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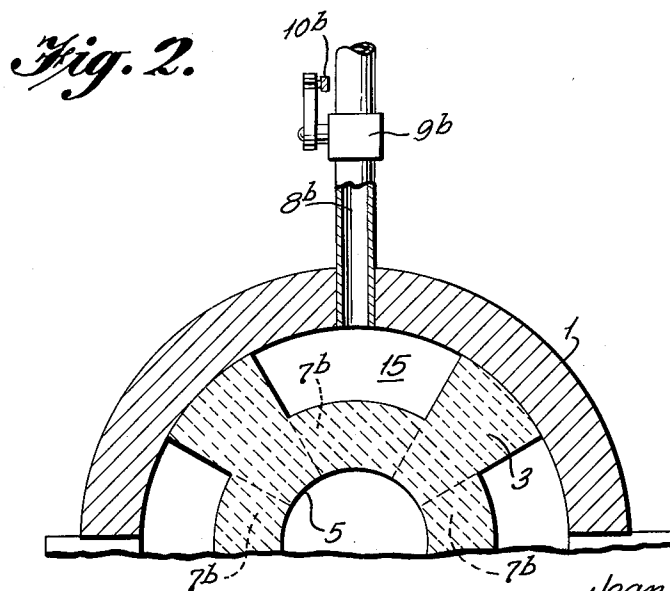
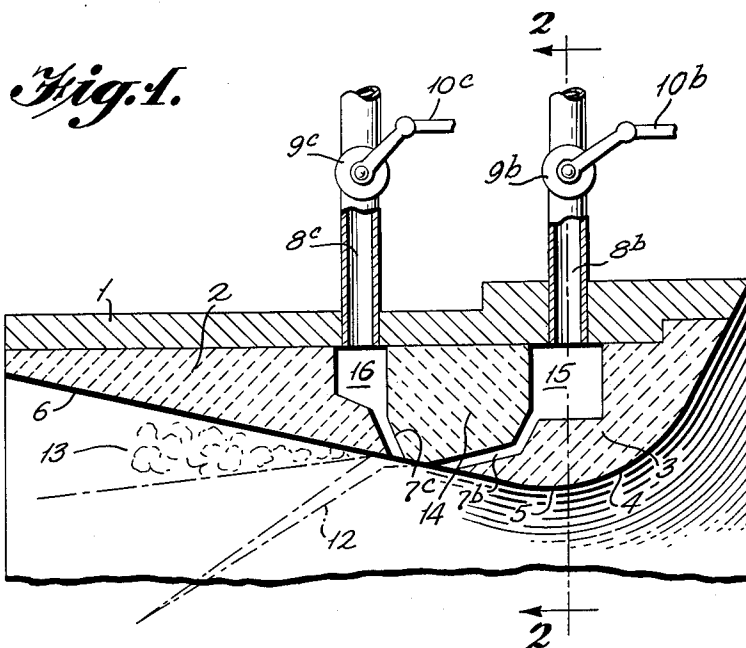
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3,233,833

METHOD AND DEVICE FOR DEFLECTING A ROCKET JET

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4 Sheets-Sheet 1



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4 Sheets-Sheet 2

Fig. 3.

