NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

REPLY TO
ATTN OF:

October 15, 1970

TO: USI/Scientific & Technical Information Division
Attention: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General
Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned
U.S. Patents in STAR

In accordance with the procedures contained in the Code GP to Code USI memorandum on this subject, dated June 8, 1970, the attached NASA-owned U.S. patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No.	:	3,270,501
Corporate Source	:	North American Aviation
Supplementary Corporate Source	:	
NASA Patent Case No.	:	XGS-01143

Please note that this patent covers an invention made by an employee of a NASA contractor. Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of Column No. 1 of the Specification, following the words ". . . with respect to an invention of. . . ."

Gayle Parker

Enclosure:
Copy of Patent

FACILITY FORM 602

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Sept. 6, 1966 JAMES E. WEBB 3,270,501

ADMINISTRATOR OF THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

AERODYNAMIC SPIKE NOZZLE

Filed March 5, 1964 2 Sheets-Sheet 1

Fig. 1

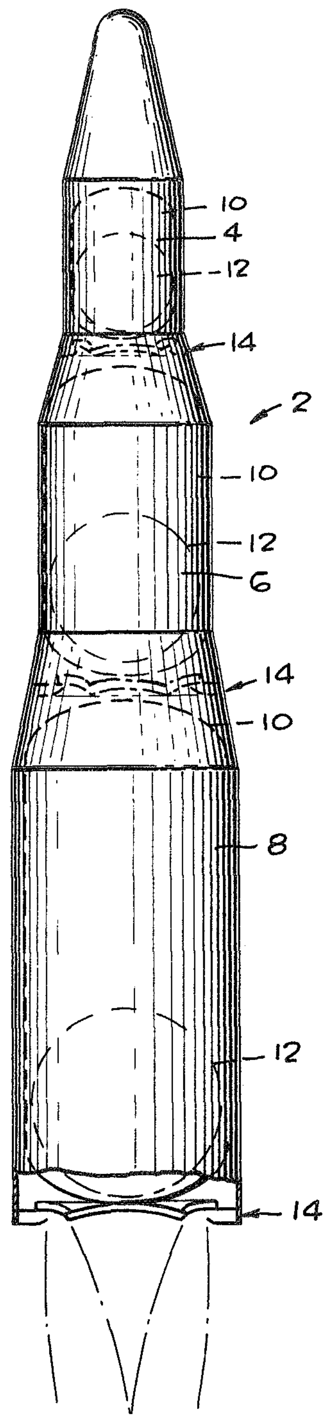
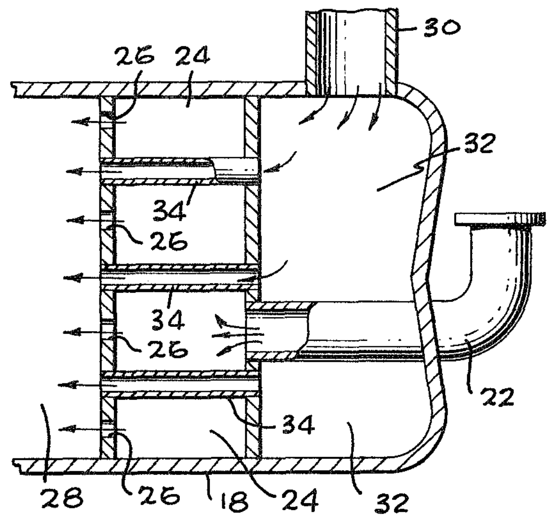


Fig. 2



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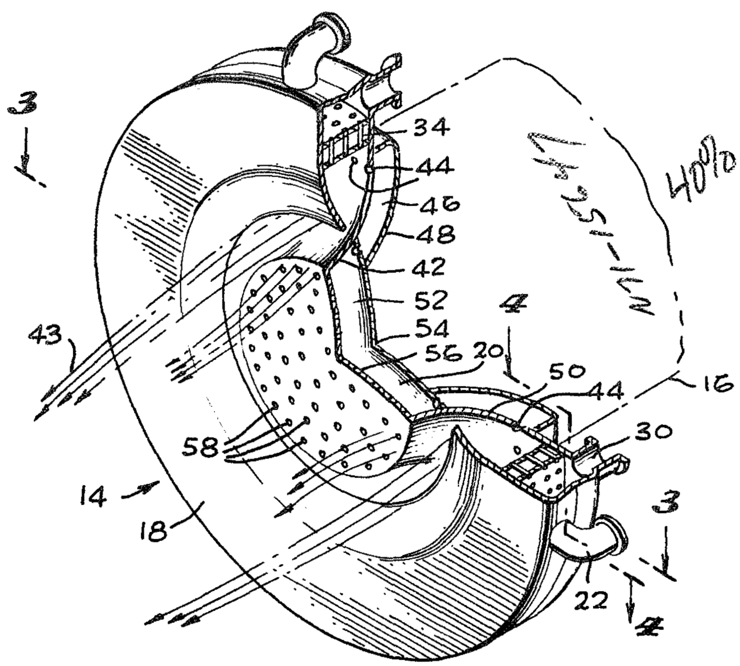
Filed March 5, 1964 2 Sheets-Sheet 2

