Feb. 7, 1950

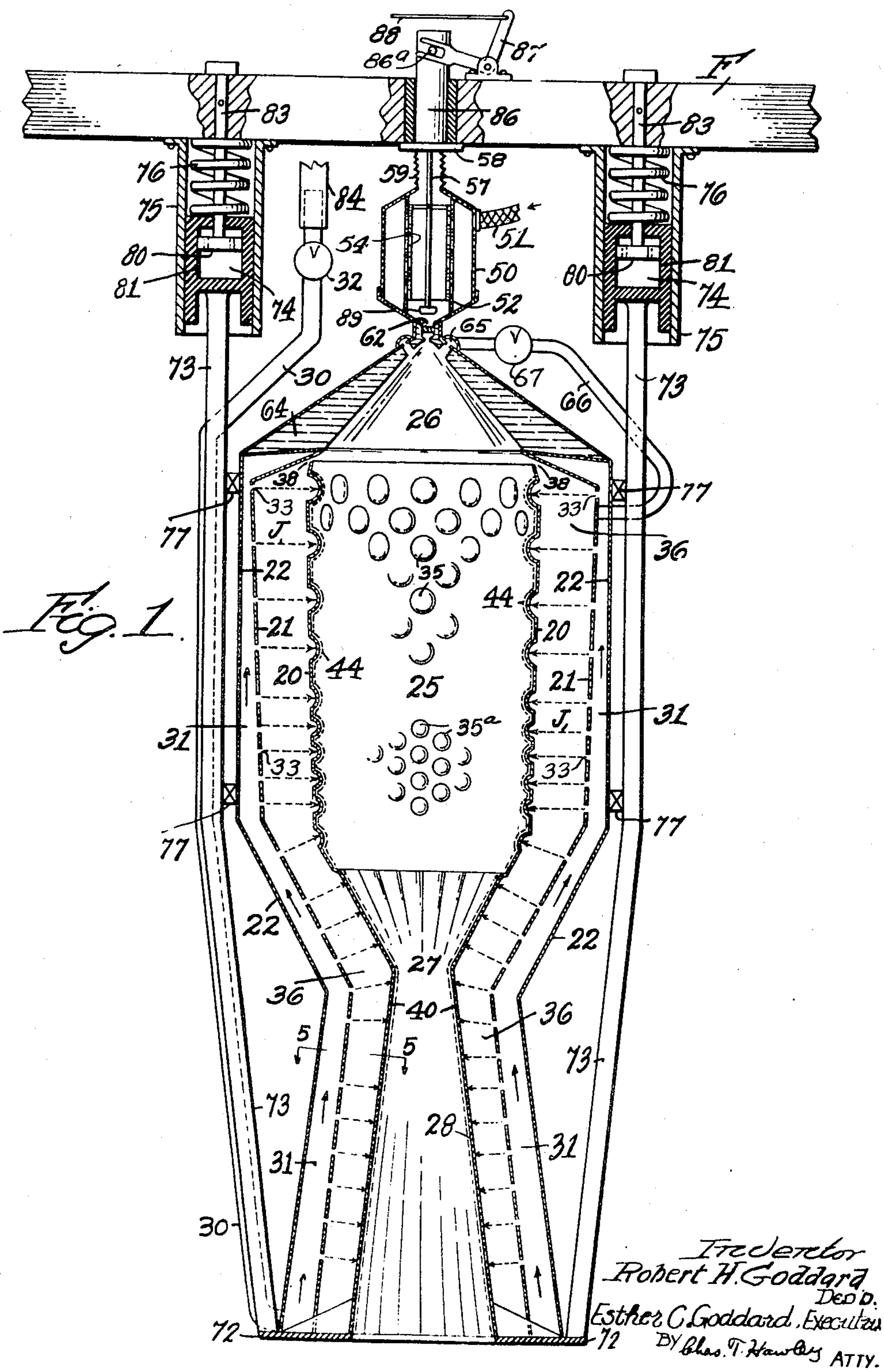
R. H. GODDARD

2,496,710

FUEL CONTROLLING APPARATUS FOR LONGITUDINALLY MOVABLE COMBUSTION CHAMBERS

Original Filed March 9, 1942

2 Sheets-Sheet 1



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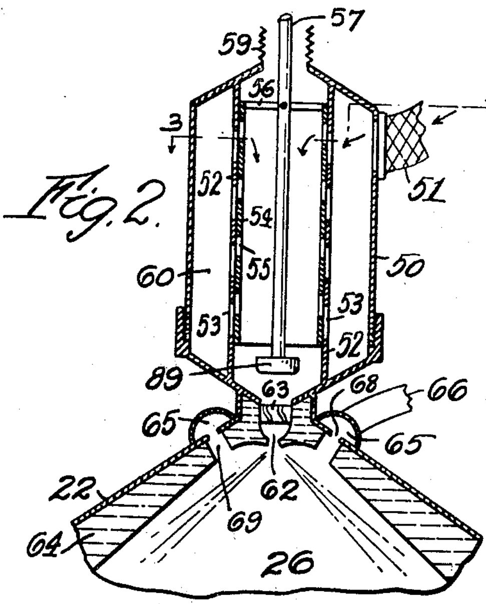

Fig. 2

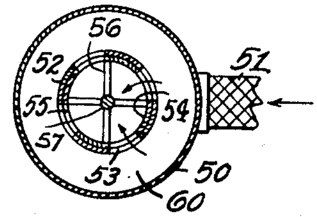

Fig. 3

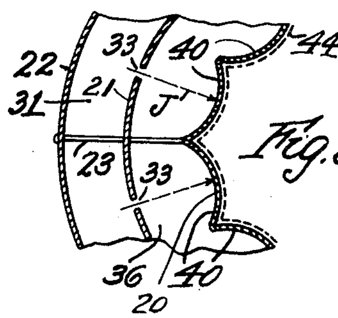

Fig. 5

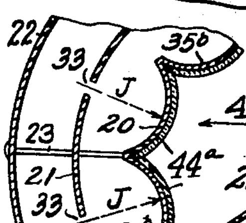

Fig. 4a

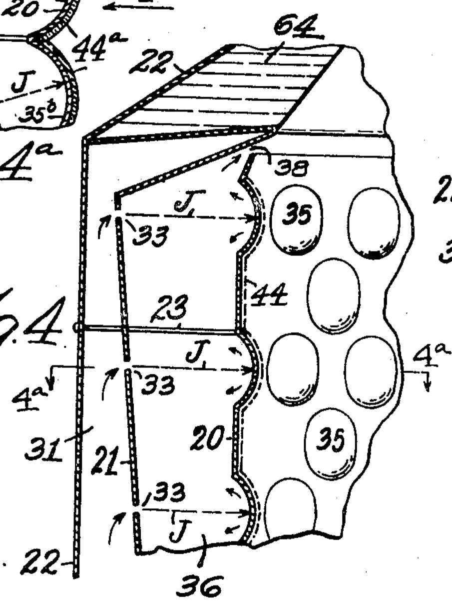

Fig. 4

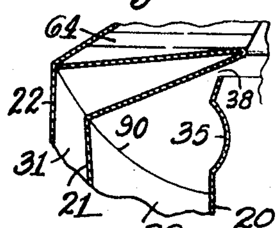

Fig. 6

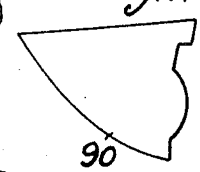

Fig. 7

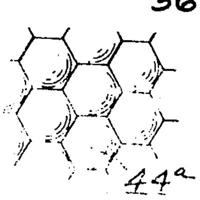

Fig. 4b

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2,496,710

FUEL CONTROLLING APPARATUS FOR LONGITUDINALLY MOVABLE COMBUSTION CHAMBERS

Robert H. Goddard, deceased, late of Annapolis, Md., by Esther C. Goddard, executrix, Paxton, Mass., assignor of one-half to The Daniel and Florence Guggenheim Foundation, New York, N. Y., a corporation of New York

Original application March 9, 1942, Serial No. 433,963, now Patent No. 2,397,658, dated April 2, 1946. Divided and this application February 14, 1946, Serial No. 647,607

2 Claims. (Cl. 60—35.6)

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This application is a division of original application Serial No. 433,963, filed by Robert H. Goddard March 9, 1942 and issued April 2, 1946 as Patent No. 2,397,658. This divisional application relates more particularly to the mounting of the combustion chamber for longitudinal reaction and to the variation of the fuel feed in response to such axial movement.

This invention relates to a combustion chamber in which mixed oxidizing and combustible gases or vapors may be continuously burned. While capable of general application, this improved combustion chamber is particularly designed and adapted for use in the propulsion of rockets or rocket craft.

