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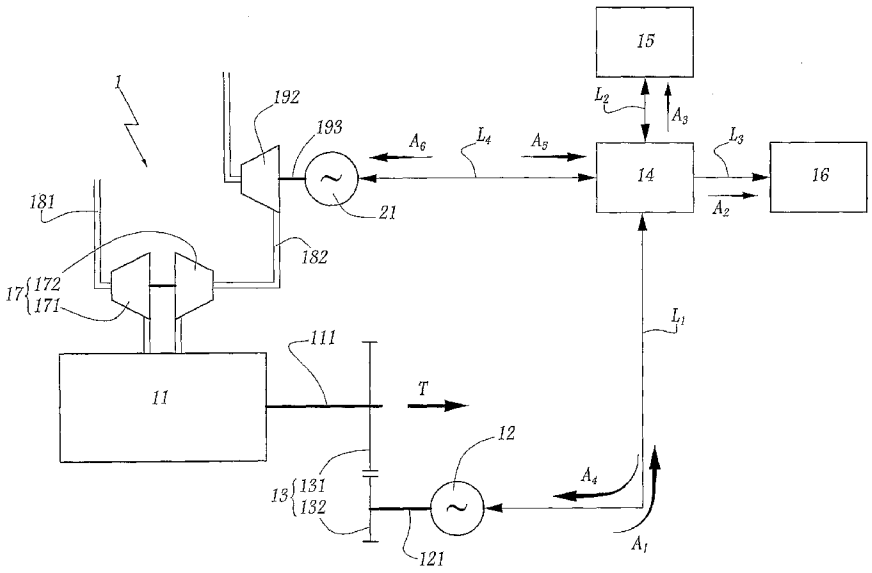
(54) **Title:** POWER UNIT FOR AN AUTOMOTIVE VEHICLE AND VEHICLE INCLUDING SUCH A POWER UNIT



(57) **Abstract:** This power unit (1) for an automotive vehicle includes an internal combustion engine (11), a first electric machine (12) electrically connected (L_1) to electrical power storage means (L_{15}) and coupled to a crankshaft of the engine, and a turbocharger (17) comprising a first turbine (172) located in an exhaust line (182) of the engine. This power unit further includes a second turbine (192), located in an exhaust line (182) of the engine (11), and a second electric machine (21) coupled (193) to the second turbine and electrically connected (L_4) to said electrical power storage means (15).

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POWER UNIT FOR AN AUTOMOTIVE VEHICLE AND VEHICLE INCLUDING SUCH A POWER UNIT

TECHNICAL FIELD OF THE INVENTION

This invention concerns a power unit for an automotive vehicle and an automotive vehicle including such a power unit.

BACKGROUND OF THE INVENTION

The reduction of fuel consumption of automotive vehicles, in particular trucks, is a major issue for the sustainability of road transport and is a vital element for the competitiveness of trucks manufacturers. A majority of trucks is fitted with a turbocharged diesel engine that runs, on the one hand, the driving wheels through a transmission and, on the other hand, auxiliary equipments, such as a lighting system or a window actuator. Some of these auxiliary equipments are usually fed by an electrical network whose electrical power is produced by an alternator driven by the internal combustion engine of the truck. In order to obtain fuel economies when running an automotive vehicle, one can consider recovering energy which would otherwise be wasted. Known techniques can limit a fraction of the energy losses. This concerns hybrid systems where braking energy is recovered through electrical power storage. In so-called "hybrid electric vehicles" or "HEVs", one uses a combination of an internal combustion engine with one or several electrical machines and some storage means such as batteries. In such vehicles, a part of the braking energy of the vehicle is stored by using the electric machines as generators and then, at an appropriate time, this energy is recovered by using the electric machines as motors.

Figure 1 shows the general layout of a hybrid power unit on an HEV which comprises an internal combustion engine 11 and an electric machine 12 mechanically coupled to the crankshaft 111 of the engine through a gear train 13. Any kind of mechanical transmission can be used instead of gear train 13, e.g. a belt and pulley transmission set, a differential gear, an epicyclic gear, etc... Machine 12 is connected via a control unit 14 to a battery set 15 and to electrical loads 16. Machine 12 can work as a generator, when it is driven by the crankshaft 111 of engine 11. In such a case, it loads the battery set 15 with electrical power. Machine 12 can also

work as a motor using power stored in battery set 15, in order to assist engine 11 for rotating crankshaft 111. Typically, engine 11 is provided with a turbocharger 17.

With such a hybrid electrical power unit, wasted energy is recovered through machine 12 only during braking of the vehicle. When the vehicle runs for a long distance without braking, e.g. on a highway, no power can be recovered through machine 12, which leads to emptying the battery set if one uses machine 12 as a motor to assist engine 11 under these conditions. Then, the only way to re-load the batteries is to use a part of the power of the internal combustion engine to drive machine 12 as a generator when possible. However, this leads to increased fuel consumption.

SUMMARY OF THE INVENTION

This invention aims at proposing a new power unit for an automotive vehicle which enables an efficient energy recovery including when the automotive vehicles run with a stabilized speed.

The invention concerns a power unit for an automotive vehicle, this unit including:

- an internal combustion engine;
- a first electric machine electrically connected to electrical power storage means and coupled to a crankshaft of the engine; and
- a turbocharger comprising a first turbine located in an exhaust line of the engine.

This power unit is characterized in that it further includes:

- a second turbine located in an exhaust line of the engine, and
- a second electric machine coupled to the second turbine and electrically connected to the electrical power storage means.

Thanks to the invention, energy recovery can be performed via the first electric machine and/or via the second electric machine, depending on the working conditions of the vehicle equipped with the internal combustion engine. Since the second electric machine is driven by the second turbine, the power generated by this second electric machine can be controlled independently of the power obtained through the turbocharger for the compression of the inlet gases on the internal combustion engine.

