Aug. 13, 1963 A. M. CADDELL 3,100,401

PRESSURE RETAINING MEANS FOR DOUBLE-ACTING PISTON ENGINES

Filed May 2, 1960 2 Sheets-Sheet 1

FIG. 1

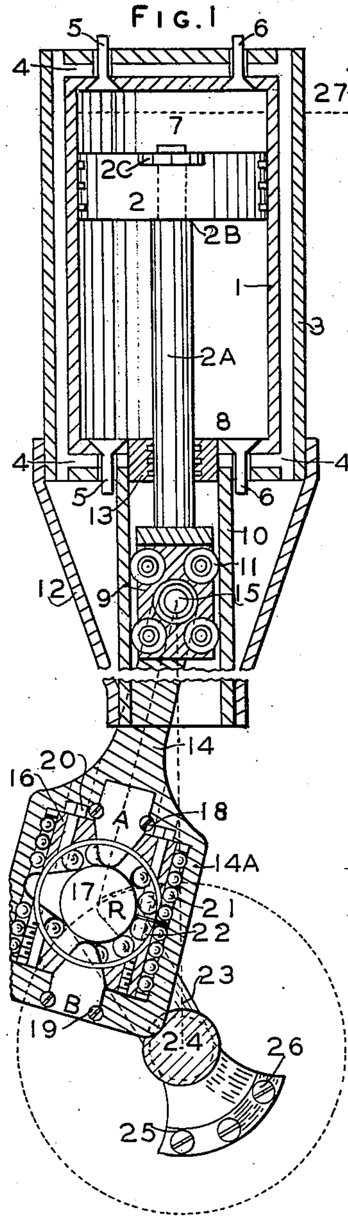

FIG. 2

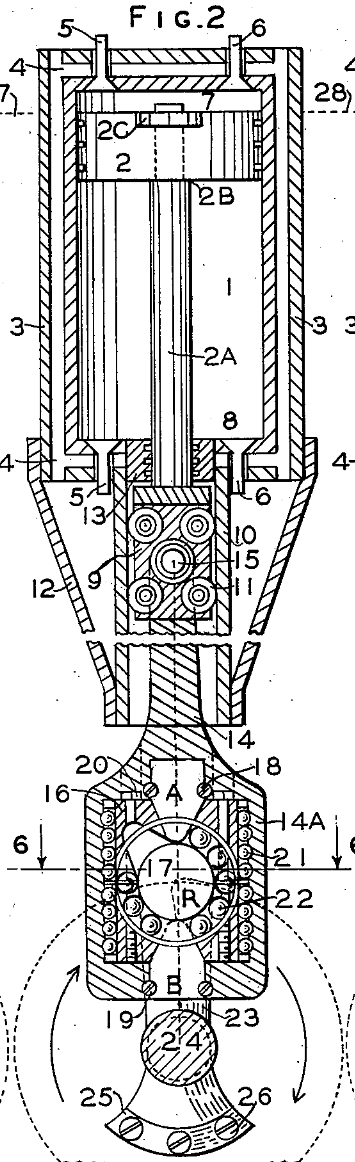

FIG. 3

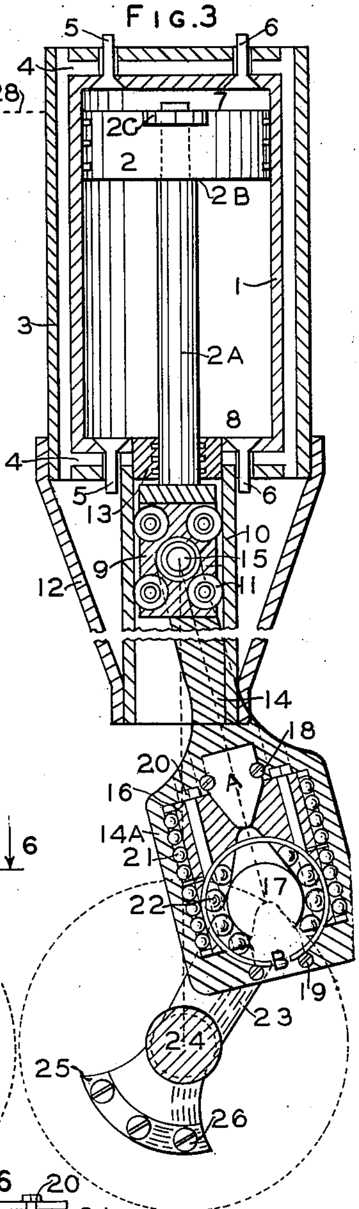

FIG. 4

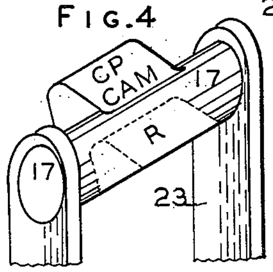

FIG. 5

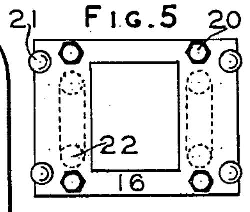

FIG. 6

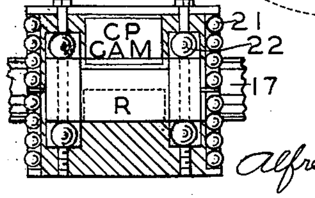

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FIG. 7

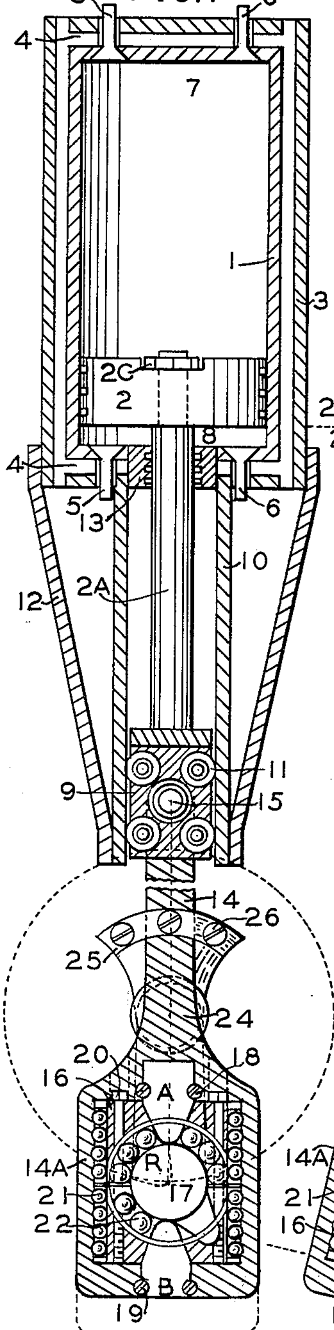


FIG. 8

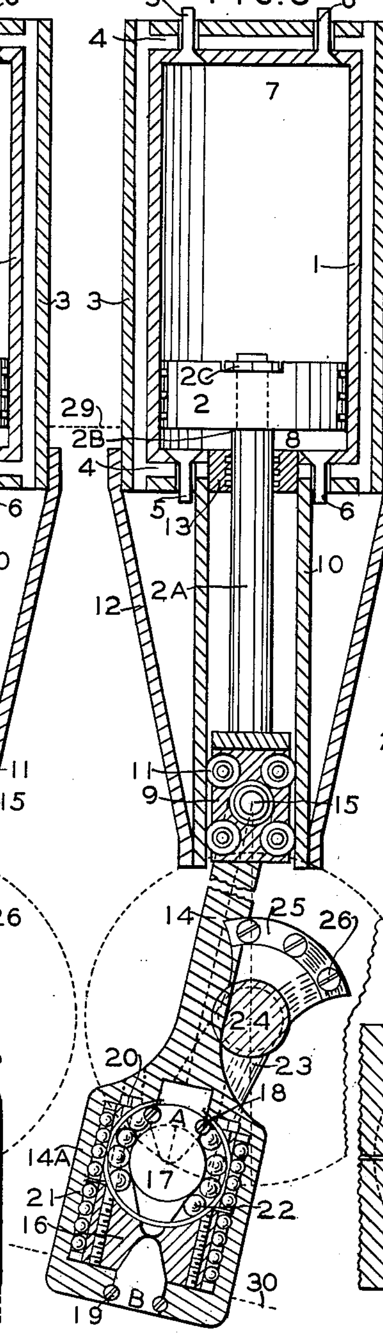


FIG. 9

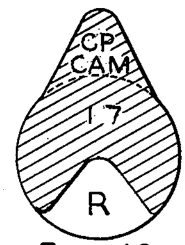


FIG. 10

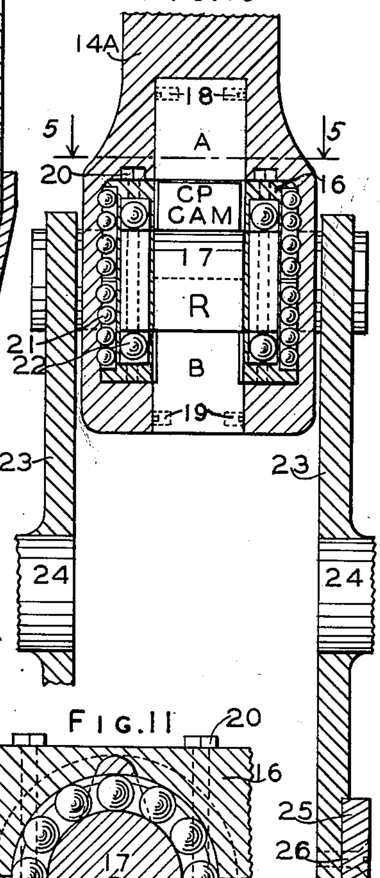
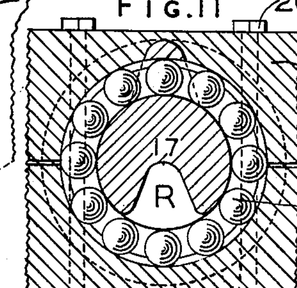


FIG. 11



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PRESSURE RETAINING MEANS FOR DOUBLE-ACTING PISTON ENGINES

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Filed May 2, 1960, Ser. No. 26,212
3 Claims. (Cl. 74—36)

This continuation-in-part application carries the same title as the application entitled Pressure Retaining Means for Double-Acting Piston Engines, filed June 16, 1959, Serial No. 820,685, which is now abandoned.

The invention is appropriate for either steam or internal combustion engines. It is described herein as applicable to the latter, with the possibility of its use in the compression ignition field standing out prominently. Basically, it has to do with an operating cycle that is totally different from that employed in conventional practice.

