June 4, 1963 P. T. BARNES 3,091,923

LIQUID PROPELLANT TANKAGE

Filed Dec. 20, 1960

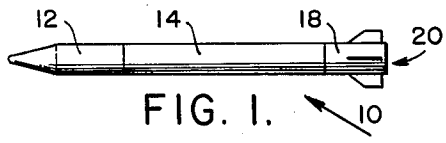


FIG. 1.

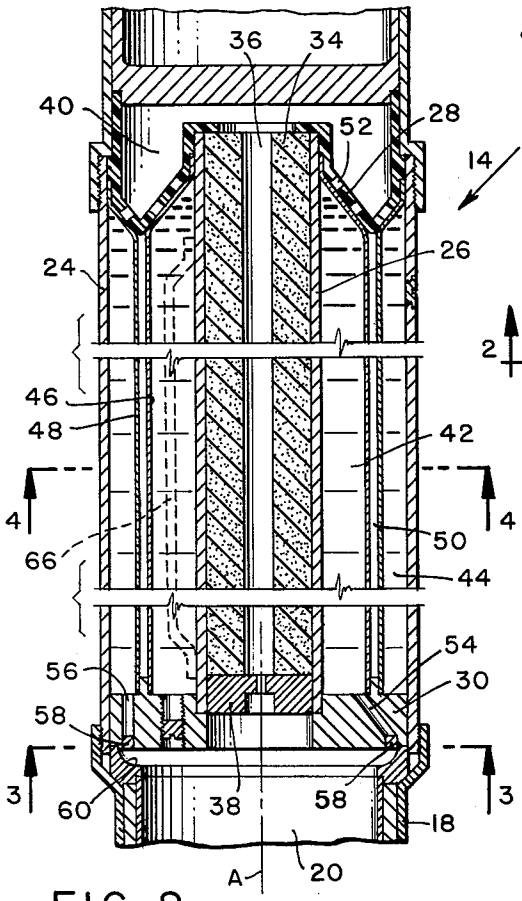


FIG. 2.

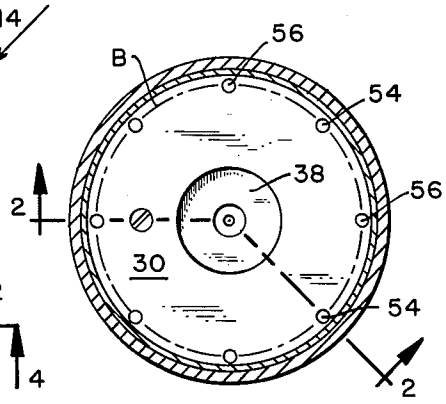


FIG. 3.

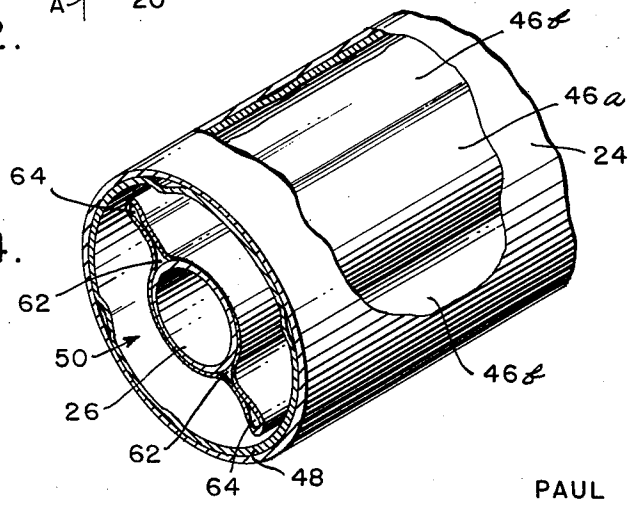


FIG. 4.

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United States Patent Office 3,091,923 Patented June 4, 1963

3,091,923
LIQUID PROPELLANT TANKAGE

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Filed Dec. 20, 1960, Ser. No. 77,253
3 Claims. (Cl. 60—35.6)
(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to rocket motors of the liquid propellant type and more particularly to improvements in tankage for same and improvements in apparatus for feeding the propellant from the tankage to the combustion unit of the rocket motor.

