

[72] Inventor **Ronald K. Pearson**
10350 Vacco St., South El Monte, Calif.
91733
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Primary Examiner—Lloyd L. King
Attorney—Fulwider, Patton, Rieber, Lee & Utecht

[54] **FLUID INJECTOR**
24 Claims, 10 Drawing Figs.
[52] U.S. Cl..... **239/127.1,**
60/258, 239/555, 239/568
[51] Int. Cl..... **B64d 33/04**
[50] Field of Search..... **239/127.1,**
127.3, 552, 568; 60/258, 260, 39.74
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ABSTRACT: A plurality of preformed individual metal platelets are stacked in registry and brazed together to form a monolithic structure capable of being machined to a desired final overall configuration of injector. Each platelet is formed on one surface with a patterned depressed area defining, with an abutting surface of a contiguous platelet, fluid flow passages exiting at one edge of the platelet in one face of the injector, aligned apertures of the stacked platelets define manifolds for conducting fluid to each platelet, and the individual platelets may be provided with baffling arrangements in the depressed area thereof for equalizing fluid pressures in the several outlets of the platelet.

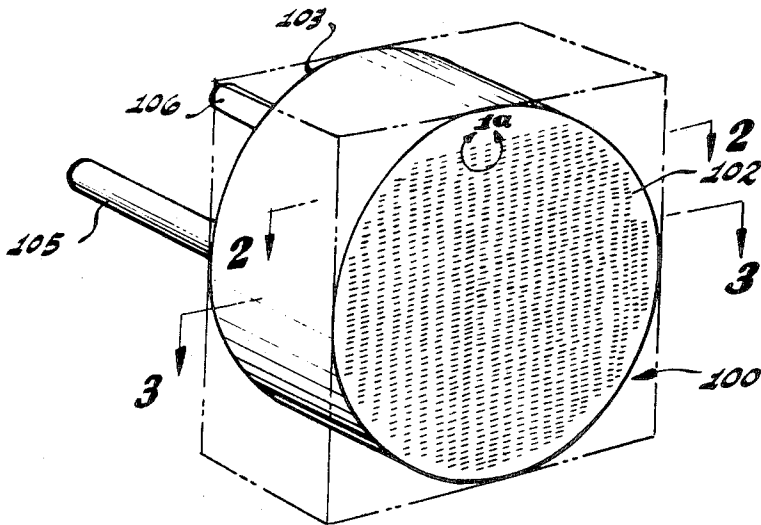


Fig. 1

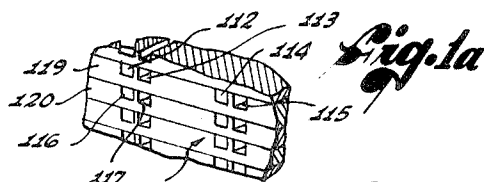
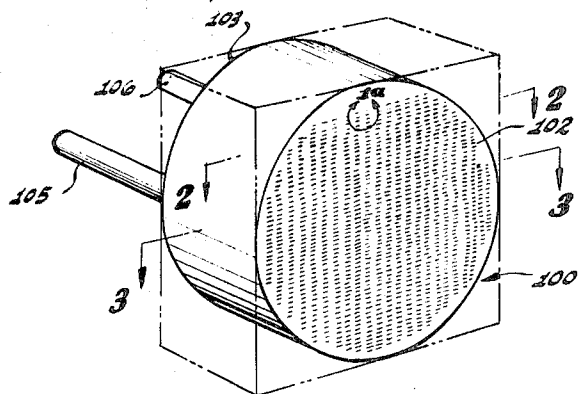


