

Jan. 25, 1966

D. H. T. HUANG ETAL
STEERABLE ROCKET MOTOR WITH GIMBALED
NOZZLE MEANS AND COOLING MEANS

3,230,708

Filed Oct. 27, 1961

4 Sheets-Sheet 1

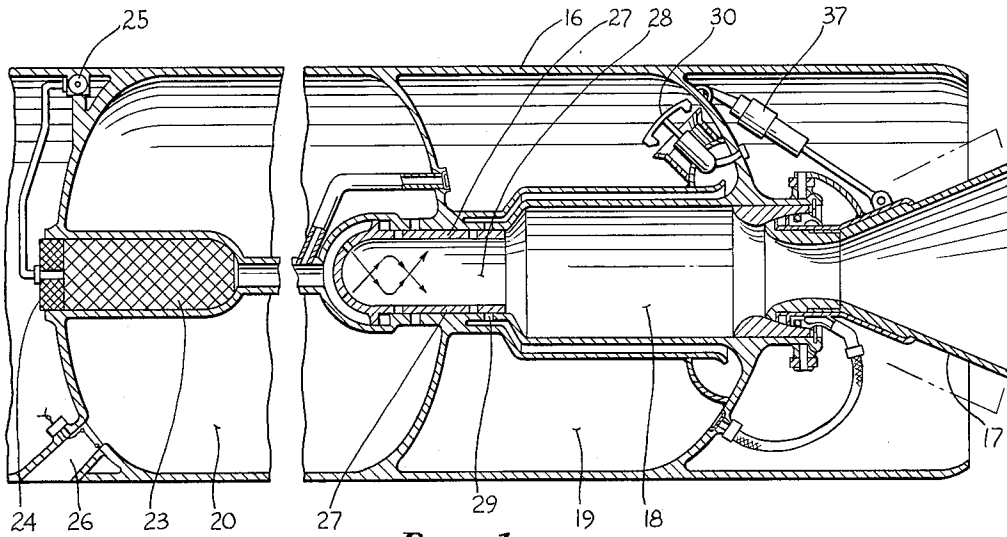


Fig. 1

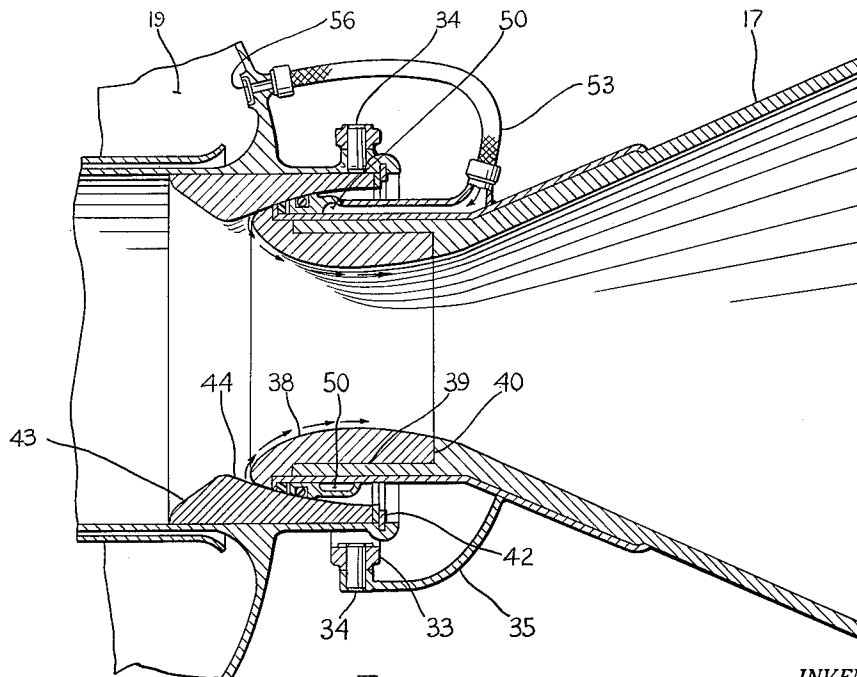


