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R. HUBER
FREE PISTON ENGINE COMPRESSED AIR
ACCUMULATOR, VARIABLE VOLUME

2,452,193

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2 Sheets-Sheet 1

Fig. 1

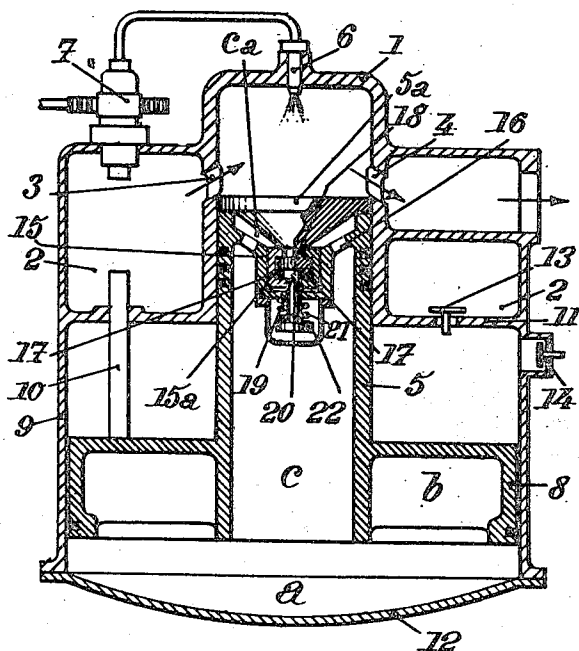
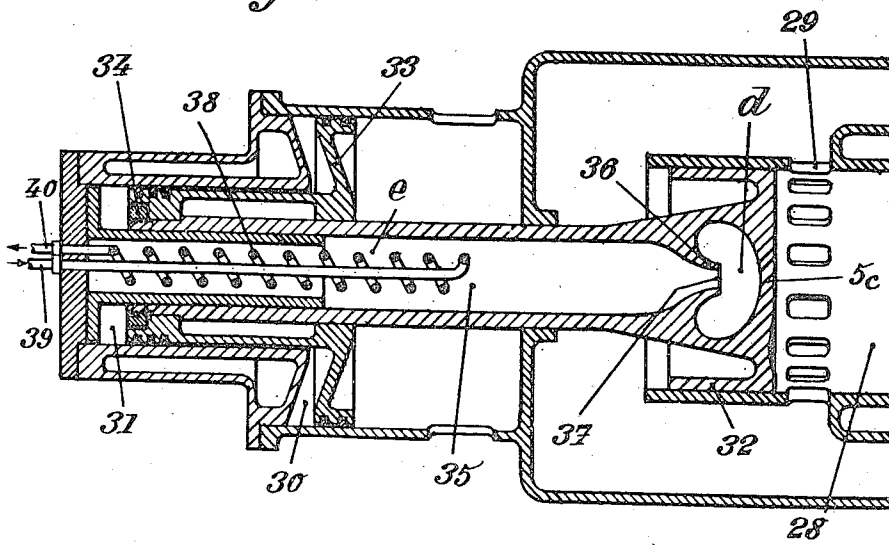


