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(54) DETECTING CONDUIT DETACHMENT OF A CRANKCASE GAS SEPARATOR

(57) The present disclosure relates in an aspect to a method of a control unit (28) of detecting detachment of a gas flow conduit (18) arranged to be attached to a crankcase gas separator (1) in fluid connection with a crankcase (41) of a combustion engine (40). The method comprises measuring (S101) a load of a motor (23) operating the crankcase gas separator (1), determining (S102) whether at least one of the measured load exceeds an upper load threshold value and the measured load is below a lower load threshold value and if so, detecting (S103) that the gas flow conduit (18) is indicated to have been detached from the crankcase gas separator (1).

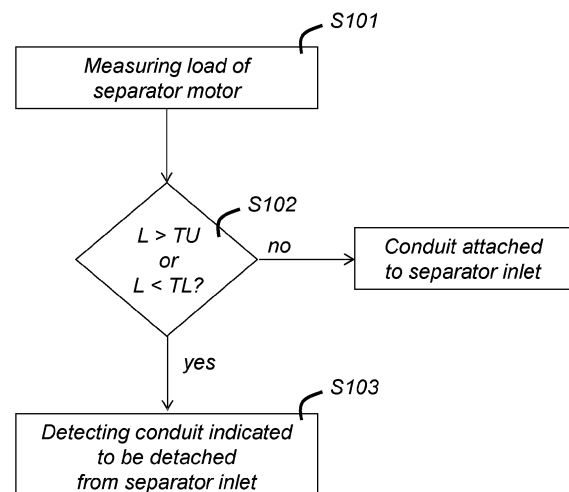


Figure 5

Description

TECHNICAL FIELD

[0001] The present disclosure relates to a method of a control unit of detecting detachment of a conduit arranged to be attached to an inlet of a crankcase gas separator in fluid connection with a crankcase of a combustion engine, and a control device performing the method.

BACKGROUND

[0002] In combustion engines, combustion gases may leak from the combustion chamber and end up inside the crankcase.

[0003] This leaking causes pressure to build up in the crankcase over time and the gases can condense and mix with the oil vapor that is present in the crankcase, which causes sludge to form or the oil to degrade. This is undesired both from an environmental and engine performance perspective. For certain types of combustion engines, legislation even requires crankcase gas to be disposed of in an environmentally friendly manner.

[0004] Hence, it is important that the crankcase is ventilated from these gases, which may be performed using a device known as a crankcase gas separator. However, an issue with known separators is that a hose or conduit from the crankcase supplying the crankcase gas to the separator easily can be disconnected from the separator, in which case ventilation will fail.

SUMMARY

[0005] One objective is to solve, or at least mitigate, this problem in the art and thus to provide a method of detecting any detachment of a conduit from an inlet of a crankcase gas separator.

[0006] This objective is attained in a first aspect by a method of a control unit of detecting detachment of a gas flow conduit arranged to be attached to a crankcase gas separator in fluid connection with a crankcase of a combustion engine. The method comprises measuring a load of a motor operating the crankcase gas separator, determining whether at least one of the measured load exceeds an upper load threshold value and the measured load is below a lower load threshold value, and if so detecting that the gas flow conduit is indicated to have been detached from the crankcase gas separator.

[0007] This objective is attained in a second aspect by a control unit configured to detect detachment of a gas flow conduit arranged to be attached to a crankcase gas separator in fluid connection with a crankcase of a combustion engine. The control unit is configured to measure a load of a motor operating the crankcase gas separator, determine whether at least one of the measured load exceeds an upper load threshold value and the measured load is below a lower load threshold value, and if so

to detect that the gas flow conduit is indicated to have been detached from the crankcase gas separator.

[0008] Advantageously, with the control device of the second aspect being configured to perform the method of the first aspect and its various embodiments, it may be detected by measuring a load of a motor operating the crankcase gas separator whether or not a gas flow conduit, such as the gas flow conduit at the inlet of the separator has been detached.

[0009] In an embodiment, the gas flow conduit is an inlet conduit arranged to be attached to an inlet of the crankcase gas separator or an outlet conduit arranged to be attached to an outlet of the crankcase gas separator.

[0010] In an embodiment, the measured load exceeding the upper load threshold value indicates that the inlet conduit has been detached from the crankcase gas separator with the inlet being open or that the outlet conduit has been detached from the crankcase gas separator with the outlet being open.

[0011] In an embodiment, the measured load being below the lower load threshold value indicates that the inlet conduit has been detached from the crankcase gas separator with the inlet being plugged or that the outlet conduit has been detached from the crankcase gas separator with the outlet being plugged.

[0012] In an embodiment, the determining of the measured load exceeding an upper threshold load value comprises determining that the measured load increases from a first lower level to a second higher level exceeding the upper load threshold value within a specified time period.

[0013] In an embodiment, the determining of the measured load exceeding an upper threshold load value comprises determining that the measured load exceeds the upper threshold load value for a specified number of sequential load measurements.

[0014] In an embodiment, the determining that the measured load exceeds the upper threshold load value for a specified number of sequential load measurements comprises determining that the measured load does not exceed a yet higher threshold load value during the specified number of sequential load measurements.

[0015] In an embodiment, the determining of the measured load being below a lower threshold load value comprises determining that the measured load is below the lower load threshold value for the specified number of sequential load measurements.

[0016] In an embodiment, the determining that the measured load is below the lower threshold load value for a specified number of sequential load measurements comprises determining that the measured load does not fall below a yet lower load threshold value during the specified number of sequential load measurements.

[0017] In an embodiment, the determining that the measured load exceeds an upper load threshold value, an operational mode of the combustion engine is selected where an expected load of the motor will not exceed the upper load threshold value.

[0018] In an embodiment, upon determining that the measured load is below a lower load threshold value, an operational mode of the combustion engine is selected where an expected load of the motor will not fall below the lower load threshold value.

[0019] In an embodiment, the measuring of a load comprises measuring a load of a motor operating the crankcase gas separator both at a first operational mode of the combustion engine and at a second operational mode of the combustion engine, and the determining comprises determining, for both operational modes of the combustion engine, whether the measured load exceeds an upper load threshold value or the measured load is below a lower load threshold value and if so, detecting that the gas flow conduit is indicated to have been detached from the crankcase gas separator.

[0020] In an embodiment, the method further comprises providing an alert that the gas flow conduit is detected to have been detached from the crankcase gas separator.

[0021] In an embodiment, the motor is configured to cause a rotating member of the crankcase gas separator to rotate in order to cause the crankcase gas to flow through the crankcase gas separator to be separated into a gaseous phase exiting the crankcase gas separator via a gas outlet and into a liquid phase exiting the crankcase gas separator via a liquid outlet.

[0022] In an embodiment, the load of the motor operating the crankcase gas separator is measured by either measuring power or current consumption of the motor.

[0023] In a third aspect, a computer program is provided comprising computer-executable instructions for causing a control unit of the second aspect to perform the method of the first aspect when the computer-executable instructions are executed on a processing unit included in the control unit.

[0024] In a fourth aspect, a computer program product is provided comprising a non-transitory computer readable medium, the computer readable medium having the computer program according to the third aspect embodied thereon.

[0025] Generally, all terms used in the claims are to be interpreted according to their ordinary meaning in the technical field, unless explicitly defined otherwise herein. All references to "a/an/the element, apparatus, component, means, step, etc." are to be interpreted openly as referring to at least one instance of the element, apparatus, component, means, step, etc., unless explicitly stated otherwise. The steps of any method disclosed herein do not have to be performed in the exact order disclosed, unless explicitly stated.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] Aspects and embodiments are now described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 schematically illustrates an internal combustion engine (ICE) according to an example in which embodiments may be implemented;

Figure 2 shows a section of a prior art centrifugal crankcase gas separator in which embodiments may be implemented;

Figure 3 illustrates power consumption of a motor driving a crankcase gas separator as a function of blow-by flow rate;

Figure 4a illustrates a measured motor load exceeding a set upper load threshold value according to an embodiment;

Figure 4b illustrates a measured motor load being below a set lower load threshold value according to an embodiment;

Figure 5 shows a flowchart illustrating a method of detecting detachment of the inlet conduit of the separator according to an embodiment;

Figure 6a illustrates a high-load operational mode of the ICE with the inlet conduit being attached;

Figure 6b illustrates a low-load operational mode of the ICE with the inlet conduit being attached;

Figure 7a illustrates a measured motor load exceeding a set upper load threshold value for a number of sequential measurements according to an embodiment;

Figure 7b illustrates a measured motor load being below a set lower load threshold value for a number of sequential measurements according to an embodiment;

Figure 8a illustrates a measured motor load exceeding a set upper load threshold value, but not exceeding a yet higher load threshold value, for a number of sequential measurements according to an embodiment;

Figure 8b illustrates a measured motor load being below a set lower load threshold value, but not falling below a yet lower load threshold value, for a number of sequential measurements according to an embodiment;

Figure 9 shows a flowchart illustrating a method of detecting detachment of the inlet conduit of the separator according to an embodiment;

Figure 10 shows a flowchart illustrating a method of detecting detachment of the inlet conduit of the se-

parator according to an embodiment; and

Figure 11 illustrates detection of an instant detachment of the conduit according to an embodiment.

DETAILED DESCRIPTION

[0027] The aspects of the present disclosure will now be described more fully hereinafter with reference to the accompanying drawings, in which certain embodiments of the invention are shown.

[0028] These aspects may, however, be embodied in many different forms and should not be construed as limiting; rather, these embodiments are provided by way of example so that this disclosure will be thorough and complete, and to fully convey the scope of all aspects of invention to those skilled in the art. Like numbers refer to like elements throughout the description.

[0029] Figure 1 schematically illustrates an internal combustion engine (ICE) 40 according to an example in which embodiments may be implemented. The ICE 40 comprises a crankcase 41 and a centrifugal separator 1 for cleaning of crankcase gas, which separator 1 is controlled by control unit 28. As is understood, the ICE 40 will in practice comprises far more components than those illustrated for brevity in Figure 1. The separator 1 will be described in detail with reference to Figure 2 below.

[0030] The ICE 30 may be a compression ignition or spark ignition four-stroke or two-stroke ICE. In a known manner, the ICE 30 comprises at least one piston arranged in a cylinder bore of the ICE 30. A connecting rod connects the piston with a crankshaft 42 inside the crankcase 41. As fuel combusts in a combustion chamber formed above the piston in the cylinder bore, the piston reciprocates in the cylinder bore and drives the crankshaft 42.

[0031] Some of the combustion gases produced in the combustion chamber flow past the piston into the crankcase 41, commonly referred to as blow-by gas. For the piston to be able to reciprocate freely, the crankcase 41 has to be ventilated. Thus, crankcase gas flows from the crankcase 41 to the centrifugal separator 1. In addition to blow-by gas, the crankcase gas may comprise, oil, other liquid hydrocarbons, soot, and other solid combustion residues.

