MEMORANDUM

TO: KSI/Scientific & Technical Information Division
   Attn: 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. : 3,460,759
Corporate Source : Lewis Research Center
Supplementary Corporate Source :
NASA Patent Case No. : XLE-04857
A rocket combustion chamber including a downstream convergent-divergent throat section and having an inner wall of high temperature material, an outer structural wall spaced from the inner wall, a plurality of regenerative coolant tubes of constant cross-section longitudinally disposed in the space between the walls, and a variable thickness, powdered-ceramic heat barrier also disposed in such space and enclosing the coolant tube and maintained at a temperature lower than the inner wall. A further object of the invention is to provide a regenerative cooling system for rocket combustion engines wherein the heat flux to the coolant is substantially reduced. Therefore, it is an object of the invention to provide a regenerative cooling system for rocket combustion engines wherein the heat flux to the coolant is substantially reduced.
generative cooling system for rocket combustion engines that is simple in construction, inexpensive to manufacture, and highly effective in operation.

Briefly, the foregoing objects are accomplished by the provision of a rocket thrust chamber including an annular, hollow, enclosure with an upstream cylindrical combustion chamber section, a contiguous downstream convergent-divergent throat section having a cross-sectional area smaller than that of the combustion chamber, and an exhaust nozzle section diverging from the throat section. The enclosure includes an annular refractory inner wall of high temperature material, an annular outer structural wall spaced from the inner wall to form a space therebetween, a plurality of longitudinally disposed regenerative coolant tubes of constant cross-section positioned in the space between such walls in side-by-side relation and having circulating fluid coolant therein, and a coating variable-thickness ceramic heat barrier also disposed in the space between the walls and encasing the coolant tubes therein. The coolant tubes are circumferentially spaced apart, at the combustion chamber section and at the exhaust nozzle section and are contiguous at the throat section. At the combustion chamber section and at the exhaust nozzle section, the tubes are circumferentially connected together by heat dispensing fins disposed between and secured to the tubes. The ceramic heat barrier is of increased thickness at the throat section. Such heat barrier may be formed, for example, from a powdered ceramic such as aluminum oxide, or magnesium oxide. Foamed ceramics or certain foamed metals may also be used.

With this structure, coolants with relatively low cooling capacity may be employed. For example, light hydrocarbon fuels may be employed.

With this construction, inexpensive standard fabrication methods may be employed since the coolant tubes are of constant cross-section. Thus, the invention provides regenerative cooling at substantially reduced cost and fabrication time.

Other objects and advantages of the invention will be apparent from the following description taken in conjunction with the drawings wherein:

FIGURE 1 is a broken front elevational view of a rocket combustion chamber constructed in accordance with the invention;

FIGURE 2 is a sectional view taken along the line 2-2 of FIGURE 1;

FIGURE 3 is a sectional view taken along the line 3-3 of FIGURE 2; and

FIGURE 4 is a sectional view taken along the line 4-4 of FIGURE 2.

Although the invention is shown and described herein with respect to its application to rocket combustion chambers, it may be employed on any type of combustion chamber using regenerative cooling.

Referring to the drawings, there is shown a rocket thrust chamber, in the form of an annular hollow elongated enclosure, generally designated as E, and including an upstream cylindrical combustion chamber or section 10, a contiguous downstream convergent-divergent throat section 12, and an exhaust nozzle section 14 diverging from and contiguous at the throat section 12. The throat section 12 has a cross-sectional area smaller than that of the combustion chamber 10.

The wall of the enclosure E comprises an annular refractory inner wall 16 of high temperature material, an annular outer structural wall 18 spaced from the inner wall to form a space therebetween, a plurality of longitudinally disposed regenerative nontapered coolant tubes 20 positioned in such space between the inner and outer walls in side-by-side relation and having circulating fluid coolant therein, and a coating variable thickness heat barrier 22 also disposed in said space between the inner and outer walls and enclosing said coolant tubes. The outer wall 18 may be formed of stainless steel. Suitable associated coolant manifolds (not shown) may be affixed at the inlet and the outlet ends of the tubes 20 to direct coolant flow therethrough in a conventional manner.

The coolant tubes 20 are circumferentially spaced apart at the combustion chamber section 10 (FIGURE 3) and at the exhaust nozzle section 14. At the throat section 12, the circumferential spacing of such tubes is contiguous, as shown in FIGURE 4. Thus, circumferential spacing between the tubes varies with the contour of the engine. This structure permits the use of coolant tubes 20 of constant cross-sectional area throughout the entire length of the thrust chamber, thereby permitting simple and inexpensive fabrication techniques. The tubes 20 may be formed of any suitable material such as, for example, stainless steel.

