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- (73) Patenthaver: **Hans Jensen Lubricators A/S, Smedevaenget 3, 9560 Hadsund, Danmark**
- (72) Opfinder: **KRISTENSEN, Nikolaj, Petersborgvej 2, 2., 9000 Ålborg, Danmark**  
**BAK, Peer, Kvisten 9, 9300 Sæby, Danmark**
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# DESCRIPTION

## FIELD OF THE INVENTION

**[0001]** The present invention relates to a method for optimizing lubrication in a large slow-running two-stroke engine. An existing lubrication system is modified for more frequent injection and lower lubricant volume per injection. For example, the large slow-running two-stroke engine is a marine engine or a large engine in power plants.

## BACKGROUND OF THE INVENTION

**[0002]** Due to the focus on environmental protection, efforts are on-going with respect to reduction of emissions from marine engines. This also involves the steady optimization of lubrication systems for such engines, especially due to increased competition. One of the economic aspects with increased attention is a reduction of oil consumption, not only because of environmental protection but also because this is a significant part of the operational costs of ships. A further concern is proper lubrication despite reduced lubricant volume because the longevity of diesel engines should not be compromised by the reduction of oil consumption. Thus, there is a need for steady improvements with respect to lubrication.

**[0003]** For lubricating of large slow-running two-stroke marine diesel engines, several different systems exist, including injection of lubrication oil directly onto the cylinder liner or injection of oil quills to the piston rings.

**[0004]** An alternative and relatively new lubrication method, compared to traditional lubrication, is commercially called Swirl Injection Principle (SIP). It is based on injection of a spray of atomized droplets of lubricant into the scavenging air swirl inside the cylinder. The helically upwards directed swirl results in the lubricant being pulled towards the Top Dead Centre (TDC) of the cylinder and pressed outwards against the cylinder wall as a thin and even layer. This is explained in detail in international patent applications WO2010/149162 and WO2016/173601. Examples of SIP lubricant injector systems in marine engines are disclosed in international patent applications WO2002/35068, WO2004/038189, WO2005/124112, WO2010/149162, WO2012/126480, WO2012/126473, WO2014/048438, and WO2016/173601. The injectors comprise an injector housing inside which a reciprocating valve member is provided, typically a valve needle. The valve member, for example with a needle tip, closes and opens the lubricant's access to a nozzle aperture according to a precise timing. In current SIP systems, a spray with atomized droplets is achieved at a pressure of, typically, 35-65 bar, which is substantially higher than the oil pressure of less than 10 bar that are used for systems working with compact oil jets that are introduced into the cylinder. In some types of SIP valves, the high pressure of the lubricant is also used to move a spring-loaded valve member against the spring force away from the nozzle aperture such that the highly pressurised oil is released

therefrom as atomized droplets. The ejection of oil leads to a lowering of the pressure of the oil on the valve member, resulting in the valve member returning to its origin and remaining there until the next lubricant cycle where highly pressurized lubricant is supplied to the lubricant injector again.

**[0005]** In such large marine engines, a number of injectors are arranged in a circle around the cylinder, and each injector comprises one or more nozzle apertures at the tip for delivering lubricant jets or sprays into the cylinder from each injector.

**[0006]** One of the currently more traditional approaches for lubrication of marine engines is disclosed in German patent document DE19743955B4 and equivalent Danish patent DK173288B1. It discloses a lubrication system in which a central controller feeds lubricant to a lubricator for each cylinder of the marine engine. The lubricator distributes lubricant to a plurality of lubricant injectors distributed around the circumference of the cylinder. The lubricator comprises a housing in which a plurality of piston pumps are arranged around a circle and driven synchronous in common by a hydraulic driven actuator piston 123. Each of the piston pumps comprises an injection plunger 119 that is pumping lubricant through a non-return valve to one of the injectors of a single cylinder. The hydraulic driven actuator piston 123 is moving over an adjustable distance between its stationary rearward end stop and a forward end stop that is adjustable by an adjusting screw. For turning the adjusting screw, it is accessible at an end cap that covers a flange of the housing, through which the adjusting screw extends.

**[0007]** In connection with injection of compact jets of lubricant into marine engine cylinders and also for lubricant quills onto the piston between the piston rings, this system has gained widespread distribution and is marketed under the trade name Alpha lubricator by the company MAN B&W Diesel and Turbo.

**[0008]** FIG. 1 illustrates an example of an Alpha lubricator as it is found on the Internet page [http://www.mariness.co.kr/02\\_business/Doosan%20Retrofit%20Service.pdf?PHPSES SID=fd56da9de6eaca2flf446512e84fcf69](http://www.mariness.co.kr/02_business/Doosan%20Retrofit%20Service.pdf?PHPSES SID=fd56da9de6eaca2flf446512e84fcf69). The drawing is slightly modified with additional reference numbers in order to explain the principle in more detail.

**[0009]** Similar to the above mentioned DE19743955B4 and DK173288B1, the Alpha lubricator 100 comprises a housing 101 in which a plurality of injection plungers 119 are arranged one a circle and driven synchronous in common by a hydraulic driven actuator piston 123. Each injection plunger 119 is arranged slidingly in a dosing channel 115 receiving lubricant from an internal volume 114 of the housing 101 through an inlet aperture 113. The inlet aperture 113 is closed by the injection plunger 119 during forward motion of the injection plunger 119 so that further forward motion by the injection plunger 119 pressurizes the received lubricant in the remaining part of the dosing channel 115 and pumps it through a non-return valve 102 into a pipe 103 and to one of the injectors of a single cylinder. During retraction of the actuator piston 123, caused by the pre-stressed spring 109, the injection plunger 119 is retracted, and vacuum created in the dosing channel 115, until the forward end of the injection plunger 119 is

retracted past the inlet aperture 113 and lubricant can flow through the inlet aperture 113 and refill the dosing channel 115.

**[0010]** The volume of lubricant pressurized by the injection plunger 119 in the dosing channel 115 and expelled through the non-return valve 102 is defined by the travel distance of the injection plunger 119 from the inlet aperture 113 to the most forward position before retraction. During the movement of the actuator piston 123 over the stroke length, the first part of the movement of the injection plunger 119 past the inlet aperture 113, and only once the injection plunger 119 has moved past the inlet aperture 113 and closed it, the lubricant is pressurised and expelled from the remaining dosing channel distance.

**[0011]** In such configuration, the dosing channel distance is less than the stroke length. However, the dosing channel distance over which the lubricant is pressurised and expelled from can also be equal to the stroke length, for example in the case where lubricant is provided through a non-return valve in the forward most part of the dosing channel. An example of such construction in a controller is disclosed in FIG. 5 of DE19743955B4.

**[0012]** The hydraulic driven actuator piston 123 is moving over an adjustable distance between its stationary rearward end stop 104 and a forward end stop 105 that is adjustable by an adjusting screw. For turning the adjusting screw 121, it is accessible at an end cap 106 that covers a flange 107 of the housing 101, through which the adjusting screw 121 extends. The flange 107 in the Alpha lubricator 100 supports the spacer 122 and contains a threading 110 for adjustment of the adjusting screw 121. The reciprocal actuator piston 123 is driven by oscillating oil pressure in the volume 108 behind the actuator piston 123, where a solenoid valve 116 shifts between two pressure levels in this volume 108 behind the actuator piston 123. Once, the lower pressure level is reached, a spring 109 load presses the actuator piston 123 back to the rear end stop. The solenoid valve 116 is regulated by corresponding signals from a control unit.

**[0013]** As can be seen in FIG. 1, a spacer 122 for basic settings of the pump stroke is provided in the 107 flange behind the end cap 106, at which the head of the adjusting screw 121 is accessible for adjustment by rotation. Accordingly, there are two adjustment features, namely a basic adjustment feature by the spacer 122 and the adjustment by the adjusting screw 121. For the spacer variation, the basis setting is delimited by the length of the threading 110 that holds the adjusting screw 121 and in which the adjusting screw 121 is rotated for adjustment. The length of the threading 110 is much less than the spacer illustrated in FIG. 1.

**[0014]** However, as explained in the following, another feature delimits a possible reduction of the stroke length 112 of the actuator piston 123.

**[0015]** In this marketed product, the Alpha lubrication system is modified as compared to the above mentioned patents DE19743955B4 and DK173288B1 in that a capacitive feedback sensor 120 is used to verify a sufficiently long stroke length of the hydraulic actuator.

**[0016]** This feedback sensor 120 is also illustrated in FIG 1. As illustrated, the hydraulic actuator piston comprises two circumferential grooves 111, and the feedback sensor 120 gives a confirmation signal of proper lubrication to the central controller if the stroke of the hydraulic actuator piston 123 is long enough for the second groove 111 to move past the feedback sensor 120. When the first and second grooves 111 pass by the feedback sensor 120, the feedback sensor 120 creates a double-pulsed signal which the central controller takes as confirmation of proper lubrication. If only one the first groove 111 passes by the feedback sensor 120, the corresponding single-pulsed signal from the feedback sensor 120 indicates to the central controller general functioning of the feedback sensor 120 and movement of the actuator piston 123 over at least a small distance but not sufficient movement of the actuator piston 123 for proper lubrication. If the feedback sensor 120 is giving any signal, a warning message is provided by the controller that the stroke was not measured as long enough for proper lubrication.

**[0017]** Although, the forward end stop 105 for the hydraulic actuator piston 123 is adjustable by the adjusting screw 121 and potentially further adjustable by the spacer 122, the minimum stroke length of the hydraulic actuator piston 123 must still be sufficiently long for the second groove 111 to move past the feedback sensor 120, as otherwise the controller is caused to register insufficient lubrication.

