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(54) **Title**: THERMAL ELECTRIC GENERATOR SYSTEM

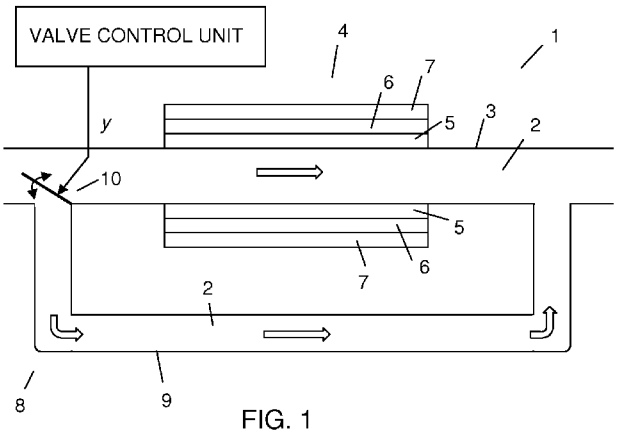

FIG. 1

(57) **Abstract**: The invention relates to a thermal electric generator system (TEG system) (1) for extracting electricity from a waste heat medium (2) in a waste heat line (3) in a vehicle, which system (1) comprises: - a TEG unit (4) comprising one or more energy storage layers (5) adapted to storing thermal energy and placed directly against the waste heat line (3), whereby thermal energy from the waste heat medium (2) is stored in said energy storage layers (5); one or more thermal electric generator layers (TEG layers) (6) adapted to converting thermal energy to electricity and placed directly against the energy storage layer (5); and - a bypass unit (8) comprising a bypass line (9) connected to the waste heat line (3) via an adjustable valve device (10) so that all or parts of the waste heat medium (2) can be led past the TEG unit (4) in the bypass line (9); and a valve control unit adapted to adjusting the valve device (10) when predetermined conditions are fulfilled, which valve control unit is adapted to adjusting the valve device (10) when vehicle signals such as, for example, brake signals or acceleration control signals indicate that the vehicle is being braked or accelerated.

WO 2011/037526 A1

Title

Thermal electric generator system

Field of the invention

The present invention relates to a thermal electric generator system for a vehicle to generate electricity from waste heat.

Background to the invention

In an electric circuit consisting of two different metals, an electric voltage occurs if the contact points where the metals meet are at different temperatures, by the temperature equalisation being converted to electrical energy. This effect, known as the Seebeck effect, is for example used for measuring temperatures by thermal electric elements. One such application is to generate electricity at remote locations, e.g. to provide power for sensors in oil lines.

A thermal electric element is a semiconductor device without moving parts. Because it produces electrical energy with high reliability, it has for example been used on space missions where solar energy is not always available.

The vehicle industry continually seeks fuel economising and environmentally friendly vehicle solutions. Fuel can be saved by utilising instead energy from the waste heat which is generated by various parts of the vehicle. Using less fuel also saves the environment. Thermal electric elements, also known as thermal electric generator elements (TEG elements), may be used in the vehicles in order to utilise waste heat.

A TEG element is typically configured to work effectively across a certain temperature range and has to be dimensioned to be able to handle the maximum temperature of the waste heat continuously without being damaged. This means that in many operating situations it will not achieve maximum efficiency.

Patent application WO 2007/002891 describes a solution to this problem for vehicles on the basis of using a heat exchanger which transfers the heat from the waste heat medium to an intermediate loop in which a thermal electric generator module is situated. However, the system's use of an intermediate loop means that it occupies a large amount of space.

Patent application WO 2008/025701 describes a thermal electric device adapted to being used in motor vehicles which comprises a thermal electric generator element and means for limit the temperature of the element. To limit the temperature of the TEG element, a working medium is used between the TEG element and the heat source. The working medium can melt and when the temperature of the heat source rises over the melting temperature of the working medium the latter partly melts, making it possible to keep the temperature of the element relatively constant.

The object of the invention is to propose an improved thermal electric system which increases the vehicle's total efficiency and protects TEG elements against too high temperatures.

Summary of the invention

The object described above is achieved by a thermal electric generator system (TEG system) for extracting electricity from a waste heat medium in a waste heat line in a vehicle. The system comprises:

- a TEG unit comprising:
  - one or more energy storage layers adapted to storing thermal energy and placed directly against the waste heat line, whereby thermal energy from the waste heat medium is stored in said energy storage layers;
  - one or more thermal electric generator layers (TEG layers) adapted to converting thermal energy to electricity and situated directly against the energy storage layer;
- a bypass unit comprising:

- a bypass line connected to the waste heat line via an adjustable valve device so that all or parts of the waste heat medium can be led past the TEG unit in the bypass line;

- a valve control unit adapted to adjusting the valve device when predetermined conditions are fulfilled, which valve control unit is adapted to adjusting the valve device (10) when vehicle signals such as, for example, brake signals or acceleration control signals indicate that the vehicle is being braked or accelerated.

Using an energy storage layer makes it possible for the heat produced from the waste heat medium to be absorbed by the energy storage layer before it reaches the TEG layer. The waste heat in the waste heat medium is in most cases not generated continuously, and having an energy storage layer makes it possible for electricity to be produced even when the waste heat medium does not supply any heat. The generation of electricity thus becomes more uniform during varying running conditions. The temperature of the heat reaching the TEG layer can also be kept down, which means that the TEG layer need not be dimensioned to cater for the maximum temperature of the waste heat medium. This means that the TEG unit occupies less space and can be used in more applications, e.g. in cramped spaces, and that the cost of producing the unit will be smaller in that fewer TEG modules need be used. The generation of electricity will then also be more effective in that the TEG layer can be dimensioned to a less extensive temperature range.

