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FLUID COOLED HOMOGENEOUS CERAMIC ROCKET MOTOR WALL STRUCTURE

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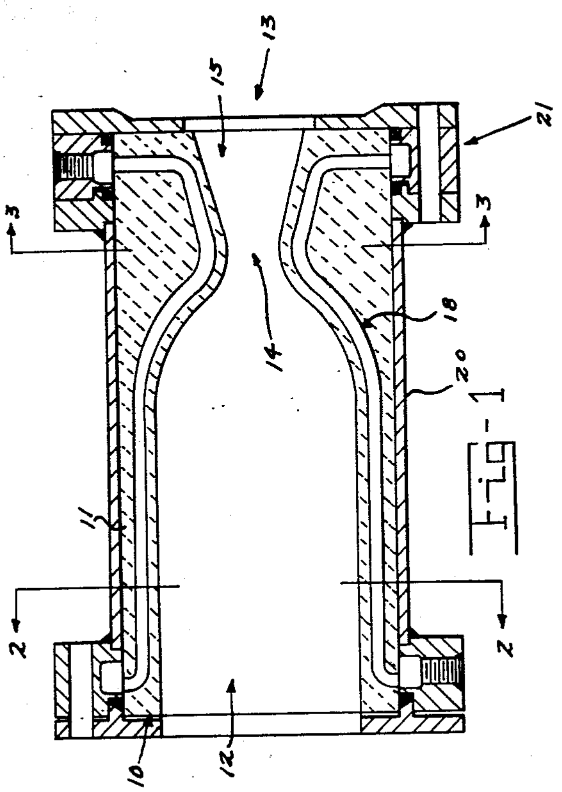

Fig-1

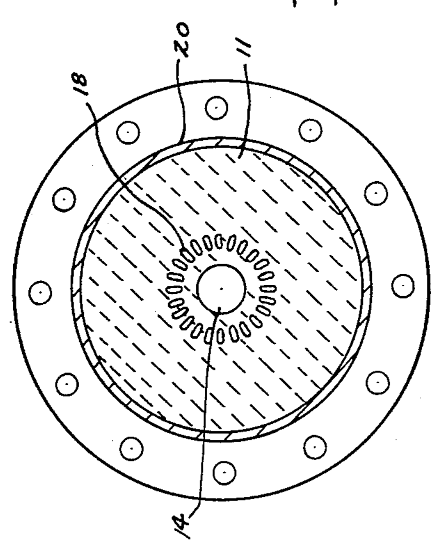

Fig-3

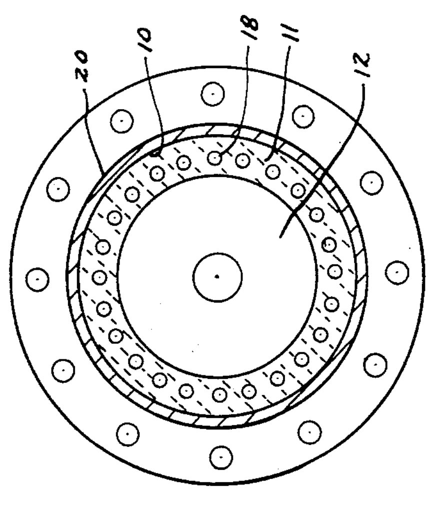

Fig-2

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FLUID COOLED HOMOGENEOUS CERAMIC ROCKET MOTOR WALL STRUCTURE

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2 Claims. (Cl. 60—35.6)

The present invention relates to a ceramic body or wall structure to confine a combustion chamber and exhaust for high temperature firing opertions in which a lightweight envelope is required for long duration, continuous service. More particularly, the present invention relates to a homogeneous, ceramic rocket motor wall assembly of the regenerative cooled type and a process for making the same.

In the manufacture and development of rocket motors, the severe conditions imposed by high temperatures and pressures developed within the combustion chamber and nozzle portion require that particular attention be given to the construction of the lining and wall structure of the rocket motor. The wall structure must be highly resistant to thermal shock, the high pressures exerted against the walls, and to the high corrosive and erosive properties of the hot expanding gases. In addition, in order to afford continuous, durable service through repeated firing operations, it is necessary that the wall structure possess high thermal conductivity and in such a way that a steady state temperature can be attained notwithstanding a tendency of the temperature within the wall structure to build up over a succession of rocket firings; also, a very low coefficient of thermal expansion should be combined with high thermal conductive properties to maintain a uniform structure over repeated firing operations.

