(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 3 763 949 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
13.01.2021 Bulletin 2021/02

(51) Int Cl.:
F15B 11/044 *(2006.01)* ***F15B 11/042*** *(2006.01)*
B66C 13/12 *(2006.01)* ***B66C 13/18*** *(2006.01)*

(21) Application number: **19185008.0**

(22) Date of filing: **08.07.2019**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(71) Applicant: **Cargotec Patenter AB**
341-81 Ljungby (SE)

(72) Inventor: **LANAS USÁN, José Luis**
50018 Zaragoza (ES)

(74) Representative: **Bjerkéns Patentbyrå KB (Gävle)**
Box 1274
801 37 Gävle (SE)

(54) **A METHOD OF CONTROLLING A HYDRAULIC SYSTEM, A HYDRAULIC SYSTEM AND A CRANE**

(57) A hydraulic system for operating a working equipment, said hydraulic system comprising a set of hydraulic cylinders (5, 6, 7), each having a first port (17, 18,19) and a second port (20, 21, 22) on opposite sides of respective piston (8, 9, 10), a tank (23) for housing hydraulic fluid, a pump (24) configured to pump hydraulic fluid from the tank (23) to each cylinder, and a set of hydraulic control valves (25, 26, 27), one for each cylinder, each control valve (25, 26, 27) being configured to control a flow of hydraulic fluid from said pump (24) to one of the first port (17, 18, 19) and the second port (20, 21, 22). The hydraulic system comprises means for determining the total return flow rate from said cylinders (5, 6, 7) to the tank (23), and a control unit (28) configured to control the flow rate of hydraulic fluid to said first or second port (17-22)) of the cylinders (5, 6, 7) on basis of the determined total return flow rate, such that a predetermined return flow rate limit is not exceeded.

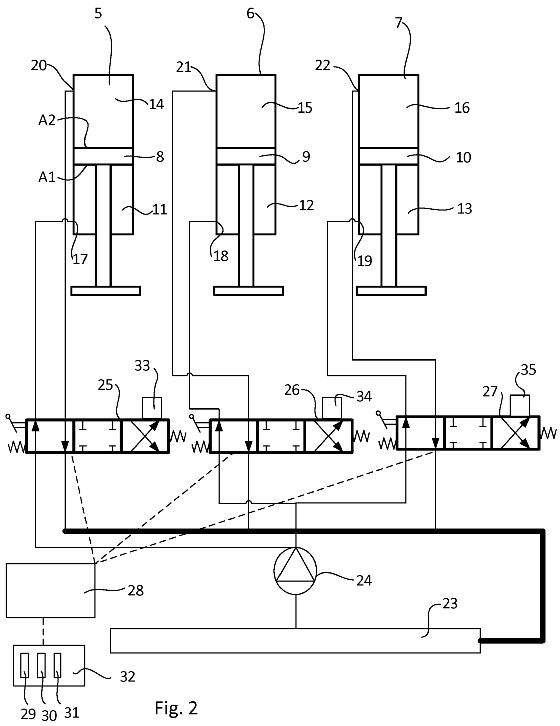

Fig. 2

EP 3 763 949 A1

Description

TECHNICAL FIELD

[0001] The present invention relates to a method of controlling a hydraulic system arranged to operate a working equipment, wherein the hydraulic system comprises

- a set of hydraulic cylinders, each cylinder being equipped with a piston which is slidingly arranged in the cylinder, wherein each piston divides its associated cylinder chamber into a first chamber and a second chamber, the first chamber being provided with a first port through which hydraulic fluid is able to enter and to exit the first chamber, and the second chamber being provided with a second port through which hydraulic fluid is able to enter and to exit the second chamber,
- a tank for housing hydraulic fluid,
- a pump configured to pump hydraulic fluid from the tank to each cylinder,
- a set of hydraulic control valves, one for each cylinder, each control valve being configured to control a flow of hydraulic fluid from said pump to either of the first port and the second port of its associated cylinder and to simultaneously allow a return flow from the other of the first port and second port of its associated cylinder to the tank.

[0002] The invention also relates to such a hydraulic system, as well as a crane provided with such a hydraulic system.

BACKGROUND AND PRIOR ART

[0003] Cranes having hydraulic systems of the type defined hereinabove are well known. Depending on the area ratios between the active areas of the pistons in the cylinders, the maximum total return flow rate of the cylinders may be high, and sometimes substantially higher than the maximum total flow rate delivered by the pump into the respective cylinders. As a consequence thereof, pressure spikes and pressure drops in the return flow can be harmful to components of the hydraulic system that are subjected to the total return flow. Such components may include hoses, valves et cetera.

[0004] The problem is often most noticeable when several crane functions are operated concurrently and by retracting piston rods of the cylinders such as during folding of cranes. There is, for example, a risk of this occurring when folding booms and retracting extension booms of a loader crane into a parked position.

[0005] One solution to the above-mentioned problem is to dimension the components subjected to such elevated stress caused by large fluid return rates such that they are able of coping with the pressure spikes caused by elevated total return flow rates. This will mean that the components are over-dimensioned for most operations performed by the crane, which do not include elevated total return flow. Over-dimensioning is costly, and it often results in bulkier and heavier components, and should therefore be avoided if possible.

[0006] It is thus an object of the invention to solve the above-mentioned problem without such over-dimensioning of components that are subjected to high stress caused by high total return flow rates.

