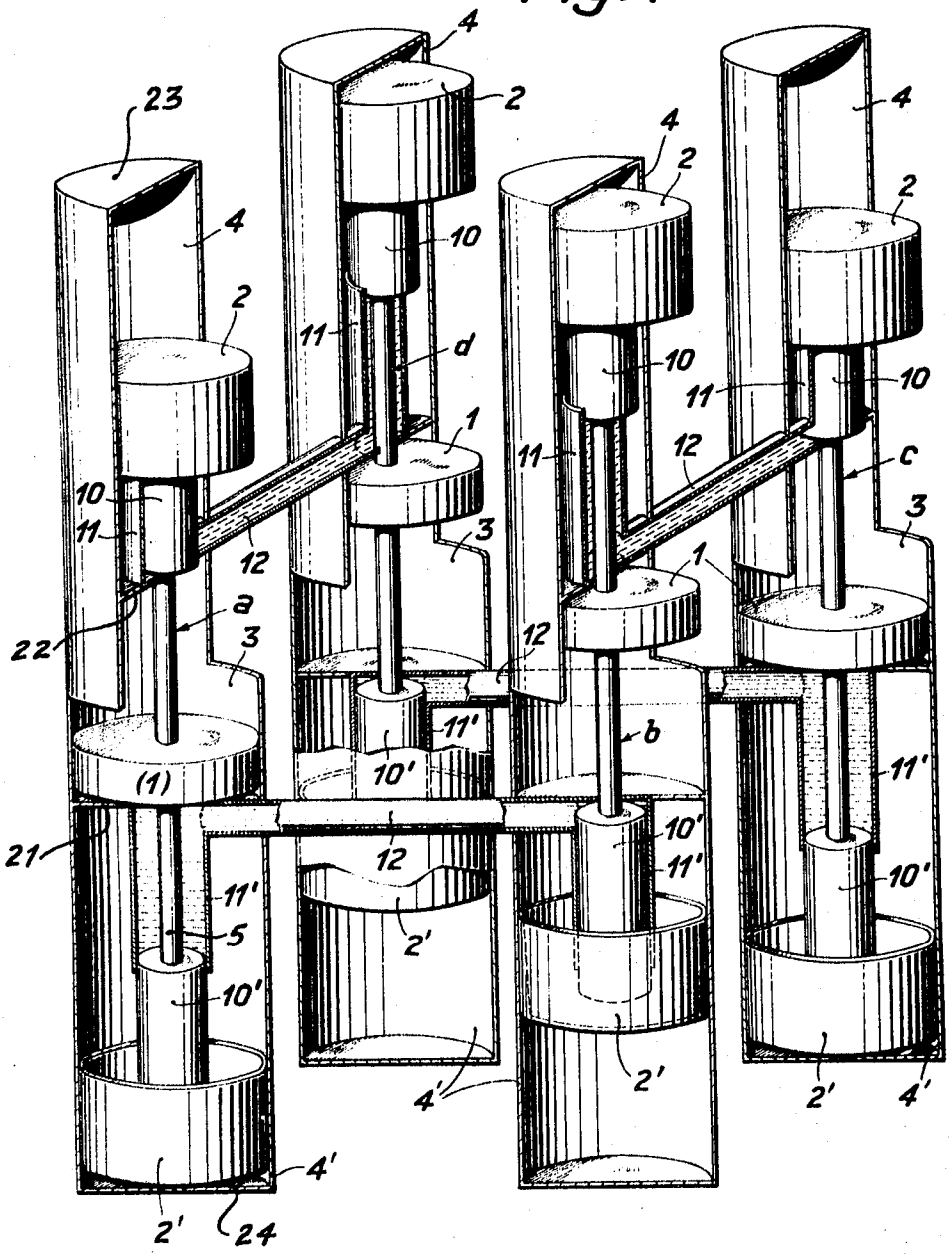
July 15, 1969 A. URBEN 3,455,501

FREE PISTON PUMPING ENGINE

Filed May 24, 1967 2 Sheets-Sheet 1

Fig. 1



Inventor:

