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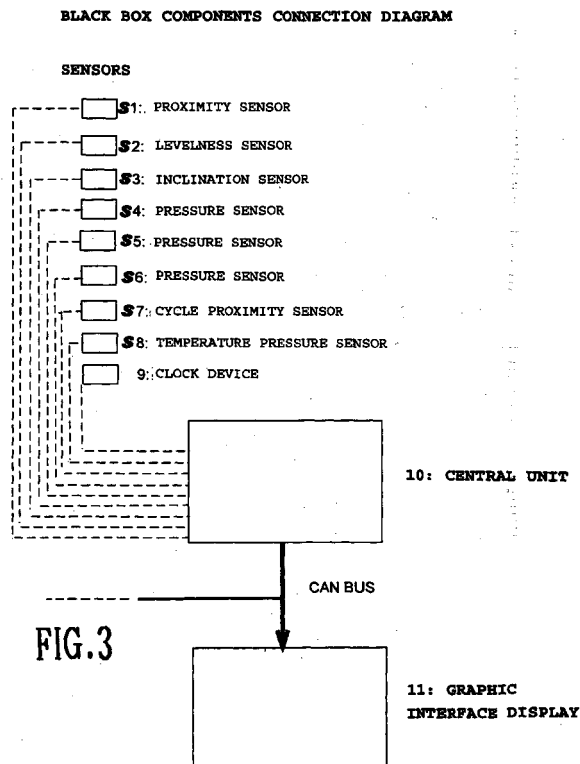
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(54) **System for controlling and monitoring the operation of self-moving machines with an articulated arm, such as concrete pumps, and maintenance method for said machines**

(57) A system for controlling and monitoring the operation of self-moving machines with an articulated arm, particularly concrete pumps, is disclosed comprising a plurality of sensors and transducers apt to collect data regarding the machine position, attitude and operating parameters, and a central unit apt to receive in real time said data, process and compare them with reference data regarding the proper use of the machine and make them comprehensible to an operator. A maintenance method based on the acquisition and comparison of the data of said system equipped with a memory device is also described.



Description

[0001] The present invention relates to a system for controlling and monitoring the operation of self-moving machines with an articulated arm, particularly concrete pumps.

[0002] Problems caused by the use of these big machines are currently well known. Drawbacks relative to the masses and high working stress involved cause the engineers to invest significant resources in the attempt to make the operation of such machines always easier and risk-free.

[0003] On the other hand, in fact, appropriate devices need to be arranged to facilitate the achievement of equilibrium and stability conditions of the truck - as the self-moving vehicle on which the articulated arm is mounted is known in the field - also and especially in difficult environments, such as a building yard. The stabilizers are usually extractable legs that come to rest some distance away from the truck center of gravity, so as to widen the support base, and support the tilting forces caused by the articulated arm, for example the concrete delivery arm of the pump, when is extended completely.

[0004] At the same time, specific and precise parameters have to be given to and have to be strictly followed by the operator to avoid turnovers or the exceeding of predetermined stress values.

[0005] Even considering that these machines are designed with high safety coefficients, inappropriate use of the same can lead to premature collapsing or unforeseeable structural problems. Such cases occur more often than one may think since the articulated arm easily lends itself to inappropriate uses.

[0006] The need for ensuring safety, however, comes in conflict with the desire for a light, slender, and economical machine. Often, to ensure certain safety standards, it becomes necessary to over-penalize the diligent customer who, by using the machine in a correct way, would not need said extra safety costly measures. This hinders the commercial competitiveness of the product on the market.

[0007] The Applicant has therefore addressed to the problem of supplying machines with an articulated arm that would help and force a generic user to operate the same in a correct manner - so that the structure is not uselessly burdened by extra safety measures - and that would be as light as possible and suited to the real needs of a specific customer - so as to achieve the highest customer satisfaction without compromising safety.

[0008] Such object is achieved by means of a system for controlling and monitoring the operation of machines with an articulated arm and by means of a maintenance method as described in the appended independent claims.

[0009] Other important aspects of the present invention are described in the dependent claims.

[0010] Details regarding characteristics and advantages of the system according to the present invention will, in any case, become more evident in the following description of one of the preferred embodiments of the same, given as an example and shown in the appended drawings, wherein:

[0011] Fig. 1 is a side elevation view of an exemplary concrete pump;

[0012] Fig. 2 is a top plan view of the truck of Fig. 1;

[0013] Fig. 3 is an exemplary diagram illustrating the connections among the different elements that form the system of the present invention; and

[0014] Figs. 4A and 4B are two illustrative drawings of the images that are displayed on a control monitor which show to the operator the operating condition of the machine.

