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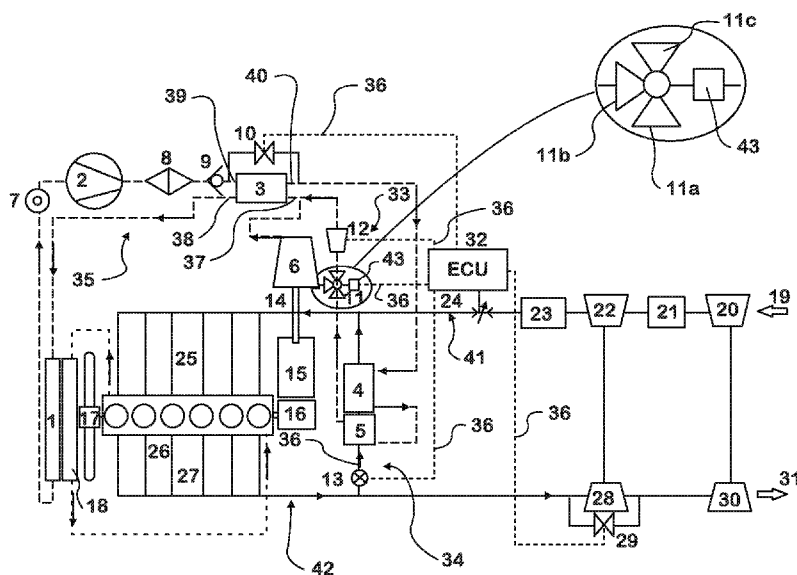
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(54) Title: TURBINE PROTECTION SYSTEM



(57) Abstract: In a system and method for a turbine protection system having a three-way valve, working fluid is heated by boiler to form saturated steam. Saturated steam is heated by superheater to change into a dry steam. Superheater may at least in-part be heated by exhaust gases from an internal combustion engine. Control module may receive information indicating, or for determining, at least one property of the working fluid that's exiting the superheater and/or entering into the three-way valve. If the working fluid is dry steam that is within a predetermined temperature and/or pressure range, three-way-valve may be positioned so that the working fluid exits a turbine side outlet of the three-way valve and flows to a turbine. Otherwise, three-way-valve may be positioned for the working fluid to by-pass the turbine, and instead flow into the pressure reducer valve.

TURBINE PROTECTION SYSTEM

BACKGROUND

[0001] Working fluids in a superheated steam form, such as a dry steam, may be used by internal combustion engines to operate a turbine. Moreover, the turbine may extract energy from the high temperature, high pressure super-heated working fluid that is flowing through the turbine to drive blades within the turbine. Rotation of the blades may be used to drive other engine components, such as, for example, a drive shaft in a vehicle or to produce electricity.

[0002] Failures of turbines are sometimes related to the condition or state of the working fluid that has entered into the turbine. For example, working fluid that enters into an operating turbine in a fluid state, or as a saturated steam, may cause pitting in the blades. Such pitting may facilitate corrosion and/or stress or fatigue cracking of the blades that may ultimately result in the failure of the turbine. Additionally, liquid working fluid or condensed working fluid from the saturated steam in the turbine may cause the development of a liquid film on the blades that may result in the undesirable depositing of particles or compounds on the blades, such as, for example, sulfate salts, that may facilitate the corrosion of the blades.

[0003] Typically, working fluid that enters a superheater is delivered to the turbine without a determination of whether the temperature of the working fluid is too high, or whether the working fluid is a saturated steam or liquid state. However, due to a number of environmental or operational conditions, the superheater and/or an upstream boiler may not be at a sufficient temperature to transform liquid working fluid to the desired state. For example, when a vehicle's engine is initially in the key-on condition, or during extreme cold weather conditions, the superheater and boiler may not have yet attained temperatures necessary for the working fluid to be transformed to a dry steam before the working fluid enters into the turbine. Further, after periods of vehicle operation, the working fluid exiting the superheater may attain temperatures that are high enough to damage the turbine.

