Jan. 12, 1965 C. A. CLARK 3,165,062

VARIABLE VOLUME PUMPING APPARATUS

Filed July 29, 1963 2 Sheets-Sheet 1

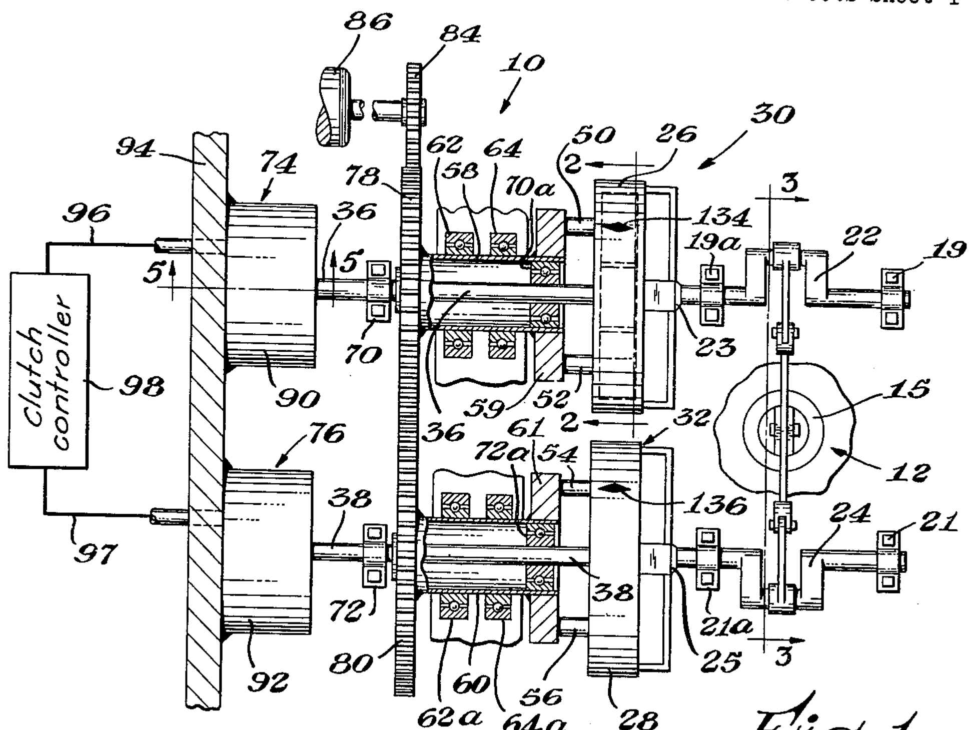

Fig. 1

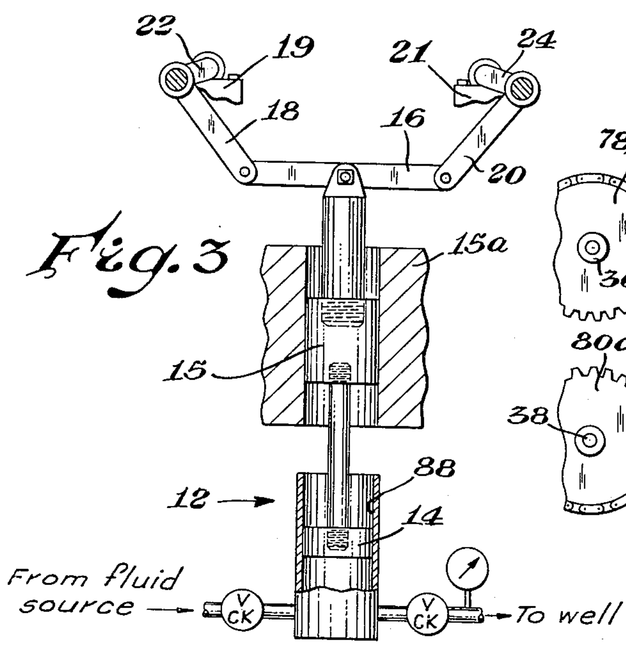

Fig. 3

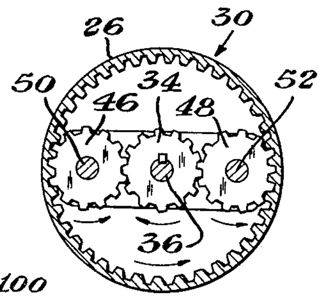

Fig. 2

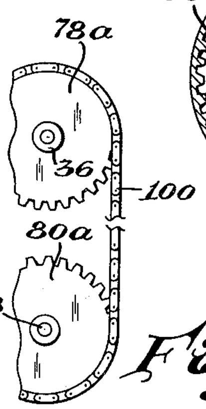

Fig. 4

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VARIABLE VOLUME PUMPING APPARATUS