An important object of this invention is to provide improved regulation of the fuel feed in a combustion chamber. In the preferred form, fuel feed is maintained in a definite relation to the axial displacement of the combustion chamber in its supporting structure, which displacement is related to changes in axial thrust produced by the combustion gases in said chamber.

This invention further relates to arrangements and combinations of parts which will be hereinafter described and more particularly pointed out in the appended claims.

Preferred forms of the invention are shown in the drawings, in which

Fig. 1 is a sectional front elevation of this improved combustion chamber;

Fig. 2 is an enlarged sectional front elevation of certain gasoline feed devices for said chamber;

Fig. 3 is a sectional plan view, taken along the irregular line 3—3 in Fig. 2;

Fig. 4 is an enlarged detail sectional front elevation of an upper portion of the combustion chamber;

Fig. 4*a* is a slightly modified detail sectional plan view, taken along the line 4*a*—4*a* in Fig. 4;

Fig. 4*b* is a fragmentary side elevation, looking in the direction of the arrow 4*b* in Fig. 4*a*;

Fig. 5 is a detail sectional plan view of certain nozzle structure, taken along the line 5—5 in Fig. 1;

Fig. 6 is a fragmentary sectional front elevation showing a braced construction; and

Fig. 7 is a front elevation of a brace or bracket.

Referring to Fig. 1, a combustion chamber is shown comprising an inner casing **20**, an intermediate casing or jacket **21**, and an outer casing **22**, said parts being held in spaced relation by tie rods or braces **23** (Fig. 4) secured to each of the casing members **20**, **21** and **22**.

The inner casing **20** comprises a cylindrical

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middle portion **25**, a conical entrance portion **26**, a conical discharge portion **27**, and a discharge nozzle **28**. A liquid oxygen supply pipe **30** is connected into the space **31** between the outer casing **22** and the intermediate casing or jacket **21** and adjacent the outer end of the nozzle **28**. The space **31** is gradually reduced in cross sectional area upward as viewed in Fig. 1 and is closed at its upper end. This gradual reduction in cross sectional area facilitates the maintenance of uniform flow. The liquid oxygen is furnished from any suitable supply under pressure, and the flow of liquid oxygen is controlled by a valve **32**.

The intermediate casing or jacket **21** is provided with a multiplicity of perforations **33** (Fig. 4) through which narrow streams or jets J of liquid oxygen are projected against the outer surface of the inner casing **20** to cool said inner casing and to prevent melting or burning thereof by the extremely hot combustion gases developed within the chamber.

Such narrow streams are superior to sprays for the reason that there is considerable friction tending to retard the motion of small drops, particularly in a gas of high pressure and density, which would reduce the speed, and hence the cooling effect, of sprays.

In order to prevent rebound and scattering of the liquid as it engages the casing **20**, recessed portions or dents **35** are provided in the casing **20**, which recessed portions are convex inward and concave outward with respect to the casing **20**. The recessed portions **35** are aligned with the jets J and as each jet strikes one of these recessed portions in substantial alignment therewith, the jet spreads out sidewise but develops enough centrifugal force to maintain the liquid in close engagement with the casing surface, so that the inner casing is thus effectually cooled. The centrifugal force is strong because of the small radius of curvature of the dents. Cooling is further facilitated by the centrifugal force causing the liquid drops and cooler gas to make contact with the wall.

Such engagement, besides cooling the casing wall **20**, also evaporates the cold liquid oxygen. The oxygen vapor or gas thus produced passes upward along the annular space **36** between the walls **20** and **21** and enters the combustion chamber as a conical sheet through an annular slot or opening **38** (Fig. 4) at the top of the cylindrical portion **25** and just below the conical entrance portion **26**. It will be noted that the annular space **36** increases in cross section upwardly, to provide increased space for the evaporated and expanding oxygen gas. The conical sheet of oxygen gas and the conical spray of gasoline vapor from a spray orifice to be described impinge from reverse directions, which causes very intimate mixture. The greater weight and volume of oxygen carries the gases well up in the entrance portion 26, where mixing mainly takes place and where active combustion is initiated.

In the lower conical portion 27 of the combustion chamber and in the discharge nozzle 28, the separate recessed portions or dents cannot be used, as they would break up the streamlined surfaces which are essential to prevent interference with the high velocity movement of the combustion gases as they approach the nozzle 28 and are discharged therethrough.

Consequently, in the portions 27 and 28 axially extending and outwardly concave ribbed portions are utilized, as shown at 40 in Figs. 1 and 5. These ribbed portions develop the same centrifugal action in a circumferential direction as the dents 35 or 35*a* but without interference with axial movement of the gases.

