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(54) Benævnelse: **FREMGANGSMÅDE TIL OVERVÅGNING AF TILSTANDEN AF MINDST ÉN KOMPONENT, DER BELASTES UNDER DRIFTEN AF ET VINDKRAFTANLÆG**

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METHOD FOR MONITORING THE STATE OF AT LEAST ONE COMPONENT WHICH IS LOADED DURING THE OPERATION OF A WIND TURBINE

The application relates to a method for monitoring the condition of at least one component of a wind power installation that is loaded during the operation of the wind power installation, comprising sensing a first temperature of a first loaded component of the wind power installation. In addition, the application relates to a monitoring system.

A constant concern in the case of a wind power installation, in particular an offshore wind power installation, is the monitoring of the loaded components of the wind power installation. A loaded component is to be understood as meaning in particular a component of a wind power installation which is subject to loads during operation of the wind power installation. In other words, forces act on the component in this case which can cause damage to the component.

In order to detect damage in particular at an early stage, the prior art EP 2 927 662 A1 discloses installing temperature monitoring of a loaded component, for example a rolling bearing of a wind power installation. In particular, the prior art proposes sensing the temperature of the loaded component and the ambient temperature. By normalising the temperature of the component with the ambient temperature, a corresponding temperature trend becomes more meaningful.

In practice, however, the method has not proven to be sufficiently reliable. Said method has not always led to the desired clarity of results, particularly according to the measuring point of the ambient temperature and/or the type of wind power installation including the corresponding components, in particular bearings. Rather, possible temperature trends remained hidden in the uncertainties and damage to a component were only discovered at a late stage or not at all.

Since it has so far not been possible to derive reliable and significant results from the temperature measurement of a loaded component, wind power installations are additionally equipped with a so-called condition monitoring system (CMS) in practice. A CMS is configured to monitor oscillations and vibrations of the wind power installation in order to identify changes and condition deteriorations at an early stage. However, the acquisition, installation and operation of such a system is associated with a high level of complexity and corresponding costs.

Therefore, the object of the application is to provide a method for monitoring the condition of at least one component of the wind power installation that is loaded during the operation of a wind power installation, which method enables damage to a loaded component to be identified reliably and with little effort, particularly at an early stage.

According to a first aspect of the application, the object is achieved by a method for monitoring the condition of at least one component of the wind power installation that is loaded during operation of a wind power installation according to claim 1. The method comprises the sensing of a first temperature of a first loaded component of the wind power installation. The method comprises:

- sensing at least one further temperature of a further loaded component of the wind power installation,
- wherein the first loaded component and the further loaded component have a thermal coupling with one another, and
- detecting damage to at least one of the loaded components based on the sensed first temperature and the sensed further temperature and at least one allowance criterion in an evaluation step.

In contrast to the prior art, according to the application damage to a loaded component is detected at an early stage by sensing the respective temperatures of two loaded components that have a thermal coupling with one another and evaluating these temperature data for detecting possible damage to at least one of the components. Additional monitoring systems such as CMS can be omitted.

A wind power installation, for example an offshore wind power installation, is generally configured to convert the kinetic energy of the wind into electrical energy by means of a rotor and a generator. A wind power installation according to the application has a large number of components that are loaded during operation. According to the application, a loaded component is understood to be a component on which a load or a force is exerted during operation.

According to the application, temperature monitoring of at least two, preferably exactly two, loaded components is carried out. The loaded components have a thermal coupling with one another. In the present case, a thermal coupling is to be understood as meaning that the first and the further component have an at least similar temperature behaviour and at least similar environmental conditions. In particular, according to the application, there is a thermal coupling when the first and the second component experience at least a similar (mechanical and/or electrical) load and, for example, have similar environmental conditions (for example, they are arranged in the same housing or the like). According to the application, a component pair consisting of two thermally coupled components can preferably always be monitored.

For example, a temperature sensing device can be provided in the wind power installation

in order to sense the first temperature of the first loaded component and/or the further temperature of the further loaded component.
It has been found that in particular the sensed temperature data of two thermally coupled components, which in particular experience at least a similar, preferably the same, load, are good indicators of damage to at least one of the monitored components.
In particular, according to the application, in an evaluation step, damage to at least one of the loaded components is detected on the basis of the first temperature and the further temperature and at least one allowance criterion. According to the application, damage is also to be understood as possible (future) damage to the component or damage at an early stage. For example, a comparison operation of the sensed first and further temperature data with one another and/or with an allowance criterion (for example a permissible temperature range and/or at least one permissible temperature limit value) can be carried out in the evaluation step. A method for the early and, in particular reliable, identification of damaged components is provided according to the application.
According to a first embodiment of the method according to the application, the method can comprise:
- determining a differential temperature by calculating the difference between the sensed first temperature and the sensed further temperature,
- wherein, in the evaluation step, damage to at least one of the loaded components is detected on the basis of the calculated differential temperature and the at least one allowance criterion.

In particular, it has been found according to the application that a differential temperature of at least similarly loaded components represents a particularly good indicator for early identification of damage. By calculating the difference, the temperature data are compared in particular with each other in such a way that (almost) only the influence from the load on the respective components remains. During fault-free operation of the loaded components, this leads in particular — on account of the at least similar loading of these components — to there being a certain temperature level (approximately 0 °C, for example, in the ideal case) as the differential temperature. In the event that one of the components is damaged, the sensed temperature of this component changes (in particular the temperature increases) and thus the differential temperature or the specific temperature level changes. In particular, the specific (e.g. ideal) temperature level (possibly with a tolerance range) can be used as the allowance criterion. Damage can be detected in a particularly reliable manner.
According to a further embodiment of the method, when damage is detected, an alarm

message can be generated and preferably a transmission to at least one terminal can be made. Alternatively or in addition, measures can be taken (automatically) to prevent at least further damage. For example, in the event of (early) identification of damage (or receiving of the alarm message), operational measures can be initiated (e.g. increased relubrication, close monitoring and/or replacement of grease introduced into a component (e.g. bearing)) and/or in the event of more extensive damage, a replacement or repair of the damaged component can be scheduled in good time. In this way, at least longer downtime of the wind power installation can be avoided.

The at least one allowance criterion can preferably include at least one reference temperature, in particular at least one differential reference temperature, of at least one (fault-free) reference wind power installation. For example, at least a plurality of wind power installations of a wind power system (or different wind power systems) can be monitored in accordance with the aforementioned. For example, a first component and a further component of a first wind power installation and the (substantially) same first component and the (substantially) same further component of a further wind power installation (according to claim 1) can be monitored. In particular, a large number of wind power installations can be monitored accordingly. The first and the further temperature, in particular the differential temperature resulting from said temperature data, in the form of a reference temperature or differential reference temperature of the at least one further (fault-free) wind power installation can be used as the allowance criterion.

In the evaluation step, in a comparison step, in particular the sensed first temperature and further temperature or the corresponding differential temperature and the reference temperature(s) or differential reference temperature can be evaluated. Damage to a component can in particular be detected by detecting a deviation between the reference temperature or differential reference temperature and the sensed first temperature and further temperature or the differential temperature. Damage can be detected in a particularly reliable manner.

The differential reference temperature can be substantially simultaneous with the corresponding differential temperature. Alternatively, the reference temperature can originate from a different time period for the same wind power installation (trend) or another comparable time period of a comparable wind power installation.