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2 Sheets-Sheet 2

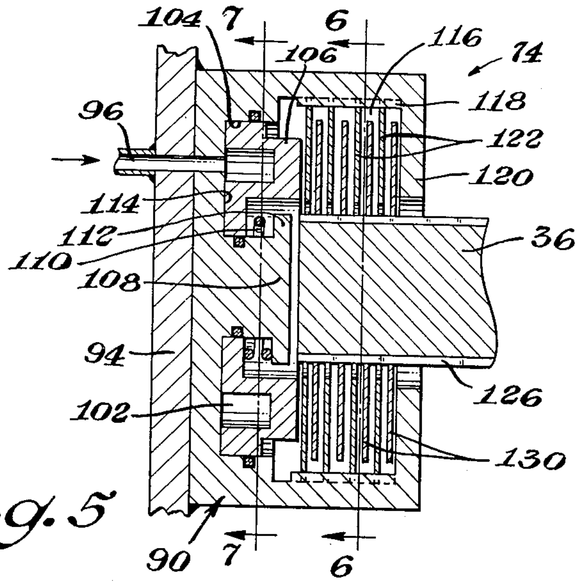

Fig. 5

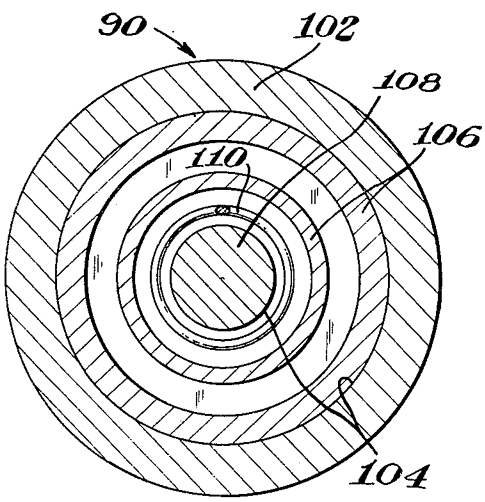

Fig. 7

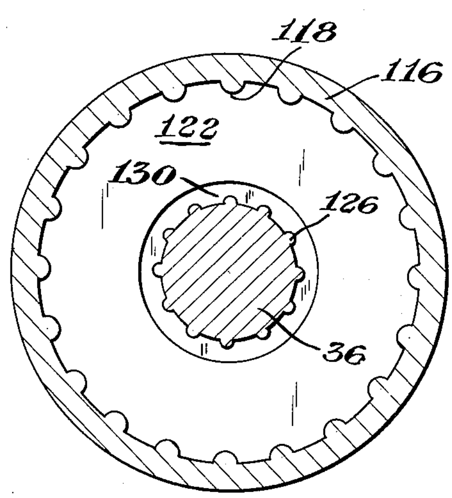

Fig. 6

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VARIABLE VOLUME PUMPING APPARATUS

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11 Claims. (Cl. 103—38)

This invention relates to pumps and particularly to reciprocating piston pumps which are capable of delivering varying volumes of fluid while the piston or pistons of the pump reciprocate at a substantially constant rate.

Other so-called "variable volume" pumps have been known for many years for specific uses, but for one reason or another these pumps are not well adapted for use in mobile service, such as oil and gas well treating service, for example. Such service requires maximum utilization of available horsepower to thereby deliver the maximum volume of pumped fluid against whatever pressure may develop without exceeding the strength limits of the equipment.

Such requirements necessitate minimum weight and bulk consistent with the achieving of other requirements, and ease and reliability in controlling the "variable volume" feature of the pump while under load.

Exceptional reliability is necessary because the pump will be used often in remote areas where facilities are not available for making major repairs and because in well treating service equipment breakdown can result in great damage to the well under treatment. For example, a pump breakdown during a well cementing job could result in the cement setting up in the well casing before displacement can be effected between the casing and well bore wall.

In conventional well treating pumping units, a power source or prime mover, usually an internal combustion engine, transmission (which may include a torque converter) and the pump are disposed on a truck.