According to further aspects of the invention, such a power unit might incorporate one or several of the following features:

- The electric machines are connected to the electrical power storage means via a power control unit which is also connected to electrical loads on the vehicle.
- At least the first electric machine, and preferably both of said electric machines can work as a generator or as a motor, depending on the working conditions of the power unit.
- The first electric machine can deliver, when it works as a motor, a maximum power which is higher than the maximum power which can be delivered by the second electric machine. In other words, the first electric machine has a higher power capacity than the second electric machine.
- The second turbine is located in the same exhaust line and downstream of the first turbine.
- According to a first embodiment of the invention, the second electric machine is coupled to the second turbine via mechanical transmission means with a fixed speed ratio.
- According to another embodiment of the invention, the second electric machine is coupled to the second turbine via an epicyclic gear train, whereas one of the outputs of the gear train is coupled to the crankshaft of the engine. According to alternative embodiments of the invention, the part of the gear train which is coupled to the crankshaft of the engine is its sun, its ring or its satellite-carrier. Similarly, the part of the gear train which is coupled to the turbine is its sun, its ring or its satellite carrier.

The invention also concerns an automotive vehicle, in particular a truck, which includes a power unit as mentioned here above. Such a vehicle is more efficient to run than known HEVs.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be explained in correspondence with the annexed figures and as an illustrative example, without restricting the object of the invention. In the annexed figures:

- figure 1 is a schematic representation of a power unit of the prior art,

- figure 2 is a view similar to figure 1 for a power unit according to a first embodiment of the invention,
- figure 3 is a view similar to figure 2 for a power unit according to a second embodiment of the invention,
- figure 4 is an enlarged view of detail IV on figure 3,
- figure 5 is a view similar to figure 4 for a power unit according to a third embodiment of the invention,
- figure 6 is a view similar to figure 4 for a power unit according to a fourth embodiment of the invention,
- figure 7 is a view similar to figure 4 for a power unit according to a fifth embodiment of the invention,
- figure 8 is a view similar to figure 4 for a power unit according to a sixth embodiment of the invention, and
- figure 9 is a view similar to figure 4 for a power unit according to a seventh embodiment of the invention.

DETAILED DESCRIPTION OF SOME EMBODIMENTS

The power unit 1 represented on figure 2 belongs to a truck and comprises an internal combustion engine 11 whose crankshaft 111 is supposed to transmit, to a non represented transmission assembly of an automotive vehicle, a torque T. Crankshaft 111 is provided with a first pinion 131 which meshes with a second pinion 132 mounted on the shaft 121 of an electric machine 12 which can work as a motor or as a generator, as indicated hereafter. Pinions 131 and 132 constitute together an example of a gear train 13 between shafts 111 and 121. Instead of gear train 13, other types of gear trains could be used, such as an epicyclic gear. Power transmission between shafts 111 and 121 can also take place via belts and pulleys or pinions, as long as the ratio of the speeds of these shafts is constant.

In other words, in this embodiment, machine 12 and shaft 111 are mechanically coupled by a transmission with fixed speed ratio, although variable speed ratio transmission means could also be used.

According to an alternative embodiment of the invention, shafts 111 and 211 might be formed by the same part. Machine 12 is then said to be integrated into engine 11.

Electric machine 12 is connected by a first electric line L_1 to a power control unit 14 which is piloted by a central non represented main control unit of the vehicle. Unit 14 is connected by an electric line L_2 to electrical power storage means which, in this example, are formed of a battery set 15. Unit 14 is also connected by a third electrical line L_3 to several electrical loads 16 such as a lighting system of the vehicle, an electrical or electronical control system, some motors for various appliances. Power in lines L_1 and L_2 can go in both directions that is, respectively, from machine 12 to unit 14 and reverse, and from unit 14 to set 15 and reverse. Power in line L_3 can go only from unit 14 to loads 16.

Engine 11 is also provided with a turbocharger 17 which comprises a compressor 171 and a turbine 172 coupled to the compressor in order to drive it. Compressor 171 and turbine 172 have a common shaft, so that they rotate together. Compressor 171 is installed in an inlet or feeding line 181 of engine 11 whereas turbine 172 is installed in an exhaust line 182 of engine 11.

A second turbine 192 is installed within line 182, downstream of turbine 172, so that it is driven by the exhaust gases exiting engine 11, similarly to turbine 172. If engine 11 has several exhaust lines, turbine 182 can be installed in an exhaust line different from the one of turbine 172.

Turbine 192 is directly coupled by its output shaft 193 to an electric machine 21 which is connected by an electric line L_4 to control unit 14.

According to an optional feature of the invention which is not represented, a reduction gear can be installed between shaft 193 and machine 21. With or without this optional feature, turbine 193 and machine 21 are mechanically coupled with a fixed speed ratio.

Electric machines 11 and 21 are connected, via unit 14, to the electrical power storage means formed by battery set 15, so that either of these machines can load these storage means or use power coming from these storage means, depending on the working conditions of unit 1.

Unit 1 works as follows: when engine 11 runs and when the vehicle is braking, electric machine 12 works as a generator and provides unit 14 with electric power, as shown by arrow A_1. Unit 14 can distribute the power between electrical loads 16 and battery set 15, as shown by arrows A_2 and A_3. When the vehicle is being accelerated, electric machine 12 can be used as a motor to assist engine 11,

thanks to the energy provided by the battery set 15 through control unit 14, as shown by arrow A_4.

Power may also go directly from one machine to the other, via unit 14, without being stored in battery set 15.