As in the former case, the main object of the invention is to obtain a large increase in power from an engine having two power strokes per revolution of the crankshaft. This is accomplished by permitting the release of energy only through a favorable leverage range on each of the power strokes, such release commencing at a point in the respective cycles, as an example, 30 degrees past top center on the first stroke and 30 degrees past bottom center on the second stroke. By virtue of such energy application, anti-leverage pounding on the crankshaft, such as presently occurs in an engine operating under the conventional cycle, is prevented. For one thing, this anti-leverage pounding constitutes a major drawback that prevents wider use of diesel engines.

Another objective is related to the foregoing one, namely, to prevent the intense vibration that accompanies the build-up of energy before the crank arrives at top center, which build-up results in broken crankshafts, the blowing off of cylinder heads and many other engine troubles.

A third objective is to make it possible to construct an engine having smaller cylinder capacity and also operate it at lower r.p.m. compared to the cubic inch displacement and high r.p.m. now necessary to attain a stated power output; and, coupled with this objective, the achievement of a very considerable saving in fuel for the horespower developed.

Although from the standpoint of a pratically unmeasurable period of time, the travel of a piston in an engine actually stops twice during a single revolution of the crank assembly, namely, at top dead center and at bottom dead center, at which centers the motion of the piston becomes reversed. For the next few degrees of the crankthrow past either top or bottom center the movement of the piston in its cylinder is comparatively slight, and it is not until approximately 30 degrees has been reached on the power stroke of the crankthrow that its travel speed commences to materially increase. From zero speed at top center to maximum at 90 degrees of the crankthrow, to zero at bottom center to maximum at 270 degrees, then to zero center again to start a new cycle—the travel speed of the piston varies between these extremes. This is true with either a single-acting piston connected directly to the crank assembly or a double-acting piston connected to the intermediary of a crosshead. In the meantime, however, regardless of such ever-changing piston speeds, the crank assembly rotates evenly and uninterruptedly throughout its cycle.

Attaining the above-named objectives is made possible by employing a new type of crank assembly that incorporates a crankpin having, relative to any position of the crankarms, an angularly disposed cam centrally and integrally formed on the crankpin's surface; also, a rod having a wrist pin connection with a crosshead on one end and a merged housing appendage on the other. This

appendage spans and encompasses a structure that is mounted upon and rotates freely around the crankpin which is integrated by means of crankarms with the crankshaft.

