ROCKET ENGINE COOLING SYSTEM

Inventors: George S. Sutherland, Mercer Island, Wash.; Donald L. Emmons, Issaquah, both of Wash.

Assignee: Rocket Research Corporation, Redmond, Wash.

Filed: July 2, 1970

Appl. No.: 52,020

U.S. Cl. 60/267, 204, 206, 207, 60/224
Int. Cl. F02k 9/02, F02k 11/02
Field of Search 60/260, 204, 206, 207, 60/224, 39.46, 39.51 R, 39.66, 261, 37, 39.12, 165/105

References Cited

UNITED STATES PATENTS

3,024,606 3/1962 Adams

3,149,460 9/1964 Rocca
3,232,048 2/1966 Stockel
3,493,177 2/1970 Bromberg

Primary Examiner—Douglas Hart
Attorney—Graybeal, Barnard, Uhlir & Hughes

ABSTRACT

An oxidizer, such as nitrogen tetroxide or fluorine, is introduced into a reaction chamber in the path of the decomposition products of hydrazine and reacts therewith to form high temperature, high thrust propulsive gases. A heat pipe surrounds the reaction chamber and includes a wick saturated with a volatile liquid, such as liquid lithium, which liquid is vaporized thereby removing heat from the chamber wall. The vaporized fluid is directed through a heat exchanger and is therein condensed back into a liquid state.

13 Claims, 5 Drawing Figures
ROCKET ENGINE COOLING SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention pertains to techniques for cooling the chamber walls of rocket engines using heat pipe principles. More particularly, it relates to two-stage bipropellant engines in which low temperature products of the first stage are reacted with an oxidizer in the second stage, and to the use of a liquid propellant or some of the low temperature products of the first stage in a heat exchanger to condense the coolant within the heat pipe.

2. Description of the Prior Art

In a heat pipe cooling system a liquid coolant is carried in a wick and is directed into a high temperature zone in which the coolant is vaporized thereby removing heat from the high temperature source. The vaporizer coolant then flows to a heat exchanger where it is condensed back into a liquid. The liquid returns to the high temperature zone by moving through the wick under the influence of capillary action. Reference is made to the detailed explanation of the heat pipe principle presented in the May, 1968 issue of Scientific America, commencing at page 38.

SUMMARY OF THE INVENTION

This invention advantageously combines heat pipe cooling principles with a two-stage hydrazine engine concept to provide a compact, high performance bipropellant rocket engine capable of long duration operation.

According to the invention the hydrazine is decomposed in a first stage reaction chamber with the said products of decomposition being used in a heat exchanger to condense a vaporizer coolant in a heat pipe. The latter is employed to cool a second stage reaction chamber in which the decomposed hydrazine is reacted with an oxidizer producing high temperature propulsive gases.

In another form of the invention a liquid propellant is used to condense the vaporized heat pipe coolant.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a longitudinal sectional view of a two-stage rocket engine embodying certain heat pipe cooling principles of this invention;

FIG. 2 is a fragmentary sectional view taken through the heat exchanger substantially along line 2—2 of FIG. 1;

FIG. 3 is a fragmentary sectional view transversely of the engine, taken substantially along line 3—3 of FIG. 2;

FIG. 4 is a longitudinal sectional view of a modified form of engine having a film cooled chamber and a heat pipe cooled nozzle; and

FIG. 5 is a longitudinal sectional view of another modified form of engine using both film and heat pipe cooling for both the reaction chamber and the nozzle.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The rocket engine of FIG. 1 comprises a reaction chamber wall 12 of stainless steel or the like terminating at its downstream end in a nozzle section 14. The chamber is divided internally into a first stage decomposition chamber 16 and a second stage reaction chamber 17, axially separated by a perforated wall 18. A fuel injector 20 introduces liquid hydrazine into the first stage reaction chamber 16. The hydrazine reacts with a catalyst, such as Shell 405, identified by the reference character 22, to form products of decomposition at a temperature of about 1,600°F. For higher thrust, these products of decomposition are reacted with an oxidizer (e.g. nitrogen tetroxide, N₂O₄; fluorine; oxygen; flex (a combination of fluorine and oxygen); that is introduced into the second stage reaction chamber 17 by an oxidizer injector 24. The reaction occurring between the oxidizer and the products of decomposition of the hydrazine produces an elevated temperature in the second stage reaction chamber (e.g. approximately 5,000°-7,000°F).

