Feb. 16, 1943. L. E. BLANCHETT 2,310,930

LEVELING DEVICE

Filed Aug. 17, 1939 3 Sheets-Sheet 1

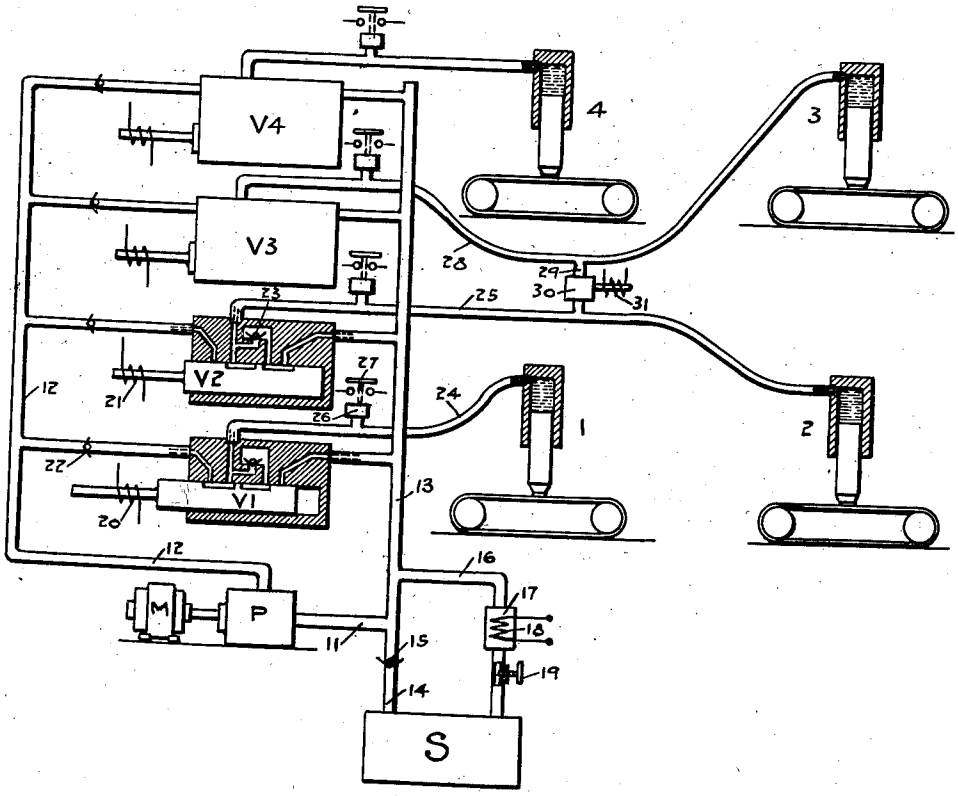


Fig. 1

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LEVELING DEVICE

Filed Aug. 17, 1939 3 Sheets-Sheet 2

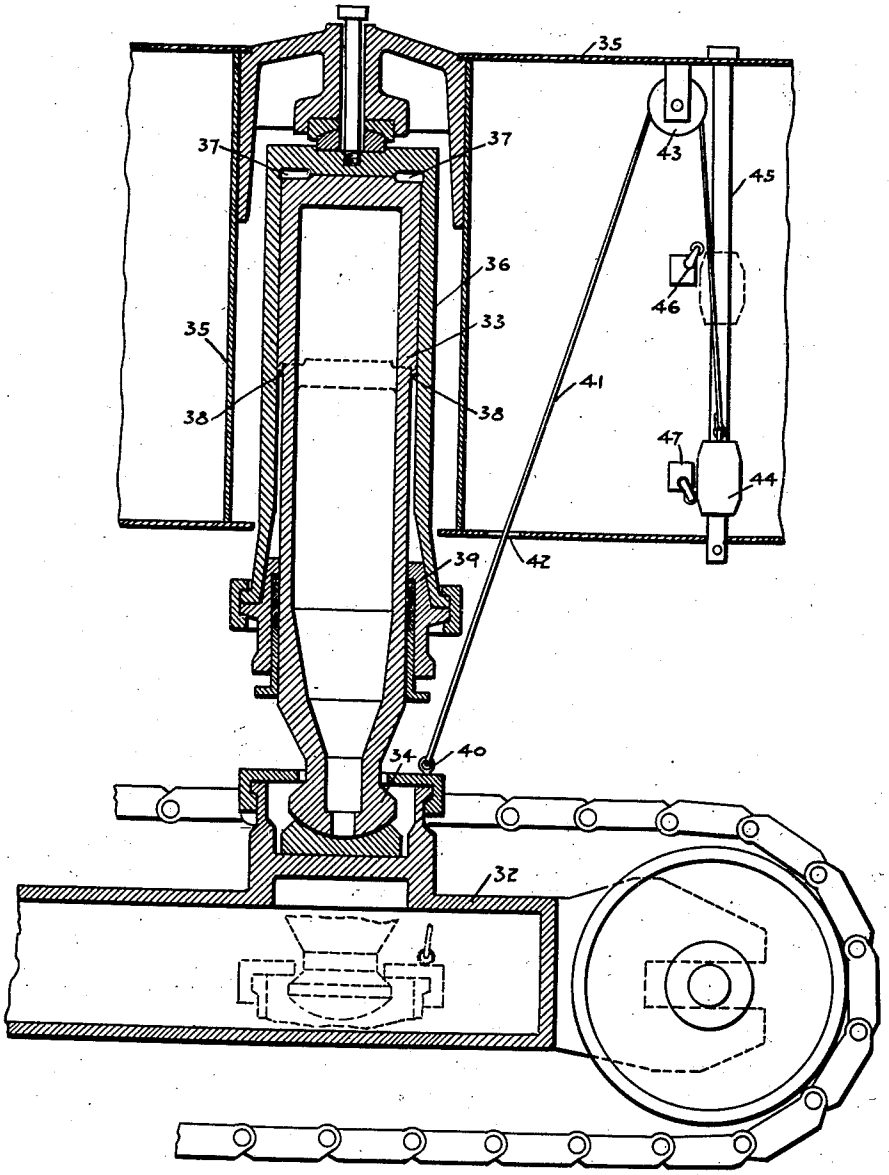


Fig. 2

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LEVELING DEVICE

Filed Aug. 17, 1939 3 Sheets-Sheet 3

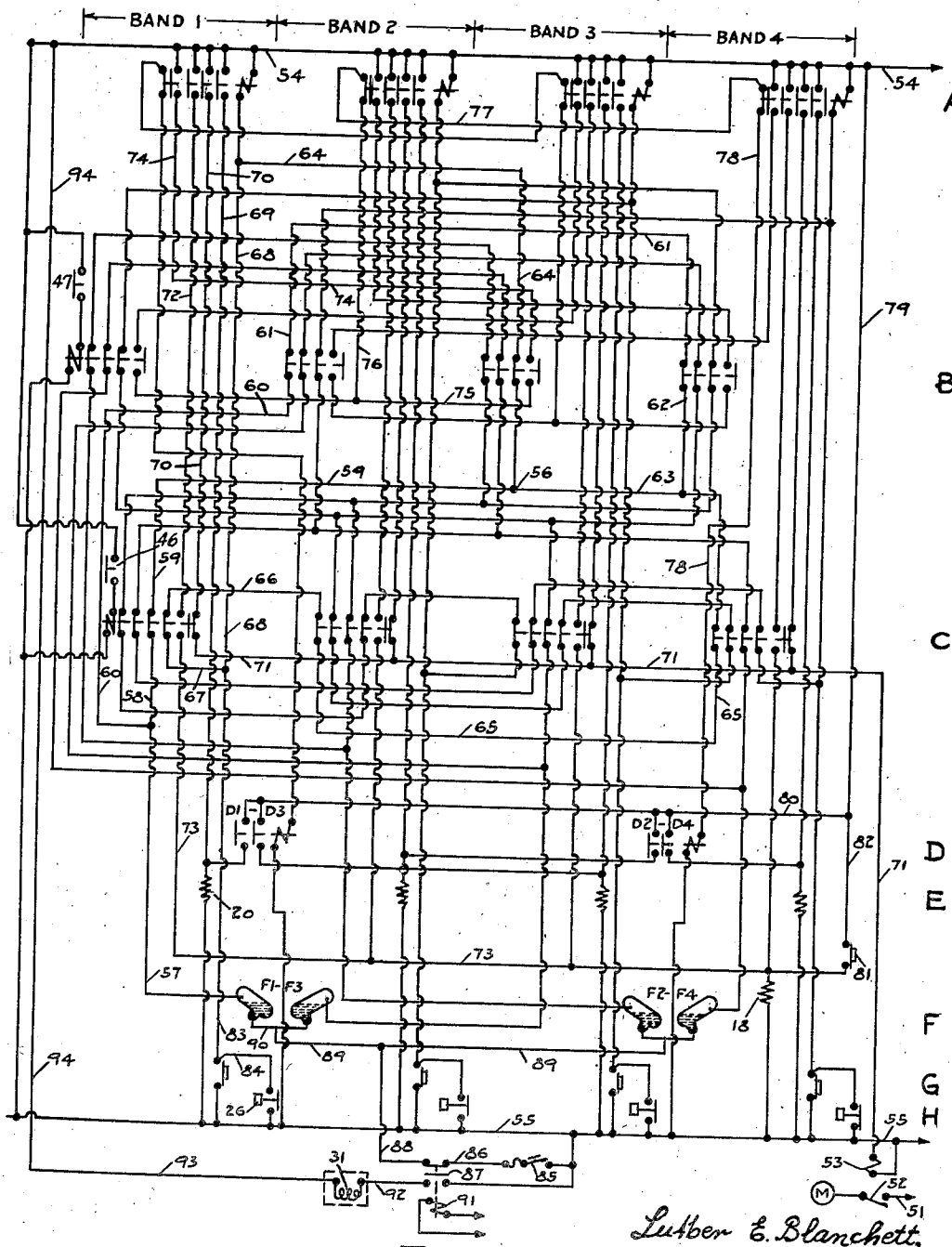


Fig. 3

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ATTORNEYS.

Patented Feb. 16, 1943 2,310,930

UNITED STATES PATENT OFFICE

2,310,930

LEVELING DEVICE

Luther E. Blanchett, South Milwaukee, Wis., assignor to Bucyrus-Erie Company, South Milwaukee, Wis., a corporation of Delaware

Application August 17, 1939, Serial No. 290,591

22 Claims. (Cl. 280—6)

My invention relates to new and useful improvements in leveling devices and more particularly to automatic leveling devices for very large revolving power excavators which have four independent sets of caterpillar traction units; each of which is placed at one of the four corners of the base, and which supports its corner by means of a power actuated jack. It is desired to control the automatic action of these jacks by means of a level responsive control.

As such machines use a very great amount of power, even when working under the best conditions, it is desirable that the power consumption shall not be unnecessarily increased by an out-of-level state; for example, if, in swinging to dump, the boom, dipper, and load had to be swung over the highest corner of the excavator.

I shall describe my invention as having hydraulic jacks, but it will be obvious that it can be equally well applied to a system using any variety of power actuated means for raising and lowering the corners.

In actual practice it has been found that there are certain other desirable functions (hereinafter referred to as "extended leveling" and "equalizing") intimately bound up with the function of leveling.

The control of these three functions ought not to be left to the operator who manipulates the specific excavating implements; as the control of the latter already occupies his hands and his feet, and above all his attention, to such an extent that no such machine is ever entrusted to any other than an experienced operator. Nor ought we to delegate the manipulation of non-automatic leveling devices to the care of another than the operator of the excavating implements, as this would invite disaster. The larger and heavier the machine, the greater the disaster.

It is the principal object of my invention to remove all such danger by entirely freeing the operator from any need of attention to the level of the machine or to the allied problems. This I accomplish by making the leveling, and all actions subsidiary thereto, such as those I have enumerated above, entirely automatic.

To this end I make use of the leveling device described and claimed in my U. S. Patent Number 2,101,837, dated December 14, 1937, to which I refer for complete particulars.

It is a further object of my invention to effect an improvement over the device shown and described in the copending Patent No. 2,202,009 to Samuel L. G. Knox, dated May 28, 1940, which patent is owned by my assignee.

The Knox device is basically sound, and constitutes a solution of the leveling problem applicable to all but exceptional situations. Yet those situations do occur in field practice, and can be met by my modification of the Knox device.