Fig. 5



INVENTOR
Robert Huber
BY
Dean Fambach & Hirsch
ATTORNEY

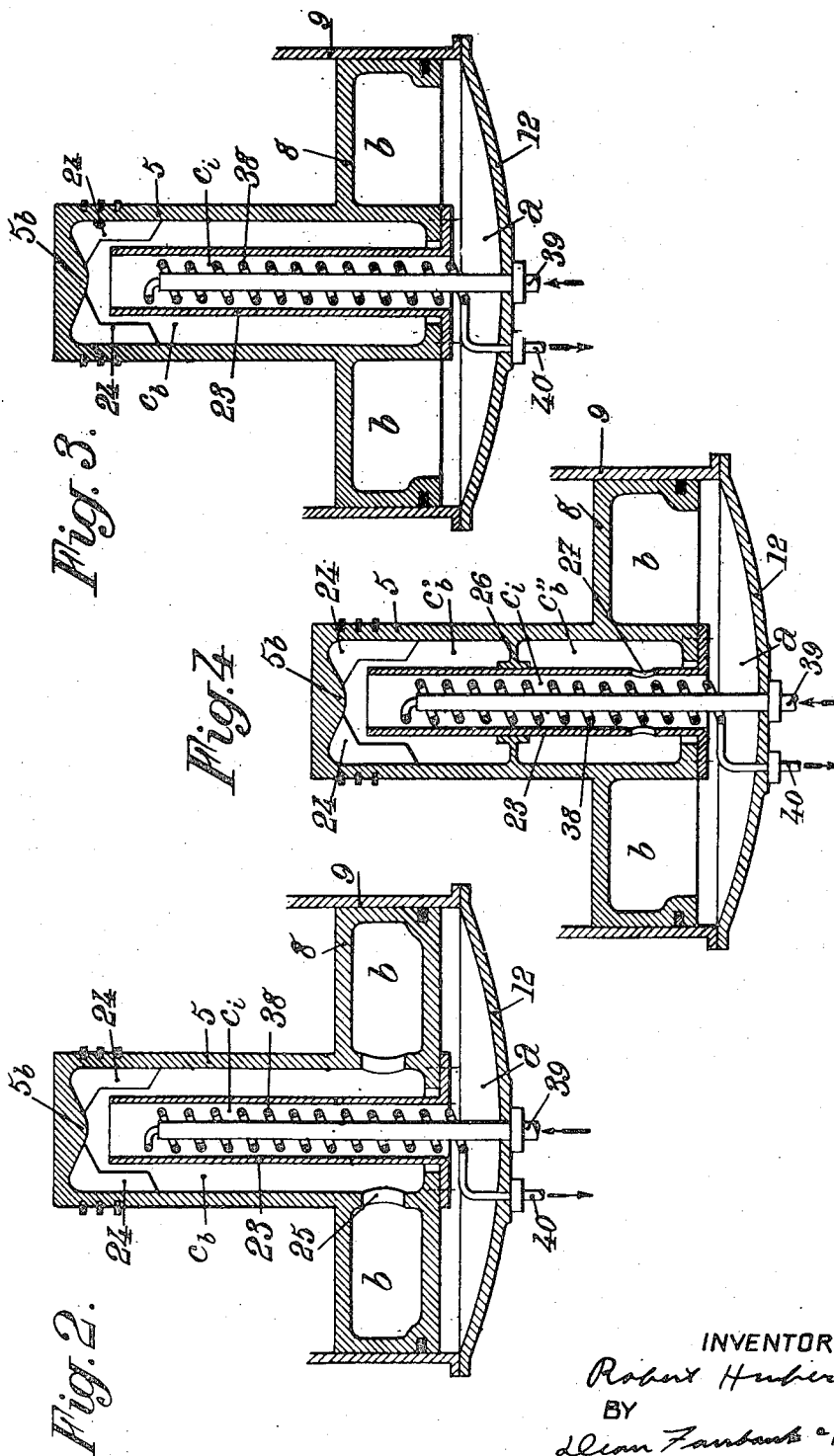
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INVENTOR
Robert Huber
BY
Ellen Fambach & Hirsch
ATTORNEY

UNITED STATES PATENT OFFICE

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FREE PISTON ENGINE COMPRESSED AIR
ACCUMULATOR, VARIABLE VOLUMERobert Huber, Paris, France, assignor to Raul
Pateras Pescara, Lisboa, PortugalApplication November 2, 1945, Serial No. 626,249
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1 The present invention relates to free piston machines including, on the one hand, a movable system comprising a motor piston working in a motor cylinder, and, on the other hand, at least one gas cushion acting as accumulator of energy for ensuring the return stroke of said movable system, and disposed, at least partly, behind the end wall of said piston.