SUMMARY

[0007] The object of the invention is achieved by means of a method of controlling a hydraulic system arranged to operate a working equipment, wherein the hydraulic system comprises

- a set of hydraulic cylinders, each cylinder being equipped with a piston which is slidingly arranged in the cylinder, wherein each piston divides its associated cylinder chamber into a first chamber and a second chamber, the first chamber being provided with a first port through which hydraulic fluid is able to enter and to exit the first chamber, and the second chamber being provided with a second port through which hydraulic fluid is able to enter and to exit the second chamber,
- a tank for housing hydraulic fluid,
- a pump configured to pump hydraulic fluid from the tank to each cylinder,
- a set of hydraulic control valves, one for each cylinder, each control valve being configured to control a flow of hydraulic fluid from said pump to either of the first port and the second port of its associated cylinder and to simultaneously allow a return flow from the other of the first port and second port of its associated cylinder to the tank, wherein said method is characterised in that it comprises the steps of:
- determining the total return flow rate from said cylinders to the tank, and
- controlling the flow rate of hydraulic fluid to said first or second ports of the cylinders on basis of the determined total return flow rate, such that a predetermined return flow rate limit is not exceeded.

[0008] According to one embodiment, the method is characterised in that, for each cylinder the associated piston has a first end surface area directed towards the first chamber and a second end surface area directed towards the second chamber, and in that -the step of determining the total return flow rate comprises an estimation of the total return flow rate on basis of information regarding the flow rate of hydraulic fluid into each respective cylinder, on basis of information regarding into which of the first and second chamber of the respective cylinder that the hydraulic fluid flows, on basis of an area ratio between the first end surface area and the second end surface area of the piston of the respective cylinder, and on basis of information regarding the flow rate through the pump.

[0009] According to one embodiment, each control valve is configured to regulate the flow rate into its associated cylinder either in a stepwise manner or in a stepless manner between zero and maximum flow rate, wherein the information regarding the flow rate of hydraulic fluid into each respective cylinder is based on information regarding a control position of each respective control valve, and that the method comprises the step of identifying said control position of the control valve. The control valves may be referred to as proportional control valves, in particular a load sensing proportional control valve. In proportional control valve, the flow rate to a cylinder is proportional to a control position of a manually operated element of a user input device. The control position may be the position of a part of the valve that is indicative of the degree of opening of the valve, and thus the flow rate into the associated cylinder. Said part may comprise a movable spool, and the means for determining said control position may comprise a spool position sensor arranged to measure how much the spool has been displaced The spool position sensor may be connected to the control unit to communicate measurement results to the control unit.

[0010] According to one embodiment, the hydraulic system comprises a user input device which comprises a manually operable element for operating the working equipment, and the flow rate through the respective control valve into each cylinder is determined on basis of the input from the manually operated element. The operator has the user input device for controlling a working equipment, such as a crane, operated by the hydraulic system. The user input device may be mounted to the crane or a separate unit connected to the control system of the crane by cables or wireless transceivers. The operator generates user input to manoeuvre the crane by pushing/pulling levers, buttons, touch screen etc. defined by said manually operable element. A control system of the hydraulic system may then issue control signals to the control valves based on the received user input.

[0011] According to one embodiment, the method is characterised in that, if it is determined that the total return flow rate is equal to or above said predetermined return flow rate limit, the flow rate of the hydraulic fluid into the cylinders is reduced with a reduction ratio such that the predetermined return flow rate limit is not exceeded.

[0012] According to one embodiment, the method is characterised in that, if it is determined that the total return flow rate approaches said predetermined return flow rate limit with a pace which is above a predetermined pace limit, and within a predetermined flow rate range, the flow rate of the hydraulic fluid into the cylinders is reduced with a reduction ratio such that the predetermined return flow rate limit is not exceeded.

[0013] According to one embodiment, said reduction ratio is equal for all the cylinders.

[0014] The object of the invention is also achieved by means of a hydraulic system for operating a working equipment, said hydraulic system comprising:

- a set of hydraulic cylinders, each cylinder being equipped with a piston which is slidingly arranged in the cylinder, wherein each piston divides its associated cylinder chamber into a first chamber and a second chamber, the first chamber being provided with a first port through which hydraulic fluid is able to enter and to exit the first chamber, and the second chamber being provided with a second port through which hydraulic fluid is able to enter and to exit the second chamber,
- a tank for housing hydraulic fluid,
- a pump configured to pump hydraulic fluid from the tank to each cylinder,
- a set of hydraulic control valves, one for each cylinder, each control valve being configured to control a flow of hydraulic fluid from said pump to one of the first port and the second port of its associated cylinder and to simultaneously allow a return flow from the other of the first port and second port of its associated cylinder to the tank, wherein said hydraulic system is characterised in that it comprises:
- means for determining the total return flow rate from said cylinders to the tank, and
- a control unit configured to control the flow rate of hydraulic fluid to said first or second ports of the cylinders on basis of the determined total return flow rate, such that a predetermined return flow rate limit is not exceeded.

[0015] According to one embodiment, the hydraulic system is characterised in that, for each cylinder the associated piston has a first end surface area directed towards the first chamber and a second end surface area directed towards the second chamber, and in that the means for determining the total return flow rate comprises the control unit, which is configured to estimate the total return flow rate on basis of information regarding the flow rate of hydraulic fluid into each respective cylinder, on basis of information regarding into which of the first and second chamber of the respective cylinder that the hydraulic fluid flows, on basis of an area ratio between the first end surface area and the second end surface area of the piston of the respective cylinder, and on basis of information regarding the flow rate through the pump.

[0016] According to one embodiment, each control valve is configured to regulate the flow rate into its associated cylinder either in a stepwise manner or in a stepless manner between zero and maximum flow rate, wherein the means for determining the flow rate of hydraulic fluid into each respective cylinder comprises means for determining a control position of each respective control valve. The control position may be the position of a part of the valve that is indicative of the degree of opening of the valve, and thus the flow rate into the associated cylinder. Said part may comprise a movable spool, and the means for determining said control position may comprise a spool position sensor arranged to measure how much the spool has been displaced, the spool position sensor may be connected to the control unit to communicate measurement results to the control unit.

