream has not always resulted. Accordingly, some of the fuel has frequently remained unburned or the fuel has had uneven or rough burning, so that optimum burning seldom has taken place.

In FIGS. 3 to 6, inclusive, there are shown in diagrammatic form several modifications of a ducted combustor embodying the essence of the present invention. These modifications disclose a few of the configurations that may be utilized to provide a controlled protected area within a portion of the fuel stream where the conditions, necessary for absolute certainty of maintenance of combustion, are maintained and properly propagated to the main body of the fuel stream.

In FIG. 3, a diagrammatic or schematic exemplification of the present invention is illustrated. The rear interior of the ramjet device **13** defines a combustion chamber **11** through which the air-fuel mixture streams at high velocity. Within this chamber **11** a duct-like passage **16** has been placed preferably coaxial with the combustion chamber **11** and having a constriction **17** adjacent to the forward-end of the duct **16** so that only a small quantity of fuel can enter through the jet-like orifice **18**. Within the duct **16** there is placed a flame holding baffle **19** behind which is a suitable ignition device **15**. Usually a flame spreader or gutter **20** is applied to the trailing edge of the duct **16** to impart turbulence to the fuel streams and expedite the commingling of the streams at the inter-face of the combusted and non-combusted fuel downstream from the duct **16**.

In the modification according to FIG. 4, there is shown a substantial open-ended duct **21** in which a burner **22** has a flared skirt **24** to provide a low area jet **24A** to produce a stagnation effect of a portion of the fuel mixture behind the burner **22**.

In the modification according to FIG. 5, the constricted nose **25** of the duct body **16** has been shaped to provide vane-like jet portions **27** which give a whirling motion to the small quantity of fuel entering into the duct **16**.

In the modification according to FIG. 6, the nose **28** of the duct **16** has been given a re-entrant jet opening to provide an annular baffle maintaining a substantially annular pool of the fuel-air mixture.

In the practical construction of devices according to the present invention, that portion of the body **13** of the ramjet which defines the combustion chamber **11** has installed therein one or more ducts **21** which are firmly anchored, as by struts **35**, to the inner wall of the combustion chamber **11**. These duct devices **21** produce a plurality of fuel channels A, B, etc., which are substantially separated from each other by the thickness of the duct walls. A suitable burner **22** is placed within one, preferably the innermost, of these channels. For example, in FIG. 4, there is shown a flare type burner **22** having an expanded skirt portion **24** which, in cooperation with the inner wall of the duct **21**, provides an annular jet opening **24A** which reduced the quantity of fuel mixture flowing through channel A of the duct **21** and which causes a small portion of the fuel to linger behind the flare **22**.

In operation, the burner **22** will be started by any suitable means, such as an electric igniter **12**, after which the flare **22** will communicate the flame to the portion of the fuel mixture lingering behind the burner **22** and that in turn will propagate flame to the fuel mixture within the duct **21**. The burning of the fuel mixture within the duct **21** will bring parts of the duct **21** and burner **22** to a temperature sufficient to produce spontaneous ignition of the fuel mixture passing through so that, in theory at least, it is unnecessary to maintain the operation of the burner **22** beyond this pre-heating period.

A further desirable effect is obtained in that the hot walls of the duct **21** communicate a large amount of heat to the fuel mixture in the adjacent channel B so that when the partially combusted material within the duct mingles with the pre-heated fuel mixture in the surrounding chamber B, ignition or flame propagation to the adjacent channel B is considerably expediated.

It frequently may be desirable to maintain a combustion chamber utilizing a plurality of sequentially ignited fuel channels. For example, in FIG. 7, there is shown a pair of ducts **31—32** which, together with the inner wall of the combustion chamber **11**, define two main fuel mixture channels B—C together with the centrally located ignition channel A. It is usually desirable to construct the ducts **31—32** of varying length, preferably increasing in length in the direction away from the igniter channel A. That is, with a centrally located ignition element **33** the innermost duct **31** will be shorter than the outermost ducts **32**, so that the ignition points progress away from the igniter element **33** as the flame is propagated downstream from the igniter **33**. In a combustor of this type, the flame will be initiated behind the burner or flame holder **34** in the portion of the mixture which is retained behind the burner **34** because of the reduced jet opening. The fuel mixture passing through alongside of the igniter **33** will then be combusted, and at the end of the inner channel A will be spread out so as to mingle with the non-combusted fuel in the next adjacent channel B, which will mix at its inter-face and combust the fuel in the intermediate channel before the termination of the second or outermost duct **32**. Preferably the outermost duct **32** is provided at or adjacent its terminal end with a restriction or flame spreader **36** which causes rapid intermingling of the combusted fuel in the intermediate channel B through the inter-face with the fuel coming through the outmost channel C. The restriction **36** of the intermediate channel B not only serves as a flame spreader but also creates an increased pressure facilitating flame propagation in the intermediate channel B. In this manner the various portions of the fuel are sequentially ignited and are thoroughly mixed so that substantially constant and complete fuel burning is secured.