In addition, according to a further embodiment of the method, the sensing of a first temperature can comprise the sensing of a first (time-dependent) temperature curve during a specific period of time. For example, an (almost) continuous measurement (monitoring) of the first temperature can be carried out. The specific periods of time can preferably be subdivided into a plurality of time intervals. For example, for each time interval (e.g. 10 minutes, preferably at least 1 hour, 1 day or 1 month), a temperature mean value can be calculated (and stored) for the first temperature values measured (almost) continuously during this time interval.

In addition, the sensing of a further temperature can include the sensing of a further (time-dependent) temperature curve during a specific period of time. For example, (almost) continuous measurement (monitoring) of the further temperature can be carried out. The specific periods of time can preferably be subdivided into a plurality of time intervals. For example, for each time interval (e.g. 10 minutes, 1 hour, 1 day or 1 month), a temperature mean value can be calculated (and stored) for the further temperature values measured (almost) continuously, for example, during this time interval.

The determination of a differential temperature can comprise the determination of a differential (time-dependent) temperature curve by calculating the difference between the sensed first temperature curve and the sensed further temperature curve. Naturally, the differential temperature curve can be determined in a time-synchronous manner. In other words, a difference between a first temperature mean value of a first time interval and a further temperature mean value of the first time interval is calculated, for example. Consequently, a difference can be calculated for a predeterminable number of further time intervals. In this embodiment, the differential reference temperature can preferably be a differential reference temperature curve in particular.

The load on a component during operation of the wind power installation is (directly or indirectly) related in particular to the electrical power generated by the wind power installation. It has been found in this regard that the temperatures of the first component and further component, in particular the corresponding differential temperature, also depend on the electrical power generated. The temperature level described above can change according to the electrical power generated. According to a further embodiment of the invention, the method comprises:

- sensing the power generated by the wind power installation during the sensing of the first temperature curve and the further temperature curve,
- wherein, in the evaluation step, temperature values of the differential temperature curve of at least one predeterminable time interval are assigned to the associated power values of the power generated during the time interval.

The evaluation can be further improved by evaluating the differential temperature curve as a function of the power generated in each case. In particular, the differential temperature T(t1) determined during the generation of a power P(t1) can be assigned to the differential temperature. For example, the differential temperature can be plotted against the electrical power generated by the wind power installation for an evaluation. In particular, the determined mean value of a differential temperature of a first time interval can be assigned to a calculated mean value for the generated power of the first time interval.

According to a further preferred embodiment, in the evaluation step at least one temperature extremum (also called the operative operating point) can be determined from the temperature values of the differential temperature curve that have been assigned to the associated power values for the at least one predeterminable time interval. The allowance criterion can be at least one reference temperature extremum of a differential reference temperature of at least one (fault-free) wind power installation. Damage can be detected at an early stage, in particular by evaluating the operative operating point. The evaluation can include, for example, a temporal evaluation and/or the comparison with at least similarly formed wind power installations.

A large number of temperature extremes from a corresponding large number of time intervals can preferably be evaluated in the evaluation step. In particular, damage can be inferred from the curve of the temperature extremes over time. For example, a specific time-dependent and maximum permissible change can be used as the allowance criterion. In particular, according to a further embodiment, it is possible for the evaluation to include the detection of changes in the temperature extremes, in particular increases in the temperature extremes. If such a change is detected, this is a particularly reliable indicator of damage to a component. In particular, this allows damage to be reliably detected at an early stage.

As has been described, two components (a component pair) are monitored in parallel. In order to determine which of the two loaded components actually has damage, according to a further embodiment of the method according to the application, in the evaluation step, when damage to a loaded component is detected, the loaded component of the two loaded components which (actually) has the damage is identified by evaluating the sign of the change in the differential temperature. For example, an increased differential temperature can indicate damage to the first component and a reduction in the differential temperature can indicate damage to the further component (or vice versa, depending on the calculated difference). In particular, it can be assumed that the measured temperature of a loaded component rises in the event of damage.

According to a particularly preferred embodiment, the first and the further loaded component can each be a mechanically loaded component. In particular, a loaded component can be a rotor bearing, generator bearing or transmission bearing. The thermal coupling according to the application can be present in particular on account of a commonly used shaft of the at least two components, in particular bearings. In addition, the two components can be arranged in the same housing, for example.

Alternatively or additionally, the first and the further loaded component can each be an electrically loaded component, in particular a transformer or converter. The thermal coupling can in particular be brought about by a substantially identical electrical load (for example similar electrical power and/or current and/or voltage). In this case too, the two components can, for example, be arranged in the same housing. Naturally, a plurality of component pairs of a wind power installation are preferably monitored.

In particular, it is possible according to the application for two similar, loaded components (with similar environmental conditions (in particular at least similar ambient temperature, e.g. ΔT < 25°, in particular ΔT < 10 °C)) to be monitored together and preferably for their differential temperature or their differential (temporal) temperature curve to be evaluated. For example, a plurality of such component pairs can be identified and monitored in the wind power installation.

A further aspect of the application is a monitoring system for monitoring the condition of at least one component of the wind power installation that is loaded during the operation of a wind power installation. The monitoring system comprises at least one temperature sensing device, configured to sense a first temperature of a first loaded component of the wind power installation. The temperature sensing device is configured to sense at least one further temperature of a further loaded component of the wind power installation. The first loaded component and the further loaded component have a thermal coupling with one another. The monitoring system comprises at least one evaluation device, configured to detect damage to at least one of the loaded components on the basis of the first temperature and the further temperature and at least one allowance criterion in an evaluation step.

The monitoring system can be used, for example, for a single wind power installation or for a wind power system or wind farm with a large number of at least structurally similar wind power installations. The monitoring system can in particular be operated according to the method described above.

The temperature sensing device can be formed from different modules, for example. The evaluation device can be arranged in the wind power installation or in a further wind power device (e.g. central control computer, SCADA system, for example of a head-end station or the like) or in a computing centre. In the last-mentioned case in particular, the evaluation device can be a central evaluation device which can monitor a plurality of wind power installations and their loaded components in each case. This makes it possible to use the fault-free wind power installations as reference wind power installations and thus the temperature data of these reference wind power installations as an allowance criterion. For example, a wireless and/or wired communication network can be provided for the exchange of data between the various devices. The alarm messages described above can also be transmitted at least in part via said communication network.

It should be noted that the term “power” in the present case should be understood to mean the “active power” unless otherwise stated. It should also be noted that the controller device can determine the at least one power setpoint on the basis of a plurality of the criteria described above. In addition, devices, modules, etc. according to the application can be formed from hardware components (e.g. processors, interfaces, storage means, etc.) and/or software components.

The scope of protection is defined by the claims.

There are a large number of possibilities for designing and further developing the monitoring method according to the application and the monitoring system according to the application. On the one hand, reference is made here to the claims dependent on the independent claims, while, on the other hand, reference is made to the description of exemplary embodiments in conjunction with the drawings. In the drawings:

Figure 1 shows a schematic view of a first exemplary embodiment of a monitoring system according to the present application;

Figure 2 shows a schematic view of a further exemplary embodiment of a monitoring system according to the present application;

Figure 3 shows a diagram of an exemplary embodiment of a method according to the present application;

Figure 4 shows a diagram having exemplary differential temperature curves according to the present application;

Figure 5 shows a diagram having an exemplary curve of the differential temperature values as a function of the generated power according to the present application;

Figure 6 shows a diagram having exemplary curves of the differential temperature values as a function of the generated power according to the present application; and

Figure 7 shows a diagram having an exemplary curve of the temperature extremes as a function of time.