**[0018]** The amount for injection by the Alpha lubricator is determined by the frequency for injection into the engine. In practice, lubricant injection by the Alpha lubricator is not performed for each revolution of the engine but typically only for each fixed number of revolutions, for example one injection for each 10 or 12 revolutions of the engine.

**[0019]** In some research projects, indications have been found that more frequent injection than one injection for each 10 or 12 engine revolutions leads to a better lubrication result for the marine engine and reduces wear in the engine cylinder. The higher injection frequency requires lower dosages per injection in order not to increase the total lubricant consumption. Documentary reference is made to the Paper No. 283 by Jensen et al. published at the CIMAC congress in Finland June 6-10, 2016 "Lubtronic SIP promise remarkably low wear rates with low CLO consumption"

**[0020]** However, when considering a possible change of the Alpha system to more frequent lubrication, this implies difficulties in that the stroke length of the actuator piston 123 cannot be reduced below the minimum stroke length as determined by the cooperation of the feedback sensor 120 with the grooves 111 in the actuator piston 123 in the Alpha lubricator 100, as already discussed above. The minimum stroke length as determined by the feedback sensor 120 is not easily reduced, as the signal is provided by fixed grooves groove 111 in the metallic actuator piston 123. Accordingly, such change of the Alpha lubricator 100 to lubrication with higher frequency is a complex task.

**[0021]** This problem is of general nature and applies equally well when modifying an Alpha system to an extent that it is specifically suitable as lubricator for SIP injection.

**[0022]** In this connection, it is put forward that the market has an increasing demand for SIP injection system due to its advantages for proper lubrication at low lubricant consumption. However, in some instances, there is a request for not exchanging the entire lubrication system of the engine but only those parts that are necessary to exchange in order to achieve the desired effect. This is not only a matter of costs but also based on interest to keep those modules of the system that appear to function well. Especially, there is a general demand to change the compact jet injection to SIP injection with a mist of lubricant.

**[0023]** In those cases where Alpha lubricators have been used for compact jet injection, and SIP injectors are mounted as a substitution for compact jet injectors, further modifications are necessary, as the SIP injectors are desired with a higher injection frequency than used for compact jet injection using Alpha lubricators. For example, a SIP injection is done for every revolution or even with more than one injection per revolution. However, as mentioned above, such upgrade appears to be a major task due to the feedback sensor.

**[0024]** Accordingly, it would be desirable to find a proper upgrade procedure.

#### **DESCRIPTION / SUMMARY OF THE INVENTION**

**[0025]** It is an objective of the invention to provide an improvement in the art. A particular objective is to provide a method for upgrade of a lubrication system for a large slow-running two-stroke engine, in particular an Alpha lubrication system. It is a further objective to provide a lubrication system suitable for SIP injection. This objective is achieved by a method of improving the lubrication of a large slow running engine. It is in particular achieved by a method for modifying a lubrication system as explained in more detail in the following.

**[0026]** The lubrication system provides lubricant to injectors for lubricating the cylinder or cylinders in a large slow-running two-stroke engine engine, for example a marine engine or a large engine in power plants. Typically, the engine is burning diesel or gas fuel. The engine comprises one or more cylinders, each with a reciprocal piston inside and with a plurality of lubricant injectors distributed along a perimeter of the cylinder for injection of lubricant into the cylinder at various positions on the perimeter during injection phases.

**[0027]** The lubrication system comprises a lubricator that is pipe-connected to each injector by a lubricant feed conduit for providing pressurized lubricant to each injector through the lubricant feed conduit during the injection phases.

**[0028]** The lubricator is of the type that comprises a housing in which a hydraulic-driven actuator piston is arranged reciprocal with a stroke length along a stroke direction. The lubricator further comprises a stroke length adjustment mechanism configured for variably adjusting the stroke length of the reciprocal hydraulic-driven actuator piston between a minimum stroke length and a maximum stroke length.

**[0029]** The lubricator further comprises a plurality of injection plungers slidingly arranged in corresponding dosing channels, wherein the injection plungers are coupled to the actuator piston in order to be moved by the actuator piston and for pressurizing lubricant in the dosing channels during this movement. When the actuator piston is moved over the stroke length, the injector plungers are moved over a corresponding length. The movement the injection plungers inside the dosing channel pressurizes the lubricant in the dosing channel while the injection plungers move over a dosing channel distance, where the dosing channel distance defines the volume of lubricant expelled from the dosing channel during the injection phase through a non-return valve and through the feed conduit to the injector for injection of the lubricant into the engine cylinder.

**[0030]** As will be apparent below, the dosing channel distance is equal to or less than the stroke length. This depends on the configuration as also discussed above.

**[0031]** The dosing channel distance is adjustable between a minimum dosing channel distance and a maximum dosing channel distance corresponding to the actuator piston's variable stroke length between the minimum stroke length and the maximum stroke length. By reducing the stroke length of the actuator piston, also the dosing channel distance is reduced and the expelled lubricant volume correspondingly.

**[0032]** The lubricator also comprises an electrical valve arranged for causing switch between hydraulic pressure levels that are acting on the actuator piston in order to hydraulically drive the actuator piston reciprocally by the switching pressure levels. Typically, the actuator piston is pre-stressed against the rear end stop by a helical spring.

**[0033]** In some concrete embodiments, the lubricator receives high pressure oil for driving the actuator piston, and the electrical valve switches between

1. a) access of the pressurized oil to the actuator piston in the injection phase and
2. b) connection between the actuator piston and a drain for drainage of oil from the actuator piston between injection phases.

**[0034]** The lubrication system further comprises a controller electrically connected to the electrical valve for controlling the timing of the switching for the injection phases by corresponding electrical signals transmitted from the controller to the electrical valve.

**[0035]** According to the above objective, the lubrication system is modified after a certain time of normal operation of the engine.

**[0036]** In more detail, the method comprises

- operating the engine with lubrication from the lubricator under control of the controller

with one injection through the lubricant injectors for each first number of engine revolutions;

- stopping the operation of the engine for modification of the lubrication system;
- modifying the lubrication system;
- continuing operation of the engine with the modified lubrication system.

**[0037]** The modification of the lubrication system comprises modifying the lubricator by reducing the dosing channel distance to less than the minimum dosing channel distance and operating the engine with reduced dosing channel distance and correspondingly reduced volume of lubricant expelled from the dosing channel per injection phase.

**[0038]** Further, the modification comprises operating the engine with lubrication from the modified lubricator at higher injection frequency with one injection phase for each second number of engine revolutions, wherein the second number is smaller than the first number.

**[0039]** As it appears from above, the upgrade results in increasing the injection frequency and reducing the lubricant volume per injection. The increased injection frequency improves the lubrication effect and reduces wear of the engine. Documentary reference is made to the Paper No. 283 by Jensen et al. published at the CIMAC congress in Finland June 6-10, 2016 "Lubtronic SIP promise remarkably low wear rates with low CLO consumption" Further reference to the SIP injection is found in the publication "SWIRL INJECTION LUBRICATION - A NEW TECHNOLOGY TO OBTAIN LOW CYLINDER OIL CONSUMPTION WITHOUT SACRIFICING WEAR RATES" by Lauritsen et al, published at the 2001 CIMAC Congress in Hamburg.

**[0040]** Advantageously, the total lubricant consumption in the continued operation of the engine with the modified lubricator is less than or equal to the lubricant consumption prior to modifying the lubrication system. As the higher frequency for injection does not compromise the aim for minimal oil consumption, the overall result is a better lubrication without increasing the environmental aspects of low consumption of lubricant.

**[0041]** In some embodiments, in particular for the Alpha lubricator, the housing comprises an internal volume containing lubricant, and the dosing channel comprises an inlet aperture that is in fluid-flow connection with the internal volume for receiving lubricant from the internal volume when the injection plungers are in the retracted position. The inlet aperture has an aperture width between a rear aperture edge and a front aperture edge and is configured to be closed by the injection plunger during motion of the injection plunger past the front aperture edge so that further motion by the injection plunger along the dosing channel distance, as measured from the front aperture edge to the most forward position of the injection plunger, pressurizes the received lubricant in the dosing channel and expels it through the non-return valve.

**[0042]** An option for modification for these embodiments is reducing of the dosing channel

distance comprises increasing the width of the inlet aperture in the forward direction. In this case, the movement of the injection plunger past the front aperture edge of the inlet aperture occurs later during the stroke of the actuator piston, and the remaining part of the dosing channel, namely the dosing channel distance, in which the lubricant is pressurized and from which it is expelled is shortened.

**[0043]** An alternative option is the provision of a further inlet channel closer to the most forward position of the injection plunger. The lubricant is then pressurized and expelled only once the injection plunger has moved past the further inlet channel. This also shortens the dosing channel distance over which the lubricant is pressurized and from which it is expelled.

**[0044]** Alternative, and potentially additional, modification of the lubrication system comprises modifying the lubricator by changing the stroke length to less than the original minimum stroke length; and operating the engine with lubrication from the modified lubricator with modified stroke length less than the original minimum stroke length and at higher injection frequency with one injection for each second number of engine revolutions, wherein the second number is smaller than the first number.

**[0045]** In some embodiments, especially as discussed above in relation to the Alpha lubricator, the lubricator prior to the modification of the lubrication system comprises a feedback sensor that is configured for measuring a stroke at least as long as a predetermined minimum displacement of the actuator piston during the injection phase and for providing a feedback signal when the minimum displacement is measured. The controller is configured for receiving the feedback signal as a confirmation for proper lubrication.

**[0046]** Optionally, the actuator piston is provided with a groove that is moving past the feedback sensor during motion of the actuator piston in the event that the stroke length is at least as long as a predetermined minimum displacement, the latter assuring proper lubricant injection. As also discussed above, reducing the stroke length to below the predetermined minimum displacement has a problem in that the modification in this case results in a lack of proper feedback signal.