Fig. 2

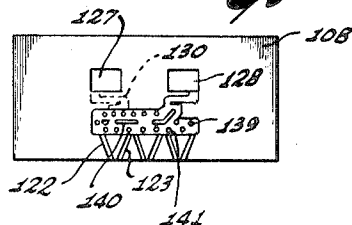


Fig. 3

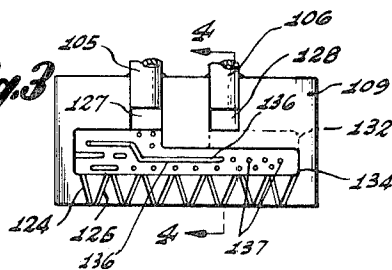


Fig. 4

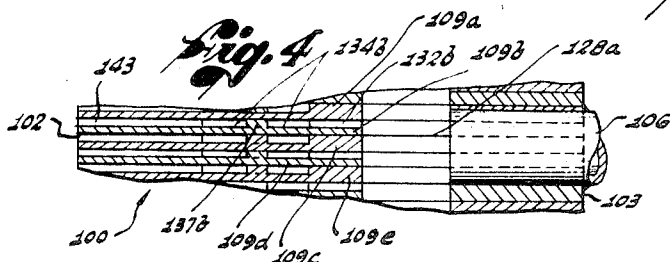


Fig. 5

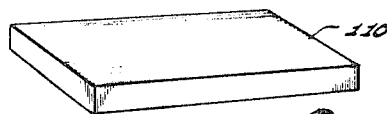


Fig. 6

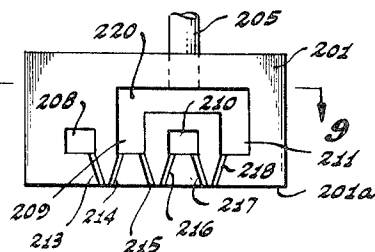


Fig. 7

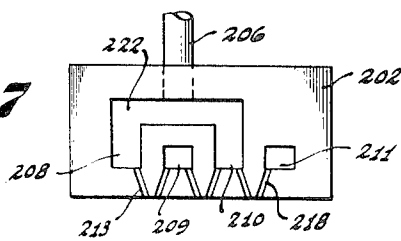


Fig. 8

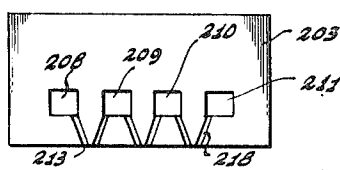
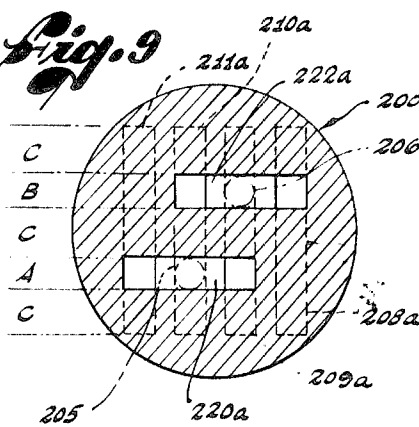


Fig. 9



INVENTOR.
RONALD K. PEARSON
 BY *Zulwider, Patton, Rieber*
Lee, and Wecht
 ATTORNEYS

FLUID INJECTOR

This is a continuation-in-part of application Ser. No. 578,275, filed Sept. 9, 1966 now abandoned.

This invention relates generally to improvements in fluid distribution and injection systems of the type utilized in propulsive devices such as rockets and the like and, more particularly, to new and improved propellant distribution and injection systems for propulsive devices, resulting in improved economy, compactness, reliability, versatility, durability, and thermodynamic performance.

In the field of liquid-fuel rocket-type propulsion, it has been the general practice to employ injectors of various types to inject liquid propellants into a combustion chamber where the propellant burns and releases energy by chemical action to supply the motive power for propulsion.

The three principal types of propellants used in such engines are monopropellants, bipropellants, and hybrid propellants. Monopropellants are single liquids. Bipropellants consist of a fuel and an oxidizer, each carried separately within the flight vehicle and being brought together in the combustion chamber of the vehicle engine. Air breathing engines carry only fuel and use atmospheric oxygen for combustion. Hybrid propellants use a combination of liquid and solid materials.

The energy of liquid propellants is released in combustion reactions which also produce the working fluid for reaction propulsion. The liquids in a bipropellant system may ignite spontaneously upon contact (hypergolic liquids), or they may require an ignition device to raise them to the flash or ignition temperature (anergolic liquids). Combustion may be initiated with a spark, a heated wire, or an auxiliary hypergolic liquid. Monopropellant combustion, which is more properly a form of decomposition, can also be initiated by the catalytic action of an active surface or by a chemical compound in solution. Ignition of common hypergolic bipropellants occur typically in a period of 1-100 milliseconds after initial contact between the fuel and oxidizer. Sometimes catalytic quantities of various materials are utilized to decrease the ignition delay of certain specific bipropellants.

During engine operation, the combustion chamber contains a turbulent, substantially heterogeneous, high-temperature reaction mixture. The liquid propellants burn with droplets of various sizes in close proximity and travelling at relatively high velocities. During combustion, very high rates of heat release are encountered. Sometimes, unstable combustion due to nonuniform mixing and burning generates swirling gases which reach high velocities within the combustion chamber and excite the resonant frequencies of portions of the engine or other parts of the vehicle structure. Hence, many rocket engines use internal baffling to prevent such high-frequency oscillation from occurring.

Overall engine performance, in contrast to theoretical propellant performance, is dependent upon effective design of the combustion chamber and injection system. Mixing and atomization are essential factors in injection of propellants into the combustion chamber. Injector and chamber design influence the flow pattern of both liquid and gases in the combustion chamber. One of these design factors is the characteristic chamber length referred to as L^* , where L^* is equal to the combustion chamber volume divided by the cross-sectional area of the nozzle throat. In general, monopropellants require larger values of L^* than bipropellants to provide the same performance in a rocket engine, due to the slower combustion exhibited by most monopropellants. For purposes of economy, it is desirable to keep L^* to its lowest value which still provides relatively efficient combustion.