Any reduction in weight which can be achieved in the coupling of power to the pump of the treating unit would permit the construction of a lighter treating unit or would permit the construction of a treating unit having an increased pumping capacity (either in volume or pressure, or both) without exceeding the normal weight limits.

Accordingly, a principal object of this invention is to provide an improved variable volume pumping apparatus which is suitable for use in treating earth wells.

Another object of this invention is to provide an improved variable volume pumping apparatus which is compact in size with respect to its pumping capacity and power utilization over a wide range of pumping pressures.

A further object of this invention is to provide an improved mobile fluid pumping system for well treating service or the like.

In accordance with this invention a piston type positive displacement pump achieves an infinitely variable stroke between maximum and minimum limits through a controlled variable phase relationship between two mechanically interlocked crankshafts. These crankshafts operate through connecting rods to an equal-legged walking beam pinned at its centerline to a plunger crosshead. Similar planetary gears, one set coupled to each crankshaft, are used to drive the crankshafts. Multiple disc clutches, one coupled between the sun gear of each planetary gear and the frame of the pump are used to establish and maintain the desired phase relationship between the crankshafts during operation. By slightly releasing one clutch to permit a predetermined rotation of the sun gear to which it is coupled, the phasing of the planetary gears coupled to each crankshaft may be changed with respect to each other. The phase relationship between crankshafts and hence the piston stroke may be changed inversely with the discharge pressure to provide a hydraulic horsepower output desirably matched to the available horsepower of the prime mover.

The invention, as well as additional objects and advantages thereof, will best be understood when the following detailed description is read in connection with the accompanying drawing, in which

FIG. 1 is a simplified plan view, partly broken away and in section, of apparatus in accordance with this invention;

FIG. 2 is a sectional view taken along the line 2—2 of FIG. 1;

FIG. 3 is a sectional view taken along the line 3—3 of FIG. 1;

FIG. 4 is a fragmentary end view of the drive gears showing chain drive coupling between the drive gears rather than directly coupled drive gears as shown in FIG. 1;

FIG. 5 is a side elevational view, in section, of a multiple disc clutch as used in FIG. 1;

FIG. 6 is a sectional view taken along the line 6—6 of FIG. 5; and

FIG. 7 is a sectional view taken along the line 7—7 of FIG. 5.

Referring to the drawing, there is shown variable volume pumping apparatus, indicated generally by the numeral 10, mounted on a common frame shown only in fragments. The apparatus includes a single action reciprocating piston-type pump 12 (see FIG. 3 especially) whose piston 14 is coupled to a crosshead plunger 15, adapted to reciprocate in the guide 15*a*, and to the center of an equal-legged walking beam 16 which in turn is coupled at its ends by connecting rods 18, 20 to crankshafts 22, 24, respectively, which are journaled in bearings 19, 21 and 19*a*, 21*a*, for example.

Each of the crankshafts 22, 24 has an end 23, 25 which is rigidly mechanically coupled to the ring gear 26, 28 of planetary gear assemblies 30, 32, respectively. The planetary gear assembly 30, shown in section in FIG. 2, is the same as the gear assembly 32.

The planet gears (46, 48 in FIG. 2) of each planetary gear assembly 30, 32 are journaled on to shafts 50, 52 (and 54, 56 in FIG. 1) which are parallel to the shafts 36, 38 onto which the sun gears (34 in FIG. 2) are journaled and which are fixedly connected by means of brackets 59, 61, respectively, to a hollow shaft 58 or 60, each of which is parallel to and surrounds one of the respective shafts 36, 38 as shown. Each of the hollow shafts 58, 60 is supported in position by two bearings 62 and 64 and 62*a* and 64*a*, respectively. A spur gear 78 or 80 is disposed on and rigidly coupled to each of the hollow shafts 58, 60, respectively, the spur gears 78, 80 being equal in size and in the number of teeth they contain. The spur gear 78 is driven by means of a gear 84 which is coupled to a prime mover such as a motor 86, for example.

The shafts 36 and 38, each rigidly coupled to the sun gear (34 in FIG. 2) of one of the planetary gear assemblies 30, 32, extend through the hollow shafts 58, 60, respectively. The shafts 36, 38, journaled in bearings 70, 72 and 70*a*, 72*a*, respectively, each have their end (see FIG. 5) which is remote from the sun gear (34 in FIG. 2) serving as or being coupled to the rotatable member of a multiple disc clutch assembly 74 or 76, respectively.

