Aug. 9, 1966 W. H. SCHILLING 3,265,357

HYDRAULIC JACK SYNCHRONIZING SYSTEM

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Fig. 1

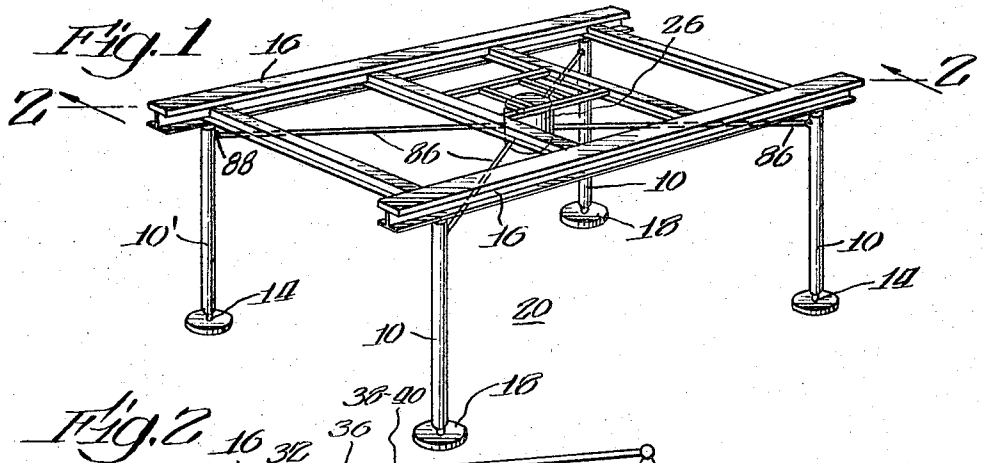


Fig. 2

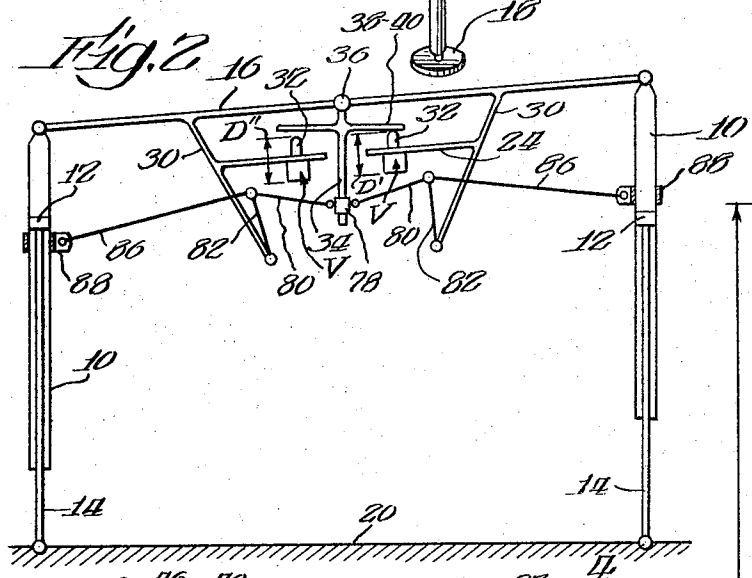


Fig. 3

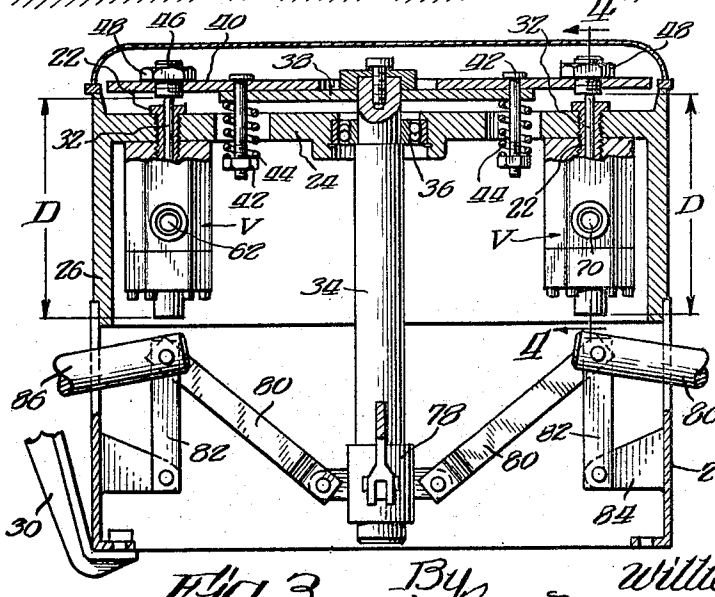