The invention is more especially, although not exclusively, concerned, among these machines, with free piston motor-compressors or auto-generators, i. e. machines of the kind above referred to including at least one motor cylinder and one compressor cylinder and in which the compressed air that is obtained is delivered to the receiver machines or elements either directly (case of motor-compressors), or after having passed, at least partly, through the motor cylinder (case of auto-generators).

The chief object of the present invention is to provide a machine of this kind which is better adapted to meet the requirements of practice than those made up to this time.

Other objects of the invention will result from the following detailed description of some specific embodiments thereof with reference to the appended drawings, given merely by way of example, and in which:

Fig. 1 is a diagrammatic axial section of a free piston auto-generator made according to the present invention;

Figs. 2 to 4 inclusive are partial similar views of three modifications;

Fig. 5 is a diagrammatic axial sectional view of a part of a motor-compressor having opposed free pistons and two stages of compression.

Supposing the invention to be applied to an auto-generator, as shown by Figs. 1 to 4 inclusive by way of example, this machine includes a motor cylinder 1 surrounded by an air reservoir 2 and provided with inlet ports 3 and exhaust ports 4, opened by motor piston 5 when the latter is at the end of its outward stroke. A fuel injector 6 is fitted in the end wall of cylinder 1 and this injector is fed from an injection pump 7. The motor piston is rigid with a compressor piston 8 of a diameter larger than that of said motor piston, said compressor piston coacting with a cylinder 9 and carrying a rod 10 for operating injection pump 7.

Cylinder 9 is limited, on the side of reservoir 2, by an annular partition 11, and on the opposite side by an end wall 12. The variable volume chamber formed between the inner face of compressor piston 8 and partition 11 is provided with

2 at least one suction valve 14 and at least one discharge valve 13, the latter advantageously provided in partition 11. Thus the air compressed during the return or inward stroke of movable system 5, 8 by the inner face of piston 8 is delivered into reservoir 2, after which it passes, through inlet port 3, into motor cylinder 1, while a mixture constituted by the combustion gases and the excess of air under pressure escapes through ports 4 (see the arrows of Fig. 1) this mixture constituting the gas under pressure to be delivered by the auto-generator.

Concerning the cushion of the energy accumulator which ensures the return of the movable system toward the end of its inward stroke, and which operates for instance by compression of the air it contains during the outward stroke of the movable system and expansion of said air during the return stroke, it is housed at least partly inside motor piston 5, which is made hollow for this purpose, whereby the air cushion is in contact with the hottest portions, in particular the crown, of this piston.

According to the invention, in order to obtain a flow of air along these portions, even during the periods for which the air cushion is out of communication with the outside (for instance during the periods corresponding to stable working conditions, for which it is not necessary to adjust the weight of air present inside the cushion by means of known adjustment means not shown by the drawing) the inside of said air cushion is divided into two parts, the ratio of the respective volumes of which varies during the working of the piston, the volume of one of these portions being for instance of constant volume while the volume of the other portion varies as a consequence of the movements of movable system 5, 8, a passage of restricted section being provided between these two portions. The means for dividing the air cushion into said two portions and forming the passage of restricted section, preferably located close to the crown thereof are constituted by a baffle provided inside said cushion. In the embodiment of Fig. 1, the air cushion is housed in the portion *a* of compressor cylinder 9 located on the outer side of piston 8, the space *b* inside said piston, and the space *c* inside the motor piston 5.

According to the embodiment of Fig. 1, the baffle is constituted by a partition 15 located on the inside of motor piston 5 and close to the crown 5*a* thereof. The portions of the cushion above referred to are housed on the one hand, in spaces *a*, *b* and most of the volume of space *c*,

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On the other hand, in compartment c_a provided between end wall $5a$ and partition 15 .

The first of these portions is of variable volume and the other of constant volume.