Fig. 2



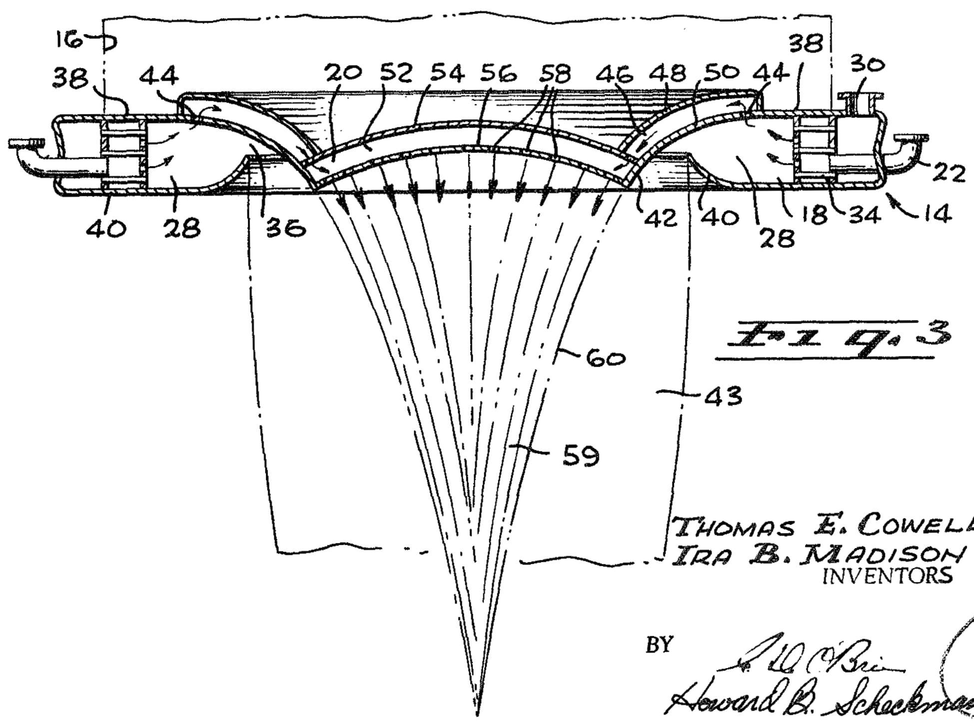


Fig. 3

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3,270,501

Patented Sept. 6, 1966

1

3,270,501

AERODYNAMIC SPIKE NOZZLE

James E. Webb, Administrator of the National Aeronautics and Space Administration, with respect to an invention of Thomas E. Cowell and Ira B. Madison

Filed Mar. 5, 1964, Ser. No. 349,781
10 Claims. (Cl. 60—35.6)

This invention relates to nozzles for propulsion engines and more specifically to an improvement in a spike nozzle.

A spike nozzle generally comprises an annular injector and a physical spike in the area surrounded by the injector. The spike is shaped generally like a cone, with the narrow part projecting from the center of the injector. The propulsion gases from the injector impinge against the surface of the spike to provide thrust. One example of a spike nozzle can be seen in British Patent 885,489 of December 28, 1961; or in the Handbook of Astronautical Engineering, published by McGraw-Hill (1961), section 20.335.

Some of the reasons a spike nozzle is preferred to a bell type nozzle are that it provides high thrust performance over a wide range of altitudes. Also a spike nozzle can be made shorter than a bell type nozzle and yield equivalent thrust performance.

However a spike nozzle still presents a number of problems. The spike for example is a disadvantage in a multi-stage rocket where a number of nozzles are used. The spike increases the length of the rocket. Also the "in-between stage" thrust structure, required due to the spike's length adds weight to the rocket.

Another problem is expense. It is expensive to fabricate a spike. Also, the material from which a spike is made is costly since the material must be capable of withstanding high temperatures.

