

**DEVICE FOR CONTROLLING LUBRICANT QUALITY AND METHOD
FOR CONTROLLING THE OPERATION OF AN INDUSTRIAL
APPARATUS USING A LUBRICANT**

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The present invention relates to the field of the continuous or discontinuous measurement of the change in quality of a lubricant circulating through an industrial apparatus.

10 The invention relates more specifically to a device that makes it possible to measure the change in properties of a lubricant within an industrial apparatus such as equipment in operation, for example an engine or a machine.

15 The present invention also relates to a method for checking the operation of an industrial apparatus, for example an engine, notably a combustion engine, or a machine, for example a rotary machine, by monitoring the quality of its lubricant.

20 More specifically, the present invention relates to the checking of marine engines, for example of the four-stroke or two-stroke type, by analyzing the oils circulating in and/or recovered from said engines.

25 These applications will be described more specifically in the remainder of the present description, but of course the device and method that form the subjects of the present invention may be applied to any type of check on an industrial apparatus involving the circulation or presence of a lubricant in order for it to operate.

30 Specifically, a lubricant is generally used in a great many items of industrial apparatus, in fact in practically all engines and machines. Said lubricant may notably contribute toward numerous essential functions, such as:

- 35
- reducing the power consumption,
 - limiting atmospheric emissions,
 - limiting wear,
 - cooling, particularly of parts said to be sensitive,
 - protection against corrosion, and/or

- improving sealing.

The machines may be electricity generator sets, turbines, notably gas or steam turbines, step-down or step-up gearboxes, hydraulic presses,
5 machine tools, compressors, transformers or even thermal equipment that use hot oil circuits.

More specifically, the engines may be items of industrial apparatus installed in any moving system of the field known as the automotive field,
10 for example in ships, trucks, vehicles, racing cars, agricultural equipment, handling and/or transport vehicles, coaches or trains.

In the field of ships' engines, a distinction is generally made between marine engines that operate on the four-stroke cycle and those that
15 operate on the two-stroke cycle. Four-stroke engines may have a high-speed or medium-speed operating cycle. Engines of the first type are engines in the low-to-moderate power band (15 to 200 kW per cylinder) derived from terrestrial engines and using fuels of the distillate type, such as marine diesel that has a low sulfur content. Their operating speed is
20 generally of the order of 1200 revolutions per minute. These engines are used for the propulsion of low tonnage ships and as electricity generator sets on board larger ships.

Medium-speed four-stroke marine engines are engines in the medium-to-
25 high power band (500 to 2000 kW per cylinder) similar in design to the high-speed four-stroke engines but which differ from the latter in the larger size of the piston-cylinder assembly. These engines generally use a fuel known as a heavy fuel oil which, because of its high sulfur content, requires a lubricant with a total base number (BN) that is high, generally
30 comprised between 30 and 65 mg of KOH/g of lubricant.

The operating speed of medium-speed four-stroke marine engines is comprised between 300 and 600 revolutions per minute. These engines are used for the propulsion of many ships, such as units of the Ro-Ro
35 type, cargo ships, tankers, ferries, or even certain container ships. They may also be used as electricity generator sets on board large ships or in diesel-electric power stations.

Four-stroke marine engines operate in a very different way to two-stroke marine engines, particularly in terms of the way in which they are lubricated. Specifically, two-stroke marine engines are very slow engines, in the high to very high power band (2000 to 6000 kW per cylinder). These engines are always made up of two parts which are lubricated separately, the two parts being the piston-cylinder assembly which is lubricated on the lost lube oil principle with highly viscous cylinder oil generally of grade SAE 50 or 60, and the crankshaft which is lubricated by a low viscosity system oil, generally of grade SAE 30.

These two-stroke engines generally use a fuel named a heavy fuel oil which, because of its very high sulfur content, generally requires cylinder oils with a total base number (BN) that can be as much as 100 mg of KOH/g of oil.

As it flows through the internal circuits of the engines or the machines, the lubricant will pick up contamination and/or the products of wear of said engines or machines. As a result, the lubricant will become degraded more or less rapidly as the industrial apparatus operates. The lubricant therefore contains a great deal of precious information regarding the operation of the engine or of the machine, regarding any contamination there might be, regarding its mechanical condition and therefore regarding its present and future functional performance.

The various degradation and/or contamination experienced by the lubricant in its service life in the engine or the machine may lead to irreversible corrosion and/or damage to sensitive parts of the engine or of the machine, for example leading to a change in the BN of the lubricant, a change in its viscosity, the appearance of metal particles, a change in the water content of the lubricant, etc.

It is these parameters that the present invention makes it possible to measure and analyze, continuously or discontinuously, in order to obtain better control over, better use and better protection of the engine or the machine.

In the case of engines (and more specifically in the case of a low-speed two-stroke crosshead marine engine), the combustion residues containing

acid gases are in direct contact with the lubricating oil inside the piston/cylinder assembly.