Fig. 2

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4 Sheets-Sheet 2

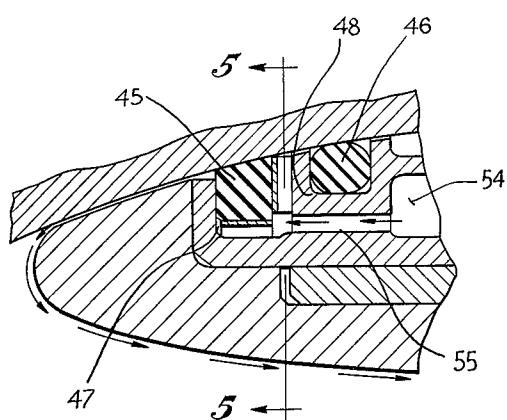
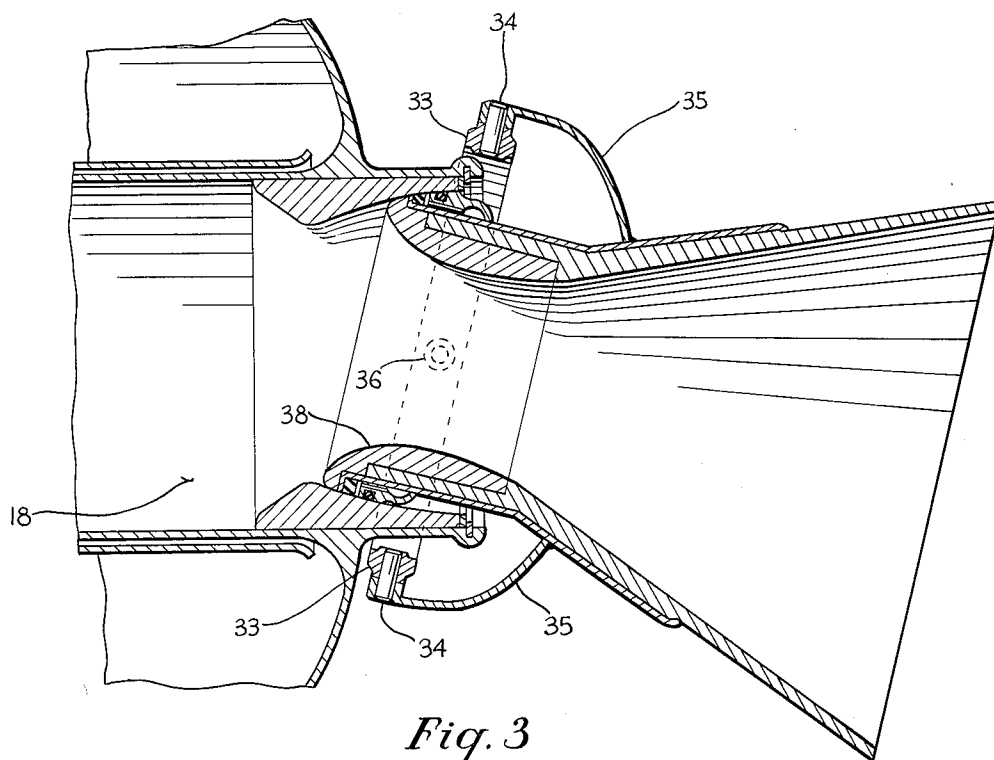
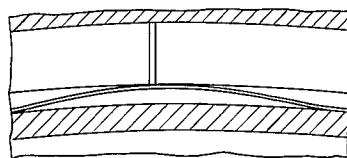
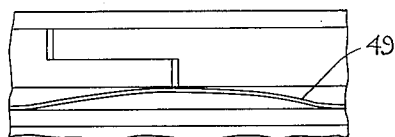