It can be mathematically demonstrated that, in a closed four-jack system with a constant oil-supply, the center of the machine can be neither raised nor lowered, and the raising or lowering of any given corner can be accomplished only by an exactly equal lowering or raising of the opposite corner. Accordingly if the jack at a low corner becomes fully extended before complete leveling occurs, or if the jack at a high corner becomes fully contracted before complete leveling occurs, then further leveling on the diagonal through that corner is impossible.

Accordingly it is one object of my invention to meet this situation by what I shall call "extended leveling." To this end, I provide means whereby, when the jack at a low corner becomes fully extended, the other three jacks are permitted to contract, and when the jack at a high corner becomes fully contracted, the other three jacks are extended. This expedient will meet the situation on any terrain except one on which the only solution would be the use of longer jacks. The reasons for this limitation on the solution of the problem will hereinafter appear.

A further object of my invention is to make provision that the feet of all four jacks shall always be firmly planted upon the terrain. This I call "equalizing," although it is to be understood that my device does not necessarily ever render exactly equal the pressure between two adjacent jacks. My automatic pressure regulation ensures that the pressure in each jack individually shall remain within prescribed limits, determined by the settings of adjustable valves.

It is a further object of my invention to improve the details of the enumerated functions.

In addition to the stated objects, I have worked out a number of novel and useful details, which will be readily evident as the description progresses.

My invention consists in the novel parts, and in the combinations and arrangements thereof, which are defined in the appended claims; and of which one embodiment is exemplified in the accompanying drawings, which are hereinafter particularly described and explained.

Throughout the description, the same reference number is applied to the same members or to similar members.

Figure 1 is a diagrammatic representation of

the hydraulic system. The jacks, which are placed at the four corners of the main base of the machine, are shown in elevation, while the piping system, valves, pump, etc., are shown in plan.

Figure 2 shows a jack and its traction unit, with the adjacent portion of the main base.

Figure 3 is a wiring diagram showing the automatic control system.

Referring particularly to Figure 1, I shall consider the lower, left hand jack as being jack number 1; the remaining jacks being numbered, as shown, counter-clockwise around the figure. In mentioning the corners, I shall consider them numbered to correspond with the jacks. Thus, jack 1 is at corner 1, etc.

In this figure, P is a pump, driven by electric motor M, or any equivalent source of power. The working fluid reaches the pump on the suction side by pipe 11, and is delivered to valves V1, V2, V3 and V4 by the pressure pipe 12. Suction pipe 11 communicates directly with a pipe 13 to the suction side of the four valves V1, etc. Pipe 11 also communicates with a pipe 14 to a sump S. A valve 15 in pipe 14 allows flow from the sump to pipe 11, but prevents flow in the contrary direction. A pipe 16 goes from pipe 13 to the sump by way of a valve 17. This valve is normally closed, but when coil 18 is actuated, free flow from pipe 13 to the sump via pipe 16 is allowed. At 19 is symbolically shown a means for adjustably constricting pipe 16. This is for adjusting the rate of flow, to prevent a too rapid settling down of the machine, in the extended leveling by lowering, to be later explained.

Valves V1, V2, etc., are shown in Figure 1 as special double-acting valves, which are solenoid governed. Valve V1 is shown in the position it takes when solenoid 20 is actuated. Valve V2 is shown in the unactuated position, i. e., there is no current passing in solenoid 21. Valves V3 and V4 do not show details, but for the case of simple leveling first discussed below, they may be considered as having momentarily the same configuration as V2.

Each of these V-valves is provided with two check valves, each of which check valves allows fluid to pass in only one direction. For example, when the V1 valve is set as shown, check valve 22 will allow flow from pressure pipe 12, through V1 and via pipe 24, to jack 1, but not in the contrary direction. When the V2 valve is set as shown, check valve 23 will allow flow from jack 2, via pipe 25, through V2, to the suction pipe 13, but not in the contrary direction.

If it were not for check valves 22, then whenever two of the V-valves are energized (i. e., in the configuration shown for V1), a free flow through these two V-valves, from that one of the two jacks having higher pressure to that one having lower pressure could occur for every immaterially small difference of pressure in the two jacks in question. If it were not for check valves 23, then whenever two or more V-valves are deenergized (i. e., in the configuration shown for V2), a similar free flow between the corresponding two or more jacks would be possible. Both of these possibilities are undesirable, as they would render nugatory the controls established for the V-valves, which controls are primarily for the purpose of preventing instability.

Although these V-valves are shown in Figure 1 as being special double-acting valves, they might each be replaced by two valves, of which one would only allow pumping fluid into the jack, and the other would only allow passage of fluid from the jack. Similarly each of the two check-valves could be built either integral with, or separate from, the valve or valves above mentioned.

Each of the pipes from the V-valve to the jack, as 24, is provided with a short branch leading to a closed box 26, which contains a pressure responsive element, so adjustable that, when the pressure in the pipe 24, for example, falls below a prescribed amount, a circuit, later to be discussed, is closed, as by contactor 27.

The pipe from some one of the four V-valves to a jack, as, for instance, pipe 25 to jack 2, and the corresponding pipe 28 to one of the adjacent jacks are connected by a pipe 29, containing a valve 30. Valve 30 is normally closed, but is open to allow free communication between pipes 25 and 28, whenever solenoid 31 is energized. The purpose of this will be explained later.

Turning now to Figure 2, it may be seen that each traction unit 32 supports a piston 33 through a universal joint 34, and that the pistons support the main base 35 of the excavator. Piston 33 operates in cylinder 36, the operating fluid being admitted to the space 37. The piston 33 is shouldered, as indicated at 38, so that when, relative to the cylinder 36, the piston is forced down far enough for shoulder 38, to abut element 39, the piston and cylinder will be prevented from separating further. This extreme extended position of the piston with respect to the cylinder is shown by dotted lines, and is the position hereinafter referred to as the "all out" position. The full line position, with the jack contracted to its limit, will be referred to as the "all in" position.

Attached to a convenient part of the traction unit 32, as at 40, Figure 2, is a wire rope 41, which passes through a hole 42 in the lower plate of the main base of the excavator, to a pulley 43 supported by the upper plate of the main base, and thence to a switch actuating weight, 44. This weight slides on a vertical guide 45, and serves to actuate limit switches, 46 and 47.