Metallic alloy wall assemblies have been successfully incorporated in rocket motor construction and have been found to include most of the properties as required: High thermal conductivity and adequate removal of the heat is achieved in providing for the regenerative cooling of the walls by circulating coolant through passages extending the length of the rocket motor. At the present time, however, the use of metallic alloys is expensive and results in a comparatively heavy wall construction which exhibits poor thermal expansion properties under the high temperature and pressure conditions present. As a result, efforts have been made to replace the metallic alloys commonly in use with newly developed refractory materials or ceramics which are lightweight, cheap and combine the high thermal conductivity and low thermal expansion characteristics desired. Also, ceramic materials are in general much easier to fabricate and have higher melting points than metallic alloys.

The main obstacles attending the use of ceramic materials are their low strength characteristics and inadequate cooling of the motor wall. To overcome these obstacles, it has been proposed to tightly incase a wall structure within an outer metallic shell so that stresses developed within the combustion chamber will be distributed to the outer shell. In order to provide uniform and efficient cooling of the motor wall, evaporative cooling has been introduced in which a porous material is utilized as the wall structure to permit uniform distribution of a coolant through the porous layer surrounding the combustion chamber and nozzle portions to thereby absorb heat by evaporation. To successfully apply evaporative cooling,

however, it is necessary to provide some means whereby the coolant may be uniformly and steadily injected into the innumerable pores surrounding the thrust chamber. It has been proposed to imbed a perforated ring within the chamber wall and force coolant through the perforations into the pore spaces; another method is to extend perforated liners throughout the motor wall as applied in refractive cooling and to circulate coolant through perforated liners. In utilizing perforated liners or rings the coolant is insulated to a certain extent and thus does not distribute itself through the perforations in proportion to the amount of coolant evaporated; also, the perforations often become clogged, and unless a sufficiently high pressure is developed within the linings, the coolant will tend to flow past the perforations into the injection chamber.

Accordingly, to obviate the difficulties above mentioned in the construction and development of rocket motor wall assemblies, especially those related to the efficient and uniform cooling of the motor wall, the present invention has as its primary purpose the provision of a low cost, unique casting process for the construction of a rocket motor wall structure utilizing a specially selected ceramic or refractory material of high thermal conductivity and a near zero coefficient of thermal expansion; wherein the motor wall is capable of reaching a steady state temperature condition permitting continuous, durable service through repeated firing operations.

Another object is to provide a rocket motor wall assembly highly resistant to thermal shock and to the corrosive and erosive properties of the high temperature combustion gases developed within the thrust chamber.

Another object is to provide a rocket motor wall assembly which furnishes means for the combined refractive and uniform evaporative cooling of the rocket motor wall in such a way as to attain optimum transfer and absorption of the heat developed by the combustion gases.

Another object is to provide a rocket motor wall assembly composed of a homogeneous, porous, ceramic body forming a continuous inclosure so as to define a combustion chamber and nozzle region of a rocket motor capable of consistent, durable performance over extended periods of time.

A further object is the provision of a simple, low unit cost process requiring a minimum number of steps in the casting and formation of a porous, ceramic motor wall enclosing means for the direct transmission of coolant-propellant uniformly throughout the length of the porous wall structure for the refractive and evaporative cooling thereof.

It is still a further object to provide a process for making a ceramic rocket motor wall capable of utilizing newly developed refractory materials to form a lightweight, inexpensive wall structure.

In accordance with the preceding objects and purposes as set forth, the chamber assembly is made up of homogeneous, ceramic casting of porous composition which incloses a combustion chamber and nozzle portion rearwardly extending from the combustion chamber and includes a plurality of ports or passageways radially spaced about the thrust chamber, each passageway following the contour of the thrust chamber to carry coolant-propellant for diffusion into the surrounding porous formation of the chamber assembly which forms the walls of the passageway. The unique process for constructing the above assembly is particularly concerned with the formation of the contoured passageways by bending and shaping a number of elongate rods having a low melting point to form the desired figuration of each passageway, forming a porous mold within which is provided a cavity shaped in the desired contour of the chamber assembly, aligning the rods within the mold to conform to the desired passageway arrangement, spacing core sections within the aligned rods to define the contour of the combustion chamber and nozzle, filling the mold cavity with a specially selected porous refractory material, followed by drying and heating the solid casting to burn out the low melting point rods to thereby form a passageway providing direct contact of the coolant with the porous wall formation.

For a more complete understanding of the objects and purposes of the invention and of the nature thereof reference is made to the following detailed description taken in connection with the accompanying drawings, in which like reference characters refer to like parts in the several figures.

Fig. 1 is a side section view of the chamber wall assembly showing the disposition of the passageway within the wall assembly.

