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(54) **SYSTEM FOR CONTROLLING A HYDRAULIC VARIABLE-DISPLACEMENT PUMP**

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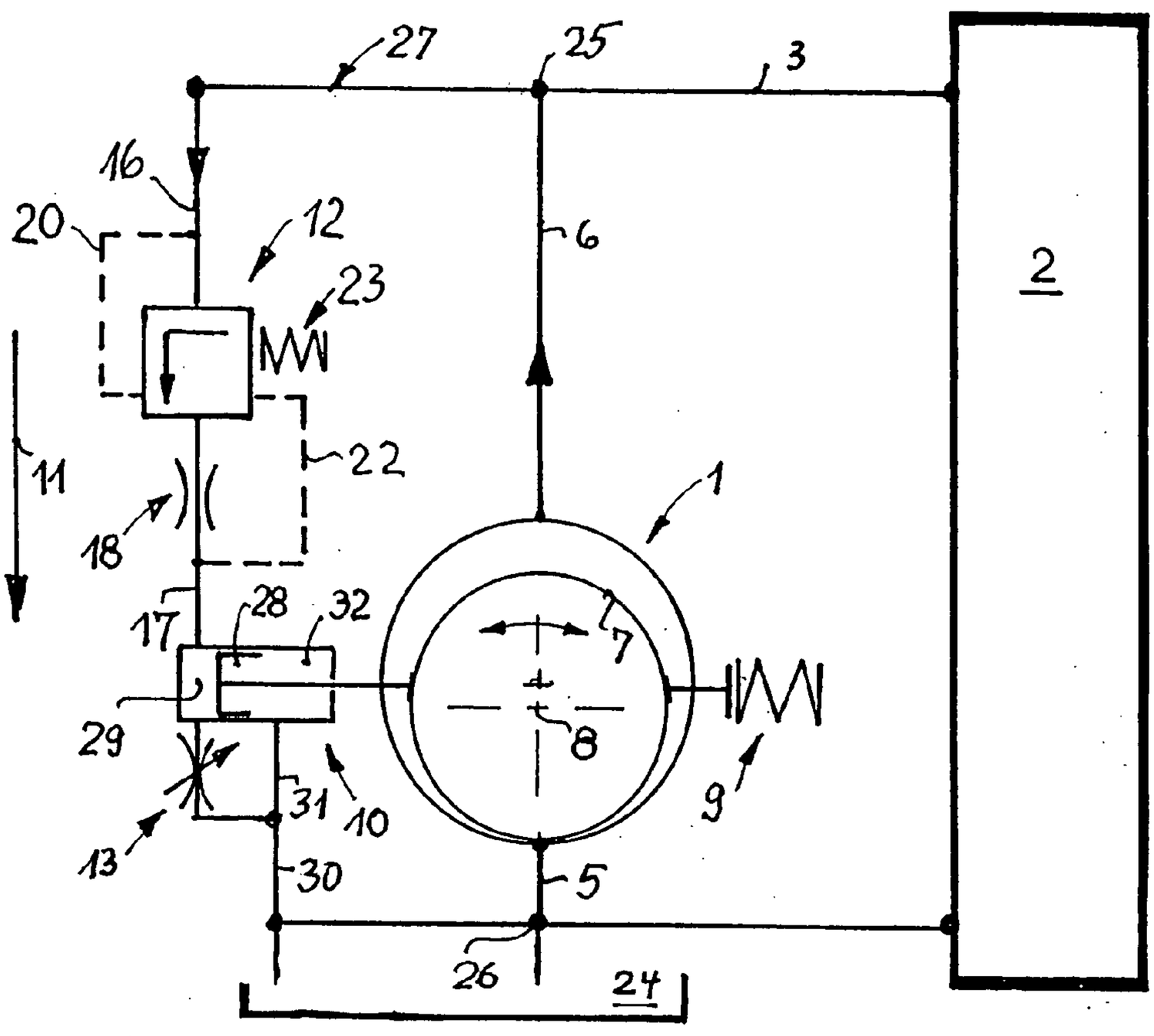
(57) **ABSTRACT**