[0032] By means of control unit 28, the rotational speed and thereby the cleaning efficiency of the centrifugal separator 1 may be controlled in a suitable way so that a required cleaning of the supplied gas is obtained, as will be discussed in more detail with reference to Figure 2 below.

[0033] A conduit 18 fluidly connects an interior of the crankcase 41 with the centrifugal separator 1. In the centrifugal separator 1, the crankcase gas is separated into a gaseous phase and a liquid phase. The separated liquid phase is lead out of the centrifugal separator via a liquid outlet 29, back to the crankcase 41. The gaseous phase is lead out of the centrifugal separator 1, via a gas

outlet 30 and an outlet conduit 35, to a fresh gas inlet of the ICE 40.

[0034] Figure 2 shows a section of a prior art centrifugal crankcase gas separator 1 for which embodiments may be implemented. The separator 1 comprises a stationary casing 2, which is configured to be mounted to a combustion engine (such as engine XX illustrated in Figure 1), such as a diesel engine. The separator 1 is mounted at a suitable position, for instance on top or at a side of the combustion engine.

[0035] It is to be noted that the separator 1 also is suitable for cleaning gases from other sources than combustion engines, for instance machine tools which frequently contains large amounts of liquid impurities in the form of oil droplets or oil mist.

[0036] The stationary casing 2 encloses a separation space 3 through which a gas flow is permitted. The stationary casing 2 comprises, or is formed by, a surrounding side wall 4, a first end wall 5 and a second end wall 6.

[0037] The separator 1 comprises a rotating member 7, which is arranged to rotate around an axis X of rotation. It should be noted that the stationary casing 2 is stationary in relation to the rotating member 7, and preferably in relation to the combustion engine to which it may be mounted.

[0038] The rotating member 7 comprises a spindle 8 and a stack of separation discs 9 attached to the spindle 8. All the separation discs of the stack 9 are provided between a first end plate 10 and a second end plate 11.

[0039] The spindle 8, and thus the rotating member 7, is rotatably supported in the stationary casing 2 by means of a first bearing 12 and a second bearing 13, the bearings being arranged one on each side of the stack of separation discs 9. The upper bearing 12 is supported by a cap 19 which by a cylindrical part surrounds an upper end portion of the centrifugal rotor shaft, i.e. the spindle 8, the upper end portion being situated axially above the upper bearing 12. The cap 19 also has an annular plain portion 20, through which the cap is supported by a partition 21 in the stationary casing 2. The plain annular portion 20 of the cap 19 is provided with through holes 22, through which the inlet conduit 18 communicates with a central space 15.

[0040] Axially above the upper bearing 12 the cap 19 supports on its inside, around the end portion of the spindle 8, a stator 24 belonging to an electrical motor 23. A rotor 25 belonging to this electrical motor 23 is supported by the end portion of the centrifugal rotor shaft, i.e. the spindle 8. A narrow annular slot 26 is formed between the motor stator 24 and the motor rotor 25. As can be seen, the electrical motor 23 in this example has no bearings of its own, through which its rotor 25 would be rotatably journalled in its stator 24. Instead, the two bearings 12 and 13, through which the rotating member 7 is journalled in the stationary casing 2, are utilized for the journalling of the rotor 25 of the electrical motor 23.

[0041] The separation discs of the stack 9 are frusto-

conical and extend outwardly and upwardly from the spindle 8. The separation discs thus comprise a flat portion 9a, which extend perpendicularly to the axis of rotation X, and a conical portion 9b, that extend outwardly and upwardly from the flat portion 9a.

[0042] It should be noted that the separation discs also could extend outwardly and downwardly, or even radially.

[0043] The separation discs of the stack 9 are provided at a distance from each other by means of distance members (not disclosed) in order to form gaps 14 between adjacent separation discs 9, i.e. a gap 14 between each pair of adjacent separation discs 9. The axial thickness of each gap 14 may e.g. be in the order of 1-2 mm.

[0044] The separation discs of the stack 9 may be made of plastic or metal. The number of separation discs in the stack 9 is normally higher than indicated in Figure 2 and may be for instance 50 to 100 separation discs 9 depending on the size of the centrifugal separator.

[0045] The rotating member 7 defines the central space 15 formed by a hole in each of the separation discs 9. In the example of Figure 2, the central space 15 is formed by a plurality of through holes 16, each extending through the first end plate 10 and through each of the separation discs 9, but not through the second end plate 11. The through holes 16 are arranged in the flat portions 9a of the separation discs.

[0046] The separator 1 comprises a gas inlet 17 for the supply of the gas to be cleaned. The gas inlet 17 extends through the stationary casing 2, and more precisely through the first end wall 5. The gas inlet 17 communicates with the central space 15 so that the gas to be cleaned is conveyed from the inlet 17 via the central space 15 to the gaps 14 of the stack of separation discs 9. The gas inlet 17 is configured to communicate with the crankcase of the combustion engine (or any other source of gas) via the inlet conduit 18 permitting the supply of crankcase gas from the crankcase to the gas inlet 17 and further to the central space 15 and the gaps 14 as explained above.

[0047] The centrifugal separator 1 comprises a drainage outlet 29 configured to permit discharge of liquid impurities separated from the gas and a gas outlet 30 configured to permit discharge of cleaned gas, as previously described with reference to Figure 1. The drainage outlet is in this example arranged as a conduit in the second end wall 6, but the drainage outlet 29 may also be embodied in the form of through holes arranged in the lower end wall 6 so that separated liquid impurities flow through the second bearing 13 as they are drained from the separation space 3. Furthermore, the gas outlet 30 is in this example arranged in the second end wall 6 at a radial distance that is shorter than the radial distance to the drainage outlet 29, but the gas outlet 30 could also be arranged e.g. in the surrounding side wall 4.

[0048] By means of control unit 28, the rotational speed and thereby the cleaning efficiency of the centrifugal separator 1 may be controlled in a suitable way so that a required cleaning of the supplied gas is obtained.

[0049] This is achieved by means of connection 27, which extend into the casing 1 and further through the cap 14 into the stator 18 of the motor. This connection 27 could also be used for supplying the electrical motor 23 with current.

[0050] The control unit 28 includes a device for driving the electrical motor 23 at different speeds. Different kinds of devices for speed regulation of motors (both direct-current and alternate-current motors) are well known. For a direct-current motor a simple device for voltage control may be used. For an alternate-current motor various kinds of frequency control equipment may be used.

[0051] The control unit 28 may further comprise a communication interface 31, such as a transmitter/receiver, via which it may receive data from the electrical motor 23 and various sensors or the engine to which the separator is mounted and further transmit data to the electrical motor 23.

[0052] The received data may for instance include data on a measured pressure from a pressure sensor 32 at the gas inlet 17, as indicated by dotted arrow "A". The transmitted data may for instance include a control signal for controlling the speed of the electrical motor 23.

[0053] The control unit 28 is further configured to carry out a method for detecting detachment of the conduit 18 from the inlet 17 of the separator 1 by measuring a load of the electrical motor 23 according to embodiments disclosed herein. For this purpose, the control unit 28 may comprise a processing unit 33, such as a central processing unit, which is configured to execute computer code instructions which for instance may be stored in a memory 34 such as a Random Access Memory (RAM), a Flash memory or a hard disk drive. The memory 34 may thus form a (non-transitory) computer-readable medium for storing such computer code instructions.

[0054] The processing unit 33 is arranged to cause the control unit 28 to carry out the method according to embodiments when an appropriate computer program comprising computer-executable instructions is downloaded to the memory 34 and executed by the processing unit 33.

[0055] The memory 34 may also be a computer program product comprising the computer program. Alternatively, the computer program may be transferred to the memory 34 by means of a suitable computer program product, such as a Digital Versatile Disc (DVD) or a memory stick. As a further alternative, the computer program may be downloaded to the memory 34 over a network.

[0056] The processing unit 33 may alternatively be embodied in the form of a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field-programmable gate array (FPGA), a complex programmable logic device (CPLD), etc. The control unit 28 may further comprise a communication interface (wired and/or wireless) over which the control unit 28 is configured to transmit and receive data, for instance to an Electronic Control Unit (ECU) of a vehicle in which the

separator 1 is arranged.

[0057] In this example, the control unit 28 is separate from the centrifugal separator 1. However, the control unit 28 may also be a part of the separator 1, such as forming a part of the electrical motor 23. Thus, the control unit 28 with all its functions could be arranged at the electrical motor 23, such as being connected to the stator 24 supported by the cap 19.

[0058] During operation, the rotating member 17 is kept in rotation by supply of current to the electrical motor 23, and contaminated gas - e.g. crankcase gas from the crankcase of an internal combustion engine - is supplied to the gas inlet 17 via the conduit 18. This gas is conducted further into the central space 15 and from there into and through the interspaces 14 between the separation discs of the stack 9. As a consequence of the rotation of the rotating member 7, the gas is brought to rotate, whereby it is pumped further on radially outwardly through gaps or the interspaces 14.

[0059] During the rotation of the gas in the interspaces 14, solid or liquid particles suspended in the gas are separated therefrom. The particles settle on the insides of the conical portions 9b of the separation discs and slide or run after that radially outwardly thereon. When the particles and/or liquid drops have reached out to the outer edges of the separation discs, they are thrown away from the rotor and hit the inner surface of the surrounding wall 4 of the stationary casing 2. The particles continue downwardly along this wall and leave the separation space 3 through the drainage outlet 29, whereas the gas freed from particles and exiting from the stack of separation discs 9 leaves the casing 1 through the gas outlet 30 and the outlet conduit 35. The path of the gas through the centrifugal separator 1 is schematically shown by arrows "C" in Figure 2.

[0060] As discussed above, the control unit 28 controls the rotational speed of the rotating part of the separator 1 by sending signals to the electrical motor 23. In this example, the control unit is configured to control the electrical motor 23 to drive at three different drive modes; a first drive mode having a first constant rotational speed of between 7.500 and 12.000 rpm and which represents a nominal speed of the separator 1, a second drive mode having a second constant rotational speed that is about 2000 rpm above the first constant rotational speed and a third drive mode having a third constant rotational speed that is about 2000 rpm below the first constant rotational speed.

[0061] Now, the separator 1 is a vital part of the emission controlling system of a diesel engine and as previously mentioned, it is crucial for the cleaning process that the conduit 18 is not removed from the inlet 17 of the separator 1 (or that the outlet conduit 35 is not removed from the gas outlet 30).

[0062] However, the inlet conduit 18 (typically a hose-type connection) can easily be disconnected from the separator 1; the conduit 18 to the separator 1 must be detachable for service reasons, which also makes it easy

to disconnect the conduit 18 from the separator 1. In many installations, the conduit 18 transporting the crankcase gases is connected to the separator 1 with a snap-fit connection.

[0063] While detachment of the inlet conduit 18 from the inlet 17 of the separator 1 will be described herein with reference to various embodiments, a similar approach may be utilized for detecting detachment of the outlet conduit 35 from the outlet 30 of the separator 1.

