

Dec. 22, 1942.

N. N. SKAREDOFF

2,306,364

INTERRUPTION INJECTION PUMP AND METHOD TO APPLY THE SAME

Filed June 27, 1940

3 Sheets-Sheet 1

FIG. 1

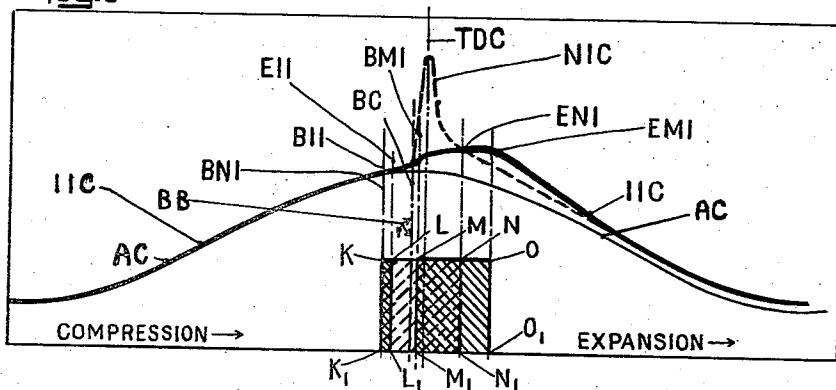


FIG. 2

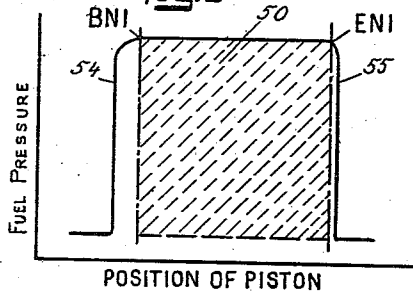


FIG. 3

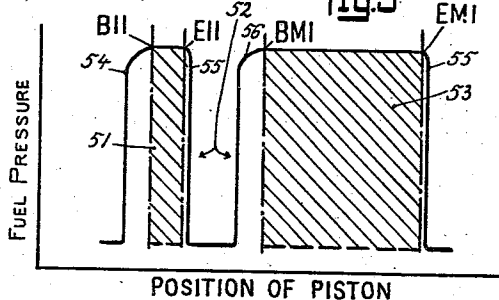


FIG. 5

FIG. 4

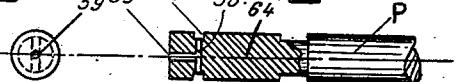


FIG. 6

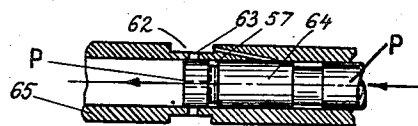


FIG. 7

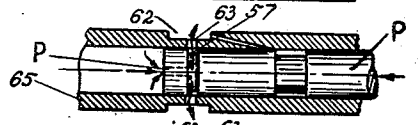


FIG. 8

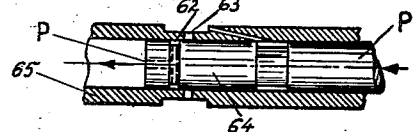


FIG. 9

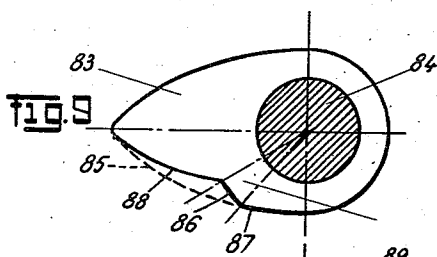
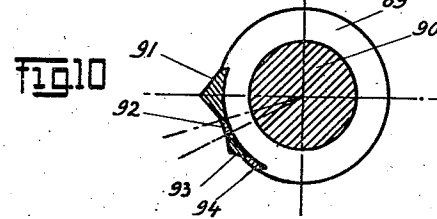


FIG. 10



Nikolai N. Skaredoff INVENTOR.

Dec. 22, 1942.