Fig. 6



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4 Sheets-Sheet 3

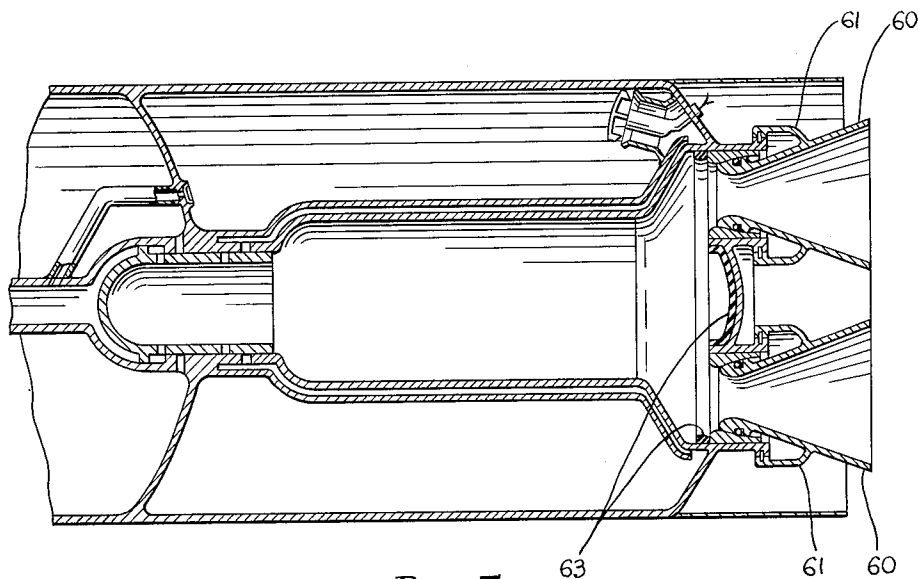


Fig. 7

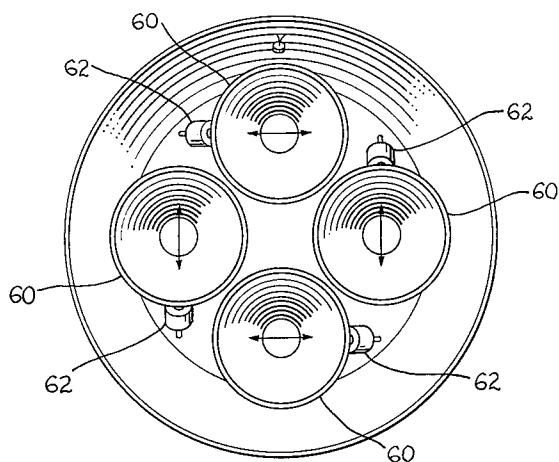


Fig. 8

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4 Sheets-Sheet 4

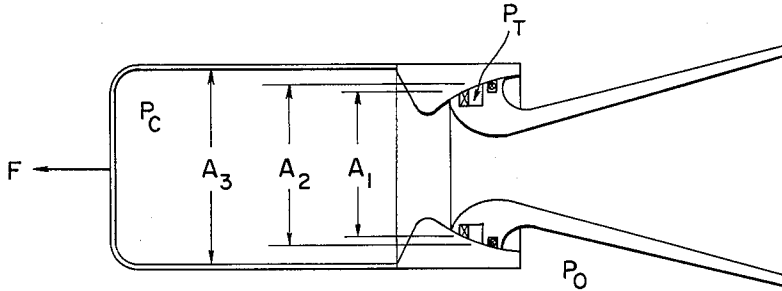


Fig. 9

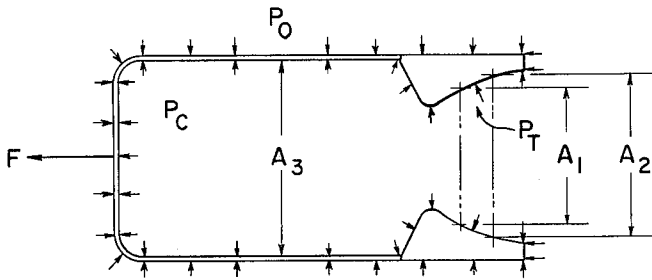


Fig. 10

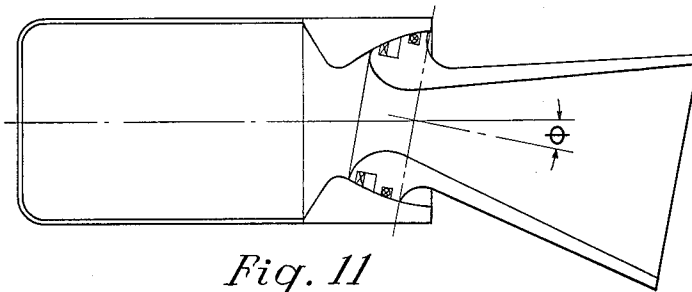


Fig. 11

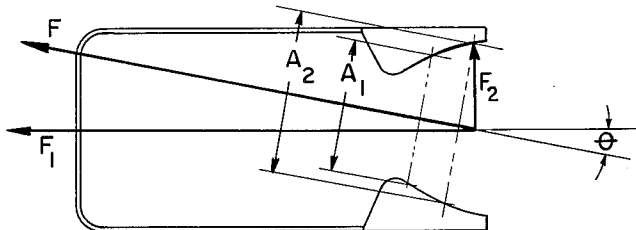


Fig. 12

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1

3,230,708

STEERABLE ROCKET MOTOR WITH GIMBALED NOZZLE MEANS AND COOLING MEANS

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9 Claims. (Cl. 60—35.55)

This invention relates generally to reaction motors and more particularly to an improved pivotal exhaust nozzle therefor.

The pivoting of jet exhaust nozzles to control the thrust vector of the escaping combustion gases of a reaction motor is known in the art. This is sometimes effected by pivoting the reaction motor as a whole with respect to its supporting frame which introduces fuel conduit and wiring problems particularly where liquid propellants are used.

In other cases, the exhaust nozzle has been pivoted with respect to the thrust chamber with attendant problems: of imbalance requiring unnecessarily large pivoting forces; of imperfect sealing of the joint resulting in leakage of hot exhaust gases and a cooling problem to prevent premature attrition of the parts and binding thereof due to distortion; of undesirably large space requirements and resulting structural load; and of lack of design simplicity resulting in greater cost and lesser reliability.