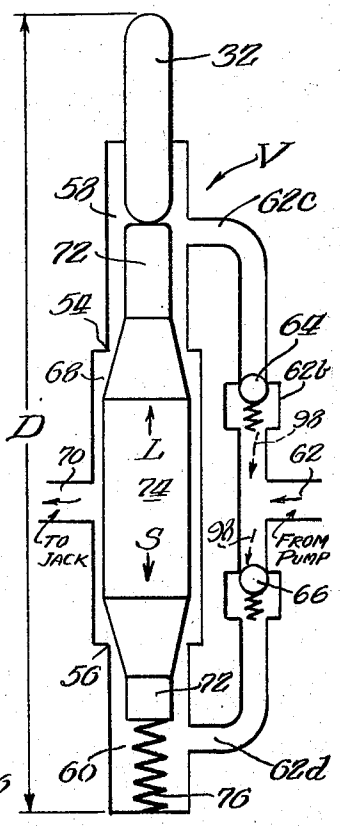


Fig. 8



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HYDRAULIC JACK SYNCHRONIZING SYSTEM

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Fig. 4 (S)

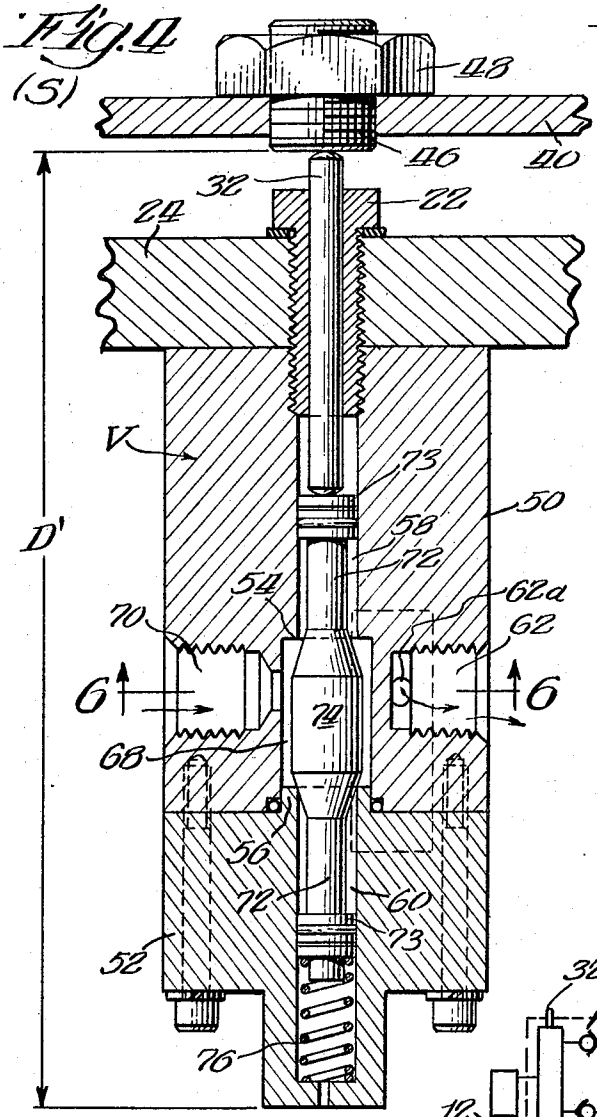


Fig. 5 (L)