5 These acid gases may be formed from the combustion of the heavy fuels, and these are notably oxides of sulfur (SO_2 , SO_3) which are then hydrolyzed upon contact with the moisture present in the combustion gases and/or in the oil. This hydrolysis generates sulfurous acid (HSO_3) or sulfuric acid (H_2SO_4).

10 The acids formed have to be neutralized, notably in order to preserve the surface of the cylinder liners and prevent excessive corrosive wear. This is generally performed by reaction with basic sites included within the lubricant.

15 The neutralization capacity of an oil can be determined by its BN or base number, which characterizes its basicity. It is usually measured in accordance with standard ASTM D-2896 and is expressed in weight equivalent of potassium hydroxide per gram of oil, or mg KOH/g. The BN is a conventional criterion for adjusting the basicity of the oils to suit the
20 sulfur content of the heavy fuel used as engine fuel, so as to be able to neutralize the sulfur contained in said fuel and liable to be converted into sulfuric acid.

25 Thus, the higher the sulfur content of a heavy fuel, the higher the BN of a marine oil needs to be. This is why marine oils with BNs varying, for example, for 5 to 100 mg KOH/g can be found on the market. There is therefore a need to adjust the BN of the lubricant to suit the sulfur content of the fuel used.

30 Furthermore, concern for the environment has, in certain zones and notably coastal zones, led to tighter requirements in terms of limiting the sulfur content in the heavy fuels used in the ships.

35 This is the case, for example, of MARPOL (Regulation for the Prevention of air pollution from ships) Annex 6 of the IMO (International Maritime Organisation) which came into force in May 2005. It sets a maximum sulfur content of 4.5% m/m for heavy fuels (those which feed two-stroke marine engines) and provides for the creation of sulfur oxides emission

control areas (SECAs). Ships entering these zones have to use heavy fuels with a maximum sulfur content of 1.5% m/m or any other alternative treatment aimed at limiting the SO_x emissions in order to comply with the specified values. The notation “% m/m” denotes the mass percentage of a compound with respect to the total weight of the heavy fuel composition or lubricant composition in which it is included.

More recently, the MEPC (Marine Environment Protection Committee) met in April 2008 and proposed amendments to MARPOL Annex 6. These amendments are summarized in table 1 below. They set out a scenario in which the maximum sulfur content restrictions become tighter with a world maximum content brought down from 4.5% m/m to 3.5% m/m by 2012. The SECAs will become ECAs (Emission Control Areas) with a corresponding drop in maximum permissible sulfur content from 1.5% m/m to 1.0% m/m by 2010 and the addition of new limits regarding NO_x contents and particulates.

Table 1: Amendments to MARPOL Annex 6

Current regulation MARPOL Annex 6		
	Overall limit	Limit in SECAs
Maximum sulfur content	4.50% m/m	1.50% m/m

Amendments to MARPOL Annex 6 (MEPC meeting 57 – April 2008)		
	Overall limit	Limit in ECAs
Maximum sulfur content	3.50% m/m on 1/01/2012	1.00% m/m on 1/03/2010
	0.50% m/m on 1/01/2020	0.10% m/m on 1/01/2015

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Ships on transcontinental routes from now on will use several types of heavy fuel according to local environmental constraints. This situation will

endure whatever the final level set for the permissible maximum sulfur content of heavy fuels.

5 Thus, for most container ships currently under construction, the use of several fuel tanks is planned, some for "high seas" fuel oil, with a high sulfur content and some for a "SECA" fuel oil with a sulfur content of 1.50% m/m or below.

10 Switching between these two categories of fuel oil may require adaptations to the engine operating conditions, particularly the use of appropriate cylinder lubricants.

15 As a result, one first solution for optimizing the cylinder lubrication of a slow-speed two-stroke engine is to select a lubricant that has a BN suited to the heavy fuel and to the operating conditions of the engine. This optimizing reduces the operational flexibility of the engine and requires a high level of technical skill on the part of the crew in defining the conditions under which the switch from one type of lubricant to another should be made. Another alternative is to have a single lubricant and to
20 optimize the engine operating conditions (level of lubrication or other combustion parameters) according to the fuel used.

This optimization could be achieved by continuous or discontinuous analysis of the BN of the lubricant in order to maintain the required level of
25 suitability between said BN of said lubricant and the sulfur content of the fuel with which the engine is being powered; the objective quite obviously being to avoid running the engine with too low a BN which would cause irreversible corrosion to the sensitive piston-cylinder parts of the engine and a rapid loss in functional performance of the lubricant inside the
30 cylinder.

In addition, mechanical wear of a four-stroke or two-stroke engine (or of a machine) needs to be able to be checked, and especially controlled, by analyzing certain physicochemical or intrinsic properties of its fuel. For
35 example, when the measurement of the specific content of certain metals (which non limitingly include Fe, Pb, Ni, Cr, Al, Cu, Sb, Ag) employed in the makeup of the sensitive parts of the engine (depending on the design of said engine) reveals that these are present in the analyzed lubricant

(either in metallic form or dissolved) then the presence of this/these said compound/s may signify that material is being torn away in the sensitive parts of the engine, thus leading to partial, or even substantial, destruction of the engine. It is therefore important, or even of overriding importance, that wear of the metallic parts of the engine be detected as early as possible, even as soon as it begins. This detection has therefore to go through the stage of a rigorous and constant analytical monitoring of the fuel during engine operation.