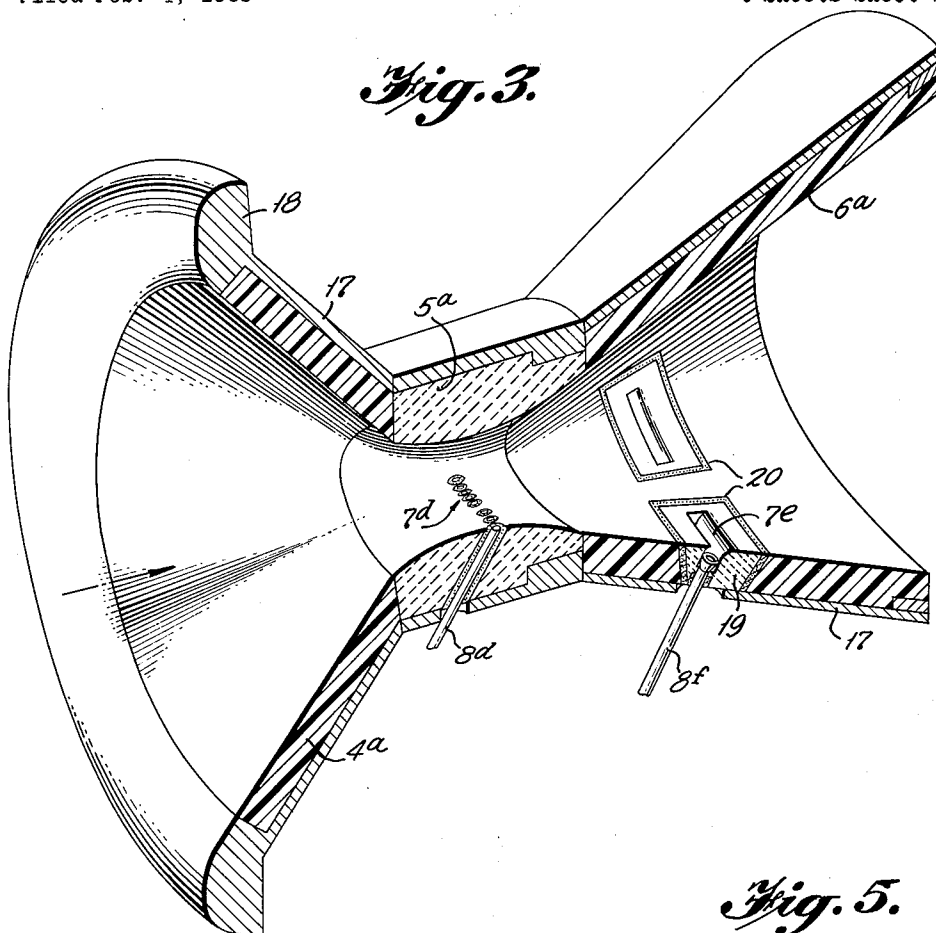


Fig. 4.

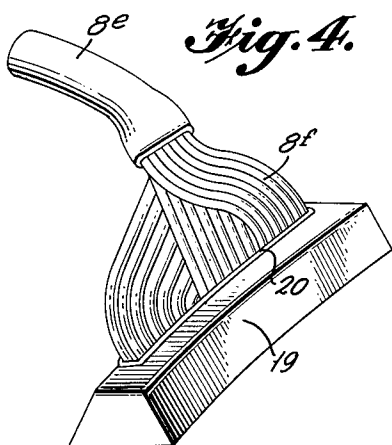
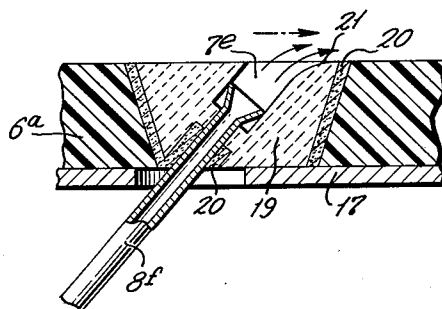


Fig. 5.



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4 Sheets-Sheet 3

Fig. 6.