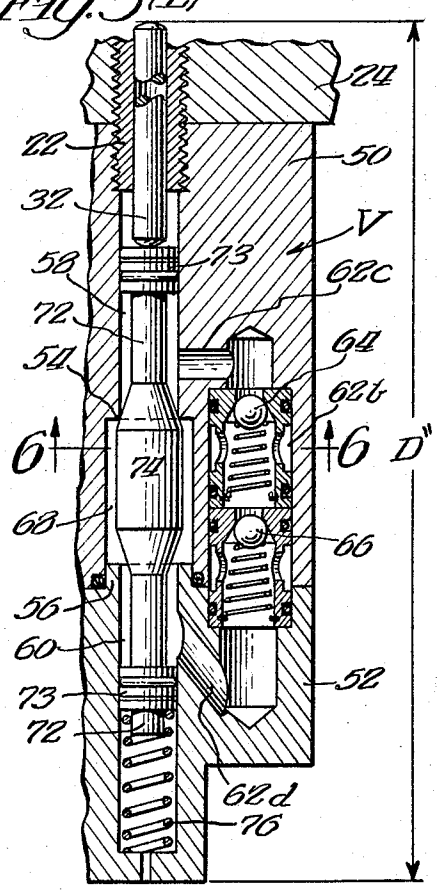


Fig. 6

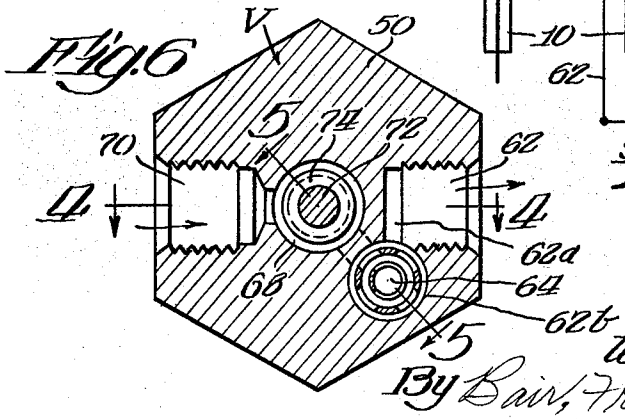
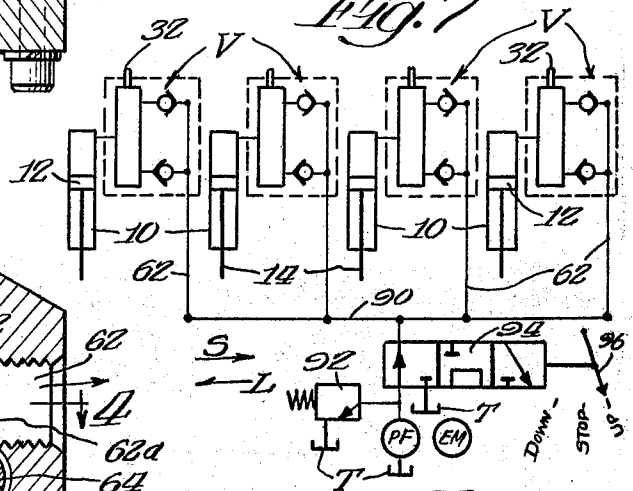


Fig. 7



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HYDRAULIC JACK SYNCHRONIZING SYSTEM

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9 Claims. (Cl. 254—89)

This invention relates to a hydraulic jack synchronizing system which is an improvement on, and simplification of, the valving arrangement of Born Patent No. 2,984,072. A load-supporting jack assembly is contemplated which has operatively associated therewith automatic synchronizing and hydraulic fluid equalizing valves to synchronize the movements of two or more hydraulic jacks acting in parallel to advance the load along a predetermined path without deviation therefrom and despite unbalanced loading of the jack units or any shifting of the load on the jacks.

Hydraulic jacks and other load-moving assemblies have many applications requiring the use of two or more jack units acting in conjunction with each other to support a load and wherein it is mandatory that the movement of all cylinders be positively and precisely synchronized both during extension and retraction of the jacks. By way of illustration of such needs, there may be mentioned the elevation and lowering of the roof of a missile-tracking station wherein in one position the roof covers a block house and its contained tracking instrument, and in another position the roof is moved horizontally onto a jack-supported track after which the track is lowered to position the roof clear of the tracking instrument. In such installations the roof corners should remain level to better than plus or minus ¼" on a 30 foot diagonal during "roof-down" or "roof-up" operations. Other uses are the elevation of precast concrete floors from their casting position at ground level to their assembled position atop vertical supporting columns and the raising of the ends of a bridge which are on opposite shores of a river, it being desirable to synchronize the operation of jacks at each end to keep the span level as it is raised.