- 10 Just as with the metals that originate from wear, it is important to check the viscosity of the lubricant, for example,
- in order to minimize the wear rate of the sensitive parts, of the engine (or of the machine), involved in the rolling or sliding contact or friction at which said lubrication is targeted,
 - 15 - to limit overheating,
 - to reduce energy consumption, and
 - to contribute to localized cooling.

20 Checking the viscosity of the lubricant also makes it possible quickly to detect that said lubricant has become contaminated with another fluid, for example the fuel, the coolant or some other lubricant.

Likewise, an excessive water content may rapidly impair the functional qualities of the lubricant, notably by forming "sludge" which impairs the quality of the lubricant and thus causes an increase in the rate of corrosion and, therefore, an increase in the rate of wear of the sensitive parts of the engine or of the machine. The presence of bacteria in the water is also a significant source of contamination which may lead to rapid degradation of said lubricant and also present a significant risk to the health of the operators in contact with said lubricant. Continuous or discontinuous measurement of viscosity, of the content in terms of products of wear and of the water content therefore offers a serious opportunity to monitor the correct operation of the engine or of the machine, to improve engine or machine performance and improve its protection against wear and against corrosion in order ultimately to improve its durability.

The lubricant flowing through a machine or an engine therefore plays a part in performing numerous functions that are essential to the operation

of an engine or of a machine, but it will suffer degradation during said operation as indicated hereinabove. It is therefore appropriate to monitor the properties of the lubricant while it is in service in order to prevent corrosion, degradation, or even failure of the machines and/or engines.

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While the analytical monitoring of a lubricating oil in service and, ultimately, the continuous or discontinuous monitoring of the operation of an engine, notably a marine engine, by analyzing its lubricant, is a powerful tool in optimizing said operation of the engine or of the machine
10 and also for preventing mechanical disorders of said industrial apparatus, this monitoring using the methods and technologies available in the existing art does nonetheless present numerous problems.

Specifically, to date there is no technical solution that is able
15 simultaneously to perform three essential functions:

- 1/ to return numerous measurements (BN, viscosity, water content, particles content, etc.),
- 2/ to return these measurements continuously for the most part, or discontinuously, at repeat frequencies that are very high for the others (in
20 a few minutes or tens of minutes) and, above all,
- 3/ to perform these measurements directly on the lubricant, as it circulates through the engine or the machine, in order to ensure that the sample/analysis pairing is truly representative.

25 The technical solutions available in the existing art all require the taking of a sample of lubricant in service, and this may present an obvious problem of representativeness and also a problem of this sample evolving over time before it has been analyzed.

30 The current solutions are generally known as "Off line" or "At line" or alternatively "mini laboratory".

Analyses performed "Off line", that is to say in external laboratories, while satisfactory in terms of their results, are not well suited to the need to give
35 consideration to sudden variations in oil quality, for example a rapid variation in BN or sudden engine wear. Specifically, the need to transport the sample to a laboratory located several hundreds of kilometers away from the ship means that the result may take several days, or several

weeks, or even several months to arrive after the corresponding sample was taken, and therefore become irrelevant by the time it has been received because the engine operating conditions have changed, or quite simply, and at the extreme, mechanical damage or even an engine failure
5 has occurred. Real-time engine or machine optimization or early detection of degradation or contamination of the lubricant therefore becomes impossible because of the excessive lead time involved in getting the results back. The same is true of real-time optimization of the operation of a marine engine such as, for example, setting its level of lubrication
10 according to the fuel and its sulfur content.

In addition, the long lead times due to the transportation of samples before analysis may cause these samples to suffer degeneration, or may even cause microorganisms to develop in these very samples, for example on
15 contact with the air and any relative moisture in the containers in which said samples are being transported, and this may introduce a greater or lesser bias into the results of certain types of analysis.

Solutions for overcoming these various disadvantages by using analysis
20 systems of the "on board" type have been proposed, said analyses being performed using a "mini-laboratory" included in a portable case.

While the analyses are relatively simple to carry out using these "mini-laboratories", the analysis techniques however remain limited, the
25 frequency of the measurements is generally every few days to once a week and above all they require a trained and qualified technician to be present on board the ship.

The same is true of "At line" analyses, that is to say analyses which
30 likewise are performed on board the ship, but using special laboratory-type analyzers. These analyses, which, de facto, represent a very substantial investment, additional workload for the ship's crew and a not insignificant amount of operator time, likewise have limited applications and require great precautions to be taken with regard to their analytical
35 specificness, notably in terms of analyzer calibrations, analyzer use and analytical maintenance. These "At line" analyses additionally require an extensive body of training and a great deal of skill on the part of the operators.

Thus, EP1485696 describes a method for determining the total base number (TBN) of a marine engine lubricant in 3 steps:

- a) measuring the infrared absorption band from 840 to 910 cm⁻¹,
- 5 b) determining the absorbance value for at least one peak of interest within said band frequency, and
- c) calculating the TBN of the lubricant from the value of the absorbance of the peak from a calculated baseline.