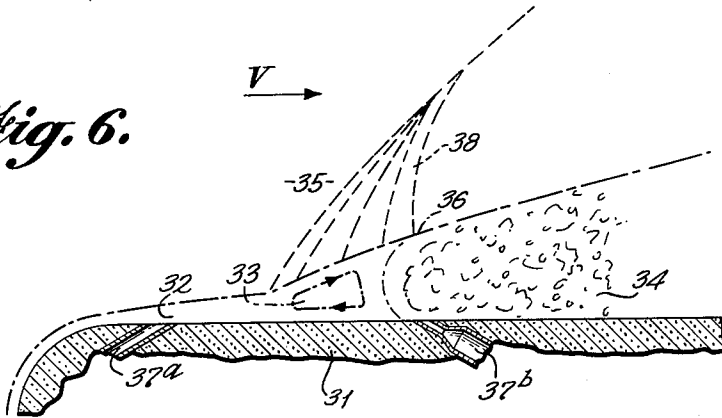
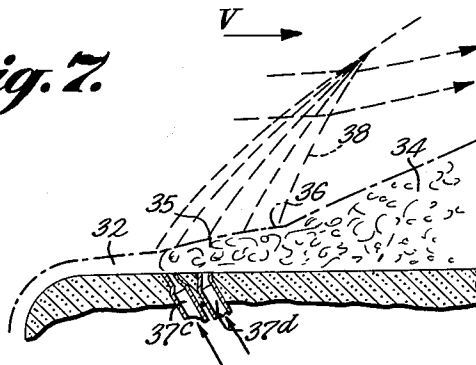


Fig. 7.



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4 Sheets-Sheet 4

Fig. 8.

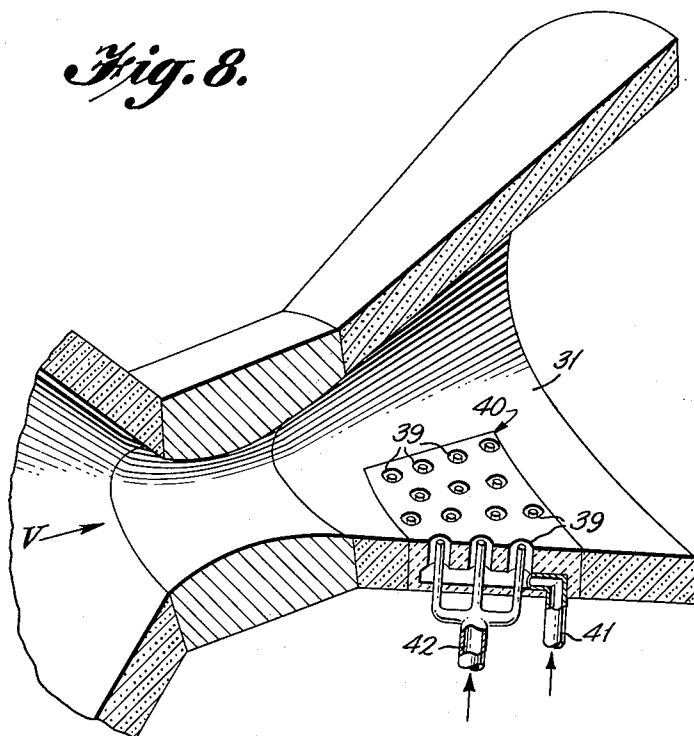
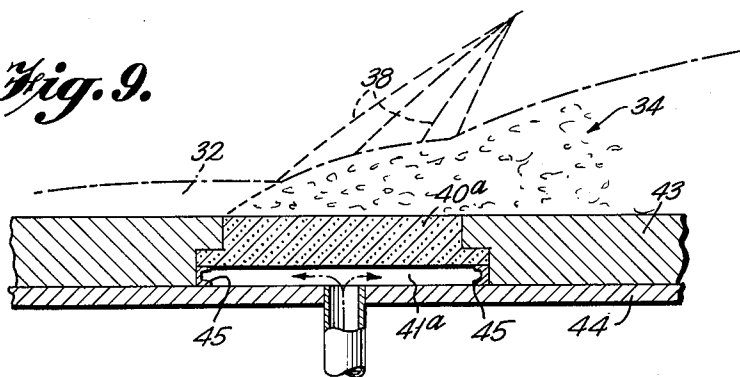


Fig. 9.



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1

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**METHOD AND DEVICE FOR DEFLECTING
A ROCKET JET**

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11 Claims. (Cl. 239—265.23)

It is well known to deflect the propulsive supersonic jet delivered by a rocket nozzle for steering purposes by means of transverse nozzles divided into sectors and supplied with a gaseous or liquid fluid under pressure. The deflection sustained by the rocket jet is caused by the momentum of the fluid and this is therefore a purely mechanical control process.