[0004] Additionally, a turbine may continue to be supplied with super-heated working fluid regardless of whether that power from the turbine is needed at that time. For example, power from a turbine that is used to drive a driveshaft in a diesel fueled vehicle may continue to receive working fluid despite the driver attempting to stop or slow the speed of the vehicle by pressing on the brake pedal. Similarly, the same turbine may continue being supplied with working fluid, and thus drive the drive shaft, while the vehicle is traveling downhill, such as down an incline, and the user is not depressing the accelerator. In such situations, the turbine may still be unnecessarily supplied with working fluid, which may further increase the risk of damage or unnecessary wear on the turbine.

BRIEF SUMMARY

[0005] An aspect of the illustrated embodiment is a turbine protection system for an engine. The turbine protection system includes a boiler that is configured to heat a working fluid. The system also includes a superheater that is configured to receive the working fluid from the boiler, the superheater being further configured to super-heat the working fluid. Additionally, the system includes a valve that has a valve inlet, a turbine side outlet, and a by-pass outlet. The valve inlet is configured to receive working fluid from the superheater. Further, the valve is configured to be moved between a first position and a second position. Moreover, the valve is configured for working fluid to (1) flow out of the valve turbine side outlet of the valve and to a turbine when the valve is in a first position, and (2) flow out of the by-pass outlet of the valve to a pressure reducer valve when the valve is in the second position. The system also includes a control module that is configured to control the movement of the valve between the first and second positions.

[0006] Another aspect of the illustrated embodiment is a turbine protection system for a vehicle that includes a boiler that is configured to heat a working fluid and a superheater that is configured to super-heat the heated working fluid. The system further includes a valve that is configured to receive the dry stream from the superheater through a valve inlet. The valve is configured to move between a first position and a second position. Additionally, the system includes a turbine that has

an inlet that is configured to receive the super-heated working fluid from a turbine side outlet of the valve when the valve is in a first position. The system further includes a pressure reducer valve configured to receive the super-heated working fluid from a by-pass outlet of the valve when the valve is in a second position.

[0007] Another aspect of the illustrated embodiment is a method for operating a turbine protection system for a vehicle. The method includes heating a working fluid and super-heating the heated working fluid to create a super-heated working fluid. The method further includes sensing the temperature or pressure of the super-heated working fluid. The super-heated working fluid is transferred to a three-way valve. The three-way valve is at a first position when the sensed temperature or pressure is within a predetermined range, such as, for example, at pressures higher than 40 bar and temperatures above 300 degrees Celsius, and at a second position when the sensed temperature or pressure is outside of the predetermined range. The super-heated working fluid is transferred to a turbine when the three-way valve is at the first position, and transferred to a pressure reducer valve when the three-way valve is at the second position. When the working fluid from the superheater is not fully superheated, the three-way valve should be opened to the second position to protect the turbine blade.

BRIEF DESCRIPTION OF SEVERAL VIEWS OF THE DRAWINGS

[0008] FIG. 1 illustrates a schematic of a turbine protection system for use in a waste heat recovery system.

DETAILED DESCRIPTION

[0009] FIG. 1 illustrates a schematic of a turbine protection system 33 for use in a waste heat recovery system 34. FIG. 1 illustrates an embodiment of the systems 33, 34 being used with a diesel engine 26. However, aspects of the turbine protection system 33 described herein may also be used with a variety of other engines, including internal combustion engines that are powered by the combustion of gasoline or petroleum fuel, among others.

[0010] As shown, air 19 for use in the operation of the engine 26, such as for use during the internal combustion process, may flow through along an air flow path 41 that includes various hoses and/or tubes. For example, as shown in FIG. 1, air 19 passes into a low pressure air compressor 20 before flowing, along a portion of the air flow path 41, to a low pressure charged air cooler 21. The air 19 then flows through a high pressure air compressor 22 and high pressure charged air cooler 23 before flowing to an air intake throttle 24. The air intake throttle 24 may be configured to move between open and closed positions, or being opened to varying degrees, so as to, for example, lower the pressure or air flow rate in the intake ports 25 of the engine 26, or increase the temperature of exhaust gas 31 from the engine 26. The air intake valve 24 (or one or more actuators operably connected to the intake valve 24) may be controlled and/or driven by an engine control unit (ECU) 32, such as, for example, through a communication and/or power cable 36.