The vehicle's total efficiency may thus increase by energy from waste heat being utilised in applications in the vehicle, e.g. it may be consumed directly by the vehicle's electrically powered ancillary units or be used to charge a battery.

Having a bypass unit makes it possible for the waste heat medium to be led past the TEG unit when the temperature of the waste heat medium becomes too high to be handled by the TEG unit. Another advantage is that the exhaust backpressure may be reduced in certain running situations.

Preferred embodiments are described in the dependent claims and in the detailed description.

Brief description of the attached drawings

The invention is described below with reference to the attached drawings, in which:

Figure 1 is a longitudinal cross-sectional view of a thermal electric generator system according to an embodiment of the invention.

Figure 2 is a block diagram of the valve control unit according to an embodiment of the invention.

Figure 3 is a longitudinal cross-sectional view of a TEG unit according to an embodiment.

Figure 4A illustrates the TEG unit in Figure 3 as seen in cross-section according to an embodiment.

Figure 4B illustrates the TEG unit as seen in cross-section in Figure 3 according to another embodiment.

Figure 4C illustrates the TEG unit in Figure 3 as seen in cross-section according to a further embodiment.

Figure 5A is a longitudinal cross-sectional view of a TEG unit according to another embodiment.

Figure 5B illustrates Figure 5A as seen in cross-section according to an embodiment.

Figure 6A is a longitudinal cross-sectional view of a TEG unit according to a further embodiment.

Figure 6B is a longitudinal cross-sectional view of a TEG unit according to yet another embodiment.

Figure 7 is a diagram of how the temperature in the TEG layer changes over time when an energy storage layer with a phase transformation material is used.

Detailed description of preferred embodiments of the invention

Figure 1 illustrates a thermal electric generator system (TEG system) 1 usable for extracting electricity from a waste heat medium 2 in a waste heat line 3. The TEG system is preferably used in a vehicle, but other areas of use are of course also possible within the scope of the invention, e.g. watercraft, aircraft, trains etc. The TEG system 1 is made up of two units. The first unit is a TEG unit 4 which comprises one or more energy storage layers 5 adapted to storing thermal energy and placed directly against the waste heat line 3. When a medium flows in the waste heat line 3, thermal energy from the waste heat medium 2 is stored in the energy storage layer 5. The TEG unit 4 comprises also one or more thermal electric generator layers (TEG layers) 6 adapted to converting thermal energy to electricity and placed directly against the energy storage layer 5. The TEG layer 6 thus absorbs from the energy storage layer 5 heat which it converts to electricity.

The TEG layer is made up, according to an embodiment, of a plurality of TEG modules which each comprise a plurality of TEG elements. A TEG element functions by the so-called Seebeck effect which makes it possible to convert temperature differences directly to electricity.

The other unit of the system 1 is a bypass unit 8 which comprises a bypass line 9 connected to the waste heat line 3 via an adjustable valve device 10 so that all or parts of the waste heat medium 2 can be led past the TEG unit 4 in the bypass line 9. The bypass line 9 is connected to the waste heat line 3 in a suitable way, e.g. by welding or injection moulding. The bypass unit 8 comprises also a valve control unit adapted to adjusting the valve device 10 when predetermined conditions are fulfilled. The valve device 10 comprises preferably a valve which is adjustable gradually to allow a specific flow of waste heat media 2 into the bypass line 9. Thus the system can adjust the flow of waste heat media 2 into the bypass line in order to protect the TEG elements in the TEG layer 6.

In the waste heat line 3 there are preferably flanges (not depicted) or the like which transfer heat from the waste heat medium 2 to the energy storage layer 5.

To achieve a temperature difference in the TEG layer 6, the system 1 comprises preferably a cooling device 7 placed adjacent to, in order to cool, the TEG layer 6. The cooling device 7 may be configured in various ways, e.g. it may have cooling flanges for air cooling or a shell through which a coolant passes. Preferably, however, the whole side of the TEG layer which faces towards the cooling device 7 is thus cooled by the cooling device 7.

A set of predetermined conditions therefore indicate how the flow of waste heat media 2 should be adjusted in the system 1. According to an embodiment, the predetermined conditions comprise temperature conditions for the temperature of one or more from among the waste heat medium 2, the energy storage layer 5, the TEG layer 6 and the cooling device 7, and the valve control unit is adapted to delivering a control signal *y* to the valve device 10 to adjust the valve and direct part or all of the flow through the bypass line 9 when one or more temperature conditions are fulfilled. By observing one or more of the aforesaid temperatures and controlling the valve device 10 accordingly, the TEG elements in the TEG layer 6 can be protected against too high temperatures which might damage them. The energy storage layer 5 may also be protected against waste heat medium 2 at too low temperatures which would cool the energy storage layer 5 instead of warming it. According to an embodiment, a temperature condition is therefore that if the temperature of the waste heat medium 2 drops below the temperature of the energy storage layer 5 the valve control unit is adapted to delivering a control signal *y* to the valve device 10 to open the valve and direct part or all of the flow through the bypass line 9. This makes it possible for the colder waste heat medium 2 to be led past the TEG unit 4 so that the waste heat medium 2 does not lower the temperature of the energy storage layer 5.