In the case of a system for controlling a hydraulic variable displacement pump, the latter is acted upon in the direction of increasingly pump capacity over an energy storage system and, in the opposite direction, over a hydraulic adjusting device, the adjustment of the variable displacement pump being controlled over a flow regulator, which is constructed especially as a restrictor and the passable cross section of which is variable and which is located in the connection between the adjusting device and the reservoir, and which, for the sudden increase in the pump capacity of the variable displacement pump, opens up a drainage cross section to the reservoir, over which cross section an almost loss-free drainage of the pressure medium, displaced by the admission over the energy storage system, is possible.



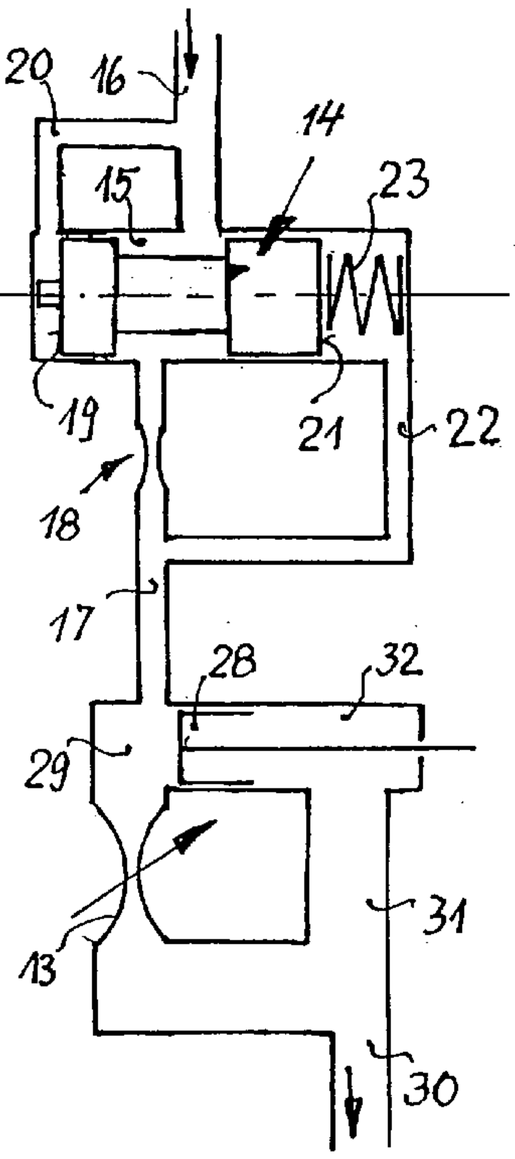

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Fig. 2

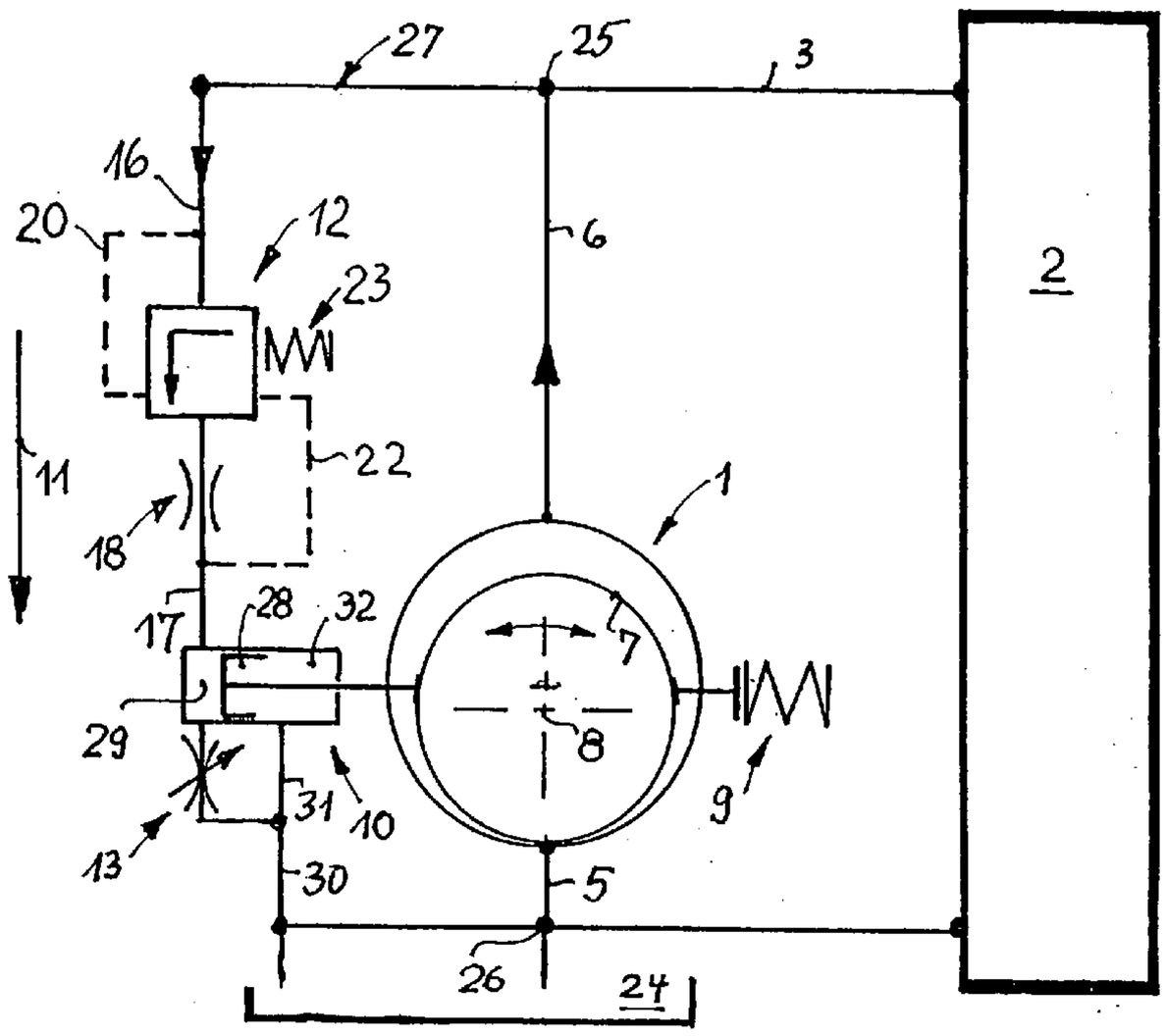
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Fig. 1

SYSTEM FOR CONTROLLING A HYDRAULIC VARIABLE-DISPLACEMENT PUMP

[0001] The invention relates to a system for controlling a hydraulic variable-displacement pump for a consumer in accordance with the introductory portion of claim **1**.

[0002] In practice, a operating system with hydraulic consumers, such as power-assisted steering devices of motor vehicles, usually employ constant-displacement pumps and excess amounts, obtained as a function of the rpm by means of the driving mechanism of the pump over the internal combustion engine of the vehicle, are decompressed and returned to the suction side of the pump. Appreciable losses and thermal loads are associated with this, especially at a higher rpm. However, these are accepted in order to have large flow rates, corresponding even to the maximum requirement of the consumer, available at all times suddenly in case of need and, with that, ensure that the respective hydraulic consumer, such as the operating cylinder, which intensifies the steering power of power-assisted steering devices is acted upon without delay. Until now, the use of hydraulic variable-displacement pumps, by means of which the pump capacity could be adapted to the respective requirement and, with that, the power dissipated reduced, has failed in practice owing to the fact that the adjusting dynamics of the pumps for increasing the pump capacity could not always satisfy requirements, which could lead to critical conditions from a comfort and also a safety point of view.