Various attempts have been made heretofore to provide a hydraulic jack system utilizing a plurality of hydraulic cylinders arranged in parallel and capable of extension or retraction under precisely controlled conditions. The Born patent above referred to discloses a satisfactory jack assembly and valve mechanism for that purpose. The present invention contemplates an extension of the Born disclosure particularly in the field of providing a valving arrangement specifically designed for keeping a load-raising platform or the like level.

One object of the present invention is to provide a hydraulic jack synchronizing system wherein a load-supporting element is raised and lowered by at least two hydraulic jacks operatively connected therewith at spaced-apart points to move the load-supporting element away from and toward a support, fluid pressure supply means being connected to both jacks for supplying fluid pressure thereto, and means being provided for maintaining a predetermined angle between the load-supporting element and the support comprising a synchronizing and pressure equalizing valve for each jack and an angle deviation-sensing means operable to adjust these valves for stopping flow of fluid pressure from the supply means to one jack when ahead of the other, the arrangement being quite sensitive to minute deviations to thereby minimize such deviations.

Another object is to provide a synchronizing and pressure equalizing valve for each jack comprising a valve body having therein opposite and aligned valve seats and first and second cavities outside of these seats, a stem extending through the seats and cavities and having a valve

head between the seats of less length than the distance between them and which is operable to seat on the valve seats one at a time, there being a pump inlet to both cavities, a check valve between the pump inlet and each of the cavities with one check valve opening away from the first cavity and the other opening toward the second cavity and the angle deviation-sensing means being operable to move the valve head in the direction of the second cavity when its corresponding jack is ahead of the other and in the direction of the first cavity when its corresponding jack is behind the other, the valve body having a central cavity between the valve seats communicating with the jack.

Still another object is to provide a synchronizing valve mechanism in a system of the character described having a novel linkage arrangement and valve actuating mechanism for sensing deviations of any one or more jacks of a plurality of jacks, and for automatically readjusting the flow of hydraulic fluid to or from the jacks for maintaining a desired attitude of the load being lifted.

A further object is to provide the actuating mechanism with means for permitting override with respect to any one or more of the synchronizing valves being actuated.

Still a further object is to provide the linkage mechanism designed so as to amplify the deviations of the load with respect to the jacks thereby providing a highly sensitive deviation-sensing means and a highly sensitive synchronizing valve system responding thereto.

With these and other objects in view, my invention consists in the construction, arrangement and combination of the various parts of my hydraulic jack synchronizing system, whereby the objects above contemplated are attained, as hereinafter more fully set forth, pointed out in my claims and illustrated in detail on the accompanying drawing, wherein:

FIG. 1 is a perspective view of a hydraulic jack synchronizing system embodying my invention and showing the same applied to lifting means in the form of tracks for the roof of a missile-tracking station;

FIG. 2 is a diagrammatic view according to the line 2—2 of FIG. 1 showing an exaggerated tilted position to illustrate the operation of angle deviation-sensing valve actuating mechanism;

FIG. 3 is a sectional view corresponding to a portion of FIG. 2 showing details of the valve actuating mechanism;

FIG. 4 is an enlarged vertical sectional view on the line 4—4 of FIG. 3 showing the valve in one operated position;

FIG. 5 is a sectional view similar to FIG. 4 showing another portion of the valve structure in another operated position;

FIG. 6 is a sectional view on the line 6—6 of FIGS. 4 and 5, FIG. 4 being also a section on the line 4—4 of FIG. 6 and FIG. 5 being a section on the line 5—5 thereof;

FIG. 7 is a complete hydraulic diagram of the hydraulic jack synchronizing system and fluid pressure supply and control means therefor, and

FIG. 8 is a diagrammatic view combining FIGS. 4 and 5 to show the complete hydraulic circuitry through the synchronizing and flow equalizing valve.

