Aug. 3, 1948. W. KILCHENMANN 2,446,423

COUPLING DEVICE FOR OPPOSED PISTONS IN FREE-PISTON ENGINES

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4 Sheets-Sheet 1

Fig. 1.

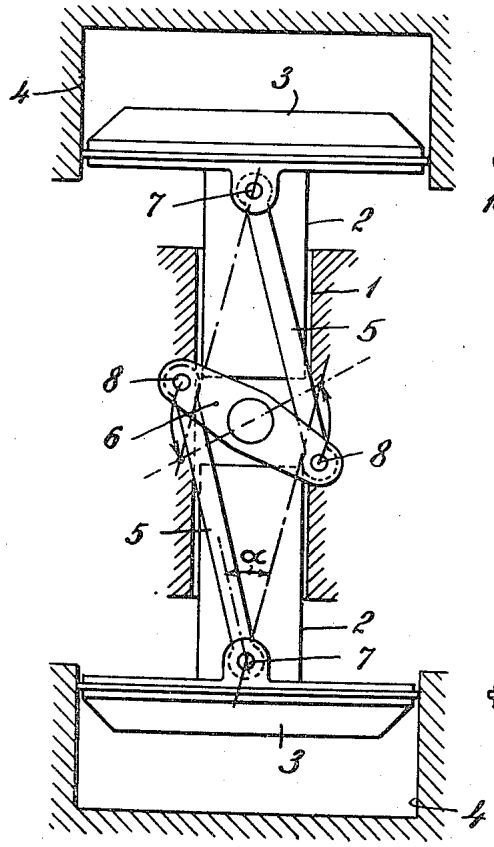

Fig. 2.

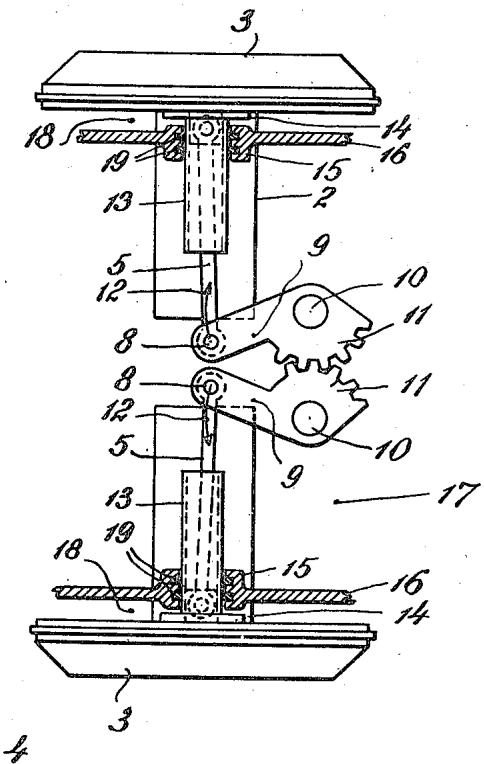

Fig. 3.

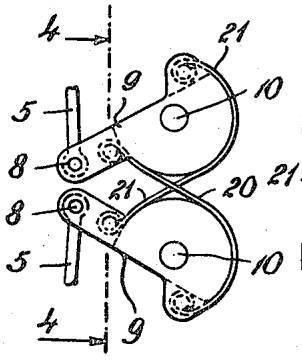

Fig. 4.