10 The same goes for WO 03/048763 which describes a method for determining the contaminants in a lubricant of a marine diesel engine. This method involves four actions on the part of the operator:

- a) obtaining a UV spectrum for what is known as a reference sample with known properties and containing known quantities of contaminants,
- 15 b) developing a calibration model,
- c) taking measurements on the samples under the same conditions,
- d) calculating the contaminant concentration.

As indicated hereinabove, while solutions do exist for monitoring the
20 operation of a marine engine by analytical monitoring of its lubricant, these techniques do not allow results to be obtained continuously, or discontinuously, with guarantee of exhaustive traceability of said operation. What is more, they generally require aptitude and know-how on the part of the sailor operating them and a not insignificant amount of
25 operator time in order to accomplish perfect analytical monitoring.

In all the cases of the solutions mentioned hereinabove, it will not systematically be possible for the sulfur and BN pairing to be monitored and/or for an engine anomaly to be detected early by monitoring the
30 quality of the engine lubricant and as a consequence, varying length periods of uncertainty that could be detrimental to the environment (too much sulfur discharged into the atmosphere) or to the engine, with risks of damage, such as irreversible breakage because the early symptoms have not been detected early enough, may result.

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The same is also true of International PCT application WO 03/091550 in which the techniques used are X-ray fluorescence spectrometry to measure

iron contents and sulfur contents in the lubricant and the fuel respectively and infrared spectrometry for measuring the BN of the lubricant.

5 It should also be noted that all these "At line" solutions which may call upon spectroscopy techniques, for example X-ray, infrared or even ultraviolet spectroscopy techniques, require equipment that is sensitive and fragile (optical internal paths) and has to be stored, sited and handled with care and at the correct temperature, etc..

10 In addition, and in general, these various analytical techniques are not particularly well suited to continuous or discontinuous operation with the lubricant being analyzed very frequently.

15 In particular, the solutions proposed are expensive, require bulky equipment, a qualified operator, need a relatively long length of time between taking the sample and obtaining the results of the analysis, and present risks of samples becoming lost or contaminated and/or cannot be applied quickly to the system being studied.

20 It is an object of the present invention to remedy all or some of these disadvantages by proposing a device and a method that make it possible to obtain, directly on the lubricant in service, continuous or discontinuous analysis results so as to allow any degradation or contamination of the lubricant to be detected early thus making it possible to optimize and/or
25 check the operation of a machine or of an engine, notably a combustion engine, and more specifically a marine engine, by monitoring the quality of its lubricant.

30 The present invention is able to perform three essential functions simultaneously, these being:

- 1/ to return numerous measurements (BN, viscosity, water content, particle content, etc.),
- 2/ to return these measurements continuously for the most part or discontinuously at very high repeat frequencies for the others (in a few
35 minutes or tens of minutes), and
- 3/ to perform measurements directly on the lubricant circulating through the engine or the machine (thus ensuring that the sample and analysis pair is truly representative).

Because of its small size on the one hand, and its high modularity on the other, the device can readily be adapted to suit practically all engines or all machines.

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To this end, a first subject of the invention relates to a device for continuously or discontinuously monitoring the change of quality of a lubricant circulating through an industrial apparatus, said device comprising, or essentially consisting of:

- 10 - a lubricant distribution assembly of the type comprising at least one lubricant piping module positioned on the body of said distribution assembly,
- at least one functional component of the measurement means type for determining at least one physicochemical property or one intrinsic
- 15 property of the lubricant connected to said piping module,
- at least one measurement system for measuring the signal generated by said functional component, and
- at least one automated control system for checking at least one functional parameter or composition parameter of the industrial apparatus
- 20 or of the lubricant, respectively.

Of the distribution assemblies that can be used in the present invention, mention may be made of the one described in WO 2007/110504 A1. That one is of small bulk and comprises:

- 25 - a body comprising at least one flat face on which at least one lubricant piping module is positioned,
- a passage for the lubricant formed inside the body,
- a calibrated filter situated on the inside of the distribution assembly for filtering the lubricant fluid before it enters the functional component
- 30 and, possibly,
- a device for preparing the lubricant for a special analysis, connected to an additional piping module which is fixed to the body of the distribution assembly.

- 35 The dimensions of the distribution assembly, which supports the functional component, may range from 100 mm to 300 mm in length, and from 20 mm to 70 mm in width, and in height. The overall size is therefore small and can be less than or equal to 300 mm x 70 mm x 70 mm.

The piping module is fixed to the flat face of the body of the distribution assembly in accordance with standard ANSI/ISA-76.00.02-2002 and, more recently, IEC 62339-1:2006.

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The distribution assembly may comprise a sample preparation device, particularly positioned on a piping module. This distribution assembly may be a sample heating or cooling unit, a unit for reducing the pressure, for checking and/or controlling the flow rate, for performing a specific filtration operation in order to prepare the sample for a particular analysis or several analyses according to the parameter(s) to be measured.