The same reference signs are used for identical elements.

Figure 1 shows a schematic view of an exemplary embodiment of a monitoring system 100, configured to monitor the condition of at least one component 102, 104 of the wind power installation 101 that is loaded during operation of a wind power installation 101.

The wind power installation 101 is designed to convert the kinetic energy of wind into electrical energy. For this purpose, a large number of components 102, 104 are arranged in the wind power installation 101. For the sake of a better overview, only two components 102, 104 are shown schematically in the present case.

The components 102, 104 experience a mechanical and/or electrical load during operation, i.e. in particular during the conversion of kinetic energy into electrical energy. The load that each component experiences is (substantially) the same. In particular, there is an arrangement of a first loaded component 102 and a further loaded component 104. In order to detect damage to at least one of the components 102, 104 at an early stage, there is joint temperature monitoring of the two loaded components 102, 104 according to the application. The two components 102, 104 therefore form a component pair in the present case.

As has already been described, there is a thermal coupling 122 between the loaded components 102, 104 on account of the substantially equal load. In this application, thermal coupling generally means that the temperature difference during fault-free operation is within a certain range (e.g. ΔT between 0 °C and 20 °C, preferably between 0 °C and 10 °C, particularly preferably between 0 °C and 5 °C). The range can depend on the type of load.

As can be seen, the monitoring system 100 comprises at least one temperature sensing device 106. The temperature sensing device 106 is configured to sense a first temperature of the first loaded component 102. Furthermore, the temperature sensing device 106 is configured in the present case to sense a further temperature of a further component 104. For example, a measuring sensor can be arranged on the component 102, 104 and/or in the component 102, 104.

The temperature device 106 can in particular be configured to determine the temperature (almost) continuously. Naturally, a suitable sampling rate can be used to limit the temperature values to be processed to a desired number. An (almost) continuous sensing enables the sensing of a (time-dependent) temperature curve. Naturally, the temperature device can also consist of separate elements.

In the present exemplary embodiment, the sensed temperature data can be transmitted to a remotely arranged evaluation device 108 (for example integrated in a central control computer). In particular, a wireless communication network 110 is provided for this purpose. The temperature device 106 and the evaluation device 108 can have suitable transmission means (transmitter, receiver). Naturally, according to other variants of the application, the evaluation device can also be integrated in the wind power installation and, for example, a wired communication network is provided.

The evaluation device 108 is configured to detect damage to at least one of the loaded components on the basis of the first temperature and the further temperature and at least one allowance criterion in an evaluation step. A more detailed description of the evaluation follows below.

Figure 2 shows a further exemplary embodiment of a monitoring system 200 according to the present application. To avoid repetition, substantially only the differences with respect to the exemplary embodiment according to figure 1 are described below. For the other components of the monitoring system 200, reference is made in particular to the statements above.

The wind power installation 201 shown has a wind turbine 214. The wind turbine 214 is connected via a shaft 216 to a generator 218. The shaft 216 is installed in parts and the generator 218 is completely installed within the housing of a nacelle of the wind power installation 201.

The part of the shaft 216 guided in the housing is supported by two rolling bearings 202, 204, in particular a front and a rear roller bearing 202, 204. Both bearings are in particular in a common housing. In the generator 218, the rotational energy obtained from the wind energy via the wind turbine 214 is converted into electrical energy and, as shown schematically, is fed to a converter (not shown) via a cable 220.

In the present exemplary embodiment, the first bearing 202 constitutes the first loaded component 202 and the further bearing 204 constitutes the further loaded component 204. A temperature sensor having a temperature sensing device 206 is arranged on each of the bearings 202, 204. The measurement values of the temperature sensors are fed to the temperature sensing device 206 or the measuring transducer 206.

In addition, in the present case, power measurement values regarding the power generated by the wind power installation 201 are fed from the generator 218 or another point to a power sensing device 222. In particular, a (time-dependent) power curve is sensed by the power sensing device 222. In addition to these parameters, a large number of further sensing devices can be provided for sensing further parameters.

The sensing devices 206, 222 can transmit data, for example by wire, via a communication network 210 to an evaluation device 208 of a central control computer (not shown). The data can be stored in a SCADA data set in said central control computer. The SCADA system stores, for example, the mean values of the various measurement values that are transmitted by the respective detection devices 206, 222 for specific time intervals (measuring intervals), for example 10 minutes in each case.

In particular, it is proposed that the first and further temperature values and preferably the power data be evaluated. The method for operating, in particular for evaluating the data, of a monitoring system according to figure 2 is explained in more detail with the aid of figure 3.

Figure 3 shows a diagram of an exemplary embodiment of a method for monitoring the condition of at least one component 202, 204 of a wind power installation 201 that is loaded during operation of the wind power installation 201 according to the present application.

In a first step 301, a first temperature of the first loaded component, in the present example the first bearing 202 of the wind power installation 201, is sensed.

In particular, a first (time-dependent) temperature curve can be sensed in the manner described above, with mean values being able to be calculated in each case for the various time intervals.

In particular, in parallel with step 301, a further temperature of the further loaded component, in the present example the further bearing 204 of the wind power installation 201, is sensed in step 302. In particular, a further (time-dependent) temperature curve can be sensed in the manner described above, with mean values being able to be calculated in each case for the various time intervals.

In parallel with this, the power, in particular a (time-dependent) power curve, of the power generated by the wind power installation 201 can be sensed in a step (not shown) in the manner described above, with mean values being able to be calculated for the various time intervals.

In a next step 303, at least the temperature data sensed in accordance with steps 301 and 302 are evaluated in such a way that damage to one of the bearings 202, 204 can be detected. Detecting damage to at least one of the loaded bearings 202, 204 on the basis of the first temperature and the further temperature and at least one allowance criterion can preferably initially include determining a differential temperature, in particular a differential temperature curve, from the first and further temperature data. In particular, the difference can be determined from the first temperature curve of the first bearing 202 and the further temperature curve of the further bearing. For example, difference mean values can be determined from the respective mean values for each measurement interval or time interval.

Exemplary differential temperature curves 430 and 432 are shown in figure 4. While the temperature T (e.g. in °C or K) is plotted on the Y axis, the X axis shows the time axis t (e.g. in days). As has already been stated, the two bearings 202, 204 are mounted on a shaft 216 (i.e. experience substantially the same load) and are also located in the same environment (nacelle housing), so in the present exemplary embodiment both bearings 202, 204 are thermally coupled. As has been described, the temperature data can be compared by calculating the difference, such that (almost) only the influences remain from the bearing load due to the generated wind power installation power and the friction acting in the respective bearings 202, 204.

As has been described, the differential (bearing) temperature is shown plotted over the time axis in figure 4, with the differential temperature curve 432 representing components operating without fault or a wind power installation operating without fault. In particular, the temperature level of the differential temperature curve 432 runs around 0 (ideal case). This differential temperature curve 432 can in particular be used as a differential reference temperature curve of a reference wind power installation, i.e. as an allowance criterion.