As previously indicated, in the field of liquid fuel rocket propulsion, one of the primary problems has been that encountered in connection with injection systems in the attempt to obtain optimum mixing and atomization of the propellants within the combustion chamber. Typically, a plurality of individual injectors would be used or, in order to provide greater discharge pore density, injectors were sometimes fabricated by means of drilling large numbers of very small holes in rela-

tively thick metal plates. Each of the tiny drill holes in these injector plates was required to be angled precisely so that alternate streams of fuel and oxidizer, when forced through the injector, would impinge and mix in a manner to achieve good combustion in the rocket motor thrust chamber. Whenever holes were not drilled close enough or small enough, or whenever hole angles deviated from specified tolerances, the expense of fabricating the injectors escalated since the injector plates had to either be scrapped or painstakingly reworked at substantial cost. Moreover, even such injector plates often did not perform well from the standpoint of resultant combustion instability.

State of the art propellant injection systems generally tend to rely upon high-propellant injection velocity to produce propellant atomization. Unfortunately, this requires high-injection pressures and tends to limit the range of variation of injection pressure. Hence, the ability to throttle the thrust of an engine using such injection systems by means of control over injection pressure is extremely limited. In connection with propellant injection problems, it is well known that the heat transfer coefficient of a rocket motor increases with decreasing combustion chamber size. State of the art injection systems, however, provide little or no cooling benefits. For this reason, small rocket engines usually become thermally limited, even when using conventional propellants. Where exotic propellants producing high-flame temperatures, e.g., 8,000° F. and more, are used, ablative combustion chambers are often incorporated into the engine design. However, it will be apparent that such ablative chambers, by virtue of their limited life, impose definite limitations over the duration of engine operation.

Hence, those concerned with the development of liquid-fuel reaction-type propulsion engines have long recognized the need for improved injection systems that provide satisfactory propellant dispersion, atomization and fuel/oxidizer mixing, as well as means for overcoming or minimizing the thermal problems encountered in small combustion chambers and with fuels producing high-flame temperatures. The present invention fulfills these needs.

Accordingly, it is an object of the present invention to provide new and improved fluid distribution and injection systems which overcome the above and other disadvantages of the prior art.

Another object is to provide a new and improved fluid injection system which provides better atomizing of the injected fluid.

A further object of the invention is the provision of a new and improved fluid injection system which provides higher mixing efficiency.

Still another object is to provide a new and improved propellant injection system for propulsive devices providing enhanced design controllable fuel/oxidizer mixing characteristics.

Yet another object of the present invention is the provision of a new and improved fluid distribution and injection system for propulsive devices which enables reduced combustion chamber volume to produce the same thrust as previous devices.

A still further object is to provide a new and improved propellant injection system capable of high-mixing efficiency at relatively low injection pressures.

Another object is to provide a new and improved propellant injection system capable of producing high-mixing efficiency over a wide range of different propellant mass flow rates and, hence, capable of enhanced throttle control.

A further object of the invention is the provision of a new and improved propellant distribution and injection system for propulsive devices which enables more stable combustion and more uniform heat distribution.

Still another object is to provide a new and improved propellant distribution and injection system for propulsive devices which improves the thermal characteristics of the propulsive devices.

Yet another object of the present invention is the provision of a new and improved propellant distribution and injection system which is relatively economical to manufacture.

A still further object is to provide a new and improved fluid distribution and injection system in a propulsive device capable of simultaneously satisfying the cooling and combustion requirements of the propulsive device.

Another object is to provide a new and improved fluid distribution and injection system for propulsive device characterized by building block capability over a relatively wide range of sizes.

Still another object is to provide new and improved propulsive devices integrally embodying fluid distribution and injection systems possessed of one or more of the aforescribed advantages.

The above and other objects and advantages of the invention will become apparent from the following more detailed description, when taken in conjunction with the accompanying drawings of illustrative embodiments thereof, and wherein:

FIG. 1 is a perspective view of a fluid injector, in accordance with the present invention, the outline of a block from which the injector is fabricated being shown in phantom;

FIG. 1a is an enlarged, fragmentary, sectional perspective view of the area 1a in FIG. 1, and illustrates the shape of the fluid discharge orifices;

FIG. 2 is a sectional view, taken along the line 2—2 in FIG. 1, and illustrates a typical injector lamination plate at the upper end of the injector;

FIG. 3 is a sectional view, taken along the line 3—3 in FIG. 1, illustrating an injector lamination plate at substantially the center of the injector and further illustrating means for introducing propellants into the injector;

FIG. 4 is an enlarged, fragmentary sectional view, taken along the line 4—4 of FIG. 3;

FIG. 5 is a perspective view of one of the bottom and top plates utilized in assembling the injector of FIG. 1;

FIGS. 6, 7 and 8 are plan views of injector lamination plates for another embodiment of a fluid injector in accordance with the present invention;

FIG. 9 is an elevational sectional view through an assembled injector utilizing the plates shown in FIG. 6, 7 and 8, the section being taken substantially along the line 9—9 in FIG. 6 and showing two conduits in phantom.