While it is necessary to cool the inner casing 20 to prevent destruction thereof, it is also desirable to prevent cooling of the gases in the combustion chamber as far as possible, and for this reason a thin refractory lining 44 is provided within the parts 25 and 27 of the combustion chamber and within the discharge nozzle 28.

This lining is preferably formed in relatively small sections or shells and is of such thickness in relation to the thickness of the casing 20 that the inner surface of the casing 20 is heated just below its softening point and that the inner surface of the lining 44 is similarly heated just below its softening point. In this way, the casing 20 is protected, while at the same time the combustion gases are maintained at the highest permissible temperature.

Small shells 44*a* of refractory material are preferable because of the tendency of unequal expansion to produce cracks over large areas. In the form shown in Figs. 4*a* and 4*b*, the recessed portions or dents 35*b* are quite close together and the shells of refractory material over the dents will be held in place by the arched or concave shape of the chamber wall.

A gasoline feed chamber 50 (Fig. 2) is provided at the entrance end of the combustion chamber, to which gasoline may be supplied through a flexible feed pipe 51. The chamber 50 contains a sleeve 52 fixed therein and having valve openings 53. A second sleeve 54 is slidable axially in the sleeve 52 and is similarly provided with valve openings 55. The second or inner sleeve 54 is connected by a spider 56 (Figs. 2 and 3) to a supporting rod 57 which is connected to a plate 58 (Fig. 1) which normally abuts the under side of a fixed frame member F. The upper end of the gasoline chamber 50 is connected by a bellows member 59 to the plate 58.

If the valve openings 53 and 55 are aligned, in whole or in part, gasoline from the outer annular space 60 in the gasoline chamber 50 will pass through the valve openings 53 and 55 and thence downward through the inner casing 54 to a nozzle opening 62, provided with any usual device 63 for imparting a whirling motion to the gasoline as it is fed through the nozzle opening 62 to the upper portion 26 of the combustion chamber, which portion has a refractory lining 64. Means for producing relative axial motion between the sleeves 52 and 54 will be hereinafter described.

The injected gasoline preferably forms a hollow cone of spray just inside the refractory lining 64, this spray meeting the oxygen gas stream from the slot 38 at a substantial obtuse angle. The slot 38 is back of the refractory lining 64 and out of line with the gasoline spray, so that gasoline cannot enter the oxygen jacket 21 accidentally, in the absence of a high speed stream of oxygen gas, and thus produce an explosive mixture when the oxygen starts to flow.

It will be noted by reference to Fig. 1 that the gasoline enters the combustion chamber as a spray from the single nozzle opening 62, whereas the oxygen enters the chamber almost entirely in gaseous condition and through the extended circumferential entrance slot 38. In order to improve the mixture and to vaporize the gasoline as much as possible, special means are provided for heating the gasoline as it enters the portion 26 of the combustion chamber, such special means being necessary in order to break up the gasoline into very fine drops in the relatively short available distance of travel.

For this purpose, an annular passage 65 is provided (Fig. 2) surrounding the discharge end of the gasoline chamber 50 and connected by a bypass pipe 66 to the upper end of the annular oxygen space 36. A shut-off valve 67 controls the flow through the pipe 66.

For most efficient operation, it is necessary that the proportions of oxygen and gasoline be correctly maintained, and as variations in the amount of oxygen supplied unavoidably occur, due to changes in the rate of evaporation of the oxygen and to other variable causes, provision is made to vary the gasoline feed with reference to variations in flow of oxygen gas or vapor to the combustion chamber.

To accomplish this regulation, advantage is taken of the reactive effect of the combustion gases issuing from the nozzle 28 against the closed or upper end of the combustion chamber 20. The more complete and perfect the combustion, the stronger will be these reactive forces.

In order to utilize these forces in the regulation of the gasoline feed, the combustion chamber is mounted on an annular plate or ring 72 (Fig. 1) and a plurality of supporting rods 73 are provided, each of which is secured to the ring 72 at its lower end. At its upper end, each of the supporting rods 73 is connected to a chambered piston 74, slidable in a fixed sleeve 75 and pressed downward by a relatively strong coil spring 76. Guide blocks 77 on the supporting rods 73 loosely engage the outer casing 22 of the combustion chamber and center the casing but without exerting pressure thereon.