[0064] If the separator 1 is disconnected the certified emission legislation is not fulfilled. Forthcoming emission legislations, e.g. Euro 7, will most likely include requirements stipulating a tamper free and/or tamper evident connection to the separator, and possibly even requiring tamper detection diagnostics to be provided.

[0065] There are two scenarios for the conduit 18 being detached from the inlet 17 of the separator 1, either:

(a) the conduit 18 is detached from the inlet 17 with the inlet 17 being left open, or

(b) the conduit 18 is detached from the inlet 17 with the inlet 17 being plugged.

[0066] In scenario (a), a result would be that the blow-by gas flow rate (i.e. air entering the inlet 17) causes a relatively high load on the separator 1 in that the rotating member 7 is caused to rotate at a higher speed with the free air flow entering the inlet 17. Thus, with an open inlet 17 the separator 1 will pump air/gas at a high and less fluctuating flow rate.

[0067] In scenario (b), a result would in contrast be that the blow-by gas flow rate causes a relatively low load on the separator 1 in that the rotating member 7 is caused to rotate at a lower speed with no or just a small amount of free air flow entering the plugged inlet 17. Thus, with a plugged inlet 17 the separator 1 will pump air/gas at a low and less fluctuating flow rate.

[0068] The load of the separator 1 may be indirectly measured by measuring power consumption of the electrical motor 23 that causes the rotating member 7 for creating the flow of blow-by gas through the separator 1; the higher the blow-by gas flow rate, the higher the power consumption of the motor 23.

[0069] In an example, at idle operation of the ICE 40, a typical blow-by flow rate is 50-60 l/m while at max ICE torque the blow-by flow rate amounts to 150 - 250 l/m, which is directly reflected in the power consumption of the electrical motor 23.

[0070] Figure 3 illustrates the power consumption of the motor 23 as a function of blow-by flow rate at 20°C and 100°C, respectively. As can be seen, for a given operational mode of the ICE 40, the power consumption of the motor 23 is linear with the blow-by flow rate.

[0071] Figures 4a and 4b illustrate two different separator load scenarios - as represented by power consumption of the motor 23 driving the rotating member 7 of the separator 1 - measured over a time period in a

sequence of measurements according to an embodiment. Typically, the measurements made for determining conduit detachment are performed during an upstart phase of the vehicle in which the separator 1 is arranged.

[0072] Reference is further made to Figure 5 showing a flowchart illustrating a method of detecting detachment of the inlet conduit 18 of the separator 1 according to an embodiment.

[0073] In a first step S101, the load L of the electric motor 23 is measured. As is understood, this may be performed by the control unit 28 measuring consumed power, or indirectly consumed current of the motor 23 operating the rotating member 7 of the separator 1. As is understood, this may be the control unit 28 directly controlling the separator 1 but may alternatively be embodied by a control unit of the vehicle in which the separator 1 is arranged, such as e.g. an ECU commonly used in trucks or cars for controlling functionality of the vehicle.

[0074] Thereafter, in step S102, it is determined whether or not the measure motor load L is either above a set upper load threshold value TU or below a set lower load threshold value TL.

[0075] With reference to Figure 4a, it is illustrated that the measured motor load exceeds a set upper load threshold value TU of 60 W.

[0076] With reference to Figure 4b, it is illustrated that the measured motor load is below a set lower load threshold value TL of 20 W.

[0077] Hence, if any of the scenarios of Figures 4a and 4b occurs, the conduit 18 to the inlet 17 of the separator 1 is detected in step S103 to have been detached.

[0078] In Figure 4a, the conduit 18 is indicated to have been detached from the inlet 17 with the inlet 17 left open while in Figure 4b, the conduit 18 is indicated to have been detached from the inlet 17 with the inlet 17 plugged. The scenario of Figure 4b could occur if a vehicle owner by purpose blocks the inlet 17 to the separator 1, and leaves the blow-by gas leaking out into the atmosphere. Advantageously, with the method of Figure 5, any removal of the conduit 18 from the inlet of the separator 1 is detected.

[0079] As is understood, while Figures 4a and 4b for brevity show 24 sequential measurements of the motor load, in practice hundreds or thousands of sequential measurements may be undertaken.

[0080] As previously mentioned, while the control unit 28 may perform all steps S101-S103, the steps may alternatively be performed by the ECU of the vehicle in which the separator 1 is installed. It may also be envisaged that some step(s) are performed by the control unit 28 while others are performed by the ECU. For instance, the control unit 28 may perform the measurement of step S101 and provide the ECU with the measured load, wherein the ECU performs steps S102 and S103.

[0081] Figures 6a and 6b illustrate motor load during two normal operational modes of the ICE 40 with the conduit 18 firmly being attached to the inlet 17 of the separator 1.

[0082] Figure 6a illustrates a high-load operational mode, where for instance a vehicle in which the ICE 40 is arranged to travel uphill causing the ICE 40 to operate at high load.

[0083] For instance, in a specified high-load operational mode, where for instance ICE load > 75%, the following conditions may prevail:

- ICE speed 1.200 ± 100 rpm,
- ICE running time >10 minutes since ignition,
- ICE oil temperature > 100°C or separator temperature within its working range (if the separator temperature is available),
- Separator speed 9.800-10.200 rpm (i.e. the speed of the rotating member)

[0084] To the contrary, Figure 6b illustrates a low-load operational mode, where for instance the vehicle in which the ICE 40 is arranged travels downhill causing the ICE 40 to operate at low rpms.

[0085] For instance, in a specified low-load operational mode, the following conditions may prevail:

- ICE running on idle,
- ICE running time >10 minutes since ignition,
- ICE oil temperature > 100°C or separator temperature within its working range (if the separator temperature is available),
- Separator speed 9.800-10.200 rpm (i.e. the speed of the rotating member)

[0086] Thus, in an embodiment, when setting the upper and lower load threshold values TU, TL, the operational mode of the ICE 40 may be taken into account such that the set threshold values TU, TL do not coincide with the motor loads that typically would occur during the measurements during which presence of the conduit 18 is to be detected.

[0087] In other words, if TU = 60 W, then the conduit presence measurement should advantageously be performed at an operational mode of the ICE 40 where such motor load typically is not reached. As illustrated in Figure 6a, some measured load values will occasionally exceed TU = 60 W, which thus could be mistaken for a detached conduit 18 which in the example of Figure 6a is not the case.

[0088] A similar reasoning can be made for Figure 6b where a low-load operational mode is illustrated.

[0089] Thus, an operational mode may be selected for the ICE 40 where an expected load of the motor 23 will not exceed the upper load threshold value TU in case detection of a detached conduit 18 with an open inlet 17 is

attempted, while an operational mode may be selected for the ICE 40 where an expected load of the motor 23 does not fall below the lower load threshold value TL in case detection of a detached conduit 18 with a plugged inlet 17 is attempted.

[0090] As is understood, numerous parameters may affect the load of the motor 23 driving the rotating member 7 of the separator 1, such as e.g. power and/or current consumption of the particular motor 23 being utilized, oil temperature, separator rotational speed, separator temperature, ICE load, vehicle mileage or separator age, engine air inlet pressure (pressure after engine filter but before turbo compressor), key ignition, etc.

[0091] As further illustrated in Figures 6a and 6b, during normal operation of the ICE 40 with the conduit 18 being correctly attached to the inlet 17 of the separator 1, the load will typically vary momentarily since the gas entering the separator 1 normally comprises oil, soot, and various particles, while in the case of a detached conduit 18, the load is relatively constant.

[0092] In an embodiment, to avoid motor load as a result of a normal operational mode of the ICE 40 being mistaken for a detected detached conduit 18, the measured load may have to exceed the set upper load threshold value TU (or be below the set lower load threshold value TL) for a specified time period, i.e. for a specified number M of sequential measurements.

[0093] With reference to Figures 7a and 7b (and again to Figures 6a and 6b), if for instance the measured load of the motor 23 is required to either exceed the set upper load threshold value TU or be below the set lower load threshold value TL for, say, $M = 10$ sequential measurements for the conduit 18 to be detected as having been detached from the inlet 17, then neither of the scenarios of Figures 6a and 6b would result in the conduit 18 being erroneously detected as being detached.

[0094] As is understood, if in practice hundreds or even thousands of sequential measurements are made, then M would be far greater than just 10 measurements, such as hundreds or thousands of consecutive measurements.

[0095] Figures 8a and 8b illustrate a further embodiment, where in addition to requiring that the measured motor load is above TU or below TL for M consecutive measurements, the measured motor load is not allowed to exceed a further still higher set upper load threshold value TU' (in this example set to 70 W) or to be below a further still lower set lower load threshold value TL' (in this example set to 10 W).

[0096] Reference is further made to the flowchart of Figure 9. Thus, after the load L of the motor 23 has been measured in step S101, it is determined in step S102 that either that the load L exceeds the set upper load threshold value TU but does not exceed the further still higher set upper load threshold value TU', i.e. $TU < L \leq TU'$, or that the load L is below the set lower load threshold TL but is not lower than the further still lower set lower load threshold value TL', i.e. $TL < L \leq TL'$, and in this example

embodiment that any of these scenarios prevail for at least $M = 10$ sequential measurements.

[0097] If so, the control unit 28 detects in step S103 that the conduit 18 is indicated to have been detached from the inlet 17 of the separator 1.

[0098] In this embodiment, an alert is further provided in step S104 that the conduit 18 has been detected to have been detached.

[0099] If the control unit 28 performs the detection, then the control unit 28 may alert the ECU of the vehicle of the detection of the detached conduit 18. If the ECU performs the detection, the ECU may provide an alert to a driver of the vehicle of the detection of the detached conduit 18, for instance via the dashboard of the vehicle. As is understood, the alert may be provided in any of the embodiments described herein.

[0100] This advantageously further ensures that a normal operational mode of the ICE 40 does not result in erroneous detection of the conduit 18 having been detached from the inlet 17 of the separator.

[0101] Advantageously, with the embodiments of Figures 7a, 7b and 8a, 8b, it may further not be necessary to adapt the setting of the load threshold values to the operational mode of the ICE 40, since in these embodiments, the measure load values are not allowed to vary to any great extent for a detached conduit 18 to be detected in contrast to a normal operational mode where the measured load values tend to vary to a far greater extent (cf. Figures 6a and 6b).

[0102] Thus, even if the measured load values partly would coincide with load values that can be expected given the applied load scenario (i.e. low-load or high-load), the small variation advantageously indicates detachment of the conduit 18.

[0103] Figure 10 illustrates a flowchart of a method of a further embodiment, where the load of the motor 23 is measured at different operational modes of the ICE 40, e.g. during the previously discussed high-load operational mode and low-load operational mode, the rationale being that if the measured motor load is the same (or at least similar) for both operational modes, then the conduit 18 must have been detached from the inlet 17 of the separator 1.

[0104] Thus, in step S101, the load of the motor 23 is measured during a low-load operational mode while in step S101, the load of the motor 23 is measured during a high-load operational mode (or vice versa).

[0105] If the conduit 18 is attached correctly to the inlet 17 of the separator 1, the measurements would result in the load values illustrated in Figure 4a for the high-load operational mode and in the load values illustrated in Figure 4b for the low-load operational mode.