The operation of this crank assembly is as follows:

A cam follower as A is mounted in the end of the connecting rod within the confines of the housing appendage. Also, a cam follower identified as B is mounted diametrically opposite cam follower A in the base of the appendage. Upon the piston arriving at top center of the crankthrow the crankpin cam follower contacts cam A, thereby temporarily lending its radial projection length to the connecting rod which prolongs the heighth of the piston at top center throughout the first 30 degrees of the first power stroke. Thereupon, the crankpin cam contacts cam follower B at bottom center and it, in turn, lends the length of its radial projection to the housing appendage, maintaining a temporary prolonged bottom center during 30 degrees on the second power stroke. Thus, the motion of the piston becomes momentarily halted at top and at bottom centers respectively and the pressure of the working fluid becomes applicable only after the apex of the crankpin cam passes in sequence the apexes of cam follower A and B during the rotation of the crankpin. It will be seen, therefore, that instead of a power stroke commencing at zero leverage, it actually commences 30 degrees past top and 30 degrees past bottom centers where leverage exerts its powerful and ever-increasing influence to the 90-degree position of each of the cycles before it tapers off until the 30-degree position has again been reached on the next succeeding cycle.

The crankpin of this invention has a recess formed therein on the side directly opposite its cam formation so that when cam follower A is engaged by the crankpin cam, cam follower B will move into this recess and, in turn, when cam follower B is engaged by the crankpin cam, cam follower A will occupy the recess. This recess serves a dual purpose: One, as a repository for the cam follower not at the moment being engaged by the crankpin cam and, two to permit cam followers A and B to maintain positive contact with the crankpin on its rounded surface when throughout the portions of the cycles these cam followers are not engaged by the crankpin cam.

Commencement of the power strokes at the delayed position on each cycle is especially important in the operation of an internal combustion engine. For, unlike steam, which exerts continuous follow-up pressure against a piston throughout a power stroke, application of energy in an internal combustion engine is limited to a single explosive impulse per revolution of the crankshaft if the engine is of the two-cycle design or every other revolution if it is of the four-cycle type.

In conventional Otto cycle engines, the power stroke covers a range from 0 degrees (top center) to approximately 125 degrees on the power stroke, during which range only the lag of the explosive impulse becomes translated into power. In contrast, in the power cycles of this invention, the range of piston travel commences at the 30-degree position past top or bottom center on the respective stroke and may extend with perfect safety throughout a range of 155 degrees on each stroke before the exhaust valve is caused to open, thus assuring maximum expansion pressure through 125 degrees in the most favorable leverage ranges of piston travel. Obviously, the greater the expansion force throughout said ranges, the greater in proportion the turning effort at the crankshaft and, by means of appropriate gearing, the greater the power output per pound of fuel will be.

In single-acting internal combustion engines of the aviation type, the fuel-air mixture is fired from 30 to 45 degrees before top center so that combustion pressure will build up to its maximum at the point of maximum compression pressure, which is at top center. Although the employment of energy in an anti-leverage position of the crankthrow is contrary to the law of physics, in conventional internal combustion engines such build-up of pressure is essential for maximum power output. This paradoxical situation is due to the slowness of flame travel compared to the speed of the crankthrow throughout its rotation.

As an example of such comparative slowness, in an aviation engine having a 6-inch bore and ignition taking place 30 degrees before top center, the flame travels from the igniter across the bore through said 30 degrees to top center at a speed of approximately 75 feet per second which, as will be observed from the following table, is considerably slower than the travel of the crankpin throughout an equivalent number of degrees.

Crankshaft revolutions per minute	Crankshaft revolutions per second	Time required for crankpin to travel through 30° of the 360° revolution, sec.
900	15	.00555
1,200	20	.00417
1,800	30	.00377
2,400	40	.00208
3,000	50	.00165

Which micro-second periods of time focus attention on the speed at which chemical reaction takes place upon the fuel-air mixture being fired and the critical relation existing between maximum combustion pressure build-up and the aforesaid speeds of crankpin rotation.

In the drawings:

FIG. 1 shows the center of the crankpin at a 30-degree-before-top-center position in the crankthrow, with the apexes of cam follower A and cam follower B riding the rounded surface of the crankpin.