With the chamber thus supported, the casings 20, 21 and 22 are under tension, rather than compression. The reason for supporting the chamber and casings under tension rather than under compression is because all of these thin structures will withstand tension but not compression, except when they are sustaining high internal gas pressure. Moreover, the thin refractory shells 44*a* cannot withstand the bending which would accompany compression. Tension, on the other hand, merely opens slightly the spaces between the shells.

With this construction, any increase in the reactive forces from the nozzle 28 will cause the chamber 20 to move upward against the pressure of the springs 76, carrying with it the gasoline chamber 50 and the outer valve sleeve 52. As the inner valve sleeve 54 normally remains fixed, the openings 53 and 55 will be more nearly aligned and the flow of gasoline will correspondingly increase. The flexible bellows member 59 permits such relative upward movement of the gasoline chamber 50.

As the thrust increases, more gasoline will be admitted through the opening 55, and this will continue until the rate of gasoline flow is such as to produce the greatest thrust for the oxygen flow that is taking place. This oxygen flow, although mainly dependent on the amount of opening of the valve 32 (Fig. 1), also depends largely on the temperature of the chamber and jacket walls. Further upward movement of the chamber 20 and gasoline chamber 50 will not increase the thrust, since the excess of gasoline over that required for best combustion will retard the oxygen flow by creating extra chamber pressure. This retardation of the oxygen flow will reduce the combustion, and the velocity of the gases from the nozzle will fall.

In order to prevent undesirable oscillations or "hunting" of the combustion chamber and particularly those produced by the coaction of the nozzle thrust acting on the valve 50 and the springs 65, perforated pistons 80 are provided in cylindrical openings 81 in the pistons 74. These perforated pistons 80 are mounted at the lower ends of rods 83 fixed in the frame F, so that a dash-pot effect is produced and oscillations of the combustion chamber are prevented. To permit upward movement of the oxygen feed pipe 30, a telescoping joint 84 (Fig. 1) is provided.

It is desirable that the nozzle opening 62 at the bottom of the gasoline chamber 50 be positively closed when the apparatus is not in use. For this purpose, the plate 58 (Fig. 1) is mounted at the lower end of a sleeve or plunger 86 slidable vertically in a bearing in the frame F and having a pin and slot connection 86a with a forked bell crank 87 and pull rod 88.

When combustion is to be discontinued, the rod 88 is pulled, depressing the sleeve 86 and forcing a valve member 89 at the lower end of the rod 57 against the lower end of the gasoline chamber 50, thereby closing the nozzle opening 62. The parts may be frictionally held in this position. When active operation of the apparatus is to be resumed, the parts are manually restored to the position shown in Fig. 1, which position will be maintained during operation by friction and by the gaseous pressures developed in the apparatus.

As the parts adjacent the annular oxygen feed slot 38 are relatively unsupported, brackets or braces 90 (Figs. 6 and 7) are provided which are vertically disposed so that they do not interfere with the flow of oxygen gas but which nevertheless firmly support the upper edge of the inner casing 20.

It will thus appear that simple and effective apparatus has been provided for cooling and continuously operating a combustion chamber and for automatically regulating the supply of fuel thereto.

Having thus described the invention and the advantages thereof, it will be understood that the invention is not to be limited to the details herein disclosed, otherwise than as set forth in the claims, but that what is claimed is:

1. In a combustion apparatus, a fixed frame, a combustion chamber having an axial discharge opening at one end, a supporting structure in which said chamber is mounted for axial movement relative to said frame in response to changes in thrust produced by the flow of combustion gases from said chamber, means to yieldingly resist such movement, means to continuously supply an oxidizing liquid under constant pressure to said chamber, means to supply liquid fuel to said chamber, and valve means to vary the fuel flow in response to changes in the axial position of said chamber relative to said frame.

2. In a combustion apparatus, a fixed frame, a combustion chamber having an axial discharge opening at one end, a supporting structure in which said chamber is mounted for axial movement relative to said frame in response to changes in thrust produced by the flow of combustion gases from said chamber, means to yieldingly resist such movement, means to continuously supply an oxidizing liquid under constant pressure to said chamber, a first valve member adapted for axial motion and radial flow and integral with said chamber, a second valve member attached to said fixed frame through a manually movable intermediate supporting device, said second valve member being freely slidable along said first valve member and with which it coacts, a bellows packing between said first valve member and said intermediate device, and a third valve member integral with said second valve member and with said intermediate supporting device and tightly closable by axial movement therewith.

ESTHER C. GODDARD,

Executrix of the Last Will and Testament of Robert H. Goddard, Deceased.

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