[0015] In Fig. 1 an exemplary machine with an articulated arm is shown, specifically a concrete pump which comprises the system of the present invention.

[0016] P identifies a concrete collection and pumping unit, which will not be described in great details since it is well-known to the skilled person in the art. A delivery duct T receives fluid concrete from pumping unit P and transports it along the articulated arm to outlet end T1.

[0017] The articulated arm shown in Figure 1 comprises four sections B1-B4.

[0018] Since the articulated arm can be extended considerably, the overall center of gravity of the machine can easily fall outside the area delimited by the natural supports of the truck, i.e. outside the perimeter delimited by wheels R. Therefore, to assure truck stability, extractable stabilizers E apt to transfer point of application of supports E1 away from the truck on the ground, at least during the operation of the pump, are provided.

[0019] According to the present invention, a plurality of attitude and position sensors S1-Sn by means of which it is possible to detect in real time data regarding the operation attitude of the entire machine is provided.

[0020] Particularly, by means of proximity sensors S1 it is possible to detect if and to what extent stabilizers E are extended outward. By means of this measurement, on the basis of known data regarding position and angle of the stabilizers relative to a pre-established point of the machine, it is possible to calculate the real stabilizing area of the machine.

[0021] A levelness sensor S2 is instead placed in a central position of the truck, for example where the two stabilizers intersect. Sensor S2 can be an electronic bubble. By means of levelness sensor S2, it is possible to instantaneously determine the machine inclination on the two planes, by allowing to process a levelness parameter that affects the correct operation of the machine.

[0022] An inclination sensor S3 is mounted near the hinge of the first section of arm B1 to determine its attitude relative to a reference axis (for example the horizontal axis). A pressure sensor S4 is instead mounted by the actuator of the first section of arm B1 to read the pressure in the hydraulic cylinder. Still another rotation

sensor (not shown) gives an indication of the rotation angle relative to a reference axis taken by a rotating tower G on which the arm B1-B4 is mounted. The readings taken by these last three sensors, along with other geometric parameters, allow to determine unequivocally the intensity and direction of the tilting moment vector of the articulated arm to the machine.

[0023] Pressure sensors S5 and S6 are also provided on the actuator of last section B4, one on the piston side and the other on the rod side. By means of these sensors it is possible to obtain a signal that is proportional to the actual and instantaneous load applied to the actuator and, therefore, to the last section of arm B4.

[0024] There are also provided proximity sensors S7, positioned close to pumping unit P, to read the pumping cycles per unit of time (for example, cycles/min) so as to determine, according to geometric parameters, the instantaneous, partial and total - over a pre-established period of time - concrete rate (m^3/hour).

[0025] Lastly, a pressure and temperature sensor S8 is placed within the pumping unit P to measure instantaneous pressure and temperature values of the oil.

[0026] All these sensors are connected to a central unit 10 (Fig. 3) that collects the signals, possibly codifies them and converts them into numerical values meaningful to the operator. Unit 10 is then connected, by means of a can-bus interface, to a display 11, preferably with a graphic interface, on which the operator can read instantaneous operation values and signals processed as specified next.

[0027] The central unit 10, in addition to supplying to the display 11 numerical indications of sensors S1-Sn, selectable and viewable as desired according to the operator's choices, combines the collected data to provide comprehensible evaluations to the operator, regarding the operation status relative to threshold predetermined values. At the same time, the software implemented in the central unit 10 can suggest to the operator in what direction corrective maneuvers should be made.

[0028] Methods that accomplish such result can be concretely implemented in a variety of ways, according to which control electronics and programming languages are used; however, the connections and logic operative sequence, embodied by the central unit, are unequivocally taught by the present invention.

[0029] A number of signals output from detecting sensors of the operating conditions of the machine are collected, possibly codified and/or decodified, and combined with geometric parameters of the machine itself to obtain data regarding forces and moments acting instantaneously; these data are then compared with predetermined threshold values to provide the operator with a comprehensible indication of current safety conditions or use of the machine capabilities.

[0030] A possible comprehensible indication displayed to the operator is shown in Figure 4A.

