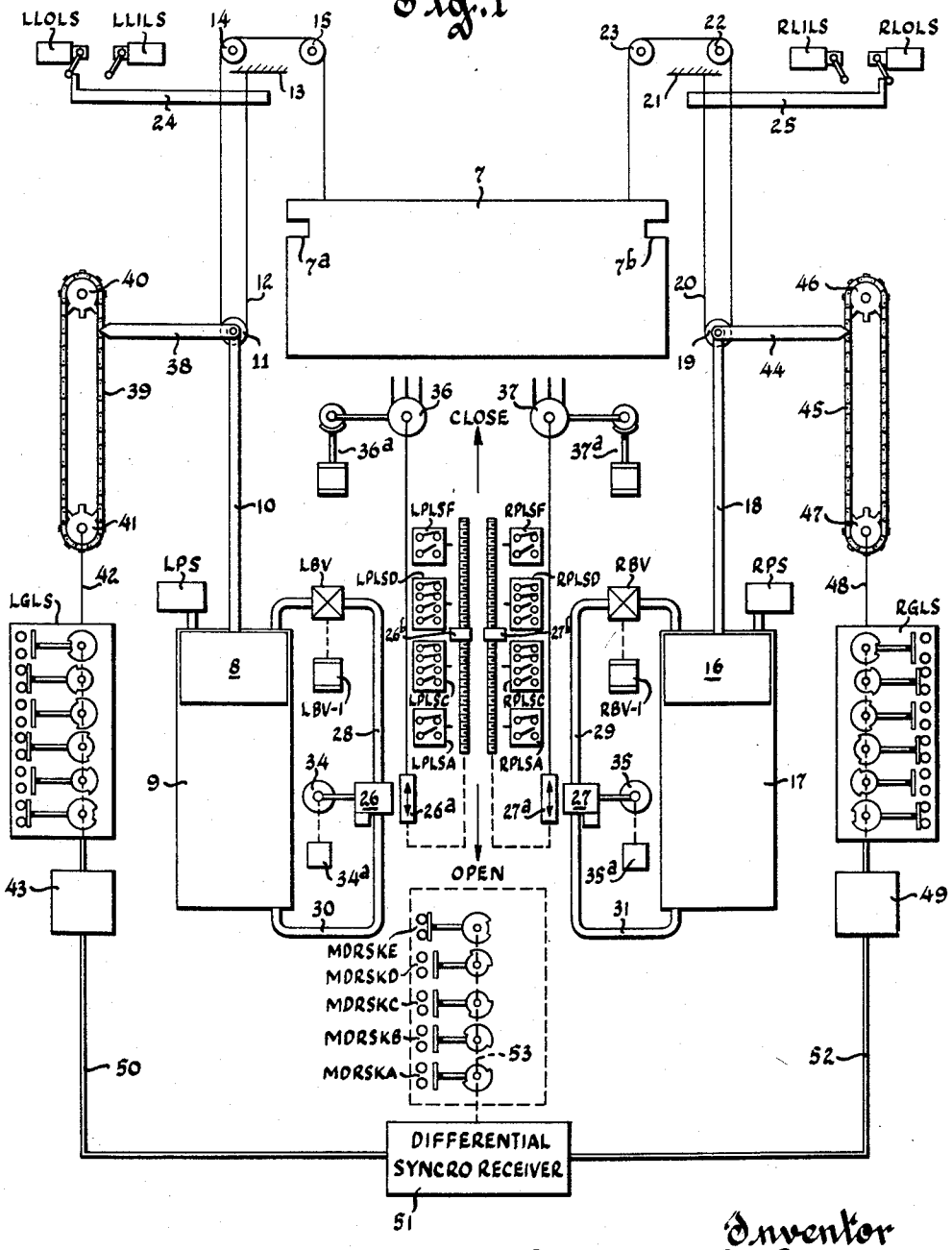
April 12, 1960 R. R. RANSON 2,932,171

SYSTEM FOR RAISING AND LOWERING LARGE MOVABLE STRUCTURES

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Fig. 1



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SYSTEM FOR RAISING AND LOWERING LARGE MOVABLE STRUCTURES

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Fig. 2

SLIDE BLOCK LIMIT SWITCHES