Each of the clutch assemblies 74, 76 has a fixed segment or part 90 or 92 which is coupled to a frame element 94 of the pumping apparatus.

Each of the bearings 19, 19*a*, 21, 21*a*, 62, 62*a*, 64, 64*a*, 70, 72, the pump 12, guide 15*a* and clutch assemblies 74, 76 are mounted on a common framework for the apparatus, which framework also carries the power source 86, the framework being attached to or supported by the mobile unit, e.g. a truck, which carries the apparatus.

Referring now to FIGS. 5, 6 and 7, as well as to FIG. 1, the structure of the multiple disc clutch assembly 74 (or 76) (perhaps more accurately called a brake in view of its use) is shown in detail.

The outer housing and frame part 90 of the clutch assembly is fixed secured to the frame 94 of the pump assembly as mentioned previously. The housing and frame part 90 is divided into two functional sections. The section 102, adjacent to the frame section 94, has a bore 104 and piston 106 disposed around a central bar 108 having an outwardly extending flange 112 at its end which is remote from the frame part 94. A piston return spring 10, disposed between the outwardly extending flange 112 of the bar 108 and the piston 106, forces the piston 106 towards the end 114 of the section adjacent to the frame 94 except when the piston is forced forward by fluid, usually oil, pumped into the bore 104 into which the piston fits. Oil is pumped into and released from the bore 104 by means of the line 96 (97 for clutch assembly 76) which is also coupled to the clutch controller 98.

The second functional part 116 of the section 90, which extends beyond the bore 104, has splines 118 on its inner wall surface and an inwardly extending flange 120 at its end which is remote from the frame section 94. A plurality of discs 122 are fitted on and carried by the hollow splined part in the space between the piston 106 and the inwardly extending flange 120.

The end of the shaft 36 (and 38), as previously mentioned, has longitudinally extending splines 126 on its end part which is telescoped within the outer housing and frame part 90 from the end thereof having the inwardly extending flange 120. The shaft 36, as previously mentioned, is rigidly coupled to the sun gear (34 in FIG. 2).

A plurality of discs 130 are fitted over and carried by the splined end of the shaft 36. The discs 122 and 130 are interleaved with one another, almost filling the space between the flange 120 and the forward end of the piston 106 when the piston is in its retracted position.

In operation, let it be assumed that the crankshafts 22, 24 are initially aligned with respect to one another to provide a maximum pumping stroke of the piston 14. Markers 134, 136 are disposed on the outer surface of the ring gear 26 or 28, in the same relative position with respect to the crankshafts which are rigidly coupled to the ring gears. The markers may be painted, cut, or etched onto the ring gears 26, 28 if the checking of their relative positions is to be determined visually (usually using a stroboscopic light source in so doing). Alternatively, magnetic or radioactive markers may be used and their positions noted during operation of the pump by suitable detectors which are generally well known in the art.

As described above, the throws of the crankshafts 22, 24 are connected in an in-phase rotational relationship, and move the piston 14 of the pump 12 backwards and forward in the pump cylinder 88 at maximum stroke length as power from the gear 84 is coupled by means of the spur gear 78 to the hollow shaft 58 and, by means of the spur gears 78, 80, to the hollow shaft 60.

The rotation of the hollow shafts 58, 60 also rotates the planet carriers 59, 61 which are used to drive the planetary gears (46, 48 in FIG. 2). The planet gears, as mentioned previously, are carried by and are free to rotate on the shafts 50, 52 and 54, 56 which extend from the respective planet carriers.

The planet gears (46, 48 in FIG. 2) are also coupled to the sun gear (34 in FIG. 2) in their respective assembly 30 or 32. The sun gears are coupled (by keyway, for example) to the shafts 36, 38, which as mentioned previously, are coupled at one end to one of the clutch assemblies 74, 76. The clutches are actually operated as brakes, the "brake" being applied to hold each shaft 36, 38 in a fixed, non-rotating position except when the phasing between the crankshafts is to be changed.

To change the phase relationship between the crankshafts 22, 24, the piston (106 in FIGS. 5 and 7) of one of the clutch assemblies 74 or 76 is retracted slightly (fluid pressure applied to the clutch assembly through the lines 96 or 97 is reduced) to permit some slippage of the discs 130. The slippage of the discs 130 permits rotation of the sun gear (34 in FIG. 2) of one of the planetary gear assemblies 30, 32. Thus, since the ring gear alone is permitted to rotate in one planetary gear assembly while both the sun gear and the ring gear are permitted to rotate in the other planetary gear assembly, the phase relationship between the two crankshafts is necessarily changed. The degree of slippage of the discs 130 is, under usual conditions of operation, carefully controlled. Stated differently, the discs 130 do not become free-running, but are maintained in a frictional contact with the discs 122 while the shaft 36 (or 38) is permitted to rotate.