Furthermore, I provide, in said partition 15 , holes 16 which constitute the passage of restricted section between the two parts in question.

Finally, according to an advantageous arrangement, partition 15 is utilized for the fixation of the piston crown $5a$ to piston 5 . For this purpose, a housing $15a$ is provided at the center of this partition, for accommodating two half-sockets 17 , of U-shaped axial section, adapted to hold together two disc-shaped parts 18 , 19 respectively rigid with crown $5a$ and a bolt 20 , the whole being kept in position by a spring 21 interposed between the bottom wall of housing $15a$ and a nut 22 carried by the end of said bolt.

When the machine is in operation, a part of the air present in the variable volume portion of the air cushion (spaces a , b and most of c) enters chamber c_a through holes 16 when movable system 5 , 8 is moving outwardly, while the air stream through holes 16 takes place in the opposed direction during the inward strokes of said system. I thus obtain a constant renewal of the air present in chamber $5a$ and, consequently, an efficient cooling of the piston end.

Figs. 2, 3 and 4 relate to modifications of the auto-generator shown by Fig. 1.

According to these embodiments, the baffle provided on the inside of motor piston 5 is constituted by a tube 23 the outer diameter of which is smaller than the inner diameter of motor piston 5 , whereby an annular space c_b is left between said tube and the wall of said piston. This tube 23 is fixed to the outer face of compressor piston 8 , so that the communication between compartment a and space c_b is through the inside of said tube, which extends to a short distance from the crown $5b$ of piston 5 , which is fitted, opposite the free end of tube 23 , with fins 24 .

The passage of restricted section which is to constitute the communication between the variable volume portion and the constant volume portion of the air cushion is constituted, in the embodiments of Figs. 2 to 4, according to the dimensions chosen, either by the inside of tube 23 , or by the interval left between the free edge of this tube and the crown $5b$ of piston 5 provided with fins which considerably restrict the section of passage. In both cases, I obtain, as a consequence of the movements of the movable system, a cooling gas stream inside motor piston 5 along the end wall thereof and the portions adjoining it.

The rate of flow of this stream depends upon the ratio of the constant volume portion to the variable volume portion. The higher this ratio, the more intensive this gas stream.

In the embodiment of Fig. 2, the constant volume portion is housed in space b inside the compressor piston 8 and space c_b inside motor piston 5 between the inner wall thereof and the outer wall of tube 23 , the communication between these two spaces being ensured by holes 25 , whereas the variable volume portion is housed in space a and the inside c_1 of tube 23 . Thus a high ratio is obtained between the two portions in question, and, consequently, an intensive cooling stream.

In the embodiment of Fig. 3, the two portions in question are housed in space c_b on the one hand and spaces a , b and c_1 on the other hand. This ratio is therefore smaller and the cooling stream less intensive than in the embodiment of Fig. 2.

In the embodiment of Fig. 4, the two portions

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in question are housed in space c_b' on the one hand and spaces a , b , c_1 and c_b'' on the other hand, the space c_b of Figs. 2 and 3 being divided, in the embodiment of Fig. 4, into two partial spaces c_b' and c_b'' , the latter being in communication, through holes 27 , with the variable volume part. The ratio above referred to and the intensity of the cooling stream are, in the embodiment of Fig. 4, still lower than in that of Fig. 3.

It results from Figs. 2 to 4 that it is easy to determine, through suitable means, the ratio of the constant volume portion to the variable volume portion, and consequently the intensity of the cooling stream.

Concerning the two-stage motor-compressor illustrated by Fig. 5, it includes, on the one hand, a central motor cylinder 28 , with inlet ports 29 (the exhaust ports are not shown), and, on the other hand, on either side of the machine, a low pressure compressor cylinder 30 , a high pressure cylinder 31 (the valves of these cylinders and the conduits through which they are connected are not shown by the drawings), and a movable system including a motor piston 32 , a low pressure compressor piston 33 and a high pressure compressor piston 34 , the two movable systems located on either side of the machine, respectively, and which move in opposite directions, being connected together, in the known manner, through suitable synchronizing means (not shown by the drawing).