The upper limit switch 46 is so placed that it will be contacted by the weight 44, only when the piston 33 is at its "all out" position, which will be when the particular corner of the main base 35 of the excavator is as far above traction unit 32 as the mechanical construction allows.

The lower limit switch 47 is so placed that it will be contacted by the weight 44 only when the piston 33 is at its "all in" position, which will be when the particular corner of the main base 35 is as near the traction unit 32 as the mechanical construction will allow. These switches, which are normally open, serve, when closed, to actuate certain relays, as will be hereinafter explained.

If it is desired to avoid metal to metal contact of piston and cylinder, these switches 46 and 47 may be placed just short of the critical position, 46 being just below, and 47 just above, the positions pertaining respectively to "all out" and "all in" positions of the piston. In the claims, whenever I refer to a jack being "fully extended" or "fully contracted," I intend not necessarily a metal to metal contact, but rather the ultimate position (possibly just short of metal to metal contact) predetermined by the maker of the machine. And, whenever I refer to "preventing the expanding" or "preventing the contracting" of a jack, I of course exclude the mere physical butting up of the piston against one end or the

other of its cylinder, and intend rather the preventing of the application of further force tending to expand or contract the jack, as the case may be.

The mechanism of such switches is well known and therefore not further described.

In the right hand margin of the electrical diagram, Figure 3, I have placed opposite certain of the instrumentalities the capital letters, A, B, C, D, E, F, G, H. Each of these letters refers collectively to the instrumentalities that are to be found across the page on a level with the particular capital letter. All the instrumentalities opposite any one letter are of the same kind, and serve the same purpose, but for different corners.

All the instrumentalities shown in Figure 3 are diagrammed as in their unenergized configuration.

The diagram naturally divides itself into four vertical columns or bands, each associated with a particular one of the four jacks; and the instrumentalities in the various columns are to be considered as numbered accordingly. Thus, of the A. B. C. E, G and H instrumentalities, the extreme left hand one of each of them, being in the first of the four columns, may be considered as relating to corner 1; and similarly the successive columns, proceeding to the right, may be considered as relating to corners 2, 3 and 4, respectively. Some of these instrumentalities may be actually located at their respective corners. Accordingly, when I wish to designate any particular one of the four instrumentalities, I shall designate it by both its letter and the number of the column in which it occurs. Thus A1 will designate the solenoid and its associated relay in the first column and at the top of the diagram. The similar solenoids and their associated relays to the right of A1 will be called A2, A3, A4, respectively. Below A1 are B1, C1, etc. Similarly, when I wish to specify a particular contact of one of the relays, I shall affix to the designation of the relay a digit corresponding to the place that contact occupies in the relay, beginning from the left. Thus the left hand contact of relay A1, shown normally closed, will be called A1—1; the next contact to the right, A1—2, etc.

If Figure 2 represents the assembly at corner 1, A1 represents a solenoid and the associated relay actuated thereby, whose primary purpose is the government of valve V1.

B1 is a relay which shifts to its actuated position whenever jack 1 is "all in"; that is, whenever weight 44, Figure 2, contacts, and thereby mechanically closes, switch 47. Such actuation of B1 calls for a very simple circuit, which besides the power source, comprises only the mechanical switch 47 and the solenoid which actuates relay B1. To avoid complicating the drawing, the corresponding circuits to actuate relays B2, and B3 and B4 have not been shown in Figure 3.

C1 is a relay which shifts to its actuated position whenever jack 1 is "all out"; that is, whenever weight 44 contacts, and thereby mechanically closes, switch 46. Such actuation of C1 calls for a very simple circuit, which, besides the power source, comprises only the mechanical switch 46 and the solenoid which actuates relay C1. To avoid complicating the drawing, the corresponding circuits to actuate relays C2, C3, and C4 have not been shown in Figure 3.

Of the D elements, there are only two, for the reason that each is associated with two opposite corners, Thus the left hand one is associated with corners 1 and 3, and the right hand one with corners 2 and 4. I shall therefore call the left-hand D element D1—D3, and the right-hand one D2—D4. Each of these D-elements, like the A-elements, consists of a solenoid and the relay actuated thereby. Their purpose will appear later.

E1 is the solenoid, shown as 20 in Figure 1, which, when energized, sets valve V1 as there shown, to allow passage of fluid from the pressure pipe 12, through V1 to jack 1. When the solenoid is unenergized, a spring, or equivalent device, shifts the plunger of valve V1 to a position like that in which I have shown V2, the valve being then set to allow passage of fluid through it from the jack to the suction line 13.

The F-elements are four mercury switches, the two elements of each pair being oppositely tilted and being held in fixed relation to each other, though the pair may be tilted either way as a unit. It follows therefore that current may pass through either one of a pair or through neither, but never through both members at the same time. These depart from the numbering system used above, in that, beginning at the left, the individual switches must be numbered F1, F3, F2, F4.

The pair of switches, F1—F3, comprise a switch unit used to bring corners 1 and 3 to the same level. They might be merely rigidly set on the main base in the diagonal between those corners, but in that case, because of the shortness of the individual elements, it would require a very considerable difference of level to cause them to function at all. Therefore I make use of the device shown and described in my patent Number 2,101,837, dated December 14, 1937. This device, by multiplying the difference of level of the ends of a much longer "base line," set in the line between corners 1 and 3, will tilt my mercury switch unit, F1—F3, into operative position, for a difference of level of only a few inches between corners 1 and 3.

The switch unit, F2—F4, is similarly arranged with respect to the diagonal from corner 2 to corner 4.

The G elements are push-buttons, all placed at the operator's station. Each provides optional manual control for raising its correlative corner, irrespective of the automatic leveling system. Their action will be better understood after the automatic leveling has been explained.

The H elements are pressure switches, of which one is shown at 26, Figure 1, which are adjustable to respond, by closing the contacts shown, whenever the pressure in the line from the V-valve to the jack falls below a prescribed minimum.

The single heavy line 51, at the lower right-hand corner of Figure 3, represents a three phase power line to the motor M, which actuates the pump P. This power line is provided with a magnetic switch 52, normally open, but closed whenever solenoid 53 is energized.

Power for the control circuits shown in Figure 3 is supplied through wire 54 at the top, and wire 55 at the bottom of the diagram.

