This invention relates to floating piston motors. In its most usual form, such a motor can be described as comprising a single cylinder chamber in which a pair of conjugate pistons are slidable in opposite symmetrical relation. The pistons are propelled away from each other on their outward stroke by the expansion of combustible mixture which is introduced into a combustion space between the two pistons, and are propelled towards each other on their inward stroke by resilient restoring means which are adapted to store energy during the outward stroke of the piston and to yield up the stored energy during the inward stroke. The restoring means may comprise ordinary spring means, or air damper means. The pistons in this type of motor are, generally speaking, basically free from any connecting rods, links, crank means, and the like, and may be directly connected to suitable load means, the character of which will depend on the particular use to which the motor is put.

One object of this invention is to provide improved resilient restoring means for propelling a piston in a floating-engine motor back on its inward stroke.

Another object lies in the provision of improved synchronizing means between pistons of a floating-piston engine.

Generally speaking, it has been generally recognized that some suitable means are necessary in order to maintain proper synchronism between the reciprocation of the two conjugate pistons and prevent them from getting out of phase or out of step, since departures from an accurately synchronized condition are conducive to a sharp drop in efficiency. Heretofore such synchronizing means have usually been provided in the form of mechanical linkages symmetrically coupled to the pistons and coupled together. Such linkages are complicated and detract from a basic advantage, of floating-piston engine over conventional combustion engines, i.e. the lack of any mechanical linkages therein. An object of this invention therefore is to eliminate such synchronizing linkages.

In floating-piston engines the fuel is generally supplied to the cylinder by injector means. Moreover, pressure lubrication means are generally utilized at least in part in connection with such engines and the loads driven thereby. Objects of this invention are to make efficient use of the fuel injector means and pressure lubrication in floating piston engines, in furthering the attainment of the objects specified hereinabove.

Further objects of the invention will appear as the disclosure proceeds.

In one aspect of this invention, there is provided a floating-piston motor comprising a cylinder and at least one motor piston displaceable therein, fuel injection and combustion means in said cylinder for driving said piston in one direction under the effect of expansion of fuel combustion gases, and fluid-pressure means adapted to store energy during displacement of said piston in said one direction and thereafter to yield up said energy to drive the piston back in the opposite direction, characterized in that said fluid pressure means comprises an auxiliary cylinder-and-piston means associated with said piston and a body of liquid within said auxiliary means adapted to be compressed to a high degree of pressure during the displacement of said motor piston in said one direction. The degree of compression to which the body of liquid is subjected is in a general range of from 100 kg/sq.cm. to 5,000 kg/sq.cm, and preferably in the range of from 1,000 kg/sq.cm. to 2,500 kg/sq.cm.

It is well-known that liquids, while considerably less compressible than gases, still are compressible. Thus a typical liquid fuel such as gas oil may possess a compressibility on the order of 65.10^{-6} per kg/sq.cm. This means that a body of such fuel when subjected to a pressure of 1,000 kg/sq.cm. will sustain a reduction in volume of about 6.5 % . By the use of liquid rather than gas as the compressible medium , therefore, the invention is able to achieve a great saving in the volume of fluid required and the space of the resilient restoring means.

In one embodiment of the invention, each piston of a dual-piston floating-piston engine has an auxiliary piston rigidly connected coaxially with it on the side of it remote from the opposite or conjugate motor piston, and the auxiliary pistons are slidable in related auxiliary cylinder chambers supported from the outer ends of the motor cylinder. As the piston assemblies are driven outwards by the expansion force of the combustion gases the auxiliary pistons act to compress bodies of liquid enclosed in the respective auxiliary cylinder chambers, so as to store up the kinetic energy of the pistons as hydrostatic pressure energy therein, and this pressure energy is then given up as kinetic energy again to propell the two piston assemblies on their inward stroke.

According to an improved feature, the auxiliary chamber may be formed with more than one compartment, which are adapted to be sealed off in succession as the auxiliary piston advances through said compartments in the outward stroke, so as to reduce the amount of liquid subjected to volume variation by the auxiliary piston and thereby increase the unit elastic reaction force developed by the liquid (or variation in elastic reaction per unit length).

I/n a motor according to the invention wherein hydraulic pressure is used especially for the fuel pumping and injecting system, while a separate system may be used for the purpose, according to one advantageous feature of the invention such system is combined into a unitary whole with the piston-restoring liquid-compression system described above. For such purpose provision is made for using the engine fuel as the liquid compressed in the auxiliary compression chambers ; and a fluid connecting means is provided between said auxiliary chamber or chambers and the fuel injection system.

According to an alternative form of embodiment, lubricant is used as the liquid compressed in the auxiliary compression chamber or chambers, and connecting means are provided from the latter to a pressure lubrication system for the motor.

According to another feature, synchronization between the reciprocation of the two conjugate pistons of a floating piston engine is achieved by providing at least one balancing conduit interconnecting the auxiliary compression chambers that are provided in association with the respective motor pistons according to the main feature described above.