The exemplary differential temperature curve 430 shown further shows a curve in which a loaded component has damage. This results from the fact that the differential temperature curve 430 has a higher temperature level (approximately 12 °C) compared to the differential reference temperature curve 432. In the evaluation step, a comparison of a specific differential temperature curve with a differential reference temperature curve can therefore be carried out. If the deviation exceeds a predeterminable threshold, it can be concluded that a component has been damaged and the process continues with step 304.

In practice, particularly a large number of at least similarly built wind power installations or their loaded components (e.g. the bearings mentioned above) can be monitored. In this case, tests have shown that damage can be identified in that the differential temperature curve with the damaged component differs significantly from the differential temperature curves of all other wind power installations.

In the event of a corresponding detection, an alarm message can be generated in step 304 and transmitted, for example, to a terminal. In particular, the user of the terminal can then initiate suitable measures, for example to repair the damage or for a more detailed inspection.

As already described above, the differential temperature can depend on the electrical power generated. This dependency is shown in figure 5; figure 5 shows a diagram in which the differential temperature values are plotted against the electrical power of the wind power installation.

The curve shown by way of example in figure 5 is particularly characteristic of a specific configuration of the two bearings 202, 204 and their current condition. The curves of wind power installations with the same configuration therefore have similar curves. It has therefore been found according to the application that the curve can be evaluated in an evaluation step 303 (as an alternative or in addition to the evaluation described above). In particular, a change in this curve over time and/or a different curve shape of at least two wind power installations of (almost) the same configuration can be interpreted as an indicator of damage, such as bearing damage. In the event of a corresponding detection, the process can continue with step 304.

It has also been found that certain points on the curve are particularly suitable for an evaluation. In particular, the point at which the differential temperature reaches an extremum, in particular a maximum, has proven to be characteristic. As a result, as an alternative or in addition to the evaluation options described above, an evaluation on the basis of this characteristic point can be carried out in the evaluation step.

Figure 6 shows two exemplary differential temperature values which were plotted against the power. Here, the differential temperature values result from the same bearings of the same wind power installation which, however, were sensed at different times. The curve (triangles) resulting from the temperature data of the bearings 202, 204 sensed at a first point in time (for example day X or month X) has a temperature extremum 638 at a power of approximately 450 kW.

The further curve (circles) resulting from the temperature data of the bearings 202, 204 sensed at a further point in time (for example day Y or month Y) has a temperature extremum 636 at a power of approximately 650 kW. The further point in time is in particular a point in time after the first point in time (Y = X+Z).

As can be seen, the temperature extremum, also called the operative operating point, has shifted from the first point in time to the second point in time. In the evaluation step, a corresponding comparison (as an alternative or in addition to the above evaluation options) can be carried out. For example, a maximum permissible change can be specified as the allowance criterion. Exceeding this change can be interpreted in the evaluation step as an indicator of damage to at least one bearing 202, 204. In particular, a change in the operative operating point (636, 638) is an indication of changes in the friction conditions in a bearing 202, 204 and thus of possible damage to a bearing 202, 204.

A particularly reliable detection of damage to a loaded component can be achieved if in the evaluation step (alternatively or additionally) a large number of temperature extremes from a corresponding large number of time intervals are evaluated. The evaluation can preferably include the detection of changes in the temperature extremes, in particular increases in the temperature extremes. In other words, a determination and a corresponding plotting of the temperature extremes or the operative operating points against time can reliably show possible changes in the loaded components. In particular, this embodiment of the evaluation according to the application makes it possible to reliably detect the smallest changes in the loaded and monitored components, such that damage to a component can be identified at an early stage, in particular many months before an operationally hazardous condition occurs.

An exemplary curve of the operative operating point of a wind power installation 201 over time is shown in figure 7. As can be seen, the operative operating point in the example initially remains stable for approximately 12 months (at approximately 4.5 K). This is shown, among other things, in a small standard deviation (e.g. 0.2 K). In particular, it can be sensed in an evaluation step that at least one maximum permissible temperature change, which can be specified as an allowance criterion, is not exceeded.

As is further identified with the reference sign 740, an exceedance of a maximum permissible temperature change can be identified for January (Jan). It can also be identified here that the maximum permissible temperature change has only been exceeded by a small amount. For example, different levels of admissibility can be specified for such a detection. A corresponding detection is a particularly reliable indicator of a change in a bearing 202, 204, in particular damage to a bearing 202, 204, which, however, does not (yet) represent an operationally hazardous condition.

As has been described, an alarm message can be sent out in step 304 upon a corresponding detection. If no measures or insufficient measures are taken to remedy the damage, the course of the operative operating point over time can look like the example shown in figure 7. In particular, the operative operating point can initially stabilise until there is a significant (further) change at reference sign 742. At this point at the latest, an exchange of the damaged bearing should be considered.

Since both bearings 202, 204 are included in the determination of the differential temperature, it can preferably be identified in the evaluation step whether the first bearing 202 or the further bearing 204 has potential damage. An increase in temperature indicates damage to the additional bearing, and a negative differential temperature indicates damage to the first bearing. The approach according to the application appears particularly promising for the rotor bearings of wind power installations described above, but can also be transferred to other bearings, such as generator bearings or transmission bearings. It is particularly important that a second measurement can be carried out in the vicinity of the system for which the same thermal conditions apply. Likewise, the approach with the mechanically loaded components described can also be transferred to electrically loaded components such as transformers or converters.

The great advantage of the method or system according to the application is in particular that these temperature data are often already available as historical data in a large number of wind power installations and can therefore be evaluated with little effort using an evaluation according to the application. This makes it possible to configured a monitoring system in order to monitor the condition of these components and to be able to react quickly to changes.

FREMGANGSMÅDE TIL OVERVÅGNING AF TILSTANDEN AF MINDST ÉN KOMPONENT, DER BELASTES UNDER DRIFTEN AF ET VINDKRAFTANLÆG

PATENTKRAV

1. Fremgangsmåde til overvågning af tilstanden af mindst én komponent (102, 104, 202, 204), der belastes under driften af et vindkraftanlæg (101, 201), i vindkraftanlægget (101, 201), omfattende:
   - registrering af en første temperatur for en første belastet komponent (102, 202) i vindkraftanlægget (101, 201),
   - registrering af mindst én yderligere temperatur for en anden belastet komponent (104, 204) i vindkraftanlægget (101, 201), og
   - detektering af en beskadigelse af mindst én af de belastede komponenter (102, 104, 202, 204) baseret på den registrerede første temperatur og den registrerede yderligere temperatur og mindst ét berettigelseskriterium i et evalueringstrin, kendetegnet ved, at den første belastede komponent (102, 202) og den anden belastede komponent (104, 204) har en termisk kobling (112, 212) med hinanden, hvor en termisk kobling foreligger, når den første komponent (102, 202) og den anden komponent (104, 204) udsættes for en i det mindste lignende mekanisk og/eller elektrisk belastning.

2. Fremgangsmåde ifølge krav 1, **kendetegnet ved, at** fremgangsmåden omfatter:
   - bestemmelse af en differentiel temperatur ved dannelse af differencen mellem den registrerede første temperatur og den registrerede yderligere temperatur,
   - hvor der i evalueringstrinnet detekteres en beskadigelse af mindst én af de belastede komponenter (102, 104, 202, 204) baseret på den dannede differentielle temperatur og det mindst ene berettigelseskriterium.