Fig. 2 is a cross sectional view taken on line 2—2 of Fig. 1 showing the spacing of the passageways within the wall assembly.

Fig. 3 is a cross sectional view taken on line 3—3 of Fig. 1 showing the flat shape of the passageways in the throat area.

Referring more particularly to the drawings, there is shown in Fig. 1 a chamber wall assembly **10** composed of a low expansion, heat resistant and porous ceramic wall formation having a cylindrical outer surface **11**, the inner periphery of the assembly forming a combustion chamber **12** extending rearwardly parallel to the outer surface **11** and converging into a nozzle portion **13** toward the rearward end of the chamber assembly. The nozzle portion, of the De Laval type, consists of a throat area **14** and exhaust section **15** diverging rearwardly away from the throat area.

Extending axially throughout the length of the chamber wall assembly and following the contour thereof are ports or passageways **18** formed so as to constitute cooling passages in direct physical contact with the porous formation of the wall assembly. The passageways **18** extend outwardly to the outer surface **11** at each end for connection to manifolds **21** in a metal shell **20** which is tightly incased about the walled assembly. As shown in Fig. 2, the passageways are circular in cross section in the combustion chamber area and are positioned at circumferentially spaced intervals adjacent the inner periphery of the combustion chamber. As illustrated in Fig. 3, the same uniform thickness is maintained between the passageways **18** and the inner surface surrounding the throat area as in the combustion chamber. This uniform thickness prevails throughout the wall assembly and is of extreme importance in maintaining uniform distribution of the coolant into the chamber wall. The passageways are also given a flatted cross sectional area in the throat area which produces a reduced cross sectional area in the throat area to cause increased velocity of the coolant flow in the throat region to counteract the increased heat transfer rates of the combustion gases passing through the throat area. Furthermore, by providing a flattened cross sectional area construction of the passageways in the assembly surrounding the throat area the same spacing is retained between the passageways when passing through the reduced cross sectional area surrounding the throat region as in the rest of the body.

The process developed to construct the above described chamber wall basically utilizes the combined properties of (1) near coefficient of thermal expansion (2) relatively high thermal conductivity (3) and high thermal shock resistance of some of the more recently developed refractory materials. Typical examples of materials which can be utilized in the casting process include aluminum refractories, zirconia compositions, many of the silicone carbides, and low expansion lithium alumino-silicate compositions. In general any material may be utilized in this process which exhibits the above properties and which can be cast in a cold casting type process. A porous mold is first formed such as, a plaster of Paris mold, with a cavity therein through the center portion of the mold which coincides with the dimensions of the outer surface of the proposed chamber wall assembly. The elongate rods, preferably of thermo plastic or lead composition or any suitable material which is flexible and will dissolve and evaporate or melt at relatively low temperature levels, are then bent and shaped to correspond with the desired contour of the passageways **18** as hereinbefore described. The rods are aligned within the cavity in annular fashion and are secured in position by means of plugs which are inserted into the mold and fastened to the ends of the rods by means of screws. Cores are then placed within the cavity and spaced concentrically within the circularly arranged rods to represent the combustion chamber and nozzle portion.

In carrying out the cold casting portion, the lithium alumino silicate compositions have been found to be most suitable. Not only do these compositions offer resistance to extreme thermal shock, but also possess low positive and negative thermal expansion properties. In addition, the compositions are of a low porosity which is sufficient to permit diffusion of the coolant into the wall formation surrounding the coolant passages for evaporative cooling but will prevent any substantial amount of coolant from circulating through the additional thickness in the outer wall section, and thus prevents the possibility of corrosive action by the coolant in contacting the outer metallic lining.

This specially selected refractory material is poured into the mold to completely surround the cores and mold assembly and to fill the cavity. The casing can then be dried either artificially or by allowing it to stand for a predetermined time and periodically draining the mold. As soon as a solid casing is formed the mold is removed along with the cores and plugs, and the casting is fired or sintered to a temperature above the melting point of the rods.

Rods of thermo plastic composition are preferred in this coolant casting process in that they will evaporate instead of melt upon subjection to the sintering or firing operation. As a result, it is not necessary to pour off the melted rod material and there is no danger of any melted residue clogging the pores in the formation surrounding the passageways and solidifying.

Where a more porous formation is required or would be advantageous, a two stage process can be applied in which a highly porous wall is formed in the first stage of the process between the rod assembly and thrust chamber by interspersing low melting point particles throughout the refractory, then burning the particles at the same time the rods are heated. A low porosity outer wall section can then be formed in the second stage of the process around the outside of the rod assembly in order to prevent any corrosive action by the propellant or coolant in contacting the outer casing. Diffusion of the coolant into the outer wall formation can also be retarded by applying a nonporous coating to the outer periphery of the rod assembly which will adhere to the wall of the passageway after the rod assembly has been melted or burned out.