Still another problem is cooling the spike and surrounding structure. The hot propulsion gases impinge against the spike and expose it to very high temperatures. In addition, the heated spike in turn transfers part of its heat to the surrounding structure. This makes it necessary to provide equipment to cool the spike and surrounding structure.

It is an object of this invention to provide a nozzle that can function like a spike nozzle but eliminates a number of the above mentioned disadvantages.

It is therefore an object of this invention to provide a nozzle that functions like a spike nozzle but eliminates the high temperature and heat transfer problems inherent in a conventional physical spike nozzle.

It is another object of this invention to provide a nozzle that functions like a spike nozzle but is lighter, less expensive, and more compact.

Essentially, the invention teaches how to construct a nozzle that forms a spike out of a fluid rather than out of physical hardware. Thus, eliminating the physical spike in prior art nozzles. The physical spike is replaced by what may be termed an aerodynamic conical spike.

The nozzle is made with a central or inner injector that ejects a propulsion stream at a subsonic velocity, and an outer circumscribed annular injector that ejects, a propulsion stream at a supersonic velocity contiguous to the subsonic propulsion stream. The supersonic propulsion stream expands on leaving the nozzle and forms the subsonic propulsion stream into a conical spike.

Thrust is derived as a result of the pressures produced on the nozzle by the momentum flux of the supersonic and subsonic propulsion streams reacting on the base of the nozzle.

There are a number of advantages in eliminating the physical spike structure. There is a reduction of cooling equipment needed, because there is no spike to cool.

2

Also, the resulting nozzle is very compact and especially suitable for rocket upper stage applications because of the savings of "inbetween stage" thrust structure. Further, the nozzle is not only cheaper to construct, but is lighter in weight.

And, finally it has been discovered, although presently the theory is not understood, that a nozzle constructed as taught by this invention, will function with higher efficiency (thrust per pound of propellant) than a comparable physical spike nozzle of the prior art.

Other objects and advantages will appear from the following description considered in conjunction with the accompanying drawings, in which:

FIG. 1 is a view of multi-stage rocket showing nozzles of this invention as used in the various stages of a rocket;

FIG. 2 is a perspective cut-away view of a nozzle showing some of its internal structure;

FIG. 3 is a cross-sectional view of FIG. 2 taken in the direction of arrows **3—3** showing the aerodynamic spike; and,

FIG. 4 is an enlarged view of a portion of FIG. 2, taken in the direction of arrows **4—4**, showing the interconnection of the fuel and oxidizer propellant inlets and the manifold construction.

Invention

Referring to the drawings, there is shown in FIG. 1 a multi-stage rocket **2**. Three stages **4**, **6**, and **8** are shown. For simplicity in explaining the invention, all stages will be assumed to be similar. Although the specific construction of each stage would depend on its mission.

Each stage has a propulsion system that may include propellants such as fuel carried in tank **10** and an oxidizer carried in tank **12**. The propellants are fed, by conventional means (not shown), to nozzle **14** where they are mixed and combusted, and then ejected as subsonic and supersonic propulsion streams to form a conical aerodynamic spike in a manner to be described.

Since the invention is in the nozzle, the following description will describe the nozzle's construction and operation. The nozzle is shown in FIGURES 2, 3 and 4.

Fuel and oxidizer are fed into the nozzle through injector **18**. Fuel from tank **10** is fed into the nozzle through injector **18** by means in the form of a fuel inlet pipe **22** that leads into fuel manifold **24**. The fuel passes through openings **26** into combustion area **28**. Oxidizer is fed into the nozzle and into combustion area **28** by means of an oxidizer inlet pipe **30** that leads into oxidizer manifold **32**. The oxidizer then passes through a plurality of hollow tube members **34** that empty into combustion area **28**. Tubes **34** pass through manifold **28** to prevent the oxidizer from mixing with the fuel until both reach the combustion area. This is important where the propellants are hypergolic and would ignite on contact.

The velocity of the combusted propellant is then increased to the supersonic level. The propellant from combustion area **28** flows through throat portion **36** defined by inwardly approaching wall surfaces **38**, **40** where the throat increases the velocity of the propellants to the supersonic level. The combusted propellants are then directed, by curved wall extension **42**, downwardly from the throat portion and ejected as a supersonic propulsion stream **43**.

