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FLUID SYSTEM AND VALVE ASSEMBLY THEREFOR

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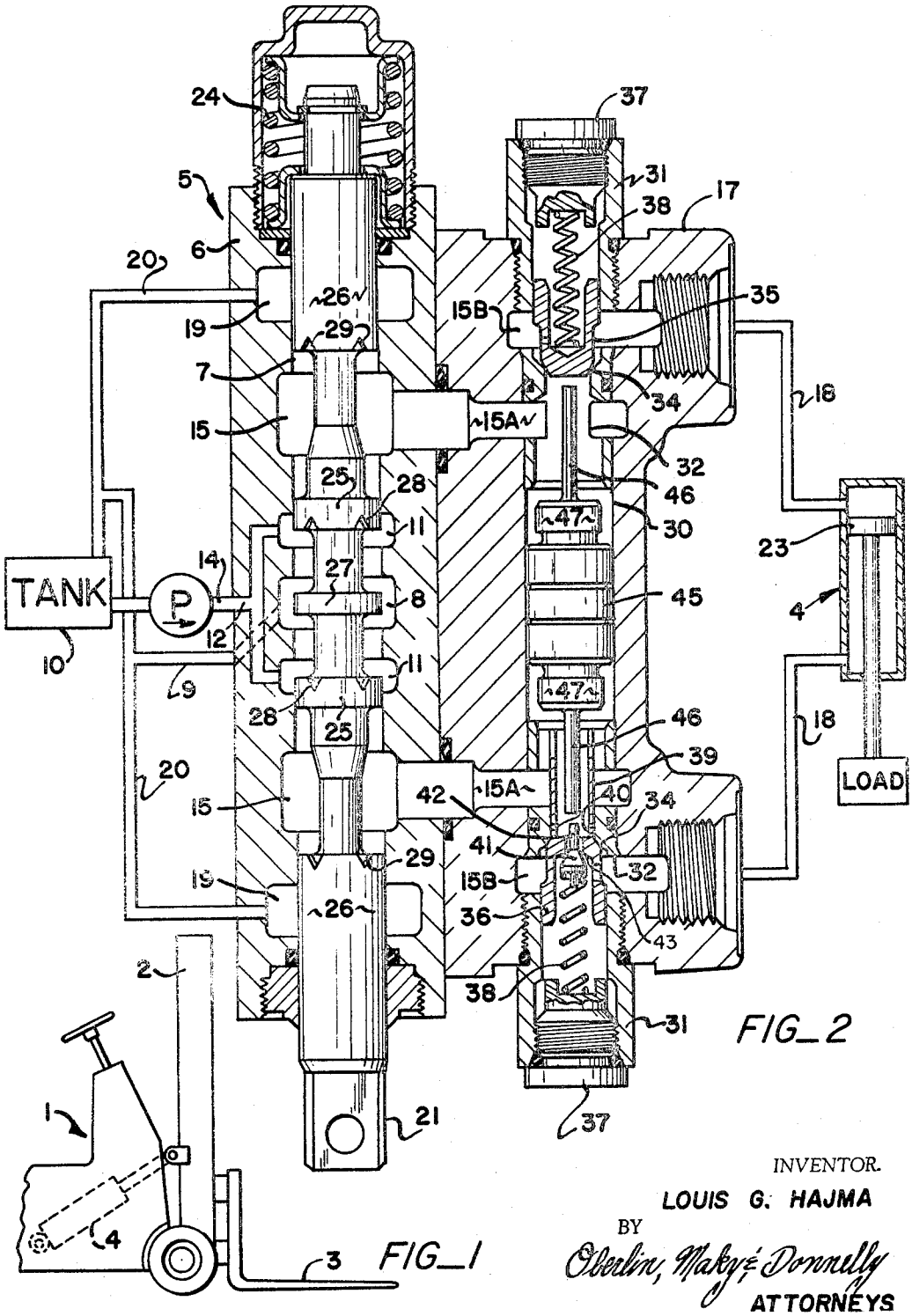


FIG_2

FIG_1

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FLUID SYSTEM AND VALVE ASSEMBLY THEREFOR

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The present invention relates generally as indicated to a fluid system and valve assembly therefor and more particularly to a directional control valve for use in controlling actuation of a fluid motor, said valve having a novel flow control means therein.