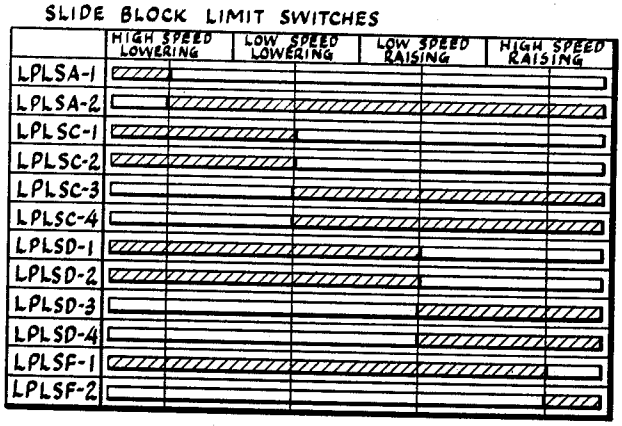


Fig. 3

SKEW LIMIT SWITCHES

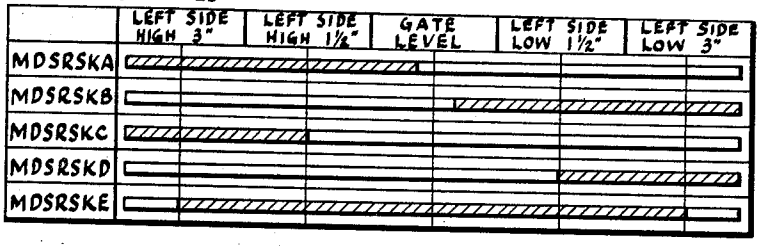
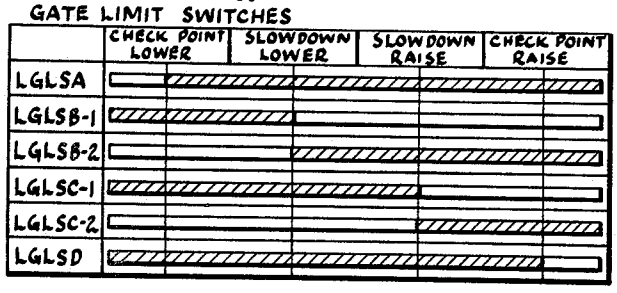
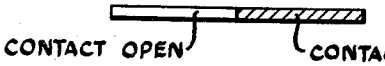


Fig. 4

GATE LIMIT SWITCHES





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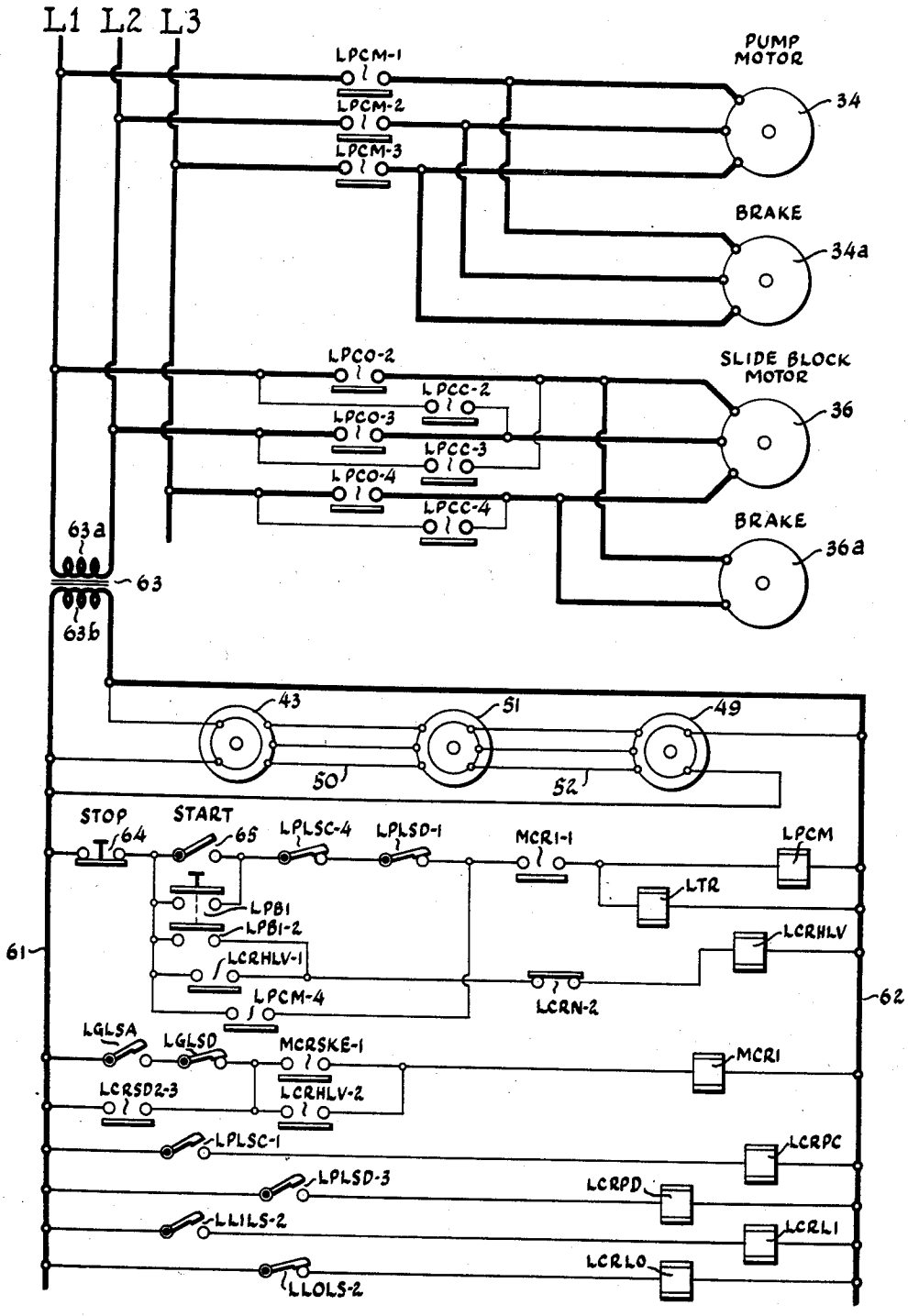
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SYSTEM FOR RAISING AND LOWERING LARGE MOVABLE STRUCTURES