[0031] On a display 11 a schematic plan view 11a of the concrete pump, with three of the four stabilizers E

partially extracted, is shown. According to the signals coming from sensors S1-Sn and to predetermined physical parameters (such as the masses of the truck and articulated arm, the stabilizers geometric parameters, and so on), central unit 10 is able to determine the operating area of the articulated arm and the area in which, instead, the arm must not be used, for example the broken line area.

[0032] At the same time, an incremental lateral bar 11b tells the operator, percentage-wise, how close it is to the predetermined threshold values, for example how close it is to the rollover threshold. When the incremental bar reaches 100% - indicative of the reaching, lacking any safety coefficient, of the predetermined threshold - an acoustic or luminous alarm is also emitted and, possibly, the operator is prevented from continuing with his intervention.

[0033] Advantageously, on the right side of the display comprehensible indications 11c to aid the operator are also displayed. For example, there are displayed arrows that can alternatively be lit the central unit 10, based on a comparison operation between the instantaneous values read by the sensors and the predetermined design values, is therefore able to suggest corrective measures to the operator, for example in what direction to move the articulated arm to reenter within the operative area, or if the arm needs to be retracted for gaining again a safety condition.

[0034] Other examples of comprehensible indications to the operator can relate to:

[0035] the stress the articulated arm end undergoes, for example to signal if it is used improperly to lift weights (that could be excessive), or

[0036] the concrete rate, for example to avoid dangerous oscillations phased with pumping frequency, or still

[0037] the truck levelness, to help and guide the operator to correctly extract the support legs of the stabilizers so as to rapidly achieve a condition of levelness, and so on.

[0038] The data used to provide the operator with comprehensible indications are also stored in a "black box", or memory device, for next use.

[0039] For example, every time the articulated arm is used in an operating area that the central unit considers inappropriate, a corresponding signal of "exceeding of the threshold" is recorded in the black-box.

[0040] The so stored data are used by the machine owner or by the company in charge of maintenance to reconstruct how the machine was used and, especially, the duration and the number of times the machine has worked close to or outside the predetermined threshold values.

[0041] These data integrated in time (value generated, for example, by a clock device 9) give a useful indication that allows to vary maintenance interventions according to need and the actual use of the machine capabilities. For example, central unit 10 is able to evaluate, based on predetermined parameters, if the time-in-

tegrated use has led to a condition that requires maintenance: in this case said unit alerts the operator signaling the need for maintenance, that can also be premature or postponed relative to what foreseeable based on average use.

[0042] Another advantageous use of the data so collected and stored in the "black box" is in connection with the design and therefore it is of interest to the machine's builder.

[0043] In fact, by analyzing the collected data over a long period of time, it is possible to determine whether the machines, in practical use, work close or not to boundary threshold conditions, allowing, at the same time, to process several use "profiles", customer- and user-type-specific.

[0044] Based on this, it is then possible to plan corrective actions to be applied in the design and manufacture, increasing safety measures (even if it were only structural strengthening) only where it is strictly necessary, to always guarantee minimum costs consistent with actual needs.

[0045] According to a preferred embodiment, the memory device is in turn interconnected, always by means of central unit 10, to a control panel (not shown) of the machine. This way, it is possible to store repetitive procedures in the memory device that are later automatically executed, by means of central unit 10, by said control panel without the operator's intervention.

[0046] The automatic procedure can be implemented, still meeting safety requirements, thanks to the fact that the central unit is able to coordinate and compare, time by time, the command of the automatic procedure with the indications regarding the operating areas determined for the specific working conditions.

[0047] For example, an operation that could be automated is the uniform pouring of concrete along a straight line keeping terminal T1 of duct T at the same distance from the ground: this operation, that manually requires a certain level of experience to coordinate all the actuators movements, can be carried out automatically and safely thanks to the system according to the present invention.

[0048] Thus, by means of the system comprising the sensors, the central unit and the memory device, it is possible to fully achieve the above mentioned objects.

[0049] In particular, with the invention it is provided a controlling and monitoring system that can detect the instantaneous operation parameters and show them in a comprehensible way to the operator, while, at the same time, helping him execute proper corrective actions to quickly reenter within the predetermined operating areas. Moreover, by means of time integration, it is possible to correctly and specifically establish the exact moment to perform maintenance operations; the system also allows to gather important information useful for the designing activity. All this is, therefore, beneficial to the final user who will have a product - intended as the sum of the machines and all relative maintenance

services - that is tailored to his specific needs.