Adauto Urben

BY Pennie, Edmonds, Morton, Taylor and Adams

ATTORNEYS

July 15, 1969 A. URBEN 3,455,501

FREE PISTON PUMPING ENGINE

Filed May 24, 1967 2 Sheets-Sheet 2

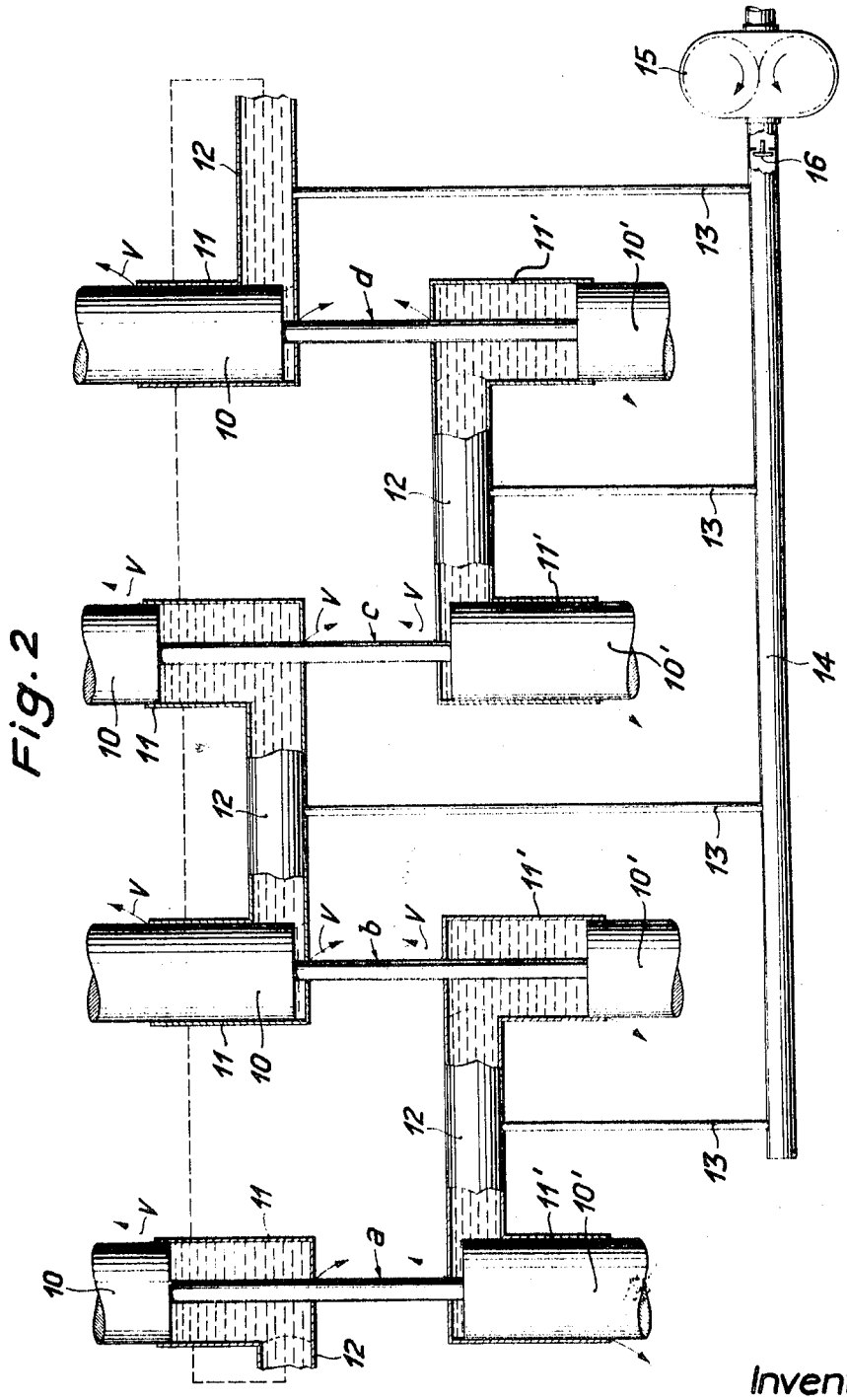


Fig. 2

Inventor:
Adauto Urben
BY Pennie, Edmonds,
Morton, Taylor and Adams
ATTORNEYS

United States Patent Office 3,455,501 Patented July 15, 1969

3,455,501

FREE PISTON PUMPING ENGINE

Adauto Urben, Winterthur, Switzerland, assignor to Sulzer Brothers Limited, Winterthur, Switzerland, a Swiss company

Filed May 24, 1967, Ser. No. 640,884
Int. Cl. F02b *71/06;* F04b *31/00;* F02d *39/10*
U.S. Cl. 230—56 1 Claim

ABSTRACT OF THE DISCLOSURE

There is disclosed a free piston pumping engine including two pairs of pumping units each including a pumping piston, two driving pistons and two synchronizing pistons with each piston working in a separate stationary cylinder. Junction conduits interconnect the synchronizing cylinders of the pumping units in pairs. A separate delivery conduit having a cross-section not greater than 10% of the cross-section of the junction conduit unobstructedly connects a pressure source to each junction conduit.