According to the invention a heat pipe HP is employed for removing some of the heat energy from the chamber walls so that conventional wall materials may be used. The heat pipe HP includes a tubular evaporator section 32 that may conform in shape to the outline of the rocket engine. It also includes a condenser section 34 which in the preferred embodiment is located between the oxidizer injector 24 and wall 18, within the flow path of the products of decomposition exiting from the first stage reaction chamber 16.

General heat pipe principles, as discussed in the aforementioned Scientific American article, are employed. The two sections 32 and 34 are joined to form a unitary evacuated chamber. Section 32 is defined by a casing 36 (preferably also made of stainless steel or the like). A wick 38 is housed within casing 36 and is shown to be in contact with the inner wall of the casing 36 which in turn is in contact with the portion of thrust chamber wall 12 which surrounds the second stage reaction chamber 17.

Preferably, the wick is formed of laminates of stainless steel screen wire (120 X 120 mesh, for example) that are spot welded together into three or four layers. However, as discussed in the aforementioned article, any material that provides sufficient numbers of small passages to provide efficient capillary action and which is compatible with the coolant is sufficient.

The heat pipe working fluid may be a liquid metal such as lithium, which has an evaporation temperature of 2,180°F at 5 psia. The vaporization temperature may be varied by varying the partial vacuum pressure in the heat pipe HP. The liquid coolant carried in the wick travels toward the nozzle end of the rocket engine and is vaporized by the heat transferred from the high temperature combustion gases. The coolant vapor then flows in the direction of the arrows 40 toward the condenser section of the heat pipe HP.

The preferred form of the condenser section 34 of the heat pipe HP is best shown in FIGS. 2 and 3. It is a tube-type heat exchanger comprising a plurality of parallel, spaced apart tubes 42 each one of which is a continuation of the heat pipe. By way of typical example, for a 1,000 pound thrust engine having a chamber pressure of approximately 100 psia and a combustion temperature of approximately 5,510°F, a seven row, seven tube per row heat exchanger is theoretically calculated to be preferred. The hydrazine flow rate for these parameters is approximately 1.3 pounds per
second with an oxidizer (nitrogen tetroxide) flow rate of approximately 1.8 pounds per second. The temperature rise of the products of decomposition through the heat exchanger is approximately 180°F, and it experiences a pressure drop of approximately 14.5 psi. The coolant flow rate (liothium) is approximately 0.0175 pounds per second and the heat transfer rate to the heat pipe at the chamber walls is approximately 147 btu per second. The calculated heat exchanger conductance of the preferred embodiment is 0.307 btu per second degrees Rankin.

It is necessary, of course, to connect the wick 38 in the condenser section 34 with the wick in the vaporization section 32. As best shown in FIG. 3, this is accomplished by welding the tubes of the heat exchanger to the thrust chamber wall 12. The wick thus provides for a liquid path and the open space around the wick forms a vapor path. The vaporized coolant is condensed to the liquid state in heat exchanger 42 and by capillary action passes through the wick 38 into the vaporization section.

In the embodiment shown in FIG. 4, the products of decomposition are again used to condense the coolant in the heat pipe HP'. One of the difficulties of the embodiment of FIGS. 1-3 is the high pressure in the thrust chamber may cause leakage into the heat pipe casing unless the welding or other connections around the heat exchanger tubes are adequate. In the form of engine shown in FIG. 4, however, this difficulty is eliminated by providing the heat exchanger externally of the thrust chamber. Suitable ducting 44 is employed to remove a portion of the products of decomposition and direct it into a heat exchanger 46 which is in heat transfer relationship with the condenser section 48 of the heat pipe HP'. In this form the vapors which leave the inner wick zone 38 surrounding the nozzle 14' condense into the outer wick zone 38' positioned next to passageway 46. In this form of engine propulsive gases which are removed for use as a condensing medium are not available as a propellant to react with the liquid oxidizer. However, the removed gases may be delivered through nozzles N for use as monopropellant thrusters to supplement the thrust produced in the main engine. Of course, other applications may also be found for the propulsive gases after they leave the heat exchanger.

In the embodiment of FIG. 4 the bipropellant reaction region or zone 47 is surrounded by annular zone 49 of decomposed gases from the catalyst bed 16. Although not shown, these same zones 47, 49 are formed during operation of the embodiment shown by FIGS. 1-3. The relatively cooler outer zone 49 lessens the cooling problem by partially protecting the chamber walls from the relatively high temperature gases in zone 47. Other forms of removing the heat energy at the condenser section 48, not shown, include (1) use of one or both of the liquid propellants to absorb heat in the condenser section 48 prior to entering injector 20 and/or 24; and (2) providing sufficient surface area of the condenser section 48 to radiate the thermal energy to the ambient environment.