3. Fremgangsmåde ifølge et af foregående krav, **kendetegnet ved, at** det mindst ene berettigelseskriterium omfatter mindst én referencetemperatur, især en differentiel referencetemperatur, fra mindst ét referencevindkraftanlæg.

4. Fremgangsmåde ifølge krav 2 eller 3, **kendetegnet ved, at**
   - registreringen af en første temperatur omfatter registrering af et første temperaturforløb i løbet af en bestemt tidsperiode,

- registreringen af en yderligere temperatur omfatter registrering af et yderligere temperaturforløb i løbet af en bestemt tidsperiode, og
- bestemmelsen af en differentiel temperatur omfatter bestemmelse af et differentielt temperaturforløb ved dannelse af differencen mellem det registrerede første temperaturforløb og det registrerede yderligere temperaturforløb.

5. Fremgangsmåde ifølge krav 4, **kendetegnet ved, at** fremgangsmåden omfatter:
   - registrering af den af vindkraftanlægget (101, 201) genererede effekt under registreringen af det første temperaturforløb og det yderligere temperaturforløb,
   - hvor temperaturværdier af det differentielle temperaturforløb for mindst ét tidsinterval, der kan forudbestemmes, i evalueringstrinnet tildeles den genererede effekts tilhørende effektværdier i løbet af tidsintervallet.

6. Fremgangsmåde ifølge krav 5, **kendetegnet ved, at**
   - mindst ét temperaturekstrem i evalueringstrinnet bestemmes ud fra temperaturværdierne, der er tildelt de tilhørende effektværdier for det mindst ene tidsinterval, der kan forudbestemmes, og
   - berettigelseskriteriet i det mindste er et referencetemperaturekstrem af en differentiel referencetemperatur i mindst ét referencevindkraftanlæg.

7. Fremgangsmåde ifølge krav 6, **kendetegnet ved, at**
   - et stort antal temperaturekstremer i evalueringstrinnet evalueres af et tilsvarende stort antal tidsintervaller,
   - hvor evalueringen især omfatter detektering af ændringer i temperaturekstremerne, især forøgelser af temperaturekstremerne.

8. Fremgangsmåde ifølge et af foregående krav 2 til 7, **kendetegnet ved, at** den belastede komponent (102, 104, 202, 204), der er beskadiget, blandt de to belastede komponenter (102, 104, 202, 204), i evalueringstrinnet identificeres ved detektering af en beskadigelse af en belastet komponent (102, 104, 202, 204) ved at evaluere fortegnet for ændringen af den differentielle temperatur.

9. Fremgangsmåde ifølge et af de foregående krav, **kendetegnet ved, at**
   - den første og den anden belastede komponent (102, 104, 202, 204) hver især

er en mekanisk belastet komponent (102, 104, 202, 204), især et rotorleje, generatorleje eller gearleje,

og/eller

- den første og den anden komponent (102, 104, 202, 204) hver især er en elektrisk belastet komponent, især en transformator eller konverter.

10. Overvågningssystem (100, 200) til overvågning af tilstanden af mindst én komponent (102, 104, 202, 204), der belastes under driften af et vindkraftanlæg (101, 201), i vindkraftanlægget (101, 201), omfattende:

- mindst én temperaturregistreringsanordning (106, 206), der er indrettet til registrering af en første temperatur for en første belastet komponent (102, 202) i vindkraftanlægget (101, 202),

hvor

- temperaturregistreringsanordningen (106, 206) er indrettet til registrering af mindst én yderligere temperatur for en anden belastet komponent (104, 204) i vindkraftanlægget (101, 201), og
- overvågningssystemet (100, 200) omfatter mindst én evalueringsanordning (108, 208), der er indrettet til at detektere en beskadigelse af mindst én af de belastede komponenter (102, 104, 202, 204) baseret på den første temperatur og den yderligere temperatur og mindst ét berettigelseskriterium i et evalueringstrin, kendetegnet ved, at den første belastede komponent (102, 202) og den anden belastede komponent (104, 204) har en termisk kobling (112, 212) med hinanden, hvor en termisk kobling foreligger, når den første komponent (102, 202) og den anden komponent (104, 204) udsættes for en i det mindste lignende mekanisk og/eller elektrisk belastning.