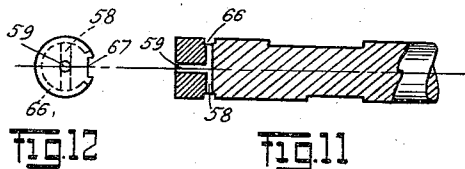
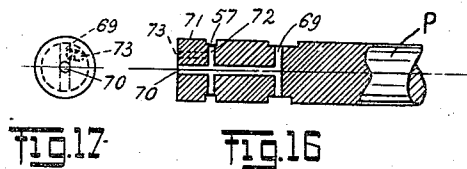
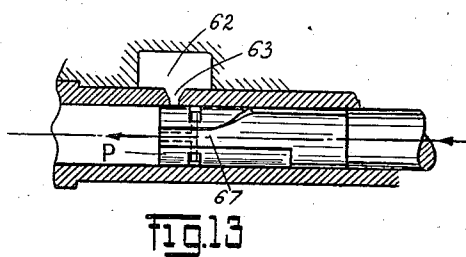
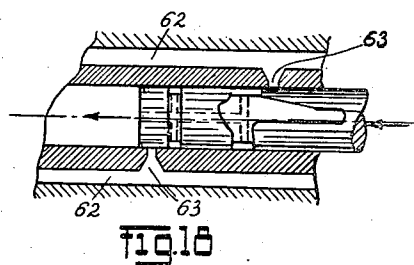
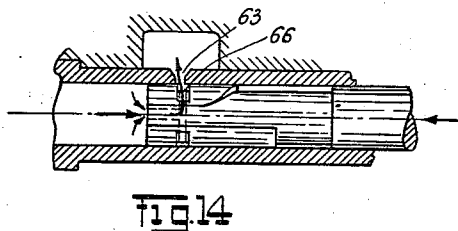
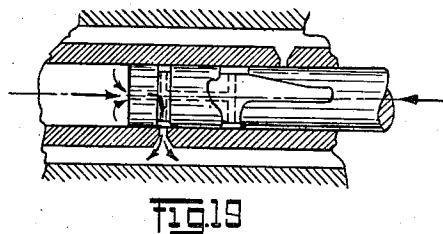
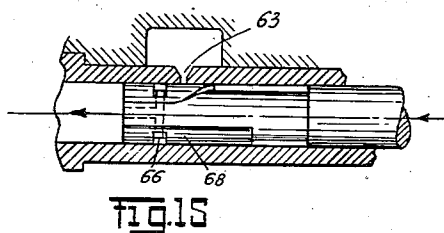
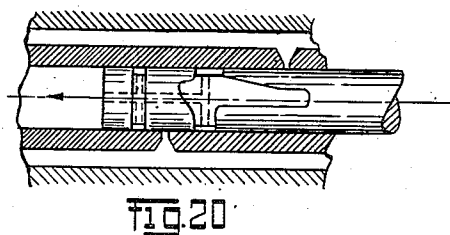
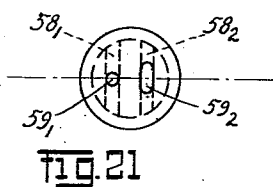
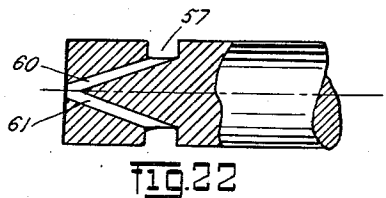
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INTERRUPTION INJECTION PUMP AND METHOD TO APPLY THE SAME

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3 Sheets-Sheet 2



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Dec. 22, 1942.