**[0047]** As the feedback sensor is an indicator for proper functioning in the lubrication system prior to modification, and the proper reading by the sensor is linked to the mechanical part of the actuator piston, a special modification is necessary, as a constant error or warning signal from the controller would not be adequate.

**[0048]** This problem can be solved by feeding the central controller with a corresponding signal from an electronic signal emulator. In this case, the lacking signal from the feedback sensor to the central controller is substituted by an emulated signal from the signal emulator such that the central controller is receiving a signal for proper lubrication from the emulator.

**[0049]** In more detail, the modifying of the lubrication system comprises providing a feedback signal emulator separate from the feedback sensor, electrically decoupling the feedback

sensor from the controller and feeding an emulated feedback signal from the feedback signal emulator to the controller for emulating proper lubrication to the controller despite the actuator piston being operated at a modified stroke length less than the minimum stroke length and with less than the predetermined minimum displacement.

**[0050]** Potentially, the central controller's function of checking for the signal from the feedback sensor or the emulator is decoupled from the central controller's function of adjustment of the total lubricant volume. Thus, even if a signal from the emulator is received by the central controller for a sufficient stroke length, the stroke length itself can be reduced to below the predetermined minimum displacement without the central controller recognizing this as a fault in the system.

**[0051]** In some embodiments, the feedback sensor is configured for providing a feedback signal with a first type of feedback signal, for example a feedback signal with a single pulse, if the feedback sensor senses displacement of the actuator piston from a position in its idle phase between injection phases and wherein the feedback sensor is providing a second type of feedback signal, for example a feedback signal with two pulses, only if the actuator piston reaches the predetermined minimum displacement during the injection phase. For this embodiment, the lubrication system is advantageously modified in causing the feedback signal emulator to provide an emulated second type of feedback signal to the controller as a consequence of receiving a first type of signal from the feedback sensor, as this indicates movement of the actuator piston. However, if no signal is received from the feedback sensor, also no signal is sent to the controller, which will then cause the controller to provide an alarm. On the other hand, if the stroke of the actuator piston is long enough to cause the feedback sensor to provide a second type of signal, the emulator would also send a second type of signal to the controller.

**[0052]** Optionally, the feedback signal emulator is equipped with LED's to ensure that the feedback sensor is in proper working condition with visual inspection.

**[0053]** This decoupling between the injected volume of lubricant and the signal from the feedback sensor eases the adjustment of the central controller to cause injection of a lower portion of lubricant per injection but at higher injection frequency.

**[0054]** Some practical ways for reducing the stroke length are outlined in the following.

**[0055]** In some embodiments, the stroke of the actuator piston is defined by a forward end stop and a rear end stop, wherein a position of the forward end stop or the rear end stop is defined by an adjustment mechanism that is adjustable between a minimum position and a maximum position, wherein the minimum position defines the minimum stroke length and the maximum position defines the maximum stroke length. The lubrication system is modified by changing the minimum position to a modified minimum position that defines the modified minimum stroke length. For example, the modified minimum stroke length is shorter than the predetermined minimum displacement

**[0056]** For example, the position of the forward end stop is defined by one end of a stroke-length adjusting screw, adjustable along the stroke length by rotation of the stroke-length adjusting screw. A way of modifying the lubrication system comprises exchanging the stroke-length adjusting screw with a longer, modified adjusting screw. Alternatively, it is possible to add material to the stroke-length adjusting in a space between the stroke-length adjusting screw and the actuator piston, thereby effectively making the screw longer and reducing the stroke length.

**[0057]** In some embodiments, the lubricator comprises a flange with a screw support that is supporting the stroke-length adjusting screw. A way of modifying the lubrication system comprises exchanging the flange or removing material from the flange by machining the flange.

**[0058]** By reducing the length of the flange when measured in a direction parallel to the stroke of the actuator piston, the screw support is displaced towards the actuator piston resulting in moving the forward end stop as defined by the stroke-length adjusting screw towards the actuator piston, which changes the minimum position.

**[0059]** A potential modification of the flange, in the case where the adjusting screw is adjustable by rotation in a thread in the flange, implies machining the flange by increasing the length of the threading in a direction towards the actuator piston and thereby increasing adjustment length of the adjusting screw. By rotation of the adjustment screw over a larger length, the stroke length of the actuator piston is decreased.

**[0060]** For example, an electrical motor is mounted onto the end of the screw for rotating it. The latter allows motorised adjustment of the position of the adjustment screw and consequently motorised adjustment of the stroke length. This allows for varying the stroke length between injections by rotation of the adjusting screw by the motor. For example, the motor is controlled by the upgrade controller so that the stroke of the actuator piston can be programmed and electronically adjusted.

**[0061]** Summarizing the above, the adjustment for more frequent injection needs the following adjustments:

1. 1) decreasing the lubricant volume per injection
2. 2) increasing the injection frequency
3. 3) potentially emulating a signal as from the feedback sensor and feeding this emulated signal into the central controller.

**[0062]** In the event that the feed rate data in the central controller cannot be set to the specific amended distance to the forward end stop, it is possible to adjust the feed rate to a correct value by taking offset in the actually desired feed rate  $F_{\text{desired}}$  and dividing this term by the ratio

R between the actual stroke length after modification and the original stroke length before modification. The stroke length as adjusted in the central controller would then be  $F_{\text{controller}}=F_{\text{desired}}/R$ .

**[0063]** Notice that R is less than 1 for a reduced stroke length. For example, if the stroke length is reduced from 12 to 6 mm, the ratio R is  $6/12=0.5$ , and the central controller would have to be adjusted to the double feed rate as compared to a standard situation where the lubricator is not modified. For example, the double feed rate can be achieved with double frequency for injection.

**[0064]** The reduction of the stroke length by the method as outlined above needs some further considerations under special conditions. For example, if a cylinder liner or piston has been changed in the engine cylinder, a higher lubricant feed rate than possible with the shortened stroke length may be desired. The higher feed volume is optionally achieved with a higher lubrication frequency. Alternatively, the stroke length is enlarged for a limited period, for example by inserting a spacer between the flange and the remaining part of the housing in order to increase the distance to the forward end stop.

**[0065]** The fact that the end stop is moved back and forth before and after the limited period requires that the feed rate data are adjusted in the central controller or an equivalent feed rate is found where the central controller is adjusted to a certain feed rate  $F_{\text{controller}}=F_{\text{desired}}/R$ , as outlined above. This expression is also valid for a spacer that is inserted during the limited period, even if the spacer enlarges the stroke length to more than the original maximum value. The overall effect is that the feed rate in the central controller may be adjusted to a different value than the actual injected volume, the difference given by the ratio for the amended stroke length as compared to the original stroke length.

**[0066]** Optionally, for the adjustment of the feed rate and frequency, an upgrade controller is electronically inserted between the central controller and the lubricator. The upgrade controller is advantageously provided as an add-on unit. It receives the control signals from the central controller, including the timing signal for the correct timing of the injection by the lubricator as well as potential signals for adjusting the stroke length by the adjusting screw. On the basis of the signals received from the central controller, the upgrade controller sends modified timing signals and modified stroke adjustment signals to the lubricator. As the upgrade controller is programmed for the modified stroke length, the signals from the central controller are transformed as necessary into modified signals in order to provide correct timing, frequency and stroke length of the lubricator.

**[0067]** Potentially, the upgrade controller also contains the above mentioned emulator for the emulated feedback sensor signal and sends the emulated feedback sensor signal to the central controller in order for the central controller to avoid registering lack of feedback sensor signals that would indicate lack of proper lubrication.

**[0068]** For clarification, it is pointed out that the term "injector" is used for an injection valve

system comprising an injector housing having a lubricant inlet port, flow-connected to the lubricant feed conduit for receiving lubricant from it for injection into the cylinder. The injector further comprises one single injection nozzle with a nozzle aperture as a lubricant outlet that extends into the cylinder for injecting lubricant from the inlet port into the cylinder in the injection phase. Although, the injector has a single nozzle that extends into the cylinder through the cylinder wall, when the injector is properly mounted, the nozzle itself, optionally, has more than a single aperture. For example, nozzles with multiple apertures are disclosed in WO2012/126480.

**[0069]** The term "injection phase" is used for the time during which lubricant is injected into the cylinder by an injector. The term "idle phase" is used for the time between injection phases. The term "injection-cycle" is used for the time it takes to start an injection sequence and until the next injection sequence starts. For example, the injection sequence comprises a single injection, in which case the injection-cycle is measured from the start of the injection phase to the start of the next injection phase. The term "timing" of the injection is used for the adjustment of the start of the injection phase by the injector relatively to a specific position of the piston inside the cylinder. The term "frequency" of the injection is used for the number of repeated injections by an injector per revolution of the engine. If the frequency is unity, there is one injection per revolution. If the frequency is  $1/2$ , there is one injection per every two revolutions. This terminology is in line with the above mentioned prior art.

**[0070]** For example, each of the injectors comprises an outlet-valve system at the nozzle configured for opening for flow of lubricant to the nozzle aperture during an injection phase upon pressure rise above a predetermined limit at the outlet-valve system and for closing the outlet-valve system after the injection phase. The outlet-valve system closes off for back-pressure from the cylinder and also prevents lubricant to enter the cylinder unless the outlet-valve is open.

**[0071]** For example, the outlet-valve system comprises an outlet non-return valve. In the outlet non-return valve, the outlet-valve member, for example a ball, ellipsoid, plate, or cylinder, is pre-stressed against an outlet-valve seat by an outlet-valve spring. Upon provision of pressurised lubricant in a flow chamber upstream of the outlet-valve system, the pre-stressed force of the spring is counteracted by the lubricant pressure, and if the pressure is higher than the spring force, the outlet-valve member is displaced from its outlet-valve seat, and the outlet non-return valve opens for injection of lubricant through the nozzle aperture into the cylinder. For example, the outlet-valve spring acts on the valve member in a direction away from the nozzle aperture, although, an opposite movement is also possible.