Accordingly, the main object of the present invention is to provide an improved reaction motor exhaust nozzle which may be easily and smoothly pivoted with respect to the motor for thrust vector control of large magnitude with a minimum performance loss and which will be free of the above and other problems of pivoted or swivelled nozzles.

An important object of the present invention is to provide an improved means for sealing and balancing pivoted exhaust nozzles of reaction motors.

Another important object of the present invention is to provide improved sealing and cooling means for a pivotal exhaust nozzle joint which will effect a controlled flow of coolant into the nozzle throat area for film cooling thereof.

A further important object of the present invention is to provide an improved means for pivoting an exhaust nozzle on a reaction motor which will support virtually all of the load, except for the seals, of the joint therebetween.

A still further important object of the present invention is to provide a gimbal mount for a pivotal exhaust nozzle which will eliminate structural loads from its joint with a reaction motor while effecting better sealing and easier pivotal movement.

Another important object of the present invention is to provide a gimbal mounting for pivotal exhaust nozzles which induces a low structural force, requires a low actuating force due to a low dynamic mass and a balancing of forces on the movable nozzle, and is simple in design to effect both reliability and a low fabrication cost.

Other objects and advantages of the invention will become apparent during the course of the following description.

In its broadest aspects the invention contemplates the removal of load and binding forces on a pivotal nozzle-motor joint accompanied by improved sealing and cooling thereof by the use of a gimbaled mount.