An exemplary embodiment of the invention will now be described for purposes of illustration but not of limitation with reference to the accompanying drawing, which is a simplified sectional view of a floating-piston engine constructed in accordance with the invention.

As shown, the engine includes a cylinder 1 having conjugate pistons 2 and 3 slidable therein. The cylinder 1 is formed with inlet ports 4 and an outlet pipe 5. Each piston is rigidly connected to a structure 6-7, bodily movable with it, which structure may include conventional guiding and power take-off means, not illustrated herein, positioned in the gaps indicated herein as 6a and 7a.

Secured on the outer end of the structure 6 or 7 is an auxiliary compressor piston 8 or 9 slidable in a sealed metallic enclosure 10 or 11 secured to the cylinder 1, and filled with a body of liquid adapted to be compressed by the auxiliary piston 8 or 9.

In the specific embodiment of the invention here illustrated, the liquid is formed by the engine fuel. The liquid fuel is supplied from a fuel tank, not shown, by way of lines 12-13. A further pair of lines 14 and 15 provided with check-valves 16 and 17 therein, serve to lead part of the compressed liquid to the fuel injector device 18 which may be conventional, whereby the invention will be seen to provide improved means for supplying fuel under pressure to the injector means of a floating-piston engine. The lines 14 and 15 are connected with the enclosures 10 and 11 at points so positioned in said enclosures that the liquid pressure obtained at the time where the piston 8 or 9 is in the act of sealing said connection, equals the pressure value required to operate the injector device 18, with due allowance of course for the pressure drop between the injector 18 and the said connections. It is noted moreover that said pressure drop is controllable.

In the exemplary embodiment shown, the sealed enclosure includes , in addition to the main compression chamber 19-20, a secondary compression chamber 21, 22, of annular form, and communicating with the main chamber through ports 23, 24 which are sealed by the piston 8 or 9 as the latter is moving into the body of liquid, i.e. during the outward stroke of the motor pistons 2 and 3. On the ports 23, 24 being sealed, the pressure in the secondary chamber 21 or 24 remains substantially constant, while it continues to increase in the main chambers 19 and 20, and it now increases at a faster rate than what would have occurred had the said ports not been sealed off. The result of this arrangement is that an increased elastic resistance is opposed to the outward motion of the piston assembly during the latter stage of the outward stroke. Further, as a result of this arrangement, the displacement of the piston assembly will vary but little with variations in engine operating speed which cause corresponding variations in the energy stored in the energy-storage devices.

In accordance with another desirable feature of the invention included in the exemplary embodiment shown, improved synchronizing means are provided between the two conjugate motor pistons, in the form of a balancing line 25 interconnecting the chambers 19 and 20 of the energy storage devices. The presence of this balancing line gives rise to interchange of energy between the two devices, so that balancing forces are set up which prevent the two pistons assemblies from falling out of step (or out of phase). Thus, assuming that one of the movable assemblies tends to lead the other, energy will be transferred from the leading assembly to the lagging side, shortening the distance travelled by the latter and correspondingly lengthening the stroke of the former and oppositely varying the forces with which the two assemblies are driven back towards their inner dead center position so as to restore synchronism.

In one experimental prototype engine built by us in accordance with the teachings of this invention, the operating characteristics were as follows :

- Power output : 15 HP.
- Pulsing frequency : 100 piston cycles per second.
- Motor cylinder bore : 70 mm.
- Piston stroke : 60 mm.
- Auxiliary cylinder bore (corresponding to piston 8 :12mm.
- Total volume of an hydraulic compression space 19-21-23 : 30 cu.cm., of which about 50% in chamber 21-23 and 50% in chamber 19.
- Useful axial contraction of the liquid body : 24 to 25 mm.
- Maximum hydraulic pressure developed, average values :
  in compartment 21 : about 800 kg/sq.cm.
  in compartment 19 : about 1,600 kg/sq.cm.

A floating piston engine constructed in accordance with the teachings of this invention has a number of important advantages, in that it simplifies the compression means previously provided and permits reduction in the weight of the movable piston assemblies and corresponding increase in the power-to-mass ratio of the engines.

This results mainly from the fact that the volume of the hydraulic compression chamber required is, as an order of magnitude, one thousand times smaller than the volume of the air cushion that has to be used in a pneumatic compression chamber for a motor of given power rating.

Among the various modifications and variations that may be conceived by those familiar with the art on the basis of the teachings given herein, the following may be more specifically mentioned :

- More than one liquid compression unit similar to those here shown may be used in connection with each motor piston assembly.

- A liquid compression unit according to the invention may be combined with a conventional air compression unit.

- An engine lubricating system may be provided , wherein at least one of the liquid compression devices of the invention operates as a pumping device for the liquid lubricant.

- Adjusting means may be associated with the sealed enclosure for increasing or decreasing the volume of liquid compressed and thereby modifying the length of stroke of the piston assemblies.