On the accompanying drawings I have used the reference numeral 10 to indicate a hydraulic cylinder, four of which are shown by way of example, 12 the pistons therein and 14 the piston rods extending from the pistons. A load-supporting element in the form of rails 16 is provided supported on the upper ends of the cylinders 10 whereas the lower ends of the piston rods 14 are provided with anchor flanges 18 adapted to be secured to a floor or other support such as shown at 20 in FIG. 2. Suitable ball and socket joints or their equivalent are provided between the upper ends of the cylinders 10 and

the rails 16, and between the lower ends of the piston rods 14 and the flanges 18 to avoid any binding which would interfere with proper operation of the jack system. The tracks 16 may be provided for the roof of a missile-tracking station, or the like or in place of the rails 16 a lifting platform or any suitable load-supporting element may be provided.

Referring to FIGS. 2 and 3 synchronizing and flow equalizing valves are shown generally at V mounted as by flanged sleeves 22 screwed thereinto after passing through a supporting wall 24 of a housing 26 having an extension portion 28 mounted on brackets 30. The brackets 30 are mounted on the rails 16 in any suitable manner and serve to rigidly support the housing 26–28 relative thereto.

The valves V are provided with valve actuating pins 32 which in turn are actuated by a tilt shaft 34 journaled in a spherical bearing 36 and having a primary actuating plate 38 and a secondary actuating plate 40. The plates 38 and 40 are bolted together at 42 and overtravel springs 44 are provided on the bolts for a purpose which will hereinafter appear. The secondary actuating plate 40 has a set screw 46 for each valve pin 32 and a lock nut 48 to retain the adjustment of the set screw once it is made.

In FIGS. 2 and 3 I illustrate two valves V for two jacks 10–12–14 whereas in FIG. 1 four jacks are shown. Two additional valves V are provided for the other two jacks of FIG. 1 in the same manner as illustrated in FIGS. 2 and 3. Some installations may required only two jacks whereas on others there may be three jacks in which case there would be three valves, and on still others there might be more than four jacks. In any case there would be a valve V for each jack.

With respect to the construction of the synchronizing and flow equalizing valve V, reference is made to FIGS. 4, 5, 6 and 8. A valve body 50–52 is illustrated, the parts 50 and 52 being bolted together for convenience of assembly. Within the valve body 50–52 is a first valve seat 54 and a second valve seat 56 opposed to each other, and outward of which are first and second cavities 58 and 60. A pump inlet 62 leads to both cavities 58 and 60 as shown in FIG. 8. As shown in FIGS. 4 and 6 this is accomplished by a passage 62^a to a bore 62^b shown in FIGS. 5 and 6. There are check valves 64 and 66 between the pump inlet and the cavities, the check valve 64 opening away from the first cavity 58 and the check valve 66 opening toward the second cavity 60. Between the valve seats 54 and 56 a central cavity 68 is provided, and communicating with this cavity is a valve outlet 70 to the jack.

Within the valve body 50–52 is a valve stem 72 having an enlarged spool-like valve head 74 thereon of a few thousandths of an inch less length than the distance between the seats 54 and 56, and having O-ring seals 73. As shown in FIGS. 3 and 8 the head 74 may be centered between the seats 54 and 56, seated on the seat 56 as shown in FIG. 4 when the head 74 is depressed by pressure against the upper end of the valve pin 32 or seated against the seat 54 (FIG. 5) when the position of the tilt shaft 34 is such that pressure is released from the valve pin in which case a spring 76 in the body portion 52 effects the valve seating operation as between the valve head 74 and the valve seat 54. Obviously the total travel of the head is only a few thousandths of an inch, this distance being shown exaggerated in FIGS. 4, 5 and 8. On the head 74 in FIG. 8 are a pair of arrows S and L. When the valve head is centered as in FIG. 8, the total length of the valve V and its pin 32 is as indicated at D (also both valves in FIG. 3). S indicates shortening of the overall length of the valve and pin as to the dimension D′ for the right-hand valve shown in FIG. 2 and in FIG. 4 whereas L indicates lengthening of this dimension to the length D″ shown for the left-hand valve in FIG. 2 and in FIG. 5.