In the drawings we have shown one embodiment of the invention. In this showing:

FIGURE 1 is a fragmentary, central, longitudinal sectional view of the invention as applied to the liquid propellant rocket power plant of a missile, vehicle, etc.;

2

FIGURE 2 is a similar view to an enlarged scale of the pivot joint of the exhaust nozzle with the rocket motor, the axes of the two being in alignment;

FIGURE 3 is a similar view angularly displaced 90° showing the pivotal nozzle swivelled to a tilted position;

FIGURE 4 is a similar view to a further enlarged scale showing seal and cooling passage details;

FIGURE 5 is a fragmentary, transverse sectional view thereof taken on the line 5—5 of FIGURE 4;

FIGURE 6 is a view similar to FIGURE 5 but taken at an angularly displaced point therefrom;

FIGURE 7 is a view similar to FIGURE 1 but showing the use of four pivotal exhaust nozzles which eliminates the need for the roll control unit disclosed in FIGURE 1;

FIGURE 8 is an aft end elevational view thereof;

FIGURES 9 and 10 are schematic views of reaction motor combustion chambers showing the areas and forces which must be considered in providing a balanced pivotal nozzle therefor, and

FIGURES 11 and 12 are schematic views.

Referring to the drawings, it will be understood that while the pivotal exhaust nozzle structure comprising the present invention is illustrated with a liquid propellant rocket motor, it is just as suitable for use on solid propellant rocket motors.

FIGURE 1 discloses a packaged, jet mixing, liquid propellant, rocket power plant casing 16 with a swivelled exhaust nozzle 17 for use as a ballistic missile powerplant, the nozzle having a gimbal mounting on the casing as will be described. A thrust chamber 18 is positioned in the casing within and concentrically of annular fuel and oxidizer tanks 19 and 20 respectively. The casing includes a solid propellant gas generator 23, an igniter 24 therefor, a roll control unit 25, a thrust termination and reversal unit 26, and a shear slide 27 controlling entry into the injection chamber 28 of thrust chamber 18, of the liquid fuel and oxidizer.

Igniting of the solid propellant in the gas generator 23 will rupture burst discs 29 to pressurize the fuel and oxidizer tanks 19 and 20, the former having a "command" shut-off valve 30, and pressure buildup will force movement of the injector slide 27 to the right to admit fuel and oxidizer to the injection and thrust chambers 28 and 18 from which the gases of combustion are exhausted by way of the exhaust nozzle 17.

The foregoing is the subject matter of other applications for Letters Patent and also concerns the present invention as to the combinations to be described and as to the source of pressurized cooling fluid for the swivelling nozzle 17.

As shown in greater detail in FIGURES 1 to 6 of the drawings, the movable nozzle 17 is provided with a gimbal mounting on the aft end of the thrust chamber wall and comprises a gimbal ring 33 pivoted for movement in a vertical plane by diametrically disposed pivot pins 34 and a pair of nozzle supporting arms 35 pivotally connected to the gimbal ring 33 for movement in a horizontal plane by diametrically disposed pivot pins 36. Thus the nozzle 17 may be readily moved or swivelled to a desired angular position with respect to the axis of the thrust chamber 18 by means of remotely controlled actuators 37 to vary the thrust vector of the rocket motor.

The desired internal contour of the throat of the nozzle 17 is provided by a ceramic or other suitable insert material 38 formed and shaped as it is put in place and serves the twofold purpose of providing proper flow characteristics for the nozzle and of helping to prevent its metallic walls from melting due to the high temperatures of the exhaust gases. It is to be noted that the forward end of the insert 38 extends beyond the end of the outturned

3

flange 39 of the nozzle 17 and is faired rearwardly into an abutting shoulder 40 therewith.

A similar protective insert 43 is positioned in the aft end of the wall of the combustion chamber by a split ring 42 and its surface 44 defines a part of a sphere against which bear a pair of sealing rings 45 and 46 seated in spaced annular recesses 47 and 48 formed in the conforming outer face of the nozzle 17 (FIGURES 2-6 inclusive). The sealing ring 45 is a high temperature seal formed of graphite segments and is held against the sealing spherical surfaces 44 by means of a compression inner ring and spring washer 49.