The torque delivered by machine 12, when it works as a motor, depends on the rotation speeds of engine 11. This torque is quite constant at low rotation speed of the engine and then decreases.

The torque delivered by engine 11 adds up with the torque delivered by machine 12 working as a motor to form the torque delivered to crankshaft 111 at low rotation speeds.

When engine 11 runs at a rotation speed greater than a reference speed, turbine 192 can deliver a significative torque which drives electric machine 21 working as a generator, so that this machine provides unit 14 with electrical power through line L_4, as shown by arrow A_5. This electrical power delivered by machine 21 can be stored in battery set 15. This electrical power can also be used by machine 12 working as a motor to increase the torque delivered by machine 12. In other words, the power generated by turbine 192 is converted by machine 21 into electrical power which is used by machine 12 and becomes a part of the power delivered to crankshaft 111 by machine 12 working as a motor. In this embodiment, the maximum power that can be added thanks to machines 12 and 21 is the maximum power that can be delivered by machine 12.

In other words, the total power obtainable on shaft 111, as a function of the rotation speed of engine 11, corresponds to the sum of powers delivered by items 11 and 12.

Therefore, the electrical units 12 and 21 of the invention enable an increase of the power available on crankshaft 111 with respect to the power purely delivered by engine 11. In other words, if one needs a given power to drive the transmission assembly of the truck, one can downsize engine 11 up to a size and configuration which provide a power which is smaller than the given power, since the power difference is provided thanks to the torque delivered by machine 12 which uses the power delivered by machine 21.

Moreover, power recovery takes place via machine 21 even when the truck does not brake, in particular when it runs with a stabilized speed since turbine 192 is driven by exhaust gases under these conditions. In practice, turbine 192 is mostly

efficient as long as engine 11 rotates at a speed much higher than the above mentioned reference speed.

Unit 14 allows to direct a part only or the totality of the power coming from second electric machine 21 towards first electric machine 12, which corresponds to a great flexibility of the invention.

In some other working conditions of unit 1, machine 21 can be used as a motor, on the basis of power provided by battery set 15 through control unit 14 as shown by arrow A_6. In such a case, turbine 192 can accelerate exhaust gases within exhaust line 182 in order to enhance air feeding to engine 11 through turbocharger 17 since the depression created in line 182 drives turbine 172 and compressor 171. This feature is optional and machine 21 can be used as generator only.

In the second embodiment of the invention represented on figures 3 and 4, the same elements as in the first embodiment bear the same references. The power unit 1 of this embodiment comprises an internal combustion engine 11, a first electric machine 12, a second electric machine 21, a turbocharger 17 which comprises, amongst others, a first turbine 172 located in an exhaust line 182 of engine 11. A second turbine 192 is also located in exhaust line 182 and can drive second electric machine 21. A power control unit 14 is electrically connected to a battery set 15, electric loads 16 and machines 12 and 21, through lines L_1, L_2, L_3 and L_4 as mentioned for the first embodiment.

An epicyclic gear train 22 is installed between the output shaft 193 of turbine 192 and the central shaft 211 of electric machine 21.

As shown in detail on figure 4, shaft 193 is provided with a pinion 194 whereas shaft 211 is provided with another pinion 212. One shaft 221 of gear 22 is provided with a pinion 222 which meshes with pinion 194, whereas another shaft 223 of gear 22 is provided with another pinion 224 which meshes with pinion 212. Shaft 221 is fast with the sun 225 of gear 22, whereas shaft 223 is fast with the outer ring 226 of gear 22. The satellite-carrier 227 of gear 22 meshes with a pinion 228 which meshes with pinion 131 fast with crankshaft 111 of engine 11.

As shown on figure 4, three fixed speed ratio transmission gears G_1, G_2 and G_3 can be identified. Gear G_1 transmits torque between shafts 193 and 221, via pinions 194 and 222. Gear G_2 transmits torque between shafts 223 and 211, via pinions 224 and 212. Gear G_3 transmits torque between carrier 227 and shaft 111, via pinion 228.

Instead of pinions, one can use for transmission gears G_1, G_2 and G_3, some transmission sets with pulleys and belts, as long as the speed ratio between shafts 193 and 221, between shafts 223 and 211 and between carrier 227 and shaft 111 remains constant.

Power transiting through gear 22 when turbine 192 drives machine 21 can be partly derivated by gear 22 to directly drive shaft 111, which increases the total torque available on shaft 111.

Depending on the relative speed of shafts 193 and 111 and on the construction of gear train 22, machine 21 can work as a generator or as a motor when it is driven by turbine 192.

The rotation speed and direction of machine 21 depend on the rotation speeds of shafts 111 and 193. Gear train 22 can be designed so that the rotation speed of shaft 211 remains within a predetermined range, including zero, under normal working conditions of motor 11.

In "hybrid" regenerative mode, that is when energy is recovered by machine 12 during breaking of crankshaft 111, a passive torque is applied by machine 12 which works as a generator and delivers electrical power to battery set 15 through unit 14. No torque is applied by machine 21 to turbine 192 and crankshaft 111.

In "compound" mode, when exhaust gazes drive turbine 192, machine 21 applies a torque on shaft 223 of gear 22, so that a passive torque is applied to shaft 193. Depending on its rotation direction, machine 21 produces or uses electrical power going to or coming from unit 14. In "compound" mode, the rotation speed of machine 21 is fixed by the respective speeds of crankshaft 111 and turbine 192, depending on the design of gear train 22 and transmission gears G_1, G_2 and G_3. When machine 21 applies a passive or braking torque on gear train 22, it is transferred to shaft 193, so that the torque is applied to crankshaft 111. Depending on its direction of rotation, machine 21 is a generator or a motor and mechanical power is transmitted to or derived from crankshaft 111 via gear train 22. Maximum torque transmission from machine 21 to crankshaft 111 takes place when engine speed is above a reference speed.