Referring to FIG. 3 the linkage for actuating the tilt shaft 34 comprises a slide bearing 78 to which is pivoted the lower end of a link 80 for each cylinder 10, the upper end of the link being pivoted to another link 82. The lower end of the link 82 is pivoted to a stationary bracket 84. A control rod 86 has its inner end pivoted to the pivotal connection between the links 80 and 82 and its outer end pivoted to a clamp 88 secured to the cylinder 10. A link, bracket and control rod arrangement such as just described is provided for each jack 10–12–14 in the system. A linkage arrangement of this kind magnifies the deviation of angle as between the plane of the rails 16 and the jacks to make the movements of the actuating plates 38 and 40 and thereby the valves V extremely sensitive to such deviation.

Referring to FIG. 7 wherein the complete hydraulic system is shown, the jacks and the synchronizing and equalizing valves have already been described. The pump inlets 62 are connected to a manifold 90 which is supplied with fluid under pressure from a hydraulic pump PF which may be driven as by an electric motor EM and has the usual pressure relief valve 92 to determine the operating pressure of the pump PF and return hydraulic fluid to the tank whenever a control valve 94 is in position shutting off the pump from the hydraulic system. The control valve 94 has three positions as indicated "UP," "STOP" and "DOWN" depending on the position of a control lever 96 for the valve. In the right-hand position shown fluid pressure is supplied to the system. In a centered position the hydraulic system is locked against return flow of fluid whereas in the left-hand position hydraulic fluid may (by responding to the load on the jacks) flow from the system back to the tank T.

Practical operation

During the installation of my hydraulic jack synchronizing system, the valves V require adjustment to maintain the desired angle of the load-supporting element 16 relative to the support 20. In most instances, the support 20 would be level and it would be desired that the load-supporting element 16 also be maintained level during raising and lowering operations. First the load-supporting element 16 is leveled and then the set screws 46 adjusted until the valve heads 74 are midway between the seats 54 and 56 (dimenison D). The lock nuts 48 are then tightened to maintain the adjustment.

After the complete hydraulic system is installed according to FIG. 7, the control lever 96 would normally be in the "STOP" position so that the output from the pump PF would flow back to the tank T through the relief valve 92. The hydraulic system above the control valve 94 at this time is completely locked against flow either inward or outward with respect to the system.

When it is desirable to raise the load-supporting element 16, the control lever 96 is shifted to the "UP" position shown in FIG. 7 whereupon the fluid pressure available from the pump PF as limited by the relief valve 92 enters the system by flowing into the manifold 90 and from thence to each of the valves V. As long as the valves remain centered (dimension D, FIGS. 3 and 8) fluid pressure flows to all four cylinders 10 of the jacks and the load-supporting element remains level.

As soon as there is even slight movement of one of the jacks ahead of the others the valves will be adjusted to reduce or stop flow of hydraulic fluid to that jack and proportionally increase flow to the others as required to bring the load-supporting element back into balance at a level attitude. In FIG. 2 this situation is shown exaggerated, the right-hand jack being ahead of the left-hand jack and accordingly tilting the actuating plate 38–40 clockwise relative to the load-supporting element 16, thereby depressing the valve pin 32 of the right-hand valve and releasing the pin 32 of the left-hand valve so that the right-hand valve head 74 is seated on the seat 56 as shown in FIG. 4 and the left-hand valve head is

seated on the seat 54 under the action of its spring 76 (FIG. 5) because the left-hand set screw 46 has been elevated by the actuating plate to disengage the valve pin. After the right-hand valve head 74 is seated on the seat 56 overtravel is permitted by the right-hand end of the primary actuating plate 38 leaving contact with the secondary plate 40 against the bias of the right-hand spring 44 on the right-hand bolt 42. Overtravel is permitted in the left-hand valve, of course, because the set screw 46 can freely leave the pin 32.

The tilted position of the load-supporting element 16 in FIG. 2 is shown greatly exaggerated whereas even .001" movement of the valve head 74 upwardly or downwardly will change the flow ratio to the different cylinders 10 to bring the load-supporting element 16 back to level position before the valve head can seat on either of the seats 54 or 56. There may be a sudden shift of load, however, that would permit such seating which, of course, calls for more drastic equalizing action accomplished by cutting off all flow to that jack cylinder which is ahead of the others. Thus the lead jack is then held back while the others catch up.