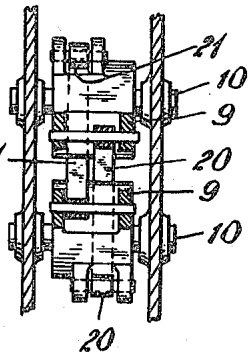

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Fig. 5,

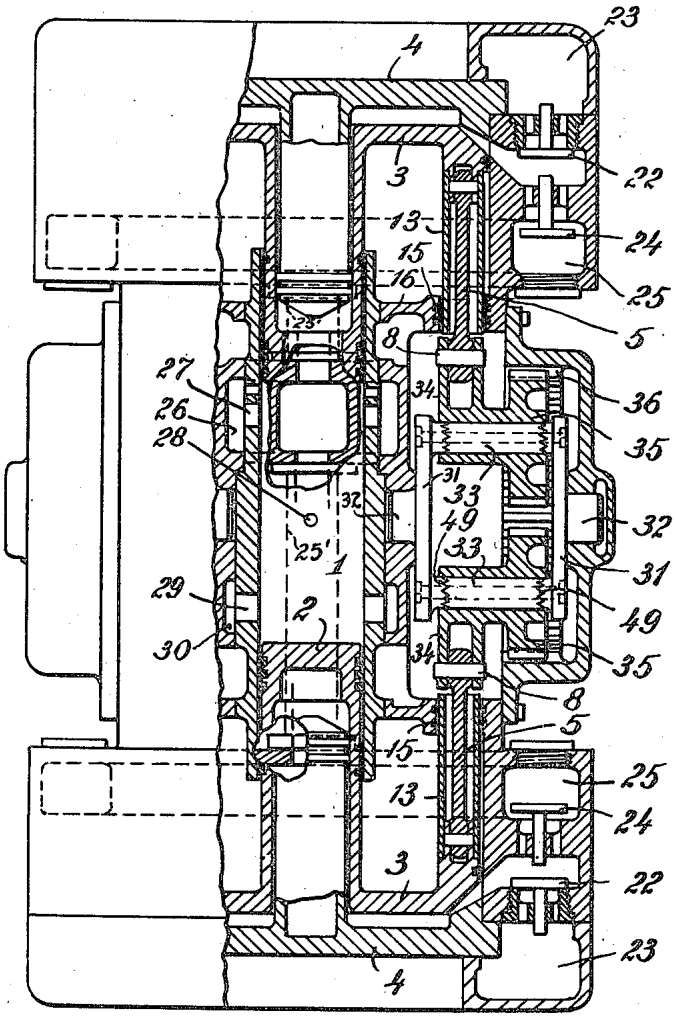

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Fig. 6,

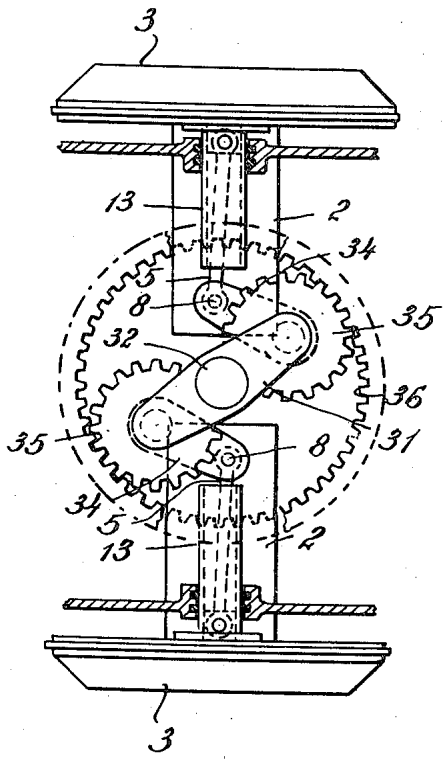

Fig. 7,

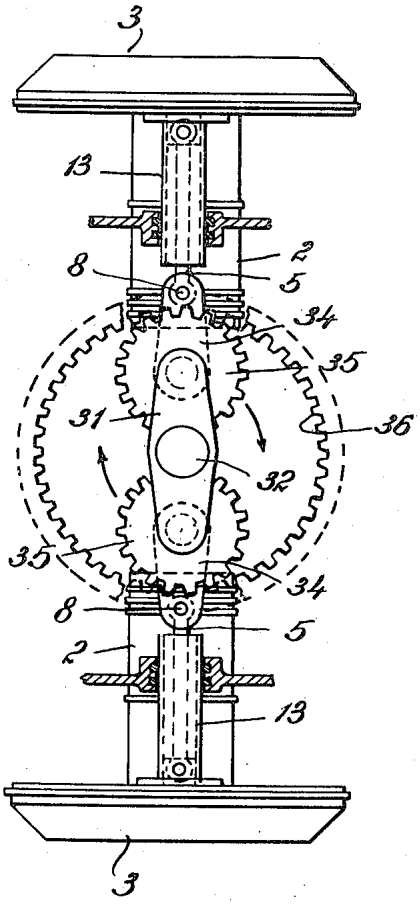

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Fig. 8,

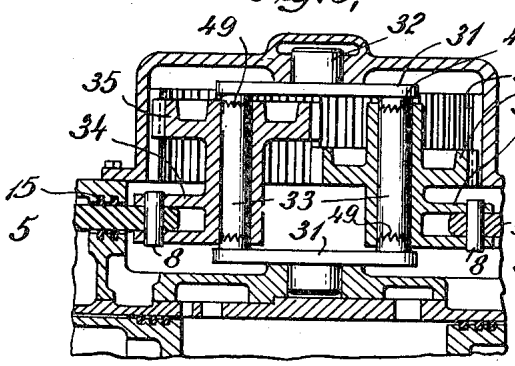


Fig. 10,

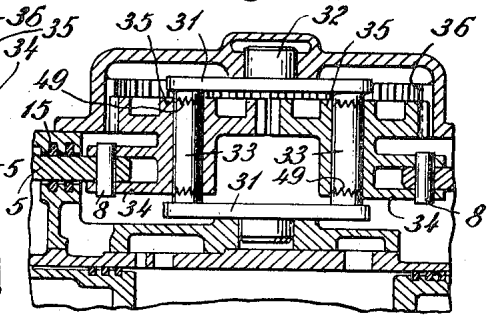


Fig. 9,

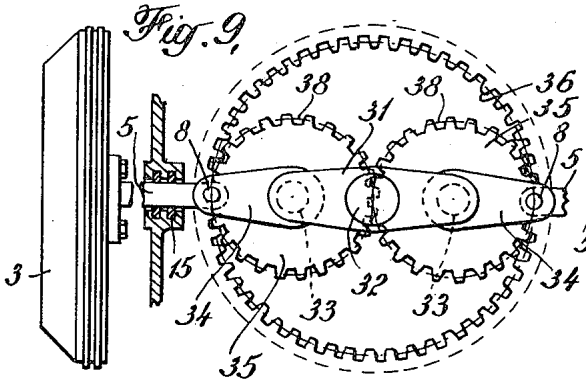
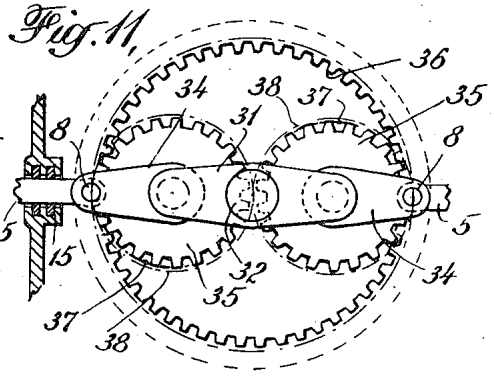


Fig. 11,



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Patented Aug. 3, 1948

2,446,423

UNITED STATES PATENT OFFICE

2,446,423

COUPLING DEVICE FOR OPPOSED PISTONS IN FREE-PISTON ENGINES

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Application November 30, 1945, Serial No. 632,044
In Switzerland October 9, 1945

10 Claims. (Cl. 123—46)

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The invention relates to a coupling device for opposed pistons in free-piston engines and consists in that two coupling members, each connected to a free piston, are connected by a gear which guides the links connecting the coupling members to the gear almost or entirely in a straight line.

In the drawings a number of embodiments of the invention are shown diagrammatically.

Fig. 1 shows a known coupling device,

Fig. 2 the design of the gear consisting of two rocking levers positively coupled to each other,

Figs. 3 and 4 show a variant of the positive connection of the levers in Fig. 2,