Briefly, and in general terms, the present invention involves a fluid distribution and injection system wherein a plurality of preformed distribution and injection laminations are united together in a stacked arrangement to build up either a unitized fluid injector alone or a complete rocket engine integrally embodying a propellant distribution and injection system, all such devices making use of laminar "controlled pore" distribution and injection arrangements.

The term "controlled pore" is used generically herein to designate laminar distribution and injection systems wherein fluid distribution, manifolding, the number of discharge orifices or pores, the size, shape, density, spacing and array of the manifolding and orifices, as well as the injection angle and L/D ratio (ratio of discharge channel length to twice the effective hydraulic radius of the discharge orifice) of each orifice are all precisely controlled parameters to impart desired performance characteristics.

Referring now to the drawings, and particularly to FIGS. 1-5 thereof, the structure of a presently preferred embodiment of a fluid injector, in accordance with the present invention, is shown. The completely assembled and finished injector is denoted generally by the numeral 100 and is illustrated in FIG. 1 of the drawings. The embodiment of the injector 100 depicted in FIGS. 1-5 is particularly suited for the distribution and injection of two dissimilar fluids, such as bipropellants, and especially for the distribution and injection of the fuel and oxidizer components of hypergolic propellants. However, as will be readily apparent to those of ordinary skill in the art from the ensuing discussion, the design of the injector 100 may be readily adapted for the distribution and injection of any type fluid.

The finished injector 100 has a circular, cylindrical body with flat end faces 102, 103, the end face 102 being provided with a plurality of precisely arranged discharge pores or orifices such as the orifices 116, 1117 in FIG. 1a, while the face 103 provides the surface through which a pair of hollow conduits 105, 106 enter the injector body for the purpose of introducing appropriate fluids which are ultimately discharged through the injector face 102. While the injector 100 in FIG. 1 is illustrated as having a circular, cylindrical shape with flat end faces, it will be apparent that the shape of the injector can be varied considerably without departing from the spirit and scope of the present invention.

As best observed in FIGS. 1a and 2-5, the injector 100 is assembled by stacking and securing together a plurality of preformed fluid distribution and discharge plates (hereinafter referred to as injector plates) such as the plate 108 in FIG. 2 and the plate 109 in FIG. 3. The injector plates 108, 109 are preferably fabricated of a material which will not react chemically with any of the fluids handled by the injector 100, such as stainless steel or the like, and are typically of the order of 0.007-0.010 inches in thickness so that a great plurality of injector plates can be stacked together to provide a large number of discharge orifices. Each of the stainless steel plates 108, 109 is provided on each face with a thin coating of another metal having a lower melting point than the base metal stainless steel, such as copper or nickel, the coating thickness being typically of the order of magnitude of 0.0005 inches or less. One surface of each of the plates 108, 109 is formed, by any technique known in the art such as chemical milling or machining, to provide the various fluid distribution and injection channels, apertures and baffles shown in FIGS. 2 and 3. A presently preferred approach in this regard is to utilize a photoetching technique, similar to the technique used in fabricating printed circuits, for forming the surface of each injector plate.

The copper clad, preformed injector plates are stacked together one above the other as laminations forming a complete injector assembly. A substantially thicker, copper clad stainless steel end plate 110 (FIG. 5) is placed at the top and bottom ends of the stacked. The stack is then subjected to mechanical pressure to hold it together (typically 10 lbs. per square inch) and is heated in a hydrogen oven to 1750° F.-1,800° F. to accomplish brazing or diffusion-bonding of all of the plates into an integral unit which has most of the properties of the parent material (stainless steel) and can be machined or otherwise worked in the normal manner for a solid block of the parent material. In this regard, the thin copper coating on each plate surface diffuses during the heating process into the steel interface so that intergranular growth takes place eliminating the distinct separate lamination character of the original mechanical assembly and providing a monolithic structure.

The resultant solid rectangular block from the aforescribed fabrication process is shown in phantom in FIG. 1, the rectangular block having been subsequently appropriately machined to provide the circular, cylindrical injector 100.

As illustrated in FIG. 1a, a plurality of discharge orifices or pores, such as orifices, 112-117, are provided in the injector end face 102 by means of superposition of distribution and injection plates such as plates 119, 120, the unetched face of each plate being in abutment with the etched face of the next adjacent plate in the stack to provide a closed perimeter for each discharge orifice and the associated distribution channels leading to each discharge orifice.

As will be observed in FIG. 1a, each of the discharge orifices 112-117 is of rectangular cross section, typical dimensions being 0.01 inches in width and 0.002 inches in height. The reason for selection of such a noncircular discharge orifice shape is to produce an unstable discharge stream characterized by greater turbulence and, hence, resulting in atomization of the discharge liquid into much smaller droplets. The improved atomizing of the injected fluid enhances the mixing efficiency of the fluid with other similarly injected fluids.