[0106] However, if the conduit 18 is detached and the inlet 17 is left open, the measurements of S101 and S101a would both be determined in step S102 to have the appearance illustrated in e.g. Figure 7a, i.e. $TU < L \leq TU'$, while if the conduit 18 is detached and the inlet 17 is plugged, the measurements of S101 and S101a would

both be determined in step S102 to have the appearance illustrated in e.g. Figure 7b, i.e. $TL < L \leq TL'$, and the conduit will be detected in step S103 to be detached.

[0107] Advantageously, this embodiment even further enables avoiding a situation where a motor load measurement performed during normal operation of the ICE erroneously would indicate the conduit 18 being detached from the inlet 17 of the separator 1.

[0108] Figure 11 illustrates an embodiment, where an instant detachment of the conduit 18 is detected, i.e. not a conduit detachment having been performed in advance, but the conduit 18 detaching during ongoing operation of the ICE 40.

[0109] Thus as can be seen, upon the conduit 18 detaching from the inlet 17 of the separator 1 at time T_0 , the load of the motor 23 (represented by either power or current consumption) will increase instantly from 40W and exceed the upper load threshold value - in this example set to 55W - at time T_1 and remain at around 57W.

[0110] Thus, in this example, if the measured load increases from a first lower level of 40 W to a second higher level of 57W (with a temporary overshoot to 60W) exceeding the upper threshold load value $T_U = 55W$ within a specified time period, in this example set to $T_1 - T_0$, the conduit 18 is detected to have detached from the inlet 17 of the separator 1.

[0111] The aspects of the present disclosure have mainly been described above with reference to a few embodiments and examples thereof. However, as is readily appreciated by a person skilled in the art, other embodiments than the ones disclosed above are equally possible within the scope of the invention, as defined by the appended patent claims.

[0112] Thus, while various aspects and embodiments have been disclosed herein, other aspects and embodiments will be apparent to those skilled in the art. The various aspects and embodiments disclosed herein are for purposes of illustration and are not intended to be limiting, with the true scope and spirit being indicated by the following claims.

Claims

1. A method of a control unit (28) of detecting detachment of a gas flow conduit (18) arranged to be attached to a crankcase gas separator (1) in fluid connection with a crankcase (41) of a combustion engine (40), comprising:

measuring (S101) a load of a motor (23) operating the crankcase gas separator (1);
determining (S102) whether at least one of the measured load exceeds an upper load threshold value and the measured load is below a lower load threshold value; and if so
detecting (S103) that the gas flow conduit (18) is

indicated to have been detached from the crankcase gas separator (1).

2. The method of claim 1, the gas flow conduit being an inlet conduit (18) arranged to be attached to an inlet (17) of the crankcase gas separator (1) or an outlet conduit (35) arranged to be attached to an outlet (30) of the crankcase gas separator (1).
3. The method of claim 2, wherein the measured load exceeding the upper load threshold value indicates that the inlet conduit (18) has been detached from the crankcase gas separator (1) with the inlet (17) being open or that the outlet conduit (35) has been detached from the crankcase gas separator (1) with the outlet (30) being open.
4. The method of claims 2 or 3, wherein the measured load being below the lower load threshold value indicates that the inlet conduit (18) has been detached from the crankcase gas separator (1) with the inlet (17) being plugged or that the outlet conduit (35) has been detached from the crankcase gas separator (1) with the outlet (30) being plugged.
5. The method of any one of the preceding claims, wherein the determining (S102) of the measured load exceeding an upper threshold load value comprises:
determining that the measured load increases from a first lower level to a second higher level exceeding the upper load threshold value within a specified time period.
6. The method of any one of the preceding claims, wherein the determining (S102) of the measured load exceeding an upper threshold load value comprises:
determining that the measured load exceeds the upper threshold load value for a specified number of sequential load measurements.
7. The method of claim 6, wherein the determining (S102) that the measured load exceeds the upper threshold load value for a specified number of sequential load measurements comprises:
determining that the measured load does not exceed a yet higher threshold load value during the specified number of sequential load measurements.
8. The method of any one of the preceding claims, wherein the determining (S102) of the measured load being below a lower threshold load value comprises:
determining that the measured load is below the lower load threshold value for the specified number of sequential load measurements.

9. The method of claim 8, wherein the determining (102) that the measured load is below the lower threshold load value for a specified number of sequential load measurements comprises:
determining that the measured load does not fall below a yet lower load threshold value during the specified number of sequential load measurements.
10. The method of any one of the preceding claims, wherein upon determining (S102) that the measured load exceeds an upper load threshold value, an operational mode of the combustion engine (40) is selected where an expected load of the motor (23) will not exceed the upper load threshold value.
11. The method of any one of the preceding claims, wherein upon determining (S102) that the measured load is below a lower load threshold value, an operational mode of the combustion engine (40) is selected where an expected load of the motor (23) will not fall below the lower load threshold value.
12. The method of any one of the preceding claims, wherein the measuring (S101) of a load comprises: measuring (S101, S101a) a load of a motor (23) operating the crankcase gas separator (1) both at a first operational mode of the combustion engine (40) and at a second operational mode of the combustion engine (40), and the determining (S102) comprises:
determining (S102), for both operational modes of the combustion engine (40), whether the measured load exceeds an upper load threshold value or the measured load is below a lower load threshold value; and if so
detecting (S103) that the gas flow conduit (18) is indicated to have been detached from the crankcase gas separator (1).
13. The method of any one of the preceding claims, further comprising:
providing (S104) an alert that the gas flow conduit (18) is detected to have been detached from the crankcase gas separator (1).
14. The method of any one of the preceding claims, wherein the motor (23) is configured to cause a rotating member (7) of the crankcase gas separator (1) to rotate in order to cause the crankcase gas to flow through the crankcase gas separator (1) to be separated into a gaseous phase exiting the crankcase gas separator (1) via a gas outlet (30) and into a liquid phase exiting the crankcase gas separator (1) via a liquid outlet (29).
15. The method of any one of the preceding claims, wherein the load of the motor (23) operating the crankcase gas separator (1) is measured by either measuring power or current consumption of the motor (23).
16. A computer program comprising computer-executable instructions for causing a control unit (28) to perform the method recited in any one of claims 1-15 when the computer-executable instructions are executed on a processing unit (33) included in the control unit (28).
17. A computer program product comprising a non-transitory computer readable medium (34), the computer readable medium having the computer program according to claim 16 embodied thereon.
18. A control unit (28) configured to detect detachment of a gas flow conduit (18) arranged to be attached to a crankcase gas separator (1) in fluid connection with a crankcase (41) of a combustion engine (40), the control unit (28) being configured to:
measure (S101) a load of a motor (23) operating the crankcase gas separator (1);
determine (S102) whether at least one of the measured load exceeds an upper load threshold value and the measured load is below a lower load threshold value; and if so to
detect (S103) that the gas flow conduit (18) is indicated to have been detached from the crankcase gas separator (1).