In order to reduce the amount of control fluid which is necessary to produce a given deflection, it has been proposed to create local fluid obstacles or expansion zones at the inner periphery of a rocket nozzle. The gas flow within said nozzle is then asymmetrically "blocked" when supersonic, by a localized shock wave at least, and deviated in every case. The control fluids proposed consisted either in a pressurized gas or, in the case of jets containing yet an excess of air or oxidizer in their exhaust state, in fuel capable to burn in said excess thereby generating supplemental motive power.

A first object of this invention is to bring an improved reduction of the control fluid amount.

Another object of the invention is to allow deflection of a jet containing no excess of air or oxidizer in its exhaust state.

Another object of the invention is to produce local and temporary fluid obstacles limited to the close vicinity of the nozzle wall.

According to this invention, two reactive liquids are successively injected in the boundary layer hugging the nozzle wall internally, in such manner as to react with each other within said boundary layer. The relatively important local expansion caused by the reaction is followed by the creation of a local shock wave, at least, which deflects the propulsive jet.

With certain reactive liquids or propellants, the time elapsing before the chemical reactions which liberate their energy are triggered is longer than the time the propulsive gas jet dwells in the nozzle. It is therefore desirable to keep the propellants inside the nozzle for an adequate length of time. In accordance with this invention, this can be achieved by injecting such a propellant upstream of the nozzle throat, in a subsonic zone, or by means of a counterstreamed injection calculated to slow down and at the same time thicken the boundary layer upstream of the injection port, the first propellant dwelling long enough in the thickened part to become hot and vaporized and to then mix and react with a second propellant.

The slowing down of the boundary layer can in certain cases go as far as creating a stagnant zone, into which can advantageously be injected, directly, a portion of the propellants utilized. When one of the propellants is injected at high speed and preferably counterstreamed, this results in a separation of the boundary layer upstream of the injection point and in the formation of a downstream wake. The jet of propellant thus creates and bounds two stagnant zones adjacent said separation and wake. In accordance with the present invention, recourse may be had to the upstream or downstream stagnant zone (according as the injection of a so-called auxiliary propellant is to take place upstream or downstream of

2

the separation), whereby to confine the two propellants therein for the time needed for them to heat up, vaporize, mix and react.

The obtainment of a zone whereat the velocities along the wall are low enough for expansion of the liquid or liquids to take place, can alternatively be ensured by injecting a multiplicity of small jets spaced out along the direction of the current, whereby the boundary layer is progressively thickened and the velocity at which the injected liquid or liquids are entrained is likewise lowered. These liquids can be introduced through the medium of rocket nozzle wall elements embodying at least one network of possibly microscopic orifices obtained by sintering or perforation and connected to suitable conduits.

The invention likewise relates to a deflecting device comprising conduits for leading in at least one liquid under pressure, which conduits being equipped with adjustment valves and have ports over the inner surface of a nozzle wall at points symmetrically arranged about the symmetry axis of said nozzle, and being further provided with means for directing the liquid or liquids along said inner surface, for example in an upstream direction.

In accordance with a specific embodiment, a plurality of reactants, of which one at least remains liquid until it enters the nozzle, are conveyed along corresponding sectors of several circular cross-sections of the nozzle, which sectors are spaced from upstream to downstream. The upstream-directed openings in certain of said sectors make it possible to very accurately localize the shock wave due to the reaction, while auxiliary sectors deliver a complement of reactive liquid into the stagnant zones created thus.

The liquids can be conveyed to the joint between two nozzle portions (preferably made of graphite), or to inserts in said nozzle forming straight spouts which are preferably made of graphite possibly covered with an electrolytically deposited metal such as tungsten in particular.

Another embodiment of this invention resides in the injection of a multiplicity of elemental jets through small ducts extending through certain elements of the nozzle wall, said elements may be made merely of porous material.

The description which follows with reference to the accompanying drawings, which are filed by way of example only and not of limitation, will give a clear understanding of the various features of this invention and of the art of carrying them into practice.