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Fig. 5a

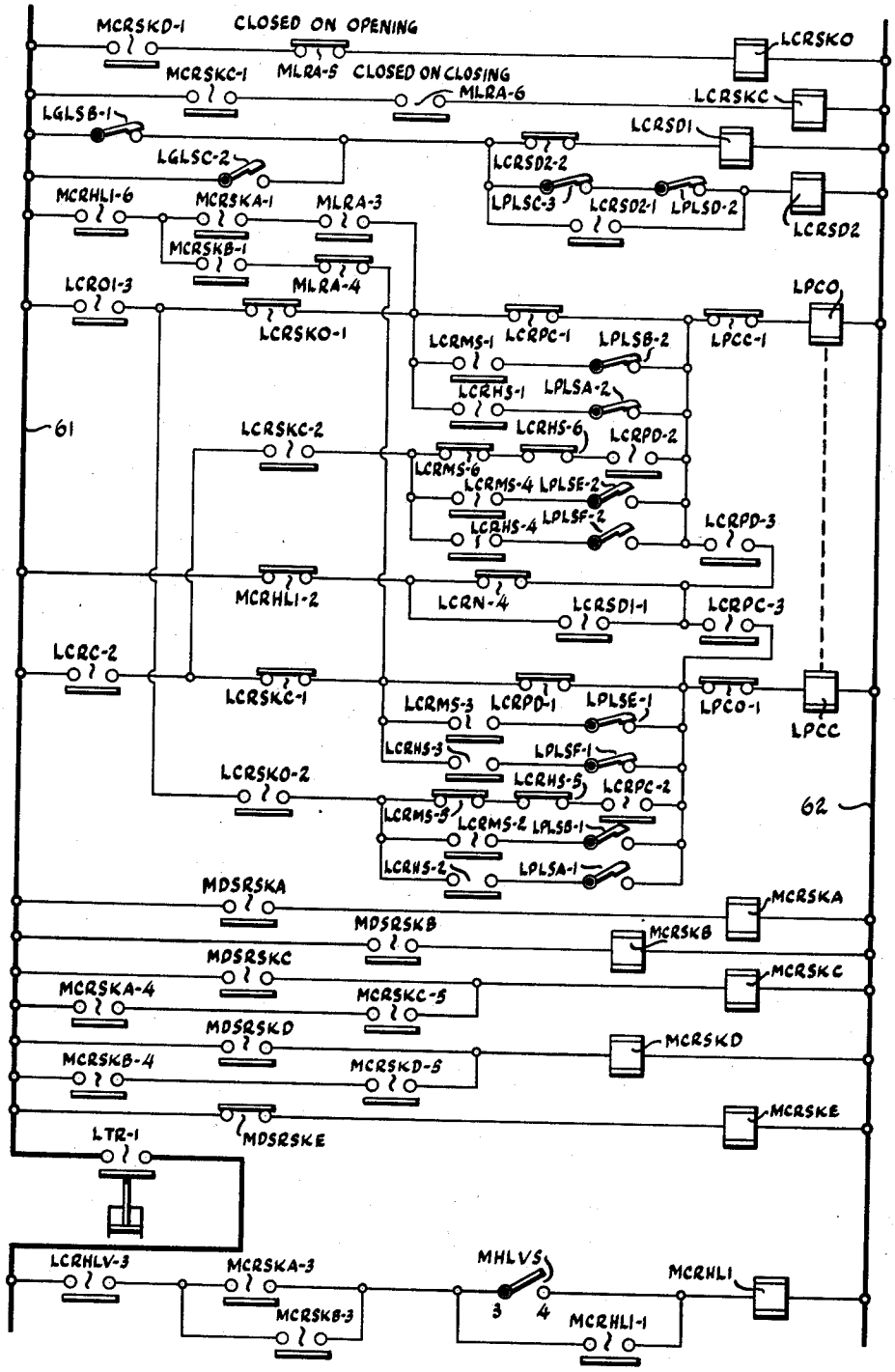


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Fig. 5b

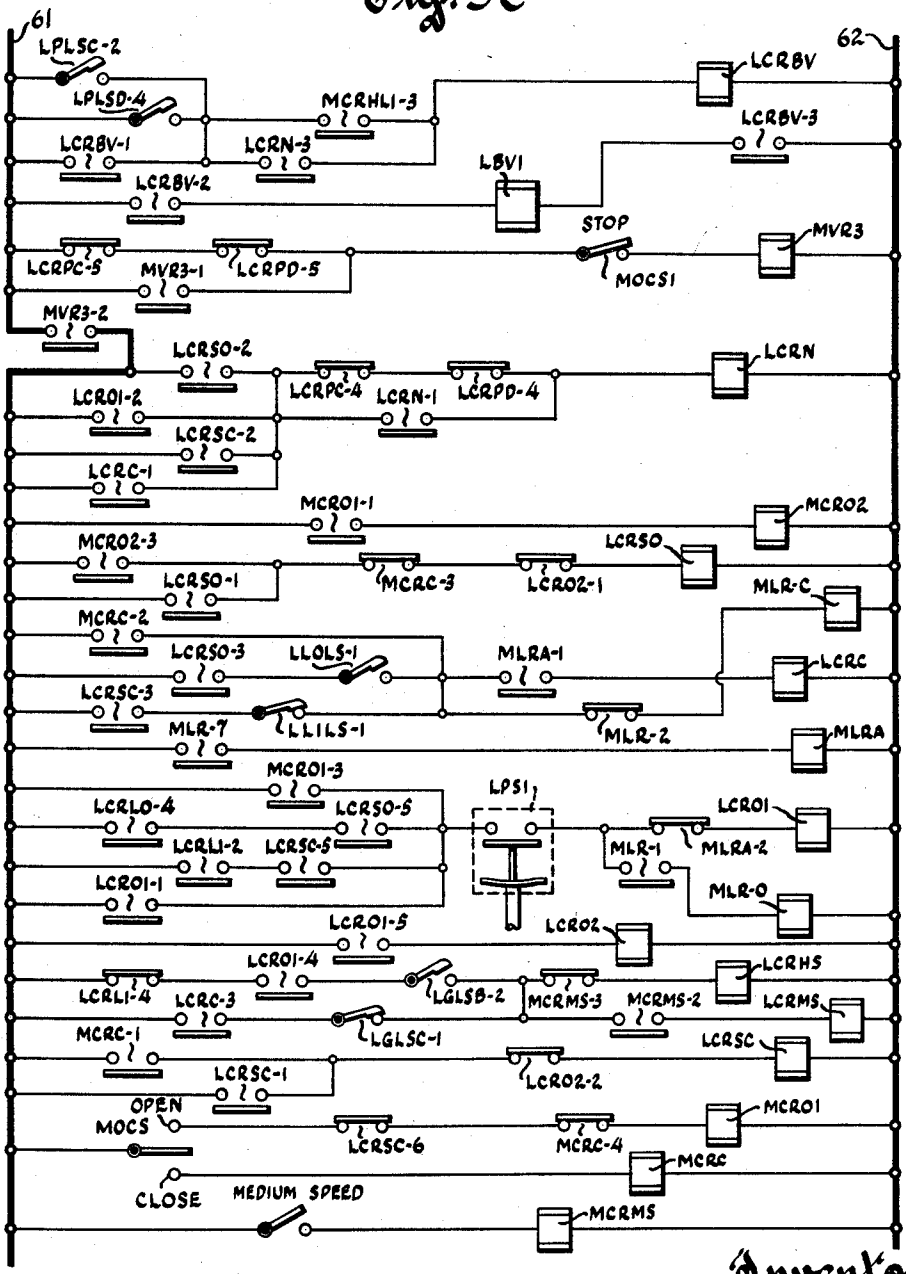


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SYSTEM FOR RAISING AND LOWERING LARGE MOVABLE STRUCTURES

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Fig. 5c



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Fig. 6

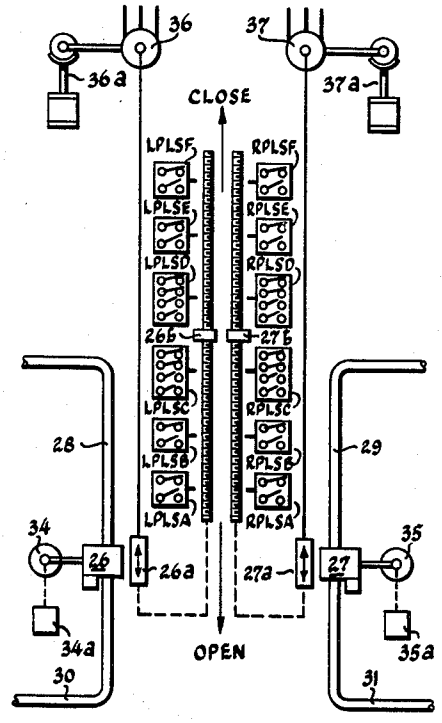
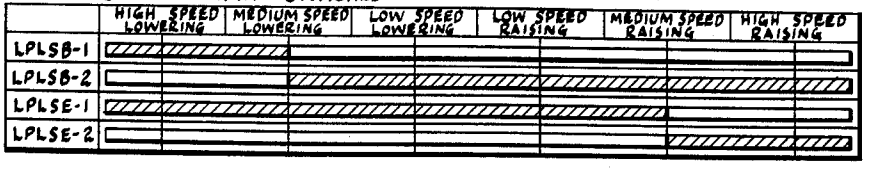


Fig. 7

SLIDE BLOCK LIMIT SWITCHES



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SYSTEM FOR RAISING AND LOWERING LARGE MOVABLE STRUCTURES

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Application November 4, 1957, Serial No. 694,348

19 Claims. (Cl. 61—28)

This invention relates to an improved system for raising and lowering large movable structures.

While not limited thereto, the present invention is particularly suitable for use with vertically movable gates in navigation locks.

Vertically movable submersible gates are now being used at the upper pool ends of navigation locks. These gates which are often in excess of 100 feet in length and 100 tons in weight move in guideways and recesses formed in the masonry side and bottom walls of the lock. Their dimensions and weight requires use of independent hoisting systems for each end of the gate. Differences in performance between the independent hoisting systems, and retardation of movement of either end of the gate due to the presence of foreign material in the guideways requires that provision be made against occurrence of skew conditions that might cause such jamming of the gate in the guideways.