The outer metal casing **20** along with the coolant manifolds **21** are first fired to a high temperature state and slipped over the wall formation. The outer casing, in cooling, will then contract to form a tightly fitting inclosure about the ceramic wall formation and will thus tend to hold the ceramic wall formation in compression. During firing operations, the outer casing will therefore relieve the wall formation of any outward stresses developed inside the combustion chamber.

In conducting the rocket motor firing operation, the propellant-coolant enters at the exhaust section of the passageways **18**, is forced through the passageways, cooling the inside surface of the chamber wall, and enters the injection system (not shown) of the combustion chamber. The ceramic material, being porous and in direct contact with the coolant flowing through the passageway, induces a certain amount of evaporation cooling to occur throughout the combustion chamber and nozzle portion, thus causing greatly increased heat transfer rates and temperature. In that the coolant is flowing through the passageways in close proximity to the nozzle portion and combustion chamber, regenerative cooling will also take place whereby the coolant will absorb much of the heat dissipated by the gases. The greater amount of heat capable of being absorbed by the combined cooling enables the wall assembly to maintain a steady state temperature notwithstanding repeated firing operations in the combustion chamber. Furthermore, the outer metal shell **20** will undergo relatively low thermal expansion, since the high temperatures of the gases will be greatly reduced before reaching the shell. This is important in order to maintain a tight casing enclosing the body of the wall assembly to thereby prevent spalling or cracking of the body during the rocket firings. It is believed that this method of construction is ideally suited for mass production with attendant low unit cost. Only one material is necessary to form the body casting, and it is not necessary to form perforated liners together with the fact that greatly increased diffusion of the coolant is accomplished compared with the use of perforated linings. And, of course, the refractory material itself can be made very inexpensively in comparison with the metallic bodies. This method may also be used for any type of conbustion chamber or high temperature aerodynamic system which requires a lightweight, cheap envelope or wall assembly for long duration, continuous service.

It is obvious that certain changes may be made in the above process and assembly as described without departing from the scope of the invention, and thus the invention is not limited to the precise details as set forth but includes any changes in alterations as generally fall within the spirit and scope of the appended claims.

What is claimed:

1. A rocket motor wall structure composed of a specially selected, homogeneous porous refractory for use in high temperature rocket firing operations, said wall structure having an elongated recess portion constituting a combustion chamber and nozzle portion, said wall structure having a plurality of longitudinal cooling passages annularly closely spaced about said central recess portion and nozzle portion in which the walls of the cooling passages are formed by the porous wall structure formation and adopted to circulate a coolant longitudinally within said cooling passages in direct physical contact with the porous wall structure formation for uniform distribution therethrough, said passages being gradually flattened to reduce the cross sectional area thereof and then gradually widened to increase the cross sectional area thereof throughout the nozzle portion, to provide a relative increase in the velocity of the flow of the coolant in the flattened reduced cross sectional area through the nozzle portion of the wall structure; and an outer nonporous metallic structure tightly inclosing said wall structure to support the same against the pressure developed within the combustion chamber during the firing operations.

2. An elongated annular homogeneous porous rocket motor wall assembly forming a combustion chamber and a rearwardly extending convergent-divergent exhaust nozzle for high temperature, high pressure operations, said wall assembly comprising, an annular inner porous refractory wall section, an annular outer porous refractory wall section inclosing said annular inner wall section, the outer surface of said inner wall section and the inner surface of said outer wall section being recessed longitudinally in complementary association with one another as to form a series of closely circumferentially spaced longitudinal cooling passages conforming to the contour of the combustion chamber and exhaust nozzle throughout the length thereof for directing a flow of coolant through said cooling passages, whereby said porous material provides for the diffusion of coolant from said cooling passages through said inner wall section for the direct evaporative cooling of said rocket motor, and an outer supporting shell member tightly encasing said outer wall section to absorb the pressure exerted from within the combustion chamber during the high temperature, high pressure operations, each of said cooling passages having a circular cross sectional area adjacent the combustion chamber, each passage converging rearwardly into a flattened cross sectional area adjacent to the convergent portion of the exhaust nozzle, and each passage further diverging rearwardly from the convergent portion to a circular cross section, the variation in cross sectional area of said cooling passages throughout the length of said wall assembly being such as to maintain a uniform circumferential spacing between said cooling passages throughout their length and to provide for the increased velocity of coolant flow through said cooling passages adjacent to the convergent portion of the exhaust nozzle.

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