In the drawings filed herewith:

FIGURES 1 and 2 are schematic radial and cross-sectional views, respectively, of a nozzle equipped with a deflector device according to the invention, utilizing two reactive liquids;

FIGURE 3 is a perspective view in partial section of a composite nozzle equipped with a two-liquid deflector device, and FIGURE 4 is a detail view thereof;

FIGURE 5 is an enlarged radial section taken through one of the spouts of FIGURE 3;

FIGURE 6 is a highly diagrammatic sectional view of a nozzle wall element provided with two propellant delivery conduits and of the various associated fluid zones;

FIGURE 7 is a similar illustration of a wall element alternatively provided with two propellant delivery conduits placed near each other;

FIGURE 8 is a schematic perspective view of a nozzle equipped with a perforated panel adapted to deliver two propellants at a multiplicity of points adjacent a wall; and

FIGURE 9 is a highly diagrammatic sectional view of a wall element made of porous material.

Reference is first had to FIGURES 1 and 2, which are respectively a longitudinal and a transverse section of a

rocket nozzle illustrated in schematic form, comprising a ferrule 1 and a multisection lining 2, 3 and 14, made of graphite for instance, whereby to jointly form the convergent section 4, a throat 5 and a divergent section 6.

The joint between lining sections 2 and 14 is made along a flat or bevelled rim 7c divided into a plurality of sectors which form injectors individually supplied through a conduit 8c equipped with a valve 9c, which valve is connected to a steering system (not shown) operating through a control 10c. Similarly the joint between lining sections 3 and 14 is made along a flat or bevelled rim 7b divided into a plurality of sectors which forms injectors individually supplied through a conduit 8b equipped with a valve 9b, which valve is connected to a steering system (not shown) operating through a control 10b.

The valves 9 regulate the flow of pressurized liquid conveyed through conduits 8 to spouts or injectors 7, which spouts may be positioned in the divergent section 6, the throat 5, or the convergent section 4 adjacent the rocket combustion chamber. Said spouts may form an obtuse angle with the upstream part of the wall, in 7c for instance, whereby to direct the liquid flow upstream and thus reduce the distance said liquid is entrained along the wall before reaction.

In the case of certain double-walled nozzles cooled by a thin sheet of internally circulating liquid, the deflector device can make use of the cooling liquid, which the circulating system then leads to sector-shaped injectors equipped with distinct control valves.

Such nozzles are usually employed for liquid-fuel rockets and are cooled by the propellants. However, this invention encompasses this contingency also, namely that wherein the liquids used for deflecting the jet are themselves reactive.

A reactive liquid, be it a monopropellant which dissociates because of the temperature of the gas in the primary flow, or a liquid which reacts chemically with the unburnt products, offers many advantages over a non-reactive liquid.

The reaction of the two propellants or reactive liquids respectively delivered by two corresponding injectors 7b, 7c is generally an exothermic one and causes the liquid used to sustain an expansion which is not only marked (thereby increasing the directional blocking of the nozzle) but also rapid (thus accurately localizing this blocking).

According to this invention, several liquids inter-react to create a localized expansion for blocking the nozzle. Such a disposition, which is shown in FIGURES 1 and 2, allows for very accurately locating the part of the nozzle whereat said expansion takes place and for increasing the dwelling time of a propellant in the nozzle.

The first sets of injectors 7b supplied through conduit 8b have ports in the nozzle, for instance somewhat downstream of the throat, and are oriented downstream. The second set of injectors 7c, positioned somewhat downstream of the injectors 7b, are supplied through conduit 8c and have ports in the nozzle with, for example, an upstream orientation. These several injectors are supplied through chambers 15, 16 embodied in the joints between the lining blocks 2, 3 and 14.

The first propellant is thus injected into the boundary layer of the primary flow, thereby thickening and slowing down the same, with an attendant temperature rise in said propellant.

The second propellant is injected with a relatively large momentum, thus assisting in localizing the blocking shock-wave 12 between the two sets of ejectors. The gaseous main flow separates from the wall and forms a wake zone 13.