[0017] According to one embodiment the hydraulic system comprises a user input device which comprises a manually operable element for operating the working equipment, and the control unit is configured to determine a position of the manually operable element and to estimate the flow through each control valve to its associated cylinder on basis thereof.

[0018] According to one embodiment, if it is determined by the control unit that the total return flow rate is equal to or above said predetermined return flow rate limit, the control unit is configured to reduce the flow rate of the hydraulic fluid into the cylinders with a reduction ratio such that the predetermined return flow rate limit is not exceeded.

[0019] According to one embodiment, the control unit is configured to determine the rate with which the total return flow approaches the predetermined return flow rate limit, wherein, if it is determined by the control unit that the total return flow rate approaches said predetermined return flow rate limit with a pace which is above a predetermined pace limit, and within a predetermined flow rate range, the control unit is configured to reduce the flow rate of the hydraulic fluid into the cylinders with a reduction ratio such that the predetermined return flow rate limit is not exceeded.

[0020] According to one embodiment, said reduction ratio is equal for all the cylinders.

[0021] The object of the invention is also achieved by means of a crane, such as a loader crane, characterised in that it comprises a hydraulic system according to the present invention.

[0022] For the implementation of the invention, the hydraulic system may comprise a computer program comprising a computer program code for causing a computer to implement a method according to the invention when the computer program is executed in the computer.

[0023] The hydraulic system may further comprise a computer program product comprising a non-transitory data storage medium which can be read by a computer and on which the program code of a computer program as defined hereinabove is stored.

[0024] Moreover, a control system of the hydraulic system according to the present invention may comprise an electronic control unit comprising an execution means and a data storage medium which is connected to the execution means and on which the computer program code of a computer program as defined hereinabove is stored.

BRIEF DESCRIPTION OF THE DRAWING

[0025]

Fig. 1 is a schematic representation of a crane according to the invention,

Fig. 2 is a schematic representation of a hydraulic system according to the invention,

Fig. 3 is a flow chart showing steps of a method according to the invention.

DETAILED DESCRIPTION

[0026] Fig. 1 illustrates a hydraulic loader crane which preferably is equipped with a hydraulic system according to the present invention. The crane comprises a body 1, a first boom section 2 articulated to the body 1, an outer boom 3 articulated to the first boom section 2, and an extension boom 4 fixed to the outer boom 3. The first boom section 2 is operated by means of a hydraulic lifting cylinder 5, the outer boom 3 is operated by means of a hydraulic outer boom cylinder 6, and the extension boom is operated by means of a hydraulic extension boom cylinder 7.The body 1 may comprise a crane column which is rotatably mounted to a crane base (not shown in Fig. 1) so as to be rotatable in relation to the crane base about an essentially vertical axis of rotation. The rotatable crane column is operated by a swivel mechanism e.g. based on a rack and pinion design comprising a hydraulic cylinder, sometimes referred to as a slewing cylinder. Alternatively, the swivel mechanism may be a so called endless slewing system comprising a motor with gear and slewing bearing to get a free rotation. In addition to this further boom extensions operated by hydraulic extension boom cylinders may be telescopically mounted to the extension boom 4 to give the crane additional reach. One or more so called jibs, may further be mounted to the outer boom 3. A jib is an additional crane boom which may be mounted to the outer end of the outer boom by means of a connecting unit with an insertion part that is received inside the foremost telescopic crane boom section of the outer boom. Jibs add further booms and hydraulic extension boom cylinders to the crane and are connected to the hydraulic system of the crane.

[0027] The lifting cylinder 5, the outer boom cylinder 6 and the extension boom cylinder 7 form part of a hydraulic system disclosed in fig. 2. Each of said cylinders 5, 6, 7 is equipped with a piston 8, 9, 10 which is slidingly arranged in the cylinder 5, 6, 7, wherein each piston 8, 9, 10 divides its associated cylinder chamber 5, 6, 7 into a first chamber 11, 12, 13 and a second chamber 14, 15, 16. Each first chamber 11, 12, 13 is provided with a first port 17, 18, 19 through which hydraulic fluid is able to enter and to exit the first chamber 11, 12, 13, and each second chamber 14, 15, 16 is provided with a second port 20, 21, 22 through which hydraulic fluid is able to enter and to exit the second chamber 14, 15, 16.

[0028] The hydraulic system further comprises a tank 23 for housing hydraulic fluid and a pump 24 configured to pump hydraulic fluid from the tank 23 to each cylinder 5, 6, 7. There is a set of hydraulic control valves 25, 26, 27, one for each cylinder 5, 6, 7, each control valve 25, 26, 27 being configured to control a flow of hydraulic fluid from said pump 24 to one of the first port 17, 18, 19 and the second port 20, 21, 22 of its associated cylinder and to simultaneously allow a return flow from the other of the first port 17, 18, 19 and the second port 20, 21, 22 of its associated cylinder 5, 6, 7 to the tank 23. The hydraulic system further comprises a control unit 28 configured to determine the total return flow rate Rtot from said cylinders 5, 6, 7 to the tank 23. The control unit 28 is also configured to control the flow rate of hydraulic fluid to said first or second ports 17-22 of the cylinders 5-7 on basis of the determined total return flow rate Rtot, such that a predetermined return flow rate limit Rmax is not exceeded.