The symmetry of the circuits shown will render unnecessary a complete discussion for each corner individually. I shall therefore, as far as may be, confine my discussion to the circuits of column 1 of the diagram and those which interlock therewith.

First, suppose that corner 1 is lower than the opposite corner 3, and that all four pistons are in intermediate positions, neither all out nor all

in. This will tilt downward the left hand end of mercury switch unit F1—F3, thereby allowing current to pass from the F1 mercury switch to the A1 solenoid over any one of four courses.

The four courses consist of the various combinations obtainable from a double path from the mercury switch F1 to a junction marked 56 on the diagram (which point is just below B3—3); and a double path from this point to A1 relay. Thus we can go from the mercury switch F1, either via wires 57, 58, contact C1—3, wire 59 to junction 56; or from mercury switch F1, via wires 57, 60, contact B2—1, wire 61, contact B4—1, wires 62, 63 to junction 56: and from junction 56 we may proceed either by B3—3, and wire 64, to the solenoid of A1; or from junction 56, via wire 63 to C4—1, wire 65, C2—1, wire 66, C1—4, wires 67, 68 to solenoid A1.

It is to be noted that all paths to solenoid A1 go through mercury switch F1, so that any A relay can only be energized when the corresponding mercury switch is tilted into action. Also, comparison of the circuits that energize the A's of two corners that are not on the same diagonal shows that ordinary leveling of one diagonal is entirely independent of anything occurring on the other diagonal; so that independent ordinary leveling of both diagonals can occur simultaneously.

The four paths from F1 to A1 solenoid will then pass through the following contacts, all normally closed, as shown:

Path *a*: C1—3; B3—3.
Path *b*: C1—3; C4—1; C2—1; C1—4.
Path *c*: B2—1; B4—1; B3—3.
Path *d*: B2—1; B4—1; C4—1; C2—1; C1—4.

Any one of the above tabulated contacts will be opened whenever the corresponding relay is actuated. Thus, for example, contacts C1—3 and C1—4 are opened, when relay C1 is actuated. We therefore note that:

Path *a* is broken if jack 1 is all out and/or jack 3 is all in, as then relay C1 and/or relay B3, respectively, is actuated.

Path *b* is broken if any one (or more) of jacks 1, 2 and 4 is all out, as then the corresponding one (or more) of relays C1, C2 and C4, is actuated.

Path *c* is broken if any one (or more) of jacks 2, 3 and 4 is all in, as then the corresponding one (or more) of relays B2, B3 and B4, is actuated.

Path *d* is broken if any one (or both) of jacks 2 and 4 is all in; and/or if any one (or more) of jacks 1, 2 and 4 is all out; as then the corresponding one (or more) of relays B2, B4, C1, C2, C4 is actuated.

It is to be noted any one of the conditions stated is sufficient to break the circuit in which it occurs. Also that path *a* is concerned only with the conditions on the 1–3 diagonal; and therefore, as the circuits for actuating solenoid A1 are symmetrical to those for actuating any other A solenoid, not even extreme conditions at the ends of one diagonal can prevent the actuation of the A solenoid for the low end of the other diagonal, when there is no extreme condition at either end of said other diagonal. The necessary and sufficient conditions for the breaking of all paths to solenoid A1 are seen to be: either jack 1 is all out and one (or more) of the other three is all in; or jack 3 is all in and one (or more) of the other three is all out. In each of these cases, further leveling on the 1–3 diagonal would only be obtainable on the given terrain by longer jacks.

A reason for the multiplicity of circuits to solenoid A1 can be shown as follows.

For simple leveling, in which only one diagonal participates, the low corner, which I have supposed to be corner 1, must be pumped, drawing fluid only from the opposite corner 3. Obviously simple leveling cannot take place if 1 is all out and/or 3 is all in. Therefore simple leveling could, in such cases, be prevented by having the circuit actuating A1 solenoid pass through both C1 and B3. Hence for this purpose, circuit *a* would be sufficient. If jack 1 is not all out and jack 3 is not all in, then regardless of conditions at jacks 2 and 4, current will energize solenoid A1 via path *a*, and jack 1 will be pumped. But, when 1 is low and all out, while no other corner is all in, we must have a course by-passing C1, in order to lower all corners to the level of corner 1. (It is to be noted that, even when corner 1 is low, solenoid A1 is unenergized if any other corner is all in, and therefore in this case jack 1 will not be pumped.) Similarly, when corner 3 is higher than corner 1, and is all in, while no other corner is all out, we must have a course by-passing B—3, in order to raise the other corners to the level of corner 3. (In this latter case, 3 being high, V3 will not be set to allow pumping into jack 3, but will be set to drain jack 3.)

If 1 is all out and lower than 3 the consequent actuation of C1 bars all paths except path *c*. Therefore A1 solenoid can still be energized if neither 2 nor 3 nor 4 is all in. The reason for this possibility is that, under these conditions, jack 1 will not be pumped, as the opening of contact C1—6 will prevent the starting of the pump; but we shall be able to lower the other three corners to the level of 1. This action requires that the A solenoid of that corner which is all out shall be energized, in order that solenoid 18, Figures 2 and 3, may be energized, to cause the general lowering, later described as "extended leveling by lowering."

The reason for the all in condition of any other corner prohibiting this leveling by lowering is: if, while 1 is all out and lower than 3, we also have 3 all in, obviously the 1–3 diagonal cannot be leveled. As before pointed out, this condition does not indicate a defect in my invention, since with any leveling device whatever, only a machine with longer jacks could be leveled on the given terrain. Or if, instead of 3, jack 2 or 4 is all in, while the 2–4 diagonal is level, evidently there cannot be a general lowering, to bring 3 to the level of 1. If jack 2 or 4 is all in and the 2–4 diagonal is not level, leveling of the 2–4 line will automatically occur, if the terrain permits, before the controls attempt to level the 1–3 line.

Still considering that corner 1 is lower than 3, and that therefore mercury switch F—1 is now passing current via one or more of the four paths described above to the solenoid A1, thereby closing four of the contacts of the relay and opening the remaining one, I shall state the function of each of the A1 relay contacts, beginning with the right hand contact, as that order will present the matter in the most easily understood manner.