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At least one functional component is connected to a piping module that complies with the NESSI (New Sampling and Sensor Initiative) recommendations for sampling systems.

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Advantageously, this functional component may be a microsensor or a microanalyzer, as known in the art as a MEMs (Micro Electro Mechanical system) or NEMs (Nano Electro Mechanical system) making it possible, for example, to measure the temperature and/or the pressure of the lubricant, the viscosity, the BN, or even the amount of undissolved iron particles contained in the lubricant. Quite specifically, the microsensor or the microanalyzer is fitted to a piping module.

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These microanalyzers are marketed, for example, by MEMs companies Schlumberger or Vectron, notably under the respective trade names of Excalibur or ViSmart™.

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More generally, the physicochemical and/or intrinsic properties measured on the lubricant may be of different kinds, for example:

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- measuring the viscosity which may make it possible to check the functional capability of the lubricant to afford effective protection to the sensitive parts of the engine against abnormal localized hot spots, said hot spots potentially leading to the onset of engine destruction, sometimes being prohibitive to its operation,
- measuring the BN which may make it possible to check the ability of the lubricant to protect the sensitive parts of the engine against the

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effects of acid corrosion due to the sulfur content of the combustion heavy fuel,

- measuring metallic particles contents, iron or other metals, present in the lubricant, which may make it possible to check correct operation of the engine (when the measured quantities are at very low levels) or detect the start of a mechanical malfunction associated with metal being ripped away from the mechanical parts (when the measured content levels increase significantly) which may be highly sensitive and essential to correct engine operation, and
- measuring the water content, that is free water and/or dissolved water, which may make it possible to assess the correct operation under normal circumstances of the engine (or of the machine) and of the auxiliaries of the lubricant circuit such as, for example, the device that continuously filters the oil, the oil/water separation performed by the design of the oil sump and/or, in addition, by centrifugal spinning.

The latter measurement may in particular make it possible to detect an accidental cause due to an ingress of water specific to the engine, or specific to the lubricant cooling circuit, or even due to malfunctioning of the auxiliary filtration, separation and lubricant treatment equipment.

In general, each microanalyzer is chosen to determine one or more clearly defined property/properties. There may therefore be as many microanalyzers as there are properties or sets of physicochemical or intrinsic properties to be checked. In particular, each physicochemical or intrinsic property measured is associated with one specific microanalyzer or microsensor.

Combined with these microanalyzers, an electronic and/or computerized system for measuring the signal or signals generated by said microanalyzers allows said signals to be formed and quantified in order ultimately to exploit them in an automated system for controlling at least one functional and/or composition parameter of the industrial apparatus and/or of the lubricant, respectively.

These results are then exploited in order, for example, to influence the level of lubricant, the engine load, the operation of a piston in the case of a two-stroke engine, the renewing (which may be partial) of the charge of oil

in a four-stroke engine or any parameter for checking the operation of the engine or the machine.

Advantageously, the distribution assembly of the device according to the invention is positioned on piping situated downstream of the engine and which is representative of the product on which the check is to be made.

The lubricant may be withdrawn from a point under pressure in the lubricating circuit, for example at a few bar. In other words, the lubricant feed to the distribution assembly may be a pressurized point of the industrial apparatus.

The oil withdrawn is introduced into the distribution assembly, analyzed by at least one microanalyzer, then reinjected back into said lubricating circuit.

More advantageously still, two similar devices may be positioned upstream and downstream of the industrial apparatus.

Specifically, one similar distribution assembly may be equipped in the same way with filter and functional component(s) and be positioned upstream of the engine or of the machine. That may make it possible to quantify more accurately, by analyzing the results before and after the industrial apparatus, for example a wear rate of said industrial apparatus, or to monitor correct operation of the auxiliary and lubricant treatment circuits (cooling, filtration or possible contamination with water or some other fluid).

The small dimensions and great modularity of the device and, more specifically, of the distribution assembly supporting the piping module or modules which itself or themselves support at least one functional component may allow said distribution assembly to be located on the marine engine in situ, that is to say as close as possible to the industrial apparatus.

The invention also relates to a method for checking an industrial apparatus involving the circulation of a lubricant, alone or in a mixture, said check being performed by continuously or discontinuously monitoring

at least one physicochemical or intrinsic property of said circulating lubricant, in which method

- the lubricant is introduced continuously or discontinuously into the device according to the invention,
- 5 - at least one physicochemical and/or intrinsic property of said lubricant is measured by an analysis means connected to a piping module positioned on the body of a distribution assembly, and
- the measured value(s) is/are processed by computerized means so that they can then be returned in the form of signals suited to controlling,
- 10 according to the nature and response of the measured property, functional parameters of the industrial apparatus and/or the lubricant, respectively.

Continuous monitoring of at least one physicochemical property is a response, in real time, without interruption, to the magnitude measured by
15 the microanalyzer. This is how the lubricating oil quality of medium-speed to high-speed four-stroke marine engines or the system oils of low-speed two-stroke engines are monitored.