FIG. 2 shows the center of the crankpin in direct line with the top center of the crankthrow and also the wrist pin in the crosshead, with the base of the crankpin cam commencing to make contact with cam follower A and cam follower B about to occupy recess R in the crankpin.

FIG. 3 shows the crankpin cam fully engaging cam follower A at the 30-degree-after-top-center position and cam follower B occupying the aforesaid crankpin recess.

FIG. 4 is a three-quarter view of the crankpin secured to crankarms which may be integrally formed with a crankshaft, not shown. In this view, the outlines of the crankpin (CP) cam are made clear as is also the recess R formed directly opposite said cam.

FIG. 5 is a view, looking downward, of the structure identified at **16** taken on the line **5—5**, FIG. 10, in which view is shown the opening in the top of said structure for permitting the in-and-out movement of cam follower A for it to be contacted by the CP cam. An identical opening is provided in the bottom of the structure for accommodating similar movements of cam follower B.

FIG. 6 is a side view of structure **16** showing perpendicular ball bearing assemblies that permit, relative to said structure, anti-frictional reciprocation of the housing appendage and, of course, the connecting rod; also, the ball bearing assembly which permits rotation of the assembly of which the crankpin is a part and the bolts that secure the halves of structure **16** to each other.

FIG. 7 shows the crankpin cam about to make contact with cam follower B at bottom center of the crankthrow and cam follower A about to occupy recess R.

FIG. 8 shows the crankpin cam fully engaging cam follower B at the 30-degree-past-bottom-center position and cam follower A occupying recess R. As will be seen, the position of the cam engagement in the second cycle is directly opposite the position of engagement shown in FIG. 3. The respective positions of the piston in the cylinders shown in FIG. 3 and in FIG. 8 may also be noted.

FIG. 9 is an enlarged end view of the crankpin showing the integrally formed cam thereon and directly opposite thereto the recess for accommodating the momentary housing of cam follower B while the crankpin cam makes contact with cam follower A, and vice versa.

FIG. 10 is a side view of the housing appendage of the connecting rod showing its encompassment of the structure identified as **16**, also the longitudinally disposed bearing assemblies to permit reciprocal travel of the appendage relative to said structure; also, the radial ball bearings that permit rotation of the appendage and structure around the crankpin and the views of cam followers A and B and the crankarms integrated with the crankshaft.

FIG. 11 is an enlarged end view of the crankpin in its relation to structure **16**, showing the radial sweep of its cam and the radial ball bearing assembly that permits rotary movement of the crankpin relative to said structure which is carried by the crankpin throughout the crankthrow.

FIGS. 1, 2, 3, 7 and 8 show cylinder **1** wherein double-acting piston **2** reciprocates in the well-known manner. This cylinder is surrounded by a jacket **3** and has channels **4** extending through its top and bottom heads and around its sides to permit circulation of a heat-absorbing fluid therethrough. Each head in each of the above figures has an intake valve **5** and an exhaust valve **6** for admitting and discharging respectively a working fluid into top chamber **7** and bottom chamber **8**. The source of the working fluid and accessories associated therewith are not shown.

Piston **2** is connected to crosshead assembly **9** by means of tie rod **2A** which has a shoulder **2B** for seating of the piston thereon, locknut **2C** securing the rod to the piston at its top. Crosshead assembly **9** reciprocates with the piston on trackways **10** which may be of an appropriate design and constructed to withstand the side thrust imposed upon the crosshead assembly by the crankthrow. Assembly **9** carries bearing assemblies **11** for maintaining these reciprocating movements against said trackways with a minimum of friction. Braces **12** secured to said cylinder construction are made available for lending rigidity to said trackways. Stuffing box **13** through which tie rod **2A** passes, is provided in the lower head of said cylinder to prevent leakage of the working fluid from chamber **8**, which chamber is shown clearly in FIGS. 7 and 8.

Connecting rod **14** is movably connected to crosshead **9** by conventional wrist pin **15** and extends centerwise to merge into housing **14A** that encompasses twin-half structure **16** which, in turn, movably encompasses crankpin **17**, shown individually in FIGS. 4 and 9 and in position in FIGS. 1, 2, 3, 7 and 8 and also in FIGS. 10 and 11. As shown in FIGS. 1, 2, 3, 7 and 8, connecting rod **14** carries in its base cam follower A, which is removably secured thereto by screw bolts **18** and which normally rides, as shown in FIG. 1, on the rounded surface of crankpin **17**. Cam follower A is a contact point for the connecting rod, crosshead and piston, and upon being acted upon by the CP cam, gradually pushes the piston upward the full distance of the radial projection of the cam.