According to an embodiment the temperature condition is that if the temperature of the waste heat medium 2 or the energy storage layer 5 or the TEG layer 6

exceeds or reaches respective predetermined maximum temperatures the valve control unit is adapted to delivering a control signal *y* to the valve device 10 to open the valve and direct part or all of the flow through the bypass line 9. The maximum temperatures of the waste heat medium 2 or the layers 5, 6 may be different, since the temperature of the heat reaching the TEG layer 6 is generally lower than that observed in the waste heat medium 2 or the energy storage layer 5. The predetermined maximum temperature for the energy storage layer 5 may for example be the phase transformation temperature for the material used in the energy storage layer 5 if the energy storage layer 5 is a latent energy store. The TEG elements in the TEG layer 6 may thus be protected against too high temperatures if, for example, the temperature of the waste heat medium 2 becomes so high that the temperature of the energy storage layer 5 starts to rise again when the material in the energy storage layer has been completely phase-transformed. A latent energy store is an energy store whose material can be phase-transformed and thus store heat. An energy store may instead be a sensible energy store, in which case heat is stored in the material without the material being phase-converted. An energy store may be both sensible and latent, albeit at different times. The predetermined maximum temperature for the energy storage layer 5 may instead be a temperature which is above the phase transformation temperature, provided that the TEG elements in the TEG layer 6 tolerate that temperature.

Figure 2 is a block diagram of the valve control unit according to an embodiment of the invention. The valve control unit here receives signals, e.g. vehicle signals which may be brake signals or acceleration control signals indicating that the vehicle is being braked or accelerated, the vehicle's speed, the engine's speed etc., in which case the valve control unit is adapted to adjusting the valve device 10 when these vehicle signals indicate that the vehicle is for example being braked or accelerated. If the system is placed round a waste heat medium 2 which generates heat when the vehicle is being braked, the valve device 10 may for example initially close the valve so that the waste heat medium is led through the TEG unit, but may after a certain time, if the vehicle is still being braked, open

the valve so that the waste heat medium, which is by then expected to have approached a temperature which is critical for the TEG layer, can be led through the bypass line so that the TEG elements will not be damaged. Similarly, where the system is placed round a waste heat medium 2 which generates heat when the vehicle is being accelerated, the valve device 10 may for example initially close the valve so that the waste heat medium is led through the TEG unit, but may after a certain time, if the vehicle is still being accelerated, open the valve so that the waste heat medium can be led through the bypass line so that the TEG elements will not be damaged. The result is simple and straightforward control of the flow of a waste heat medium 2 in the waste heat line 3 without direct temperature measurements having to be made. The above example is merely illustrative and it is implicit that the valve control unit may control the valve device 10 in other ways based on a plurality of various other vehicle signals. Figure 2 also shows temperature signals received in the valve control unit, which is another embodiment of the invention described below.

The valve control unit also comprises with advantage a processor unit and a memory to process signals received by the unit and carry out necessary steps and calculations for determining a control signal *y* to the valve device 10.

The temperatures of the waste heat medium 2, the energy storage layer 5, the TEG layer 6 and the cooling device 7 may be arrived at in various ways. According to an embodiment one or more temperature sensors are provided in the system 1 to measure the temperature in, for example, the waste heat medium upstream and downstream of the TEG unit and in the bypass line 9. Other sensors may also be provided in the system, e.g. flow sensors. These sensor signals may then be sent to the valve control unit. A direct way of measuring the temperatures is thus achieved. According to another embodiment, the temperatures of the energy storage layer 5 and/or the waste heat medium 2 and/or the TEG layer 6 are modelled by using respective theoretical models of the vehicle's subsystems. In this embodiment it is preferable that no temperature sensors are used in the TEG system, which may be an advantage in rendering

the TEG system less complicated and reducing the number of its components. The respective theoretical models may be in the valve control unit, as illustrated in Figure 2, but may instead be situated elsewhere, in which case with advantage only the modelled temperatures need be sent to the valve control unit in the form of temperature signals. To model the temperature of the energy storage layer 5 it is possible to use a theoretical model of how the energy storage layer 5 behaves in the vehicle and how the waste heat energy in the waste heat medium 2 is transferred in the energy storage layer 5 and absorbed by the TEG layer 6. The temperature of the waste heat medium 2 may be modelled by using, for example, engine data, exhaust temperature and/or exhaust flow, engine load and information about fuel use, engine speed, pressure and/or gas flow. The temperature of the TEG layer 6 may similarly be modelled by describing how it behaves in the vehicle.

The temperature of the TEG layer 6 may according to an embodiment be arrived at by measuring the electricity generated from the TEG layer 6, in which case a certain measured current corresponds to a certain temperature difference in the TEG layer 6. It is then preferable to use also the temperature of the cold side or the warm side of the TEG layer 6 in order to arrive at the temperature of the TEG layer 6. The temperature of the cold side may be arrived at by observing the temperature in the cooling device 7, and the temperature of the warm side may be arrived at by observing the temperature of the energy storage layer 5.

According to a further embodiment, the system 1 receives information from a predictive system in the vehicle which predicts the nature of the vehicle's coming itinerary. This information may for example be obtained by map data and the vehicle's location, e.g. by a map database and GPS. Knowing for example when and for how long the itinerary slopes and bends, when intersections with traffic lights occur etc., makes it possible to determine the application of, for example, acceleration and braking, all of which the valve control unit can take into account when determining control signals to the valve device 10. The result is intelligent control of the valve device 10, with no need for direct temperature measurements.

Figure 3 illustrates an example of a TEG unit 4 in a longitudinal cross-sectional view, comprising an energy storage layer 5, a TEG layer 6 and a cooling device 7 which is here depicted as a layer which covers the TEG layer 6. The waste heat medium 2 flows here through a waste heat line 3. According to this embodiment, all of the layers 5, 6, 7, i.e. the TEG unit 4, are situated coaxially about at least part of the extent of the waste heat line 3.