The shock wave 12 and the wake zone 13 have been represented on the figures. Adjustment is facilitated by the use of liquids. The method of construction of the nozzles according to this invention by no means implies

unusual difficulties, the injection chambers 15, 16 and the injectors 7 being easy to machine within the joints.

The enlarged view of FIGURE 6 provides a clearer picture of the manner of operation of a device of the type shown in FIGURE 1. FIGURE 6 shows two sets of conduits 37a and 37b placed side by side and perpendicularly to the plane of the figure (or alternatively two single ejectors of notable development in the same direction), embodied in a nozzle wall 31. A first propellant is introduced through the upstream conduit or conduits 37a which may be termed auxiliary conduits) into the boundary layer 32, which it heats up and partly vaporizes. The second propellant is counterstream injected under relatively larger impulse, through the downstream conduit or conduits 37b. This second injection produces a slightly upstream separation of the boundary layer, in conjunction with a shock wave 38 which deflects the primary gas flow V, and this separation bounds an upstream stagnant zone 35, in which there exist currents travelling at much lower velocity than the primary jet, and even back-flowing currents. The propellant injected into the boundary layer upstream of said stagnant zone mixes with the second propellant in this zone, in which zone the mixture ignites. It then continues to burn in the progressively accelerated wake 34 until its exit from the nozzle, while preventing entrainment of the primary flow. The upstream ejector 37a must be sufficiently distant from the downstream ejector 37b to ensure suitable heating of the first propellant and substantial thickening of the boundary layer 32, whereby to produce a large mixture area 33.

FIGURE 7 illustrates an alternative embodiment, which operates in very similar fashion to the device of FIGURE 6 and in accordance with which the propellant ejectors are juxtaposed.

A first conduit 37c, which may have a considerable transverse development and be preferably turned facing upstream, delivers a first propellant into the boundary layer, where its relatively large momentum generates a shock wave and then damps out into a wake 34 preceded by a downstream stagnant zone 35. A second conduit 37d, which may be termed an auxiliary conduit, debouches downstream from the first conduit and at a small distance therefrom, in such manner that the small local velocities and backflowing currents prevailing in the downstream stagnant zone 35 enable the second propellant to dwell therein for at least as long as is necessary for the reaction to be initiated. In other words, the purely aerodynamic boundary layer 32, which is disturbed by the flow of the first propellant, is extended by a stagnant zone 35 which, from a point 36 onwards, is transformed into an over-pressure wake 34 fed by the reaction gas. The flow is separated from said wake by a boundary surface.

FIGURES 3 to 5 relate to an embodiment of the invention wherein the composite type nozzle comprises a graphite throat 5a and convergent and divergent walls 4a and 6a respectively, made of a laminated plastic-base material. A metal ferrule 17 supports the various nozzle sections and forms at 18 a flange whereby it can be joined to the rocket casing. In this specific example, a dual injection system is illustrated.

A first set of injection nozzles 7d can be formed, as shown in FIGURE 3, by pipes 8d sealed directly by a cement into the graphite block 5a constituting the throat.

A second set of nozzles 7e, disposed in an area lined with a suitable plastic, such as the divergent section 6a, is provided with graphite inserts 19 (four, say) which are rigidly united with the plastic by a cement 20 and are preferably trapezium-shaped in section. The delivery conduits 8e divide into pipes 8f, each of which is sealed into the insert 19 or retained by means of a flared terminal portion. Said insert 19 can be protected against the erosion that chiefly results from the reaction, by the electrolytic deposit of a metal having a high melting point, such as tungsten. The liquid is deflected about the rounded edge 21 and continues to hug the wall.

5

FIGURES 8 and 9 illustrate other possible embodiments of the device, which allow for creating, in the boundary layer, a zone wherein the velocities are sufficiently damped to enable the physical or chemical expansion of the injected liquid to take place.

In accordance with the alternative form of construction, shown on FIG. 8, the conduits 37 are replaced by a plurality of small holes or bores 39, which are disposed in a pattern of several arrays along the direction of flow. Small pipes branching from a supply pipe 42 are arranged concentrically to small pipes branching from another supply pipe 41 and end in the holes 39 respectively.