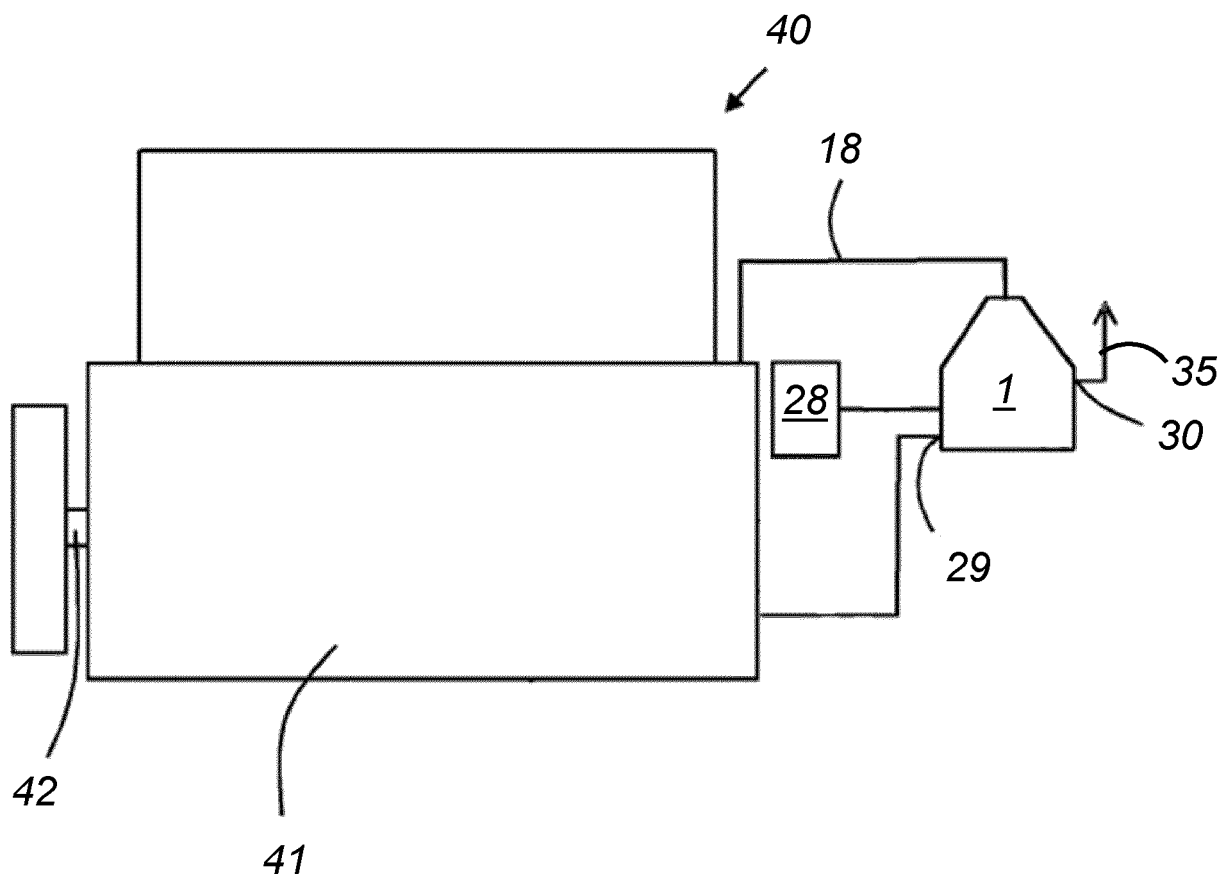


Figure 1

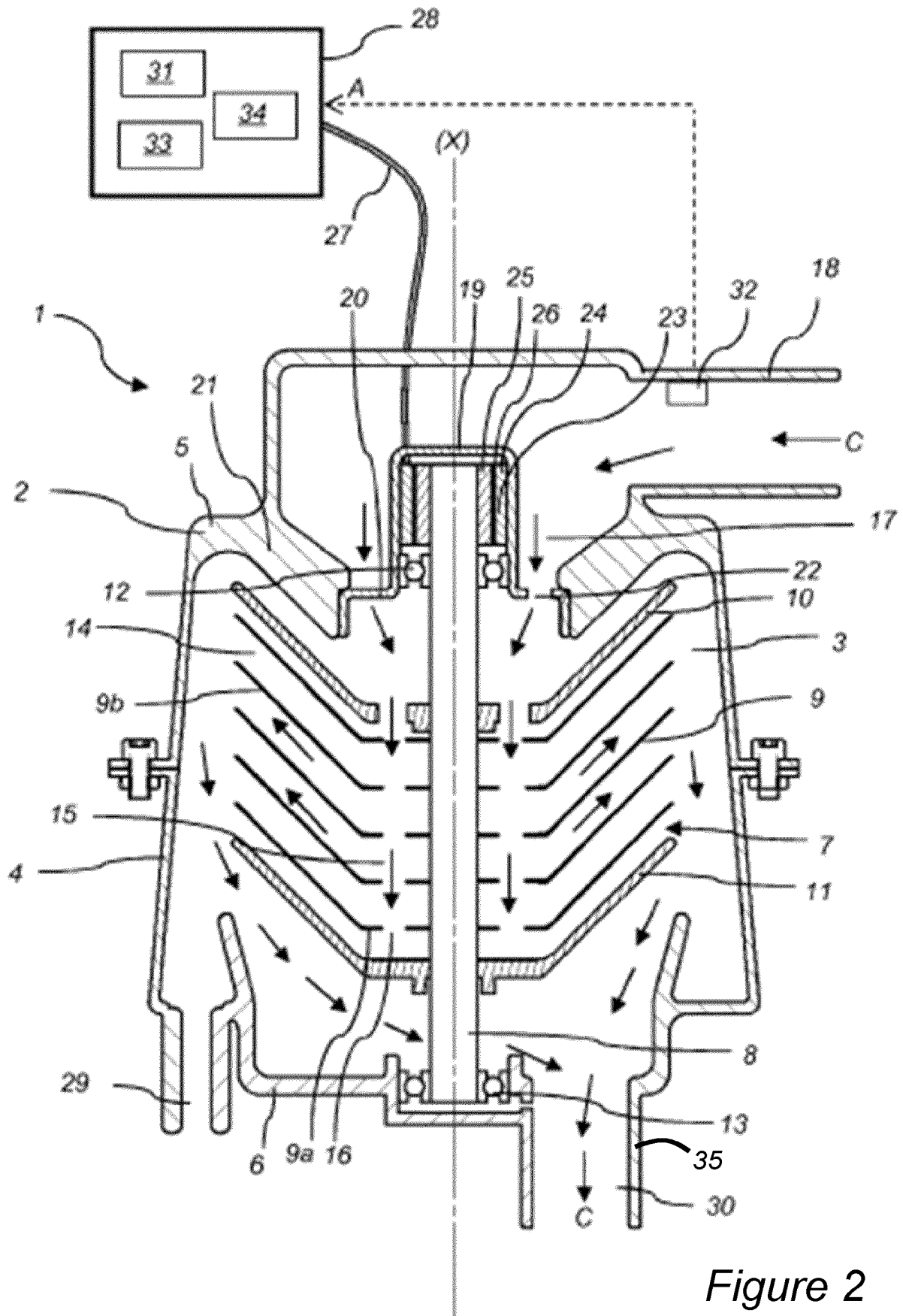
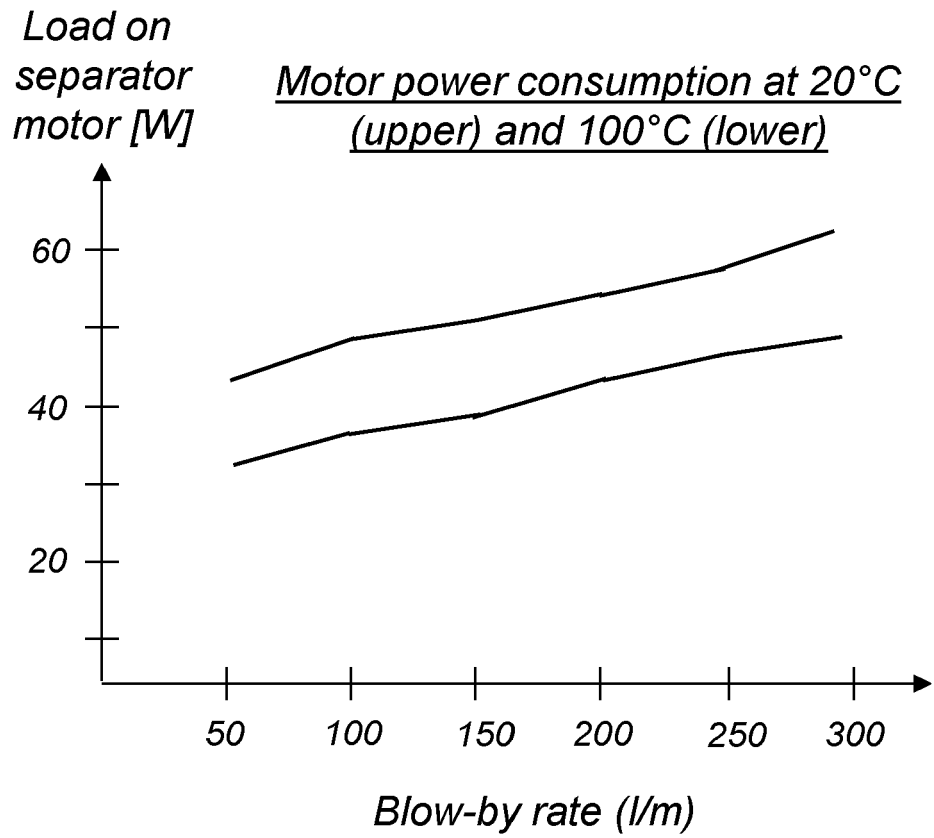