It is to be noted that the forward end of the nozzle 17 will be accurately located with respect to the combustion chamber aft end insert 43 by means of the gimbal ring mounting which will carry all structural loads if any. Thus, the high temperature seal 45 and the O-ring seal 46 provide a sealing function only.

Pressurized fuel is introduced between the seals 45 and 46 against the spherical seating and sealing surface 44 by means of an annular passage 50 which is connected with the fuel tank 19 by means of a flexible conduit 53 (FIGURE 2), a fuel manifold 54 mounted on the nozzle 17, and by axial passages 55. The conduit 53 is initially sealed at its tank end by a burst disc 56 and as explained, all of the burst discs will be ruptured by generator gas pressure prior to movement of the injector slide 27.

The pressurized fuel introduced between the seal rings 45 and 46 at a pressure P_t will flow forwardly in a fluid film and around the forward end of the nozzle insert 38 as indicated by the arrows (FIGURE 4), the combustion chamber gas pressure head P_c being lesser. This provides a controlled flow of fuel into the throat area for film cooling.

The disclosure of FIGURES 7 and 8 is identical with the structure just described except that a plurality of exhaust nozzles 60 is employed each having a gimbal mounting 61, a vector control actuator 62, and heat resistant insulating inserts 63.

In the arrangement shown, the four nozzles replace the roll control unit 25 of FIGURE 1 by utilizing a pair of the nozzles as a couple for roll control. The nozzle pairs would be actuated by the vector control actuators 62 in one plane only as indicated by the arrows in FIGURE 8 and thus enable complete control as to pitch, yaw and roll. The degree of tilt of the exhaust nozzles, whether in one plane or swivelling as shown in FIGURE 3, is up to the angle θ with respect to the axis of the combustion chamber 18 and adequate for all control purposes.

As is now readily apparent the swivelling movement of the nozzles 17 or 60 as effected by the actuators 37 and 62 for vector control, is free and easy and free from binding due to the gimbal mounting, the functioning of the seals as seals only, the cooling of the passage between the inserts 38 and 43 and of the nozzle throat, and of the balanced nature of the nozzles as will now be explained.

As seen in FIGURES 9, 10 and 12, the forces and areas involved have been indicated as follows:

P_c =Chamber pressure (p.s.i.)

P_t =Fuel tank pressure (p.s.i.)

P_0 =Ambient pressure (p.s.i.)

F =Rocket thrust (lb.)

A_3 =Equivalent area at chamber I.D. (in.²)

A_2 =Equivalent area at O ring seal dia. (in.²)

A_1 =Equivalent area at high temperature seal dia. (in.²)

In designing the balanced movable nozzles 17, 60, the combustion chamber is taken as a free body and P_c is assumed constant throughout the chamber. If the nozzle is balanced by itself, there will be no interacting forces between the chamber and the nozzle mechanically except through the gimbal mount.

As seen from FIGURE 10, the rocket thrust F will

4

be the resultant force of the pressures acting on the inner and outer surfaces of the chamber. Thus:

$$F = [P_c A_3 - P_c (A_3 - A_1) + P_t (A_2 - A_1)] - [P_0 A_3 - P_0 (A_3 - A_2)] \quad 1$$

$$(or) \quad F = P_c A_1 + P_t (A_2 - A_1) - P_0 A_2 \quad 2$$

$$(or) \quad F = A_2 (P_t - P_0) - A_1 (P_t - P_0) \quad 3$$

If F , P_t , P_c and P_0 are known, the value of A_1 can be derived from a convenient value of A_2 or vice versa to produce the balanced movable nozzle of the present invention.

When the nozzle is at a tilted position (FIGURES 11 and 3), all of the pressure and pressure areas on the nozzle are not essentially changed. Therefore, the nozzle is still in a balanced condition and will not impose any forces to the chamber.