It is a primary object of the present invention to provide an improved system for raising and lowering large vertically movable structures with a high degree of inherent safety in its operation.

Another object is to provide a system of the aforementioned type which affords automatic skew correction if the skew is within predetermined limits both during normal running and during acceleration.

A further object is to provide a system of the aforementioned type which provides automatic stopping of the structure if such skew exceeds the aforementioned predetermined limits.

A still further object is to provide a system of the aforementioned type wherein following extreme skew stopping or shut down, automatic leveling of the structure will occur when such operation is initiated by the operator.

Other objects and advantages of the invention will hereinafter appear.

In carrying out the invention I provide duplicate hydraulic hoisting systems for each end of a movable structure such as a gate of a navigation lock. Such systems comprise pistons connected through cables and pulleys to the gate ends, electric motor driven fluid meter-pump having connection with opposite ends of the piston cylinders and having slide block control elements which are movable in reverse directions from a center or neutral zone to afford various metering and pumping rates for the meter-pump to afford raising and lowering of the respective ends of the gate. These slide block control elements are driven in reverse directions by reversible electric motors. A control system is provided for the latter motors and permits selection of raising and lowering operation and initiation of leveling following stopping because of an extreme skew condition. The control incorporates means continually comparing the difference in level between the ends of the gates during raising and lowering and if skew therebetween exceeds a given