When A1 relay is actuated, that is, when one or more of the four paths *a*, *b*, *c*, *d*, is not broken, A1—5 closes, thereby sending current via wire 69, through solenoid E1, which is shown in Figure 1 as solenoid 20 of valve V1. This contact therefore sets jack 1 open to the pressure side of

the pump. It is to be noted that the closing of this contact, while necessary for the pumping of jack 1, does not necessarily mean that corner 1 is being pumped up, as an additional requirement is that the pump shall be started.

A1—4 closes, sending current via wire 70, C1—6, wire 71, to solenoid 53 which starts the pump motor M, unless jack 1 is all out, in which case this circuit is broken by the opening of the C1—6 contact.

A1—3 closes. If jack 1, though lower than 3, is all out, and therefore C1 is actuated, current will pass from A1—3 via wire 72, C1—5, wire 73, to solenoid 18, which, as described in connection with Figure 1, opens the valve 17 from the suction pipe to the sump. This action, which I am calling "extended leveling by lowering," drains all jacks whose V-valves are not actuated, and therefore brings all corners down to the level of corner 1. The setting of the V-valves will then be as shown in Figure 1, so that energizing of solenoid 18 will allow jacks 2, 3 and 4 simultaneously and directly to drain into the sump. If in this process the level of the other diagonal is disturbed, say, by 2 becoming lower than 4, the A2 solenoid will be energized, and will shut off V2 from the suction pipe; so that no more fluid will be drawn from jack 2 until the lowering of corner 4 has again brought the 2–4 line level, whereupon solenoid A2 will be deenergized, and the lowering of both will be resumed. When 3 reaches the level of 1, or if 3 becomes all in before reaching the level of the all out corner 1, the lowering action ceases. In the latter case—3 all in while 1 is still all out—the situation is again seen to be one which only longer jacks can cure.

A1—2 closes, and if 1 is low but not all out, while 3 is all in and the 2–4 line is not being leveled, that is, B3 is actuated, while solenoids A2 and A4 are not energized, current will pass from A1—2, by wire 74, B3—4, wires 75, 76, A2—1, wire 77, A4—1, wire 78, solenoid D2—D4, to power line 55. The solenoid will close relay D2—D4, and current will flow from control feed wire 54 (top of diagram), via wires 79, 80, through relay D2—D4, where it divides and energizes both solenoids E2 and E4. These solenoids set V2 and V4 open to the pressure side of the pump, and as A1—4 has started the pump, corners 2 and 4 will be raised towards the level of corner 3, which is supposed to be high and all in. This is "extended leveling by raising."

It is to be noted that current to energize D2—D4 passes through both A2—1 and A4—1, normally closed, so that if either of these is energized by reason of diagonal 2–4 being out of level, the general raising will be postponed until 2–4 is first leveled. "Extended leveling" by raising one diagonal can therefore only occur when that diagonal is level, and, of the other two corners, one is low and the other is all in. It is to be noted that, in such a case, all three low corners are pumped; for, in addition to the pumping of corners 2 and 4 due to "extended leveling" just described, the mere lowness of corner 1 also simultaneously causes the pumping of jack 1 by what I have called "simple leveling."

A1—1, normally closed, will open when A1 solenoid is energized. This contact and the A3—1 contact bear the same relation to the D1—D3 "extended leveling by raising," as contacts A2—1 and A4—1 do to the D2—D4 raising, discussed just above. That is, as all paths from the solenoid of D1—D3 go through both A1—1 and A3—1, general raising to meet a possible all in and high condition of corner 2 or 4 will be postponed until after the 1–3 diagonal has been leveled.

I have provided optional manually controlled means for "extended leveling by lowering," by the push button 81, Figure 3. When this button, which is at the operator's station, is pressed, current flows via wires 79, 82, push button 81, to solenoid 18, also shown in Figure 1. Then any jack whose A solenoid is unenergized can drain into the sump; that is, any corner that is not lower than its opposite, will settle down to a lower position.

I have also provided optional manual means for raising any corner that is not all out. These are the G push-buttons, which are also at the operator's station. Thus, if G1 is pressed, current passes to A1 solenoid via wires 83 and 68; and as A1—5 sets V1 to allow flow to jack 1, the A1—4 starts the pump if 1 is not all out, this raises corner 1.

These various push-buttons can at times be used to accelerate the process of leveling.

The pressure switches, such as 26, Figure 1, are shown in Figure 3 at H. If the pressure in jack 1 falls below the value for which the switch is set, switch H1, which is the contactor 27 of Figure 1, closes, allowing current to pass via wires 84, 83, and 68, to solenoid A1, thereby closing relay A1 and sending current through E1, thus having the same effect as the pressing of the push-button G1 just previously discussed.

The only path from control feed wire 55 to the four mercury switches F1, etc., is through hand switch 85, wire 86, upper contact of relay 87 (to be described), wire 88 to a wire 89. The wire 89 connects with a wire 90 connecting the normally low points of the individual mercury switches F1 and F3, which together constitute the switch unit F1—F3; and with a similar wire in the switch unit F2—F4. Hand switch 85 allows a manual cutting out of the entire automatic leveling system, for example, during repairs, while still leaving the G push-buttons and the H pressure switches ready to perform their functions.

Relay 87 is a magnetic relay, actuated by the energizing of solenoid 91, which is in some circuit that is energized only when the machine is being propelled from one place to another. During propelling, the upper contact breaks all connection to the automatic leveling system; and the lower contact closes, sending power through wire 92, solenoid 91, wires 93 and 94 to feed wire 54. Energizing of solenoid 31 opens valve 30, Figure 1, in pipe 29, which allows free communication between the pipes from two certain ones of the V-valves to the corresponding jacks. Thus during propelling, the automatic leveling being rendered inoperative, the opening of this valve 30, Figure 1, will prevent the machine from at any time standing upon only three feet, owing to some unevenness of the ground over which it is passing.

It is obvious that many features of my device, as explained above, could be reversed, while clearly remaining within the spirit of my invention. Such a reversal could be accomplished in various ways. For example: We might reverse the action of the V-valves, by having them "normally" (i. e., when their solenoids, E1, etc., are unenergized), set to allow pumping, instead of being open to draining. The individual mercury switches, F1, F2, etc., would then each require to have a tilt opposite to that shown in Figure 3. And in place of the D1—D3, D2—D4 relays for extended level-

ing by raising, we would have two relays for lowering opposite corners in pairs. But all such changes, with the concomitant changes in the electrical diagram which they require, are well within the ability of any competent engineer, and are therefore not herein illustrated, in order to avoid undue length of this application.