FIG. 2 shows the center of the crankpin at top center of the crankthrow, with the CP cam about to contact cam follower A. FIG. 3 shows the center of the crankpin at 30 degrees past top center on the crankthrow and the apex of the CP cam riding on the apex of cam follower A, the added distance brought into being by the linear dimension of said CP cam being temporarily added to the length of the connecting rod thus making possible retention of the piston, as shown in FIG. 3, at the same heights in the cylinder as the heighth attained by the piston when the center of the crankpin, as shown in FIG.

2, was at top center of the crankthrow. The length, or radial projection, of the CP cam thus compensates for what normally would be the travel distance of the piston between top center of the crankthrow and the aforesaid 30 degrees on the power stroke.

In connection with this double-acting piston, a double-acting cam follower arrangement is provided. That is, just as the aforesaid cam follower A responded to the contact made by the CP cam, just so is provision made to cause retention of the piston when the crankpin arrives at bottom center of the crankthrow at the commencement of the second cycle. For this purpose, cam follower B, which is mounted in the base of housing appendage **14A** and secured thereto by bolts **19**, is provided. As shown in the various figures, particularly FIG. 7, this cam follower is positioned in said appendage directly opposite cam follower A, in which figure it will be seen that cam follower B is about to be acted upon by the CP cam, the center of the crankpin being at the 180-degree position of the crankthrow.

By referring particularly to FIG. 9, which is an end view of crankpin **17**, it will be seen that a recess R is formed in the underside thereof directly opposite its cam. In FIG. 2, the immediacy of the CP cam contacting cam follower A and cam follower B about to enter the crankpin's recess, will be observed. In FIG. 7, the opposite cam follower action takes place. The walls comprising recess R have rounded corners to smoothen the in-and-out movements of cam followers A and B.

The halves of twin-half structure **16** are made secure to each other by bolts **20**. This structure carries in its sides a plurality of bearing assemblies which contact the inner walls of appendage **14A** and thereby eliminate most of the friction that otherwise would occur during the rapid reciprocal movements of the appendage relative to the non-reciprocal movement of structure **16**.

Radial bearing assemblies **22** are mounted between twin-half structure **16** and longitudinal bearing assemblies **21**. Assemblies **22** permit rotation of structure **16** and all with which it is associated around crankpin **17** throughout the crankthrow. As shown in FIG. 10, crankarms **23** are made integral with crankpin **17** on each end thereof, which arms are, in turn, made integral with crankshaft **24**. Balance weights **25**, secured by bolts **26**, are positioned on these crankarms for effecting a smooth running balance of the engine.

Dotted line **27** between FIGS. 1 and 2 shows the difference in travel of the piston from the 30-degree-before-top-center position and the top center position in FIG. 2, and dotted line **28** between FIGS. 2 and 3 indicates the artificial heighth of the piston made possible by the CP cam contacting cam follower A. Dotted line **29** between FIGS. 7 and 8 shows the position of the piston in the cylinder relative to the center of the crankpin at bottom center and at the 30-degree-after-bottom-center position on the second power stroke respectively. Dotted line **30** in FIGS. 7 and 8 indicate the extent of reciprocal travel of the housing appendage in accordance with the dictates of the CP cam.

Should this invention be employed in a steam engine, a set of operating conditions different from those employable in an internal combustion engine would naturally obtain. Steam introduced against a piston follows it in its cylinder at constant pressure throughout as many degrees as desired before the steam is cut off. Therefore, by halting the piston's travel as herein described until the 30-degree position on each power stroke has been reached there would result a great saving in steam for the power developed. The points of introduction and cut-off are all important in steam engine economy.

It will no doubt be obvious that a position other than that of 30 degrees past top and bottom centers of the crankthrow may prove more advantageous than the example selected, in which case differently sized and differently shaped cam followers may be employed, the selection thereof depending largely upon the speed of engine operation desired.