[0050] It is also possible to greatly simplify several automatic operations, so as to make the machine safe to use even by less expert operators.

5 **[0051]** The present invention, however, is not limited to the particular embodiments illustrated herewith, which are merely examples not limiting the scope of the present invention, but several modifications are, in fact, possible, all within an expert's reach, without departing from the scope of the invention.

Claims

- 15 1. System for controlling and monitoring the operation of self-moving machines with an articulated arm, particularly concrete pumps, **characterized in that** it comprises a plurality of sensors and transducers apt to collect data regarding the machine position, attitude and operation parameters, and a central unit, apt to receive in real time said data, to process and compare them with other reference data regarding the proper use of the machine and make them comprehensible to an operator.
- 25 2. System as in Claim 1), wherein said central unit is also connected to a display on which said comprehensible data are graphically displayed.
- 30 3. System as in Claim 2), wherein said data are made comprehensible on said display by definition means of an operating area of the machine, safety threshold proximity percentage bar means and mark means apt to indicate a course of action suggested to the operator to solve an operative risk situation.
- 35 4. System as in any one of the previous claims, wherein there is further provided a memory device connected to the central unit and apt to store said data.
- 40 5. System as in Claim 4), wherein there is further provided a clock device apt to supply a signal that allows said data to be time integrated.
- 45 6. System as in Claims 4) or 5), wherein said central unit is further connected to a control panel of the machine, said memory device storing also automatic procedures data that can be executed by the control panel through the central unit.
- 50 7. Maintenance method for a self-moving machine with an articulated arm, particularly a concrete pump, **characterized in that** it comprises the steps of:
 - 55 - collecting over time, in a system as in any one of Claims 4) to 6), the operating data of the machine;

- establishing a fatigue frequency proportional to the ratio of the number of times the machine has worked close to the predetermined operating thresholds to the time;
- comparing the total operating time and said fatigue frequency with predetermined threshold values; 5
- determining when to start a maintenance procedure according to said comparison. 10