In missiles which are propelled by liquid propellant rocket motors, a common arrangement is to store the propellant in rigid elongated tanks extending longitudinally within the missile and to introduce a pressurized gaseous medium directly into the tankage to pressurize the propellant to cause it to flow through the feed lines leading out of the tankage. During missile flight the body of liquid only partially fills the tankage and assumes a position of equilibrium determined by the gravity forces and set-back forces due to the missile acceleration, and the gaseous medium fills the portion of the tankage not filled by propellant. An example of such arrangement is disclosed in U.S. Patent 2,954,670 to R. R. Helus et al. A disadvantage of this arrangement is that the mouths of the tank outlets must at all times be covered by the body of liquid propellant, or else the gaseous medium will enter the feed lines and interfere with combusion. The arrangement is therefore limited in its use to an operational environment providing the conditions under which the body of liquid may be maintained over the outlets, as for example, by locating the tank outlets at the rear end of the tankage in missiles having a vertical flight trajectory so that the force of gravity will maintain the body of liquid in position covering the outlets, or likewise locating the outlets at the rear end in missiles which continuously accelerate during the period over which propellant is fed to the combusion unit so that the force of set-back will maintain the body of liquid in position covering the outlets.

Certain recent developments have been directed to a missile having a relatively long range, and which follows a nominally horizontal trajectory, and which after a short initial acceleration reaches a constant terminal velocity with zero acceleration. During such flight the elongated tankage is in a horizontal attitude and the only force acting on the liquid is gravity which maintains the body of liquid in an equilibrium position extending horizontally between the tank ends, so that the end walls become progressively uncovered as the tankage empties, and therefore are not a suitable location for outlets. The only zone of the tank walls which remain continuously covered with liquid until the tank is emptied is that portion of the longitudinal walls which happens to be disposed downward, but since such missiles are seldom roll stabilized it is impossible to predetermine which portion this is. It will be apparent that it is difficult if not impossible to employ the described prior art arrangement for such missiles. Also, with the described prior art arrangement, the liquid may slosh in the partially filled tanks producing hydrodynamic shocks in the feed lines. These shocks can become regenerative through their effects on the combustion and in turn the missile ballistics, and some failure of missiles have been

attributed to this effect. Further, in this prior art arrangement, the pressurizing gaseous medium is usually produced by a combustion type gas generator and contains tiny unburned particles of the oxidant and fuel. When introduced directly into the contact with the propellants within the tankage, these unburned particles cause a small scale reaction within the tankage, which constitutes an explosion hazard.

An object of the present invention is to provide novel and improved propellant tankage and feed apparatus for use in a liquid propelled rocket motor.

Another object is to provide tankage and feed apparatus, which is not dependent in its operation on forces of gravity or acceleration.

Another object is to provide propellant tankage and feed apparatus in which the propellant is not subject to sloshing within the tankage.

Another object is to provide tankage and feed apparatus of the type employing a combustion type gas generator as propellant pressurizing means, which is not subject to explosion hazard.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

FIG. 1 is a side elevation of a missile employing the present invention;

FIG. 2 is a partial longitudinal section of the missile of FIG. 1, taken along line 2—2 of FIG. 3;

FIG. 3 is a transverse section taken along line 3—3 of FIG. 2, and

FIG. 4 is a perspective view taken along line 4—4 of FIG. 2 showing the position of the parts after propellant is expelled from the tankage.

Referring to the drawing, and in particular to FIG. 1, a missile 10 comprises a nose section 12 which may house the payload, not shown, a mid-section 14 containing liquid propellant tankage and feed apparatus, and a tail or rear section 18 forming a rocket motor combustion chamber 20 in which the liquid propellants are reacted to produce propulsion gases which exhaust through an exhaust nozzle at the rear end of the missile.

Referring now to FIG. 2, the tankage and feed apparatus comprises a rigid cylindrical outer casing 24 having an axis A. Co-axially extending within the bore of casing 24 is a rigid central tube 26, supported at its front end by an annular spacer 28, of plastic or other suitable material, and at its rear end by an annular member 30 of heat resistant metal. The bore of central tube 26 forms the combustion chamber of a gas generator sub-assembly comprising a slow burning solid propellant grain 34 adapted to burn along the surface of its central perforation 36, and an orifice unit 38 at the rear end of the bore through which the products of combustion may exhaust into combustion chamber 20. The front end of perforation 36 opens to a pressure chamber 40 formed ahead of tube 26, and when grain 34 is ignited chamber 40 is filled and pressurized with gaseous products of combustion.