Many types of igniter elements may be utilized in any of the various embodiments of the present invention. For example, in FIG. 4 the pyrotechnic flare type of burner **22** is shown, while in FIG. 7 there is disclosed a bleeder type burner **33** in which a small quantity of fuel mixture is withdrawn from the main fuel stream and introduced into the burner cavity where it is ignited by any suitable means, such as an electric spark **15**. Instead of introducing a portion of the fuel mixture, a special fuel may be piped into the burners from an auxiliary source as shown in FIGS. 5 and 9. Obviously the type of burner utilized in any particular combustor will be determined by the exigencies of the occasion.

Sometimes it is found desirable to provide a plurality of sequentially operating igniters so that if for any reason unequal or burst type combustion should occur at one of the burners, another burner will be available to maintain combustion in spite of this undesirable operation. Accordingly, in FIG. 9, there is shown a plurality of sequentially arranged ducts **40** and **41** each of which is provided with a burner **42** and a jet-like passage **43** for retaining flame behind the burner **42** so that, in the event either of the burners **42** should fail to operate either momentarily or permanently for any reason, the other burner **42** will maintain the operation of the device in spite of the failure of one of the burners **42** therein.

The multiple burners **42** are preferably provided with a fuel—usually gaseous—from an auxiliary source, not shown, of sufficient capacity to supply a supporting flame until the parts have been heated to the point where automatic ignition takes place.

While a simple duct system having one or more con-

centric ducts, according to the present invention, is quite satisfactory in the smaller missiles, it is found desirable in the larger missiles to provide a plurality of burners or ducts acting in parallel. For this purpose I have shown, in FIG. 8, a plurality of parallel operating ducts 50 arranged in annular formation and supported by means of an annular frame 51 secured within the combustion chamber 11. Each of the ducts 50 which may be of a plurality of stages contains at least one duct member and preferably more, the innermost duct being provided with a burner 52 substantially as described in connection with the preceding figures.

In the operation of this multiple parallel unit each of the burners 52 will be ignited and propagate flame to the immediate surrounding duct; also the ducts 50 define a fairly large space between the ducts and the wall 13 through which the fuel mixture flows. Because of the configuration, rapid mixing of combusted and heated uncombusted fuel occurs at the trailing end of the ducts 50 and develops very complete utilization of the fuel.

In the intermediate size devices it is found that an annular type duct is more satisfactory and simpler to build than a plurality of parallel operating ducts 50. In this modification according to FIG. 10 there is shown a plurality of substantially concentric duct-like members 55—56 defining a plurality of annular channels about an inner tubular member 57 through which usually no fuel or other material is expected to pass. A shroud-like member 58 of annular formation is provided which substantially closes an inner annular channel so that a small quantity of the fuel mixture may pass behind the shroud into a protected area 59 in which a plurality of igniter devices 60 may be installed. The shroud 58 likewise cooperates with the next adjacent duct 55 to provide an annular jet-like opening 61 through which a quantity of fuel passes to produce a stagnant or pool-like area behind the shroud 58 where burning can be maintained under the most favorable conditions. The intermediate duct 55 then operates to provide a plurality of channels

A′—B′—C′ so that at the trailing edge of the intermediate duct 55 the combusted material from the inner channel A′ is mixed with and ignites the mass of fuel mixture in the intermediate channel B′ and the likewise combusted material from the intermediate channel B′ intermingles with and combusts the material in the exterior or outermost channel C′; preferably this annular second channel is provided with suitable restrictions 62—63 to produce the desired high pressure within the intermediate channel B and extreme turbulence in the downstream portion of the commingled fuel streams.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than specifically described.

What is claimed is:

1. A flame holder unit comprising a plurality of flame holders each having a duct and a burner in the duct, said burner having a flared skirt at its aft end and extending in close space relation to the wall of said duct to define an annular orifice for retarding fuel flow at the aft end of said burner, means for spreading flame at the aft end of each of said ducts, and means for supporting said burners in an annularly arranged cluster.

2. The arrangement as set forth in claim 1, wherein said first mentioned means comprises a convergent nozzle and said supporting means includes a duct defining a hub, struts radiating from said hub, and a ring connecting the corresponding outer end of said struts.

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