Having now completely described and illustrated one embodiment of my invention, it is evident that I have provided a completely automatic system, capable of leveling the largest portable machine, on any terrain except such as absolutely demands longer jacks.

I wish it to be understood that my invention is not to be limited to the specific form or arrangement of parts hereinbefore described, except insofar as such limitations are specified in the appended claims.

I claim:

1. A heavy mobile machine comprising: a base; four ground-engaging units; four jacks each being connected to and supported by one of the four ground-engaging units, and all being connected to and supporting the base; means to expand each jack; means to release each jack, so as to permit it to contract; two level-responsive control devices, each responsive to the departure from level of one of a pair of mutually perpendicular normally horizontal lines in the base; controls for the expanding and releasing of the jacks, including means to set each jack to expand when its end of its diagonal is low; characterized by having means to prevent the application of power tending to expand any jack whenever either (*a*) it is fully extended, or (*b*) the diagonally opposite jack is fully contracted and either or both of the other two jacks is fully extended.

2. A heavy mobile machine comprising: a base; four ground-engaging units; four jacks, each being connected to and supported by one of the four ground-engaging units, and all being connected to and supporting the base; means to expand each jack; means to release each jack, so as to permit it to contract; two level-responsive control devices, each responsive to the departure from level of one of a pair of mutually perpendicular normally horizontal lines in the base; controls for the expanding and releasing of the jacks, including means to set each jack to expand when its end of its diagonal is low; characterized by having means to prevent the application of power tending to expand each jack whenever the diagonally opposite jack is fully contracted and either or both of the other two jacks is fully extended.

3. A heavy mobile unit according to claim 2, characterized further by having a single fluid pressure pump to actuate selectively all four jacks, and further having means whereby, when any given jack is fully extended and its corner is low compared with the opposite corner, or when any given jack is fully contracted and its corner is high compared with the opposite corner, and in either case none of the other three jacks is in the opposite extreme position, these other three jacks will be directly and simultaneously actuated to level the device.

4. A heavy mobile unit according to claim 2, characterized further by having a single fluid pressure pump to actuate selectively all four jacks, and further having means whereby, when any given jack is fully extended and its corner is low compared with the opposite corner, and none of the other three jacks is fully contracted, the other three jacks will be directly and simultaneously released.

5. A heavy mobile unit according to claim 2, characterized further by having a single fluid pressure pump to actuate selectively all four jacks, and further having means whereby, when any given jack is fully contracted and its corner is high compared with the opposite corner, and none of the other three jacks is fully extended, the other three jacks will be directly and simultaneously expanded.

6. A heavy mobile unit according to claim 1, characterized further by having means, with respect to each jack, responsive to the pressure in such jack, whereby, when the pressure in that jack falls below a predetermined minimum and that jack is not fully extended, that jack will be expanded.

7. A heavy mobile unit according to claim 2, characterized further by having means, with respect to each jack, responsive to the pressure in such jack, whereby, when the pressure in that jack falls below a predetermined minimum and that jack is not fully extended, that jack will be expanded.

8. A heavy mobile unit according to claim 1, characterized further by having means, with respect to each jack, responsive to the pressure in such jack, whereby, when the pressure in any jack falls below a predetermined minimum and that jack is not in a predetermined extreme position, that jack will be actuated to assume such a firm contact with the ground as will restore the pressure so as not to be below the predetermined minimum.

9. A heavy mobile unit according to claim 2, characterized further by having means, with respect to each jack, responsive to the pressure in such jack, whereby, when the pressure in any jack falls below a predetermined minimum and that jack is not in a predetermined extreme position, that jack will be actuated to assume such a firm contact with the ground as will restore the pressure so as not to be below the predetermined minimum.

10. A heavy mobile machine, comprising: a base, four ground-engaging units; four jacks, each being connected to and supported by one of the four ground-engaging units, and all being connected to and supporting the base; means to expand each jack; means to release each jack, so as to permit it to contract; two level-responsive control devices, each responsive to the departure from level of one of a pair of normally horizontal lines on the base, which lines are at substantially right angles to each other; characterized by having means, with respect to each jack, responsive to the pressure in such jack, whereby, when the pressure in any jack falls below a predetermined minimum and that jack is not fully extended, that jack will be expanded.

11. A heavy mobile machine, comprising: a base; four ground-engaging units; four jacks, each being connected to and supported by one of the four ground-engaging units, all being connected to and supporting the base; means to expand each jack; means to release each jack, so as to permit it to contract; two level-responsive control devices, each responsive to the departure from level of one of a pair of normally horizontal lines on the base, which lines are at substantially right angles to each other; characterized by having means, with respect to each jack, responsive to the pressure in such jack, whereby, when the pressure in any jack falls below a predetermined minimum and that jack is not in a predetermined extreme position, that jack will be actuated to

assume such a firm contact with the ground as will restore the pressure so as not to be below the predetermined minimum.

12. A heavy mobile machine, comprising: a base; four ground-engaging units; four fluid-pressure jacks, each being connected to and supported by one of the four ground-engaging units, and all being connected to and supporting the base; means to expand each jack; means to release each jack, so as to permit it to contract; two level-responsive control devices, each responsive to the departure from level of one of a pair of normally horizontal lines on the base, which lines are at substantially right angles to each other; having also one single fluid pressure pump to actuate selectively all four jacks, and a fluid pressure piping system; characterized by the fact that the level-responsive control devices are electrical, and control the piping system to effect the transfer of fluid between the jacks; and further characterized by having means whereby, when any given jack is fully extended and its corner is low compared with the opposite corner, or when any given jack is fully contracted and its corner is high compared with the opposite corner, and in either case none of the other three jacks is in the opposite extreme position, these other three jacks will be directly and simultaneously actuated to level the device.

13. A heavy mobile unit according to claim 12 characterized further by having means, with respect to each jack, responsive to the pressure in such jack, whereby, when the pressure in any jack falls below a predetermined minimum and that jack is not in a predetermined extreme position that jack will be actuated to assume such a firm contact with the ground as will restore the pressure so as not to be below the predetermined minimum.