It is known in the art to provide check valves between a spool type directional control valve and a fluid motor in order to prevent leakage of fluid from the motor. In the usual arrangement when the flow of fluid is in one direction through the directional control valve to a port of the fluid motor, the associated check valve will be opened by fluid pressure acting thereon, and when the flow of the fluid is in the opposite direction from the same port of the motor and through the directional control valve to a tank or reservoir, a fluid pressure operated plunger will be provided to engage the check valve to move it to open position thereby to permit such return flow. In some installations, particularly those in which the load on the fluid motor imposes a relatively high pressure in the return circuit, one difficulty encountered in such check valve arrangement is that when the valve spool is held in a metering position to control the rate of return flow thus to control the rate of actuation of the fluid motor, the check valve in the loaded return circuit tends to chatter and pound on its seat with consequent damage, aside from objectionable noise and squealing. High pressure pulses may also damage other components of the system.

Accordingly, it is a principal object of this invention to provide a fluid pressure-mechanically actuated check valve which eliminates the aforementioned difficulties encountered in known constructions.

It is another object of this invention to provide a spool valve assembly having a pilot-operated check valve assembly associated therewith in the loaded return circuit, the pilot check being initially opened by a fluid pressure-actuated plunger to commence return flow, followed by opening of an orificed main check, at which time, the plunger defines a cushioning chamber or dashpot with the spool valve housing to preclude rapid pulsating movements of either the pilot or main checks with consequent elimination of such chattering and squealing.

Other objects and advantages of the present invention will become apparent as the following description proceeds.

To the accomplishment of the foregoing and related ends, the invention, then, comprises the features hereinafter fully described and particularly pointed out in the claims, the following description and the annexed drawings setting forth in detail a certain illustrative embodiment of the invention, this being indicative, however, of but one of the various ways in which the principle of the invention may be employed.

In said annexed drawing:

FIG. 1 is a fragmentary side elevation view of the front portion of a hydraulically operated fork lift truck which is of character such as to impose a load in the return fluid circuit when the mast is actuated forwardly from rearwardly tilted load holding position; and

FIG. 2 illustrates in cross-section one embodiment of the present invention in a fluid system, the section of the valve assembly passing through the axes of the valve spool and fluid pressure-plunger actuated check valves.

Referring first to FIG. 1, there is illustrated therein a typical fork lift truck 1 having an upright mast 2, a lift fork 3 movable upwardly and downwardly along said mast 2 as by a fluid motor (not shown) to raise and lower a load thereon, and a fluid motor 4 for tilting the mast 2 rearwardly about a pivot (not shown) at its lower end to correspondingly tilt the load on the fork 3 for ease of transport from one place to another. As evident, even when the mast 2 is tilted rearwardly, a heavy load on the fork 3 will impose a substantial clockwise moment on the mast 2 and fork 3 structure whereby when the rod end of motor 4 is communicated with a fluid reservoir, there will be substantial fluid pressure in the return circuit. It has been found that if an ordinary plunger actuated check valve is installed in this return circuit, the positioning of the valve spool of the directional control valve in a metering position for controlled speed of forward tilting of mast 2 causes chattering of the check valve with possible damage to the check valve or its seat. Moreover, high pressure pulses may damage other components of the fluid system. It is to be understood that a fork lift truck 1 has been illustrated merely as a typical example of a fluid pressure operated device in which the problem of metering return flow under substantial fluid pressure may arise.

Referring now in detail to FIG. 2, the spool-type directional control valve 5 may be of more or less conventional form comprising a housing 6 having a bore 7 therethrough which is intersected axially therealong starting at the middle by a bypass passage 8 connected by way of conduit 9 with a tank or reservoir 10; a pair of pressure feed passages 11—11 straddling the bypass passage 8 and leading to inlet passage 12 which is connected by conduit 14 to pump P; a pair of cylinder passages 15—15 straddling feed passages 11—11 and adapted to be connected with the ports of a double acting fluid motor 4 via passages in the check valve housing 17 and conduits 18—18; and a pair of tank passages 19—19 straddling the cylinder passages 15—15 and having fluid communication with the tank 10 by way of conduits 20—20.