Lastly, as shown in FIGURE 9, the holes or bores can be microscopic and very numerous if the wall element 40a which replaces one injector such as 7b is made of porous material, such as sintered metal, in which case the chamber 41a could be formed between the liner 43 of nozzle wall 44 and said wall 44 itself. In such cases, leaktight seals 45 could be provided, but the chamber could alternatively be embodied in the wall element, as shown in FIG. 1.

It is of course to be clearly understood that this invention is by no means limited to the specific embodiments described hereinabove by way of example, but that it also covers all alternative embodiments that can be obtained by applying such equivalent technical means as result, in particular, in locally slowing down the boundary layer in a nozzle and in thereby assisting the expansion of at least one liquid.

What is claimed is:

1. A method for deflecting a gas jet discharged at supersonic velocity by a propulsive nozzle having a convergent divergent transverse section, said method comprising the steps of admitting at two successive points with respect to the gas jet motion, respectively, a first and second reactive liquid in metering flow into the gaseous boundary layer hugging said nozzle internally, said liquids being adapted to react upon contact with each other and to expand with formation of a local shock wave which deflects said gas jet.

2. A method as claimed in claim 1 wherein at least one reactive liquid is injected in an upstream direction with respect to the gas jet motion to create in the boundary layer a stagnant zone where the reaction takes place.

3. A method for deflecting a hot jet discharged at supersonic velocity by a solid convergent divergent nozzle, said method comprising the steps of delivering and second reactive liquid in metered flow into the gaseous boundary layer hugging said nozzle internally, and delivering a second liquid capable of reacting with said first liquid in said boundary layer downstream said first liquid, said reactive liquids reacting with each other locally in the boundary layer and causing a local shock wave to deflect said gas jet.

4. In combination with a propulsive nozzle of convergent divergent transverse section discharging a gas jet at supersonic velocity, a deflecting device comprising a first set of injectors regularly spaced along a cross section of the divergent part of said nozzle, directed inwardly thereof and associated with means for individually supplying either of said first injectors with a pressurized first reactive liquid, a second set of injectors regularly spaced along a cross section of said nozzle and directed inwardly thereof, the injectors of said second set being respectively located in longitudinal correspondence with the injectors of the first set and associated with means for individually supplying either of said second injectors with a second pressurized liquid capable of reacting with the first liquid injected by the corresponding first injector, whereby the reaction of said liquids produces a localized shock wave deflecting said gas jet.

5. A deflecting device according to claim 4 wherein the injectors of one set each consists of a cluster of pipes of small section disposed in a single row in the vicinity of the nozzle and joined at a distance from said nozzle to a common supply conduit.

6. A deflecting device according to claim 4 wherein an injector forms an arcuate slot in a transverse joint surface between two internal lining sections of said nozzle, said slot being connected to a supply conduit.

7. A deflecting device according to claim 4 wherein the injectors of said second set are oriented upstream with respect to the gas jet motion, the liquid injected by one of said injectors thereby forming a stagnant zone in the boundary layer of the gas jet hugging said nozzle internally and the reaction of this liquid thereby being localized with precision.

8. A deflecting device according to claim 7 wherein an injector joins onto the inner surface of said nozzle through an upstream rounded edge assisting the adhesion of the liquid injected to said surface.

9. A deflecting device according to claim 4 wherein one set of injectors is constituted by a plurality of porous elements regularly spaced along a cross section of said nozzle and each connected to a supply conduit.

10. A deflecting device according to claim 4 wherein the corresponding injectors of the two sets respectively delivering said two reactive liquids are pierced through a common plate which lines said nozzle locally and form a two directional network of bores.

11. A deflecting device according to claim 10 wherein the bores delivering the first reactive liquid are supplied through a common first conduit opening into a distribution chamber embodied in said plate, the second reactive liquid being delivered through a network of pipes of smaller cross section than said bores and traversing said bores, said pipes being connected to a common second supply conduit.

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