**[0072]** For example, the central controller or the upgrade controller or both comprise a computer or is connected by an electronic wired or wireless connection to a computer, where the computer is of the type that is configured for monitoring parameters for the actual state and motion of the engine, such that the amount and timing of the lubricant injection is controlled on the basis of the parameters.

**[0073]** Optionally, the injectors are SIP injectors configured to provide a mist of lubricant into the scavenging air of the cylinders. A spray of atomized droplets, also called mist of oil, is important in SIP lubrication, where the sprays of lubricant are repeatedly injected by the injectors into the scavenging air inside the cylinder prior to the piston passing the injectors in its movement towards the TDC. In the scavenging air, the atomized droplets are diffused and distributed onto the cylinder wall, as they are transported in a direction towards the TDC due to a swirling motion of the scavenging air towards the TDC.

**[0074]** Examples of such injectors for SIP injection are disclosed in WO2012/126473. Additional options for SIP injectors with electrical valves are found in Danish patent applications DK2017 70936 and DK2017 70940.

**[0075]** For example, the injectors comprise a nozzle with a nozzle aperture of between 0.1 and 1 mm, for example between 0.2 and 0.5mm, and are configured for ejecting a spray of atomized droplets, which is also called a mist of oil.

**[0076]** The atomization of the spray is due to highly pressurized lubricant in the lubricant injector at the nozzle. The pressure is higher than 10 bar, typically between 20 bar and 120 bar for this high pressure injection. An example is an interval of between 30 and 80 bar, optionally between 35 and 60 bar. The injection time is short, typically in the order of 5-30 milliseconds (msec). However, the injection time can be adjusted to 1 msec or even less than 1 msec, for example down to 0.1 msec.

**[0077]** Also, the viscosity influences the atomization. Lubricants used in marine engines, typically, have a typical kinematic viscosity of about 220 cSt at 40°C and 20 cSt at 100°C, which translates into a dynamic viscosity of between 202 and 37 mPa·s. An example of a useful lubricant is the high performance, marine diesel engine cylinder oil ExxonMobil® Mobilgard™ 560VS. Other lubricants useful for marine engines are other Mobilgard™ oils as well as Castrol® Cyltech oils. Commonly used lubricants for marine engines have largely identical viscosity profiles in the range of 40-100°C and are all useful for atomization, for example when having a nozzle aperture diameter of 0.1-0.8 mm, and the lubricant has a pressure of 30-80 bar at the aperture and a temperature in the region of 30-100°C or 40-100°C. See also, the published article on this subject by Rathesan Ravendran, Peter Jensen, Jesper de Claville Christiansen, Benny Endelt, Erik Appel Jensen, (2017) "Rheological behaviour of lubrication oils used in two-stroke marine engines", *Industrial Lubrication and Tribology*, Vol. 69 Issue: 5, pp.750-753, <https://doi.org/10.1108/ILT-03-2016-0075>.

## **SHORT DESCRIPTION OF THE DRAWINGS**

**[0078]** The invention will be explained in more detail with reference to the drawing, where

FIG. 1

is a reproduction of a drawing of an Alpha controller s published on the Internet site [http://www.manness.co.kr/02\\_business/Doosan%20Retrofit%20Service.pdf?PHPSESSID=fd56da9de6eaca2f1f446512e84fcf69](http://www.manness.co.kr/02_business/Doosan%20Retrofit%20Service.pdf?PHPSESSID=fd56da9de6eaca2f1f446512e84fcf69)

FIG. 2

is a sketch of part of a cylinder in an engine;

FIG. 3

a) illustrates an example of a lubricator before modification, b) illustrates an enlarged part of the lubricator around the inlet aperture, and c) illustrates the lubricator section of FIG. 3b after modification of the inlet aperture to a larger width;

FIG. 4

illustrates a modification relatively to FIG. 3a after modification by provision of a new inlet aperture closer to the non-return valve from which the lubricant is expelled;

FIG. 5

illustrates an example of a lubricator after modification by increasing the length of the adjusting screw;

FIG. 6

a) illustrates an example of a lubricator where the spacer as illustrated in FIG. 3a has been removed and the lubricator flange has been modified by machining;

FIG. 7

illustrates an alternative embodiment, wherein an upgrade controller is electronically inserted between the controller and the lubricator.

## DETAILED DESCRIPTION / PREFERRED EMBODIMENT

**[0079]** FIG. 1 is a reproduction of a drawing of an Alpha controller s published on the Internet site [http://www.mariness.co.kr/02\\_business/Doosan%20Retrofit%20Service.pdf?PHPSESSID=fd56da9de6eaca2f1f446512e84fcf69](http://www.mariness.co.kr/02_business/Doosan%20Retrofit%20Service.pdf?PHPSESSID=fd56da9de6eaca2f1f446512e84fcf69).

**[0080]** For the method as described herein, this drawing of the Alpha lubricator serves as example for a concrete embodiment of a lubricator that is modified. Accordingly, the explanation as given in the introduction applies for the explanation of the modification equally well.

**[0081]** FIG. 2 illustrates one half of a cylinder of a large slow-running two-stroke engine, for example marine diesel engine. The cylinder 1 comprises a cylinder liner 2 on the inner side of the cylinder wall 3. Inside the cylinder wall 3, there are provided a plurality of injectors 4 for injection of lubricant into the cylinder 1.

**[0082]** As illustrated, the injectors 4 are distributed along a circle with the same angular distance between adjacent injectors 4, although this is not strictly necessary. Also, the arrangement along a circle is not necessary, seeing that an arrangement with axially shifted

injectors is also possible, for example every second injector shifted towards the piston's top dead centre (TDC) relatively to a neighbouring injector.

**[0083]** As illustrated, the injectors 4 receive pressurised lubrication oil from a lubricator 11 through lubrication supply lines 9. The supplied oil is typically heated to a specific temperature, for example 50-60 degrees. The lubricator 11 supplies pressurised lubrication oil to the injectors 4 in precisely timed pulses, synchronised with the piston motion in the cylinder 1 of the engine. The injection by the lubricator 11 is controlled by a controller 12. For the synchronisation, the controller 12 monitors parameters for the actual state and motion of the engine, including speed, load, and position of the crankshaft, as the latter reveals the position of the pistons in the cylinders.

**[0084]** Each of the injectors 4 has a nozzle 5 with a nozzle aperture 5' from which lubricant is ejected under high pressure into the cylinder 1, for example in the form of a compact jet or as a fine atomized spray 8 with miniature droplets 7 for SIP injection.

**[0085]** For example for SIP injection, the nozzle aperture has a diameter of between 0.1 and 0.8 mm, such as between 0.2 and 0.5 mm, which at a pressure of 10-120 bar, for example 20 to 100 bar or 20 to 120 bar, optionally 30 to 80 bar or even 50 to 80 bar, or even at higher pressure than 120 bar, atomizes the lubricant into a fine spray 8, which is in contrast to a compact jet of lubricant. The swirl 10 of the scavenging air in the cylinder 1 transports and presses the spray 8 against the cylinder liner 2 such that an even distribution of lubrication oil on the cylinder liner 2 is achieved.

**[0086]** Optionally, the cylinder liner 2 is provided with free outs 6 for providing adequate space for the spray 8 or jet from the injector 4.

**[0087]** The lubricator 11 is connected to a supply conduit 14 for receiving lubricant from a lubricant supply 15, including an oil pump, and a return conduit 13 for return of lubricant, typically to an oil reservoir, optionally for recirculation of lubricant. The lubricant pressure in the supply conduit 14 is higher than the pressure in the return conduit 13, for example at least two times higher. The lubricant supply conduit 14 is also used for supplying lubricant for lubrication in addition to driving the actuator piston.

**[0088]** FIG. 3a illustrates an example of a lubricator 11 before modification. The numbering is equal to the modified prior art lubricator of FIG. 1.

**[0089]** FIG. 3b illustrates an enlarged part of the lubricator 11 around the inlet aperture 113 for the dosing channel 115 with the injection plunger 119. The inlet aperture 113 comprises a front aperture edge 113a and a rear aperture edge 113b, which in common define the width of the aperture 113.

**[0090]** FIG. 3c illustrates the lubricator section of FIG. 3b after modification of the inlet aperture 113 to a larger width, which is best seen by the increased distance between the front

aperture edge 113a and rear aperture edge 113b.

**[0091]** FIG. 4 illustrates a modification relatively to FIG. 3a and 3b by provision of a new inlet aperture 113' with a corresponding new front aperture edge 113a' and rear aperture edge 113b' closer to the forward end of the dosing channel 115, so that the dosing channel distance is reduced as compared to the lubricator 11 prior to modification.

**[0092]** FIG. 5 illustrates an example of a lubricator 11 after modification of the adjusting screw 121 has been made longer. In this example, the middle section 121A of the adjusting screw 121 has been made longer. The longer adjusting screw reduces the stroke length 112 of the actuator piston 123.

**[0093]** FIG. 6 illustrate an example of a lubricator 11 after modification where spacer 122 as illustrated in FIG. 3a has been removed and the lubricator flange 107 has been modified by machining where the length of the threading 110 has been increased in order for the adjusting screw 121 to move closer to the actuator piston 123, which decreases the stroke length 112.