BACKGROUND OF THE INVENTION

Field of the invention

The invention relates to free piston engines useful as pumps, compressors and the like.

The prior art

Free piston pumping engines have been heretofore proposed, but difficulty has been experienced in holding the piston units thereof in the proper relative phases. The mechanical synchronizing devices hertofore proposed have been relatively complicated and have not in all instances been readily applicable.

Summary of the invention

It is an object of the invention to produce a free piston engine substantially simpler than those heretofore proposed in respect of the phasing or synchronizing devices employed, more compact as regards the space required for these synchronizing means, and having greater flexibility in the disposition of the various parts of the engine.

Brief description of the drawing

The invention will now be further described in terms of a non-limitative exemplary embodiment and with regard to the accompanying drawings, wherein:

FIG. 1 is a diagrammatic perspective view of a free piston engine according to the invention; and

FIG. 2 is a diagram showing the synchronizing or phasing interconnection of the piston units of the engine of FIG. 1, elements of FIG. 1 appearing in a developed view in FIG. 2.

The free piston engine of FIG. 1 includes four piston units *a*, *b*, *c* and *d*, each of which includes a central pumping or compressor piston **1** with internal combustion engine or driving pistons **2** and **2'** on either side of that pumping piston, synchronizing pistons **10** and **10'** likewise on opposite sides of the piston **1**, and a piston rod **5** to which the five pistons are affixed. The pumping pistons **1** move in pumping cylinders **3**, the engine pistons in engine cylinders **4** and **4'**, and the synchronizing pistons in synchronizing cylinders **11** and **11'**. These five cylinders are fixed with respect to each other and with their associated piston unit make up one of the four pumping units of the engine of FIG. 1. The cylinders have been shown only fragmentarily for purposes of illustration.

The pumping cylinders are limited by partitions **21** and **22** which serve as heads for the synchronizing cylinders **11** and **11'**. Inlet and outlet valves, together with pump intake and delivery conduits, not shown, are provided in each of the pumping cylinders on each side of the pumping piston therein. These elements may be conventional in nature and have therefore not been shown. The engine cylinders are closed by heads **23** and **24** which with those cylinders may include fuel and combustion air inlet and exhaust valves and, optionally, ignition means. The engine pistons may operate on either two or four stroke cycles, and may employ spark ignition or may be of the diesel type. All of these elements, which may likewise be conventional, have not been shown in the drawing.

As is shown in FIG. 1, the axes of the piston units *a*, *b*, *c* and *d*, and therefore the piston rods **5**, are parallel to each other and are disposed at the angles of a quadrilateral parallelogram, which may for example be a square. For balancing of the linear and moment inertia forces the phasing of the piston units is such that the pistons of two diagonally opposite units are in the same phase while circumferentially adjacent units are in opposite phase. Thus, in FIG. 1, when the pistons of the units *a* and *c* are at the lower limit of their travel (as seen in that figure), the pistons of the units *b* and *d* are at the upper end of their travel. When the pistons of the units *a* and *c* are moving upwardly those of the units *b* and *d* are moving downwardly and vice versa.

For synchronization of the piston motions, i.e. for preservation thereof in the relative phase relation just described, the piston units are provided each with two synchronizing pistons **10** and **10'** which cooperate with synchronizing cylinders **11** and **11'**. In each piston unit the two synchronizing pistons, like the two engine pistons, are in opposite phases of their cyclical motions with respect to their cylinder heads. Thus when an engine piston **2'** is at the top of its stroke, adjacent its cylinder head **24**, the engine piston **2** of that unit is at the bottom of its stroke, at maximum distance from its cylinder head **23**. Similarly, when a synchronizing piston **10** is at the top of its stroke, adjacent its cylinder head **22**, the synchronizing piston **10'** of that unit is at the bottom of its stroke, at maximum distance from its cylinder head **21**. The space between each synchronizing piston and the head of the cylinder in which it moves may be referred to as a synchronizing space.

The synchronizing spaces of piston units which operate out of phase are coupled together by junction conduits **12**. More particularly, the conduits **12** interconnect, as between out-of-phase pumping units, synchronizing spaces thereof which are similarly positioned on their respective pumping units so as to be themselves out of phase when their pumping units are out of phase, in accordance with the intended operation of the engine. Thus the synchronizing space of cylinder **11** on unit *d* is connected via a junction conduit **12** with the synchronizing space of cylinder **11** on unit *a*, while the synchronizing space of cylinder **11'** on unit *a* is connected by another junction conduit **12** to the synchronizing space of cylinder **11''** on unit *b*. Similarly the synchronizing spaces of cylinders **11** of units *b* and *c* are interconnected and, lastly, the synchronizing spaces of cylinders **11'** on units *c* and *d* are interconnected. The cylinders **11** and **11'** and the conduits **12** are filled with a hydraulic fluid such as oil and constitute as to each such pair of coupled piston units a set of communicating vessels.