On the other hand, should the system be in the lowering cycle the pressure from the pump has been eliminated so that oil can now flow back from the jack through the check valve 64 as shown by the dotted arrow 98 in FIG. 8. Should a certain jack be behind the others in raising or ahead in the lowering cycle, the valve assembly will become longer (L) causing the valve head 74 to seat on the seat 54. This permits oil to flow from the pump through the check valve 66 to the jack on the raising cycle but prevents back flow on the lowering cycle.

From the foregoing specification it will be obvious that I have provided a hydraulic jack synchronizing system in which two or more hydraulic jacks are synchronized by a simple valve having a single valve head movable between opposite valve seats and provided with check valves arranged in such a way that flow between the jack and the pump is stopped or permitted depending on the automatic adjustment of the synchronizing valve as it responds to angle-deviation-sensing means in the form of linkage that actuates the valve. The several valves meter the oil to the jacks in direct proportion to the requirements for keeping the load level or at any desired angle for which the angle-deviation-sensing and valve-actuating mechanism is set. A spool-type of valve is used having metal-to-metal seats and the arrangement has a relatively long operation life as the valve head is seated by relatively light spring pressure afforded by the springs 44 and 76 and the provisions described for overtravel. In most operations the spool 74 of the valve floats between the valve seats without ever contacting either of them which, of course, further contributes to a long operating life for the valve. The check valves 64 and 66 are arranged parallel and back-to-front to prevent back flow from the jack during an extension phase and permit metered return of oil during a retraction cycle. When dimension D is shortened (S) as to the dimension D', no oil can pass from the pump to the jack.

My synchronizing system is outstanding because of simplicity and ease of installation. In summary, it synchronizes the action of two or more hydraulic cylinders so that all cylinders maintain the same rate of speed regardless of the distribution of load on the cylinders. Its operation can best be described by using as an example the lifting of a platform by four cylinders, one at each corner of the platform. When pressure is applied to the cylinders, the platform moves upward, each corner moving in unison with each other corner so that the platform remains perfectly level during the entire lifting operation. When the pressure is relieved each cylinder keeps in perfect step with each other cylinder and the entire platform moves downwardly maintaining at all times a perfectly level attitude. This result is achieved by measuring the angle between the cylinder and the platform which should be 90° if the platform is to remain level. Whenever the angle increases above or decreases below 90° a simple synchronizing valve increases or decreases the flow of hydraulic fluid to provide the necessary correction. The system is entirely independent of the loading of the platform and of the diameter of the cylinders. The system will work perfectly even if different pumps are used on each cylinder which can be an advantage if the platform is a bridge in which two cylinders are separated from two other cylinders by a river.

Accuracy within a fraction of an inch of levelness for each 10 feet of length can easily be attained. By holding the parts to closer tolerances and applying superfinish techniques, a supersensitive synchronizing valve for accuracy of a few thousandths of an inch per 10 feet of length can be achieved.

Some changes may be made in the construction and arrangement of the parts of my hydraulic jack synchronizing system without departing from the real spirit and purpose of my invention, and it is my intention to cover by my claims any modified forms of structure or use of mechanical equivalents which may reasonably be included within their scope.

I claim as my invention:

1. In a hydraulic jack synchronizing system, a load-supporting element, at least two hydraulic jacks operatively connected therewith at spaced apart points to move said load-supporting element away from and toward a support, fluid pressure supply means connected to both jacks for supplying fluid pressure thereto, means for maintaining a predetermined angle between said load-supporting element and the support comprising a synchonizing valve for each jack, angle deviation-sensing means operable to adjust said valves for reducing the flow of fluid pressure from said supply means to one of said jacks when ahead of the other, each of said valves comprising a valve body, opposed valve seats and first and second cavities therein outward of said valve seats, a central cavity between said seats, a stem extending through said valve seats and cavities and having a valve head between the seats of less length than the distance between them, a pump inlet to both of said first and second cavities, a check valve between said pump inlet and each of said first and second cavities, one check valve opening away from said first cavity and the other opening toward said second cavity, said angle deviation-sensing means being operable to move said valve head in the direction of said second cavity when its corresponding jack is ahead of the other and in the direction of said first cavity when its corresponding jack is behind the other, and an outlet to the jack from said central cavity.