The powers respectively delivered by engine 11, machine 12 and machine 21 can add up to constitute the total power obtainable on shaft 111. Power transmitted

from turbine 192 to shaft 111 follows both an electrical way, via machines 21 and 12, and a mechanical way, via gear train 22 and transmission gear G_3.

Therefore, the total power obtainable with this embodiment is larger than the total power obtainable with the first embodiment with similar items 11, 12 and 21. In other words, for a given total power to be transferred to shaft 111, engine 11 can deliver a smaller power in the second embodiment. It can be downsized and more economical. Similarly, machine 12 can be smaller and more economical than in the first embodiment.

Machine 21 can also be used as a motor. In such a circumstance, shaft 193 may be braked or blocked, which induces that at least a part of the power generated by machine 21 goes to crankshaft 111 through transmission gears G_2 and G_3 and gear train 22.

Here again, power control unit 14 can allow to easily control electric machines 12 and 21 in order to obtain the desired total power on crankshaft 111.

As shown on figures 5 and 7, the external ring 226 of an epicyclic gear 22 can be used to transmit power to crankshaft 111. As shown on figures 6 and 7, the satellite-carrier 227 of an epicyclic gear 22 can be used for this purpose. As shown on figures 7 and 9, the satellite carrier 227 of epicyclic gear train 22 can be coupled to shaft 193. As shown on figures 6 and 8, one can couple the outside ring 226 of epicyclic gear 22 to shaft 193.

In the embodiments of figures 3 to 9, electric machine 12 is the main source of power addition to engine 11. It is more powerful than machine 21. For example, machine 12 can have a nominal power between 100 and 150 kW, whereas machine 21 has a nominal power between 5 and 50 kW.

In all the embodiments of the invention, depending on the working conditions of engine 11, machine 21 can be used as a generator in order to load battery set 15 when the speed of the engine increases or is above a limit value. The torque generated by this electric machine working as a motor in some conditions can be used by this machine in order to improve the working conditions of the engine, either by acting on exhaust line 182, as in the first embodiment, or by acting directly on the crankshaft 111 of the engine, as in the second to seventh embodiments.

In all embodiments of the invention, machine 12 can be an alternator/starter machine, which is a relatively low power hybrid machine.

LIST OF REFERENCES

1 power unit
11 internal combustion engine
111 crankshaft
112 pinion
12 electric machine
121 shaft
13 gear train
131 pinion
132 pinion
14 control unit
15 battery set
16 electrical loads
17 turbocharger
171 compressor
172 turbine
181 inlet line
182 exhaust line
192 turbine
193 output shaft
194 pinion
21 electric machine
211 shaft
212 pinion
22 epicyclic gear train
221 shaft
222 pinion
223 shaft
224 pinion
225 sun
226 ring
227 satellite-carrier
228 pinion

A_1	arrow
A_2	arrow
A_3	arrow
A_4	arrow
A_5	arrow
A_6	arrow
L_1	electric line
L_2	electric line
L_3	electric line
L_4	electric line
G_1	transmission gear
G_2	transmission gear
G_3	transmission gear
T	torque

CLAIMS

1. A power unit (1) for an automotive vehicle said unit comprising:
   - an internal combustion engine (11),
   - a first electric machine (12) electrically connected (L_1) to electrical power storage means (L_{15}) and coupled to a crankshaft of said engine, and
   - a turbocharger (17) comprising a first turbine (172) located in an exhaust line (182) of said engine,

   characterized in that said power unit further includes:
   - a second turbine (192) located in an exhaust line (182) of said engine (11), and
   - a second electric machine (21) coupled (193; 22) to said second turbine and electrically connected (L_4) to said electrical power storage means (15).

2. Power unit according to claim 1, characterized in that said electric machines (12, 21) are connected to said electrical power storage means (15) via a power control unit which is connected to electrical loads (16) on said vehicle.

3. Power unit according to claims 1 or 2, characterized in that at least said first electric machine (12) can work as a generator or as a motor, depending on the working conditions of said power unit (1).

4. Power unit according to claim 3, characterized in that both electric machines (12, 21) can work as a generator or as a motor, depending on the working conditions of said power unit.

5. Power unit according to any of the previous claims, characterized in that said first electric machine (12) can deliver, when it works as a motor, a maximum power which is higher than the maximum power which can be delivered by said second electric machine (21).

6. Power unit according to any of the previous claims, characterized in that said second turbine (192) is located in the same exhaust line (182) and downstream of said first turbine (172).

7. Power unit according to any of the previous claims, characterized in that said second electric machine (21) is coupled to said second turbine (192) via mechanical transmission means (193) with a fixed speed ratio.

8. Power unit according to any one of claims 1 to 6, characterized in that said second electric machine (21) is coupled to said second turbine (192) via an epicyclic gear train (22) and in that one of the outputs (221, 223, 228) of said gear train is mechanically coupled to said crankshaft (111).

9. Power unit according to claim 8, characterized in that the sun (225) of said gear train (22) is coupled to said crankshaft (111).

10. Power unit according to claim 8, characterized in that the ring (226) of said gear train (22) is coupled to said crankshaft (111).

11. Power unit according to claim 8, characterized in that the satellite-carrier (227) of said gear train (22) is coupled to said crankshaft (111).

12. Power unit according to one of claims 8, 10 and 11, characterized in that the sun (225) of said gear train (22) is coupled to said turbine (192).

13. Power unit according to one of claims 8, 9 and 11, characterized in that the ring (226) of said gear train (22) is coupled to said turbine (192).