At the combustion chamber section 10 and the exhaust nozzle section 14 wherein the tubes 20 are spaced apart, such tubes may be circumferentially connected together by heat-dispensing fins 24 disposed between and secured to the tubes as shown in FIGURE 3. Such fins 24 function to absorb heat from the heat barrier 22 and transfer it to the coolant in the coolant tubes 20.

The heat barrier 22 may be formed of any suitable heat shielding materials such as foamed or powdered ceramics or certain foamed metals. Aluminum oxide and magnesium oxide may be effective in this application. In the preferred form, the heat barrier 22 is of increased thickness in the throat area section 12 where higher operational temperatures are encountered.

With the above structure, fluid (rocket fuel) coolants having relatively low coolant capacities may be employed. For example, light hydrocarbon fuels may be used.

The inner surface of the inner wall 16 may be covered with a suitable oxidation resistant coating 26.

With the above structure, wherein a heat barrier 22 plus coolant tubes 20 with constant cross-sectional area are employed, a simple and highly inexpensive system of regenerative cooling is provided. The invention effects a simple lower cost fabrication method for regeneratively cooled rocket thrust chambers and provides effective cooling with coolants having low cooling capability. With the preferred construction, the heat flux through the thrust chamber wall is a function of a total thermal resistance of the wall consisting of the gas side film resistance, the refractory metal wall resistance, the thermal barrier material resistance, the cooling fluid transport resistance. The design variable used to control inner wall temperature and heat flux is thermal barrier thickness. In one form of the invention, the tube diameter and thermal barrier thickness is such that the inner wall temperature will be the maximum allowable for the oxidation resistant coating 26. Such condition will occur at or near the throat 12. At other points of the chamber the heat barrier thickness may be adjusted to maintain a somewhat lower wall temperature.

The invention has many advantages over previous regenerative cooling structures such as:

(a) The pressure seal needed to maintain the hot combustion gases is provided by a solid, contoured, refractory metal inner wall 16 rather than by a brazed assembly of tapered tubes or channels. The simplicity, reliability, and ease of manufacture of this design are manifest.

(b) The regenerative cooling tubes 20 have constant cross-sectional area and are simply shaped to conform to the desired thrust chamber contour. This eliminates the costly and intricate procedures of tapering the tubes to provide a precise flow area at each axial station.

(c) Control of wall temperature and heat flux is accomplished by initial sizing of coolant tubes 20 and by varying the heat barrier 22 thickness. Additional control is provided by the use of fins 24 between the tubes.
at the injector (10) and nozzle (14) ends where they are spread apart.

(d) The use of a heat barrier material 22 and high temperature inner wall material 16 makes possible a large reduction in wall heat flux. This facilitates the use of marginal coolants, such as the light hydrocarbon fuels and also extends the range of application of other coolants, such as RP-1. The invention may also have application for throttling engines in which the coolant jacket discharge temperature tends to rise as the chamber pressure decreases.

Thus, the invention features the use of a regenerative thrust chamber structure, wherein the wall temperature is controlled by varying the thickness of the heat barrier material 22 rather than by coolant passage area change (as in prior structures), in conjunction with a refractory metal inner wall 16 which allows the use of higher wall temperatures than are allowable with more common materials of construction. The heat barrier material 22 is confined within the annular space between the inner wall 16 and outer wall 18 structures.

The terms and expressions which have been employed are used as terms of description, and not of limitation, and there is no intention, in the use of such terms and expressions, of excluding any equivalents of the features shown and described or portions thereof, but it is recognized that various modifications are possible within the scope of the invention claimed.

What is claimed is:

1. In a rocket thrust chamber including an annular elongated hollow enclosure with an upstream cylindrical combustion chamber section, a contiguous downstream convergent-divergent throat section having a cross-sectional area smaller that that of the combustion chamber section, and an exhaust nozzle section diverging from and contiguous with the throat section, said enclosure comprising:
   (a) an annular refractory inner wall of high temperature material,
   (b) an annular outer structural wall spaced from the inner wall to form a space therebetween,
   (c) a plurality of longitudinally disposed regenerative coolant tubes of constant cross-section positioned in said space between said inner and outer walls in side-by-side relation and having circulating fluid coolant therein, said coolant tubes being contiguous at the throat section of the thrust chamber and circumferentially spaced apart at the combustion chamber section and at the exhaust nozzle section,
   (d) heat-dispensing fins disposed between and secured to said circumferentially spaced tubes at said combustion chamber section and said exhaust nozzle section for circumferentially connecting the same,
   (e) and a coating variable-thickness heat barrier also disposed in said space between said walls and encaising said coolant tubes.

2. The structure of claim 1 wherein said coolant tubes are formed of stainless steel.