[0011] Air 19 may flow from the intake ports 25 to be used in the combustion process in the engine 26. As shown, the engine 26 is operably connected to a transmission 16. The resulting hot exhaust gas 31 produced by the combustion of fuel may flow from the engine 26 through exhaust ports 27 and along an exhaust gas flow path 42. At least a portion of the hot exhaust gas 31 may be diverted from the exhaust gas flow path 42 at an exhaust gas recirculation (EGR) valve 13, as discussed below in more detail. As further shown, the engine 26 may be cooled by the flow of coolant that flows in a loop between a radiator 18, which may be cooled by a fan 17, and the engine 26.

[0012] In the embodiment illustrated in FIG. 1, exhaust gas 31 that is not diverted by the EGR valve 13 may continue to flow along the exhaust gas flow path 42 and be delivered to a high pressure turbine 28. The exhaust gas 31 may then at least assist in driving the high pressure turbine 28. Power generated by the high pressure turbine 28 may at least in part be used to power or drive the high pressure compressor 22. The exhaust gas flow path 42 may also include a high pressure turbine by-pass valve 29 that opens when the pressure of the exhaust gas 31 in or approaching the high pressure turbine reaches and/or exceeds a predetermined

value. As shown in FIG. 1, the high pressure turbine by-pass valve 29 (or an actuator operably attached thereto) may be controlled or driven by the ECU 32. Accordingly, the ECU 32 may receive sensed data, such as a sensed pressure at or upstream of the high pressure turbine by-pass 28, that is used by the ECU 32 in determining whether to open and/or when to close the high pressure turbine by-pass valve 29.

[0013] Exhaust gas 31 flowing along the exhaust gas flow path 42 may then flow from the high pressure turbine 28 or high pressure turbine by-pass valve 29 to a low pressure turbine 30. The low pressure turbine 30 may also be configured to be driven by the exhaust gas 31. As illustrated, the operation of the low pressure turbine 30 may be used to power or drive the low pressure air compressor 20. Exhaust gas 31 exiting the low pressure turbine 30 may then be released from the exhaust gas flow path 42. For example, the exhaust gas 31 may be outputted from the low pressure turbine 30 to an exhaust gas after-treatment system, an ancillary system that continues to utilize heat in the exhaust gas 31, or into the environment.

[0014] A working fluid, such as a refrigerant, such as R245fa or Ethanol, among others, is used to drive a turbine 6, such as turbine 6 used to drive a drive shaft 14 of a motorized vehicle. The working fluid may flow along a working fluid pathway 35. As shown, working fluid may enter a boiler 4, which may heat at least a portion of the working fluid into a wet or saturated steam. The temperature and/or pressure of the working fluid exiting the boiler may vary for different types of working fluids. As discussed below, heat used to convert the working fluid into the saturated steam may at least be partially provided by exhaust gas 31. The saturated steam, as well as potentially working fluid that was not converted to a saturated steam, may then flow out of the boiler 4 and into a superheater 5.

[0015] Besides being configured to receive saturated steam that is outputted from the boiler 4, the superheater 5 may also be configured to receive hot exhaust gas that has been diverted from the exhaust gas flow path 42 to the EGR flow path 36 at the EGR valve 13. As shown in FIG. 1, the EGR valve 13 (or an actuator operably connected to the EGR valve 13) may be controlled or driven by the ECU 32.

Accordingly, the ECU 32 may determine and/or instruct the EGR valve 13 when to at least partially open so as to divert exhaust gas 31 into the EGR flow path 36, as well as instruct the EGR valve 13 when to close or remain closed.