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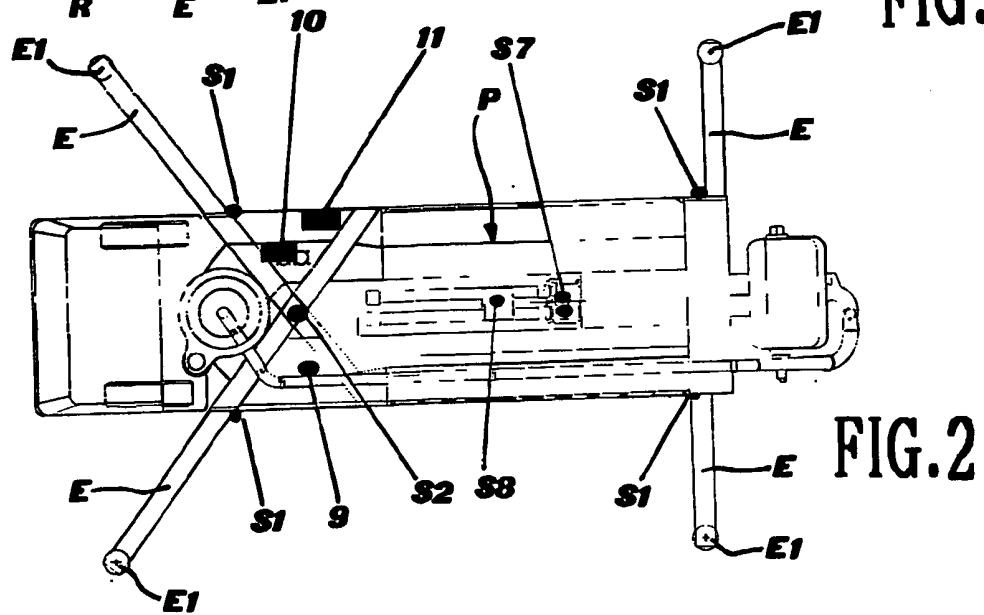
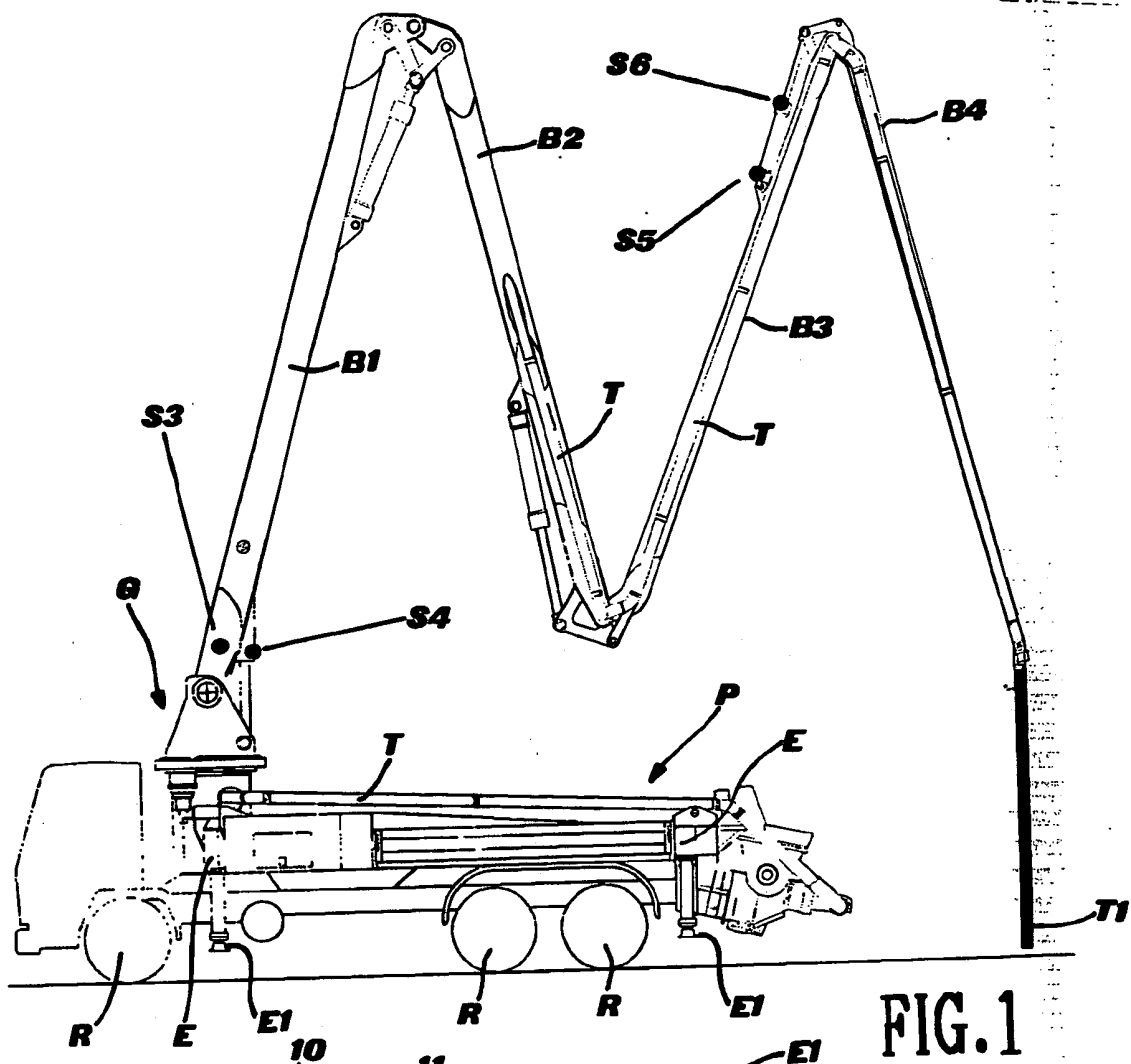
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