It will also be noted in FIG. 1a that the discharge orifices in the injector face 102 are provided in closely spaced pairs, such as the pair 112, 113, the pair 114, 115 and the pair 116, 117. The atomized discharge stream or spray emanating from the discharge orifice of any one orifice pair is directed at such an angle that it impinges directly upon the stream emanating from the other discharge orifice of the same pair. The manner in which this is accomplished is best observed in FIGS. 2 and 3 where it is noted that the discharge channels leading up to the exit orifices, e.g. the channels 122, 123 of the plate 108 in FIG. 2 and the channels 124, 125 of the plate 109 in FIG. 3, are angled to converge and thereby produce convergent discharge streams. By controlling the angle of convergence between the discharge channels, and the spacing between the discharge orifices in each orifice pair, the zone of intersection of the emergent discharge streams, and its spacing from the injector face 102, can be rather accurately controlled. The latter further enhances design control over the mixing efficiency of injected fluids. In addition, the angular emergence of each discharge stream from the injector 100 also amplifies the instability of the discharge stream and thereby further enhances the atomizing capabilities of the injector.

It will be apparent from the description thus far that, by controlling the depth and length of each discharge channel, effective control over the L/D ratio of each discharge channel and orifice can be readily provided and, further, since mixing efficiency is high and mixing takes place close to the injector end face 102, combustion will likewise initiate very close to the injector face 102, with a consequent reduction in the value of L^* .

Referring now more particularly to FIGS. 2, 3 and 4, each of the injector plates 108, 109 includes a pair of rectangular apertures 127, 128 which, once the plates are assembled in a stacked arrangement, are in registry with the corresponding apertures 127, 128 of every other injector plate. Hence, when the plate stack is brazed or diffusion-bonded together, the walls defining all of the apertures 127, 128 are united together to define a pair of fluid manifolds 127a, 128a extending through the entire plate stack from top to bottom. In this regard, each of these manifolds, such as the manifold 128a in FIG. 4 formed by the superposed apertures 128, are in fluid communication with the discharge orifices of alternate plates in the stack. To this end, each of the plates such as 108 and 109 alternate in their fluid distribution pattern such that alternate plates in the stack communicate with alternate manifolds. This alternate distribution pattern is indicated by the dotted fluid distribution channel section 130 for the plate 108 in FIG. 2 and by the dotted channel section 132 for the plate 109 in FIG. 3.

As best observed in FIGS. 2 and 3 of the drawings, the major distinction structurally between the plates 108 and 109 resides in the number of discharge orifices which they provide for the injector face 102 and the particular fluid distribution arrangement for equalizing discharge pressure across all of the discharge channels, since the discharge channels are at varying distances from the manifold distribution apertures 127, 128 through which fluid is distributed to all of the plates comprising the injector 100.

The reason for having different plate types such as 108 and 109 providing a different number of discharge orifices, is that since the chordal width of the circular injector 100 diminishes in proceeding either up or down from a horizontal plane through the center of the circular injector 100 in FIG. 1, the number of discharge orifices which can be provided (assuming no reduction in discharge orifice size or spacing between orifices) likewise diminishes. Hence, plates such as 108 in FIG. 2 providing a minimum number of discharge orifices are used at the upper and lower ends of the injector 100 in FIG. 1, while plates such as 109 in FIG. 3 providing a maximum number of discharge orifices are used at the central, maximum width zone of the injector 100. Other plate types, providing a number of discharge orifices intermediate that provided by the plate 108 and that provided by the plate 109 are used in

the injector zones between the plates 108 and plates 109. Of course, it will be apparent that the discharge orifices may be of any size and spacing, as well as being located in any desired array along the injection face 102, without in any way departing from the spirit and scope of the invention, the embodiment shown in FIGS. 1-5 being merely representative of a typical, presently preferred embodiment for hypergolic propellants.

Referring again to the plate 109 in FIG. 3, the region between the manifolds and the discharge channels such as 124, 125 includes a large etched zone 134 containing a plurality of raised ribs 136 and protuberances 137 for the purpose of regulating the fluid pressures at the entrance of each discharge channel. A similar etched zone 139, raised ribs or baffles 140, and smaller protuberances 141 are provided for the plate 108 in FIG. 2. Such a distribution arrangement is provided for every plate in the injector stack, the particular arrangement or baffles and protuberances being custom-tailored for each plate in order to provide the desired pressure distribution across the discharge channel entrances.

As best observed in FIGS. 1, 3 and 4, the fluid conduits 105, 106 enter through the rear face 103 of the injector 100 and communicate with the manifolds defined by the superposed apertures 127, 128 of the injector plate stack.

The aforescribed structural relationship between the fluid conduits, manifolds, fluid distribution zones and discharge channels is best illustrated by the enlarged sectional view shown in FIG. 4. In FIG. 4 a plurality of injector plates 109a, 108b, 109c, 109d and 109e are shown in their normally stacked arrangement and bonded together. The fluid conduit 106 penetrates through the rear face 103 of the injector 100 and is in fluid communication with the manifold 128a. The manifold 128a communicates with alternate plates 109b, 109d, etc. For example, the manifold 128a is in fluid communication with the distribution zone 134b of the plate 109b via the channel 132b. Protuberances such as 137b in the fluid distribution zone 134b equalize the discharge pressures at the entrances of the discharge channels, such as the discharge channel 143 of the plate 109b.