Discontinuous monitoring of at least one physicochemical property is a
20 cyclic response to the magnitude measured by the microanalyzer. For example, when monitoring cylinder oil quality, and more specifically the quality of the seepage oil, of a low-speed two-stroke marine engine the distribution assembly of which is first of all filled with lubricant, then isolated from the circuit of said lubricant so that the microsensor or the
25 microanalyzer can perform the analysis. A new cycle then recommences, after a space of a few tens of seconds, or even of minutes or quite simply of hours, according to the type of measurement(s) to be taken to suit the type(s) of engine or machine phenomenon that is/are to be detected or monitored.

30 The lubricant withdrawn may be continuously reinjected after analysis into the lubricating circuit of the industrial apparatus.

The continuous monitoring of at least one physicochemical or intrinsic
35 property may notably be performed on the lubricating oils of medium-speed to high-speed four-stroke marine engines and on the system oils of low-speed two-stroke engines.

The discontinuous monitoring of at least one physicochemical or intrinsic property may be performed on the cylinder oils of low-speed two-stroke marine engines.

- 5 The functional parameter of the industrial apparatus may be the power of the engine, the nature of the lubricant and/or the level of lubrication.

10 The invention finally relates to the use of the device and of the method that form subjects of the present invention on board a ship for checking the operation of an engine, notably a medium-speed to high-speed four-stroke engine or a low-speed two-stroke engine.

15 In another of its aspects, the invention relates to the use of the device or of the method according to the invention to make it possible to optimize certain operating parameters, such as the level of engine lubrication, particularly in the case of low-speed two-stroke engines.

20 Yet another aspect of the invention relates to the use of the device or of the method according to the invention for optimizing the value of the BN of the lubricant, particularly as a function of the sulfur content measured, for example in real time, on the fuel, notably the heavy fuel.

25 Yet another aspect of the invention relates to the use of the device or of the method according to the invention to optimize the lubricant formulation continuously, that is to say in real time and on the basis of the results of the measurements taken by the microsensors and/or the microanalyzers, and thus reduce the lubricant consumption to the minimum level required for correct engine or apparatus operation and also improve the impact on the environment by reducing emissions into the atmosphere. This
30 optimization may notably be achieved according to the sulfur level measured in the heavy fuel.

35 Of course, this alternative form can more easily be performed if the ship has a mixing unit (for mixing basic oil/additives/booster, etc.).

The invention may also, for example, be used to check the operation of a machine, for example a rotary machine, or quite simply, thanks to its small size, for the on-board checking of the operation of an automobile engine,

or even a racing engine, so that it can be used at the limits of its mechanical performance.

5 The invention is now described with reference to the accompanying nonlimiting drawings in which:

- figure 1 is a schematic depiction of the device according to the invention applied, for example, to four-stroke marine engines and to the system oils of low-speed two-stroke engines or to any type of lubricating circuit of an industrial equipment operating with a lubricant under pressure.

10 - figure 2 is a schematic depiction of the device according to the invention as applied, for example, to two-stroke marine engines and, more specifically, to the analytical monitoring of the cylinder oils of these engines, said oils being collected at the bottom of said cylinders in the form of seepage oil. More generally, this is an analysis performed on a fluid collected in discontinuous dripping at atmospheric pressure, the analytical monitoring of which dripping allows for optimization.

20 In figure 1 and for four-stroke and two-stroke marine engines for system oil, the device comprises:

- a distribution assembly (2) positioned downstream of a marine engine (M),
- at least one piping module (6) positioned on the body of the distribution assembly (2),
25 - at least one functional component (8) connected to the piping module (6),
- at least one measurement system (10) for measuring the signal generated by the functional component (8),
- at least one automated control system (12) for checking at least
30 one functional parameter or composition parameter respectively of the industrial apparatus (in this case the marine engine) or of the lubricant in circulation.

35 The lubricant is withdrawn continuously from a point (A) of the lubricating circuit of the engine (M). At the point (A) the pressure may vary, for example, from 1 to 5 bar. The tapping-off point at which the lubricant is withdrawn here is a single point positioned downstream of the engine (M).

The lubricant is introduced, via the piping (1), into the distribution assembly (2), said distribution assembly (2) being bypassed by the piping (3) through which the lubricant circulates, in order to ensure the correct flow rate through the lubricating circuit of the engine (M).

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On leaving the distribution assembly (2) the lubricant is reinjected into the lubricating circuit (in this instance a closed circuit) by the piping (4).

10 The distribution assembly (2) consists of a body (5) on which, and more specifically on one of the flat faces of which, is fixed a piping module (6). This piping module (6) feeds the functional component (8) with lubricant to be analyzed. A filter (7) may be present, and notably may be positioned along the longitudinal axis of the distribution assembly, this filter ensuring that the lubricant is filtered before it enters the piping module (6) and
15 ultimately the functional component (8).

Quite obviously, the distribution assembly (2) may consist of several flat faces on which several piping modules (6) are positioned, these themselves being connected to several functional components (8), also
20 known as microsensors or microanalyzers or MEMs or NEMs. The latter configuration makes it possible, in a very small analysis space, to obtain responses from several microanalyzers, that is to say responses of measurements of several physicochemical or intrinsic properties which have been determined in real time on the lubricant.