**[0094]** A variable adjustment of the stroke length by the adjusting screw 121 is potentially done by turning the adjusting crew 121 with a motor, for example DC motor, mounted to the end cap of the lubricator and controlled by the upgrade controller 19. This allows for electronic regulation of the stroke length, for example by the upgrade controller 16. It opens for a possibility of adjusting the stroke length between injections, for example based on operation parameters of the engine.

**[0095]** FIG. 7 illustrates an alternative embodiment, wherein an upgrade controller 16 is electronically inserted between the controller 12 and the lubricator 11.

**[0096]** The upgrade controller 16 is used for the adjustment of the feed rate and frequency. It receives the control signals from the controller 12, including the timing signal for the correct timing of the injection by the lubricator 11 as well as potential signals for adjusting the stroke length by the adjusting screw. On the basis of the signals received from the controller 12, the upgrade controller 11 sends modified timing signals and modified stroke adjustment signals to the lubricator 11. As the upgrade controller 16 is programmed for the modified stroke length, the signals from the controller 12 are transformed as necessary into modified signals in order to provide correct timing, frequency and stroke length of the lubricator 11.

**[0097]** For the case that the lubricator 11 comprises a feedback sensor 120, as illustrates in FIG 1 and FIG. 3a, the upgrade controller 16 also contains a signal emulator for emulated feedback sensor signals and sends the emulated feedback sensor signal to the controller 12 in order for the controller 12 to avoid registering lack of feedback sensor signals that would indicate lack of proper lubrication.

**[0098]** With reference to FIG. 3a, it is observed that the actuator piston 123 comprises two grooves 111A, 111. When the actuator piston moves, the first groove 111A will cause the

feedback sensor 120 to give a first pulse in the feedback signal. Only if the stroke 112 is long enough to also move the second groove 111 past the feedback sensor, a further pulse is generated in the feedback signal. In the prior art system, the controller 12 would receive a double pulse in the feedback signal from the feedback sensor 120 if the stroke 112 was long enough for both grooves 111A and 111 to move past the feedback sensor 120. Only in the case of a feedback signal with a double pulse, the prior art controller 12 would read this as an indication for proper lubrication. As mentioned by the above examples, the reduced stroke length in the modified lubrication system results in the feedback sensor 120 only giving a single pulse. This single pulse is received by the upgrade controller 16 and recognised that the actuator piston 123 has moved for injection and is accepted as a signal for proper injection. In order to emulate the correct signal to the original controller 12, the emulator in the upgrade controller 16 creates an emulated double pulse signal and transmits it to the controller 12 in order to avoid the controller 12 giving an alarm due to a stroke 112 that is too short for the acceptance of the controller 12.

**[0099]** Accordingly, the upgrade controller has the potential to receive a feedback signal with the following options:

1. 1) one pulse only - indicating that the actuator piston 123 has moved but less than the stroke length of the prior-upgrade lubrication system - the upgrade controller 16 sends an emulated double pulse signal to the controller 12 in order to emulate to the controller 12 that the lubrication has been proper:
2. 2) a double pulse - indicating that the actuator piston 123 has moved at least as much as the stroke length of the prior-upgrade lubrication system - the upgrade controller 16 sends an emulated double pulse signal to the controller 12 in order to emulate to the controller 12 that the lubrication has been proper:
3. 3) no pulse received - indicating that the actuator piston is not moving or a fault in the feedback sensor - the upgrade controller does not send an emulated signal to the controller in order to cause an alarm situation. The latter can be further supported by an option of the upgrade controller itself causing a warning signal in such situation. Such warning signal is potentially a visual signal and/or an audio signal. Examples are flashing lights, warning messages on a surveillance computer interface, as well as warning sounds.

## **REFERENCES CITED IN THE DESCRIPTION**

Cited references

This list of references cited by the applicant is for the reader's convenience only. It does not

form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

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**PATENTKRAV**

1. Fremgangsmåde til forbedring af smøringen af en stor langsomt kørende motor, hvor motoren omfatter en cylinder (1) med et reciprokerende stempel indeni og med et flertal af smøremiddelinjektorer (4) fordelt langs en omkreds af cylinderen (1) til indsprøjtning af smøremiddel ind i cylinderen (1) ved forskellige positioner på omkredsen under indsprøjtningssfasen; hvor motoren yderligere omfatter et smøresystem for at tilvejebringe smøremiddel til injektorerne (4) i indsprøjtningssfaserne;

hvor smøresystemet omfatter en lubrikator (11), der er rørforbundet til hver injektor ved hjælp af en smøremiddel-tilførselsledning (9) for at tilføre tryksat smøremiddel til hver injektor gennem smøremiddel-tilførselsledningen (9) i indsprøjtningssfasen;

hvor lubrikatoren (11) er af den type, der omfatter et hus (101), i hvilket et hydraulisk drevet aktuatorstempel (123) er anbragt reciprokerende langs en slaglængde, hvor lubrikatoren (11) endvidere omfatter en justeringsmekanisme (110) for slaglængden (112), som er konfigureret til variabel indstilling af slaglængden (112) af det reciprokerende hydraulisk drevne aktuatorstempel (123) kun mellem en original minimal slaglængde og en original maksimal slaglængde;

hvor lubrikatoren (11) endvidere omfatter et flertal af indsprøjtningsslempler (119), der er anbragt glidende i tilsvarende doseringskanaler (115), hvor indsprøjtningsslemplerne (119) er koblet til aktuatorstemplet (123) for at blive bevæget af aktuatorstemplet (123) over slaglængden og som konsekvens deraf at tryksætte smøremiddel i doseringskanalerne (115) over en doseringskanal-afstand til at udstøde det tryksatte smøremiddel fra doseringskanalen (115) gennem en énvejs-ventil (102) og gennem tilførselsledningen (9) til injektoren (4) til indsprøjtning af smøremidlet ind i motorcylinderen (1); hvor doseringskanal-afstanden definerer volumenet af smøremiddel, der udstødes fra doseringskanalen (115) under indsprøjtningssfasen; hvor doseringskanal-afstanden kan indstilles mellem en minimal doseringskanal-afstand og en maksimal doseringskanal-afstand af en lubrikator før modifikation og som er etableret ved at justere slaglængden mellem den originale minimale slaglængde og den originale maksimale slaglængde for aktuatorstemplet (123);

hvor lubrikatoren (11) omfatter en elektrisk ventil, der er indrettet til at forårsage omskiftning mellem hydrauliske trykniveauer, der virker på aktuatorstemplet

(123), til hydraulisk at drive aktuatorstemplet (123) reciprokerende ved hjælp af de omskiftende trykniveauer;

5 hvor smøresystemet omfatter en styreenhed (12) elektrisk forbundet til den elektriske ventil (116) til styring af tidspunktet for omskiftet til indsprøjtningfaserne ved hjælp af tilsvarende elektriske signaler sendt fra styreenheden til den elektriske ventil (116);

hvor fremgangsmåden omfatter

10 - at operere motoren med smøring fra lubrikatoren (11) under kontrol af styreenheden (12) med én indsprøjtning gennem smøremiddelinjektorerne (4) for hvert første antal af motoromdrejninger;

- at stoppe motorens drift til modificering af smøresystemet;

- at modificere smøresystemet;

- at fortsætte drift af motoren med det modificerede smøresystem;

15 **kendetegnet ved, at** modificeringen af smøresystemet omfatter at modificere lubrikatoren (11) ved at reducere doseringskanal-afstanden til mindre end den minimale doseringskanal-afstand for lubrikatoren før modifikation og at operere motoren med smøring fra den modificerede lubrikator (11) ved højere indsprøjtningfrekvens med én indsprøjtningfase for hvert andet antal motoromdrejninger, hvor det andet antal er mindre end det første antal, og med reduceret doseringskanal-afstand og tilsvarende reduceret  
20 mængde smøremiddel udstødt fra doseringskanalen (115) per indsprøjtningfase.

2. Fremgangsmåde ifølge krav 1, hvor fremgangsmåden omfatter justering af det samlede smøremiddelforbrug i den fortsatte drift af motoren med den modificerede lubrikator til mindre end eller lig med smøremiddelforbruget inden modificering af smøresystemet.  
25

3. Fremgangsmåde ifølge krav 1 eller 2, hvor huset omfatter et indre volumen (114) indeholdende smøremiddel, og doseringskanalen (115) omfatter en indløbsåbning (113), der er i fluid-strømningsforbindelse med det indre volumen (114) til modtagelse  
30 af smøremiddel fra det indre volumen (114), når indsprøjtningstemplerne (119) er i den tilbagetrukne position; hvor indløbsåbningen (113) har en åbningsvidde mellem en bageste åbningskant og en forreste åbningskant og er konfigureret til at blive lukket af indsprøjtningstemplet (119) under bevægelse af indsprøjtningstemplet (119) forbi den forreste åbningskant, således at yderligere bevægelse af indsprøjtningstemplet (119)

langs doseringskanal-afstanden, målt fra den forreste åbningskant til den allerforreste position af indsprøjtningstemplet (119), tryksætter det modtagne smøremiddel i doseringskanalen (115) og udstøder det gennem énvejs-ventilen (102); hvor reduktionen af doseringskanal-afstanden omfatter at øge vidden af indløbsåbningen (113) i fremadgående retning eller at tilvejebringe en yderligere indgangskanal tættere på den allerforreste position af indsprøjtningstemplet (119).

4. Fremgangsmåde ifølge krav 1 eller 2, hvor reduktionen af doseringskanal-afstanden omfatter ændring af slaglængden af aktuatorstemplet (123) til mindre end den originale minimale slaglængde; og hvor fremgangsmåden omfatter at operere motoren med smøring fra den modificerede lubrikator med ændret slaglængde, der er mindre end den originale minimale slaglængde.