Figures 4A, 4B and 4C depict various examples of how the TEG unit may be configured. In Figure 4A, the layers 5, 6, 7 are placed coaxially along the waste heat line 3 and have substantially circular cross-sections with respective different radii. In Figure 4B the layers 5, 6, 7 are placed round the waste heat line 3 and have a substantially octagonal cross-section, and in Figure 4C they are placed round the waste heat line 3 and have a substantially square cross-section. Other shapes, e.g. rectangular, hexagonal, decagonal etc. are also conceivable for the layers 5, 6, 7. It may be advantageous for the TEG layer 6 to lie planar against the energy storage layer 5, thereby increasing the heat absorption capacity, in which case the embodiments depicted in Figures 4B and 4C and other shapes which result in a flat surface from the waste heat line 3 are preferred. Alternatively the energy storage layer 5 may be configured to lie directly against a circular cylindrical waste heat line 3 on one side, while the other side of the energy storage layer 5 is configured to lie flat against a TEG layer 6. The energy storage layer 5 will then have a curved side, as depicted in, for example, Figure 4A, which fits to the waste heat line, and an opposite side which may consist of a plurality of flat part-sides, as for example depicted in Figure 4B or 4C, on which the TEG layer fits, as for example depicted in Figures 4B and 4C respectively.

According to an embodiment depicted in Figures 5A and 5B the waste heat line 3 is divided into a plurality of ducts 11 to achieve large thermal contact surface and the system comprises a TEG unit 4 with TEG layers placed between and outside the ducts. Figure 5A depicts parts of the TEG unit 4 in a longitudinal cross-section and Figure 5B depicts a cross-section of the TEG unit. It is thus possible

for the waste heat to be exposed to a large surface in order to obtain as much heat as possible from the waste heat medium. Another advantage is that two TEG layers 6 may share a cooling device 7, as illustrated in the central layers in the diagrams. The TEG unit 4 depicted in the diagrams may of course comprise a larger number of ducts with further TEG layers 6.

The system 1 may be used together with various applications. For example, the system 1 may be situated on the exhaust pipe in a vehicle to utilise waste heat in the exhaust gases. The system 1 may according to another embodiment be in the heat exchanger on a retarder in a vehicle. This makes it possible for more energy to be utilised in that the heat generated by the retarder need not be transferred to a cooling medium and it is easier to achieve a larger temperature difference between the warm and cold sides of the TEG unit 4. The TEG unit 4 may according to another embodiment be placed round the hydraulic oil line in the vehicle's retarder.

According to an embodiment, heat from various waste heat sources in the vehicle is conveyed to the waste heat line 3 on which the system 1 is situated. The vehicle thus needs only one system. The heat from various waste heat sources may for example be transferred through heat exchangers and be passed on to the waste heat medium 2 in the waste heat line 3.

According to the embodiments depicted in longitudinal cross-section in Figures 6A and 6B the system comprises a energy storage layer 5 partly situated upstream of and directly close to the TEG layer, in order to absorb heat from the waste heat medium 2 before heat is absorbed in the portion of the energy storage layer 5 which is placed between the TEG layer 6 and the waste heat line 3. This makes it possible for further heat to be stored before it reaches the TEG layer 6, and when the temperature of the waste heat medium 2 drops, heat can be released from the energy storage layer 5 to warm the waste heat medium 2. This makes it possible for more heat to be utilised from the waste heat medium 2 and for the time for which the TEG layer actively converts heat to electricity to be shortened. Figure

6A illustrates the energy storage layer 5 as an elongate layer of the already applied energy storage layer 5 between the waste heat line 3 and the TEG layer 6. Figure 6B illustrates the energy store 5 likewise as an elongate layer of the already applied the energy storage layer 5 between the waste heat line 3 and the TEG layer 6, with the addition that the energy storage layer 5 which is outside the TEG layer 6 has an increased thickness to be able to store more thermal energy.

A TEG element is made of various materials for producing electric current and comprises according to an embodiment metallic material. The TEG element preferably comprises any of the following materials: $B_4C/B_9C(F)$, Si/SiGe(N), SIGe/Si, BiTe/SbTe or PbTe SL. Using any of these materials may achieve high efficiency in the TEG element.

The energy storage layer 5 comprises according to an embodiment a material which is phase-transformed at a certain temperature. Thermal energy storage is thus effected by a phase change process. Phase transformation materials are usually within the range 80ºC to 1000ºC. Usual phase transformation materials are water, salt hydrates and paraffins. By using a phase transformation material it is possible for heat from the waste heat medium 2 to be stored as described above, and be used later when the temperature of the waste heat medium drops. During the phase transformation, energy is transformed according to the formula

$$Q = m \cdot \Delta h_{phase\ change} \qquad (1)$$

where Q is thermal energy in joules, $\Delta h_{phase\ change}$ is the phase change enthalpy in joules/kg for the material of the energy storage layer and m is the weight of the energy storage layer 5 in kg.

When no phase transformation takes place, energy called sensible thermal energy is stored according to the formula

$$Q = \int_{T_1}^{T_2} m \cdot c \cdot dT \qquad (2)$$

where *c* is the specific heat capacity of the material in joules/kg·K. The thermal energy *Q* from these two processes illustrated by formulae (1) and (2) is stored and delivered respectively when temperature passes a phase transition. It is preferable to use for the energy storage layer 5 a material which contains fluorides, carbonates, chloride, hydroxides or nitrates, since phase transformation for these materials takes place somewhere in the range 200ºC to 800ºC, the range within which the TEG layer 6 is preferably dimensioned for use in a vehicle. Another embodiment uses in the energy storage layer 5 sensible material with good heat conduction capacity, e.g. steel or copper.