[0029] The control unit 28 forms part of a control system of the hydraulic system and may comprise an electronic control unit comprising an execution means and a data storage medium which is connected to the execution means and on which a computer program code of a computer program is stored. The computer program may comprise a computer program code for causing a computer to implement a method according to the invention when the computer program is executed in the computer. The control unit 28 may also comprise a computer program product comprising a non-transitory data storage medium which can be read by a computer and on which the program code of a computer program as defined hereinabove is stored. A user input device 32 configured to allow a user to send control signals to the control unit 28 on basis of which the operation of the control valves is controlled also forms part of the control system. The user input device 32 may be remote from the crane structure. For example it may comprise a remote control device configured to be carried by an operator

[0030] The total return flow rate Rtot may be obtained by providing one or more flow meters in the hydraulic system, for the purposes determining Rtot by direct measurement of the return flow rate. However, in the embodiment disclosed, the control unit 28 is configured to estimate, or calculate, Rtot on basis of input that it receives continually regarding the operation and the structural characteristics of the cylinders 5-7. Input from sensors like flow meters, pressure sensors and/or temperature sensors located at various positions in the hydraulic system may further be used to verify that the estimations are reasonable. Such sensor input may be further used to modify the estimations, if needed.

[0031] For each cylinder 5, 6, 7 the associated piston 8, 9, 10 has a first end surface area A1 directed towards the first chamber 11, 12, 13 and a second end surface area A2 directed towards the second chamber 14, 15, 16. The return flow rate Ri from each cylinder 5, 6, 7 is thus dependent on the area ratio A1/A2 and on the direction of flow (i.e. if the hydraulic fluid flows into the first port 17, 18, 19 or into the second port 20, 21, 22), and, needless to say, the flow rate into the cylinder. The ratio A1/A2 may be different for different cylinders. For some cylinders, like the slewing cylinder, the ratio A1/A2 may be 1.

[0032] The control unit 28 is thus configured to estimate the total return flow rate Rtot on basis of information regarding the flow rate of hydraulic fluid into each respective cylinder, on basis of information regarding into which of the first and second chamber 11-16 of the respective cylinder 5, 6, 7 that the hydraulic fluid flows, on basis of an area ratio A1/A2 between the first end surface area A1 and the second end surface area A2 of the piston 8, 9, 10 of the respective cylinder 5, 6, 7, and on basis of information regarding the flow rate through the pump 24.

[0033] Each control valve 25, 26, 27 is configured to regulate the flow rate into its associated cylinder 5, 6, 7 either in a stepwise manner or in a step-less manner between zero and maximum flow rate, by displacing a spool in the control valve. The control valves 25, 26, 27 are proportional valves arranged so as to regulate the flow rate through the valve 25, 26, 27 towards the respective cylinder 5, 6, 7 on basis of an order from an operator. The input user device 32 comprises manually operable elements, for example levers, knobs, touch screens or the like, which are schematically represented with reference number 29, 30, 31 in fig. 2. In a preferred embodiment, the manually operable element 29, 30, 31 is arranged on a remote control device which is physically separated from the control valves 25, 26, 27 and designed so as to enable an operator to operate the crane functions from a remote position. Alternatively, the control valves may be controlled with an input user device physically connected to the control valves. Each control valve may further be monitored by a spool position sensor (33, 34, 35) arranged to measure how much the spool has been displaced, the spool position sensor may be connected to the control unit 28 to communicate measurement results to the control unit 28.The control unit 28 is thus configured to estimate the return flow rate Ri of each cylinder 5, 6, 7 on basis of the position of said manually operable element 29, 30 ,31, which gives an indirect information about the fluid flow rate into each respective cylinder 5, 6, 7 and, or, by input from the measurements of the spool position sensor (33, 34, 35). The measurements from the spool position sensor may further be combined with information regarding the flow rate through the pump (24).

[0034] In addition to cylinders other hydraulic components such as motors or hoists may further be part of the hydraulic system and generate contributions to the return flow. The output flow from these components may further be estimated in accordance with user input signals and input flow, and also be reduced using a similar method as for the cylinders.

[0035] Regenerative cylinders may further be part of e.g. the hydraulic system for the extension boom system. When these cylinders are in regenerative mode there is no, or little, return flow. This should of course be taken into account in the estimations of the return flow. The control system may monitor the mode of the regenerative cylinders (if they are in normal operation or regenerative operation mode) and the estimations of return flow may be performed accordingly.

[0036] If it is determined by the control unit 28 that the total return flow rate Rtot is equal to or above said predetermined return flow rate limit Rmax, the control unit 28 is configured to reduce the flow rate of the hydraulic fluid into the cylinders 5, 6, 7 with a reduction ratio Red such that the predetermined return flow rate limit Rmax is not exceeded.

[0037] In a further developed embodiment, the control unit 28 is also configured to calculate the rate V (measured, for example, in litres/seconds^2, l/s^2) with which the total return flow approaches the predetermined return flow rate limit Rmax. If it is determined by the control unit 28 that the total return flow rate approaches said predetermined return flow rate limit Rmax with a pace which is above a predetermined pace limit Vmax, the control unit 28 is configured to reduce the flow rate increase of the hydraulic fluid into the cylinders with a reduction ratio such that the predetermined return flow rate limit Rmax is not exceeded. Preferably, the reduction of the flow rate increase is applied in a predetermined flow rate range close to the predetermined return flow rate limit.

[0038] The above-mentioned reduction ratio is equal for all the cylinders.

[0039] Fig. 3 shows a flow chart in which an embodiment of the method according to the invention is disclosed.