When the stroke length of the piston 14 is to be changed, the clutch controller 98 is operated to partially release, momentarily, the fluid pressure on the piston 106 of one of the clutch assemblies 74, 76 to permit slippage of one clutch by a predetermined amount, thereby changing the phase relationship between the crankshafts 22, 24 as one sun gear (34 in FIG. 2) is rotated (usually slowly) with respect to the other sun gear. Such changing of position is usually at a slow rate as compared with the rate of rotation of the crankshafts 22, 24. The length of the piston stroke is at a maximum when the crankshafts 22, 24 are in phase as shown in FIG. 3 (rotating counter to one another). Piston stroke length decreases as the crankshafts become out-of-phase with respect to each other, that is, the length of the piston stroke is at a minimum when one of the connecting rods 18, 20 is at its most forward position with respect to the piston 14 and the other connecting rod is at its most rearward position with respect to the piston 14. Since both connecting rods 18, 20 are connected to the walking beam 16 which is coupled at its center to the crosshead 15, the movement of the piston 14 is a resultant of the movement of the two connecting rods 18, 20. When the connecting rods are in maximum out-of-phase relationship, the movement of the piston 14 is practically zero as the walking beam pivots around its point of attachment to the crosshead.

When the phase relationship of the crankshafts is at an intermediate point between the in-phase relationship and the maximum out-of-phase relationship there will be some rocking of the walking beam about its point of attachment to the crosshead, and also some forward and backward motion of the piston 14.

It should be noted that in the apparatus thus far described, the rotation of the drive shafts 36, 38 has been in opposite radial direction because of the coupling together of the spur gears 78, 80.

The same changing in-phase relationship of the crankshaft throws also may be achieved with the clutch assemblies 74, 76 if the drive shafts 36, 38 are coupled, as by the spur gears 78*a*, 80*a* and chain drive 100 shown in FIG. 4, for example, to rotate in the same radial direction. The pressure on a piston of one of the clutches may be released sufficiently to permit controlled rotation of one (usually) sun gear (34 in FIG. 2), as previously described, thus changing the phase relationship between the crankshafts. The crankshafts 22, 24 may be brought into a closer "in-phase" relationship by rotating either one of the sun gears until the crankshafts 22, 24 are aligned to the required degree. Stated differently, if one sun gear has been rotated in relation to the other sun gear to establish an out-of-phase relationship between the crankshafts, an "in-phase" relationship between the crankshafts may be accomplished by rotating the earlier moved sun gear until the crankshaft which coupled to that planetary gear assembly is again in-phase with the other crankshaft. Alternatively, the previously un-moved sun gear may itself be rotated until the two crankshafts are aligned with one another.

The apparatus described above provides means whereby, by changing the phase relationship between the crankshafts in appropriate amounts, constant horsepower may be applied to the pump 12 even though the pressure head against which the pump works may vary over a wide range. When the pressure head is low enough to permit such operation, keeping the two crankshafts operating on an in-phase relationship results in maximum volume being displaced through the pump 12. As the pressure head increases one of the clutches of the assemblies 74 or 76 is allowed to slip in a controlled manner to cause one of the crankshafts 22 or 24 to be moved in an increasingly out-of-phase relationship with respect to the other so that the available driving horsepower may be used to drive the piston 14 in increasingly shorter strokes and thus deliver less volume at a higher pressure.

Also, since the pump output can be continuously varied between practically no output and maximum output, there is no need for a torque converter or an additional speed varying transmission to be interposed between the power source and the pump apparatus providing the coupling between the power source 86 and the gear 84 does not cause the shafts 58, 60 to be rotated at excessive speeds.

While the apparatus has been illustrated as driving a single barrel single action reciprocating piston pump, a triplex pump, either single or double acting, or other multiple cylinder pump, such as a quintiplex pump, for example, may be coupled to suitable crankshafts which are substituted for the crankshafts 22, 24 and which are driven by the ring gears 26, 28.

The apparatus of the invention permits the power source to operate at a substantially constant r.p.m. rate even though the pumping rate varies widely. Thus, this apparatus is well adapted to be driven by turbines or by an internal combustion piston-type engine operating at an optimum r.p.m. rate.