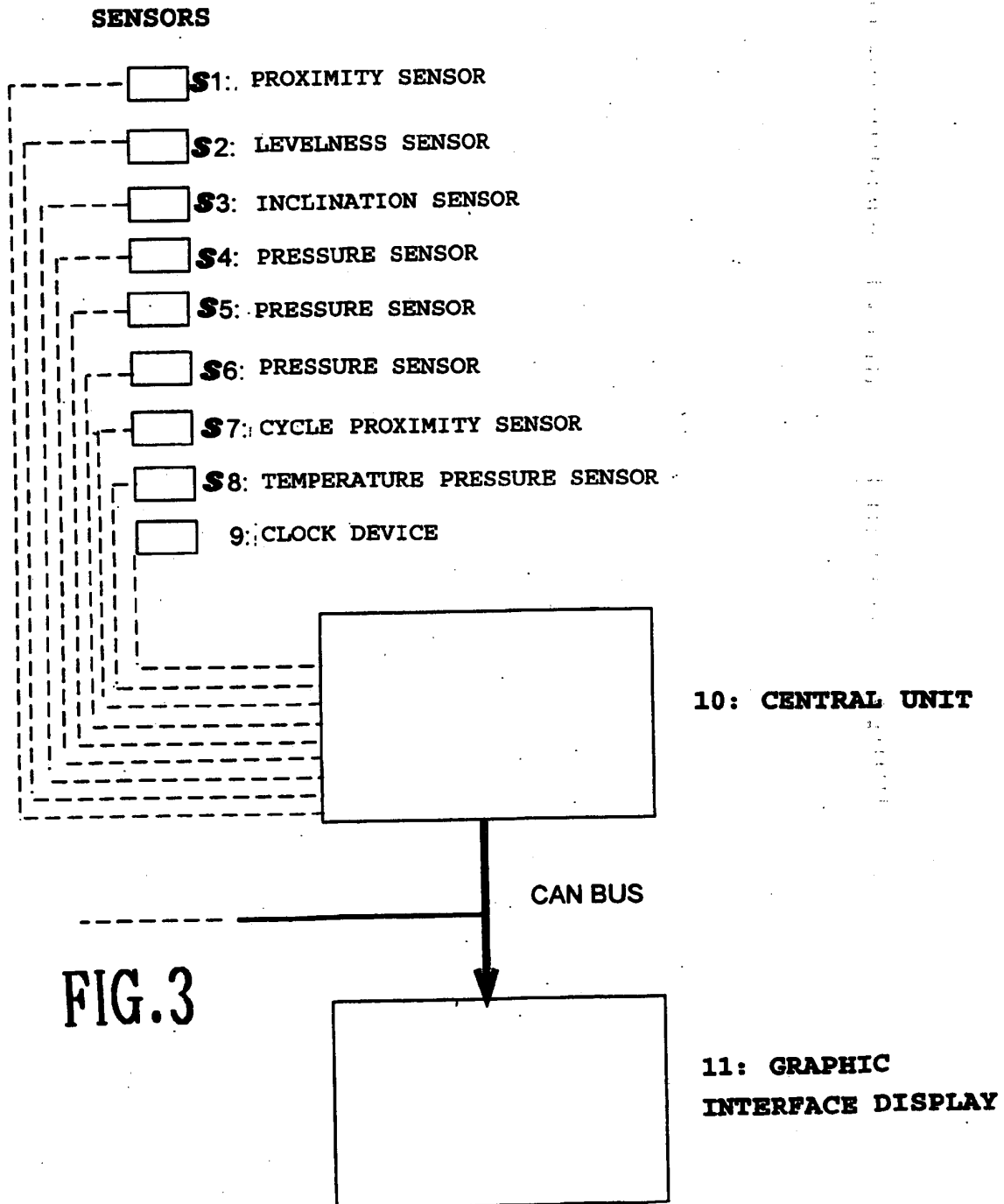
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BLACK BOX COMPONENTS CONNECTION DIAGRAM