N. N. SKAREDOFF

2,306,364

INTERRUPTION INJECTION PUMP AND METHOD TO APPLY THE SAME

Filed June 27, 1940

3 Sheets-Sheet 3

FIG. 24

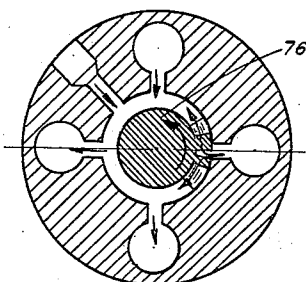


FIG. 23

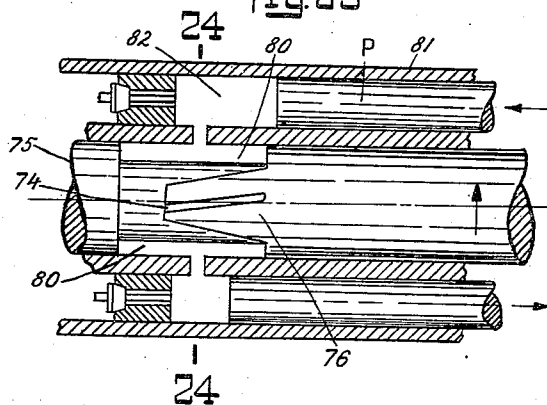


FIG. 25

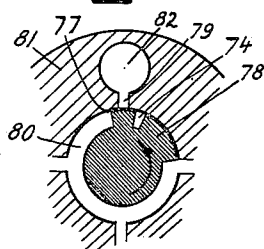


FIG. 26

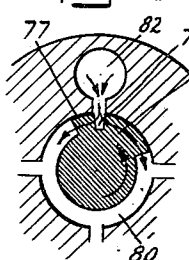


FIG. 27

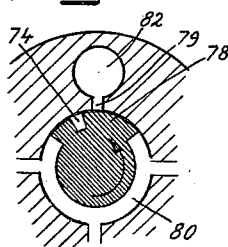


FIG. 28



FIG. 29



FIG. 30

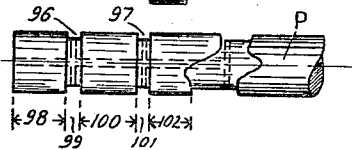
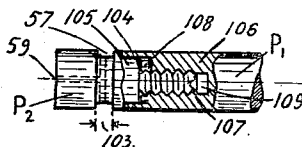


FIG. 31



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UNITED STATES PATENT OFFICE

2,306,364

INTERRUPTION INJECTION PUMP AND
METHOD TO APPLY THE SAME

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New York, N. Y.

Application June 27, 1940, Serial No. 342,638

2 Claims. (Cl. 103—41)

This invention relates to a new method and new devices for elimination in toto or in part of the so-called detonation in internal combustion engines operating on a two or four-stroke Diesel cycle, and on the Otto cycle using fuel injection pumps.

This invention also is designed to improve the control of the combustion of fuel inside of a cylinder of an internal combustion engine.

For the convenience of the description, this specification will refer to a single cycle occurring during the operation of the engine. The word "injection" will indicate the individual injection occurring during the said cycle. The amount or quantity "injected" during each cycle will be referred to as the total fuel charge, or "charge."

The total fuel charge, according to this invention, is to be divided into two parts, i. e. the "initial injection" and the "main injection," the initial injection being a fraction of the total fuel charge, and the main injection or the "remainder of injection" comprising the remainder of the fuel charge. The interval of time between the termination of the initial injection and the beginning of the main injection, will be referred to in this specification as the "interruption" of the injection, or the "injection interruption."

In engines operating on a Diesel cycle or on a Kadenacy-Diesel cycle, the injection is preferably to be divided into two parts, comprising a small initial injection followed by an interruption, after which interruption the main fuel charge is injected. For engines operating on an Otto cycle, the injection of the fuel charge may also be divided into an initial charge followed by the interruption, whereafter the main charge may be injected. The initial charge may be equal to, smaller, or larger than the main injection. The period of interruption may be timed in accordance with the kind and/or amount of fuel employed. One or more interruptions may be used, dividing the fuel charge accordingly into corresponding fractions. This applies to Diesel engines as well as for Otto cycle engines.

This invention refers to an "interrupted injection cycle," hereinafter described as IIC, which is characterized by a new, accurate, and more efficient control of the combustion of fuel inside of the working cylinder.