The subsonic stream is ejected by inner injector **20**. Inner injector **20** is circular and is carried within outer annular injector **18**. Means are provided to bleed a selected amount of combusted propellant from combustion area **28** of the outer injector and feed it to inner injector **20**. Combusted propellant flows to inner injector **20** through bleed openings **44** in wall **38**, then through a connecting passage **46** formed by walls **48** and **50**, and then into manifold **52** formed by walls **54**, **56** and side wall **42**. The propellant is then ejected out of the injector through a plurality of openings **58** in wall **56**.

It will be noted that propellant fed to inner injector **20** does not pass through a throat. This propellant in fact expands in manifold **52** and remains at a subsonic velocity level and it is thus ejected as subsonic velocity stream **59**, and formed into an *aerodynamic conical spike* by the action of supersonic velocity stream **43**.

The numbers and sizes of bleed openings **44** in annular injector **18** are chosen to provide a selected amount of bleed off. Where a rocket is constructed for reuse, bleed openings **44** can be provided with adjustable valves (not shown) to vary the amount of propellant for a particular mission.

In terms of relative amount of fluid flow passing through the outer and inner injectors, it has been determined that satisfactory results can be obtained where about 5% of the propellant stream is ejected from the inner injector, and the remaining 95% ejected from the outer injector, or a ratio of 1 in 20. It will be apparent that this amount can vary widely depending on such factors as for example relative velocities, pressures and masses of the fluid streams.

While inner injector's wall **56** is shown as dome shaped, this shape does not form the aerodynamic conical spike and is not necessary to the invention. The aerodynamic conical spike is formed by the coaction of the supersonic and subsonic velocity propulsion streams. The spike would be formed just as well if wall **56** were flat.

While propulsion fluid for inner injector **20** is obtained from combustion area **28**, it can be obtained from other sources. This is not critical to the invention. As an example, the subsonic propulsion fluid may be obtained from the turbine exhaust (not shown), or a separate gas generator (not shown).

It will be noted that curved wall **42** does not extend beyond a plane that would pass through wall **40** forming the end of the nozzle. As a result the nozzle is quite compact and uses up little room.

Operation

Propellants are fed to outer injector **18** of nozzle **14** through fuel inlet **22** and oxidizer inlet **30**. They are then combusted in combustion area **28**. A major proportion of the combusted propellants then pass through a throat portion **36** where the velocity is increased to the supersonic level and are ejected from the nozzle.

A small portion of the combusted propellants are bled off through openings **44** in combustion area **28** and fed to inner injector **20** through passage **46** which leads into manifold **52** of the inner injector. This bled off propellant expands in manifold **52** thus lowering its temperature. The bled off propellant is then ejected through openings **58** in manifold **52** without passing through a throat so its velocity is in the subsonic level.

On ejection, subsonic stream **59** is exposed to the high temperature radiation from contiguous supersonic stream **43**, and is compressed by the expanding supersonic stream. This heats and speeds up the flow of the subsonic stream and ultimately increases the effective use of the subsonic stream by providing increased thrust. In this flow, a boundary surface **60** is formed between subsonic and supersonic fluid streams **43, 59** where the static pressures of both are equal, and forms the subsonic stream into an aerodynamic conical spike. This boundary **60** converges in the rear direction (downward in FIG. 3) to a location where an aerodynamic throat is formed by supersonic stream **43** and causes the subsonic stream to pass through the "throat" where its velocity will become sonic and then supersonic. This coaction of the two streams causes the subsonic stream to produce increased pressure on the base of the inner injector.

As mentioned previously, thrust is derived as a result of pressures produced on the inner and outer injectors, and the momentum flux of the main supersonic and subsonic streams.

It should be understood that it is not intended to limit this invention to the herein disclosed form, but that the invention includes such other forms or modifications as are embraced by the scope of the appended claims.

What is claimed is:

1. A method of providing thrust for a spike-free, shroud-free propulsion nozzle, comprising:

the step of expelling a first propulsion stream at a subsonic velocity in a selected amount from said nozzle;

the step of expelling a second propulsion stream at a supersonic velocity from said nozzle; and,

the step of directing said supersonic propulsion stream contiguous to said subsonic propulsion stream, to form said subsonic propulsion stream into the shape of an aerodynamic conical spike, and also forming an aerodynamic throat to increase the velocity of said subsonic stream to a supersonic level.

2. A method as set forth in claim **1** including the step of expelling said first subsonic propulsion stream at a flow rate that is $\frac{1}{20}$ of the flow rate of said second supersonic propulsion stream.