[0040] An embodiment of the method comprises the following steps:

S1) deciding for each cylinder 5, 6, 7 if there is a flow of fluid into that cylinder, and the rate of that flow, as measured in, for example, litres per minute, by sensing the control position of a manually operated element 29, 30, 31 used for controlling the operation of the working equipment by controlling the flow through a control valve 25, 26, 27, which controls the flow of hydraulic fluid into each cylinder 5, 6, 7, and, or, by receiving input signals from the spool position sensor (33, 34, 35) representing a displacement of a spool of the control valve,
S2) deciding, for each cylinder 5, 6, 7, into which of said first chambers 11, 12, 13 or second chambers 14, 15, 16 that the hydraulic fluid flows by sensing the position of the manoeuvrable element 29, 30, 31, and, or, by receiving input signals from the spool position sensor (33, 34, 35) representing a displacement of a spool of the control valve,
S3) calculating the return flow rate Ri for each cylinder 5, 6, 7 on basis of the information in a) and b) and on basis of the area ration A1/A2 for each cylinder 5, 6, 7,
S4) determining the total return flow rate Rtot by summing the return flow rates Ri of the respective cylinders 5, 6, 7,
S5) comparing the total return flow rate Rtot with the predetermined return flow rate limit Rmax, and
S6) goto S1 if Rtot≤Rmax, or
S7) if Rtot>Rmax, applying a reduction ratio corresponding to Rtot/Rmax on the requested flow rate indicated by the manually operated elements 29, 30, 31 such that Rtot≤Rmax.

[0041] Steps S1-S7 are repeated repeatedly during operation of the crane comprising the hydraulic system in order to make sure that Rmax is not exceeded. The control unit 28 may be configured to allow occasional exceeding of Rmax under special circumstances, but, preferably, the inventive method is applied continually during operation of the crane. Rmax is a predetermined return flow rate limit. For a hydraulic system according to the invention one or more return flow rate limits may be defined, e.g. one limit that may be occasionally exceeded and one limit that should not be exceeded due to risk of system failure. The reduction rate may be further increased if it is estimated that the limit that should not be exceeded is approached.

[0042] It is assumed that the pump 24 operates at constant nominal effect. As an alternative to reducing a control signal from the manually operated elements 29, 30, 31 to their respective control valve with a reduction ratio corresponding to the calculated Rtot/Rmax, the output of the pump 24 could be reduced with a reduction ratio corresponding to Rtot/Rmax.

Claims

1. A method of controlling a hydraulic system arranged to operate a working equipment, wherein the hydraulic system comprises

- a set of hydraulic cylinders (5, 6, 7), each cylinder (5, 6, 7) being equipped with a piston (8, 9, 10) which is slidingly arranged in the cylinder (5, 6, 7), wherein each piston (8, 9, 10) divides its associated cylinder chamber into a first chamber (11, 12, 13) and a second chamber (14, 15, 16), the first chamber (11, 12, 13) being provided with a first port (17, 18, 19) through which hydraulic fluid is able to enter and to exit the first chamber (11, 12, 13), and the second chamber (14, 15, 16) being provided with a second port (20, 21, 22) through which hydraulic fluid is able to enter and to exit the second chamber (14, 15, 16),
- a tank (23) for housing hydraulic fluid,
- a pump (24) configured to pump hydraulic fluid from the tank (23) to each cylinder,
- a set of hydraulic control valves (25, 26, 27), one for each cylinder, each control valve (25, 26, 27) being configured to control a flow of hydraulic fluid from said pump (24) to either of the first port (17, 18, 19) and the second port (20, 21, 22) of its associated cylinder and to simul-

taneously allow a return flow from the other of the first port (17, 18, 19) and second port (20, 21, 22) of its associated cylinder to the tank (23), wherein said method is **characterised in that** it comprises the steps of:
- determining the total return flow rate from said cylinders (5, 6, 7) to the tank (23), and
- controlling the flow rate of hydraulic fluid to said first or second port (17-22)) of the cylinders (5, 6, 7) on basis of the determined total return flow rate, such that a predetermined return flow rate limit is not exceeded.

2. A method according to claim 1, **characterised in that**, for each cylinder the associated piston (8, 9, 10) has a first end surface area directed towards the first chamber (11, 12, 13) and a second end surface area directed towards the second chamber (14, 15, 16), and **in that**

- the step of determining the total return flow rate comprises an estimation of the total return flow rate on basis of information regarding the flow rate of hydraulic fluid into each respective cylinder, on basis of information regarding into which of the first and second chamber (14, 15, 16) of the respective cylinder that the hydraulic fluid flows, on basis of an area ratio between the first end surface area and the second end surface area of the piston (8, 9, 10) of the respective cylinder.

3. A method according to claim 2, **characterised in that** each control valve (25, 26, 27) is configured to regulate the flow rate into its associated cylinder either in a stepwise manner or in a step-less manner between zero and maximum flow rate, and **in that** the information regarding the flow rate of hydraulic fluid into each respective cylinder is based on information regarding a control position of each respective control valve (25, 26, 27), and that the method comprises the step of identifying said control position of the control valve (25, 26, 27).

4. A method according to claim 1 or 2, **characterised in that** the hydraulic system comprises a user input device (32) which comprises a manually operable element (29, 30, 31) for operating the working equipment, and that the flow rate through the respective control valve (25, 26, 27) into each cylinder (5, 6, 7) is determined on basis of the input from the manually operated element.

5. A method according to any one of claims 1-4, **characterised in that**, if it is determined that the total return flow rate is equal to or above said predetermined return flow rate limit, the flow rate of the hydraulic fluid into the cylinders (5, 6, 7) is reduced with a reduction ratio such that the predetermined return flow rate limit is not exceeded.