Axially reciprocable in said bore 7 is the valve spool 21 which has alternate lands and grooves, as shown, to cooperate with the aforesaid passages 8, 11, 15, and 19 to enable control of the motor piston 23 to move it upwardly or downwardly as viewed in FIG. 2, or to lock it at any desired position. The spool 21 is shown in its neutral position in which it is yieldably held by the spring-centering mechanism 24 operatively associated with the upper end of the spool 21. In this neutral position, the spool lands 25—25 block fluid communication between the adjacent pressure feed and cylinder passages 11 and 15, whereby there is no flow of fluid under pressure to either end of the fluid motor 4. Similarly, the lands 26 block communication between the adjacent cylinder and return passages 15 and 19 so that the piston 23 cannot move in either direction. However, because the spool 21 is axially slidable in the bore 7 (without a large number of packing rings between all the lands of the spool 21 and the bore 7) there would be leakage of fluid which, except for the check valves herein provided, would permit creeping of the piston 23 under the influence of a load thereon. The output of pump P is bypassed to tank 10 by reason of the open communication between both feed passages 11 and bypass passage 8.

It can be seen that when the spool 21 is shifted downwardly from its neutral position, the central land 27 blocks fluid communication between the lower feed passage 11 and bypass passage 8 and the upper land 25 opens fluid communication between upper feed passage 11 and upper cylinder passage 15 while upper feed passage is gradually cut off from bypass 8 by metering slots 28. Thus, as hereinafter explained in detail, fluid under

pressure may be conducted to the upper end of the motor 4. At the same time, the lower land 26 opens fluid communication between the lower cylinder and return passages 15 and 19 via the metering slots 29 to permit return of fluid to the tank 10 from the bottom port of the motor 4.

When the spool 21 is shifted upwardly from the neutral position, the flow of fluid to and from the motor 4 will be reversed, i.e., fluid under pressure will be conducted to the bottom port of the motor 4 to raise the piston 23 and the return fluid from the top port of the motor 4 will be returned to the tank 10.

Secured to the spool valve housing 6 is a check valve housing 17 which is provided with a bore 30 therethrough which is intersected by upper and lower cylinder passages 15A—15A which register with the respective cylinder passages 15—15 of the spool valve housing 6. Said bore 30 is also intersected by another pair of upper and lower cylinder passages 15B—15B which communicate with conduits 18—18.

In the bore 30 of said check valve housing 17 are tubular bushings 31 which have openings or slots 32 registering with the respective cylinder passages 15A—15A and which provides seats 34—34 for the check valves 35 and 36. The ends of said bushings 31 are closed by screw plugs 37—37 which serve as backup members for the check valve biasing springs 38—38. The top check valve 35 herein is shown as being of more or less conventional form biased by spring 38 directly into engagement with the seat 34 and guided in the top bushing 31.

The bottom check valve 36 is a main check valve member which has a tubular extension 39 slotted through its upper end and having orifices 40 axially offset through the wall thereof adjacent the seat 34. The main check valve member 36 is provided with a seat 43 for a pilot check valve member 41 which has an axial extension 42 defining an annular orifice through which fluid flows when the pilot check valve member 42 is unseated.

Reciprocable in the bore 30 between the bushings 31 is a fluid pressure actuated plunger 45 which has rod-like extensions 46 at its opposite ends to engage and open the respective check valve 35 and pilot check valve 41. The plunger 45 also has portions 47 which, as hereinafter explained in detail, have relatively close fitting telescopic fits in the ends of the bushings 31 so as to define cushioning chambers or dashpots, to preclude rapid pulsating movements of the plunger 45.