Figure 7 is a diagram of how the temperature changes in the TEG layer when a phase transformation material is used in the energy storage layer 5. One axis represents the temperature in the TEG layer, T_{TEG}. The other axis represents time, t. The diagram illustrates how the heat from the waste heat medium 2 warms the energy storage layer 5, which in turn warms the TEG layer for the period denoted by ref. 73. When the energy storage layer 5 has been warmed to the phase transformation temperature for the material of the energy storage layer 5, denoted by ref. 72 in Figure 7, the material is transformed to another phase for a period denoted by ref. 74. During that period there is no change in the temperature of the energy storage layer 5 nor in the temperature of the TEG layer 6. After the phase transformation period the temperature continues to rise in the energy storage layer 5, and hence also in the TEG layer 6 if the temperature of the waste heat medium is high enough. The critical temperature for the TEG layer 6 is represented by a broken line, ref. 71, and if the temperature of the TEG layer rises above it the TEG elements therein may be damaged. It is therefore preferable that the bypass line 9 be connected before the critical temperature is reached, i.e. during or before the period indicated schematically as 75 in Figure 7, in order to lead the waste heat medium round the TEG unit 4.

The invention relates also to a vehicle which comprises one or more of the systems described above.

The present invention is not limited to the embodiments described above. Various alternatives, modifications and equivalents may be used. The abovementioned embodiments therefore do not limit the scope of the invention, which is defined by the attached claims.

Claims

1. A thermal electric generator system (TEG system) (1) for extracting electricity from a waste heat medium (2) in a waste heat line (3) in a vehicle, which system (1) comprises:

- a TEG unit (4) comprising:

- one or more energy storage layers (5) adapted to storing thermal energy and placed directly against the waste heat line (3), whereby thermal energy from the waste heat medium (2) is stored in said energy storage layers (5);

- one or more thermal electric generator layers (TEG layers) (6) adapted to converting thermal energy to electricity and placed directly against the energy storage layer (5);

- a bypass unit (8) comprising:

- a bypass line (9) connected to the waste heat line (3) via an adjustable valve device (10) so that all or parts of the waste heat medium (2) can be led past the TEG unit (4) in the bypass line (9);

- a valve control unit adapted to adjusting the valve device (10) when predetermined conditions are fulfilled, c h a r a c t e r i s e d in that the valve control unit is adapted to adjusting the valve device (10) when vehicle signals such as, for example, brake signals or acceleration control signals indicate that the vehicle is being braked or accelerated.

2. A thermal electric generator system according to claim 1, in which the TEG layer (6) comprises a plurality of TEG elements.

3. A thermal electric generator system according to claim 1 or 2, comprising a cooling device (7) placed adjacent to, in order to cool, the TEG layer (6).

4. A thermal electric generator system according to any one of the foregoing claims, in which said predetermined conditions comprise temperature

conditions for the temperature of one or more from among the waste heat medium (2), the energy storage layer (5), the TEG layer (6) and the cooling device (7), and the valve control unit is adapted to delivering a control signal *y* to the valve device (10) to adjust the valve and direct part or all of the flow through the bypass line (9) when one or more temperature conditions are fulfilled.

5. A thermal electric generator system according to claim 4, in which a temperature condition is that if the temperature of the waste heat medium (2) drops below the temperature of the energy storage layer (5) the valve control unit is adapted to delivering a control signal *y* to the valve device (10) to open the valve and direct part or all of the flow through the bypass line (9).

6. A thermal electric generator system according to either of claims 4 or 5, in which said temperatures are measured by using temperature sensors.

7. A thermal electric generator system according to either of claims 4 or 5, in which the temperatures of the energy storage layer (5) and/or the waste heat medium (2) and/or the TEG layer (6) are modelled by using respective theoretical models of the vehicle's subsystems.

8. A thermal electric generator system according to any one of the foregoing claims, in which the waste heat line (3) is divided into a plurality of ducts (11) to achieve large thermal contact surface, which system comprises TEG layers (6) placed between and outside the ducts.

9. A thermal electric generator system according to any one of claims 1 to 7, in which the TEG unit (4) is arranged coaxially round at least part of the extent of the waste heat line (3).

10. A thermal electric generator system according to any one of the foregoing claims, which system is placed in the heat exchanger on a retarder in a vehicle.

11. A thermal electric generator system according to claim 10, in which the TEG unit (4) is placed round the hydraulic oil line in a vehicle's retarder.

12. A thermal electric generator system according to any one of the foregoing claims, in which heat from various waste heat media in the vehicle is conveyed to the waste heat line (3).

13. A thermal electric generator system according to any one of the foregoing claims, in which the TEG elements comprise any of the following materials:
$B_4C/B_9C(F)$, Si/SiGe(N), SIGe/Si, BiTe/SbTe, PbTe SL etc.

14. A thermal electric generator system according to any one of the foregoing claims, in which the energy storage layer (5) comprises a material which is phase-transformed at a certain temperature, e.g. comprising fluorides, carbonates, chloride, hydroxides or nitrates.

15. A thermal electric generator system according to any one of the foregoing claims, comprising an energy storage layer (5) partly placed upstream of and immediately close to the TEG layer, in order to absorb heat from the waste heat medium (2) before heat is absorbed in the portion of the energy storage layer (5) which is situated between the TEG unit (6) and the waste heat line (3).