I further provide, on either side of the machine, a return energy accumulator the air cushion of which is housed in a hollow cylindrical portion of piston 32 carried by crown $5c$ and extending on the outer side thereof.

According to the invention, I provide the above mentioned baffle forming a communication passage near the crown $5c$ of the piston and constituted by a partition 36 , for instance in the shape of a nozzle. This baffle divides the inside of the energy accumulator air cushion into two portions, one of which, d , has a constant volume, while the other, e , has a variable volume, the communication between these two parts taking place through the restricted section aperture 37 formed in partition 36 .

In this way, I obtain, during the displacements of the pistons, an air stream which, during the outward strokes thereof, flows from part e toward part d , and in the opposite direction during the inward strokes of the pistons. I thus obtain an intensive cooling of the crown $5c$ of motor piston 32 .

According to another feature of my invention, instead of evacuating to the outside the calories absorbed by the air of the cushion exclusively through the wall of cylinder 9 , I provide, inside said cushion, cooling means, for instance constituted by a coil 38 , with a cooling water inlet 39 and outlet 40 . Preferably, coil 38 , fixed with its cooling water inlet and outlet on the outer end wall 12 , extends inside the piston (see Figs. 2 to 5).

In a general manner, while I have, in the above description, disclosed what I deem to be practical and efficient embodiments of the present invention, it should be well understood that I do not wish to be limited thereto as there might be changes made in the arrangement, disposition and form of the parts without departing from the principle of the present invention as comprehended within the scope of the accompanying claims.

What I claim is:

1. A free piston machine which comprises, in combination, a motor cylinder, a motor piston freely movable in said cylinder including a crown and a cylindrical hollow portion extending outwardly from said crown, means for accumulating, during every outward stroke of said pistons, energy for producing the next inward stroke thereof, said last mentioned means including a gas cushion at least partly contained in the hollow portion of said piston, and a tube having its outer wall at a distance from the inner wall of said cylindrical portion of the piston, carried by said piston and extending inwardly to a short distance of said crown, said tube being interposed between a part of said cushion located inside said piston and the remainder of said cushion.

2. A free piston machine which comprises, in combination, a motor cylinder, a motor piston freely movable in said cylinder including a crown and a cylindrical hollow portion extending outwardly from said crown, means for accumulating, during every outward stroke of said pistons, energy for producing the next inward stroke thereof, said last mentioned means including a gas cushion at least partly contained in the hollow portion of said piston, a tube having its outer wall at a distance from the inner wall of said cylindrical portion of the piston, carried by said piston and extending inwardly to a short distance of said crown, said tube being interposed between a part of said cushion located inside said piston and the remainder of said cushion, and cooling fins carried by the inner wall of said piston about the inner end of said tube.

3. A free piston machine which comprises, in combination, a motor cylinder, a motor piston freely movable in said cylinder including a crown and a cylindrical hollow portion extending outwardly from said crown, a hollow piston carried by said cylindrical portion around the outer end thereof, means on the outer side of said last mentioned piston forming therewith a variable volume chamber, means for accumulating, during every outward stroke of said pistons, energy for producing the next inward stroke thereof, said last mentioned means including a gas cushion at least partly contained in the hollow portions of said pistons and said variable volume chamber, and a tube having its outer wall at a distance from the inner wall of said cylindrical portion of the motor piston, carried by said pistons and extending inwardly to a short distance of said crown, said tube being interposed between said variable volume chamber and a part of said cushion located inside at least one of said pistons.