When the spool 21 is moved upwardly from neutral position, fluid under pressure is conducted from the inlet passage 12 through the lower feed passage 11 into the lower cylinder passages 15 and 15A, whereupon the fluid under pressure acting on the effective area of the seat 43 will unseat the main check valve 36 for flow of fluid under pressure through the orifices 40, lower cylinder passage 15B and lower conduit 18 into the bottom port of the motor 4, thus to move the piston 23 therein upwardly. The fluid under pressure in the lower portion of bore 30 also acts on the entire effective area of the plunger 45 to move it upwardly until its upper rod portion 46 engages the upper check valve 35 to move the latter away from its seat 34 to permit return flow of fluid from the motor 4 through upper conduit 18, upper cylinder passages 15B, 15A, and 15, to the upper return passage 19 and thence to the tank 10 by way of the conduit 20. It is to be noted that when the plunger 45 is thus moved upwardly the upper extension 47 thereof telescopes within the upper bushing 31 to form a cushioning chamber or dashpot which precludes rapid movements of the plunger even though there may be pulsations, or other variations in fluid pressure and fluid flow. However, in this case, there will be relatively high pressure in the pressure circuit acting on the plunger 45 and the return circuit will be at relatively low pressure even when the upper metering slots 29 are used for metering the return flow. Thus, the pressure in the return circuit acting on the effective area of the upper extension cannot force the plunger 45 downwardly whereby the check valve 35 will be kept fully open without opportunity for chattering or bouncing on its seat 34.

Now, when the spool 21 is shifted downwardly, fluid under pressure in the inlet passage 12 and upper feed passage 11 flows through the upper cylinder passages 15 and 15A to unseat the upper check valve 35, whereby fluid under pressure is conducted by way of the upper cylinder passage 15B, and upper conduit 18 into the top port of the motor 4 to move the piston 23 downwardly. The fluid under pressure in the bore 30 acts on the plunger 45 and urges it downwardly so that its lower rod-like extension 46 engages the stem 42 of the pilot check valve 41.

In the illustrated embodiment of the invention a heavy load on the piston 23 may result in a fluid pressure of substantial magnitude, for example, several hundred p.s.i. in the return circuit holding the pilot check 41 and the main check 36 against their respective seats. However, the fluid pressure in the upper cylinder passage 15A acts on the entire effective area of the plunger 45 to force it downwardly to unseat the pilot check valve 41. Herein, the effective area of the plunger 45 is about 36 times the area of the pilot valve seat and thus a fluid pressure in the upper cylinder passage 15A exceeding 1/36 of the fluid pressure in the return circuit will be effective to move the plunger 45 downwardly to open the pilot check valve 41. When the pilot check valve 41 has thus been opened, fluid is returned to the tank 10 from the bottom port of the motor 4 via lower conduit 18, lower cylinder passage 15B, the annular orifice around the stem 42 of the pilot check valve, the lower cylinder passage 15A, the lower metering slots 29, the lower return passage 19, and the lower conduit 20.

After the return metering slots 29 are wide open or the spool 21 has been moved to a position where the upper edge of the lower land 26 is below the upper edge of lower return passage 19, there will be a substantial pressure drop at said annular orifice whereby inlet pressure in upper cylinder passage 15A will continue to move the plunger 45 downwardly until the end of its lower portion 47 engages the upper end of the tubular extension 39 of the main check valve 36. Thus additional return flow of fluid is permitted through the orifices 40 of the main check valve 36 so that the piston 23 is allowed to move downwardly at its maximum rate of speed. At the time that the lower portion 47 of the plunger 45 engages the upper end of the tubular extension 39, said portion 47 enters the upper end of the bushing 31 (a sliding fit) to thus define a cushioning chamber or dashpot which precludes rapid pulsating movements of the plunger 45 and corresponding movements of either the pilot check valve 41 or the main check valve 36.