amount initiates readjustment of the slide block control element of the meter-pump associated with the leading end of the gate until the gate ends are again substantially in level. If such correction is ineffective and the skew increases beyond a predetermined greater amount the latter means initiates immediate shut down of both hydraulic systems and setting of valves in the hydraulic lines to stop and hold the gate in the position then attained. Following such shut down automatic leveling of gate ends can be effected by manual initiation of such operation.

The accompanying drawings illustrate a preferred embodiment of the invention which will now be described in detail, it being understood that the embodiment illustrated is susceptible of modification in respect of details without departing from the scope of the appended claims.

In the drawings:

Figure 1 is a schematic showing of a vertical lift gate from a navigation lock together with hydraulic hoists for each end of the gate and certain of the control means therefor;

Fig. 2 is a chart depicting the operation of certain limit switches shown in Fig. 1;

Fig. 3 is a chart depicting the operation of certain other limit switches shown in Fig. 1;

Fig. 4 is a chart depicting the operation of still other limit switches shown in Fig. 1;

Figs. *5a* to *5c* diagrammatically depict the electrical hook-up of an electrical control system for the apparatus shown in Fig. 1;

Fig. 6 depicts a modification of a portion of the system shown in Fig. 1; and

Fig. 7 is a chart depicting the operation of additional limit switches used in the modified system of Fig. 6.