Figure 2

*Figure 3*

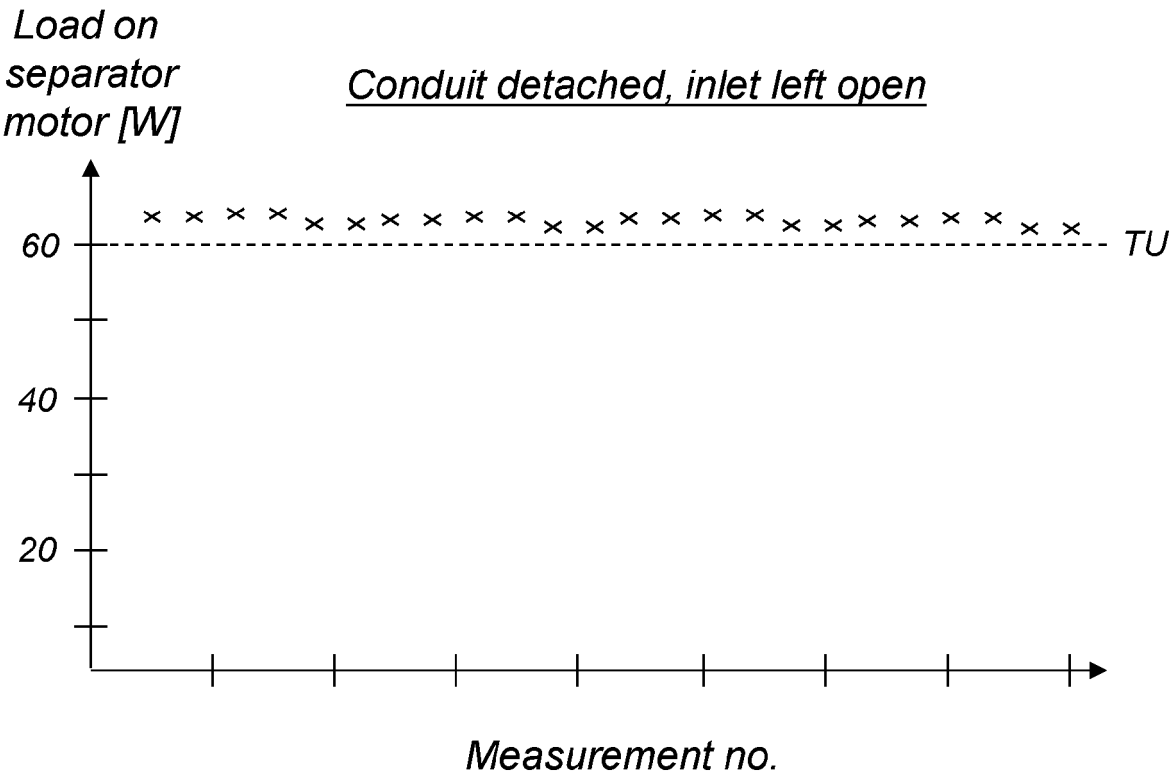


Figure 4a

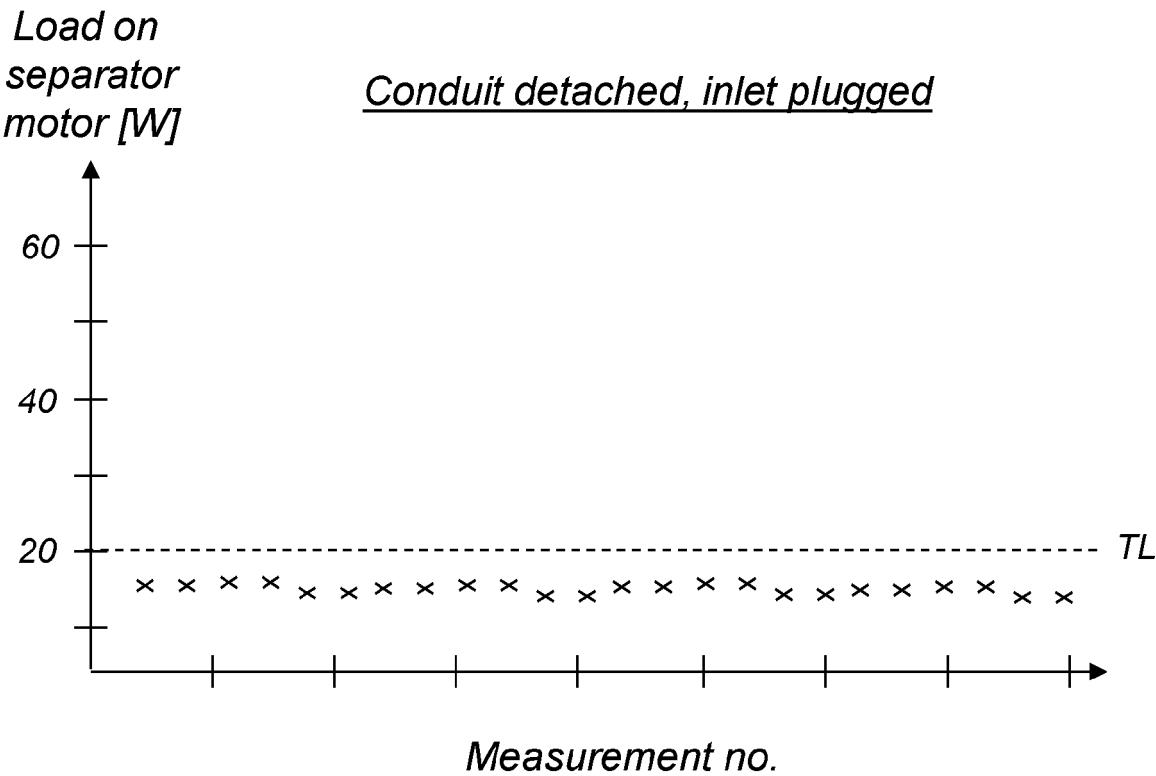
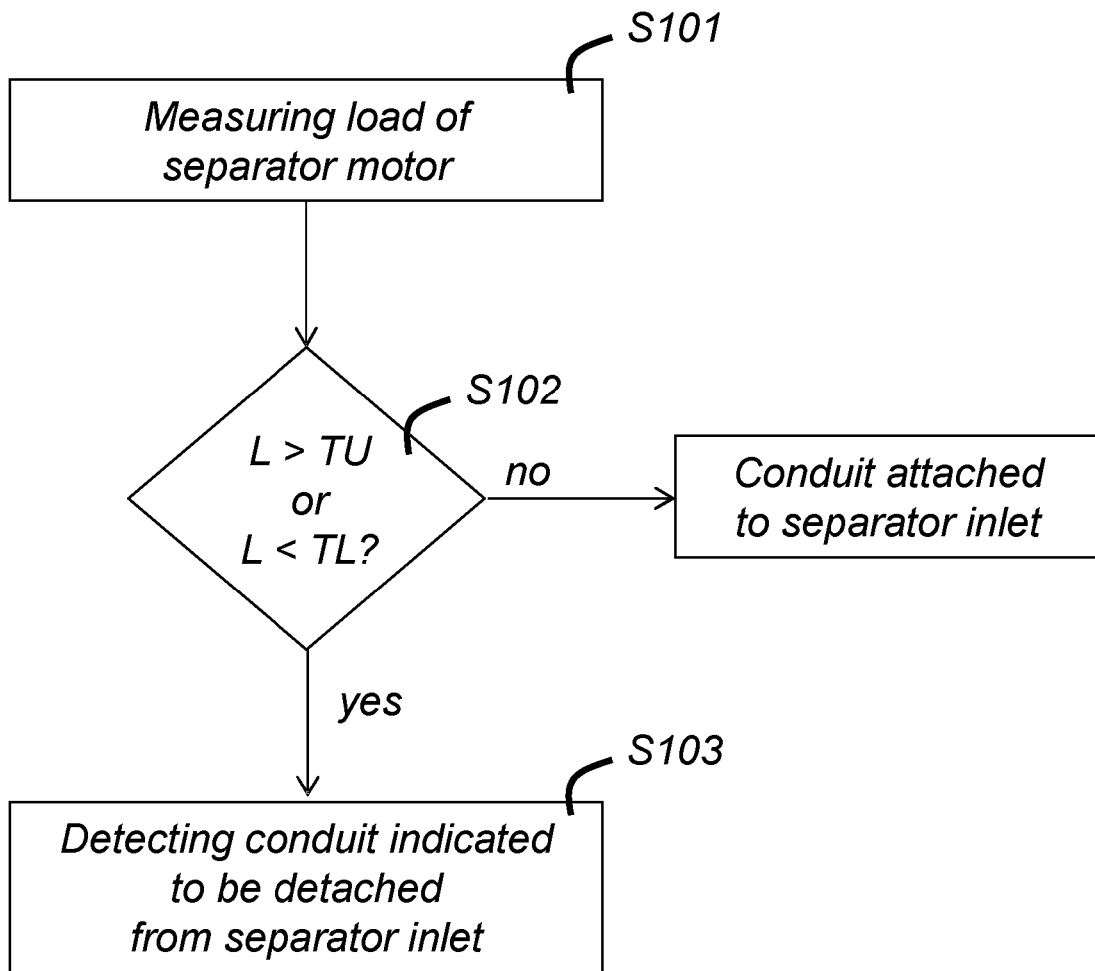