5. Fremgangsmåde ifølge krav 4, hvor lubrikatoren (11) inden modificeringen af smøresystemet omfatter en feedbacksensor, der er konfigureret til at måle en forudbestemt minimal forskydning af aktuatorstemplet (123) under indsprøjtningsfasen og til at tilvejebringe et feedbacksignal, når den minimale forskydning måles; hvor styreenheden (11) er konfigureret til at modtage feedbacksignalet som en bekræftelse på korrekt smøring; hvor modificeringen af smøresystemet omfatter at tilvejebringe en feedbacksignalemulator (16) separat fra feedbacksensoren, at afkoble feedbacksensoren elektrisk fra styreenheden (12) og at tilføre et emuleret feedbacksignal fra feedbacksignalemulatoren (16) til styreenheden (12) for at emulere korrekt smøring til styreenheden (12) på trods af, at aktuatorstemplet (123) drives med en modificeret slaglængde mindre end den originale minimale slaglængde og med mindre end den forudbestemte minimale forskydning.

6. Fremgangsmåde ifølge krav 4 eller 5, hvor slaglængden af aktuatorstemplet (123) er defineret af et forreste endestop (105) og et bagerste endestop (101), hvor en position for det forreste endestop (105) eller bageste endestop (101) er defineret ved en justeringsmekanisme, der er justerbar mellem en minimumsposition og en maksimalposition, hvor minimumspositionen definerer den minimale slaglængde og maksimalpositionen definerer den maksimale slaglængde; hvor modificeringen af smøresystemet omfatter ændring af minimumspositionen til en modificeret position, der definerer den modificerede minimale slaglængde.

7. Fremgangsmåde ifølge krav 6, hvor positionen for det forreste endestop er defineret af den ene ende af en slaglængdejusteringsskrue (121), der kan indstilles langs slaglængden (112) ved rotation af slaglængdejusteringsskruen (121); hvor modificeringen af smøresystemet omfatter at udskifte slaglængdejusteringsskruen (121) med en længere, modificeret justeringsskrue (121) eller at tilføje materiale til slaglængdejusteringen i et mellemrum mellem slaglængdejusteringsskruen (121) og aktuatorstemplet (123) og derved reducere slaglængden (112).
8. Fremgangsmåde ifølge krav 6, hvor positionen for det forreste endestop er defineret af én ende af en slaglængdejusteringsskrue (121), som kan indstilles langs slaglængden ved rotation af skruen; hvor lubrikatoren omfatter en flange (107) med en skrue-understøtning, der understøtter slaglængdejusteringsskruen (121); og hvor modificeringen af smøresystemet omfatter udskiftning af flangen (107) eller fjernelse af materiale fra flangen (107) ved bearbejdning af flangen (107) og som et resultat deraf forskydning af skruunderstøtningen mod aktuatorstemplet (123) og bevægelse af det forreste endestop (105) som defineret af slaglængdejusteringsskruen (121) mod aktuatorstemplet (123) for at ændre af minimumspositionen.
9. Fremgangsmåde ifølge krav 8, hvor justeringsskruen (121) er justerbar ved drejning i et gevind (110) i flangen (107), og hvor modifikation ved bearbejdning af flangen (107) indebærer en forøgelse af længden af gevindet (110) i en retning mod aktuatorstemplet (123) for at øge justeringslængden af justeringsskruen (121), og hvor fremgangsmåden omfatter at flytte af justeringsskruen (121) tættere på aktuatorstemplet (123) ved rotation af justeringsskruen (121) i gevindet (110) og derved reducere slaglængden 112.
10. Fremgangsmåde til modificering af et smøresystem til forbedring af smøringen af en stor langsomt kørende motor, hvor motoren er af den type, der omfatter en cylinder (1) med et reciprokerende stempel indeni og med et flertal af smøremiddelinjektorer (4) fordelt langs en omkreds af cylinderen (1) til indsprøjtning af smøremiddel ind i cylinderen (1) ved forskellige positioner på omkredsen under indsprøjtningsskridter; hvor smøresystemet er konfigureret til at tilføre smøremiddel til injektorerne i indsprøjtningsskridterne;

hvor smøresystemet omfatter en lubrikator (11) med tilslutninger til at blive rørforbundet til hver injektor ved hjælp af en smøremiddel-tilførselsledning (9) og til at tilføre tryksat smøremiddel til hver injektor gennem smøremiddel-tilførselsledningen (9) i indsprøjtningssfaserne;

5 hvor lubrikatoren (11) er af den type, der omfatter et hus (101), hvori et hydraulisk drevet endvidere omfatter en slaglængdejusteringsmekanisme, som er konfigureret til variabel indstilling af slaglængden af det reciprokerende hydraulisk drevne aktuatorstempel (123) kun mellem en original minimal slaglængde og en original maksimal slaglængde;

10 hvor lubrikatoren endvidere omfatter et flertal af indsprøjtningstempler (119), der er anbragt glidende i tilsvarende doseringskanaler (115), hvor indsprøjtningstemplerne (119) er koblet til aktuatorstemplet (123) for at blive bevæget af aktuatorstemplet (123) over slaglængden og som konsekvens deraf at tryksætte smøremiddel i doseringskanalerne (115) over en doseringskanal-afstand til at udstøde det tryksatte smøremiddel  
15 fra doseringskanalen (115) gennem en énvejs-ventil (102) og gennem tilførselsledningen (9) til injektoren (4) til indsprøjtning af smøremidlet ind i motorcylinderen (1); hvor doseringskanal-afstanden definerer volumenet af smøremiddel, der udstødes fra doseringskanalen (115) under indsprøjtningssfasen; hvor doseringskanal-afstanden kan indstilles mellem en minimal doseringskanal-afstand og en maksimal doseringskanal-afstand for en lubrikator før modifikation og som er etableret ved at justere slaglængden  
20 mellem den originale minimale slaglængde og den originale maksimale slaglængde for aktuatorstemplet (123);

hvor lubrikatoren (11) omfatter en elektrisk ventil (116), der er indrettet til at forårsage omskiftning mellem hydrauliske trykniveauer, der virker på aktuatorstemplet (123), til hydraulisk at drive aktuatorstemplet (123) reciprokerende ved hjælp af de omskiftende trykniveauer;

hvor smøresystemet omfatter en styreenhed (12) elektrisk forbundet til den elektriske ventil (116) til styring af tidspunktet for omskiftet til indsprøjtningssfaserne ved hjælp af tilsvarende elektriske signaler sendt fra styreenheden til den elektriske ventil (116);

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**kendetegnet ved, at** fremgangsmåden omfatter modificering af smøresystemet ved at modificere lubrikatoren (11) ved at reducere doseringskanal-afstanden til mindre end den minimale doseringskanal-afstand for lubrikatoren før modifikation.

11. Fremgangsmåde ifølge krav 10, hvor reduktionen af doseringskanal-afstanden omfatter ændring af slaglængden af aktuatorstemplet (123) til mindre end den originale minimale slaglængde.

5 12. Fremgangsmåde ifølge krav 11, hvor smøremidlet (11) inden modificeringen af smøresystemet omfatter en feedbacksensor (120), der er konfigureret til at måle en forudbestemt minimal forskydning af aktuatorstemplet (123) under indsprøjtningssfasen og til at tilvejebringe et feedbacksignal, når den minimale forskydning måles; hvor styreenheden (11) er konfigureret til at modtage feedbacksignalet som en bekræftelse på  
10 korrekt smøring; hvor modificeringen af smøresystemet omfatter at tilvejebringe en feedbacksignalemulator (16) separat fra feedbacksensoren, at afkoble feedbacksensoren elektrisk fra styreenheden (12) og at tilføre et emuleret feedbacksignal fra feedbacksignalemulatoren (16) til styreenheden (12) for at emulere korrekt smøring til styreenheden (12) på trods af, at aktuatorstemplet (123) drives med en modificeret slaglængde mindre  
15 end den originale minimale slaglængde og med mindre end den forudbestemte minimale forskydning.

13. Fremgangsmåde ifølge krav 11, hvor feedbacksensoren (120) er konfigureret til at tilvejebringe et feedbacksignal med en første type feedbacksignal, hvis feedbacksensoren (120) registrerer forskydning af aktuatorstemplet (123) fra en position i sin tomgangsfasen mellem injektionsfaser, og hvor feedbacksensoren (120) kun tilvejebringer en anden type feedbacksignal, hvis aktuatorstemplet når den forudbestemte minimale forskydning under injektionsfasen; hvor feedbacksignalemulatoren (16) leverer en emuleret anden type feedbacksignal til regulatoren (12) som en konsekvens af at modtage  
20 en første type signal fra feedbacksensoren (120), men ikke hvis der ikke modtages noget signal fra feedbacksensoren (120).

14. Fremgangsmåde ifølge et hvilket som helst af kravene 11-13, hvor stemplet i aktuatorstemplet (123) er defineret af et forreste endestop (105) og et bagerste endestop (101), hvor en position af det forreste endestop (105) eller bageste stopstop (101) er defineret af en justeringsmekanisme, der er justerbar mellem en minimumsposition og en maksimalposition, hvor minimumspositionen definerer minimumslaglængden, og den maksimale position definerer den maksimale slaglængde; hvor modificeringen af  
30

smøresystemet omfatter ændring af minimumspositionen til en modificeret position, der definerer den modificerede minimale slaglængde.

- 5 15. Fremgangsmåde ifølge krav 14, hvor positionen for det forreste endestop er defineret af den ene ende af en slaglængdejusteringsskrue (121), der kan indstilles langs slaglængden (112) ved rotation af slaglængdejusteringsskruen (121); hvor modificeringen af smøresystemet omfatter at udskifte slaglængdejusteringsskruen (121) med en længere, modificeret justeringsskrue (121) eller at tilføje materiale til slaglængdejusteringen i et mellemrum mellem slaglængdejusteringsskruen (121) og aktuatorstemplet  
10 (123) og derved reducere slaglængden (112).