[0016] The superheater 5 may use heat from the hot exhaust gas 31 to at least partially assist in converting the saturated steam entering into the superheater 5 into a dry steam. The temperature of the dry steam exiting the superheater 5 may vary depending on engine operating conditions. According to some applications, the dry steam exiting the superheater may have a temperature that is at least 10 degrees Celsius higher than the saturated vapor line at a given. For example, according to certain embodiments, the superheater 5 may be a convection superheater that transfers heat from the exhaust gas 31 to convert the saturated steam to the dry steam. According to other embodiments, rather than diverting exhaust gas 31 to an EGR flow path 36, the superheater 5 may be positioned in one or more combustion chambers in the engine 26. According to such embodiments, the superheater 5 may be a radiant superheater 5 that uses the heat generated during the combustion of fuel in the internal combustion engine 26 to convert the saturated steam into a dry steam.

[0017] According to the embodiment illustrated in FIG. 1, the diverted exhaust gas 31 may exit the superheater 5 and flow into the boiler 4. At least a portion of the heat remaining in the exhaust gas 31 that enters the boiler 4 may then be used to at least assist in the conversion of the working fluid into a saturated steam, as previously discussed. The exhaust gas 31 may then exit the boiler 4 and enter into the air flow pathway 41, where the exhaust gas 31 may be mixed with air 19 that is being delivered to the intake ports 25 of the engine 26.

[0018] Working fluid outputted from the superheater 5 has been converted into dry steam. However, in some instances, the outputted working fluid from the superheater 5 may include saturated steam or working fluid that is in a liquid state. Accordingly, the illustrated embodiment employs a turbine protection system 33 having a three-way valve 11 to control the working fluid that may pass into the turbine 6. More specifically, the system 33 employs a three-way valve 11 to

prevent, or at least minimize the potential for, working fluid that is not in a dry stem form from entering into the turbine 6. Further, the three-way valve 11 may prevent working fluid from entering into the turbine 6 when power from the turbine 6 is not needed, such as when the vehicle in which the turbine protection system 33 is used is braking or going down an incline.

[0019] As shown in FIG. 1, the three-way valve has an inlet 11a, a turbine side outlet 11b, and a by-pass outlet 11c. Working fluid from the superheater 5 flows into the three-way valve 11 through the inlet 11a. When the three-way valve 11 is in a first position, such as an open position, the three-way valve 11 is configured for the working fluid that entered through the inlet 11a to flow out of the turbine side outlet 11b so that the working fluid may flow into the turbine 6. The flow of the superheated working fluid through the turbine 6 may cause the rotation of blades within the turbine 6 that results in the turbine 6 driving the rotation of a drive shaft 14 that is operably connected to a torque converter 15. The working fluid may then exit the turbine 6 at a significantly reduced pressure. When the three-way valve 11 is in a second position, such as a closed position, the three-way valve 11 prevents fluid from flowing out of the turbine side outlet 11b, and instead flows out of the valve 11 through the by-pass outlet 11c.

[0020] Operation of the three-way valve 11 may be controlled by a control module, such as, for example, the ECU 32. According to an embodiment, information or data pertaining to the temperature, pressure, and/or state of the working fluid, superheater 5, and/or exhaust gas 31 is used by the ECU 32. For example, one or more temperature and/or pressure sensors may be used to indicate or determine the state of working fluid exiting the superheater 5. According to such embodiments, the ECU 32 may receive information or data from temperature and/or pressure sensors, such as, for example, sensors that detect the temperature and/or pressure at or around the superheater 5, working fluid leaving or entering the superheater 5, and/or the exhaust gas 31 entering or leaving the superheater. Using such information or data, the ECU 32 may determine, in real time, whether the working fluid is in a proper state or condition for entry into the turbine 6.

[0021] For example, if the ECU 32 determines that working fluid that has exited the superheater 5 is not at super-heated temperatures and/or the working fluid is in a liquid form, the turbine side outlet 11b of the three-way valve 11 may be closed so that working fluid does not enter into the turbine 6. By controlling whether the working fluid is allowed to enter into the turbine 6, the turbine protection system 33 may protect the turbine 6, such as, for example, protecting turbine blades inside the turbine 6 from exposure to saturated steam or liquid working fluid that may cause or facilitate undesirable pitting, cracking, or corrosion of the turbine blades. In such situations, the working fluid may exit the three-way valve 11 through the by-pass outlet 11c. If, however, the ECU 32 determines the working fluid is in suitable condition for entry into the turbine 6, the three-way valve may be opened, or remain opened, so that the working fluid may exit the three-way valve 11 through the turbine side outlet 11b.