14. A heavy mobile machine, comprising: a base; four ground-engaging units; four fluid-pressure jacks, each being connected to and supported by one of the four ground-engaging units, and all being connected to and supporting the base; means to expand each jack; means to release each jack, so as to permit it to contract; two level-responsive control devices, each responsive to the departure from level of one of a pair of normally horizontal lines on the base, which lines are at substantially right angles to each other; having also one single fluid pressure pump to actuate selectively all four jacks, and a fluid pressure piping system; characterized by the fact that the level-responsive control devices are electrical, and control the piping system to effect the transfer of fluid between the jacks; and further characterized by having means whereby, when any given jack is fully extended and its corner is low compared with the opposite corner, or when any given jack is fully contracted and its corner is high compared with the opposite corner, and in either case none of the other three jacks is in the opposite extreme position, these other three jacks will be directly and simultaneously actuated to level the device; and by having means to render the leveling inoperative during travel of the machine; and by having means to change the support to a three-point support on all four jacks during travel of the machine.

15. A heavy mobile machine comprising: a base; four ground-engaging units; four fluid-pressure jacks, each being connected to and supported by one of the four ground-engaging units, and all being connected to and supporting the base; means to expand each jack; means to release each jack, so as to permit it to contract; characterized by having a single fluid pressure pump to actuate selectively all four jacks and by having means to level the machine within the limits of travel of the jacks, by mere interchange of fluid between the jacks; and by having means for directly and with complete simultaneity effecting extended leveling, whenever complete leveling by mere interchange of fluid is rendered impossible by reason of one jack reaching an extreme position.

16. A heavy mobile machine comprising: a base; four ground-engaging units; four fluid-pressure jacks, each being connected to and supported by one of the four ground-engaging units, and all being connected to and supporting the base; means to expand each jack; means to release each jack, so as to permit it to contract; characterized by having a single fluid pressure pump to actuate selectively all four jacks and by having means to level the machine within the limits of travel of the jacks, by mere interchange of fluid between the jacks; and by having means for extended leveling, namely means whereby, when any given jack is fully extended and its corner is low compared with the opposite corner, or when any given jack is fully contracted and its corner is high compared with the opposite corner, and in either case none of the other three jacks is in the opposite extreme position, these other three jacks will be directly and simultaneously actuated to level the device.

17. A heavy mobile machine according to claim 16, characterized further by having means to render the leveling inoperative during travel of the machine, and for then changing the support to a three-point support on all four jacks, by opening free communication between two of the jacks.

18. A heavy mobile machine comprising: a base; four ground-engaging units; four jacks, each being connected to and supported by one of the four ground-engaging units, and all being connected to and supporting the base; means to expand each jack; means to release each jack, so as to permit it to contract; two level-responsive control devices, each responsive to the departure from level of one of a pair of mutually perpendicular normally horizontal lines in the base; controls for the expanding and releasing of the jacks, including means to set each jack to release when its end of its diagonal is high; characterized by having means to prevent the releasing of any jack whenever either (*a*) it is fully contracted, or (*b*) the diagonally opposite jack is fully expanded and either or both of the other two jacks is fully contracted.

19. A heavy mobile unit according to claim 18, characterized further by having means whereby, when any given jack is fully extended and its corner is low compared with the opposite corner, or when any given jack is fully contracted and its corner is high compared with the opposite corner, and in either case none of the other three jacks is in the opposite extreme position, these other three jacks will be directly and simultaneously actuated to level the device.

20. A heavy mobile machine comprising: a base; four ground-engaging units; four jacks, each being connected to and supported by one of the four ground-engaging units, and all being connected to and supporting the base; means to expand each jack; means to release each jack, so as to permit it to contract; two level-responsive control devices, each responsive to the departure from level of one of a pair of mutually

perpendicular normally horizontal lines in the base; controls for the expanding and releasing of the jacks, including means to set each jack to contract when its end of its diagonal is high; characterized by the fact that the jacks are fluid pressure jacks; that each jack is normally set to receive fluid; that the controls are electrical; that there is a pump to force fluid into selected jacks whenever the pump is actuated; that the level-responsive control is set to actuate the pump when and only when at least one diagonal is unlevel; that as to each jack there is an electric circuit to actuate the pump and to set the jack to discharge fluid when the corner at that jack is higher than the opposite corner, this circuit consisting of two halves which are in series: the first half consisting of two parallels, of which parallels one passes through a switch hereinafter called I, and the other passes through three switches hereinafter called II, III, IV, respectively; and the second half of said circuit consisting of two parallels, of which parallels one passes through a switch hereinafter called V, and the other passes through two switches hereinafter called VI, VII, respectively: all said switches being normally closed, I opening when the jack opposite to the given jack is fully expanded, II and V opening when the given jack is fully contracted, III opening when one of the jacks adjacent to the given jack is fully contracted, IV opening when the other of the adjacent jacks is fully contracted, VI opening when one of the adjacent jacks is fully expanded, and VII opening when the other of the adjacent jacks is fully expanded.

21. A heavy mobile machine comprising: a base; four ground-engaging units; four jacks each being connected to and supported by one of the four ground-engaging units, and all being connected to and supporting the base; means to vary the effective length of each jack between extreme positions of full contraction and full expansion; two level-responsive control devices, each responsive to the departure from level of one of a pair of mutually perpendicular normally horizontal lines in the base; controls for varying the effective length of the jacks, including means to set each jack to vary when its diagonal is unlevel; characterized by having means to prevent the application of power tending to vary any given jack in the direction of or beyond one of its extreme positions whenever either (*a*) the given jack is in that extreme position, or (*b*) the jack diagonally opposite the given jack is in the other extreme position and either or both of the other two jacks is in the extreme position of the given jack.

22. A heavy mobile machine comprising: a base; four ground-engaging units; four jacks, each being connected to and supported by one of the four ground-engaging units, and all being connected to and supporting the base; means to vary the effective length of each jack between extreme positions of full contraction and full expansion; two level-responsive control devices, each responsive to the departure from level of one of a pair of mutually perpendicular normally horizontal lines in the base; controls for varying the effective length of the jacks, including means to set each jack to vary when its diagonal is unlevel; characterized by having means to prevent the application of power tending to vary any given jack in the direction of or beyond one of its extreme positions whenever the diagonally opposite jack is in the other extreme position and either or both of the other two jacks is in the extreme position of the given jack.

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