[0003] In the case of a system, working with a hydraulic variable-displacement pump and disclosed in the DE 197 22 495 A1, as acknowledged in the introductory portion of claim **1**, the variable-displacement pump, which is constructed as a rotary vane pump, is acted upon, in the direction of an adjustment to a rate of delivery by an energy storage system in the form of a spring and, in the opposite direction, by a hydraulic regulating unit, the latter being connected in a return line, which is branched off from the high-pressure intake to the consumer, discharges excessive amounts pumped and drains into a reservoir. In the return line, there is a flow-control valve in the direction of flow to the reservoir and a restrictor as flow regulator discharging into the reservoir and, between the flow-control valve and the restrictor, the control pressure for a control valve is branched off, over the spool valve of which the cross section of the connection of the hydraulic control device of the variable displacement pump to the high-pressure connection between the pump and the consumer or to the reservoir is controlled. Such a control is relatively complex and the sudden adjustment of the variable displacement pump, aimed for in the case of this solution in the sense of a sudden increase in the pump capacity or in the system pressure, is dependent on that, initially, by applying a control pressure at the flow-control valve, the high-pressure connection of the return line is reset and, by these means, the control pressure at the control valve is lowered in order to open the connection between the hydraulic regulating unit and the reservoir, which passes over the control valve, and so, over the energy storage system in the form of a spring, achieve an appropriate adjustment of the pump, which, in view of the different controlling elements which are to be energized, excludes a spontaneous adjustment of the variable adjustment pump and likewise excludes the loss-affected configuration of the discharge path over the control valve.

[0004] It is an object of the invention to provide a simplified system for controlling a hydraulic variable displacement pump, which makes possible a practically sudden response in the changing over of the variable displacement pump to higher, especially maximum flow rates and, with that, also a sudden increase in the operating pressure of the system.

[0005] This is achieved with the distinguishing features of claim **1**, according to which the discharging cross section of the controlling device is maximized towards the reservoir, when the variable displacement pump is adjusted to the maximum pump capacity, in such a manner, that there is quasi unrestricted drainage, so that the sudden changeover of the variable displacement pump over the energy storage system becomes possible. A constantly high regulating power turns out to be advantageous for the energy storage system within the scope of the invention. For this purpose, the energy storage system is formed, for example, by a highly tensioned spring and the spring advisability also has a high spring rate. Within the scope of the invention, it proves to be advantageous for the sudden changeover aimed for, if the displaced volume is used to fill the spaces resulting from the changeover, that is, for example, in relation to a piston as control element, if the volume, displaced from the pressure space on the cylinder side is passed to the back of the piston, such a short-circuit connection usually making particularly short pipeline distances and large transfer cross sections possible.

[0006] For energizing the hydraulic control device, which is controlled quantitatively within the scope of the inventive solution, the flow regulator preferably is energized as a function of control parameters specified on the part of the consumer. In relation to the use, for example, of the inventive system for vehicles, other information, which can be derived, for example, from driving dynamics, can be taken into consideration preventively, so that, in energizing the flow regulator, a change in the requirement behavior of the consumer, which is to be expected, can also already be taken into consideration for adjusting the variable displacement pump in an anticipatory manner.

[0007] Within the scope of the invention, the flow-control valve may also, optionally, be constructed adjustably and, if necessary, be provided with an additional energizing device, especially with regard to expanding the inventive basic concept to further functions.

[0008] Within the scope of the invention, an adjustable restrictor may be used in the simplest manner as a flow regulator, so that the adjustment of the pump, or optionally also its adjustment to other control positions may also be attained within the scope of the invention by simple means.

[0009] For the flow-control valve, a construction with a control piston, operating as a pressure-maintaining valve, has proven to be appropriate. It controls the cross section of the passage from the high-pressure side to the hydraulic control device and is spring-loaded on the high-pressure side and in the opposite direction. A pressure, which corresponds to the pressure exerted in the pipeline connection between the flow-control valve and the flow regulator and is exerted on the subsequent measurement restrictor downstream from the flow control valve, is superimposed on the spring loading.