It will be apparent that each of the injector plates distributes only one type of fluid since only one of the fluid manifolds is in fluid communication with the distribution arrangement for each injector plate. Therefore, when convergent streams impinge upon each other in exiting from discharge channels, such as the discharge channels 124, 125 from the plate 109 in FIG. 3, the impinging streams consist of the same fluid. This is referred to in the art as "like on like" impingement. However, since alternate injector plates are in fluid communication with alternate manifolds, each injector plate will provide like on like impingement for a different fluid than each of the next adjacent plates in the stack. Hence, if one injector plate is spraying fuel, then the plates on either side of the fuel plate will be spraying oxidizer. The finely atomized fuel and oxidizer sprays from alternate injector plates mix very efficiently and, in the case of hypergolic fluids, produce combustion upon contact.

The aforescribed laminar, controlled pore injector 100 is capable of injecting propellants into a combustion chamber at the same and higher rates as prior art injection systems, but at substantially lower injection pressures. In this regard, the injector of the present invention relies more upon a high number of discharge orifices, stream impingement and means for introducing instability into the stream to accomplish atomization, than upon the high-injection velocities primarily relied upon by prior art injection systems to accomplish atomization. Hence, high mixing and combustion efficiencies can be obtained at relatively low discharge pressures and stream velocities. This makes the injector of the present invention susceptible to a relatively wide range of throttle control over the output thrust of a rocket engine in which the injector is used, since the discharge pressure can be varied over a wide range to provide a wide range of different mass flow rates for the injector propellants.

In addition, the injector 100 has more uniform heat distribution across the injection face 102 and, as previously indicated,

is capable of providing burning relatively close to the surface 102 which results in a lower value of L^* . Furthermore, by virtue of more uniform mixing accomplished by the injector 100, combustion is more stable and the need for baffles within the engine to prevent swirling gases from reaching high velocities and frequencies resonant to the engine or associated equipment is obviated. Moreover, the injector 100 is relatively inexpensive to manufacture by the techniques previously outlined, and is more durable and reliable than previous injectors because of improved thermal characteristics.

Referring now more particularly to FIGS. 6-9 of the drawings, there is shown an alternate embodiment of an injector constructed in accordance with the present invention. The injector of FIGS. 6-9 is designed for like on unlike impingement, i.e., each injector plate distributes and discharges sprays of two different fluids, as opposed to the like on like impingement arrangement of FIGS. 1-5 wherein each individual injector plate discharges a spray of only a single fluid.

A sectional view through a completed injector 200 is shown in FIG. 9 and is made up of a stacked assembly of injector plates 201, 202 and 203 (designated as types A, B and C in FIGS. 6, 7 and 8, respectively) which are held together and diffusion-bonded into an integral unit in the same manner previously described for the injector 100 of FIG. 1. Similarly, the various apertures and channels of the injector plates 201, 202 and 203 are preformed prior to assembly by the same techniques described in connection with the formation of the apertures, channels and baffles, etc. for the plates 108 and 109 in FIGS. 2 and 3, respectively.

A pair of hollow, fluid conduits 205, 206 (corresponding to the conduits 105, 106 in FIGS. 1 and 3) enter through the rear of the injector 200 for the purpose of conveying fuel and oxidizer, respectively, to the manifold distribution system within the injector.

The injector plate 201 (type A) in FIG. 6 includes a plurality of spaced apart, distribution apertures 208, 209, 210 and 211 located along a line parallel to the forward edge 201a of the injector plate. A plurality of shallow discharge channels 213-218, corresponding to the discharge channels 122, 123 in FIG. 2 and 124, 125, etc. in FIG. 3, extend from the apertures 208-211 to the edge 201a of the injector plate 201. These discharge channels are angled so that a discharge channel from any one distribution aperture converges towards a discharge channel from a next adjacent distribution aperture. Hence, the fluid sprays emanating from these discharge channels impinge upon one another for efficient mixing. The exit openings provided by the discharge channels 213-218 at the edge 201a of the injector plate 201 from the fluid discharge orifices or pores in the finished injector 200 when the injector plates are stacked and bonded together.

An apertured section 220 in the injector plate 201 bridges between the distribution apertures 209, 211 so that the apertures 209, 211 are in fluid communication with each other. Hence, any fluid introduced to the apertured section 220, as by the conduit 205, is likewise introduced to both of the apertures 209, 211.

Referring to FIG. 7, it will be observed that the injector plate 202 (type B) is identical to the injector plate 201 with the exception that, instead of an apertured section 220 connecting the apertures 209, 211 together, the plate 202 has an apertured section 222 which connects the distribution apertures 208, 210 together. Hence, fluid introduced to the apertured section 222, as by the conduit 206, is also distributed to both of the apertures 208, 210.