Fig. 1 shows a vertical lift gate **7**, such as is used in the upper pool end of a navigation lock. It may be assumed that gate **7** moves in, and, portions of its left and right-hand sides are overlapped by guideways (not shown) formed in the side walls of the lock. Also it may be assumed that in its lowermost or "open" position that the lower portion of the gate is disposed in a recess or well (not shown) formed in the bottom wall of the lock, which communicates with the aforementioned guideways.

A hydraulic piston **8**, which is reversely movable within a cylinder **9**, has a connecting rod **10** on the upper end of which is rotatably mounted a plurality of pulleys, depicted by pulley **11**. A plurality of cables, depicted by cable **12**, are affixed at one end to an abutment **13**, pass around the pulley **11**, over idler pulleys **14** and **15** and are secured at their other ends to gate **7** adjacent the upper left-hand end thereof. Similarly, a piston **16**, which moves in a cylinder **17** has a connecting rod **18** on which is mounted a plurality of pulleys **19**. Cables **20** which are affixed at one end to abutment **21** pass around the pulleys **19**, around idler pulleys **22** and **23** and are attached at their other ends to gate **7** against the upper right-hand end thereof. It will be seen that when fluid is pumped into cylinders **9** and **17** above pistons **8** and **16** to move the latter downwardly, gate **7** will be caused to move upwardly, and that when fluid is exhausted from cylinders **9** and **17** above pistons **8** and **16**, the gate will move downwardly under its own weight.

When the gate is in its upper or "closed" position holding latches **24** and **25** are inserted by motive means (not shown) into recesses *7a* and *7b* of the gate to relieve the weight of the gate from the cables and hydraulic system. When lowering operation of the gate is initiated, as will hereinafter be fully described, latches **24** and **25** are withdrawn before the gate commences to lower. When the gate is in its lower or "open" position it may be assumed to rest at its lower end on bumpers (not

shown) which relieves the weight of the gate from the cables and hydraulic system.

Associated with the cylinders 9 and 17 are the fluid power meter-pumps 26 and 27, respectively. Meter-pumps 26 and 27 are a well known form of variable displacement pump, such as shown in Ferris Patent No. 2,074,068, issued March 16, 1937. These pumps, have slide block control elements 26*a* and 27*a*, respectively.

It is a characteristic of such pumps to have a center slide block position of indeterminate width wherein the pump functions neither as a "pump" nor as a "metering" device. As will be hereinafter more fully explained, in order to avoid control complications I arbitrarily provide a "neutral" zone of slide block positioning of a width sufficient to insure that the pump will definitely function as a "pump" when it is moved beyond the limit of such neutral zone in one direction and will definitely function as a "metering" device when moved beyond the opposite limit of such zone. If moved upwardly as depicted in Fig. 1, they may be assumed to move into the "pumping" region whence they may be assumed to cause meter-pumps 26 and 27 to pump fluid upwardly into the conduits 28 and 29, which communicate interiorally at the upper ends of cylinders, and within limits the farther the slide blocks are moved into the "pumping" regions, the greater will be the displacement or rate of fluid pumping. Conversely, if the slide blocks are moved out of their "neutral" zones downwardly as depicted in Fig. 1, they may be assumed to cause meter pumps 26 and 27 to meter fluid out of conduits 28 and 29, into the conduits 30 and 31 which communicate interiorally at the lower ends of cylinders 9 and 17. Within limits the farther the slide blocks are moved into their "metering" regions the greater will be the metering rate or displacement.

Valves LBV and RBV are interposed in conduits 28 and 29, respectively, and are provided with solenoid operating windings LBV1 and RBV1 which, when energized afford opening of brake valves LBV and RBV to permit fluid flow into or out of the upper ends of cylinders 9 and 17. When windings LBV1 and RBV1 are de-energized flow of fluid in the respective hydraulic system is stopped and the positions of the pistons in the cylinders maintained to hold the gate ends in a position corresponding thereto.

Meter-pumps 26 and 27 are driven by A.C. electric motors 34 and 35, respectively, and the latter motors are provided with electromagnetic brakes 34*a* and 35*a*. Brakes 34*a* and 35*a* insure against operation of pumps 26 and 27 as hydraulic motors in the event of simultaneous power failure to motors 34 and 35 and brake valves LBV and RBV. Slide block 26*a* is movable in reverse directions as aforedescribed by a reversible A.C. electric motor 36 having an electromagnetic brake 36*a*, and slide block 27*a* is similarly movable by an A.C. electric motor 37 having an electromagnetic brake 37*a*.