In the drawings, wherein like reference characters refer to like parts throughout the several views,

Figure 1 is a diagrammatical view of the pres-

sure variation in the cylinder during compression and power stroke.

Figure 2 is a diagrammatical representation of the fuel pressure during injection using normal injection cycle.

Figure 3 is a diagrammatical representation of fuel pressure during injection using interrupted injection cycle.

Figure 4 is a longitudinal cross-sectional view of an injection pump piston with parts broken out.

Figure 5 is a plan-view of Figure 4.

Figures 6, 7, and 8 represent longitudinal cross-sectional views of the injection pump, barrel and piston, with parts broken out.

Figures 9 and 10 represent schematically a plan-view partly in cross-section of cams of an injection pump.

Figure 11 represents a longitudinal cross-sectional view with parts broken out, of a piston of a Bosch injection pump converted to provide interrupted injection.

Figure 12 represents a plan-view of Figure 11.

Figures 13, 14 and 15 represent longitudinal cross-sectional views with parts broken out, of the Bosch injection pump converted to provide the interrupted injection shown in three different positions of the piston.

Figure 16 represents a longitudinal cross-sectional view with parts broken out, of a piston of a General Motors injection pump converted to provide interrupted injection.

Figure 17 represents a plan-view of Figure 16.

Figures 18, 19 and 20 represent longitudinal cross-sectional views with parts broken out, of the General Motors injection pump converted to provide the interrupted injection shown in three different positions of the piston.

Figure 21 represents a plan-view of a piston.

Figure 22 represents a longitudinal view with parts broken out, of another piston.

Figure 23 represents a longitudinal cross-sectional view with parts broken out of an EX-Cell-O injection pump, converted to provide the interrupted injection.

Figure 24 represents a cross-sectional view 24—24 of Figure 23.

Figures 25, 26 and 27 represent cross-sectional views with parts broken out of Figure 23, following the plane 24—24, showing the rotary valve in three different positions.

Figures 28 and 29 represent a longitudinal side-view with parts broken out, of a variation of the piston-design for interrupted injection.

Figure 30 represents a longitudinal side-view

of a variation of the piston-design for multiple interruption-injections, with parts broken out.

Figure 31 represents a longitudinal side-view with parts broken out, of a piston for interrupted injection with provision for adjustment of the interruption.

Figure 1 diagrammatically represents one of the main methods of this invention, wherein the sequence of events inside the working cylinder during part of one cycle is demonstrated. The curve AC represents an air cycle of an engine with the top dead center of the piston marked TDC. The curve IIC represents the pressure variation inside of the working cylinder during the IIC (interruption injection cycle); and the curve of the normal injection cycle, hereinafter designated as NIC, represents the variation pressure inside of the working cylinder operating on a normal injection cycle.

In a normal injection cycle, the injection begins at a point marked BNI (beginning of normal injection), and steadily continues until the point ENI (end of normal injection) is reached. Due to the lag of ignition, the combustion starts to occur only at point BIC (beginning of internal combustion). During that interval, a considerable portion of fuel has already entered the combustion space, and when the ignition occurs, the entire quantity of the fuel already present in the combustion space, starts to burn at once at an uncontrollable rate of speed, thus producing an excessively rapid pressure rise which causes the engine to knock or detonate. Inasmuch as this occurs near the top dead center position of the piston, in which region it can move only very slowly, the magnitude of pressure attained is also considerably in excess of what the engine was originally designed to produce. When the piston begins to move on its expansion stroke, the injection is practically completed, and the pressure drops rapidly.

When interrupted injection cycle (IIC) is applied, instead of normal injection cycle (NIC), the fuel injection starts at a point BII (beginning of interruption injection), and continues until the entire initial amount of fuel is injected, and stops at a point marked EII (end of interruption injection). The piston continues on this compression stroke and the period of the lag of ignition has elapsed, this initial quantity of fuel begins to burn at a point marked BB (beginning of ignition) on the diagram. At this point, the main injection commences substantially at a point marked BMI (beginning of main injection) and continues until the total amount of fuel required, is injected.

It is to be noted that one of the main aspects of this invention is the providing of the said interruption, i. e. the interval during which the initial fuel charge begins to burn and produces an open flame, into which the remainder of the fuel charge is then injected. It is also to be noted that such an interruption can be chosen in accordance with the characteristics of the engine and the fuel used. Due to the fact that the main fuel charge, according to this invention, is injected into the open flame, the time required to ignite (lag of ignition) is reduced to such an extent, that no appreciable quantity of fuel can accumulate in the combustion space without being burned as fast as it enters. The rate of injection can be easily controlled by injection mechanism, to inject only so much fuel into the combustion space as is necessary to maintain a certain ratio behind the receding piston on

its expansion stroke. In this way, all undue stresses on an engine are eliminated, and a useful and even working mechanism caused by smooth torque, is obtained.

Since the pressure rise inside of the combustion space is very slow and limited in magnitude, no detonation can be produced. The injection is terminated at a point EII after which the conventional expansion follows:

The quantities of fuel injected are represented by the shaded areas, as follows:

KK₁NN₁ represent the amount of fuel injected during the NIC. KK₁LL₁ represent the amount of fuel delivered during the initial injection, and LL₁NN₁ represents the interruption between the initial and main injections. MM₁OO₁ represent the amount of fuel delivered during the main injection.

Figure 2 represents the NIC with shaded area 50 showing the amount of fuel delivered to the cylinder, and similarly represented by KK₁NN₁, shown in Figure 1.

Figure 3 diagrammatically shows the IIC with shaded area 51 representing the initial injection similar to KK₁LL₁ as shown in Figure 1, and area 53 represents the main injection similar to MM₁OO₁, as shown in Figure 1. The interruption is represented by interval 52 between the areas 51 and 53.

Lines 54, 55 and 56 on Figures 2 and 3, represent diagrammatically the rise and fall of fuel pressure in the compression chamber of the pump before discharge pressure is reached, and after delivery valve is closed.

It is to be noted that Figures 1, 2 and 3 are diagrammatical views, and do not limit the relation between the quantities of fuel injected initially, and the times employed for the termination of such initial injection and the interval of the main injection, and also do not limit the relation between the time of the injection and the position of the piston at which the injection occurs. By way of example:

1. The initial quantity, instead of being smaller than the main injection, as shown in Figures 1 and 3, can be equal to, larger, or smaller than the main injection.

2. The relations between the three time-intervals, necessary for (1) the initial injection, (2) the interruption, and (3) the main injection, are not limited by the ratio shown diagrammatically in Figures 1 and 3, and can be varied according to the type of engine and fuel employed.

Presuming, for instance, that the magnitude of the interruption interval is governed by the speed of the engine and the ignition characteristic of fuel used, then the interruption interval should be approximately equal to, or slightly smaller than the ignition lag of the fuel used. This, however, does not limit the invention herein described to any other arrangements.

Another example of arrangement of the said three time-intervals, may, for instance, be as follows:

For a Diesel engine having a total injection period of about 20 degrees, and operating on a fuel with ignition lag amounting to 10 degrees at operating speed, the initial injection will start about 14 degrees before top dead center TDC, and then continue until about 10 degrees before top dead center TDC, and then be interrupted for about 9 or 10 degrees, with the main injection commencing about 1 degree before TDC, and continued until the full amount of fuel is delivered into the cylinder, depending upon the

load of the engine. This is given by way of example only, and does not limit the invention thereto.

The timing at which the initial and main injections are designed to occur is also not limited to that shown on Figures 1 and 3, and can be varied to produce the best results in accordance with the type of engine and fuel employed.

This new method is not limited to a single interruption as shown in Figures 1 to 7 inclusive. More than one interruption during a single cycle can be used, as shown diagrammatically in Figure 28. If several interruptions are used, the first interval may, for instance, be longer than the second one; the first initial charge equal to, greater or smaller than the second charge;— and the remaining fuel charge equal to, greater or smaller than the initial charge.

The open flame created by the initial interruption injection reduces the lag of ignition of the main fuel charge when it begins to arrive in the combustion space, to such a degree that no appreciable amount of fuel can accumulate in the combustion space without being ignited. The fuel is burned as fast as it enters the combustion space, giving accurate control of the pressure inside the cylinder, and thereby offering a smooth and efficient operation of the engine.

One of the advantages of the interruption injection consists in that it offers a possibility of using a cheap fuel of a low cetane number in high-speed engines without detonation or other harmful effects. By way of example, a modern high-speed Diesel engine will not satisfactorily operate on a fuel having a cetane number below 60. The interruption injection properly designed for fuel with a cetane number of, for instance, around 20, will operate with equal efficiency and no detonation, as if a high-grade fuel were being used, for instance, a fuel with cetane number around 80. It must be pointed out that if an exceedingly high-grade fuel, for instance, cetane number 80, is employed, the interruption injection may not show any considerable improvement of performance, inasmuch as it is designed preferably to permit the operation of the engine on a low-grade fuel.

One aspect of a practical realization of this invention, is shown in Figures 4 to 8 inclusive, 11 to 20 inclusive, and consists as shown on Figure 4, in providing the piston P with interrupter-passage consisting of a concentric groove 57 and drilled passage 58, connecting the opposite sides of the groove and by drilled passage 59 connecting passage 58 with the top of the piston P. Instead of having one passage 58, there can be a plurality of them, 58₁, 58₂, as shown on Figure 21, each having any desirable cross-section. Instead of one connecting passage 59, there may also be more than one connecting passage, 59₁, 59₂, as shown on Figure 21.

The operation of the interruption-injection pump, as shown on Figures 6, 7 and 8, is as follows:

On the delivery stroke, the pump piston displaces oil from the cylinder back to the suction chamber 62 until the top of the piston P covers the suction port 63. Then, the initial injection starts, and is continued until the concentric groove 57 and the suction port 63, as shown on Figure 7, begin to register. An open passage is then provided between the compression chamber above the top of the piston P and the suction chamber 62 by means of drilled-passages 58 and 75

59, and concentric groove 57. During the time that concentric groove 57 and suction port 63 are in register, the oil displaced by the moving piston P will flow back into the suction chamber 62 instead of being delivered to the injector, not shown on the drawings, being self-evident. As soon as suction port 63 is covered by the lower portion—63—of the piston P, the interrupter-passage is closed and the main fuel injection begins, and continues until terminated by means in accordance with the design of the pump, and not concerned with this invention.

Figure 6 represents the relative positions of the piston P and barrel 65 during the initial injection. Figure 7 represents the relative position of the piston P and barrel 65 during the interruption period. Figure 8 represents the relative positions of the piston and barrel during the main injection.

The arrangements shown on Figures 4 to 8, inclusive, can be employed to convert a Guiberson fuel pump to provide interruption injection.

Still another aspect of a practical realization to provide an interruption injection, is shown on Figure 9, wherein instead of providing the piston P with the interrupter-passage, the piston P may be retained in its original design, but the contour of the operating cam should be modified so that the motion of the piston is arrested, or substantially arrested, for the interruption of the injection. Cam 83 is schematically represented on Figure 9, mounted on the shaft 84. In dotted lines, 85, is shown the normal contour of the operating cam, without modification for the interruption. The modification is achieved by provided section 86 interposed between the section of the cam 87, sufficient to produce the initial injection, and the section 88 sufficient to complete the injection. During the time that the piston follower is operated by section 86 of the cam, the forward motion of the piston P is arrested to produce the interruption.

For better comprehension of Figure 9, sections 86, 87 and 88 of the cam are shown intersecting at sharp angles, but, in reality, they should be blended into a smooth curve to ensure gradual and quiet operation. Furthermore, it is to be noted that section 86 of the cam should preferably follow the circular arc concentric with the shaft. However, a suitable modification may be made to compensate the inertia of the piston and the compressibility and viscosity of the fuel.

Another aspect of a practical realization to provide an interruption injection, is shown on Figure 10, wherein the cam operating the injection valve in a common rail system, is converted to provide interruption injection. The cam 89, mounted on a shaft 90, is provided with removable operating sections 91, 92, 93, 94 rigidly affixed to the cam 89 by suitable means; the section 93 provides sufficient lift of the fuel valve to give the initial injection; section 92 provides the interruption during which the valve is closed, and 91 lifts the valve for the main injection. Section 92 can be made of different dimensions to provide adjustment for the duration of the interruption, and for this reason, section 94 is introduced to permit section 92 to be augmented or diminished for a predetermined measurement, while section 94 is correspondingly diminished or augmented for a predetermined measurement. Sections 92 and 94 have a contour substantially concentric with the axis of the

shaft, to provide the closure of the injection valve.

Figures 11 to 15, inclusive, represent a practical realization for converting a Bosch fuel pump to provide interrupted injection.

In a piston of a Bosch pump, in accordance with this invention, a partial, preferably concentric groove 66 is provided which will not communicate with the existing fuel-return slot 67 of the original Bosch design. Groove 66 is connected to the top of the piston P by drilled passages 58 and 59.

Figures 13, 14 and 15 show the operation of the modified Bosch pump for the interruption injection cycle, as follows:

On the delivery stroke, the pump piston P displaces oil from the cylinder back to suction chamber 62, as shown on Figure 13, until the top of the piston P covers the suction port 63. The initial injection is then started, and is continued until the partial concentric groove 66, and the suction port 63, as shown on Figure 14, begin to register. An open passage is thus provided between the compression chamber above the top of the piston P and the suction chamber 62 by means of drilled passages 58 and 59, as shown on Figure 14, and partial concentric groove 66. During the time that partial concentric groove 66 and suction port 63 are in register, the oil displaced by the moving piston P, flows back into suction chamber 62, instead of being delivered to the injector. As soon as suction port 63 is covered by the lower portion 68 of the piston P, the interrupter passage is closed and the main fuel injection is then continued until terminated.

Another aspect of a practical realization of this invention, is shown on Figures 16 to 20 inclusive, representing the conversion of a General Motors fuel pump provided for interrupter injection. The piston P of such a pump, is originally provided with drilled passages 69 and the central fuel-return passage, 70. The passage 70 in a General Motors pump has the same function as the fuel-return slot 67 provided in the Bosch pump. According to this invention, a concentric groove 57 is provided near the top 71 of the piston P and drilled-passage 72 connecting the groove 57 with the drilled-passage 70. Inasmuch as the General Motors design provides the said passage 70 which is used in their design only to control the amount of fuel injected, it bears no similarity to this invention. However, inasmuch as the General Motors pump already has a drilled-passage 70, a part of this said passage 70 could be combined with groove 57 by means of a drilled-passage 72, to provide the interruption injection, subject of this invention. However, if desired, at least one separate drilled passage 73 could be provided as shown in dotted lines on Figures 16 and 17, if a separation of the functions is desired.

Figures 18, 19 and 20 represent the sequence of events as correspondingly indicated in Figures 13, 14 and 15 for the Bosch pump.

If desired, instead of using the drilled-passage as shown for the Bosch pump and the General Motors pump, on Figures 11 to 20 inclusive, said drilled-passages may be made in the form shown in Figures 21 and 22, wherein a drilled-passage 58 may have a desirable cross-section, for instance, a circular one, for 59₁, and a rounded parallelogram 59₂, or any other contour.

Instead of providing drilled-passages 58 and 59, they can be both merged into a single pas-

sage 60 drilled at an angle as shown on Figure 22. Instead of one single passage 60, two or more such passages may be provided to connect with the interrupter-passage 57, for instance, 60 and 61, as shown on Figure 22.

Another aspect of a practical realization of this invention is illustrated in Figures 23, 24, 25, 26, and 27, representing schematically the EX-Cell-O pump converted to produce the interrupted injection. For this purpose, a groove 74 is provided parallel, or substantially parallel, to the leading edge 75 of the rotary valve 76 as shown in Figure 23. The groove 74 has the same function as grooves 57 or 66, previously described herein for the modifications for Bosch and General Motors. It is to be noted that groove 74 divides the rotary valve 76 into sections 77 and 78 whereby when section 77 of the rotating valve 76 covers the suction port 79 of the corresponding piston P, the oil is prevented from flowing back to the suction chamber 80 and is displaced to the injector by the moving piston P in the cylinder 81.

As soon as the groove 74 begins to register in the suction port 79 an open passage is provided between pressure chamber 82 and the suction chamber 80 by means of suction port 79, and groove 74. During the time that groove 74 registers with suction port 79, the oil is displaced back into suction chamber 80, i. e. interruption is thus provided as shown on Figure 26, and thereafter, as shown on Figure 27, when the rotary valve 76 continues to rotate, and section 78 covers the suction port 79, the fuel in the pressure chamber 82 is again forced to the injector, thus beginning the main injection.

Still another aspect of the practical realization of this invention, is illustrated on Figures 28 and 29, wherein is shown a groove 95 having the same function as the interrupter grooves previously described herein, consisting of a groove inclined in respect to the axis of the piston, and having an irregular or curved contour 95₁ as shown in Figure 29.

Still another aspect of the practical realization of this invention, is shown on Figure 30, wherein instead of making one interrupter groove 96 providing a single interruption, a second interruption groove 97 is also made, thus providing a first initial injection, a first interruption, thereafter a second injection and then a second interruption, after which second injection the remainder of the fuel charge is then injected. Instead of two grooves, a plurality of grooves may be provided, as, for instance, in long-stroke pistons and slow-rotative speeds, in which a plurality of grooves may be desirable.

The relative dimensions of the relationships 98, 99, 100, 101 and 102, as shown on Figure 30, are not limited to the ratios of schematically given dimensions shown on Figure 30, and may be varied to obtain the desired results.

Another aspect of the practical realization of this invention, is illustrated on Figure 31, which shows a piston P provided with groove 57, and drilled passages 58 and 59, having means to adjust the width 103 of the interrupter groove 57 to make possible the adjustment of the same pump to operate on various kinds of fuels. The piston P is divided into two different sections, P₁ and P₂. P₁ is provided with a cylindrical recess 104 into which part 105 of P₂ fits. On the bottom of this recess 104, there is a drilled and female threaded recess 106 into which the male threaded extension 107 of P₂ is screwed in. A washer 108

is inserted between the bottom of parts 105 and the bottom of the recess 104, the thickness of the washer chosen to provide the desirable proper width 103 of the groove 57. If desirable, a locking device may be inserted below the threaded extension 107 to prevent P₂ from becoming unscrewed during operation.

Having now particularly described and ascertained the nature of the said invention, and in what manner the same is to be used, I declare that what I claim is:

1. In a fuel injection pump of an internal combustion engine, having a piston reciprocating in a cylinder provided with at least one suction port for the admission of the fuel into the working chamber of said pump, characterized by means comprising: a piston provided with at least one preferably concentric groove near the top of the said piston of the said pump, a passage provided in the interior of the body of the said piston establishing a communicating passage between the said groove and the head of the said piston,

whereby when the said groove registers with at least one said suction port of the said pump, there is provided an interruption of the delivery of fuel during the time said groove is in register with said suction port in the barrel of the said pump.

2. In a fuel injection pump of an internal combustion engine, having a piston reciprocating in a cylinder provided with at least one fuel-return slot and at least one suction port for the admission of the fuel into the working chamber of said pump, characterized by means comprising: a piston provided with a concentric groove partially encircling it, but not communicating with the said fuel-return slot of the said piston, said groove being in communication with the head of the said piston by means of at least one passage provided inside of the said piston, establishing a communication between the head of the said piston and the said groove, whereby interrupted injection of the character referred to is produced.

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