Having described my invention, I claim:

1. The combination with a rotatable crank assembly and a reciprocating crosshead, of a rod and associated construction movably connecting said crosshead with the crank assembly for permitting halts for a period of time in the movements of said crosshead, said assembly establishing a first and a second crankthrow cycle having a top and a bottom center respectively, said crank assembly including a crankpin having a center and a rounded surface and a cam having a base and an apex projecting radially therefrom, a cam follower mounted in the rod at the end opposite said crosshead and having an apex for normally contacting said rounded surface, an enveloping structure forming part of said construction mounted on said crankpin and carrying radial bearings positioned on each side of the crankpin cam for permitting, relative to said structure, uninterrupted rotation of the crankpin, said rod terminating in an appendage having sides and a base and carrying bearings for permitting simultaneously with said rotation reciprocal movement of said structure, a second cam follower mounted in the base of said appendage, said second cam follower having an apex for normally contacting the rounded surface of said crankpin, the base of said crankpin cam during the first crankthrow cycle contacting the apex of the rod cam follower at said top center and subsequently lending its radial length thereto for halting said crosshead at said top center until the apex of said crankpin cam passes the apex of said rod cam follower at a location in the cycle past top center, the base of said crankpin cam during said second cycle thereafter contacting the apex of said second follower cam follower at bottom center and subsequently lending its radial length thereto for halting the crosshead at said bottom center until the apex of said crankpin cam passes the apex of said second follower at a location in the cycle past bottom center.

2. The combination with a rotatable crank assembly and a reciprocating crosshead of a rod and associated construction movably connected to said crosshead and to the crank assembly for permitting periodic halts in the movements of the crosshead, said assembly having a crankshaft and a crankpin for establishing a first and a second cycle during every revolution of the assembly, a top and a bottom center of said cycles, said crankpin having a rounded surface, a cam having a base and an apex integrally formed on and extending radially from said surface, a first cam follower having an apex and being mounted in the end of the rod opposite said crosshead for momentarily contacting said rounded surface, said rod terminating in an appendage comprising a housing, a second cam follower mounted in said appendage and having an apex for momentarily contacting the rounded surface of the crankpin, the latter apex being positioned opposite to and facing the apex of the first follower, the base of said crankpin cam during the first of said cycles making contact with the apex of the first follower at said top center and subsequently lending thereto its radical length until the apex of the crankpin cam passes the apex of the first follower at a location in the cycle past top center, the base of said crankpin cam thereafter making contact with the apex of the second cam follower at said bottom center and subsequently lending thereto its radial length until the apex of said crankpin cam passes the apex of the second follower at a location past bottom center in said second cycle.

3. The combination with a rotatable crank assembly functioning in a first and a second cycle together with a reciprocating crosshead, of a rod and associated construction movably connected to said crosshead and to the crank assembly for permitting halts in the movements of the crosshead while said assembly rotates uninterruptedly through said cycles, said assembly having a crankshaft, crankarms and a crankpin for establishing a top and a

bottom center of said cycles, said crankpin having a rounded surface and being integrated with said crank-arms and said crankshaft, a cam integrated with said rounded surface, said cam having a base and extending radially to an apex, said apex being positioned at an angle trailing in the direction of rotation relative to the crank-arms, said associated construction including an enveloping structure anti-frictionally mounted on said crankpin for permitting relative thereto the rotation of said crankpin, said construction also having an appendage comprising a housing having sides and a base and means for anti-frictionally encompassing said structure, a cam follower mounted in the end of the rod opposite said crosshead and terminating in an apex for momentarily contacting said rounded surface, a second cam follower mounted in the base of said appendage and being positioned opposite the apex of said rod cam follower, the base of said crankpin cam establishing contact with the apex of said rod cam follower when the center of the crankpin is in line with the center of said crankshaft and said top center for permitting retention of said crosshead at top center until the apex of said rod cam follower comes in line with the center of said crankpin cam at a position in said first cycle a number of degrees past the top center thereof, the base of said crankpin cam thereafter establishing contact with the apex of said second cam follower when the center of said crankpin is in line with the center of said crankshaft and said bottom center for permitting retention of said crosshead at bottom center until the apex of said second cam follower comes in line with the center of said crankpin cam at a position in said second cycle a number of degrees past bottom center, a recess formed in said crankpin diametrically opposite the cam thereof for alternately and sequentially serving as a repository for said rod cam follower and said second cam follower during each revolution of the crank assembly, said enveloping structure being comprised of twin halves, means for securing said halves to each other, each half having an aperture for permitting the apex of the rod cam follower and the apex of the second cam follower to contact the rounded surface of said crankpin when said followers are not being engaged by said crankpin cam.

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