4. A free piston machine which comprises, in combination, a motor cylinder, a motor piston freely movable in said cylinder including a crown and a cylindrical hollow portion extending outwardly from said crown, a hollow piston carried by said cylindrical portion around the outer end thereof, means on the outer side of said last mentioned piston forming therewith a variable volume chamber, means for accumulating, during every outward stroke of said pistons, energy for producing the next inward stroke thereof, said last mentioned means including a gas cushion at least partly contained in the hollow portions of said pistons and said variable volume chamber, a tube having its outer wall at a distance from the inner wall of said cylindrical portion of the motor piston, carried by said pistons and extending inwardly to a short distance of said crown, said tube being interposed between said variable volume

chamber and a part of said cushion located inside at least one of said pistons, and cooling fins carried by the inner wall of said motor piston about the inner end of said tube.

5. A free piston machine which comprises, in combination, a motor cylinder, a motor piston freely movable in said cylinder including a crown and a cylindrical hollow portion extending outwardly from said crown, a hollow piston carried by said cylindrical portion around the outer end thereof, the spaces inside said two pistons being in communication, means on the outer side of said last mentioned piston forming therewith a variable volume chamber, means for accumulating, during every outward stroke of said pistons, energy for producing the next inward stroke thereof, said last mentioned means including a gas cushion at least partly contained in the hollow portions of said pistons and said variable volume chamber, and a tube having its outer wall at a distance from the inner wall of said cylindrical portion of the motor piston, carried by said last mentioned piston and extending inwardly to a short distance of said crown, said tube opening at its outer end into said variable volume chamber and at its inner end into the space inside said motor piston close to said transverse wall thereof.

6. A free piston machine which comprises, in combination, a motor cylinder, a motor piston freely movable in said cylinder including a crown and a cylindrical hollow portion extending outwardly from said crown, a hollow piston carried by said cylindrical portion around the outer end thereof, means on the outer side of said last mentioned piston forming therewith a variable volume chamber in communication with the inside of said second mentioned piston, means for accumulating, during every outward stroke of said pistons, energy for producing the next inward stroke thereof, said last mentioned means including a gas cushion at least partly contained in the hollow portions of said pistons and said variable volume chamber, and a tube having its outer wall at a distance from the inner wall of said cylindrical portion of the motor piston, carried by said last mentioned piston and extending inwardly to a short distance of said crown, said tube opening at its outer end into said variable volume chamber and at its inner end into the space inside said motor piston close to said transverse wall thereof.

7. A free piston machine which comprises, in combination, a motor cylinder, a motor piston freely movable in said cylinder including a crown and a cylindrical hollow portion extending outwardly from said crown, a hollow piston carried by said cylindrical portion around the outer end thereof, means on the outer side of said last mentioned piston forming therewith a variable volume chamber in communication with the inside of said second mentioned piston, means for accumulating, during every outward stroke of said pistons, energy for producing the next inward stroke thereof, said last mentioned means including a gas cushion at least partly contained in the hollow portions of said pistons and said variable volume chamber, a tube having its outer wall at a distance from the inner wall of said cylindrical portion of the motor piston, carried by said last mentioned piston and extending inwardly to a short distance of said crown, said tube opening at its outer end into said variable volume chamber and at its inner end into the space inside said motor piston close to said transverse wall thereof, and a transverse annular partition between the outer wall of said

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tube and the inner wall of said cylindrical hollow portion of the motor piston, at an intermediate point of said tube, thus dividing the annular space between said tube and said portion of the motor piston into two compartments, the outer one of which is in communication with said variable volume chamber.

8. A free piston machine which comprises, in combination, a motor cylinder, a motor piston freely movable in said cylinder including a crown and a cylindrical hollow portion extending outwardly from said crown, means for accumulating, during every outward stroke of said pistons, energy for producing the next inward stroke thereof, said last mentioned means including a gas cushion at least partly contained in the hollow portion of said piston, a tube having its outer wall at a distance from the inner wall of said cylindrical portion of the piston, carried by said piston and extending inwardly to a short distance of said crown, said tube being interposed between a part of said cushion located inside said piston and the remainder of said cushion, and a coil for circulation of cooling liquid mounted inside said hollow portion of the motor piston.