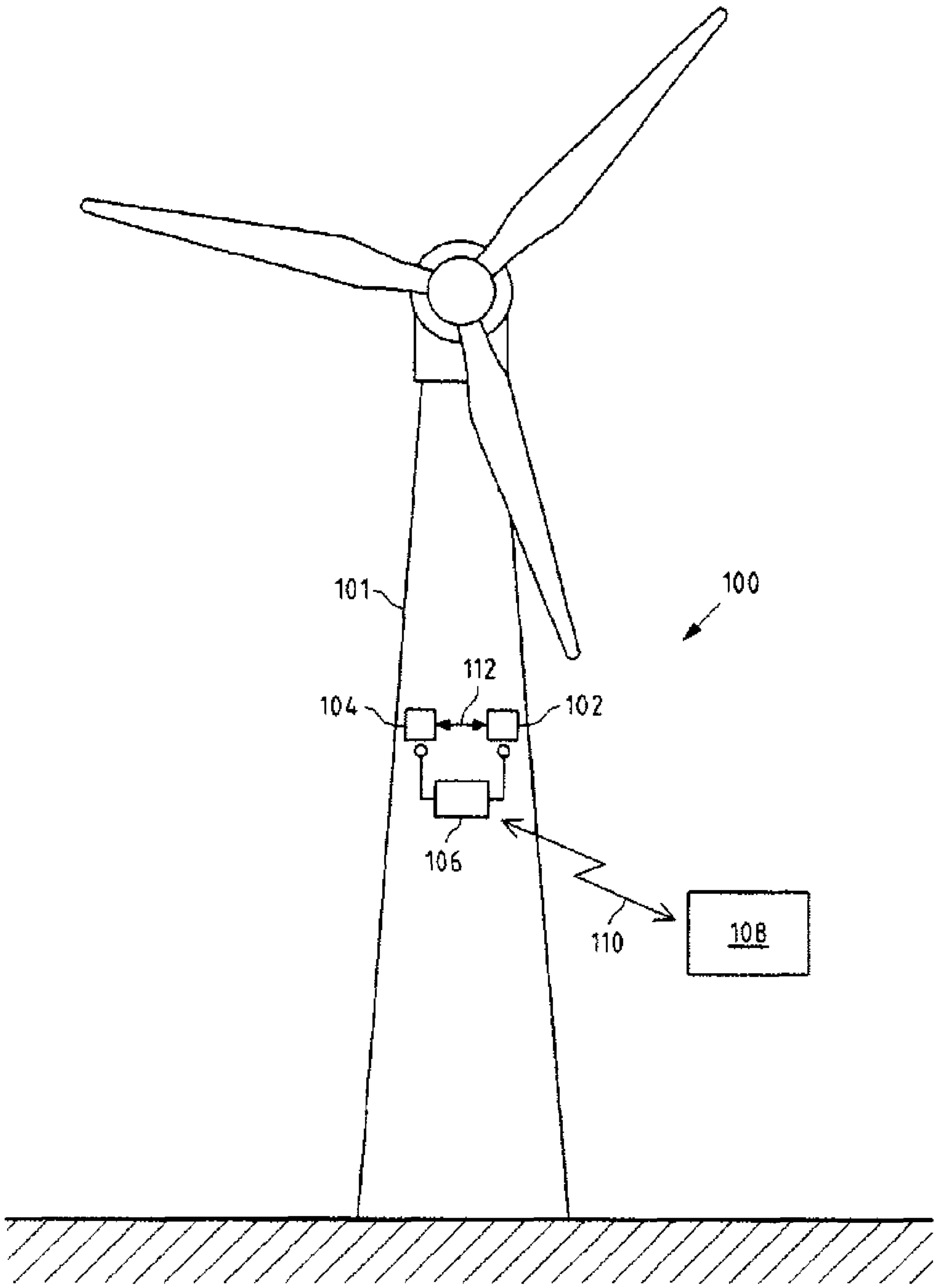

Fig.1

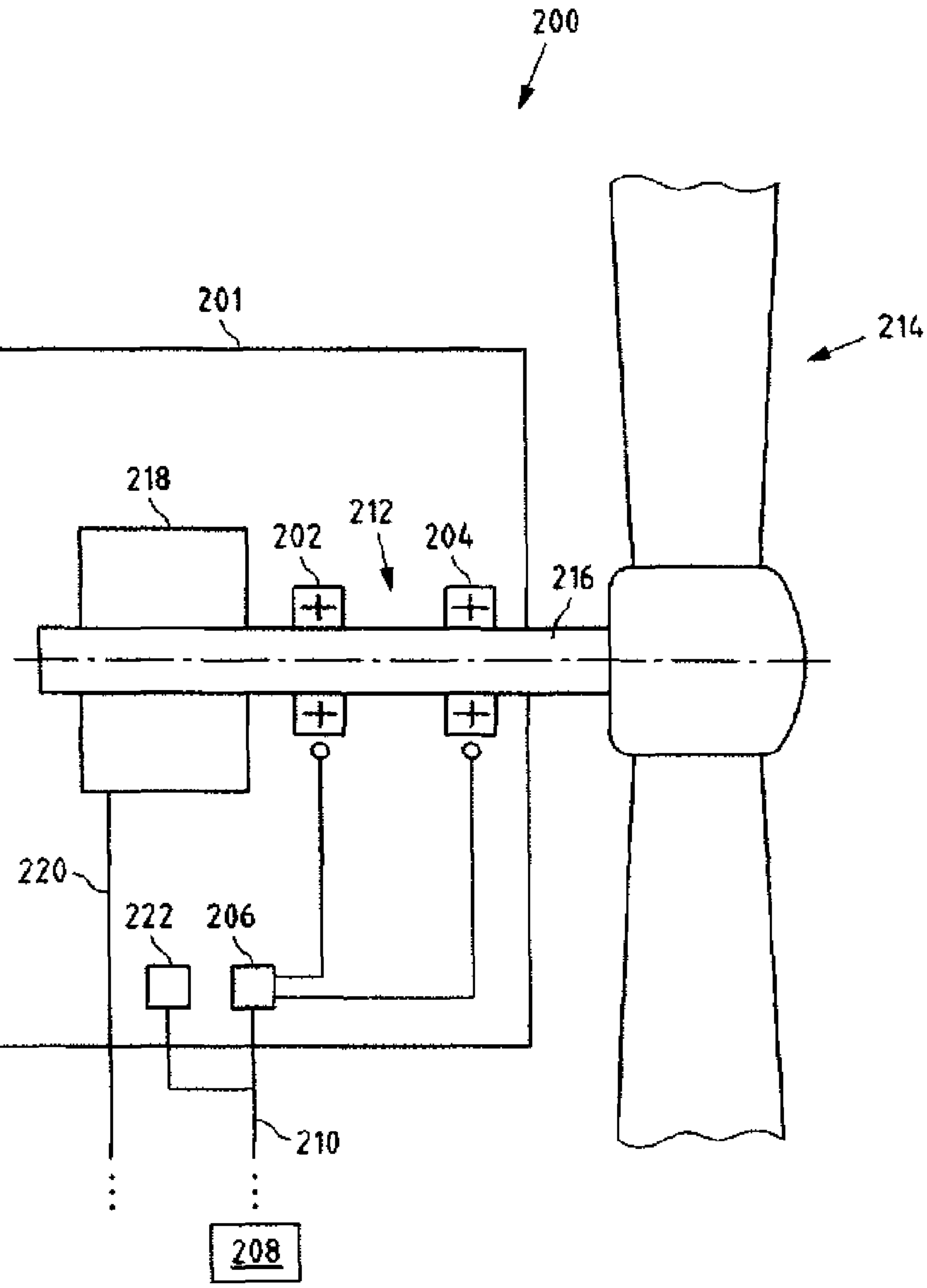

Fig.2

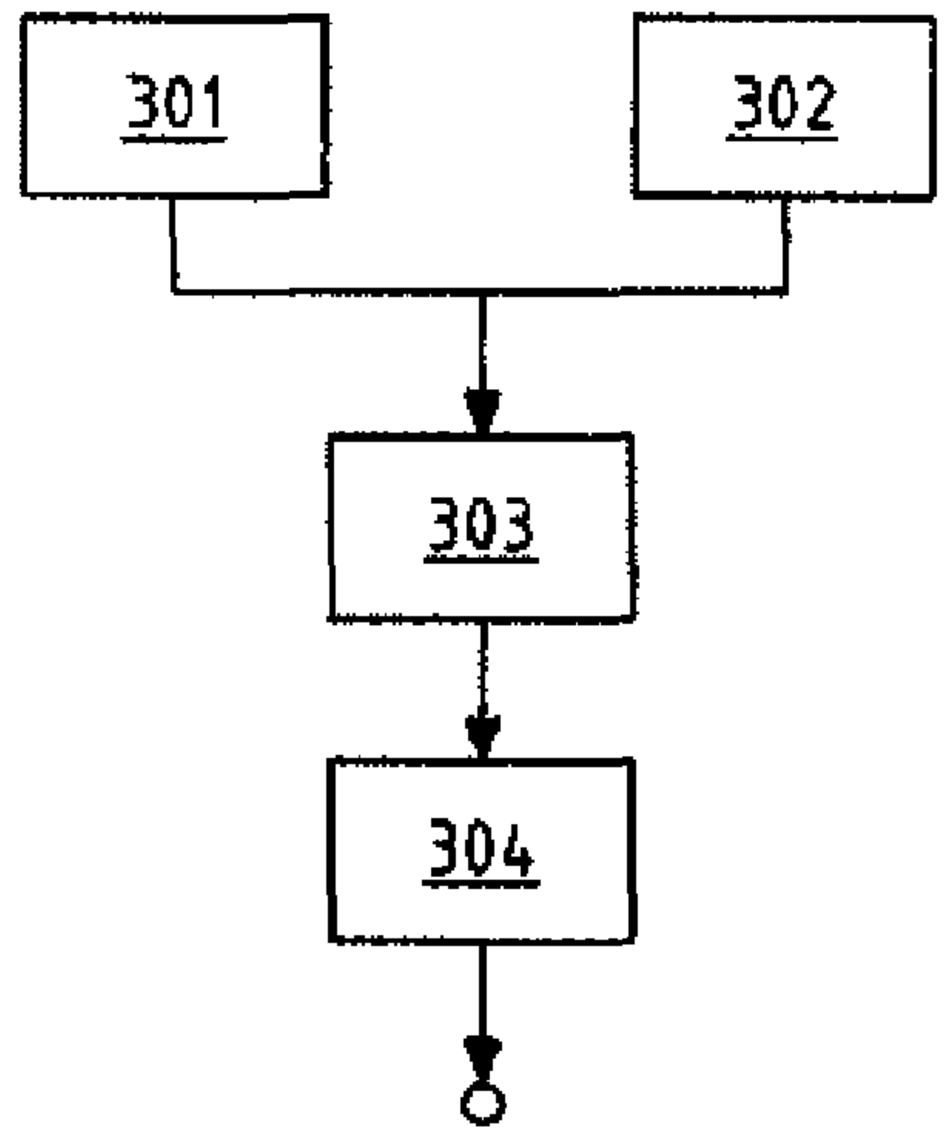