Motor 36 in driving slide block 26*a* concurrently drives a traveling nut follower 26*b* in a corresponding direction from a "neutral" zone to successively operate limit switches LPLSD and LPLSF as the slide block moves into its "pumping" region. As the slide block moves into its "metering" region limit switches LPLSC and LPLSA are operated by the follower 26*b*. Motor 37 similarly drives a traveling nut follower 27*b* in corresponding direction with slide block 27*a* to successively operate limit switches RPLSD and RPLSF as slide block 26*b* is moved into its "pumping" region, and to successively operate limit switches RPLSC and RPLSA as the latter slide block is moved into its "metering" region. The aforementioned limit switches are reset in reverse order as the associated slide blocks are moved back into their neutral zones from their pumping and metering regions. Fig. 2 depicts the sequence and open-closed direction of the various contacts of limit switches LPLSA, LPLSC, LPLSD and LPLSF. This will also hold true for limit switches RPLSA, RPLSC, RPLSD and RPLSF. When latch 24 is fully withdrawn as depicted in Fig. 1 it trips a limit switch LLOLS and when fully inserted it trips a limit switch LLILS. Similarly, latch 25 when fully withdrawn trips a limit switch RLOLS and when fully inserted trips a limit switch RLILS.

A member 38 attached at one end to connecting rod 10 is connected at its other end to a roller chain 39 which runs on an idler sprocket wheel 40 and a sprocket wheel 41 which has a shaft 42 affixed thereto. Shaft 42 rotates to operate gate position limit switches LGLS–A, LGLS–B, LGLS–C and LGLS–D to operate them in accordance with the elevation of the left end of the gate which will hereinafter be more fully described and also drives a synchro transmitter 43. Similarly, a member 44 which is attached to one end to connecting rod 18 is connected at its other end to a roller chain 45 which runs on an idler sprocket wheel 46 and a sprocket wheel 47 which has a shaft 48 affixed thereto. Shaft 48 similarly operates gate position limit switches RGLS–A, RGLS–B, RGLS–C and RGLS–D in accordance with the elevation of the right end of the gate, and also drives a synchro transmitter 49. Fig. 4 depicts the sequence of operation and open-closed directions for the contact limit switches LGLS–A, LGLS–B, LGLS–C and LGLS–D and it may be assumed that the same will hold for the contact limit switches RGLS–A, RGLS–B, RGLS–C and RGLS–D.

Synchro transmitter 43 is electrically connected by a cable 50 to a differential synchro receiver 51, and synchro transmitter 49 is electrically connected by a cable 52 to receiver 51. Receiver 51 has an output shaft 53 which rotates to various angular positions in either direction in accordance with (*a*) the difference in amount of angular rotation between shafts 42 and 48, and (*b*) whichever of the latter shafts has the greater angular rotation. In accordance with the direction and degree of its rotation, shaft 53, by means of five cams fixed thereto operates five skew limit switches MDSRSKA to MDSRSKE, inclusive. Fig. 3 depicts the open-closed operating conditions for each of the limit switches MDSRSKA to MDSRSKE. As will hereinafter be apparent, these latter switches are the means by which operation of the hydraulic hoisting and lowering systems associated with the left and right-hand ends of the gate are coordinated. Except for such coordination, and certain to be described control function initiating switches, the left and right-hand hoisting and lowering systems and the control therefor essentially operate independently.

Cylinders 9 and 17 have associated therewith pressure switches LPS and RPS, respectively, which function in the control system now to be described.

Figs. 5*a* to 5*c* depict the electrical hook-up of the motors, brakes, valves and limit switches, etc., described in connection with the hydraulic hoisting and lowering mechanism aforedescribed in connection with the left-hand end of gate 7, together with others to be described relays, contactors and control function initiating switches. The diagrams of Figs. 5*a* to 5*c* should be considered as constituting a single diagram with each succeeding diagram connected to the bottom of the preceding diagram, and with the individual portions of the control supply buses 61 and 62 connected continuously. It is to be understood that, except for the control function initiating switches and limit switches MDSRSKA to MDSRSKE, the hydraulic hoisting and lowering control system associated with the right-hand end of the gate would be a duplicate of that depicted in Figs. 5*a* to 5*c*, and for the sake of simplicity its description beyond that heretofore made will be dispensed with. Thus all further description of operation will be in terms of the left end of the gate, but the various modes of operation will also hold true for the right end.

The relays, contactors and switches associated solely with the left end system are prefixed by the letter "L" and those of a master character by "M." The following symbol designations hereinafter used in connection with

certain relays, contactors and limit switches have the meanings as below set forth:

C=Closing
CR=Control relay
GLS=Gate position limit switch
HLV=Hand leveling
HS=High speed
LI=Latches in
LO=Latches out
LR=Latched relay
LR–C=Latched relay coil closing
LR–O=Latched relay coil opening
N=Automatic operation relay
PC=Power contactor
PCC=Power contactor closing
PCM=Power contactor main
PCO=Power contactor opening
SC=Closing sequence
SD1=Slow down initiation
SD2=Slow down completion
SKC=Skew on closing
SKO=Skew on opening
SO=Opening sequence
VR=Voltage relay