Figs. 5 to 7 a gear formed by a rocker arm and cranks,

Figs. 8 and 9 a gear with the connecting links guided in a straight line, and

Figs. 10 and 11 a variant of Figs. 8 and 9.

In known free-piston engines (Fig. 1) there work in the combustion cylinder 1 two power pistons 2 which move contrarily to each other and are rigidly connected to the compressor pistons 3 in the compressor cylinders 4. In order to ensure the opposed motion of the free pistons 2, 3, a coupling device consisting of coupling members 5 and the rocker arm 6 is provided.

When the free-piston engines are of short construction the coupling rods 5 cannot be guided by means of a crosshead, but it is necessary to link them up to the compressor pistons 3. The coupling rods 5 are connected to the rocking arm 6 by the connecting link 8.

When the free pistons 2, 3 are in the end position of their stroke the coupling device comes into an outstretched position in which the rocking arm 6 lies parallel to the cylinder 1. The rocking arm 6 is then thrown over on to the other side by its momentum, so that in the next inward stroke the coupling device comes to lie in the position shown by chain-dotted lines. Not only, therefore, is a relatively large angle of deviation α of the coupling rods 5 to be reckoned with, but great forces present themselves in the link pins 7 and turn the compressor pistons 3 about their axes if only one of the two rocker arms 6 on the two sides of the cylinder 1 swings over.