If it is desired to decelerate the downward movement of the piston 23 and the load acting thereon, the spool 21 may be shifted upwardly from its full flow position, whereby the lower metering slots 29 will be effective to restrict the return flow of fluid from the motor 4 to cause a pressure build-up in the lower cylinder passages 15 and 15A which acts on the effective area of the lower portion 47 (about ½ the effective area of plunger 45) tending to move the plunger 45 upwardly to thus partially close the orifices 40 for decreased return flow and additional build up of pressure in the lower cylinder passage 15B and lower conduit 18, but any such movement of the plunger 45 will be slow and gradual because of the effect of the cushioning chamber aforesaid. Accordingly, for a specified restriction through the lower metering slots 29, the main check valve 36 may be caused to slowly or gradually "hunt" back and forth to achieve a condition where the flow through the orifices 40 is varied as desired to maintain predetermined speed of movement of the piston 23 and its load.

Of course, when the restriction through the lower metering slots 29 is greater than the flow through the annu-

lar orifice around the pilot stem **42**, a portion of the output of pump P is diverted to the bypass passage **8** through the upper metering slots **28**, whereby there is lower pressure and lower flow of fluid to the motor **4** through the upper cylinder passages **15** and **15A** whereby the substantial return pressure eventually acts on the entire effective area of the plunger **45** with approach of the pilot check valve **41** toward its seat. With very low rate of return flow through the lower metering slots **29** there will be a very low pressure drop across the pilot check valve **41**, whereby the spring **38** will seat the pilot check valve **41** if the pressure in the upper cylinder passage **15A** has decreased sufficiently to permit such upward movement of the plunger **45**.

It has been found that the pilot check valve **41** in combination with the main check valve **36** with the cushioning chamber defined by the lower portion **47** of the plunger **45** after it enters the upper end of the lower bushing **31** eliminates objectionable chattering which would otherwise occur if a conventional check valve, such as check valve **35**, were employed in a return circuit in which the fluid may be under substantial pressure due to a load on the fluid motor, as in the case of the fluid motor **4** employed in a fork lift truck **1**.

In the illustrated embodiment of the invention the orifices **40** and the annular orifice around the pilot valve stem **42** are of such size in relation to the capacity of the pump P as to preclude any possibility of cavitation of the upper end of the fluid motor **4** so that even when the spool **21** is moved downwardly to its full open position, there can never be a negative pressure in the upper cylinder passages **15** and **15A**, and thus there will always be sufficient positive pressure in this case to keep the plunger **45** downward in the position maintaining the pilot check valve **41** in its open condition. With a substantial pressure drop across pilot check **41** there will only be a relatively low pressure in that portion of the return circuit which includes the lower cylinder passages **15** and **15A**. That low return pressure therefore cannot force the plunger **45** upwardly for chattering or alternate opening and closing of the pilot check valve **41**.

Other modes of applying the principle of the invention may be employed, change being made as regards the details described, provided the features stated in any of the following claims, or the equivalent of such, be employed.

I therefore particularly point out and distinctly claim as my invention:

1. A directional control valve comprising a housing having a bore intersected axially therealong by inlet, cylinder, and return passages which are adapted to be connected, respectively, with a fluid pressure source, a fluid motor, and a reservoir; a valve spool reciprocable in said bore to positions selectively opening fluid communication between said cylinder passage and said inlet and return passages; still another passage in said housing intersecting said bore, said another passage being in fluid communication with said inlet passage when said cylinder passage is communicated with said return passage as aforesaid; a check valve in said cylinder passage opened by fluid pressure when said cylinder passage is communicated with said inlet passage; and a fluid pressure actuated plunger means in said another passage operative to be moved to a position opening said check valve when said cylinder passage is communicated with said return passage and said another passage is communicated with said inlet passage; said check valve comprising pilot and main checks of which the former has a relatively small effective area as compared with the effective area of said plunger means, whereby a lower pressure acting on said plunger means than on said pilot and main checks tending to close the same will still be effective to cause said plunger means to open said check valve as aforesaid, thereby permitting return flow of fluid through said check valve to said return passage; said spool having metering means variably to restrict return flow from said cylinder passage to said return passage and thus to build up pressure in said cylinder passage tending to oppose movement of said plunger means in a direction opening said check valve; said plunger means being operative first to engage said pilot check to open the same and then said main check if the fluid pressure acting on said plunger means exceeds that which builds up in said cylinder passage due to metering by said spool as aforesaid.