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Connected to the measurement system (10) by an electrical connection (9), the functional component (8) emits a signal representative of the property being measured, and which will be shaped in said measurement system (10) in order to then control the automated
30 system (12) via the electrical connection (11).

Depending on the nature of the property measured, according to the calibration of the automated system (12), data is sent for monitoring and optimizing the engine (M) via the link (13) or, if the ship is equipped for
35 example with an automated unit for topping up with fresh lubricant, commands to modify the composition of the lubricant are sent along the link (14).

In figure 2 and for two-stroke marine engines, notably for the analytical monitoring of the cylinder oils and, in particular, for analyzing the seepage oils, the device according to the present invention consists of:

- a distribution assembly (20),
- 5 - at least one piping module (21) positioned on the body of the distribution assembly (20),
- at least one functional component (22) connected to the piping module (21),
- a least one measurement system (23) for measuring the signal
10 generated by the functional component (22),
- at least one automated control system (24) for checking at least one functional or composition parameter of the industrial apparatus or the circulating lubricant, respectively,
- at least one device (29) to allow pressure to be applied to the
15 lubricant inside the distribution assembly.

Just one cylinder (C) of the two-stroke engine (M) has been depicted in figure 2, but the device described applies to each of the cylinders of the marine engine.

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The cylinder (C) of the two-stroke marine engine (M) is fed with fresh oil via the piping (26); the cylinder lubricating system being of the lost lubricant type, also known in the art as "lost oil lubrication".

25 The seepage oil, contaminated with products of combustion, is withdrawn at the low point (A) of the cylinder, at atmospheric pressure, and flows discontinuously, via the piping (25) into the distribution assembly (20), via a manifold (27).

30 The rate of flow in the manifold (27) may vary for example from 0.1 to 30% of the initial lubricating level.

A device for pretreating the seepage oil (28) is positioned in the collection system (27) in order for example to perform an initial filtration on the
35 lubricant before it is analyzed.

The analysis cycle consists of the following steps:

- a) the slop outlet (34) is isolated to allow the analysis device (20) to be filled. A continuous purge of the analysis device (20) may be performed by the arrival of the product being analyzed before the slop outlet (34) is closed,
 - 5 b) when the analysis device (20) is completely filled in a minimum length of time thanks to the need for small working volumes for the microsensors or microanalyzers, a device (29) automatically isolates the seepage oil inlet,
 - 10 c) like in the case of the four-stroke engines, the functional component (22) emits over the electrical connection (30) a signal representative of the property being measured which will then be shaped in the measurement system (23) in order thereafter to control the automated system (24) via the electrical connection (31),
 - 15 d) at the end of the analysis cycle, the slop outlet (34) is opened to empty the analysis device (20),
 - e) after this emptying, the analysis cycle is reset by the closing of the slop outlet (34).
- 20 Depending on the nature of the measured property, according to the calibration of the automated system (24), data for monitoring and optimizing purposes are sent to the engine (M) via the link (32), or, if for example the ship is equipped with an automated unit for altering the engine lubricating level, commands to alter this level of lubrication are sent
- 25 out over the electrical link (33).

The device and method which form the subjects of the present invention make it possible to reduce lubricant consumption to the minimum required, make it possible to check correct operation of the engine in order to

30 operate it at the optimum level, and also make it possible effectively to detect a variation in the BN, a variation in the viscosity, the onset of metal being torn away, an accidental ingress of water into the lubricating circuit and thus make it possible to react rapidly before the phenomenon worsens and potentially leads to more or less partial destruction of the

35 engine and the shutting down of said engine or of the apparatus and, ultimately, the ship finding itself immobile on the high seas.

The results of the continuous or discontinuous measurements of said parameters hereinabove are made available on board the ship very quickly and notably with lead times which are markedly improved over the conventional analyses of the existing art.

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Specifically, present day conventional measurements require the taking of samples, the sending of these samples to a port, their onwards carriage to a laboratory responsible for the type of analysis required, the return of the analytical results to the ship, it being possible for this process to take
10 several weeks to detect, for example, that the iron content is at the limit or that the water content of the lubricant is abnormal, this being discovered long after the start of the anomaly, it being possible for said anomaly to be prohibitive to correct operation of the engine.

15 In addition, the on-line measurements by microsensors or microanalyzers offer performance in terms of repeatability which is markedly superior to the repeatability of the measurements performed in a laboratory, said repeatability being very much influenced by the quality and training of the staff.