9. A free piston machine which comprises, in combination, a motor cylinder, a motor piston freely movable in said cylinder including a crown and a cylindrical hollow portion extending outwardly from said crown, means for accumulating, during every outward stroke of said pistons, energy for producing the next inward stroke thereof, said last mentioned means including a gas cushion at least partly contained in the hollow portion of said piston, a tube having its outer wall at a distance from the inner wall of said cylindrical portion of the piston, carried by said piston and extending inwardly to a short distance of said crown, said tube being interposed between a part of said cushion located inside said piston and the remainder of said cushion, and a coil for circulation of cooling liquid mounted inside said tube.

10. A free piston machine which comprises, in combination, a motor cylinder, a motor piston freely movable in said cylinder and including a crown and a cylindrical hollow portion carried by said crown on the outer side thereof and having its axis at right angles to the general plane of said crown, means for accumulating energy during every outward stroke of said piston to produce the next inward stroke thereof, said means including said cylindrical hollow portion of the piston, a part rigid with said cylinder arranged to form with said cylindrical hollow portion a chamber of a volume variable during the reciprocating movement of said piston and a mass of gas permanently enclosed in said chamber, and a baffle rigid with one of the two last mentioned parts which form together said variable volume chamber, said baffle being arranged to leave between a portion of said chamber adjoining said crown and the remainder of said chamber a restricted passage located close to said crown.

11. A free piston machine which comprises, in combination, a motor cylinder, a motor piston freely movable in said cylinder and including a crown and a cylindrical hollow portion carried by said crown on the outer side thereof and having its axis at right angles to the general plane of said crown, means for accumulating energy during every outward stroke of said piston to pro-

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duce the next inward stroke thereof, said means including said cylindrical hollow portion of the piston, a part rigid with said cylinder arranged to form with said cylindrical hollow portion a chamber of a volume variable during the reciprocating movement of said piston and a mass of gas permanently enclosed in said chamber, and a baffle rigid with said cylindrical hollow portion of the piston, said baffle being arranged to leave between a portion of said chamber adjoining said crown and the remainder of said chamber a restricted passage located close to said crown.

12. A free piston machine which comprises, in combination, a motor cylinder, a motor piston freely movable in said cylinder and including a crown and a cylindrical hollow portion carried by said crown on the outer side thereof and having its axis at right angles to the general plane of said crown, means for accumulating energy during every outward stroke of said piston to produce the next inward stroke thereof, said means including said cylindrical hollow portion of the piston, a part rigid with said cylinder arranged to form with said cylindrical hollow portion a chamber of a volume variable during the reciprocating movement of said piston, a mass of gas permanently enclosed in said chamber, and a baffle rigid with one of the two last mentioned parts which form together said variable volume chamber, said baffle being arranged to leave between a portion of said chamber adjoining said crown and the remainder of said chamber a restricted passage located close to said crown, and a coil for circulation of cooling liquid provided in said chamber.

13. A free piston machine which comprises, in combination, a motor cylinder, a motor piston freely movable in said cylinder and including a crown and a cylindrical hollow portion carried by said crown on the outer side thereof and having its axis at right angles to the general plane of said crown, means for accumulating energy during every outward stroke of said piston to produce the next inward stroke thereof, said means including said cylindrical hollow portion of the piston, a part rigid with said cylinder arranged to form with said cylindrical hollow portion a chamber of a volume variable during the reciprocating movement of said piston, a mass of gas permanently enclosed in said chamber, and a baffle rigid with one of the two last mentioned parts which form together said variable volume chamber, said baffle being arranged to leave between a portion of said chamber adjoining said crown and the remainder of said chamber a restricted passage located close to said crown, and a coil for circulation of cooling liquid provided in said hollow portion of said piston.

ROBERT HUBER.

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