2. The valve of claim **1** wherein said plunger means and housing define a dashpot therebetween which resists rapid movements of said plunger means and thus prevents chattering of said check valve.

3. The valve of claim **1** wherein said pilot check constitutes a flow restrictor means which effects a substantial pressure drop in the portion of the cylinder passage downstream of said pilot check, whereby there will be less pressure in said cylinder passage tending to resist movement of said plunger means toward said check valve as the restriction of said metering means is lessened.

4. The valve of claim **3** wherein said main check constitutes a variable flow restrictor means; and wherein said plunger means and housing define a dashpot therebetween at the time that said plunger means engages said main check, whereby rapid movements and chattering of said main check are prevented.

5. A directional control valve comprising a housing having a bore intersected axially therealong by an inlet passage, a pair of cylinder passages, and a pair of return passages which are adapted to be connected, respectively, to a pressure source, a double-acting fluid motor, and a reservoir; a valve spool reciprocable in said bore to positions selectively opening fluid communication between said cylinder passages and said inlet and return passages; a check valve in each cylinder passage opened by fluid pressure when the associated cylinder passage is communicated with said inlet passage; and a fluid pressure actuated plunger means in said housing the opposite ends of which are exposed to the fluid pressure in said cylinder passages, said plunger means being adapted to be moved by the fluid pressure in the cylinder passage which is communicated with said inlet passage to a position opening the check valve which has its associated cylinder passage communicated with said return passage; one of said check valves comprising pilot and main checks of which the former has a relatively small effective area as compared with the effective area of said plunger means, whereby return flow of fluid is initiated even when the pressure in the associated cylinder passage tending to close said pilot and main checks is higher than the pressure acting on said plunger means to open said check valve as aforesaid; said plunger means, when moved to open said one check valve, being operative first to engage and open said pilot check to permit return flow therethrough and then to engage and open said main check to permit additional return flow therethrough.

6. A directional control valve comprising a housing having a bore intersected axially therealong by inlet, cylinder, and return passages which are adapted to be connected, respectively, with a fluid pressure source, a fluid motor, and a reservoir; a valve spool reciprocable in said bore to positions selectively opening fluid communication between said cylinder passage and said inlet and return passages; still another passage in said housing intersecting said bore, said another passage being in fluid communication with said inlet passage when said cylinder passage is communicated with said return passage as aforesaid; a check valve in said cylinder passage opened by fluid pressure when said cylinder passage is communicated with said inlet passage; and a fluid pressure actuated plunger means in said another passage operative to be moved to a position opening said check valve when said cylinder passage is communicated with said return passage and said another passage is communicated with said inlet passage; said check valve comprising pilot and main checks of

which the former has a relatively small effective area as compared with the effective area of said plunger means, whereby a lower pressure acting on said plunger means than on said pilot and main checks tending to close the same will still be effective to cause said plunger means to open said check valve as aforesaid, thereby permitting return flow of fluid through said check valve to said return passage; said main check having a tubular portion extending in the direction of said plunger means and being provided with a valve seat for said check valve adjacent the inner end of said tubular portion, said tubular portion being slotted adjacent its free end to permit flow of fluid through said pilot check and tubular portion when said pilot check is open and said plunger means is in engagement with said tubular portion.

7. The valve of claim 6 wherein said plunger means has an extension which is adapted to project into said tubular portion to open said pilot check when said cylinder passage is communicated with said return passage as aforesaid, said plunger extension being longer than said tubular portion, whereby said pilot check will be opened by said extension prior to opening of said main check by said plunger means.

8. The valve of claim 7 wherein said cylinder passage has a seat therein for engagement by said main check, and said tubular portion slidably engages the walls of said last-mentioned seat, said tubular portion being provided with a plurality of orifices therethrough adjacent said last-mentioned seat, whereby when said main check is moved to the open position as aforesaid, fluid is permitted to pass through said orifices to said return passage via said tubular portion and slots.

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