[0022] The turbine protection system 33 may also be configured to prevent the passage of working fluid from the three-way valve 11 to the turbine 6 under a variety of other circumstances. For example, during certain driving situations, power from the turbine 6 is unnecessary, such as, for example, when a driver of vehicle having the system 33 is depressing a brake pedal, or when the vehicle is traveling downhill. In such situations, the ECU 32 may be provided with information or data that allows the ECU 32 to determine that operation of the turbine 6 at that time is unnecessary. The ECU 32 may then have the three-way valve 11 be moved to, or remain at, a second or closed position, where working fluid flows through the by-pass outlet 11c of the three-way valve 11 rather than through the turbine side outlet 11b. For example, the ECU 32 may send power or instructions to a control unit or controller 43 that is configured to move the three-way valve 11 from a first to a second position, and vice versa.

[0023] The turbine protection system 33 also includes a pressure reducer valve 12, such as, for example, an expansion valve or variable orifice valve, among others. Fluid that flows out of the by-pass outlet 11c may then flow into the pressure reducer

valve 12. The pressure reducer valve 12 is configured for the reduction of the pressure of the working fluid.

[0024] Working fluid exiting the turbine 6 or pressure the reducer valve 12 then flows through a return fluid inlet 37 of a recuperator 3 before exiting through a return fluid outlet 38. The recuperator 3 also includes a supply fluid inlet 39, through which cooled working fluid enters the recuperator 3 before exiting through a supply fluid outlet 40. The recuperator 3 is a heat transfer device that is configured to transfer at least a portion of heat entrained in the working fluid that enters the recuperator 3 through the return fluid inlet 37 to the cooler supply working fluid that enters the recuperator 3 through supply fluid inlet 39. The working fluid exiting the recuperator 3 through the return fluid outlet 38 then passes to a condenser 1, where the temperature of the entering working fluid is reduced. Cooling of the working fluid temperature may allow for the creation of more power from the turbine 6 due to an increased enthalpy difference through the turbine 6 that is provided by increasing the turbine 6 expansion ratio.

[0025] Cooled working fluid exits the condenser 1. According to the illustrated embodiment, working fluid that exits the condenser 1 may flow through a sight glass 7. The working fluid may be pumped through the working fluid pathway 35 by a pump 2. While the illustrated embodiment demonstrates the pump 2 as being positioned downstream of the sight glass 7, the pump 2 may be located at a variety of locations along the working fluid pathway 35. The working fluid pathway 35 also includes a filter 8 that is configured to remove debris and possibly other contaminants or materials from the working fluid. In the illustrated embodiment, the working fluid may then pass from the filter 8 to a check valve 9. The working fluid may then flow into either the recuperator 3 through the supply fluid inlet 39, or flow through a by-pass valve 10 of the recuperator 3. The by-pass valve 10 of the recuperator 3 controls the low side pressure of the condenser 1 and the high side pressure on the boiler 4 and superheater 5. Working fluid may then flow from the recuperator 3 or by-pass valve 10 and into the boiler 4. The working fluid may then

again be subjected to heat in both the boiler 4 and superheater 5, as previously discussed.