In the embodiment shown in FIG. 5 the heat exchanger is supplied through line 50 with a liquid propellant P₁ or P₂ as the condensing medium. The liquid propellant P₁ or P₂ may be one of the two propellants of a bipropellant rocket or it may be the liquid propellant used with the second thrust level stage of an engine such as in the embodiments of FIGS. 1-4. In this embodiment the absorbing wick region 52 is shown located upstream of the injector head 54, as a colinear extension of the wick region 56 which immediately surrounds the reaction chamber wall 58 and nozzle 60.

The propellants are injected into the combustion chamber with a fraction of one of the propellants being injected along the chamber wall 58, thereby providing a barrier to reduce heat transfer from the combustion gases to the heat pipe wall 56. The propellant is delivered as a liquid film or sheath 64 along the inner surface of chamber wall 56. It is soon vaporized and becomes a vaporous film 66 shown to continue flowing along walls 58 and 60.

What is claimed is:

1. A rocket engine having a thrust chamber comprising:
   a primary reaction zone within said chamber having a propellant which forms primary propulsive gases at a relatively low temperature;
   a secondary reaction zone in the path of said primary discharge gases;
   an oxidizer inlet in said path for introducing an oxidizer into said primary discharge gases, said oxidizer and said primary discharge gases reacting to form secondary propulsive gases at a temperature substantially greater than said primary propulsive gases;
   means for cooling the thrust chamber walls surrounding said secondary reaction zone, said means including a liquid coolant; and
   heat exchanger means disposed to be contacted by at least a portion of said primary propulsive gases and communicating with said cooling means for receiving said coolant, whereby the relatively low temperature primary propulsive gases are used to cool the coolant.

2. The rocket engine defined by claim 1, wherein said cooling means includes an evacuated heat pipe having a wick and said coolant includes a fluid that is a liquid at the temperature of said primary propulsive gases and vaporizes at the temperature of said secondary propulsive gases.

3. The rocket engine defined by claim 2, wherein said coolant includes lithium and said propellant includes hydrazine.

4. The rocket engine defined by claim 3, wherein said oxidizer is nitrogen tetroxide, fluorine, oxygen, or combinations of fluorine and oxygen.

5. The rocket engine defined by claim 1, wherein said primary propulsive gases include the products of a catalytically decomposable monopropellant.

6. The rocket engine defined by claim 2, wherein said heat exchanger means includes a plurality of tubes disposed within said thrust chamber each tube containing an extension of said wick and an open vapor channel.

7. The rocket engine defined by claim 2, wherein said heat exchanger is located externally of said thrust chamber and further including duct means for directing at least a portion of said primary propulsive gases out of said thrust chamber.
8. The rocket defined by claim 7, wherein said primary propulsive gases are passed through a monopropellant thruster after leaving said heat exchanger.

9. A method of cooling the chamber walls of a bipropellant engine comprising:
   generating a relatively low temperature, low thrust fuel gas within a reaction chamber;
   introducing an oxidizer into the path of said fuel gas for combustion into a higher temperature, higher thrust propulsive gas and as a result heating the chamber walls;
   cooling said chamber walls by circulating a coolant there around; and
   cooling said coolant by passing the coolant through said propulsive fuel gas upstream of said oxidizer.

10. The method defined by claim 9, wherein said step of generating fuel gas within said chamber includes catalytically decomposing hydrazine.

11. The method of claim 9, wherein said coolant is passed indirectly through said propulsive fuel gas within said chamber.

12. In a system wherein a chemical fuel component of fluid form is consumed and a heated article is cooled by a recirculated fluid coolant, the method comprising:
   decomposing the fuel component to form decomposition products;
   passing the coolant in indirect heat exchange relationship with the article to be cooled;
   then passing the heated coolant in indirect heat exchange relationship with at least a portion of the decomposition products of said fuel component, so that the latter can receive heat from and thus cool the former; and
   delivering the heated decomposition products of said fuel component into a combustion chamber for same while at the same time recirculating the now cooled coolant back into indirect heat relationship with said article.

13. A method of cooling the chamber walls of a bipropellant engine comprising:
   generating a relatively low temperature, low thrust fuel gas within a reaction chamber;
   introducing an oxidizer into the path of a first portion of said fuel gas for combustion into a higher temperature, higher thrust propulsive gas and as a result heating the chamber walls;
   cooling said chamber walls by circulating a coolant thereabout; and
   cooling said coolant by directing a second portion of said fuel gas out from the reaction chamber and into indirect heat exchange with said coolant.