Referring now to FIG. 8, the injector plate 203 (type C) has the same arrangement of fluid distribution apertures 208-211 and discharge channels 213-218 as the injector plates 201 and 202 of FIGS. 6 and 7, respectively. However, the injector plate 203 does not have any apertured sections 220 or 222 bridging between any pair of distribution apertures. Hence, none of the distribution apertures 208-211 in the injector plate 203 are in fluid communication with each other.

Referring now to FIG. 9, it will be apparent that the type A injector plates of FIG. 6 are stacked so that the walls defining the apertured section 220 for a plurality of plates are in registry and collectively define a horizontally extending manifold 220a of sufficient height to receive the fuel conduit 205 shown in phantom. Similarly, a plurality of type B injector plates are stacked together in registry with one another to collectively define a horizontally extending manifold 222a which receives the oxidizer conduit 206, also shown in phantom.

The type A and type B plate groups of FIG. 9 are separated by a type C plate group to isolate and prevent fluid communication between the two distribution manifolds 220a and 222a. In addition to isolating the type A and type B plate groups from each other, the type C plates are used at all other injector locations other than those necessary to build up the manifolds 220a and 222a.

In the injector 200 of FIG. 9, all of the distribution apertures 208-211 of all of the injector plates of every type are in registry and define four vertically extending manifolds 208a-211a, respectively. The manifolds 209a and 211a are in fluid communication with each other by virtue of the manifold 220a, whereas the manifolds 208a and 210a are in fluid communication with each other via the manifold 222a. Hence, alternate vertical manifolds through the injector plates convey alternate fluids introduced via the conduits 205 and 206. It will be apparent, therefore, that the arrangement of converging discharge channels 213-218 for the injector plates 201, 202 and 203 in FIGS. 6, 7 and 8, respectively, is such that each discharge channel of a convergent pair sprays a different fluid than the other discharge channel of the same convergent pair. In this manner, the injector 200 provides a like on unlike fluid injection pattern.

Except for the difference in spraying format, i.e., like-on-unlike discharge vs. like-on-like discharge, the injector 200 of FIGS. 6-9 otherwise performs and possesses all of the advantages of the injector 100 illustrated in FIGS. 1-5.

The controlled pore techniques and apparatus of the present invention satisfy a long existing need in the propulsion art for distribution and injection systems which are economical, compact, durable, and having improved thermodynamic performance and throttle control characteristics.

It will be apparent from the foregoing that, while particular forms of the invention have been illustrated and described, various modifications can be made without departing from the spirit and scope of the invention. In this regard, while the specific embodiments of the invention described herein are directed to systems for distributing and injecting more than one fluid, such systems can readily be adapted for the discharge of only a single fluid, such as a monopropellant. Accordingly, it is not intended that the invention be limited, except as by the appended claims.

1. A fluid injection device comprising:

a monolithic injection body composed of a stack of injection plates in contacting superposition, said injector body having an injection surface defined by corresponding edges of said plates and in which a plurality of fluid discharge pores are defined in each of said edges, each of said pores intersecting one surface only of the corresponding plate, said plurality of pores of each plate being laterally separated from the plurality of pores of the adjacent plate by less than the thickness of the edge of said adjacent plate.

2. A fluid injection device as set forth in claim 1 and further including a plurality of fluid discharge channels within said injection body, each of said discharge channels terminating in a different one of said discharge pores.

3. A fluid injection device as set forth in claim 2 wherein said discharge channels are angled within said injection body such that the fluid stream emitted from one of said discharge pores impinges upon the fluid stream emitted from a second of said discharge pores.

4. A fluid injection device as set forth in claim 1 in which:

a plurality of fluid flow discharge channels are formed within said body, each discharge channel terminating at one of its ends in one of said discharge pores, whereby each discharge pore in said injection surface is associated with a single discharge channel; and

fluid distribution means formed integrally within said body for distributing a fluid to be injected to said discharge channels.

5. A fluid injection device as set forth in claim 1 wherein said discharge pores are of noncircular shape.

6. A fluid injection device as set forth in claim 1 including fluid distribution means formed within said injector body by said plates for distributing fluid to be injected to said discharge pores.

7. A fluid injection device as set forth in claim 6 wherein said means distributes a first fluid to some of said discharge pores and distributes a second fluid to others of said discharge pores.

8. A fluid injection device comprising:

a plurality of preformed fluid distribution and injection planar laminations assembled in contacting superposition in a stack and bonded together to form a monolithic unit, said unit having at least one discharge surface defined by superposed edges of said laminations,

each of said superposed edges of said laminations being formed with a plurality of spaced-apart discharge pores defining a row of said pores that is laterally separated from an adjacent row by less than the thickness of the edge of the lamination in which said adjacent row is formed;

a plurality of fluid flow discharge channels formed within said monolithic unit between said laminations, each discharge channel communicating with one of said discharge pores in said injection surface, whereby each discharge pore is associated with a single discharge channel;

and fluid distribution means formed within said unit by said laminations for distributing fluid to be injected to said discharge channels and associated discharge pores.