[0010] Further details and distinguishing features of the invention arise out of the claims. Moreover, the invention is

explained below by means of an example, which diagrammatically shows a system for controlling a hydraulic variable displacement pump for a consumer.

[0011] In the system for controlling a hydraulic variable displacement pump **1** for a consumer **2**, shown in **FIG. 1**, the consumer **2** is in a supply cycle with a variable displacement pump **1** between a suction pipeline **5** and a pressure pipeline **6** and connection of the consumer **2** to the pressure pipeline **6** over the supply pipeline **3** and to the suction pipeline **5** over the drainage pipeline **4**, with a connection to the reservoir **24** on the suction side. A return pipeline, symbolized by the return pipeline **27**, extends between connections **25** and **26** on the pressure side and the suction side respectively and is shown as being in the transition from the pressure pipeline **6** to the intake pipeline **3** or from the drainage pipeline **4** to the suction pipeline **5**. There is a flow control above **12** and a flow regulator **13** in the return pipeline **27** in the flow direction from the connection **25** on the pressure side to the connection **26** on the suction side.

[0012] The variable displacement pump **1** is shown highly diagrammatically as a rotary vane pump with a lifting ring **7**, which can be adjusted relative to a rotor, which is not shown, with an axis **8** attached to the housing for changing the pump capacity of the variable displacement pump **1**. On the one hand, an energy storage device **9**, formed by a spring arrangement, and, on the other, a hydraulic control device **10**, illustrated by a piston-cylinder arrangement, are provided as control device. The lifting ring **7** can be adjusted over the spring arrangement, which forms the energy storage device **9**, in the sense of raising the pump capacity and, when acted upon in the opposite direction over the control device **10**, that is, against the force of the spring, in the sense of lowering the pump capacity.

[0013] With respect to its supply, the hydraulic control device **10** lies in the return pipeline **27** between the flow regulating above **12** and the flow regulator **13**, the free cross section of which is variable and which is formed, for example, by an adjustable restrictor.

[0014] Supplementary to its symbolic representation in **FIG. 1**, the flow-control valve **12** is shown diagrammatically and constructively in **FIG. 2** and comprises a pressure-maintaining valve in the form of a control slide valve **14**, which, depending upon its position, connects the pipeline section **16** of the return pipeline **27**, starting out from the pressure side (pressure pipeline **6**), over an annular channel **15** with the pipeline section **17**, which runs out to the hydraulic control device **10** and in which there is a measurement restrictor **18**. The control slide valve **14** is acted upon at the front side by pressure and moreover, on its front, high-pressure side **19** over the branch **20** to the pipeline section **16**, and at its opposite front side **21** over the branch **20**, which starts out from the pipeline section **17** downstream from the measurement restrictor **18**, a compensation spring **23** being supported additionally at the front side **21**.

[0015] The hydraulic control device **10** is shown as a piston cylinder unit, the piston **28** being supported at the lifting ring **7** and the pipeline section **17** discharging into the pressure space **29**, which is bounded by the piston **28** and going over into the pipeline section **30** of the return pipeline **27** containing the flow regulator **13**. As shown in **FIG. 2**, the dimensions of the cross section of this pipeline section **30** with regard to the maximum amount flowing through are such that an almost loss-free drainage and thus unrestricted drainage towards the suction side of the reservoir **24** is possible. Correspondingly, and this is not shown, the passable cross section of the flow regulator **13**, which is constructed as an adjustable restrictor, is adapted to such a maximum drainage cross section.

[0016] In view of an as unrestricted a drainage and as rapid a pressure relief as possible in the pressure space **29**, it is furthermore advantageous if a branch **31** of the pipeline **30** discharges in the rear area **32** of the piston, so that, as shown diagrammatically, the volume, displaced in each case when the variable displacement pump **1** is changed over to a higher pumping capacity by way of the energy storage device **9**, is used to fill cavities resulting from the changeover. This is done along the shortest path. Such a short-circuit connection may also be realized, and this is not shown, internally in the housing of the variable displacement pump. With such a short-circuit connection, it is not only possible to avoid pressure differences, which retard the adjustment, but also even to use the remaining residual pressure even for adjusting the piston, in addition to the regulating power of the energy storage system **9**. The cross section of the pipeline **13**, leading to the reservoir **24**, can also be reduced by such a short-circuit connection.