6. A method according to any one of claims 1-5, **characterised in that**, if it is determined that the total return flow rate approaches said predetermined return flow rate limit with a pace which is above a predetermined pace limit, and within a predetermined flow rate range, the flow rate of the hydraulic fluid into the cylinders (5, 6, 7) is reduced with a reduction ratio such that the predetermined return flow rate limit is not exceeded.

7. A method according to claim 5 or 6, **characterised in that** said reduction ratio is equal for all the cylinders (5, 6, 7).

8. A hydraulic system for operating a working equipment, said hydraulic system comprising:

- a set of hydraulic cylinders (5, 6, 7), each cylinder being equipped with a piston (8, 9, 10) which is slidingly arranged in the cylinder, wherein each piston (8, 9, 10) divides its associated cylinder chamber into a first chamber (11, 12, 13) and a second chamber (14, 15, 16), the first chamber (11, 12, 13) being provided with a first port (17, 18, 19) through which hydraulic fluid is able to enter and to exit the first chamber (11, 12, 13), and the second chamber (14, 15, 16) being provided with a second port (20, 21, 22) through which hydraulic fluid is able to enter and to exit the second chamber (14, 15, 16),
- a tank (23) for housing hydraulic fluid,
- a pump (24) configured to pump hydraulic fluid from the tank (23) to each cylinder,
- a set of hydraulic control valves (25, 26, 27), one for each cylinder, each control valve (25, 26, 27) being configured to control a flow of hydraulic fluid from said pump (24) to one of the first port (17, 18, 19) and the second port (20, 21, 22) of its associated cylinder and to simultaneously allow a return flow from the other of the first port (17, 18, 19) and second port (20, 21, 22) of its associated cylinder to the tank (23), wherein said hydraulic system is **characterised in that** it comprises:
- means for determining the total return flow rate from said cylinders (5, 6, 7) to the tank (23), and
- a control unit (28) configured to control the flow rate of hydraulic fluid to said first or second port (17-22)) of the cylinders (5, 6, 7) on basis of the determined total return flow rate, such that a predetermined return flow rate limit is not exceeded.

9. A hydraulic system according to claim 8, **characterised in that**, for each cylinder the associated piston (8, 9, 10) has a first end surface area directed towards the first chamber (11, 12, 13) and a second end surface area directed towards the second chamber (14, 15, 16), and **in that**

- the means for determining the total return flow rate comprises the control unit (28), which is configured to estimate the total return flow rate on basis of information regarding the flow rate of hydraulic fluid into each respective cylinder, on basis of information regarding into which of the first and second chamber (14, 15, 16) of the respective cylinder that the hydraulic fluid flows, on basis of an area ratio between the first end surface area and the second end surface area of the piston (8, 9, 10) of the respective cylinder.

10. A hydraulic system according to claim 9, **characterised in that in that** each control valve (25, 26, 27) is configured to regulate the flow rate into its associated cylinder either in a stepwise manner or in a step-less manner between zero and maximum flow rate, and **in that** the means for determining the flow rate of hydraulic fluid into each respective cylinder comprises means for determining a control position of each respective control valve (25, 26, 27).

11. A hydraulic system according to claim 8 or 9, **characterised in that** it comprises a user input device (32) which comprises a manually operable element (29, 30, 31) for operating the working equipment, and that the control unit (28) is configured to determine a position of the manually operable element (29, 30, 31) and to estimate the flow through each control valve (25, 26, 27) to its associated cylinder (5, 6, 7) on basis thereof.

12. A hydraulic system according to any one of claims 9-11, **characterised in that**, if it is determined by the control unit (28) that the total return flow rate is equal to or above said predetermined return flow rate limit, the control unit (28) is configured to reduce the flow rate of the hydraulic fluid into the cylinders (5, 6, 7) with a reduction ratio such that the predetermined return flow rate limit is not exceeded.

13. A hydraulic system according to any one of claims 9-12, **characterised in that** the control unit (28) is configured to determine the rate with which the total return flow approaches the predetermined return flow rate limit, and that, if it is determined by the control unit (28) that the total return flow rate approaches said predetermined return flow rate limit with a pace which is above a predetermined pace limit, and within a predetermined flow rate range, the control unit (28) is configured to reduce the flow rate of the hydraulic fluid into the cylinders (5, 6, 7) with a reduction ratio such that the predetermined return flow rate limit is not exceeded.

14. A hydraulic system according to claim 12 or 13, **characterised in that** said reduction ratio is equal for all the cylinders (5, 6, 7).