16. A vehicle comprising one or more systems (1) according to any one of claims 1 to 15.

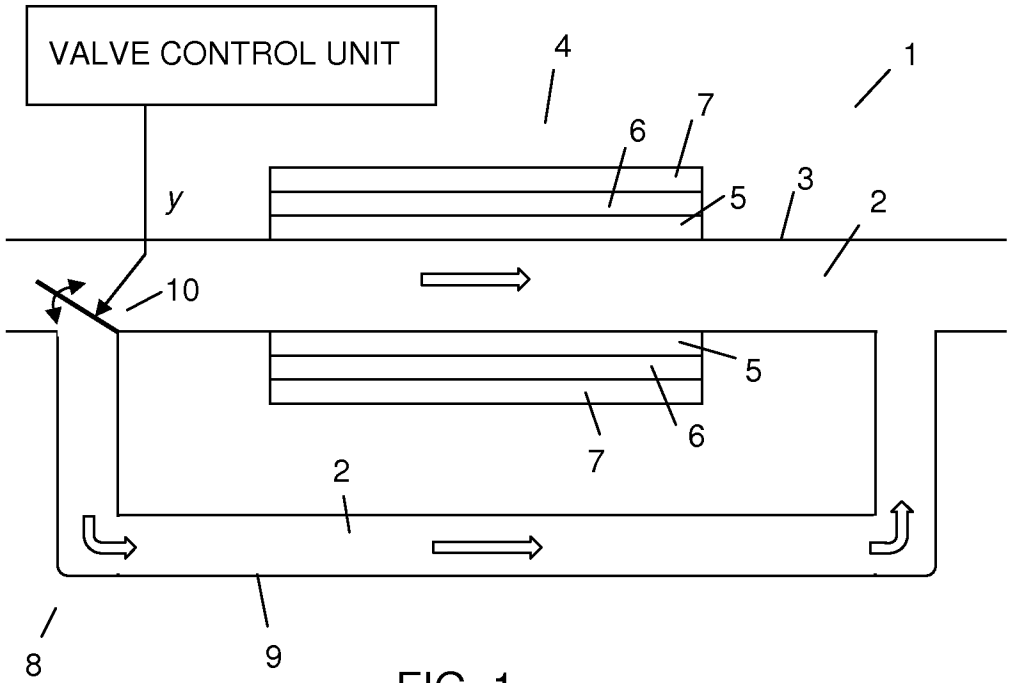
VALVE CONTROL UNIT
4
1
6
7
y
5
3
2
10
5
6
7
2
8
9

FIG. 1

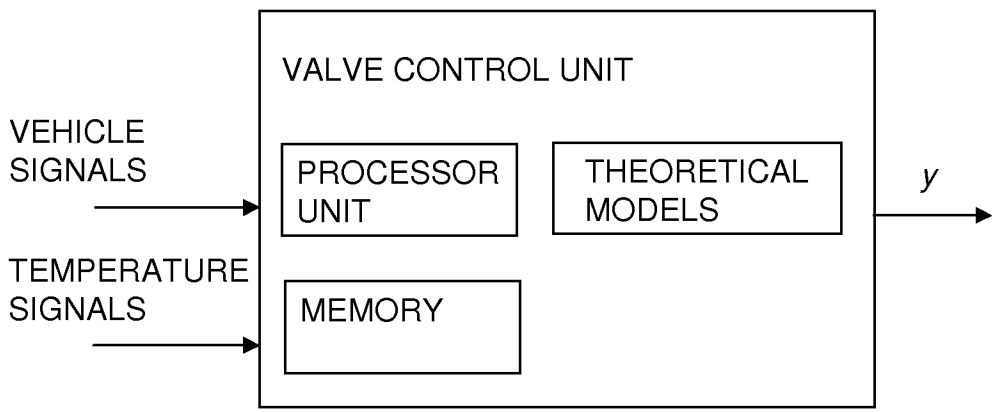
VALVE CONTROL UNIT
VEHICLE SIGNALS
PROCESSOR UNIT
THEORETICAL MODELS
y
TEMPERATURE SIGNALS
MEMORY