If the chamber is again taken as a free body, the following conditions exist as shown in FIGURE 12.

From Equation 3:

$$F_1 = A_2 \cos \theta (P_t - P_0) - A_1 \cos \theta (P_t - P_c) \quad (or)$$

$$F_1 = F \cos \theta$$

$$F_2 = A_2 \sin \theta (P_t - P_0) - A_1 \sin \theta (P_t - P_c) \quad (or)$$

$$F_2 = F \sin \theta$$

Since the value of the chamber pressure P_c decreases toward the aft end of the chamber, Equation 3 may be corrected after the actual calibration of the chamber.

It will now be apparent that the improved movable nozzle construction and its gimbal mounting as described herein comprise important advances in the art and afford material advantages. In liquid or solid propellant reaction power plants in ballistic missile applications, thrust vector control of large magnitude with minimum performance loss is provided.

The supplying of coolant through the balanced nozzle rather than through the aft end of the combustion chamber as in the prior art facilitates film cooling to the nozzle throat area and the conventional seals employed achieve positive sealing against hot gases. Moreover, the improved arrangement induces low structural loads and requires low gimbal actuating force due to the low dynamic mass and the balancing of forces on the movable nozzle. Additionally, due to the simplicity of design, the arrangement has minimum space requirements while attaining both reliability and low fabrication costs.

It is to be understood that the form of our invention herewith shown and described is to be taken as a preferred example of the same and that various changes in the shape, size and arrangement of parts may be resorted to without departure from the spirit of the invention or the scope of the subjoined claims.

What is claimed is:

1. The combination with a reaction motor combustion chamber having a spherical seat at and within its aft end; of an exhaust nozzle having its forward end shaped at least in part to conform with the spherical seat, a gimbal connected to the aft end of the chamber and to said nozzle and swivelly mounting said nozzle for universal movement against and with respect to the seat, and means for introducing a fluid coolant through the wall of said universally mounted nozzle and against the spherical seat.

2. The combination recited in claim 1 wherein said coolant is introduced under a pressure greater than that of the combustion chamber gases to provide a coolant film flow around the forward end of the nozzle and over the throat area thereof.

3. The combination recited in claim 1 wherein spaced seals are mounted in the forward end of said nozzle and bear against the spherical seat to prevent the leakage of hot gases therealong.

5

4. The combination recited in claim 3 wherein a fluid coolant is introduced between said seals against the seat from the wall of said nozzle.

5. The combination recited in claim 4 wherein said coolant is introduced under a pressure greater than that of the combustion chamber gases to provide a coolant film flow around the forward end of the nozzle and over the throat area thereof.

6. In combination, a reaction motor combustion chamber, an annular insert mounted in the aft end thereof and having a spherical face, an exhaust nozzle having a forward end at least partially conforming with and seated against said spherical face, a gimbal mounted on said chamber and supporting said nozzle against said face for universal swivelling movement with respect thereto, spaced seals mounted on said forward conforming end, and means for introducing a fluid coolant through the wall of said universally mounted nozzle and between said seals and against said face to prevent leakage of hot combustion gases past said seals.

7. The combination recited in claim 6 wherein said coolant is introduced under a pressure greater than that of the combustion chamber gases to provide a controlled coolant film flow around said end of said nozzle and over the throat area thereof.

8. In combination, a reaction motor having a combustion chamber, a gimbal mounted and balanced exhaust nozzle at its aft end communicating therewith, a fuel tank, conduit means including burst discs connecting said tank

6

with said chamber and the forward part of said nozzle, and pressure means operative to pressurize said fuel, burst said discs and deliver fuel to said chamber for combustion and through the nozzle wall to the universally swivelling forward end portion of the nozzle to cool it.

9. The combination recited in claim 8 wherein spaced seals are mounted on said end portion, and said coolant fuel is introduced between said seals to provide a coolant film flow around said end portion of said nozzle and over the throat area thereof.

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