CLAIMS

1. A turbine protection system for an engine comprising:
 - a boiler configured to heat a working fluid;
 - a superheater configured to receive the working fluid from the boiler, the superheater configured to super-heat the working fluid;
 - a valve having a valve inlet, a turbine side outlet, and a by-pass outlet, the valve inlet configured to receive working fluid from the superheater, the valve configured to be moved between a first position and a second position, the valve also configured for working fluid to (1) flow out of the valve turbine side outlet of the valve and to a turbine when the valve is in a first position, and (2) flow out of the by-pass outlet of the valve to a pressure reducer valve when the valve is in the second position; and
 - a control module configured to control the movement of the valve between the first and second positions.
2. The turbine protection system of claim 1, wherein the pressure reducer valve is an expansion valve.
3. The turbine protection system of claim 1, wherein the pressure reducer valve is a variable orifice valve.
4. The turbine protection system of claim 1, wherein the control module is an electronic control module.
5. The turbine protection system of claim 4, further including a pressure sensor operably connected to the control module, the control module being configured to move the position of the valve when the pressure sensed by the sensor is below a predetermined level.

6. The turbine protection system of claim 4, further including a temperature sensor operably connected to the control module, the control module being configured to move the position of the valve when the temperature sensed by the sensor is above a predetermined level.

7. The turbine protection system of claim 4, wherein the control module is configured to move the valve to a second position when the control modules senses or determines power is not required from the turbine.

8. A turbine protection system for a vehicle comprising:

a boiler configured to heat a working fluid;

a superheater configured to super-heat the heated working fluid;

a valve configured to receive the dry stream from the superheater through a valve inlet, the valve configured to move between a first position and a second position;

a turbine having an inlet, the inlet configured to receive the super-heated working fluid from a turbine side outlet of the valve when the valve is in a first position; and

a pressure reducer valve configured to receive the super-heated working fluid from a by-pass outlet of the valve when the valve is in a second position.

9. The turbine protection system of claim 8, further including a control module configured to control the position of the valve.

10. The turbine protection system of claim 9, wherein the control module is configured to move the valve from a first position to a second position when the temperature of the super-heated working fluid is above a predetermined value.

11. The turbine protection system of claim 9, wherein the control module is configured to move the valve from a first position to a second position when the pressure of the super-heated working fluid is below a predetermined value.

12. The turbine protection system of claim 9, wherein the control module is configured to move the position of the valve when a brake pedal of the vehicle is depressed.

13. The turbine protection system of claim 9, wherein the control module is configured to move the position of the valve when the vehicle is traveling down an incline.

14. A method for operating a turbine protection system for a vehicle comprising:

heating a working fluid;

super-heating the heated working fluid to create a super-heated working fluid;

sensing the temperature or pressure of the super-heated working fluid;

transferring the super-heated working fluid to a three-way valve;

positioning the three-way valve at a first position when the sensed temperature or pressure is within a predetermined range;

positioning the three-way valve at a second position when the sensed temperature or pressure is outside of the predetermined range;

transferring the super-heated working fluid to a turbine when the three-way valve is at the first position; and

transferring the super-heated working fluid to a pressure reducer valve when the three-way valve is at the second position.

15. The method of claim 14, further including the step of positioning the three-way valve at a second position when a control unit determines power from the turbine is not required.