In order to remove these disadvantages two rocking levers 9 are provided in Fig. 2 whose axes of rotation 10 are arranged outside of the longitudinal axes of the coupling members 5 by the length of the levers 9. These rocking levers 9 have toothed segments 11 which positively effect the opposed motion of the connecting links 8 and

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thus of the free pistons 2, 3. The connecting links 8 move in the arcs 12, whose camber is relatively slight, so that the deviations of the coupling rods 5 are small. There is scarcely any reaction on the compressor pistons 3.

Furthermore it is possible to arrange a protective pipe 13 around the coupling rods 5, this pipe being tightly fixed against the compressor piston 3 by means of the flange 14 and guided through the oil sealing means 15 in the walls 16. The walls 16 separate the gear space 17 from the spaces 18 in the compressor cylinders 3. In the gear space 17 oil is sprayed, and the oil scraper rings 19 in the seals 15 prevent the spaces 18 of the compressor cylinders 3 and the power pistons 2 from being dirtied with gear oil. At the same time the consumption of gear oil is kept low.

In Figs. 3 and 4 the rocking levers 9, instead of the toothed segments 11 in Fig. 2, are so connected by flexible steel bands 20, 21 that positive coupling is ensured whatever the direction of motion.

The compressor pistons 3 in Fig. 5 draw in air during the inward stroke through several suction valves 22 arranged around the compressor cylinder 4, these valves all being connected to the annular space 23 which is in communication with the surrounding air or with a supply of already compressed air in a manner not shown in the drawing.

The air compressed during the outward stroke of the pistons 3 flows through delivery valves 24 (Fig. 5) which are also arranged around the compressor cylinder 4 into the annular delivery space 25, which is connected by a conduit 25' to the annular space 26 and the combustion cylinder 1, so that in the outer end position of the stroke of the power pistons 2, the compressed air flows into the combustion cylinder 1 through the admission ports 27 as scavenging and combustion air. When the power piston 2 moves inwards the combustion air in the combustion cylinder 1 is compressed and at the end of this stroke fuel is injected through one or more fuel valves 28. The combustion gases force the pistons 2 apart and escape through the exhaust ports 29 into the exhaust space 30, which is in communication with the surrounding air or with a power gas consumer according to the employment and the method of working of the free-piston engine.

The coupling members 5 are connected by a gear. This has a rocker element 31, which is supported on both sides by means of the pins 32, and two crankpins 33 around which the cranks 34 turn, the latter being provided with a toothed

wheel 35. The toothed wheels 35 engage with the stationary toothed rim 36 in such a way that the connecting links 8, which connect the coupling members 5 to the cranks 34, are guided almost in a straight line, as can be seen from Figs. 6 and 7. The external diameter of the toothed wheels 35 is smaller than the distance between their centres of rotation, the crankpins 33. In this way the toothed wheels 35 can be arranged in the same plane, as Fig. 5 shows.

In Figs. 8 and 9 the coupling members 5 are screwed tight to the compressor piston 3 and are themselves surrounded by the oil seals 15. For the connecting links 8 are guided in a straight line owing to the fact that the length of the crank 34 is equal to the distance of its centre of rotation from the point of rotation of the rocker element 31 and the pitch circle diameter of the toothed wheels 35 is equal to the distance between their centres of rotation, i. e. between the crankpins 33. For this to be so, however, it is necessary to arrange the toothed wheels 35 in different planes, as shown in Fig. 8.

The movement of the connecting links 8 on a straight line and the rigid connection of the coupling rods 5 to the compressor piston 3, however, are possible without the space for the coupling gear being enlarged (Figs. 10 and 11) if the toothed wheels 35 have teeth so undercut that the addendum circle 37 of the toothed wheels 35 is smaller than the pitch circle 38 of their toothing. Although now the pitch circle 38 is equal to the distance between the centres of rotation of the toothed wheels 35, it is nevertheless possible to arrange these two wheels 35 in one plane once more. For the play between them necessary for free turning corresponds to the difference between the addendum circle 37 and the pitch circle 38.