Fig.3

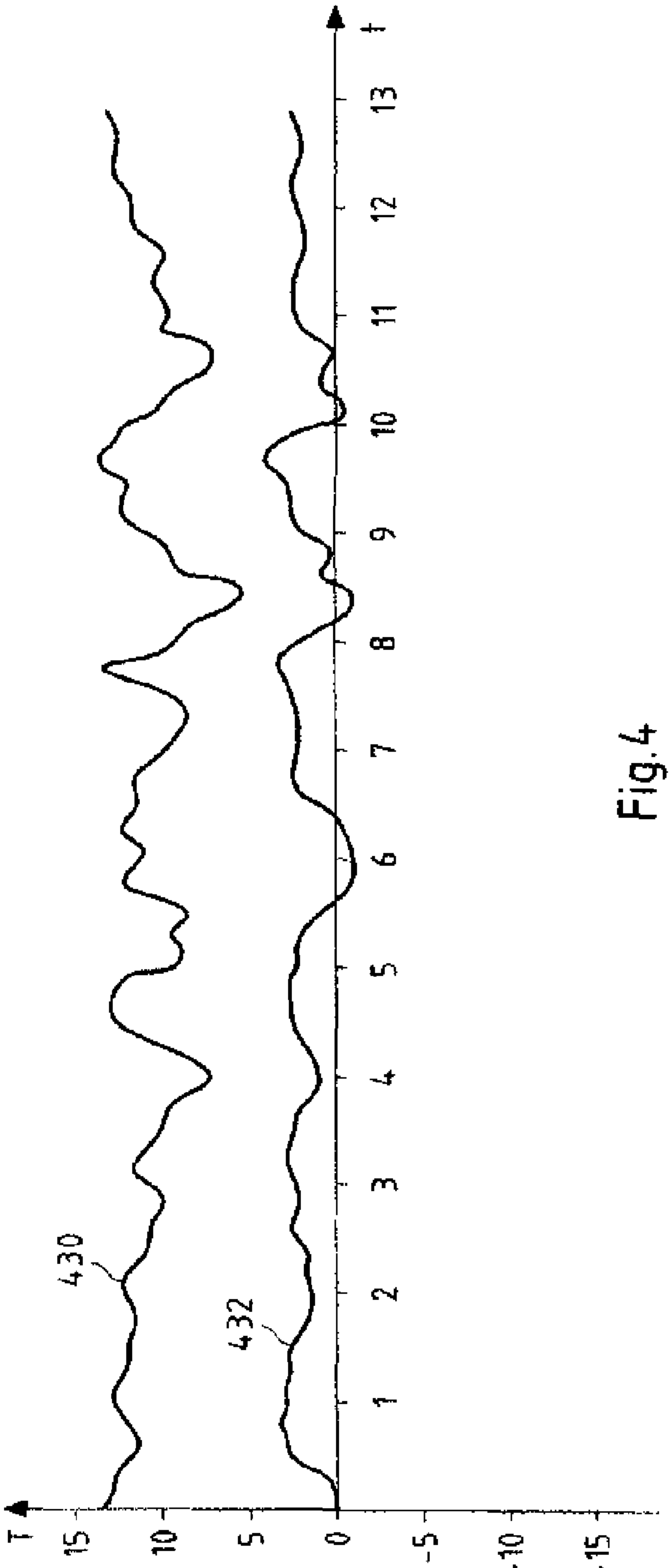

Fig.4

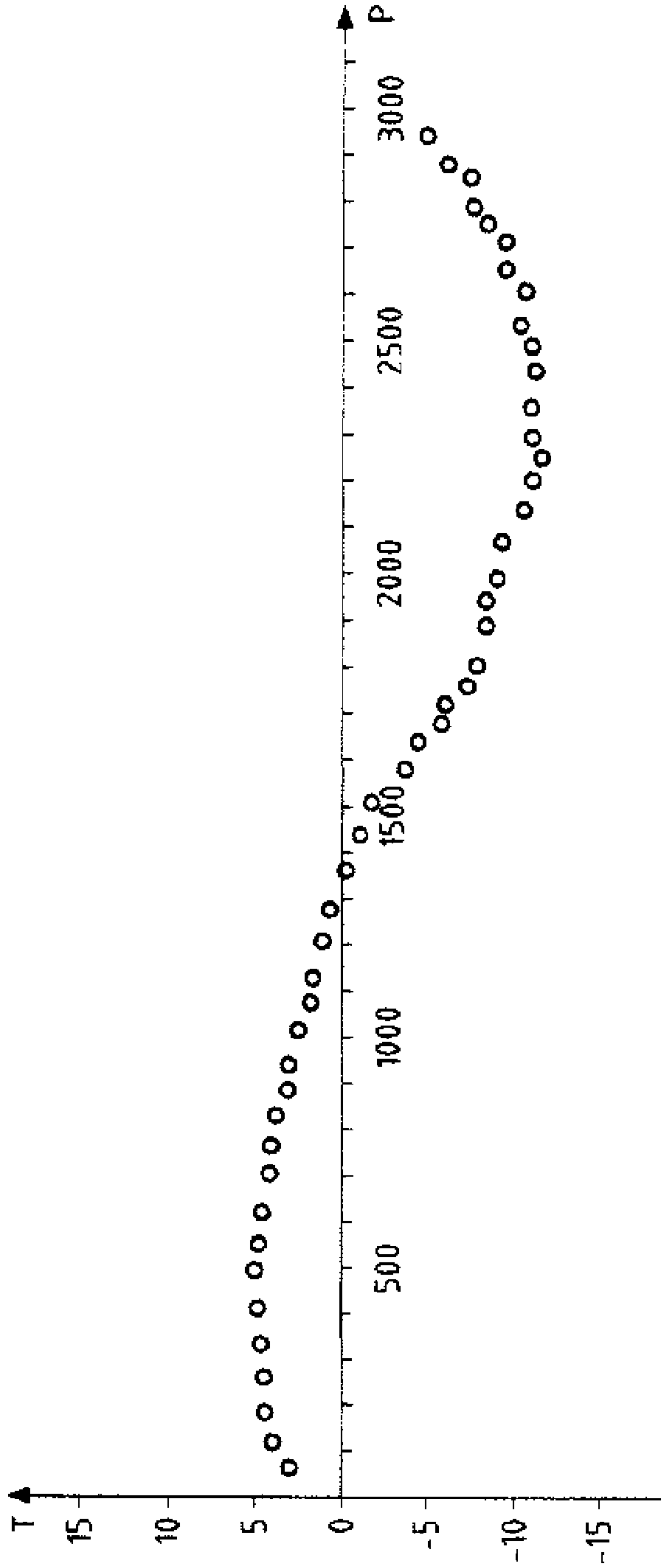

Fig.5