The annular space between tube 26 and casing 24 contains inner and outer concentric annular propellant chambers or compartments 42 and 44 for storing liquid oxidant and liquid fuel, respectively. Inner compartment 42 is formed between tube 26 and a surrounding cylindrical wall 46 made of a ductile metal, such as soft aluminum. Outer compartment 44 is formed between casing 24 and an inner concentric cylindrical wall 48, made of like metal. Walls 46 and 48 are in spaced relationship forming an annular pressure chamber 50 therebetween. It is to be noted that spacer 28 merely

serves to provide support and is not fitted against walls 46 and 48 with such tightness that it seals off communication of gases between chamber 40 and chamber 50, openings 52 serving to better permit such communication. Propellant storage compartment 42 is provided at its rear end with a circularly arranged set of equiangularly spaced outlet passages 54, and compartment 44 is provided with a similar set of passages 56. As best shown in FIG. 3 passages 54 and 56 open into the combustion chamber along a common reference circle B with the passages of one and the other set angularly alternating about the circle. Passages 54 and 56 are initially closed by suitable burst diaphragms or blow-out plugs 58 adapted to open upon the pressure thereacross exceeding a predetermined value. In combustion chamber 20 there is provided a deflector ring forming an annular deflector surface 60 which confronts the openings of passages 54 and 56 and deflects the streams of liquid propellants which will issue from the passages radially inward toward axis A, causing streams of oxidant and fuel to impinge against one another and react in the atmosphere of the hot gases issuing rearwardly from orifice unit 38.

The tankage and feed apparatus operates to feed propellant into combustion chamber 20 as follows: The gas generator sub-assembly is ignited and fills chamber 40, and in turn chamber 50 with its gaseous products. In chamber 50, the gases serve as a pressurizing medium exerting a force against ductile walls 46 and 48. This force squeezes wall 46 against tube 26, which is a rigid member, and wall 48 against the casing 24, likewise rigid, pressurizing the liquid propellant in the respective compartments and forcing it out through outlet passages 54 and 56 into the combustion chamber. As the volume of liquid in compartments 42 and 44 decreases the gases will progressively deform wall 46 radially inwardly and wall 48 radially outwardly, with ductile metal of the walls undergoing irreversible or permanent strain. The radially inwardly deformation of wall 46 is in the nature of the wall being collapsed or buckled to a final position shown in FIG. 4 in abutting relationship against tube 26. The radially outward deformation of wall 48 is in the nature of the wall drawn out or stretched in peripheral directions until wall 48 is fully distended in an abutting relationship against casing 24 to its final position shown in FIG. 4. Preferably the front ends of the compartments are inclined relative to the respective rigid members so that they may more easily collapse. It is to be noted that when wall 46 is fully collapsed against tube 26 and wall 48 fully distended against casing 24, the volume of compartments 42 and 44 has been reduced to zero and this reduction in volume has been added to pressure chamber 50.

Walls 46 and 48 are essentially elongated members which are subject to lateral stress and supported only at their ends, and in accordance with general principles of structural strength are weakest in resisting the lateral stresses in a region midway between their ends. Accordingly one of the functions served by the ductile metal of the walls is to exhibit rigidity and internal stiffness to resist pinching off of the compartments in this weaker region before the propellant is fully expelled. It will be apparent that the likelihood of pinching off is greater in the case of wall 46 which buckles than wall 48 which distends, and it has been found that the capability of wall 46 to resist the pinching effect is substantially improved by so choosing its physical characteristics, including the relative diameter of wall 46 to tube 26, that it follows a predetermined mode of deformation in which it progressively deforms to a final position shown in FIG. 4, forming substantially diametrically opposed wall portions 46*a* which abut against tube 26 and similarly opposed wall portions 46*b* which form longitudinally extending folds. Further, with this mode of deformation, longitudinally extending pockets 62 and 64 are formed at the base and the bight, respectively of each fold, and these pockets provide effective channels communicating the front and rear ends of the tanks as long as any propellant remains therein.