2. A system according to claim 1 wherein said angle deviation-sensing means comprises a shaft mounted for tilting movement, an operative connection from said shaft to each of said synchronizing valves to simultaneously actuate them in opposite directions, a slide bearing on said shaft and a link connection from said slide bearing to each of said hydraulic jacks.

3. A system according to claim 2 wherein each of said link connections comprises a first link having one end pivotally mounted on said load-supporting element and extending substantially parallel to said shaft, a second link pivoted to the free end of said first link and to said slide bearing, said second link extending in an angular direction from said first link to said slide bearing, and a third link extending substantially parallel to said load supporting element and connected with a hydraulic jack to sense deviation of the angle between it and said load-supporting element.

4. A system according to claim 2 wherein said operative connection includes two elements and spring means to normally effect movement of one simultaneously with the other, said spring means permitting overrun movement of the element connected with said shaft when the second one effects seating of said synchronizing valve.

5. In a hydraulic jack synchonizing system, a load-supporting element, at least two hydraulic jacks operatively connected therewith at spaced apart points to move said load-supporting element away from and toward a support, fluid pressure supply means connected to both jacks for supplying fluid pressure thereto, means for maintaining a predetermined angle between said load-supporting element and the support comprising a synchonizing valve for each jack, angle deviation-sensing means operable to adjust said valves for reducing the flow of fluid pressure from said supply means to one of said jacks when ahead of the other, each of said valves having opposed valve seats, a valve head normally positioned between said seats and out of contact therewith, a pump inlet to both of said seats, an outlet to the jack from between said seats, a check valve between said pump inlet and one of said seats, a check valve between said pump and the other of said seats, said check valves opening, one toward its valve seat and the other away from its valve seat, means biasing said valve head toward the first of said last two mentioned seats and said deviation-sensing means being operable to move said valve head against such bias and toward the second of said valve seats when the jack corresponding to that particular valve moves ahead of the other jacks.

6. A system according to claim 5 wherein said angle deviation-sensing means comprises a tilt shaft, an operative connection from said tilt shaft to each of said synchronizing valves to simultaneously actuate them in opposite directions, a slide bearing on said shaft and a link connection from said slide bearing to each of said hydraulic jacks.

7. A system according to claim 6 wherein said link connections comprise first links having one end pivotally mounted on said load-supporting element and extending substantially parallel to said shaft, second links pivoted to the free ends of said first links and to said slide bearing, said second links extending in angular directions from said first links to said slide bearing, and third links extending substantially parallel to said load-supporting element and connected with said hydraulic jacks to sense deviations of angle between them and said load-supporting element.

8. A system according to claim 5 wherein said angle deviation-sensing means comprises a tilt shaft, an operative connection from said shaft to each of said synchronizing valves to simultaneously actuate them in opposite directions, a slide bearing on said tilt shaft, and link connections from said slide bearing to said hydraulic jack, said operative connection comprising a primary arm and a secondary arm, said primary arm being carried by said tilt shaft, said secondary arm being normally in engagement with said primary arm and cooperable with said synchronizing valves to actuate them, and spring means biasing said secondary arm into engagement with said primary arm.

9. In a hydraulic synchonizing system, a load-supporting element, at least two hydraulic jacks operatively connected therewith at spaced apart points to move said load-supporting element away from and toward a support, fluid pressure supply means and control valve means connected to both jacks for supplying fluid pressure thereto or permitting return of fluid pressure therefrom, means for maintaining a predetermined angle between said load-supporting element and said jacks comprising a synchronizing valve for each jack and angle deviation-sensing means operable to adjust said valves for reducing the flow of fluid pressure from said supply means to one of said jacks when it is ahead of the other and for increasing the flow of fluid pressure from said supply means to said one of said jacks when it is behind the other, each of said valves comprising a valve body, opposed valve seats and first and second cavities therein outward of said valve seats, a central cavity between said seats, a stem extending through said valve seats and cavities and having a valve head between the seats of less length than the distance between them, a pump inlet to both of said first and second cavities, a check valve between said pump inlet and each of said first and second cavities, one check valve opening away from said first cavity and the other opening toward said second cavity, said angle deviation-sensing means being operable to move said valve head in the direction of said second cavity when its corresponding jack is ahead of the other and in the direction of said first cavity when its corresponding jack is behind the other, and an outlet to the jack from said central cavity.

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