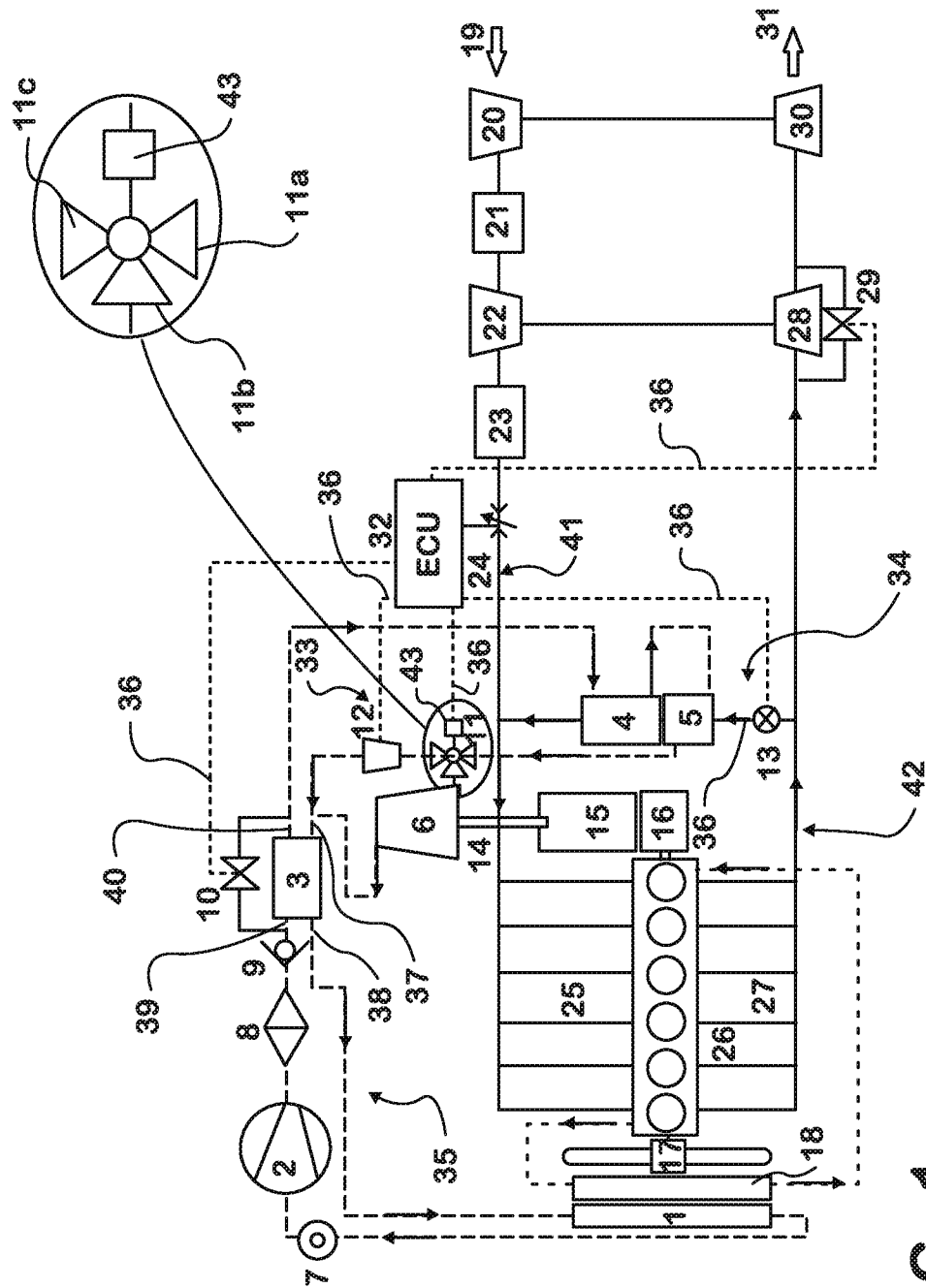


FIG. 1

INTERNATIONAL SEARCH REPORT

International application No.

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A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - F01K 7/24 (2013.01)

USPC - 60/646

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(8) - F01D 17/00, 17/02; F01K 7/24, 13/00, 13/02; G05B 9/03, 15/00 (2013.01)

USPC - 60/645, 646; 290/40R; 415/1, 13, 15; 700/70, 79

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
CPC - F01K 7/24, 13/00, 13/02 (2013.01)

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

Minesoft PatBase, Google Patents, Google

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 2 175 104 A1 (FENG) 14 April 2010 (14.04.2010) entire document	1-15
Y	US 3,974,644 A (MARTZ et al) 17 August 1976 (17.08.1976) entire document	1-15
Y	US 6,152,085 A (DETHIER et al) 28 November 2000 (28.11.2000) entire document	2
Y	US 2011/0023491 A1 (REND0 et al) 03 February 2011 (03.02.2011) entire document	3
Y	US 5,241,817 A (GEORGE JR) 07 September 1993 (07.09.1993) entire document	12, 13
A	US 4,471,620 A (BINSTOCK et al) 18 September 1984 (18.09.1984) entire document	1-15
A	US 4,425,762 A (WAKAMATSU et al) 17 January 1984 (17.01.1984) entire document	1-15



Further documents are listed in the continuation of Box C.



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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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