FIG. 2

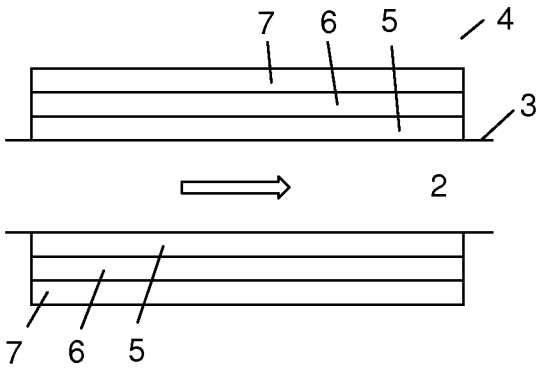

FIG. 3

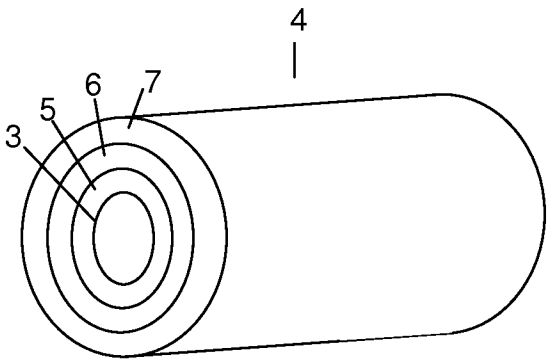

FIG. 4A

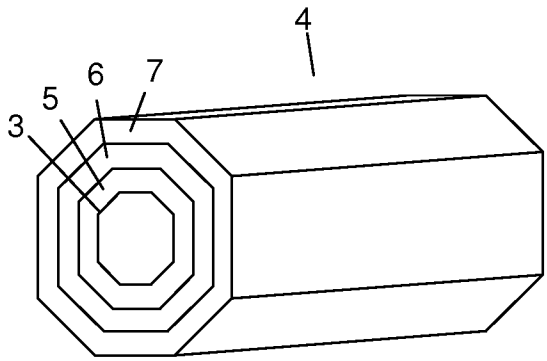

FIG. 4B

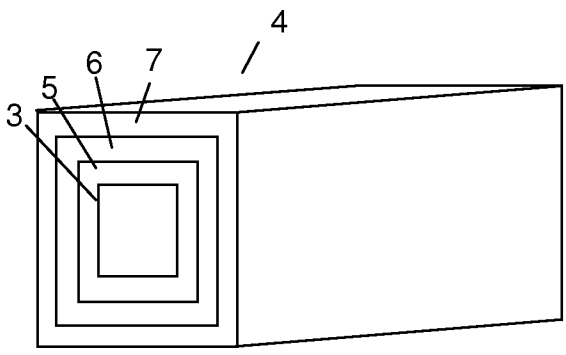

FIG. 4C

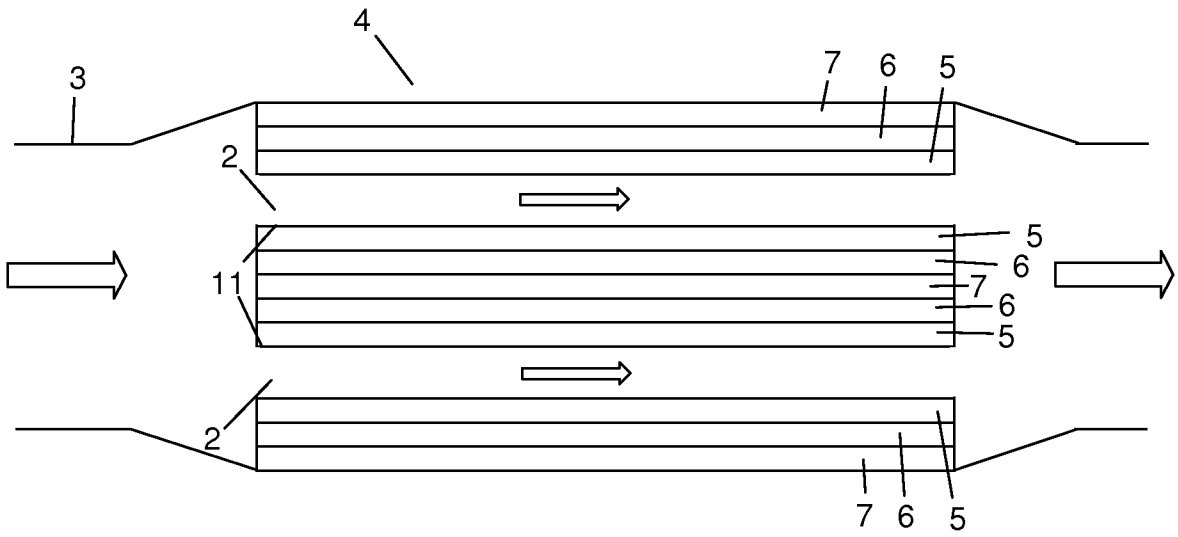

FIG. 5A

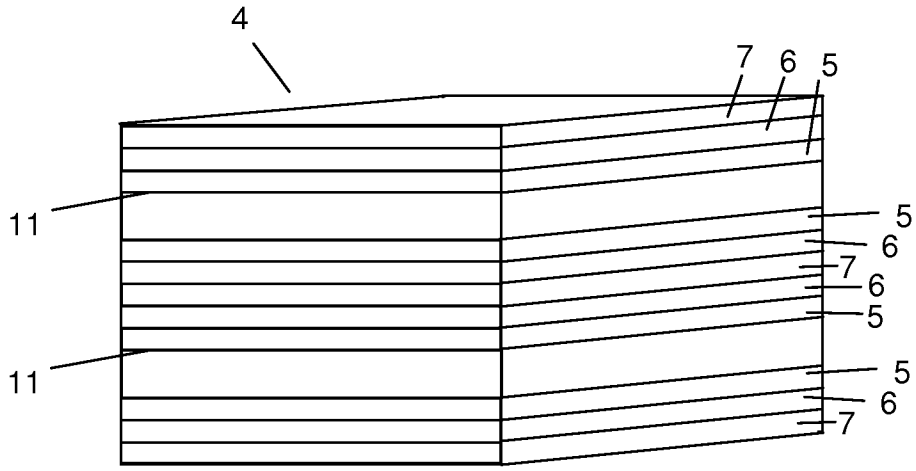

FIG. 5B

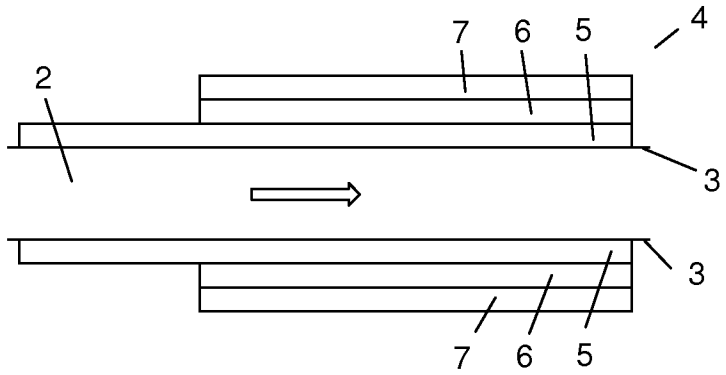

FIG. 6A

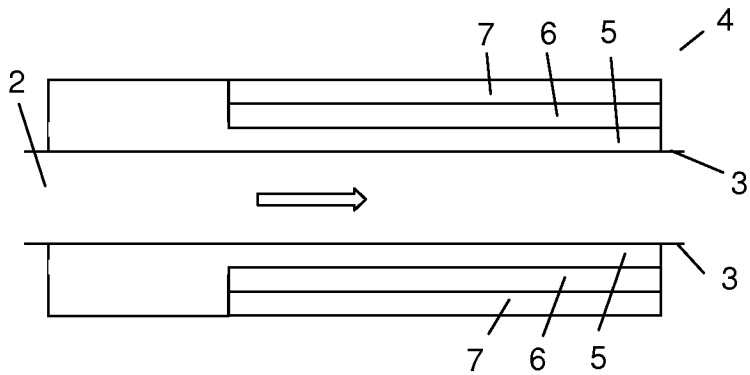

FIG. 6B

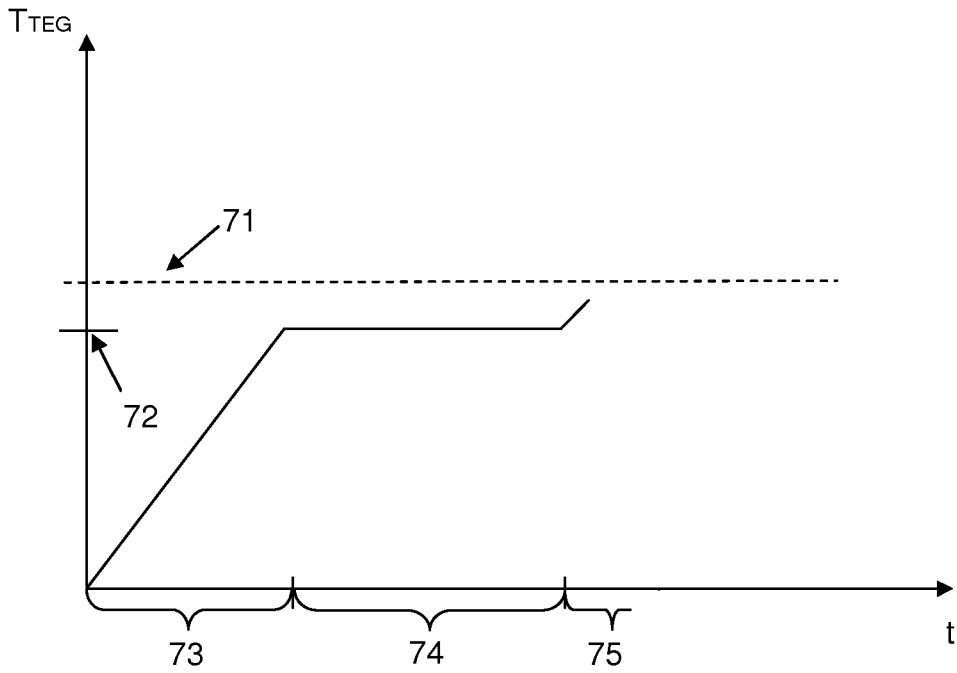

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2010/051014

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet
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)

IPC: F02G, F01N, H01L

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

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2000312035 A, KUBOTA CORP, 2000-11-07: (abstract) Retrieved from: PAJ database; Original document: paragraphs [0011], [0016], [0018], [0026], figures 2-3	1-7,9-13, 15-16
Y		8,14
	--	
A	JP 11229867 A, NISSAN MOTOR CO LTD, 1999-08-24: (abstract) Retrieved from: PAJdatabase; Original document: paragraphs [0054], figure 1	1-16
	--	
Y	JP 07012009 A, MITSUBISHI MOTORS CORP, 1995-01-17: (abstract) Retrieved from: PAJdatabase; Original document: figures 1, 2	8
	--	