9. A fluid injection device as set forth in claim 8 wherein said fluid distribution means includes manifold structure for distributing a first fluid to a first group of said discharge channels and pores and manifold structure for distributing a second fluid to a second group of discharge channels and pores, said first and second groups of discharge channels and pores being mutually exclusive.

10. A fluid injection device as set forth in claim 8 wherein all of said discharge channels and discharge pores in the same row receive the same fluid whereby a like-on-like fluid injection pattern is provided by each row.

11. A fluid injection device as set forth in claim 8 wherein alternate discharge channels and pores in the same row receive different fluids whereby a like-on-unlike fluid injection pattern is provided.

12. A fluid injection device as set forth in claim 8 wherein said discharge channels are angled in planes parallel to the planes of said laminations within said unit such that the fluid stream emitted from one discharge pore in a row impinges upon the fluid stream emitted from an adjacent discharge pore in the same row.

13. A fluid injection device as set forth in claim 8 wherein said discharge channels and associated discharge pores are of noncircular cross-sectional shape.

14. A fluid injection device as set forth in claim 8 wherein the shape of said discharge pores in said injection surface is rectangular.

15. A fluid injection device as set forth in claim 8 introducing distribution means formed within said unit by said laminations for utilizing at least a portion of a fluid to be injected, prior to injection, for cooling selected portions of said unit.

16. A fluid injection device as set forth in claim 8 including means formed between each pair of adjacent laminations for regulating the discharge pressures at each of said discharge pores in the same layer.

17. A fluid injection device as set forth in claim 8 wherein said laminations, prior to assembly and bonding, include a thin coating of a material having a lower melting point than the primary material comprising said laminations in said integral unit.

18. A fluid injection device as set forth in claim 17 wherein said primary material is stainless steel and said thin coating is comprised of copper.

19. A fluid injection device having a high density of discharge orifices in an injection face thereof, comprising:

a plurality of injector plates;

means to secure said plurality of injector plates together in contacting superposition as an integral stack with said injector plates arranged for defining an injection face of the device with edges of said plurality of injector plates;

the edge of each of said injector plates at said injector face being formed with a plurality of spaced-apart fluid discharge orifices comprising ends of a corresponding plurality of fluid channels formed in a first side of said injector plate;

each of said orifices and the corresponding channel being bounded along one side by a confronting surface portion of a second side of an adjacent injector plate;

whereby to define an injection face with a high density of discharge orifices comprising adjacent rows of orifices, each of which rows of orifices is laterally separated from an adjacent row by less than the thickness of the plate in which each such row of orifices is formed.

20. A device as in claim 19 wherein said plurality of fluid channels of each plate have adjacent fluid channels that are angularly related for intersection for the jets of fluid emitted therefrom.

21. A device as in claim 19 wherein each of said plates is formed with an opening therethrough comprising a portion of a fluid distribution means and some, at least, of said fluid channels of some of said plurality of plates are in fluid communication with said opening of the corresponding plate.

22. A device as in claim 19 wherein

each of said plates is formed with a pair of openings therethrough comprising a portion of a first and a second fluid distribution means of said device, respectively, with alternate ones of said plates having all of the fluid channels thereof in fluid communication with said one fluid distribution system,

while the remaining plates have all of the fluid channels thereof in fluid communication with said second fluid distribution means.

23. A device as in claim 19 wherein

each of said plates is formed with a pair of openings therethrough comprising a portion of a first and second distribution means of said device, respectively, each of said plates having some of the fluid channels thereof in fluid communication with said first fluid distribution means,

while the remaining fluid channels of each plate have fluid communication with said second fluid distribution means.

24. A device as in claim 19 wherein:

each of said plates on said first side thereof is formed with a depressed manifold zone having fluid communication with inner ends of some, at least, of said plurality of fluid channels of the plate,

said manifold zone having areas thereof divided by upstanding protusions comprising integral parts of the plate that are adapted and arranged to regulate fluid pressure at said inner ends of said fluid channels.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,612,397 Dated October 12, 1971

Inventor(s) RONALD K. PEARSON

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, line 9, after "propulsive" delete "device" and insert therefor --devices--.

Column 4, line 4, after "116," delete "1117" and insert therefor --117--; line 16, after "FIG" delete "," and insert therefor --.--; line 41, after "the" (first occurrence) delete "stacked" and insert therefor --stack--; line 61, after "face" delete "12" and insert therefor --102--; line 68, after "cross" and before "section" insert a hyphen (-).

Column 5, line 56, after "discharge" delete "pressure" and insert therefor --pressures--.

Column 6, line 17, after "rangement" delete "or" and insert therefor --of--; line 29, delete "108b" and insert therefor --109b--.

Column 7, line 50, after "201" delete "from" and insert therefor --form--.

Column 9, lines 67 and 68, after "8" delete "introducing" and insert therefor --including--.

Signed and sealed this 11th day of July 1972.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents