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(54) **Low consumption internal combustion engine, incorporating a system for the super-expansion of the exhaust gases**

(57) The present invention suggests the combination (fig. 2) of a conventional multi-cylinder engine, conveniently a most common non-modified four cylinders Otto or Diesel engine, hereinafter called "first engine"(1), with a second piston engine, hereinafter called "second engine"(2) having a similar constructional configuration as the first engine, that is in particular:
a) a crankshaft synchronised or in common with the first engine
b) same valve distribution system, i.e. a twin camshaft for separately driving the inlet and the outlet valves, except that the cam profiles are opportunely modified Said second engine is however modified to eliminate or deactivate the injection as well as the ignition systems, so as to operate as simple expanding chamber, the exhaust gases of the first engine being led to flow into said chambers and further expand therein, thanks to a particular design of the second engine's cam (6,7) profiles.

The transfer of said gases takes place through a simple new component called "capacitor"(3), which is fluidly connected, and closely mounted (see fig.2), to the exhaust pipe of the first engine (1) on one side, and fluidly connected to the inlet ducts of the second engine (2) on the other side, to form a common sealed volume between the two engines.

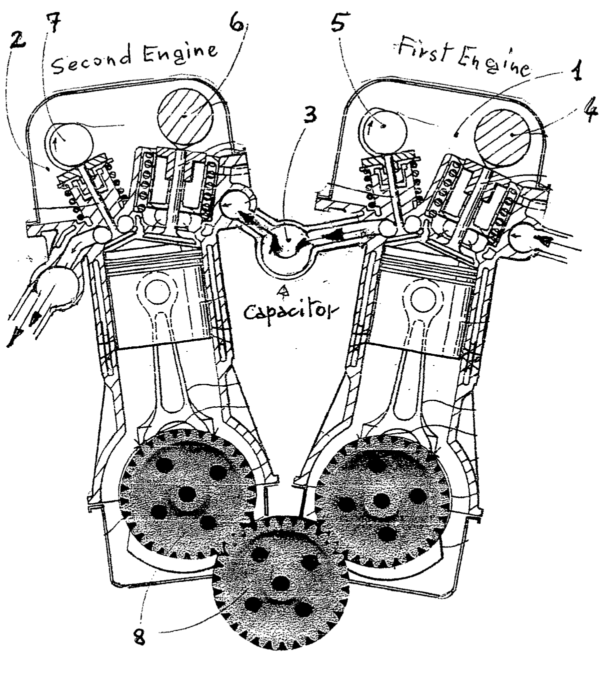

FIG. 2

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Description

Field of the invention

[0001] This invention relates to piston type, positive displacement, internal combustion engines and particularly a method for performing the a so-called "super-expansion" thermodynamic cycle by means of conventionally manufactured internal combustion engines.

Background of the invention

[0002] In order to gain power from the considerable amount of energy contained in the exhaust gases of the internal combustion engines, conventionally discharged in the mufflers and dispersed into atmosphere, various systems have been adopted or suggested, as for example the well known turbo-compressors used for supercharging the engines with the effect of increasing their specific power, their torque and the flexibility of use over a certain range of speed. However, the effect on total efficiency has proved to be marginal and depending on how the power level is managed. Other methods for recuperating the energy dispersed in the exhaust system have been developed, or are under development, with turbines driving electrical generators or with steam generators to drive steam piston engines or turbines.

[0003] A further solution has been suggested by the PCT publication: WO2005/012692, dated 10/02/2005, which represents the closest prior art to the present invention. It is suggested therein to extend the thermodynamic cycle (Otto or Diesel) of a conventional four-stroke internal combustion engine, by four additional strokes allowing to double the expansion volume and thus further exploit the energy of the hot gases at the end of the incomplete expansion occurring within the conventional engines.

[0004] This solution, based on a novel unconventional engine configuration, called "Multi-cylinder barrel-type engine", entails a radical modification of the structure, of the dynamics and of the components of the conventional internal combustion engine.

Therefore, the suggested method for performing such an 8-stroke "super-expansion thermodynamic cycle" requires a considerable development effort and corresponding modifications to the current manufacturing process, thus not practicable although the potential gain in efficiency, as predicted by a computer-assisted investigation on said thermodynamic cycle, is of the order of 40%.

Scope of the invention

[0005] It is therefore the main object of the present invention to disclose a method and a system for performing said "8-stroke super-expansion cycle" , which is seen as a thermodynamic evolution of the four-stroke cycle Otto or Diesel and promise a very attractive gain in efficiency (in the order of 40% over the present values) according to a computer-assisted investigation, by using a conventional engine type with minor modifications. This would allow a quick and easy manufacture of a demonstrator, which could also serve as a test bench for further development of this new technology.

[0006] Other objects and related advantages of the invention will be recognized from the following detailed description taken in conjunction with the accompanying drawing's sheets, in which:

Fig. 1 represents a block diagram of the engines combination according to the invention defined in claim 1.

Fig. 2 gives a schematic vertical section of a first embodiment of the invention according to claim 2

Fig. 3 gives a schematic plan view of a first embodiment of the invention according to claim 2

Fig. 4 represents a schematic illustration, as a vertical section, of a second embodiment of the invention according to claim 3

Fig. 5 represents a schematic illustration, as a plant view of a third embodiment of the invention according to claim 4

Detailed Description

[0007] Reference is made to Figs 2 and 3, where **a first embodiment** is schematically represented, consisting in a combination of a first (1) and a second (2) engines disposed parallel to each other and having conveniently the same n° of cylinders, the same displacement, identical crankshaft and same housing structure, so that they can be easily reciprocally assembled and their crankshafts dynamically connected, through a pairs of gears: in this way the two engines are constraint to run at a synchronised speed and are able to exchange torque and power. A gas capacitor (3), thereinafter called "capacitor", is interposed between the first and the second engine in order to tightly transfer the exhaust gases from the first engine to the inlet duct of the second engine.

A current four-cylinder engine, operating along a 4-stroke Otto or Diesel cycle, has being selected in this example, as the "first engine", which runs in a fully conventional mode, with the only exception that the exhaust gases are conveyed to the capacitor (3), and not to a conventional exhaust system (muffler) In such a type of engine, as it is well known, <u>a unitary gas quantity</u> (corresponding to the displacement volume of a single cylinder) is expelled, by said first engine in operation, every half revolution and pushed into the capacitor. Furthermore, supposing that an established intermediate pressure is kept constant in the capacitor (which will appear to be realistic with the following explanations), and keeping in mind that it is common practice, in the four cylinder engines, to make pistons run two by two in parallel with a phase differential of 180˚, it is evident to the person skilled in the art, that being the two crankshafts synchronised, the equivalent unitary amount of gas expelled from one cylinder (e.g. the n˚1), is admitted into two cylinders of the second engine (e.g. the n˚ 5 and 6), when the relevant inlet valves are kept open during only half aspiration stroke of the relevant two parallel piston, i.e. during only a quarter of the engine's revolution. And this is what occurs with the intended specially profiled cams (6) of the inlet camshaft, which cams in fact are made to shut the inlet valves at approximately middle stroke of the pistons in all four cylinders and at every revolution.

[0008] It is further evident, always referring to Figs 2 and 3, that during the first half stroke of the expelling piston (n˚1) of the first engine, and of two aspirating pistons (n˚ 5, 6) of the second engine, the pressure in the capacitor will decrease, but in the second half of the same stroke the pressure will soon recover due to the fact that the two inlet valves of pistons n˚5,6 remain closed, while said expelling piston n˚1 completes its second half of the stroke. In the mean time said unitary gas quantity flown into the cylinders 5 and 6 during the 1st half stroke period, undergoes a second expansion (super-expansion) during the 2nd half stroke, since the volume displaced by the two pistons doubles after the shutting of the inlet valves. In the following stroke (2nd half rev.) said two pistons (n˚5 and 6) expel the said super-expanded quantity of gas to atmosphere through the two outlet valves kept open by the outlet camshaft (7). It is then observed that during said second stroke (2nd half engine's rev) another cylinder (e.g. the n˚4) of the first engine performs its expulsion phase, in its turn, by expelling another unitary amount of gas (at said intermediate pressure), which amount , through the capacitor is simultaneously admitted into the other two aspirating cylinders (the n˚7 and 8) of the second engine, while the first two cylinders n˚5,6 becomes ready to admit a 3rd unitary volume, coming from expelling piston n˚ 2 during the following 3rd stroke, and so on..... with the following 3rd and 4th strokes. Thus, at the end of the 4-strokes cycle (of the first engine), the second engine conclude two expansion/expulsion cycles on each pair of cylinders, so that, during steady operation, the same amount of gas is flowing in series through the two engines. It is then possible to conclude that the intermediate pressure which automatically builds up in the capacitor sensitively depends on the shutting time dictated by the inlet valve cams (7).

[0009] To facilitate the control of the intermediate pressure in the capacitor, a variable pressure-relief valve could conveniently be mounted on the capacitor. It is clear, finally, that while the first engine delivers to the main shaft its own power as in conventional operation, the second engine is adding, to the main output shaft, through the second crankshaft and the relevant gears (8) a supplementary power which is able to extract from the exhaust gases, during the super-expansion phase.

[0010] It is to be noted that the second engine do not need to have the same n˚ of cylinders nor the same displacement volume as the first engine: the person skilled in the art will promptly see that, although not convenient, it is sufficient for the second engine to have a single cylinder and at least about the same displacement in order to correctly operate in combination as an expanding chamber, provided of course that the overhead cams profiles are opportunely designed as above explained.

[0011] **In a second embodiment,** a conventional V-Engine configuration is suggested to be adopted to equally perform of a super-expansion cycle as illustrated in the scheme of Fig. 4

[0012] In a 2 or 4 or 6 or 8 or more cylinders V-Engine conventional lay-out, in fact, one disposes of two-cylinder banks, each containing a single or 2 or 3 or 4 or more pistons on-line, all supported on a single crankshaft.

[0013] It is understandable how such type of engine can be transformed in a combination of "first engine" and "second engine", as before defined, by applying the following simple modifications:

a) interchange and modify the inlet and outlet overhead camshafts of one bank to drive the inlet and outlet valves as in a conventional 1 or 2 or 3 or 4 cylinder on-line engine, which would then represent the "first engine",

b) modify the injection and ignition systems in the one bank to operate as in an on-line 2 or 3 or 4 cylinder engine

c) modify the inlet and outlet camshaft profile in the second bank, as above explained for the "second engine" in the first embodiment,

d) deactivate or suppress the injection and sparking system in the second bank,

e) Replace the air admission collector/filter assembly, conventionally located in the space between the two banks, by a "gas capacitor" similar to that of the first embodiment, tightly connected on one side to the admission pipes (which due to the modification under point a) above, become exhaust pipes) of the one bank, and on the other side to the admission pipes of the second bank

f) Replace, in the opposite side, the exhaust collector of the one bank, by a conventional air admission collector and filter assembly (re-dimensioned for half airflow).

[0014] It also appears that in such a configuration the single crankshaft represents the automatic integration of the first and second engine's crankshafts, since all the 2, or 4, or 6, or 8, pistons are supported on the same central crankshaft already before the modifications. In conclusion, the one bank cylinders (first engine) operate along a conventional 4-strokes cycle delivering the power of a conventional engine, and at the same time the second bank cylinders (second engine) operate as expansion chambers performing the "super-expansion" and adding supplementary power onto the same output shaft, again without addition of fuel consumption.

[0015] In a third embodiment, illustrated by the scheme of fig. 5 a further simpler configuration of conventional 4-strokes engine is suggested to be used for performing the "super-expansion" cycle, which is the **classic multi-cylinders in-line engines,** ranging from the 2- to 16- (or more-) cylinders engines. Therein, in fact, the opportune modification of the overhead camshafts and injection systems (similar to above suggested modifications to the one bank of the V-engines) makes it possible to let only **one first half of the cylinders** staggered (as illustrated in fig. 5) or contiguous (not illustrated) to operate as active internal combustion engine (**first engine**).

Furthermore the modification to the cams profiles as well as the suppression of the injection/ignition systems (as already explained in the first embodiment) on **the second** remaining **half of the cylinders** allows to transform them in an expanding chambers **(second engine)** able to perform the "super-expansion" portion of the cycle. Clearly the crankshafts of the first and second engines are already integrated in the unmodified common crankshaft/output-shaft.

[0016] One has also to clarify that, although reference has been often made here above and in the fig. 2, to a cam-shaft-drive system for actuating the inlet or outlets valves, the definition of the invention given in claim 1 is intended to include all possible alternatives regarding the type of gas distribution system of the first and second engines and of the relevant actuating system, i.e. the invention can be equally performed with the use of any other type of valve and of any other type of valve actuating system, for example by means of electromagnetically driven valves.

[0017] For all the embodiments, the expected increase in efficiency is always in the order of 40%, by logic transfer of the results of the computer-assisted investigation cited on page 2, since the performed thermodynamic cycle is always the same.

[0018] In conclusion, the main merit of the presently disclosed engine-compound is that of indicating an easy method for applying the technology of the "super-expansion cycle" (as defined in the above mentioned patent publication) onto the current constructional technology for the internal combustion engine, thus allowing to **retain all the advantages of this highly performing technology.** Of course, the above described engine-compound presents the drawback of a higher specific weight and dimensions with the respect to the conventional engine, it is however to be stressed that all the particular solutions proposed by the above **2nd and 3rd embodiments,** or by any other more accurate design based on this invention, reveal all the industrial interest which could be raised in the field of stationary engines, for driving electrical generators, or in the field of naval propulsion, wherein the problem of weight and dimensions represents a minor factor.

[0019] Moreover, the **1st embodiment,** reveals itself of special interest as it suggests a reliable method for empirically proving the considerable efficiency increase to be obtained on the internal combustion engines, as predicted by the a. m. computer-assisted analysis, by the application of said "super-expansion cycle". This 1st embodiment, in fact, provides for completely separate "first and second engines" which is particularly useful for making measurements and investigating the most suitable operating conditions during development tests.

Claims

1. **An internal combustion piston-type engine** including a system for the super-expansion of the hot exhaust gases, comprising a conventional engine, thereafter called **"first engine"** (1) **characterized in that it comprises:**

   a) a **second piston-type engine,** thereafter called **"second engine"** (2) dynamically coupled to, or integrated with, the first engine and having deactivated or suppressed fuel injection and ignition systems; and
   b) a gas capacitor (3) connected to the exhaust manifold of the first engine and to the inlet manifold of the second engine defining a sealed volume for buffering at an intermediate pressure the exhaust gases of the first engine, transiting to the second engine, whereby the second engine acts as a super-expansion chamber, its gas distribution system having **the inlet valve driving device** (6) adapted to allow the admission of said gases for only a portion of the stroke of the aspirating pistons , **at each and every revolution** of the second engine, and **the exhaust valve driving device** (7) adapted to allow the exhaustion of the super-expanded gases, during the entire piston expulsion stroke, **at each and every revolution** of the second engine.

2. The internal combustion piston-type engine according to Claim 1,
   further characterized in that:

   the **"second engine"** consists of one **engine identical** and fixedly mounted to the first engine, on the side of the exhaust duct, said second engine being so modified as to:

   a) adjust the valve driving system (6 and 7), in the way defined under item b) of claim 1;
   b) provide a mounting support system such that the power output shafts of the two engines are connected through gears (8), in order to synchronize their speeds and in order to exchange the torque and the power

separately generated by each of the first and second engine.

3. the internal combustion piston-type engine according to Claim 1, **further characterized in that** the first and second piston engines are integrated together to form a V-Engine , whereby :

a) **a first cylinder bank (9)** of the V-Engine has the overhead distribution, as well as the fuel injection and ignition systems modified to operate as, respectively, an In-line-Cylinder engine, thus representing the **"first engine";**
b) **the second cylinder bank (10)** of the V-Engine has the valve driving system, e.g. the camshafts, modified in order to allow the admission and exhaust gases coming from the first cylinder bank, in the way defined under items b) of claim 1, so as to operate for the super-expansion of the exhaust gases generated by first cylinder bank, thus representing the **"second engine";**
c) the exhaust-gas gas **capacitor** (3) is mounted in the space between the two cylinder banks, in the place normally reserved to the inlet manifold and air admission system in the conventional V-Engines;
d) the air admission system and the inlet manifold for the first cylinder bank (9), is placed on the side opposite to the gas capacitor, in the space normally reserved to the exhaust system in the conventional V-Engines;
e) the crankshafts of the first and second engines are integrated to form the single crankshaft of the entire V- Engine, whereon the first and second engine are able to add their separately developed output power.

4. The internal combustion piston-type engine according to Claim 1 **further characterized in that** the first and second piston engines are integrated together to form a conventional In-Line Engine (Fig. 5), whereby :

a) a first half of the in-line cylinders , staggered (n° 1+3+5+7) or contiguous, has the overhead distribution system, as well as the fuel-injection and ignition systems modified to operate as an In-Line Engine, thus representing the **"first engine";**
b) the remaining **second half of the in-line cylinders** (n° 2+4+6+8), has the overhead valve driving device, e.g. the cam's profiles, modified in order to allow the admission, the super-expansion and the exhaustion of the hot gases in the way defined under item b) of claim 1, so as to operate for the super-expansion of the exhaust gases generated by the first half of the in-line cylinders, thus representing the **"second engine";**
c) the gas **capacitor** (3) as defined in claim 1 is mounted in the space normally reserved to the exhaust collector manifold in order to receive the exhaust gases from the first half of cylinders and to re-distribute them to the second half of cylinders;
d) on the opposite side of the in-line cylinders the air admission ducts (11) are limited to feed the first half of cylinders, whereas in correspondence of the second half of cylinders the inlet ducts are transformed in exhaust ducts of the second engine for evacuating the gases after the final super-expansion;
e) the crankshafts of the first and second engines are integrated in a single linear common crankshaft which supports all the pistons of the engine and on which the first and second engines are able to add up their separately developed output powers.

5. The internal combustion piston-type engine according to Claim 1 to 4, **further characterized in that** the valve actuation system in the second engine is of electromagnetic type.

6. The internal combustion piston-type engine according to Claim 2 to Claim 4, **further characterized in that:**

the gas capacitor (3) is equipped with an **over pressure limiting valve,** capable of being calibrated to control the level of the intermediate pressure between the first (1) and the second (2) engines.

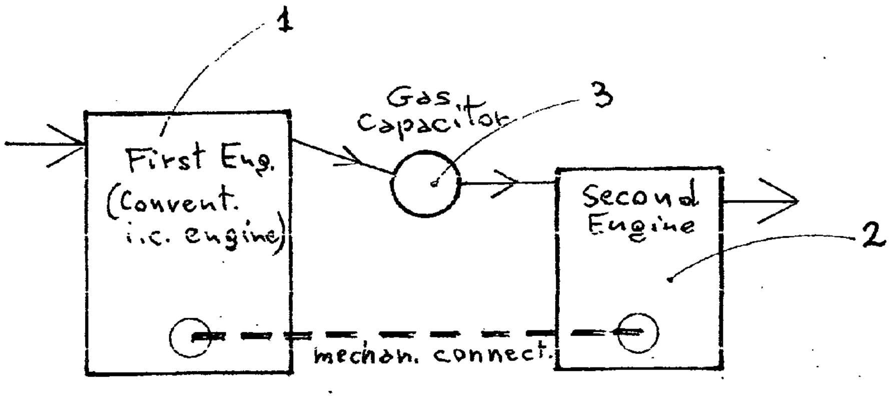
1
Gas
Capacitor
3
First Eng.
(Convent.
i.c. engine)
Second
Engine
2
mechan. connect.

FIG. 1

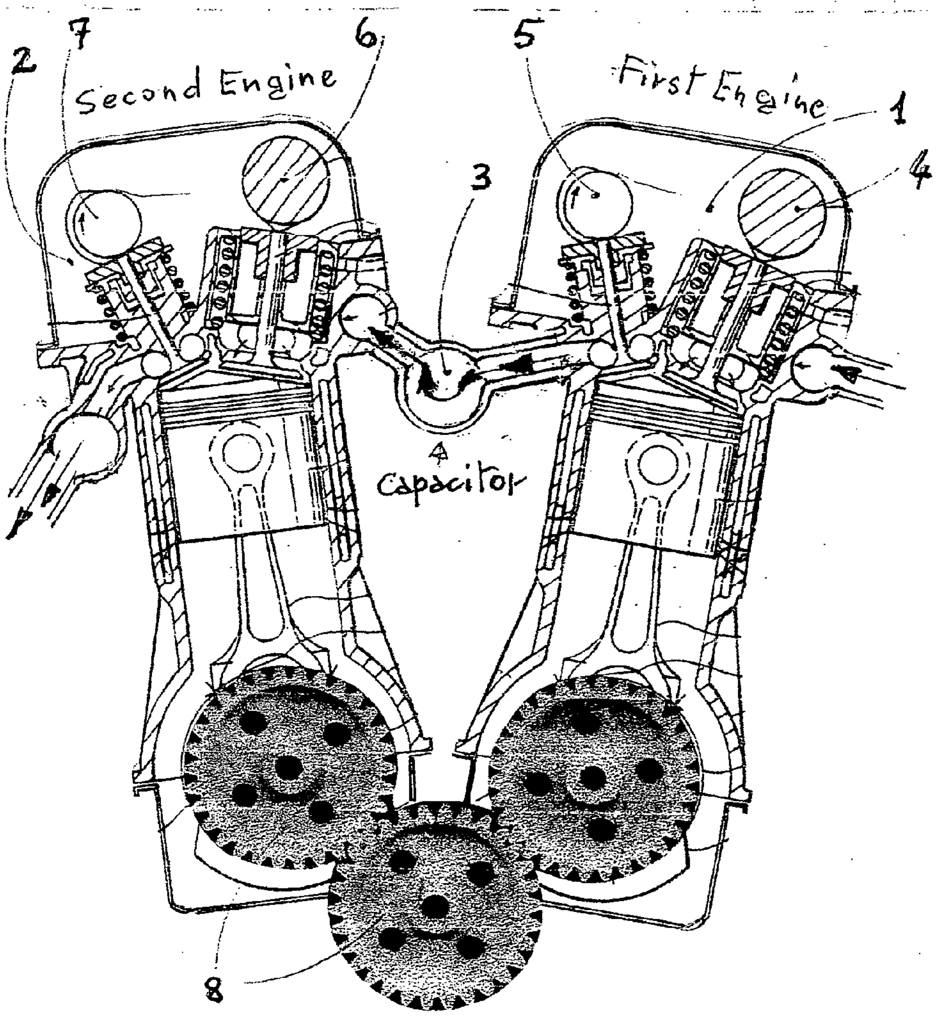
2
7
6
5
Second Engine
First Engine
1
3
4
4
capacitor
8

FIG. 2

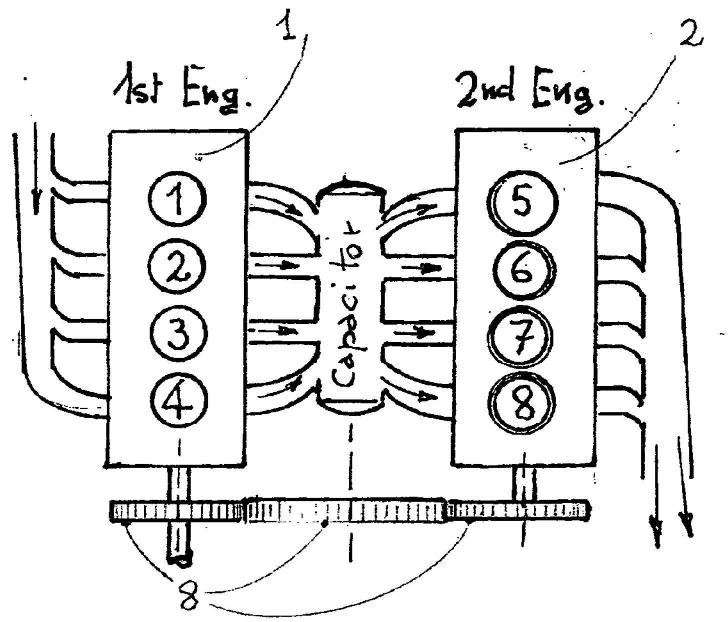

FIG 3

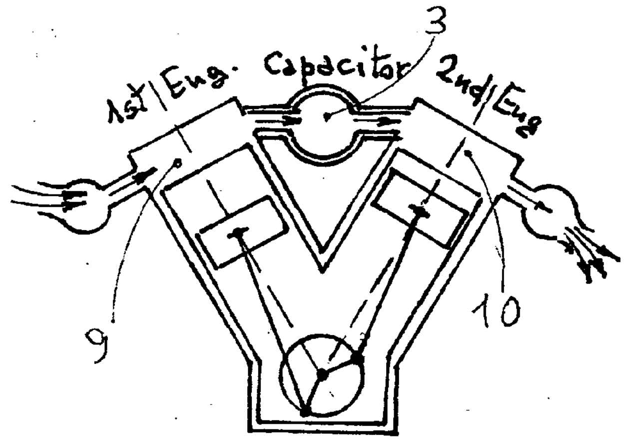

FIG 4

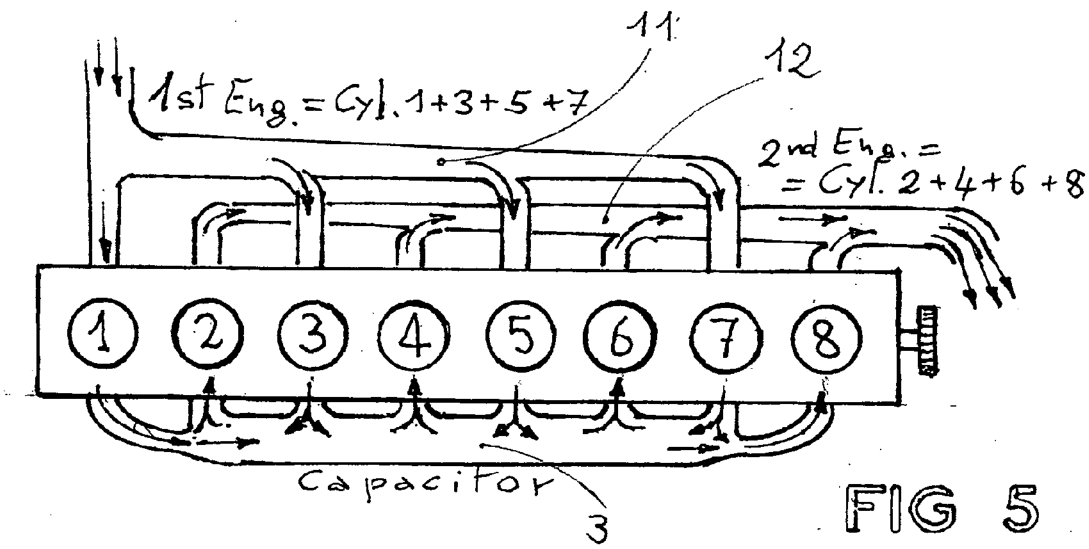

FIG 5

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 08 00 6918

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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A	WO 99/58831 A (ARMER & FRANK MOTORS LLC [US]) 18 November 1999 (1999-11-18) * page 9, line 21 - line 25 * * page 9, line 30 - line 31 * * page 13, line 4 - line 6 * * page 17, line 21 - page 18, line 14 *	1-6	
A	US 2004/123821 A1 (HU LUNG TAN [CA]) 1 July 2004 (2004-07-01) * abstract; figures *	1	TECHNICAL FIELDS SEARCHED (IPC)
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	10 September 2008	Coniglio, Carlo

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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1

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10-09-2008

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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