FIG. 2 shows a diagram of the synchronizing pistons and cylinders in the engine of FIG. 1, and of their interconnecting conduits **12**, as if the engine of FIG. 1 had been developed on a plane. For simplicity and clarity the pumping and engine pistons have been omitted from FIG. 2. Thus, the axes of the four piston units which in the structure of FIG. 1 are disposed at the corners of a parallelogram, lie in FIG. 2 in a common plane. The conduit **12** leading to the right from the upper synchroniz-

ing cylinder **11** of the piston unit *d* is coupled with the conduit **12** extending to the left from piston unit *a* as indicated by the dash line in FIG. 2.

FIG. 2 also shows apparatus for supplying of hydraulic fluid to the synchronizing cylinders. Since a certain amount of leakage is unavoidable, as indicated by the arrows V in FIG. 2, the individual junction lines **12** are connected through delivery lines **13** to a common supply line **14** fed from a pump **15**. This pump maintains the hydraulic fluid in the cylinders **11**, **11'** and conduits **12** under a pressure above atmospheric and thereby insures replacement of hydraulic fluid lost through leakage.

The supply line **14** can be provided with a check valve **16**, if necessary in view of the nature of the feed pump **15**.

As is evident from FIG. 2, the delivery lines **13** of the synchronizing system are connected together by means of a supply line **14**. This has the result that small irregularities in the synchronous motions of the piston units can be tolerated, the resultant motions of hydraulic fluid in the delivery lines **13** exerting a substantial damping effect so that critical oscillations of the system are avoided and so that oscillations in general are rapidly damped out. To this end the delivery lines **13** are so dimensioned that they exert a strong throttling effect on the hydraulic medium by comparison to the effect thereon of the junction lines **12**. Thus with normal length ratios the cross-section of the delivery lines should amount at most to 10% of the cross-section of the junction lines **12**. The term "normal length ratios" may be understood as the length ratios of delivery lines **13** to junction lines **12** each of them being made no longer than absolutely necessary. In a particular case with a diameter of 40 cm. for the synchronizing pistons **10** and **10'** and with a motion frequency for the pistons of 350 cycles (i.e. 700 strokes) per minute, a cross-section of 200 square centimeters for the junction lines **12** and of one square centimeter for the delivery lines **13** was found suitable.

As a result of the fact that all of the junction lines **12** are connected to each other via the delivery lines **13** and supply line **14**, it is possible to effect or to tolerate an axial shift of all of the piston units, for example, in the event of too heavy a supply of fuel to the driving pistons on one side of the pumping pistons. This requires that the pistons be subjected to a centering action independently

of the operation of the synchronizing pistons. In the embodiment illustrated, this centering action is provided by the buffering compression action in the engine and pumping cylinders. Advantageously, supplementary buffer spaces and synchronizing means may be employed in accordance with the disclosure of the copending application of Anton Steiger entitled Free Piston-Type Internal Combustion Engine which is assigned to the assignee hereof and which has been filed concurrently with the present application. Buffers employing mechanical springs may also be used as supplementary synchronizing means.

While the invention has been described herein in terms of a presently preferred embodiment, the invention itself is not limited thereto but rather comprehends all modifications on and departures from that embodiment properly falling within the spirit and scope of the appended claim.

I claim:

1. A free piston internal combustion pumping engine comprising a plurality of pumping units, said plurality being an even multiple of two, each of said units including a pumping piston, a driving piston, a synchronizing piston, means coupling said pistons together, and a pumping cylinder, an engine cylinder and a synchronizing cylinder surrounding said pumping, driving and synchronizing pistons respectively, said engine further comprising junction conduits interconnecting the synchronizing cylinders of said pumping units in pairs, a source of hydraulic fluid under pressure, and a separate delivery conduit unobstructedly connecting said source to each of said junction conduits, said delivery conduits having each a cross-section not greater than 10% of the cross-section of the junction conduits to which they respectively connect.

References Cited

UNITED STATES PATENTS

2,139,425	12/1938	Steiner	230—56 XR
3,106,896	10/1963	Van Der Lely et al.	103—54
3,182,895	5/1965	Panhard	230—56

ROBERT M. WALKER, Primary Examiner

U.S. Cl. X.R.

123—46