It will be apparent that the pressurizing gases apply a large quantity of heat to walls 46 and 48, and unless the heat is conducted away from the walls as fast as it is generated it will cause the relatively thin ductile walls to burn through. It has been found that the liquid propellant within the compartments provides an effective medium for transmitting the heat away from the walls, provided that the propellant actually wets the inside surface of the walls. However, it has been further found that anything which interferes with the continuous wetting of the wall materially reduces the heat transmitting capacity and can cause burning through at such zone. Even the presence of the small percentage of free volume, conventionally left in tankage to compensate for temperature changes and sometimes called ullage, can cause bubbles to form along the inside surface of the wall, which interferes with the heat transfer and can cause burning through. Therefore, in order to insure continuous complete wetting of the entire inside surfaces of walls 46 the propellant storage compartments are preferably filled completely, leaving no space whatsoever. It is to be noted that it is possible to do this because ductile walls 46 and 48 will stretch or be drawn out upon initial thermal expansion and will wrinkle and unwrinkle upon subsequent temperature cycling.

As a possible modification, a bent rod 66, shown in dotted lines in FIG. 1, may be affixed to tube 26 to provide an elongated abutment in compartment 42 to prevent the aforesaid pinching off effect during deformation of wall 46.

In contra-distinction to the prior art, it will be apparent that the propellant tankages are completely filled with propellant at all stages during their emptying, and therefore there is no problem of gases entering outlet passages 54 and 56 and no problem of sloshing. Also, since the pressurizing gaseous medium is never in direct contact with the liquid propellant in the tankage, there is no danger of explosive reaction therebetween.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. In combination with a rocket motor of the liquid bi-propellant type including propellant tankage and pressurizing apparatus, the improvements, comprising; a series of concentric cylindrical walls including a first rigid wall, a second deformable wall surrounding and spaced from said first wall forming a first annular chamber therebetween to contain one of said propellants, a third deformable wall surrounding and spaced from said second wall forming a second pressurizable second chamber between the second and third walls, a fourth rigid wall surrounding and spaced from said wall forming a third chamber between the third and fourth walls to contain the other of said propellants, said first and third chambers each have an end closure having a propellant outlet, and means for pressurizing the second chamber to pressurize the propellants in the first and third chambers and expel same through the propellant outlets, said second and third walls each being constructed of metal of such ductility that it permanently deforms under decreasing volume of propellants in the first and third chambers said third wall adapted to deform to a final position having its outer surface abutting said fourth wall and said second wall adapted to deform to a final position forming substantially diametrically opposed semi-cylindrical portions abutting said first wall and other substantially diametrically opposed flat collapsed substantially abutting portions extending in radial directions having folds at their outer ends.

2. Apparatus in accordance with claim 1 wherein the diameters of the second and fourth walls are so proportioned that the outer edges of said diametrically opposed flat folded portions are adapted to project radially outward to a position beyond the initial position of said third wall.

3. In combination with a rocket motor of the liquid propellant type having a combustion chamber, the improvements comprising; a pair of concentric walls forming an annular chamber therebetween for containing liquid propellant, said pair of walls comprising an initially cylindrical outer wall and a cylindrical rigid inner wall, a propellant outlet at one end of said chamber for delivering the propellant to the combustion chamber, means for applying gas pressure to the outer surface of the outer wall to pressurize the propellant contained in said annular chamber and expel same through said outlet, said outer wall being constructed of unreinforced ductile sheet metal and having a circumferential length, relative to the circumferential length of said inner wall, such that under said gas pressure it deforms to a final position, said final

position comprising a pair of substantially diametrically opposed semi-cylindrical portions abutting said inner wall and a par of substantially diametrically opposed collapsed portions extending in opposite radial outward directions from said inner wall, each having a retroverted fold at its outer end, each fold having a longitudinally extending channel therein, the walls of each collapsed portion between said fold and a position near the inner wall being in abutting relation to prevent flow of liquid therethrough, and another longitudinally extending channel disposed between said position and said inner wall, whereby four longitudinally extending channels are provided through which liquid may flow to said outlet when the outer wall is collapsed to final position.

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