15. A crane, **characterised in that** it comprises a hydraulic system according to any one of claims 8-14.

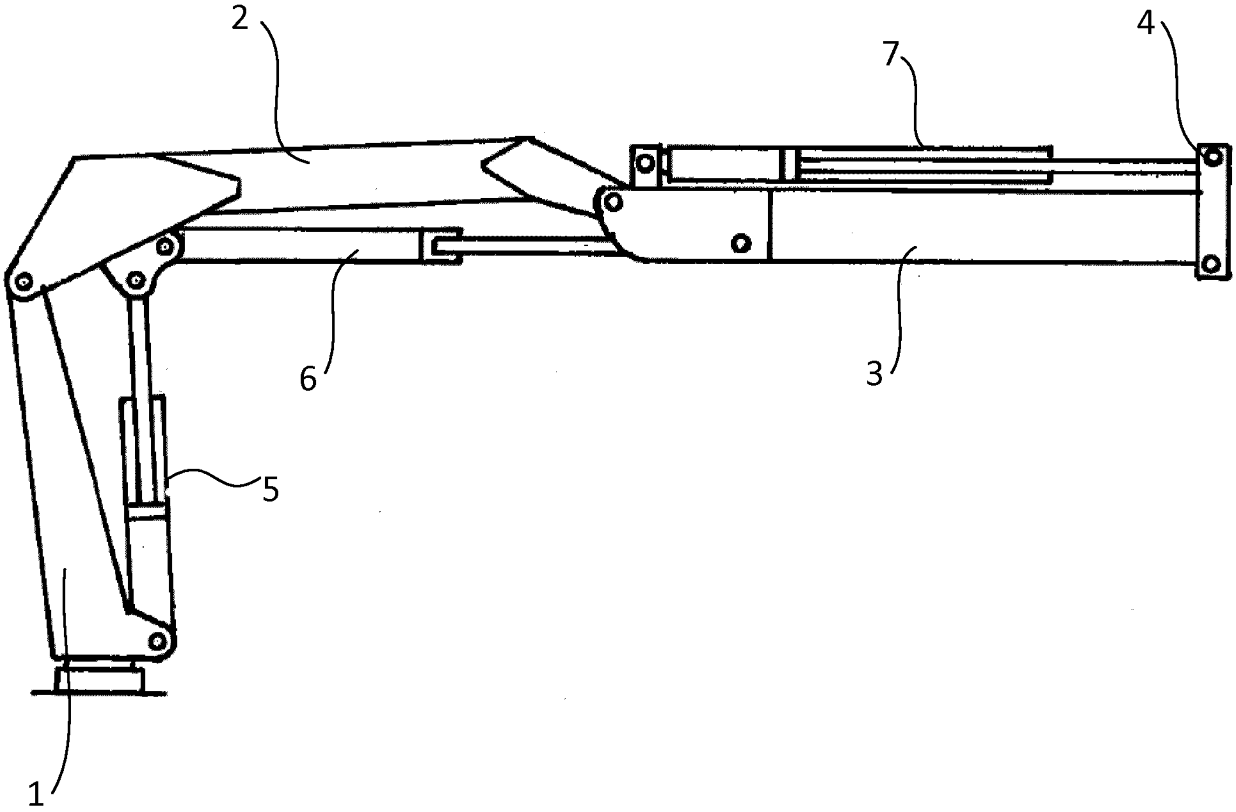

Fig. 1

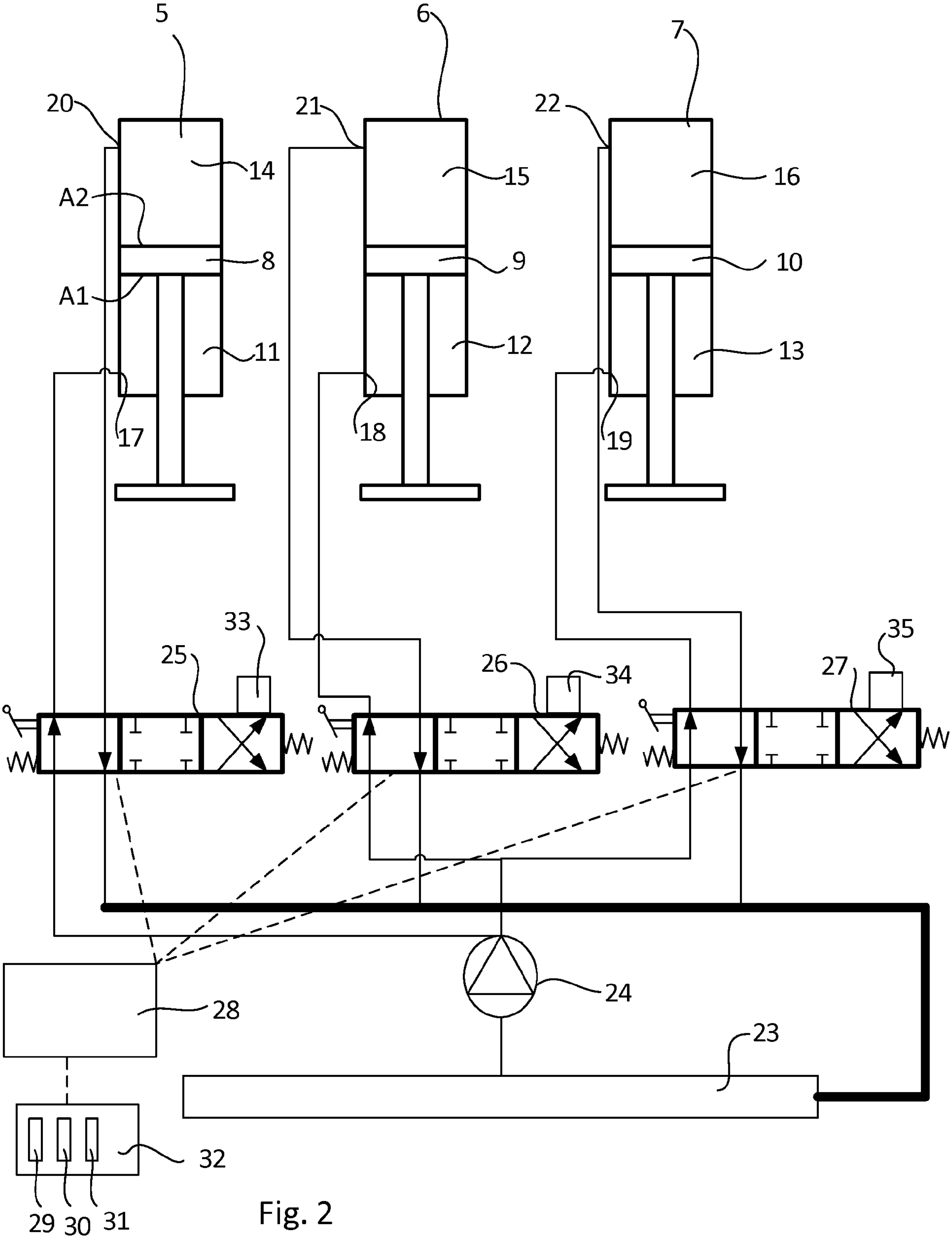
5
6
7
20
21
22
14
15
16
A2
8
9
10
A1
11
12
13
17
18
19
33
25
26
34
35
27
24
28
23
32
29
30
31