Because the pump is driven by two crankshafts, the bearing loading on the individual connecting rods is reduced. A single pump may deliver either a large volume at moderate pressures or smaller volume at high pressures. In fixed stroke reciprocating piston-type pumps a so-called "high-volume" pump has a relatively low maximum pumping pressure in order to prevent overloading of the connecting rod bearings or to prevent the stalling of the prime mover. Conversely, a so-called "high pressure" fixed stroke piston pump is limited in the volume it can pump at lower pressures because of the maximum safe r.p.m. rate of the crankshaft even though the connecting rod bearings may not be overloaded and the horsepower capabilities of the prime mover are not exceeded.

Pumping apparatus in accordance with this invention is more versatile than conventional apparatus in that it is good both as a high pressure-low volume pump and as a low pressure-high volume pump and it admits of continuous variation of the relationship between pressure or volume during operation. Also, because no intermediate torque converter or speed varying transmission is used, the apparatus is more compact and lighter than a conventional unit of similar work capabilities.

An additional advantage of apparatus in accordance with this invention is that the multiple disc clutch assemblies 74, 76 are light in weight yet can hold extremely large loads without slippage. Such clutches, however, are easy to control, by suitably adjusting the fluid pressure which drives the clutch actuating piston, to permit a controlled slow slippage to permit any desired movement of the sun gears with respect to each other.

What is claimed is:

1. A portable pumping unit comprising in combination a prime mover and a variable displacement pump, said pump comprising a frame, a cylinder and piston reciprocal therein, a crosshead, means for mechanically coupling the piston to the crosshead to reciprocate the piston with reciprocation of the crosshead, a walking beam having a central part and two end parts, said crosshead being pivotally coupled to said central part of said walking beam, a pair of crankshafts, each of said crankshafts having at least one throw, a pair of connecting rods, one of said connecting rods being pivotally coupled to one end part of said walking beam and to a throw on one of said pair of crankshafts, the other connecting rod being pivotally coupled to the other end of the walking beam and to a throw on said other crankshaft, a pair of planetary gear assemblies each comprising a sun gear, at least one planetary gear and a ring gear, said planetary gear being coupled to a rotatable planet carrier element, one of said crankshafts being operatively coupled to the ring gear of one of said planetary gear assemblies, the other of said pair of crankshafts being operatively coupled to the ring gear of the other of the planetary assemblies, a pair of drive shafts, means for coupling said prime mover to said drive shafts and for rotating each of said drive shafts at least approximately at the same rate, one of said drive shafts being operatively coupled to one of said planet carriers, the other of said drive shafts being operatively coupled to the other of said planet carriers, a pair of multiple disc clutch assemblies each having a fixed segment and a rotatable segment, the rotatable segment of each clutch assembly being fixedly coupled to the sun gear of one of said planetary gear assemblies and the fixed segment of each clutch assembly being rigidly coupled to said frame, and means for actuating said clutch assemblies independently of one another.

2. A pumping unit in accordance with claim 1, wherein said crankshafts are disposed parallel to one another.

3. A pumping unit in accordance with claim 1, wherein said drive shafts are disposed parallel with one another.

4. A pumping unit in accordance with claim 1, wherein the means for coupling the prime mover to the drive shafts includes means for rotating the drive shafts in opposite radial direction to one another.

5. A pumping unit in accordance with claim 1, wherein said means for actuating said clutch assemblies includes a hydraulic system coupled to a piston of each clutch assembly.

6. A pumping unit in accordance with claim 1, wherein said prime mover is coupled to said drive shafts through fixed-ratio gear means.

7. A pumping unit in accordance with claim 1, wherein said prime mover is a gas turbine.

8. A pumping unit in accordance with claim 1, wherein said prime mover is a reciprocating piston-type internal combustion engine.

9. A pumping unit in accordance with claim 1, wherein the sun gear, planetary gear and ring gear in one planetary gear assembly are the same as the corresponding part in the other planetary gear assembly.

10. A pumping unit in accordance with claim 1, wherein the longitudinal axis of the crank throw of each crankshaft is offset from the longitudinal axis of its crankshaft by an equal amount.

11. A pumping unit in accordance with claim 1, wherein the point of coupling of the crosshead to the walking beam is along a line perpendicular to and bisecting a line drawn between the points of coupling of the connecting rods to the walking beam.

No references cited.