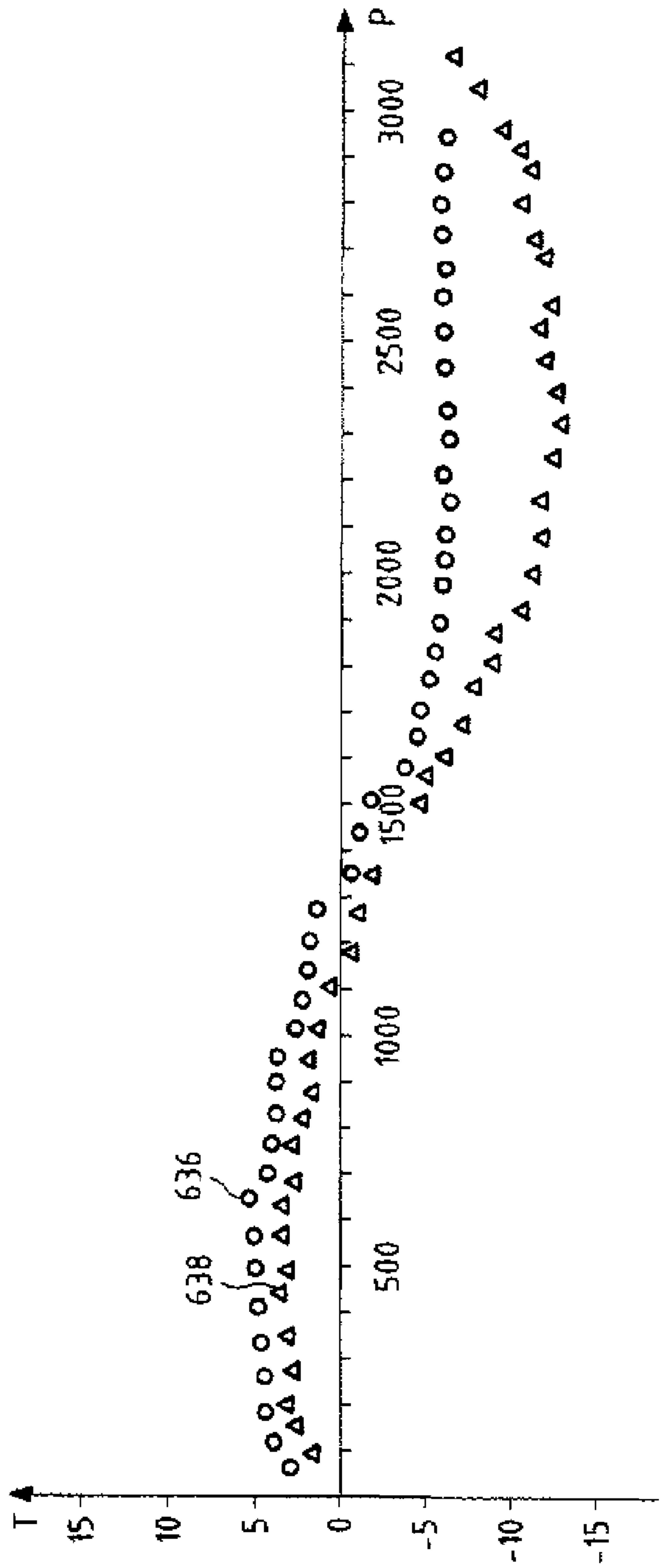

Fig.6

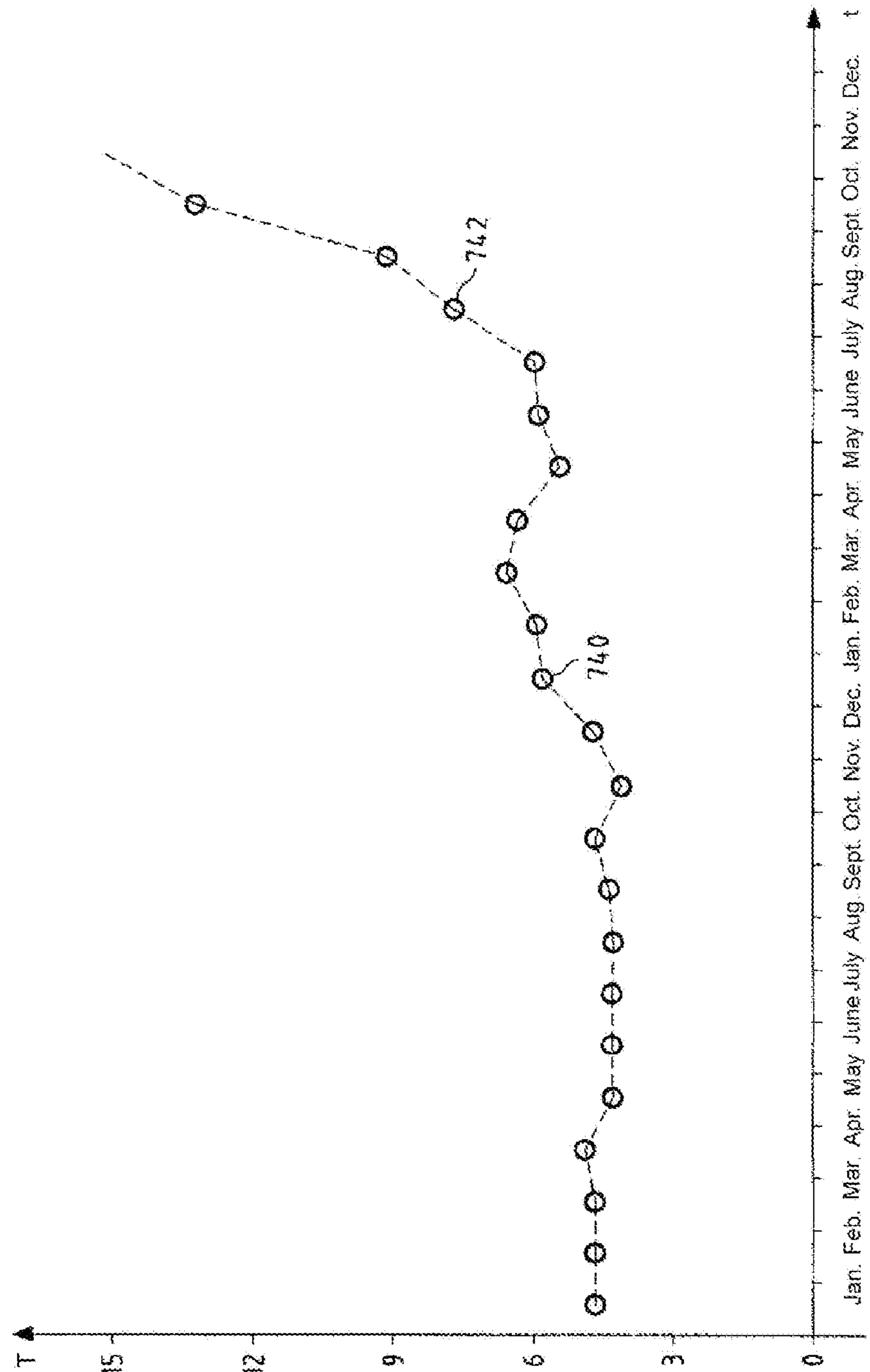
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Fig.7