CLAIMS

1. A device for continuously or discontinuously monitoring the change of quality of a lubricant circulating through an industrial apparatus (M),
5 said device comprising, or essentially consisting of:
- a lubricant distribution assembly (2) of the type comprising at least one lubricant piping module (6) positioned on the body (5) of said distribution assembly (2),
 - at least one functional component (8) of the measurement means
10 type for determining at least one physicochemical property or one intrinsic property of the lubricant connected to said piping module (6), the functional component being a microsensor or a microanalyzer, and said property being chosen from the temperature, the pressure, the viscosity, the BN, the metallic particles content, the water content;
 - 15 - at least one measurement system (10) for measuring the signal generated by said functional component (8), and
 - at least one automated control system (12) for checking at least one functional parameter or composition parameter of the industrial apparatus (M) or of the lubricant, respectively;
 - 20 - characterized in that the microanalyzer is a MEMs (Micro Electro Mechanical system) or a NEMs (Nano Electro Mechanical system).
2. The device as claimed in claim 1, characterized in that the
25 distribution assembly (2) comprises a filter (7).
3. The device as claimed in claim 1 or 2, characterized in that the distribution assembly (2) comprises a sample preparation device.
- 30 4. The device as claimed in claim 3, characterized in that the sample preparation device is positioned on a piping module (6).
5. The device as claimed in any one of claims 1 to 4, characterized in that the microanalyzer or the microsensor is suited to the piping
35 module (6).

6. The device as claimed in any one of claims 1 to 5, characterized in that the microsensor or the microanalyzer allows the measurement of the quantity of undissolved iron particles contained in the lubricant.
- 5 7. The device as claimed in one of claims 1 to 6, characterized in that a specific microanalyzer or a specific microsensor is associated with each physicochemical or intrinsic property measured.
8. The device as claimed in any one of claims 1 to 7, characterized in
10 that the distribution assembly is positioned on piping situated downstream of the engine.
9. The device as claimed in any one of claims 1 to 8, characterized in
15 that the lubricant feed to the distribution assembly (2) is a pressurized point (A) of the industrial apparatus (M).
10. The device as claimed in any one of claims 1 to 9, characterized in
20 that two similar devices are positioned upstream and downstream of the industrial apparatus (M).
11. A method for checking an industrial apparatus involving the circulation of a lubricant, alone or in a mixture, said check being performed by continuously or discontinuously monitoring at least one physicochemical or intrinsic property of said circulating lubricant, in which
25 method said property is chosen from the temperature, the pressure, the viscosity, the BN, the metallic particle content, the water content, and
- the lubricant is introduced continuously or discontinuously into the device as claimed in any one of claims 1 to 10,
 - at least one physicochemical and/or intrinsic property of said
30 lubricant is measured by an analysis means connected to a piping module positioned on the body of a distribution assembly, the analysis means being a microsensor or a microanalyzer, and
 - the measured value(s) is/are processed by computerized means so
35 that they can then be returned in the form of signals suited to controlling, according to the nature and response of the measured property, functional parameters of the industrial apparatus and/or the lubricant, respectively;

- characterized in that the microanalyzer is a MEMs (Micro Electro Mechanical system) or a NEMs (Nano Electro Mechanical system).

12. The method as claimed in claim 11, characterized in that the
5 lubricant withdrawn is continuously reinjected after analysis into the lubricating circuit of the industrial apparatus.

13. The method as claimed in claim 11 or 12, characterized in that the
continuous monitoring of at least one physicochemical or intrinsic property
10 is performed on the lubricating oils of medium-speed to high-speed four-stroke marine engines and on the system oils of low-speed two-stroke engines.

14. The method as claimed in claim 11 or 12, characterized in that the
15 discontinuous monitoring of at least one physicochemical or intrinsic property is performed on the cylinder oils of low-speed two-stroke marine engines.

15. The method as claimed in any one of claims 11 to 14, characterized
20 in that the functional parameter of the industrial apparatus (M) is the power of the engine.

16. The method as claimed in any one of claims 11 to 15, characterized
in that the functional parameter is the type of lubricant.
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17. The method as claimed in any one of claims 11 to 16, characterized
in that the functional parameter is the level of lubrication.

18. The use of the device as claimed in any one of claims 1 to 10 or of
30 the method as claimed in any one of claims 11 to 17 on board a ship to check the operation of an engine, particularly of a medium-speed to high-speed four-stroke engine or of a low-speed two-stroke engine and preferably a low-speed two-stroke crosshead engine.

19. The use of the device as claimed in any one of claims 1 to 10 or of the
35 method as claimed in any one of claims 11 to 17 to optimize the level of lubrication of the engine.

20. The use of the device as claimed in any one of claims 1 to 10 or of the method as claimed in any one of claims 11 to 17 to optimize the BN value of the lubricant, particularly as a function of the measured sulfur content of the fuel.

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21. The use of the device as claimed in any one of claims 1 to 10 or of the method as claimed in any one of claims 11 to 17 to optimize the formulation of the lubricant continuously, notably as a function of the measured sulfur content of the heavy fuel.

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22. The use of the device as claimed in any one of claims 1 to 10 or of the method as claimed in any one of claims 11 to 17 to check the operation of a machine, for example a rotary machine.

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23. The use of the device as claimed in any one of claims 1 to 10 or of the method as claimed in any one of claims 11 to 17 to check the operation of an automobile engine.

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24. The use of the device as claimed in any one of claims 1 to 10 or of the method as claimed in any one of claims 11 to 17 to check the operation of a racing vehicle engine, particularly in order to use it at the limit of its mechanical performance.