14. Power unit according to one of claims 8 to 10, characterized in that the satellite carrier (227) of said gear train (22) is coupled to said turbine.

15. An automotive vehicle, in particular a truck, including a power unit (1) according to any of the previous claims.

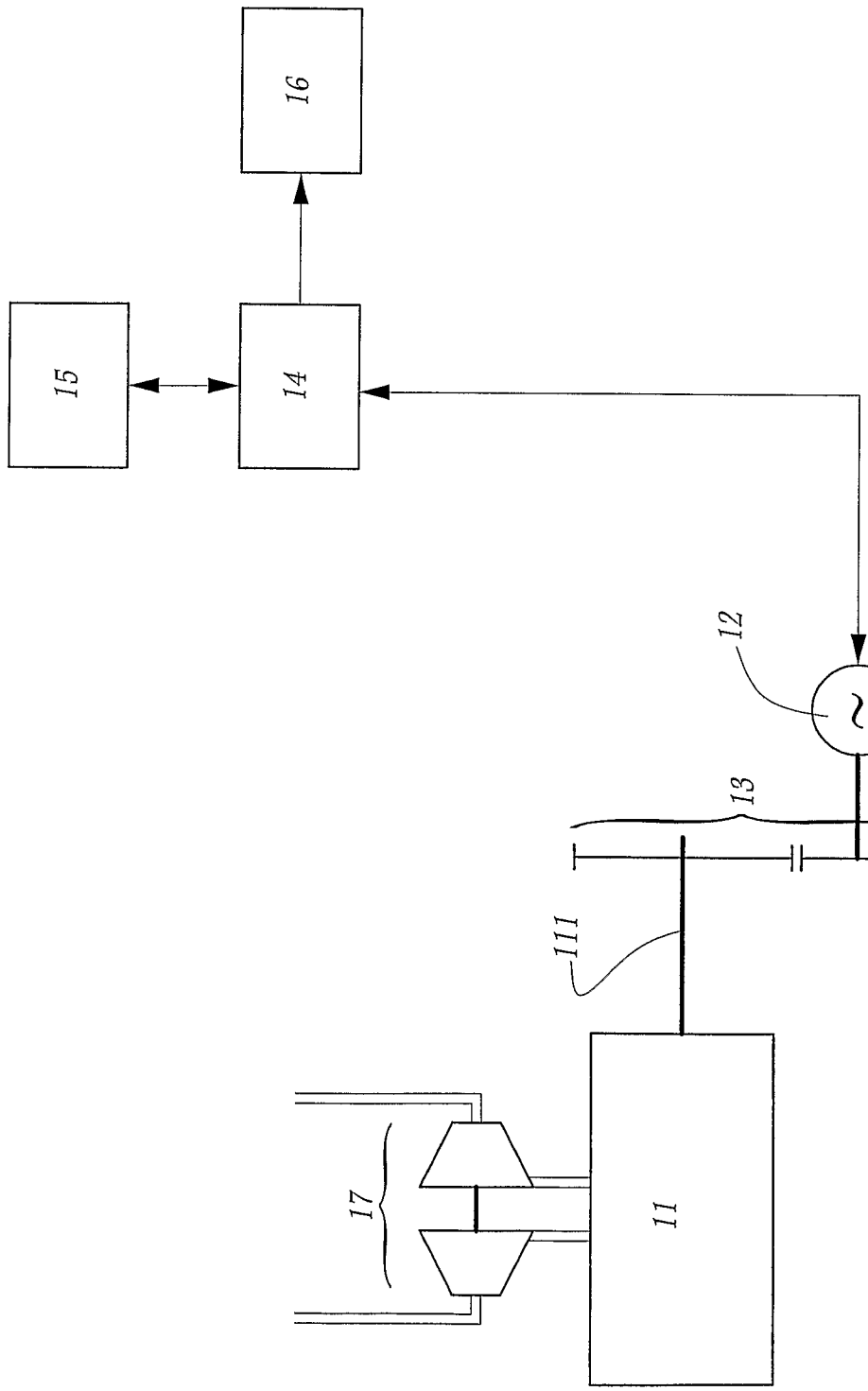

Fig. 1

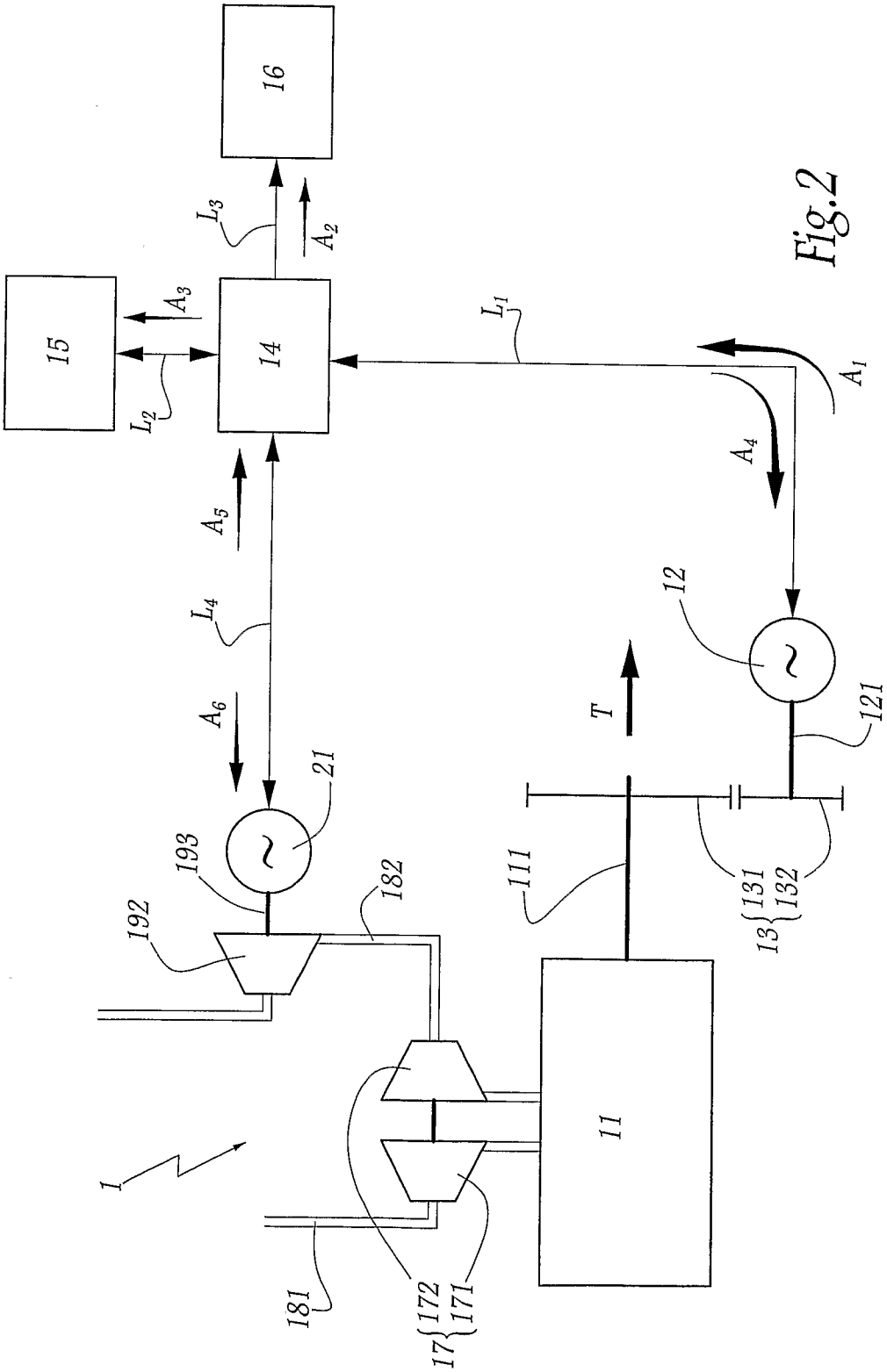
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Fig.2

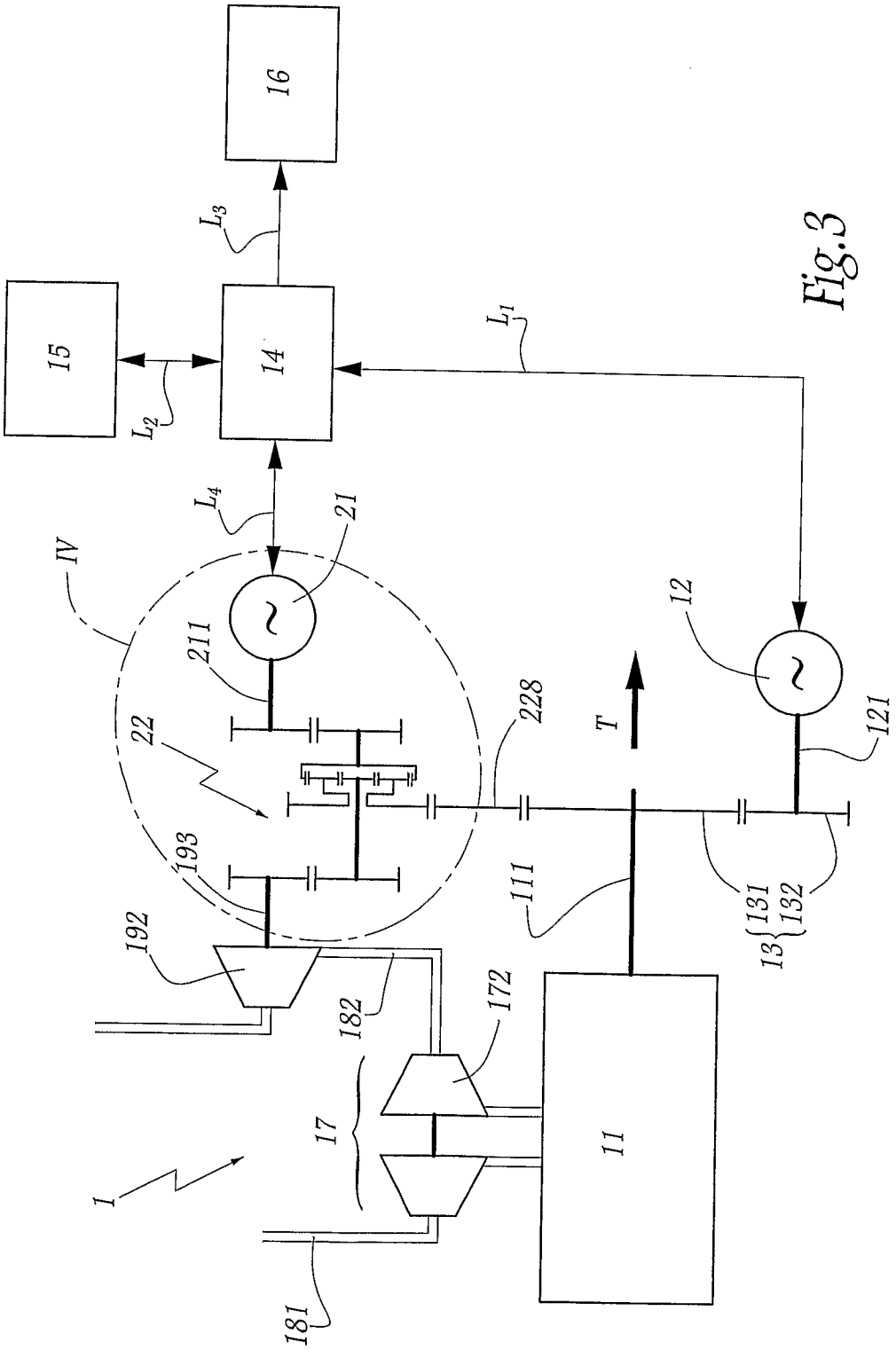
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Fig.3