## DRAWINGS

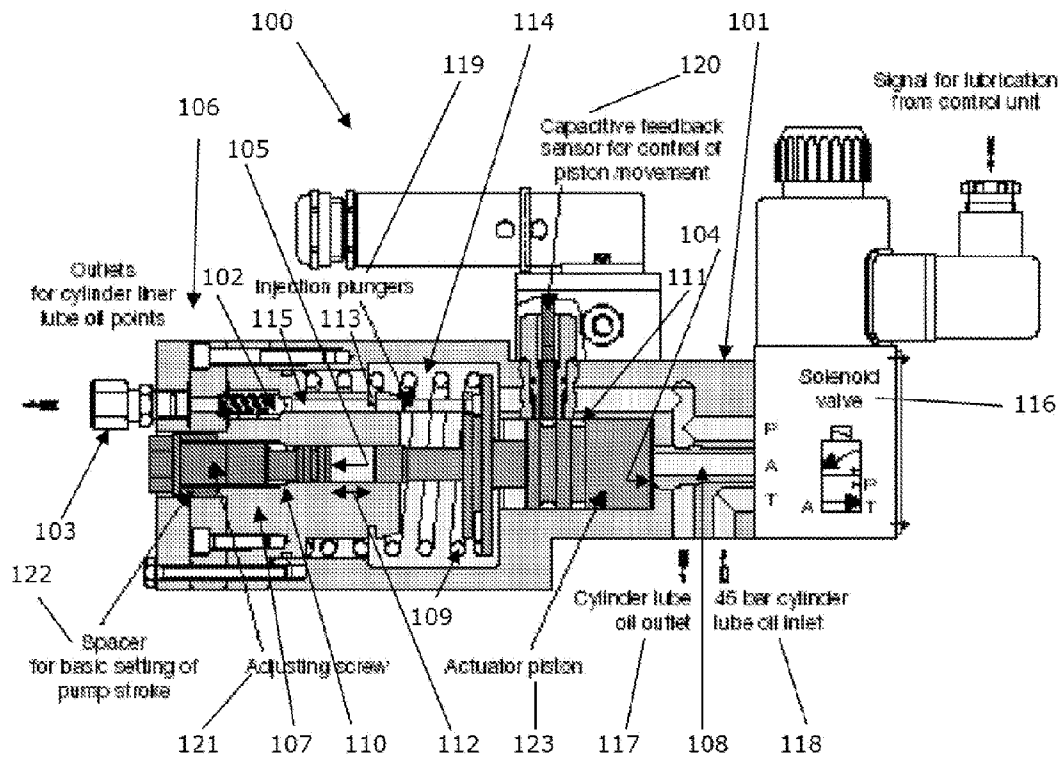


FIG. 1

(prior art - reproduced from

[http://www.mariness.co.kr/02\\_business/Doosan%20Retrofit%20Service.pdf?PHPS ESSID=fd56da9de6eaca2f1f446512e84fc69](http://www.mariness.co.kr/02_business/Doosan%20Retrofit%20Service.pdf?PHPS ESSID=fd56da9de6eaca2f1f446512e84fc69).

The drawing is slightly modified with additional reference numbers in order to explain the principle in more detail.)