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 January 2011	17-01-2011
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Marianne Dickman / EÖ Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2010/051014

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2008025701 A2 (SIEMENS AKTIENGESELLSCHAFT), 6 March 2008 (06.03.2008), page 6, line 19 - line 23; page 15, line 8 - page 16, line 4, figures 1-5, abstract ---	14
A	JP 2005117755 A, TOYOTA MOTOR CORP, 2005-04-28: (abstract) Retrieved from: PAJ database; Original document: figures 8-10 ---	15
A	JP 6081639 A, MITSUBISHI MOTORS CORP, 1994-03-22: (abstract) Retrieved from: PAJ database; Original document: figures 1-4 ---	1-16
A	JP 2008223758 A, NGK INSULATORS LTD, 2008-09-25: (abstract) Retrieved from: PAJ database; Original document: figures 1-9 ---	1-16
A	JP 2007016747 A, MAZDA MOTOR CORP, 2007-01-25: (abstract) Retrieved from PAJdatabase; Original document: figures 1, 2 --- --------	1-16

International patent classification (IPC)
F02G 5/02 (2006.01)
F01N 5/02 (2006.01)
H01L 35/30 (2006.01)

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/SE2010/051014

WO	2008025701	A2	06/03/2008	CN	101512784 A	19/08/2009
				DE	102006040853 B	14/02/2008
				US	20100186399 A	29/07/2010