[0017] Pursuant to the invention, the sudden decrease in pressure in the pressure space **29** is attained by maximizing the drainage cross section, including the cross section of the fully opened restrictor, which forms the flow regulator **13**. This is accomplished at a low cost. Admittedly, minor delays may be associated with the hard design of the energy storage system appropriate for this purpose with the constantly high regulating power, for example, by using a spring, which is under a high tension and preferably also has a high spring rate for adjusting in the opposite direction. However, no noticeably disadvantageous effects are associated with these delays either energetically or with respect to the function of the system.

[0018] As a result of the design of the flow-control valve **12**, as the pressure drops in the pipeline section **17**, which runs out to the control device **10**, the passable cross section from the pipeline section **16** to the pipeline section **17** is decreased by the control slide **14**, so that, when the passable cross section of the flow regulator **13** expands, there is initially a rapid decrease in pressure in relation to the hydraulic control device **10**. Correspondingly, there is also a decrease in pressure in pipeline section **16**. Accordingly, if, starting out from an appropriate energizing of the flow regulator **13** by enlarging the drainage cross section, the pressure of the control device **10** is relieved, the flow into the control device over pipeline section **17** is also simultaneously reduced, even if only briefly, until the flow rate is adjusted once again over the flow-control valve **12** working as a pressure-maintaining valve. A corresponding regulating effect also results in the case of a demand request over the consumer **2** with a reduction in pressure in the intake pipeline **3** and a corresponding reduction in the pressure in the pipeline section **16** of the return pipeline **27**, so that the response behavior of the system is also affected positively in this way.

1. System for controlling a hydraulic variable-displacement in which a variable displacement pump is acted upon in its control direction, corresponding to the increase in the

pump capacity, over an energy storage system, and, in the opposite direction, over a hydraulic control device, which is controlled at a return pipeline that is branched off from the a high pressure intake, discharges excess amounts pumped and runs out into a reservoir, and furthermore, is controlled as a function of the return pipeline pressure between a flow-control valve in the return pipeline and a flow regulator downstream therefrom, a connection to the reservoir, variable in the discharging cross section, being assigned to the control device, the flow regulator forming the connection of variable discharging cross section to the reservoir and that the control device is located in the return pipeline between the flow-control valve and the flow regulator, the discharging cross section of the control device, controlled over the flow regulator, being controlled in such a manner with respect to the reservoir that, when the variable displacement pump is adjusted to the maximum pump capacity, the size of the drainage cross section is maximized for an unrestricted drainage.

2. The system of claim 1, wherein the flow regulator is controlled as a function of control parameters specified by the consumer.

3. The system of claim 1, wherein the flow regulator is controlled as a function of parameters determined by the consumer environment.

4. The system of claim 1, wherein the flow regulator is an adjustable restrictor.

5. The system of claim 1, wherein a measurement restrictor is disposed downstream, in the direction of the control device, from the flow-control valve controlling the passable cross section of the hydraulic control device and that a control piston, which is constructed as a pressure-maintaining valve, is acted upon by pressure, on the one hand, through the connection to the pressure side of the variable displacement pump and, in the opposite direction to this, by a spring as well as over a branch, which is connected downstream from the measurement restrictor.

6. The system of claim 1, wherein the control device is adjusted, the volumes of the control device, which change in opposite directions (pressure space, rear area) are connected with one another and communicate with little loss.

7. The system of claim 1, wherein the system is a control agent of a power-assisted steering system.

8. The system of claim 1, wherein the system is for a transmission.

9. The system of claim 1, wherein the variable displacement pump is as a rotary vane pump.

10. The system of claim 1, wherein the system is for a continuous variable automatic transmission (CVT).

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