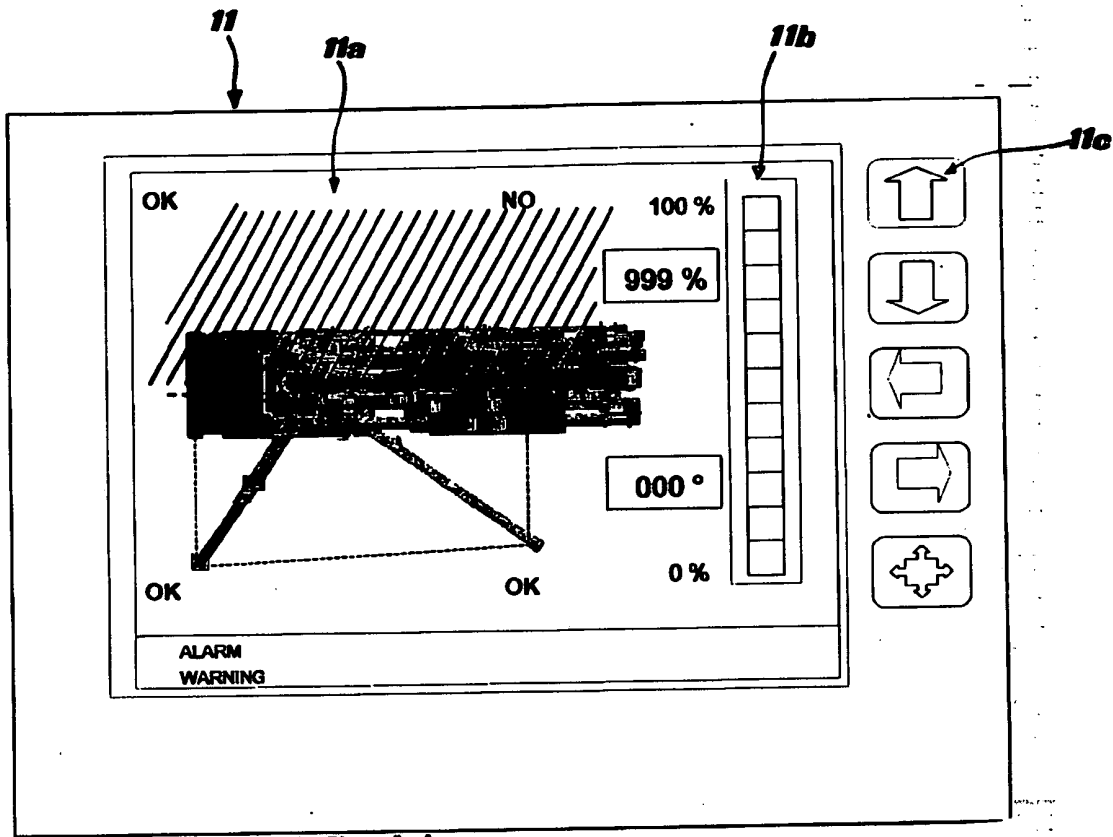


FIG. 4A

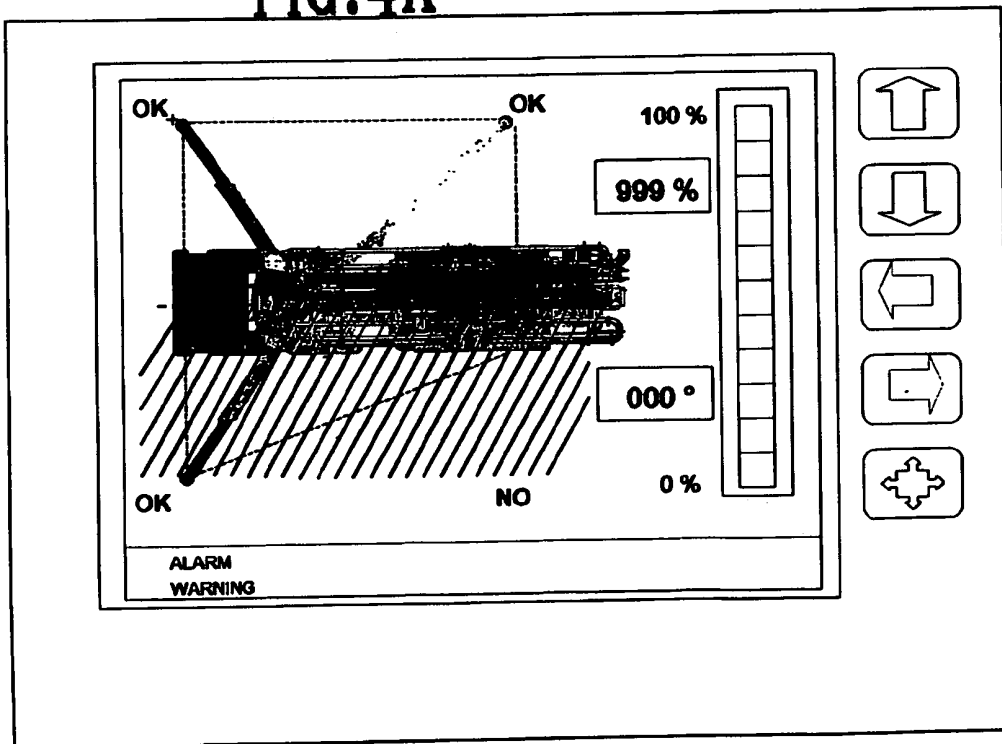


FIG. 4B



European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 03 10 1118

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