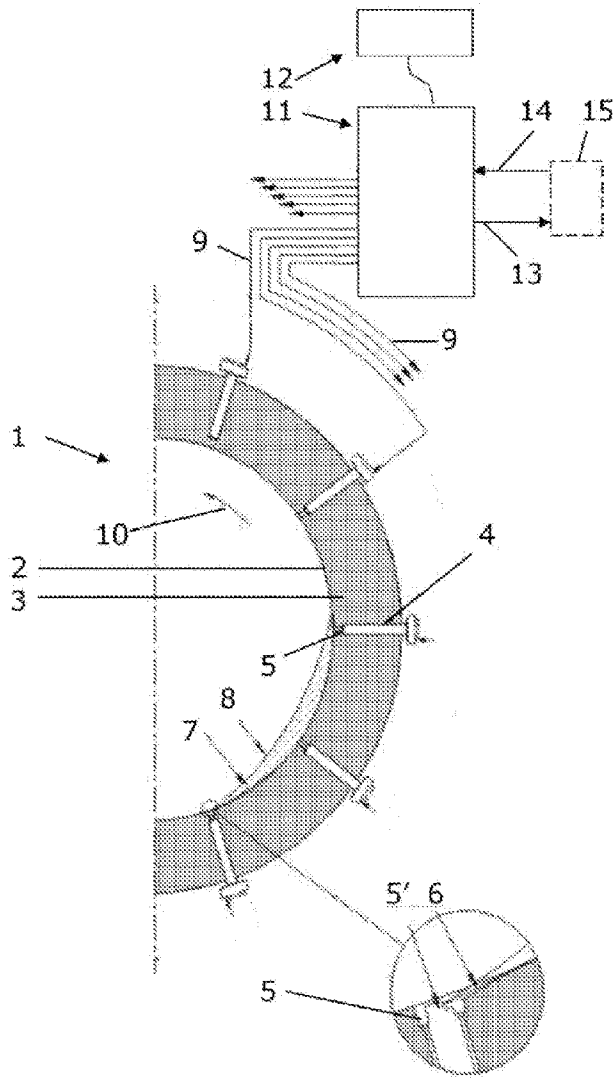


FIG. 2

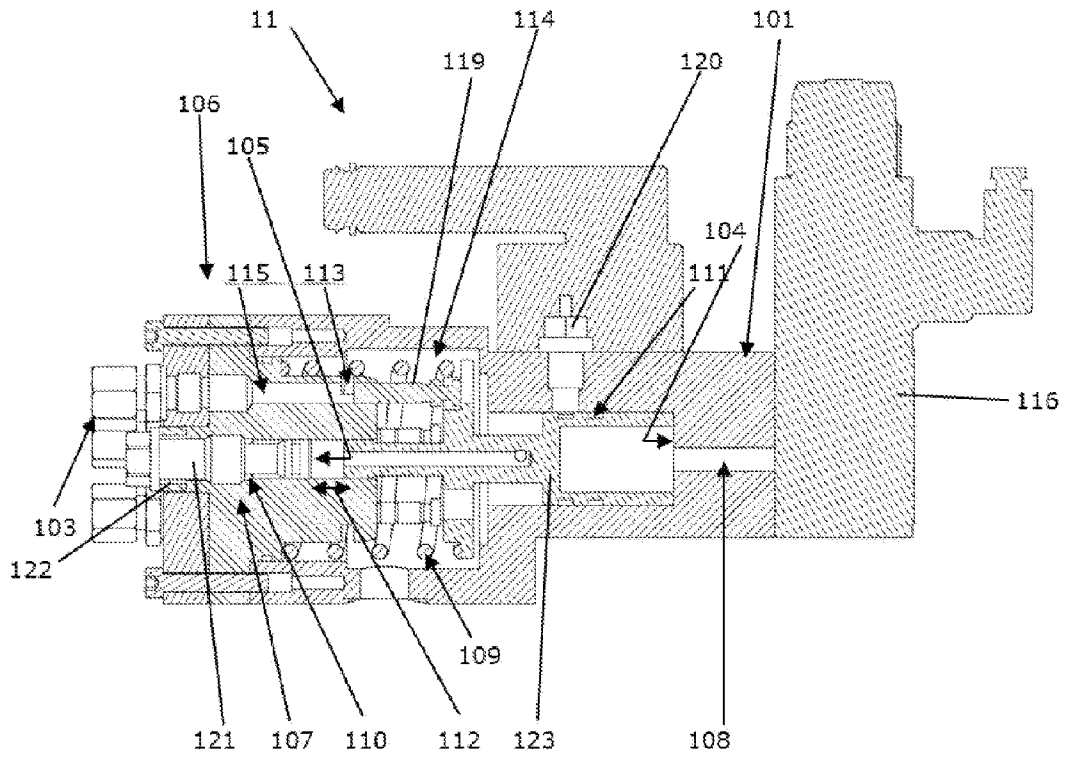


FIG. 3a

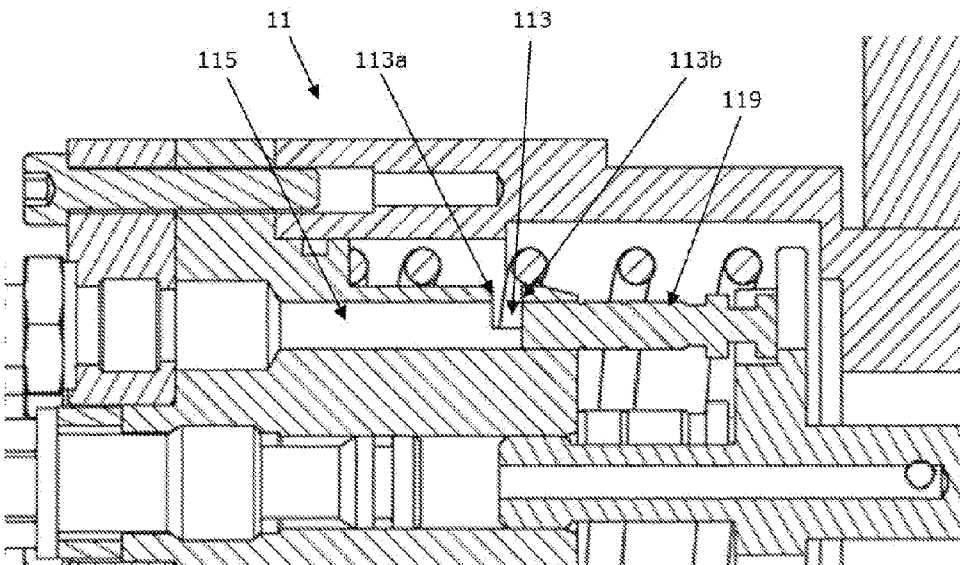


FIG. 3b

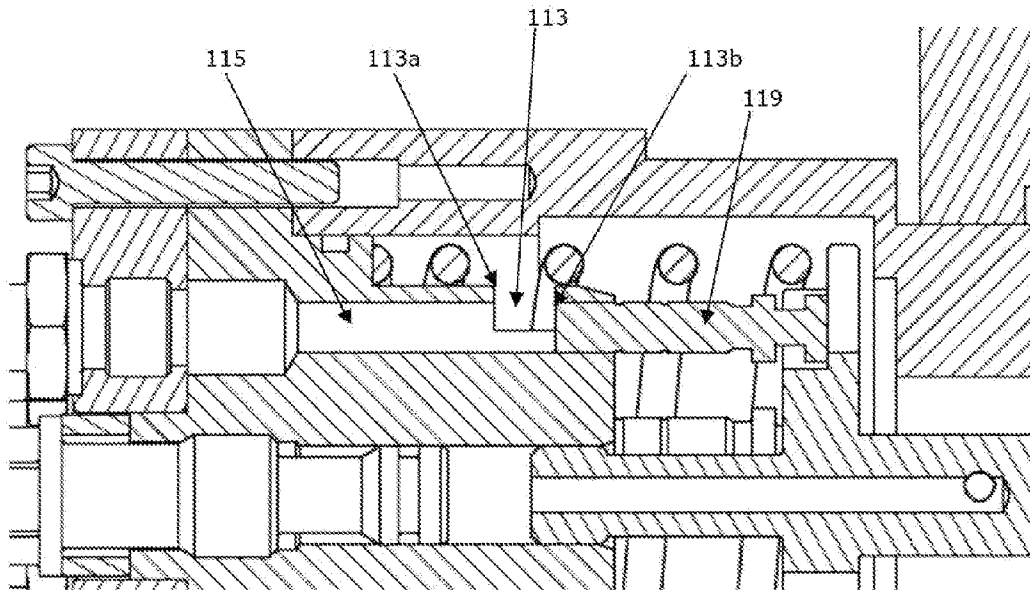


FIG. 3c

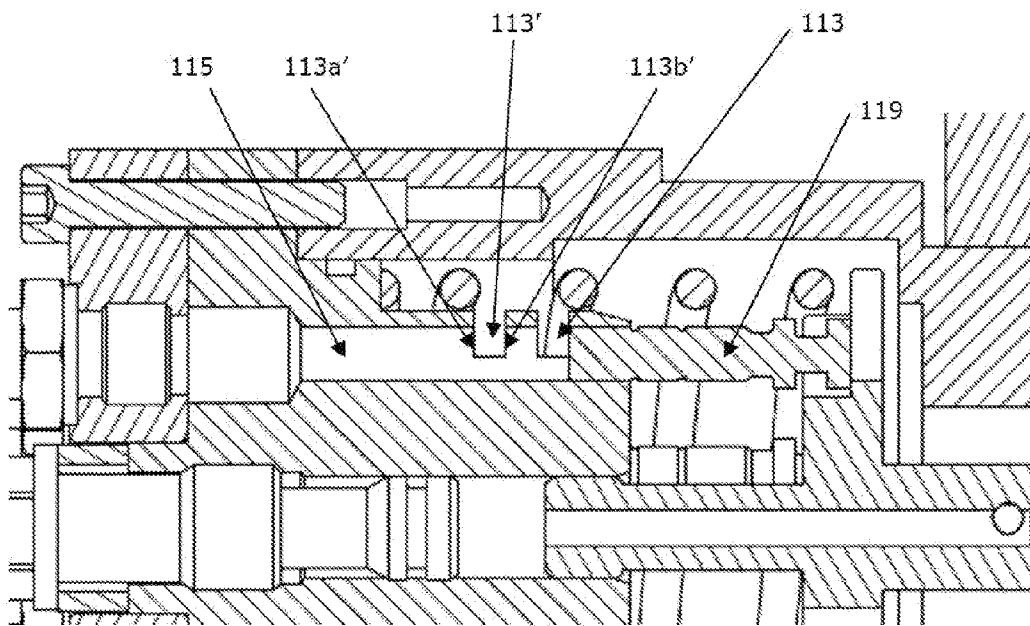


FIG. 4

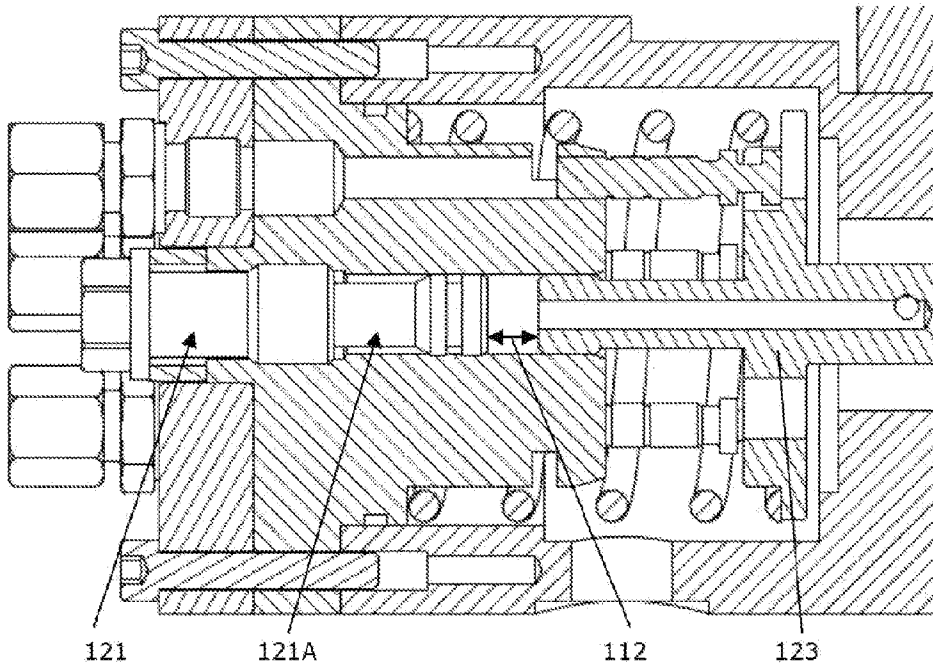


FIG. 5

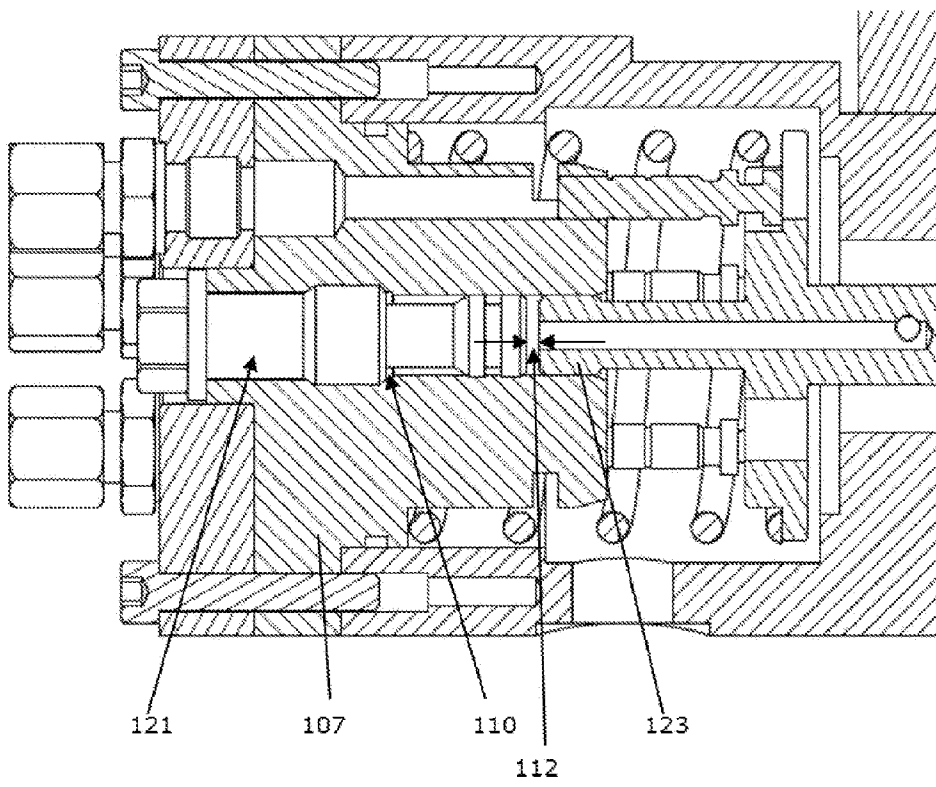


FIG. 6

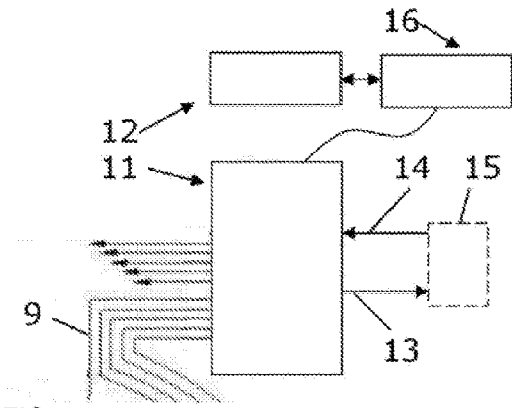


FIG. 7