3. In a spike-free, shroud-free propulsion nozzle, the combination comprising:

a first injector constructed to eject a first propulsion stream at a subsonic velocity;

a second injector circumscribing said first injector and constructed to eject a second propulsion stream at a supersonic velocity; and,

structure to direct said second propulsion stream contiguous to said first subsonic propulsion stream to form said first propulsion stream into an aerodynamic conical spike.

4. In a spike-free, shroud-free propulsion nozzle, the combination comprising: support structure;

an annular injector carried by said support structure;

said annular injector constructed with a throat portion to impart supersonic velocity flow to said propulsion stream;

an inner injector, carried by said annular injector, within the area circumscribed by said annular injector;

means to feed a propulsion stream in a selected amount to said inner injector;

said inner injector constructed with an outlet to impart subsonic velocity flow to said propulsion stream; and,

said annular ejector's throat including structure positioned to direct said supersonic velocity propulsion stream contiguous to said subsonic velocity propulsion stream to form said subsonic velocity stream into an aerodynamic conical spike.

5. In a propulsion nozzle, the combination comprising: support structure;

an annular injector carried by said support structure;

said annular injector constructed with a combustion area leading to a throat portion;

means to feed propellants to said annular injector's combustion area to create a propulsion stream;

said throat portion of said annular injector constructed to impart supersonic velocity flow to said propulsion stream;

an inner injector, carried by said annular injection, within the area circumscribed by annular injector;

means to feed a propulsion stream in a selected amount to said inner injector;

said inner injector constructed with an outlet to impart subsonic velocity flow to said propulsion stream; and,

said annular ejector's throat including structure positioned to direct said supersonic velocity propulsion stream contiguous to said subsonic velocity propulsion stream, to form said subsonic velocity fluid propulsion stream into an aerodynamic conical spike and also forming an aerodynamic throat to increase the velocity of the subsonic stream to a supersonic level.

6. A device as set forth in claim **5** wherein said nozzle is constructed to eject 5% of the propulsion stream from said inner injector and 95% of the propulsion stream from said annular injector.

7. In a propulsion nozzle, the combination comprising: support structure;

an annular injector carried by said support structure;

said annular injector constructed with a combustion area leading to a throat portion, said combustion area and throat portion including a common end wall;

means to feed propellants to said annular injector's combustion area to create a propulsion stream;

said throat portion of said first injector constructed to impart supersonic velocity to flow to said propulsion stream;

an inner injector, carried by said annular injector, within the area circumscribed by annular injector;

means connected to said annular injector to feed a propulsion stream in a selected amount to said inner injector;

said inner injector constructed with an outlet to impart subsonic velocity flow to said propulsion stream and,

said annular ejector's throat including structure that ends short of a plane passing through said end wall and positioned to direct said supersonic velocity propulsion stream contiguous to said subsonic velocity propulsion stream to form said subsonic velocity propulsion stream into an aerodynamic conical spike, and also forming an aerodynamic throat to increase the velocity of said subsonic stream to a supersonic level.

8. In a propulsion nozzle, the combination comprising: support structure;

an annular injector carried by said support structure;

said annular injector constructed with a combustion area leading to a throat portion;

means to feed propellants to said annular injector's combustion area to create a propulsion stream;

said throat portion of said first injector constructed to impart supersonic velocity to flow of said propulsion stream;

an inner injector, carried by said annular injector, within the area circumscribed by annular injector;

means to obtain combusted propellant from said annular injector's combustion area and to feed a selected amount to said inner injector;

said inner injector constructed with an outlet to impart subsonic velocity flow to said propulsion stream; and,

said annular ejector's throat including structure positioned to direct said supersonic velocity propulsion stream contiguous to said subsonic velocity propulsion stream, to form said subsonic velocity propulsion stream, into an aerodynamic conical spike, and also forming an aerodynamic throat to increase the velocity of said subsonic stream to a supersonic level.

9. A device as set forth in claim **8**, wherein said means to obtain said combusted propellant for said inner injector includes a passage interconnection between said combustion area and inner injector, and said combustion area and inner injector are provided with openings to permit flow of combusted propellant in a selected amount from said combustion area to said inner injector.

10. In a propulsion nozzle:

means to eject 5% of the propulsion stream centrally from the propulsion nozzle at a subsonic velocity;

means surrounding said first means, to eject 95% of the propulsion stream at supersonic velocity, and;

means to direct said supersonic propulsion stream contiguous to said subsonic propulsion stream, to form said subsonic velocity propulsion stream into an aerodynamic conical spike.

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