Figure 4b

*Figure 5*

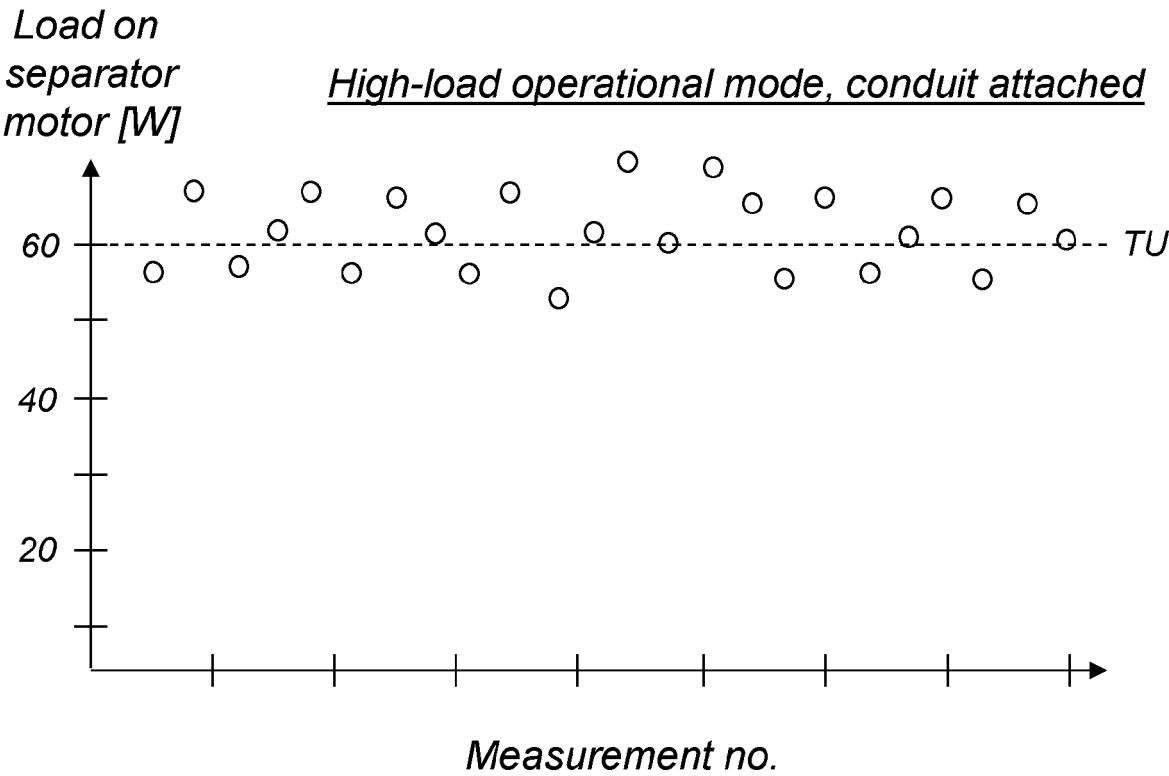


Figure 6a

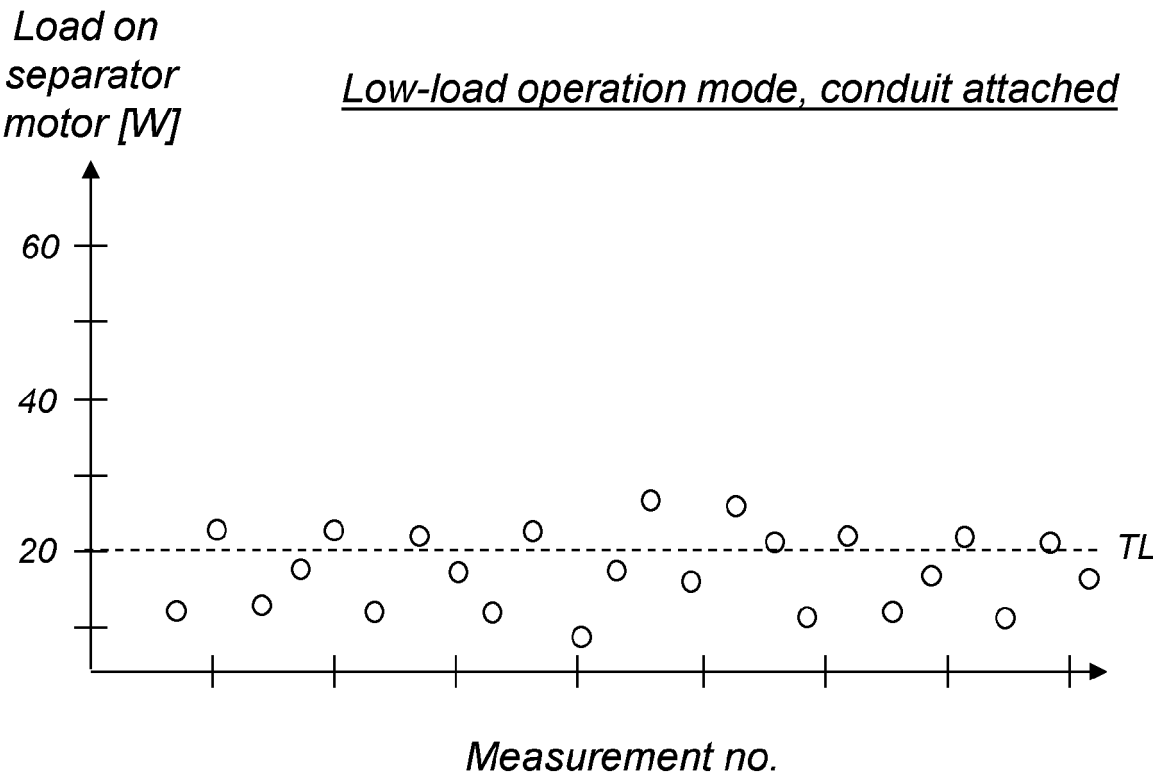


Figure 6b

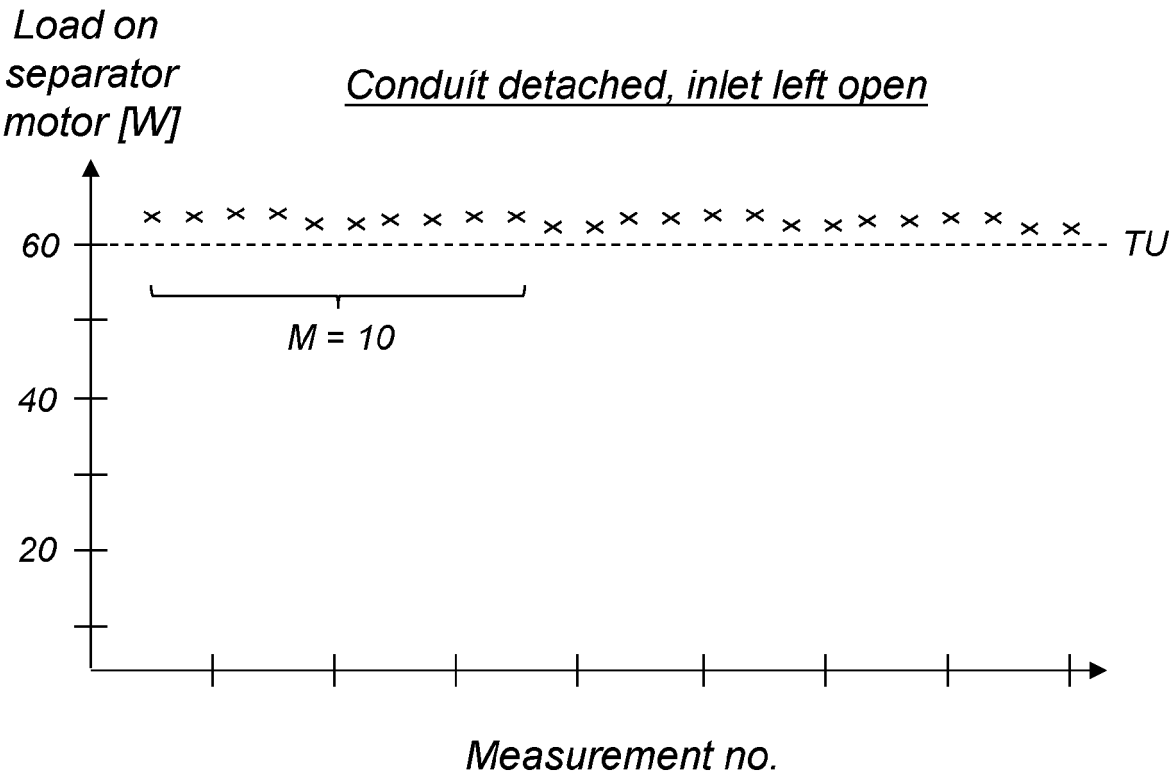


Figure 7a

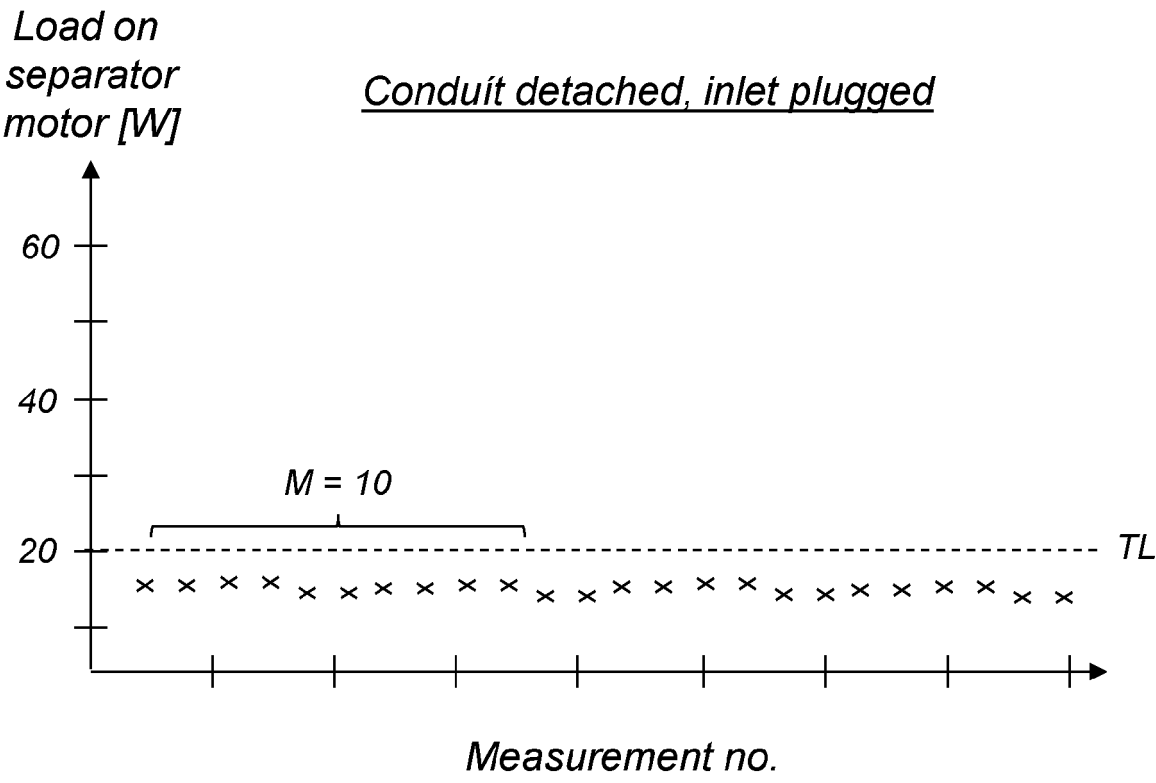


Figure 7b

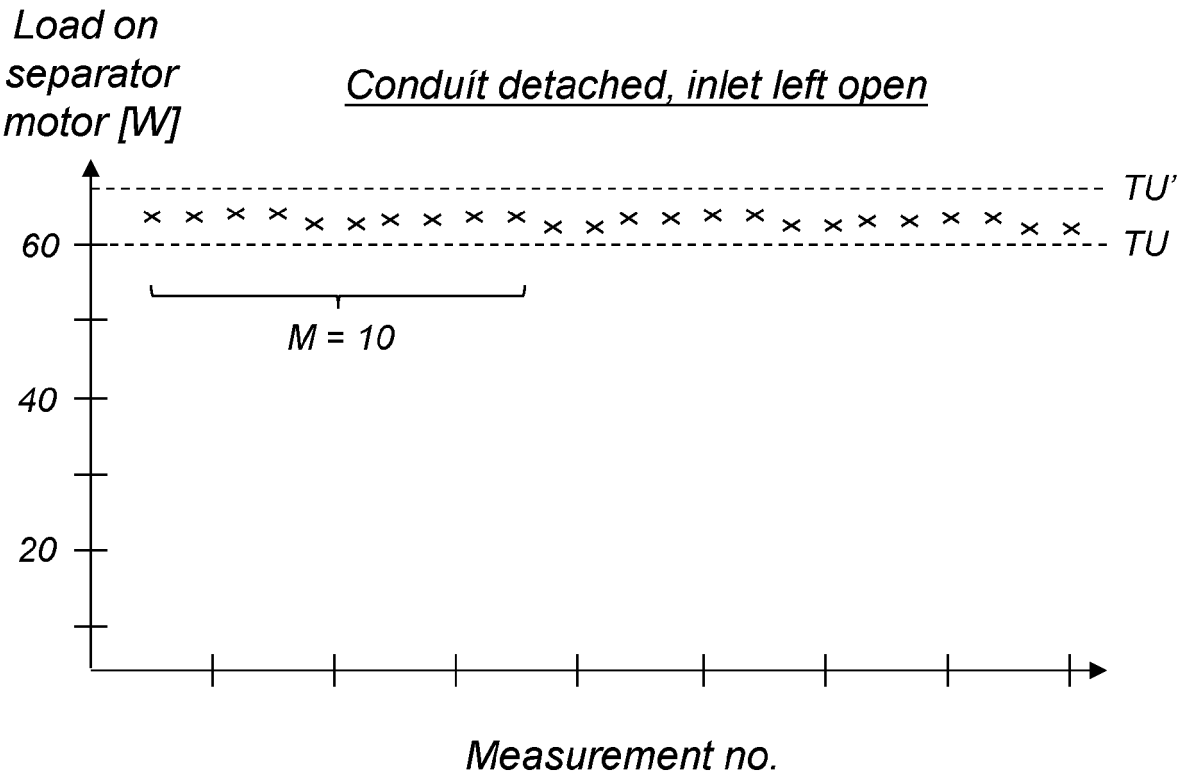


Figure 8a

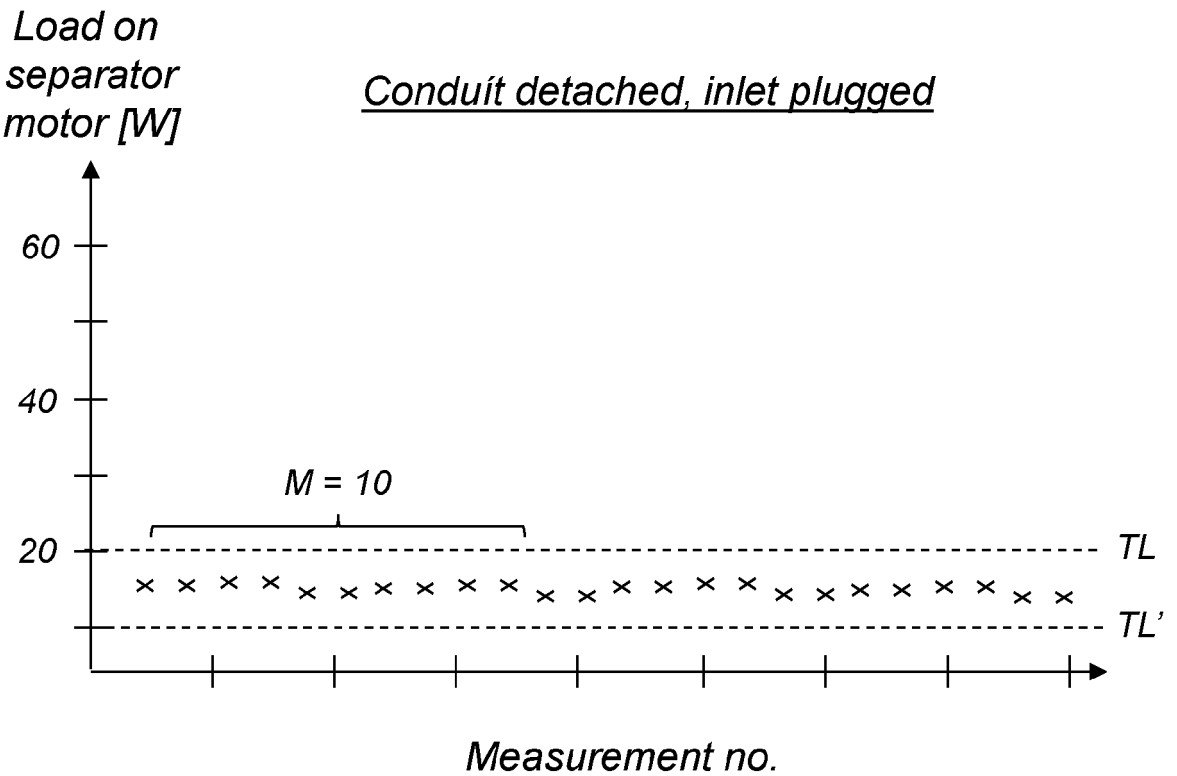


Figure 8b

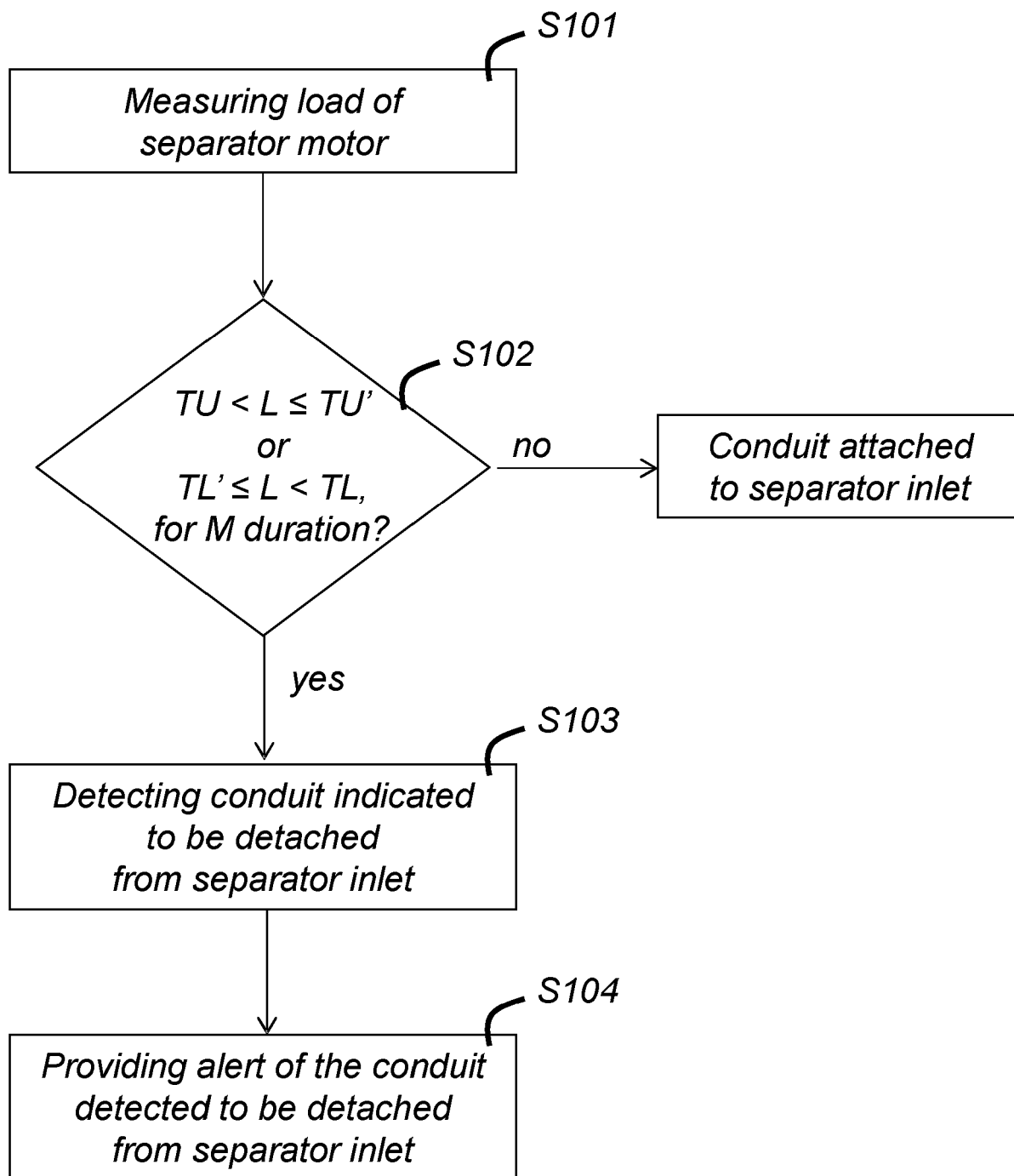


Figure 9

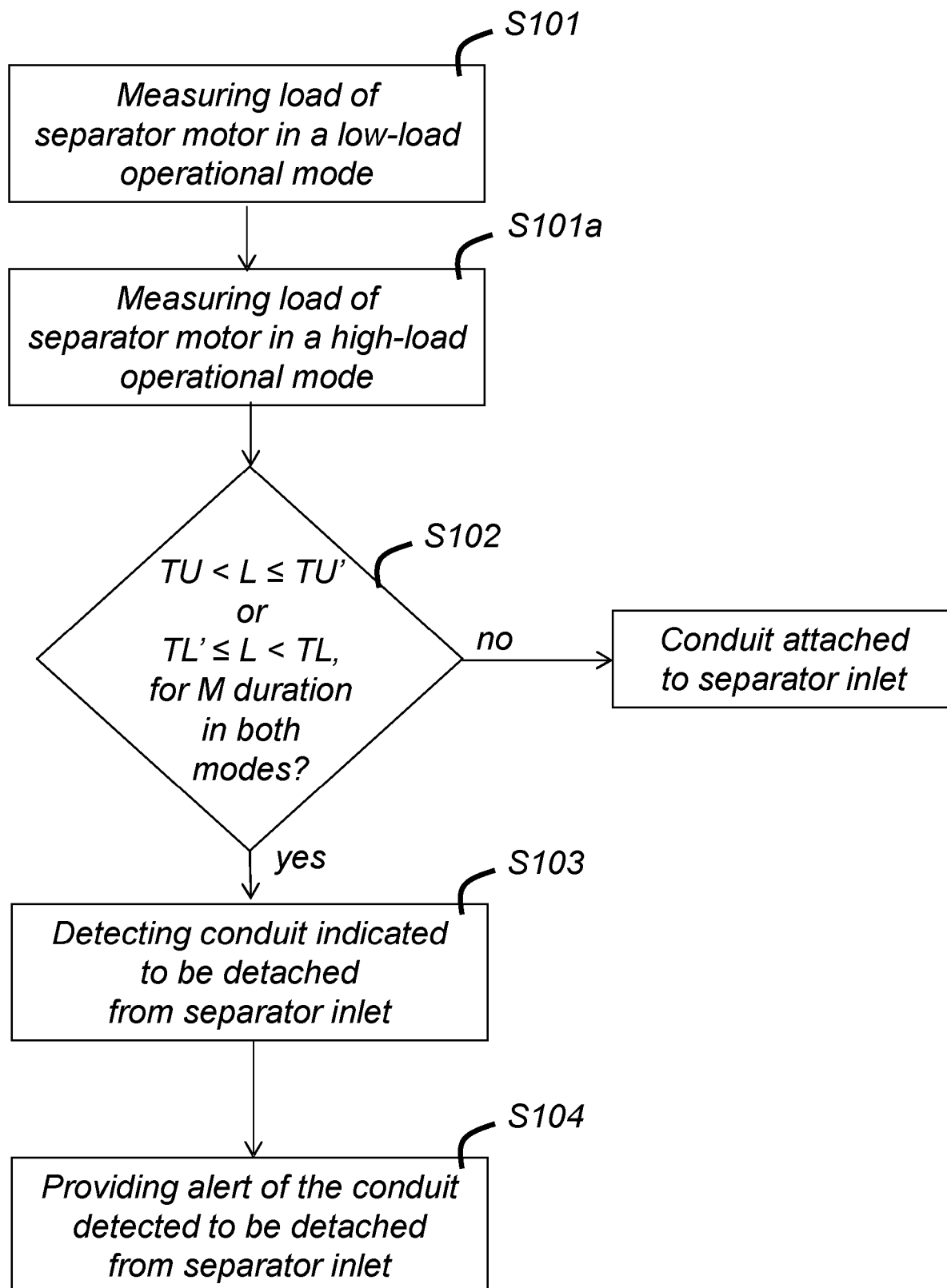
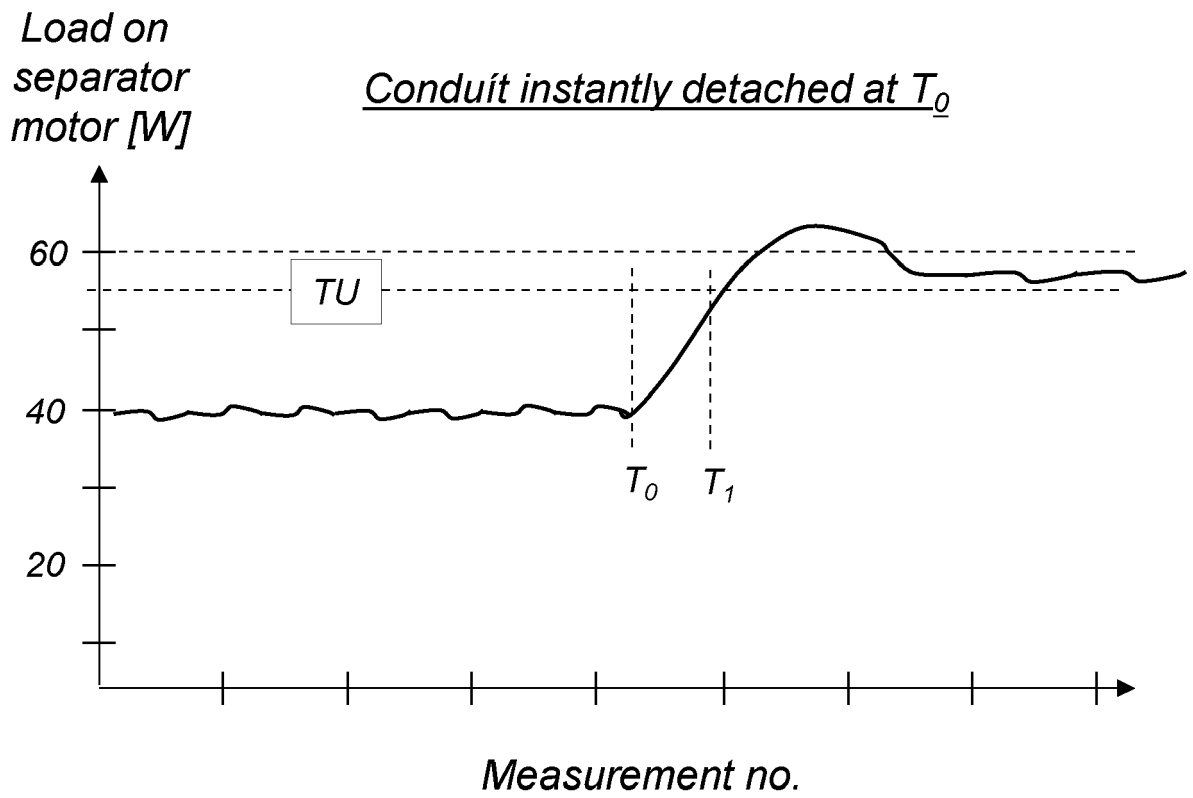


Figure 10





EUROPEAN SEARCH REPORT

Application Number

EP 23 18 1423

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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A	* paragraphs [0001], [0007], [0012] - [0015], [0028], [0063] - [0070]; figures 1-4 *	3, 4, 7, 9-11	F01M13/02 F01M13/04
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			F01M B04B B01D F02D
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
The Hague		6 December 2023	Ducloyer, Stéphane
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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