Fig. 2

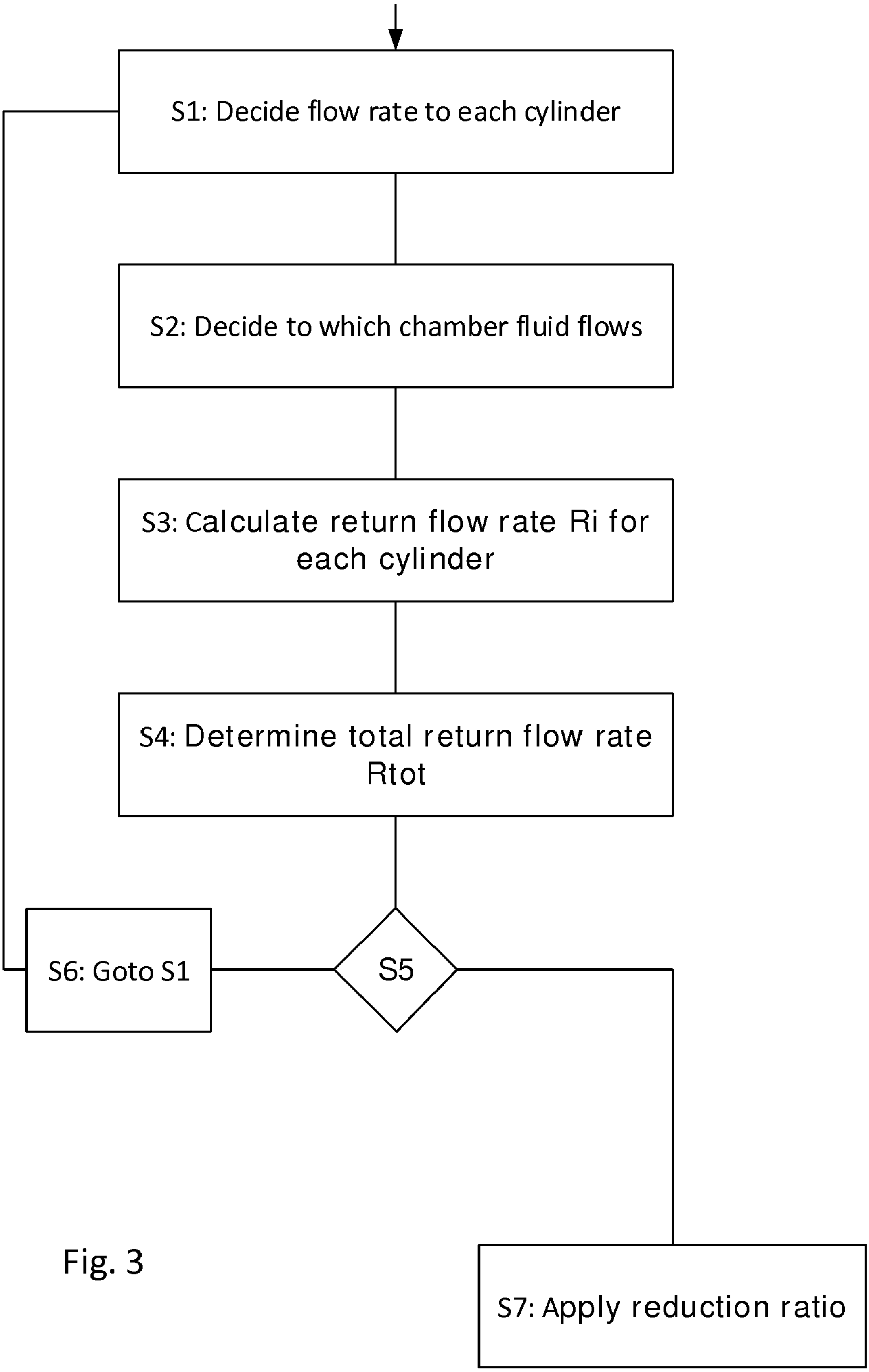
S1: Decide flow rate to each cylinder
S2: Decide to which chamber fluid flows
S3: Calculate return flow rate Ri for each cylinder
S4: Determine total return flow rate Rtot
S6: Goto S1
S5
S7: Apply reduction ratio

Fig. 3

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 19 18 5008

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 2012/253528 A1 (WAN LIANG [CN] ET AL) 4 October 2012 (2012-10-04) * paragraphs [0040] - [0049] * -----	1-15	INV. F15B11/044 F15B11/042 B66C13/12 B66C13/18
A	JP S62 75107 A (KOMATSU MFG CO LTD) 7 April 1987 (1987-04-07) * abstract * -----	1,8	

TECHNICAL FIELDS SEARCHED (IPC)

F15B
B66F
B66C

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	8 January 2020	Toffolo, Olivier

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 19 18 5008

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

08-01-2020

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2012253528 A1	04-10-2012	CN 101824916 A	08-09-2010
		EP 2520739 A1	07-11-2012
		PL 2520739 T3	28-02-2018
		US 2012253528 A1	04-10-2012
		WO 2011116700 A1	29-09-2011
JP S6275107 A	07-04-1987	JP H0668281 B2	31-08-1994
		JP S6275107 A	07-04-1987

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82