Instead of providing the rocker element 31 for guiding the links 8 in a straight line with teeth in order to produce the necessary movement of the cranks 34, this movement can equally well be obtained by means of a flexible steel band and drum gear arranged to operate as the full equivalent to the two gear arrangements illustrated in Figs. 8–9 and Figs. 10–11. The arrangement of this steel band and drum gear parallels that of the toothed wheel gear in the same way that the steel band and plane segment gear of Figs. 3–4 parallels the operation of the toothed segment gear of Figs. 1–2. That is to say, that the fixed shaft in the position of the pins 32 would carry rotatably mounted the rocker element 31 and an independently rotatably mounted drum linked by steel bands to two drums of half the diameter mounted on crank pins 33 rigidly affixed to cranks 34. The diametral difference between the drums thus secures the same straight line movement with the identical diametral difference between the pitch circles of the stationary toothed rim 36 and the toothed wheels 35 to which the large drum and the two small drums are respectively geometrical equivalents.

The parts of the rocker element 31, the crankpins 33 and the lateral parts are connected up by toothed couplings 49 (Fig. 5), the end faces of the crankpins 33 having teeth which engage with the teeth of the lateral parts and in which bolts are provided which pass through these parts and hold them together.

I claim:

1. In a free piston engine, the combination including an internal combustion cylinder, two power pistons in said combustion cylinder working opposed to each other, a compressor cylinder arranged at each end of said combustion cylinder, a compressor piston in each of said compressor cylinders attached to the adjacent power piston, a connecting rod pivotally connected to each of said compressor pistons, and gear means linking and pivotally connected to said connecting rods arranged to insure the opposed motion of said pistons with only a small angle of deviation of said connecting rods.

2. The combination of claim 1 in which the gear means include two rocking levers whose axes of rotation are arranged outside the longitudinal axes of the connecting rods by approximately the length of said levers and toothed segments positively coupling said levers.

3. The combination of claim 1 in which the gear means include a rocker element having crank elements rotatably mounted on the extremities thereof, each of said crank elements including a crank arm proper pivotally connected to one of the connecting rods and a toothed member, and a stationary rack adapted to engage said toothed members to guide the points of connection between said crank arms proper and said connecting rods substantially in a straight line during rotation of said rocker element.

4. The combination of claim 1 in which the gear means include a rocker element having crank elements rotatably mounted on the extremities thereof, each of said crank elements including a crank arm proper pivotally connected to one of the connecting rods and a toothed member, the radius of each of said crank arms proper being equal to the distance from the center of its pivot on said rocker element to the center of rotation of said rocker element, and a stationary rack adapted to engage said toothed members to guide the points of connection between said crank arms proper and said connecting rods substantially in a straight line during rotation of said rocker element.

5. The combination of claim 1 in which the gear means include a rocker element having crank elements rotatably mounted on the extremities thereof, each of said crank elements including a crank arm proper pivotally connected to one of the connecting rods and a toothed member, the external diameter of said toothed members being smaller than the distance between the centers of their pivots on said rocker element, and a stationary rack adapted to engage said toothed members to guide the points of connection between said crank arms proper and said connecting rods substantially in a straight line during rotation of said rocker element.

6. The combination of claim 1 in which the gear means include a rocker element having crank elements rotatably mounted on the extremities thereof, each of said crank elements including a crank arm proper pivotally connected to one of the connecting rods and a toothed member, said toothed members being mounted on said rocker element in different planes and with their pitch circle diameter equal to the distance between the centers of their pivots on said rocker element, and a stationary rack adapted to engage said toothed members to guide the points of connection between said crank arms proper and said connecting rods substantially in a straight line during rotation of said rocker element.

7. The combination of claim 1 in which the gear means include a rocker element having

crank elements rotatably mounted on the extremities thereof, each of said crank elements including a crank arm proper pivotally connected to one of the connecting rods and a toothed member, said toothed members having a pitch circle diameter equal to the distance between the centers of their pivots on said rocker element and having teeth so undercut that the addendum circle is smaller than the pitch circle, and a stationary rack adapted to engage said toothed members to guide the points of connection between said crank arms proper and said connecting rods substantially in a straight line during rotation of said rocker element.

8. The combination of claim 1 including a protective pipe rigidly attached to each of the compressor pistons surrounding the connecting rods and an oil seal engaging and guiding said pipe and closing off the space occupied by the gear means from the compressor cylinders.

9. The combination of claim 1 in which the gear means include a rocker element supported at two points on its axis of rotation.

10. The combination of claim 1 in which the gear means include a multi-part rocker element, the separate parts of said element being operably connected by means of toothed couplings.

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