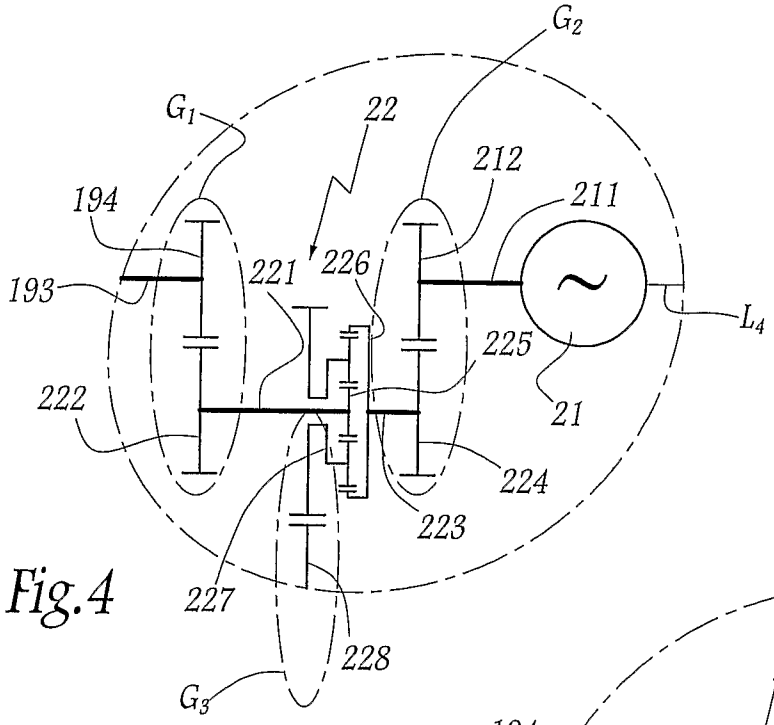

Fig.4

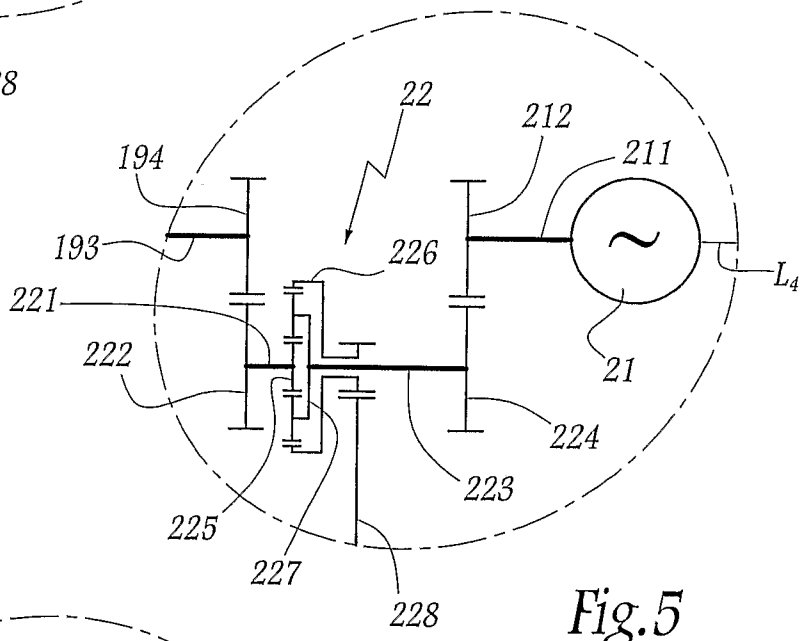

Fig.5

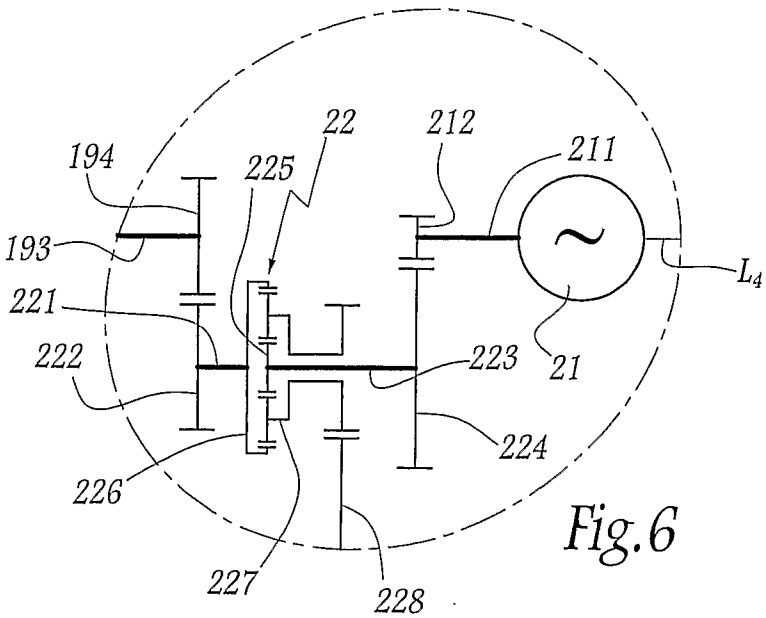

Fig.6

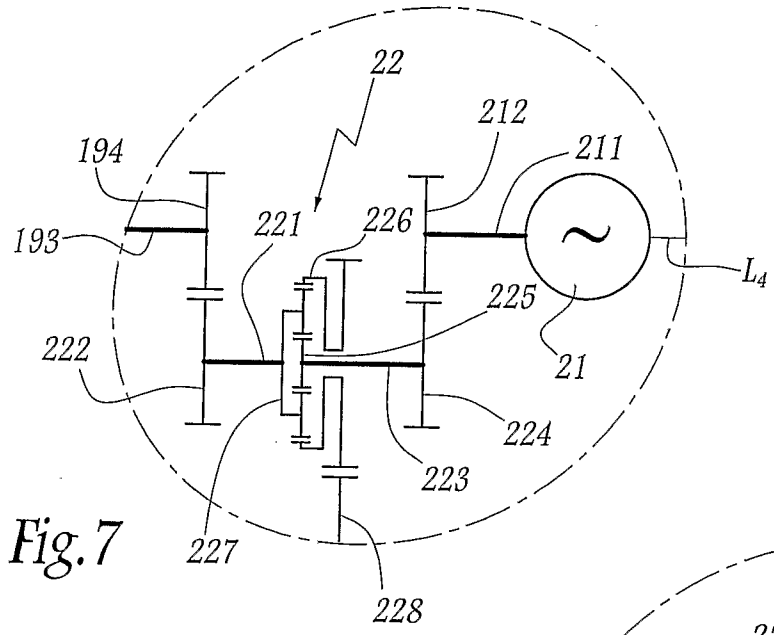

Fig.7

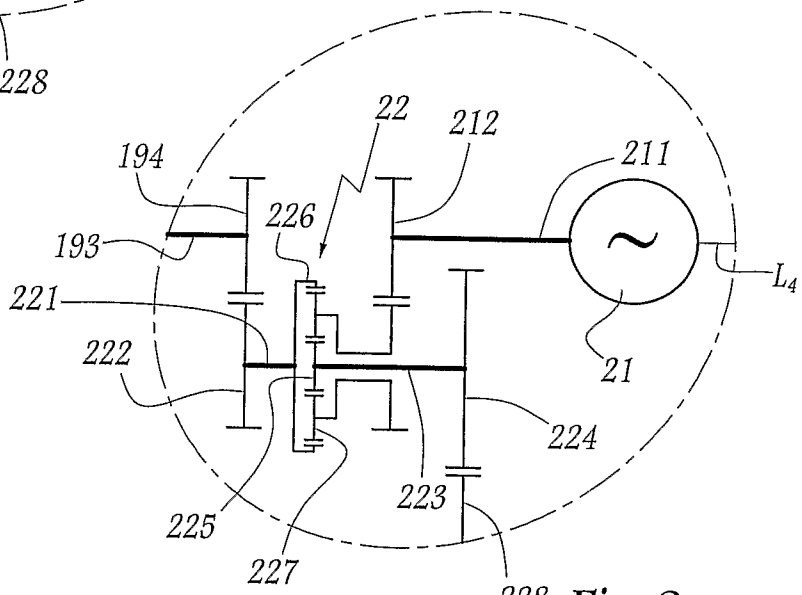

Fig.8

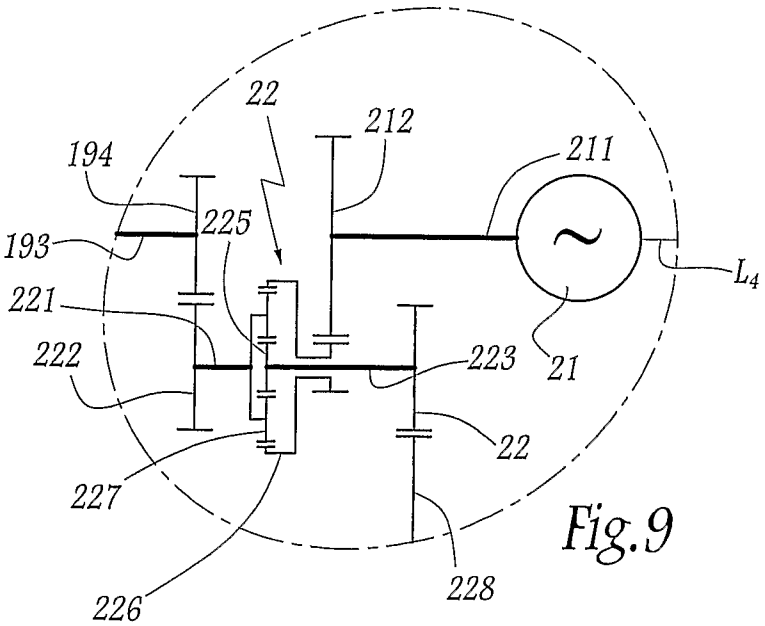

Fig.9

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2006/004097

A. CLASSIFICATION OF SUBJECT MATTER
INV. B60K6/22 B60K6/365 B60K6/485 F02B39/10 F02B41/10
ADD. F16H3/72 B60W10/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B60K F02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 352 064 A1 (ISUZU CERAMICS RES INST CO [JP]) 24 January 1990 (1990-01-24) column 3, line 30 - column 4, line 57; figure 1	1-7,15
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Y	column 4, lines 7-45; figure 1	8,10-12, 14
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
27 August 2007	05/09/2007

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Vogt-Schilb, Gérard

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2006/004097

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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