Now considering Fig. *5a*, it shows a polyphase A.C. power supply comprising supply lines L1, L2 and L3. The supply terminals of pump motor **34** are connectable to supply lines L1, L2 and L3 by closure of contacts LPCM–1, 2 and 3 of contactor LPCM. The electromagnetic release winding of brake **34***a* is also concurrently energized to permit motor **34** to drive meter-pump **26** wherein supply connections are completed to such motor. The supply terminals of slide block motor **36** are connectable to supply lines L1, L2 and L3 for operation in one direction upon closure of contacts LPCO–2, 3 and 4 of contactor LPCO and such supply terminals are connectable to the same supply lines in a different manner to operate the motor in reverse direction upon closure of contacts LPCC–2, 3 and 4 of contactor LPCC. The brake release winding of brake **36***a* is energized whenever power connections are completed to motor **36**, and deenergized to stop motor **36** whenever the power connections are interrupted to the motor.

A transformer **63** has its primary winding **63***a* connected across supply lines L1 and L2 and has the end terminals of its secondary winding **63***b* connected to the buses **61** and **62**, respectively. The input terminals of synchro transmitters **43** and **49** are connected across the end terminals of winding **63***b*. The aforementioned cable **50** between transmitter **43** and differential receiver **51** comprises three electrical conductors as does the cable **52**.

The control system of Figs. 1 and *5a* to *5c*, affords (*a*) Normal Closing Operation, (*b*) Normal Opening Operation, (*c*) Automatic Skew Correction, (*d*) Extreme Skew Shut Down, and (*e*) Manually Initiated Automatic Leveling from Extreme Skew Shut Down Condition. A complete description of the positions of the system shown in Figs. *5a* to *5c* will be made in connection with detailed descriptions of the foregoing types of operation which are set forth hereinafter under subheadings bearing the foregoing operation designations.

The condition of the hoisting system depicted in Fig. 1 is that obtaining when the gate is in its lower or "open" position resting on the bumpers, and the condition of the electrical control system depicted in Figs. *5a* to *5c* is that obtaining with power supply lines L1, L2 and L3 deenergized.

If for any reason either of the slide block control elements is not in its "neutral" zone, it will be driven back into such zone, and both must be in their neutral zones before drive of the fluid pumps and the remainder of the control system can function. Assume the slide block control element **26***b* is outside of its neutral zone in the "closing" region. Thus, contact LPLSDB of slide block limit switch LPLSD will be closed to complete an energizing circuit for relay LCRPD. Contacts LCRPD–3 of relay LPCRPD thereupon close to complete an energizing circuit for contactor LPCO from line **61** through the then closed contacts MCRHL1–2, LCRN–4, LCRPD–3 and LPCC–1 and contactor LPCO to line **62**. Brake **36***a* will then be released and motor **36** energized to drive slide block element **26***b* back into the neutral zone and will continue until contacts LPLSD–3 re-open to deenergize relay LCRD–3. If slide block element **26***b* is out of the "neutral" zone, but in the "opening" direction, contacts LPLSC–1 of limit switch LPLSC will be closed to energize relay LCRPC resulting in closure of contact LCRPC–3 of the latter. Consequently an energizing circuit for contactor LPCC will be completed from line **61** through the then closed contacts MCRHL1–2, LCRN–4, LCRPC–3 and LPCO–1 and contactor LPCC to line **62**. Motor **36** will then be energized to drive slide block **26***b* in the "closing" direction back into its "neutral" zone whereupon limit switch contacts LPLSC–1 open to deenergize relay LCRPC.

Normal closing operation

Upon operation of a master "start" switch, drive of the fluid pumps is started, and then, following operation of a master "closing-opening" switch to "closing" position, the slide block driving motors are started and drive the slide block control elements out of their "neutral" zones in a direction affording operation of the meter-pump at increasing rate or displacement. The brake valves in the conduits leading from the meter-pump to the upper ends of the cylinders are then opened and fluid pumped into the cylinders. The pistons are thereby accelerated downwardly in the cylinders and thereby move gate **7** upwardly at an increasing rate. When the slide blocks of the meter-pumps reach a given position in their "pumping" region, movement thereof is stopped and fluid is then pumped into the cylinders at a high rate to raise gate at a corresponding high speed. When the gate reaches a certain position in its upward travel the slide block control elements of the meter-pumps are driven in the opposite direction toward their "neutral" zones so the displacement or rate of the meter-pump outputs are reduced, and rate of movement of the pistons and gate **7** is correspondingly reduced to a predetermined slow or creeping speed.

If the gate has slowed down to creeping speed when it reaches its upper normal position the holding latches are inserted. However, in the event the gate has not slowed down to creeping speed when it reaches that position all operation of the control system will immediately stop.

When the insertion of the holding latches is completed, the slide block control elements of the meter-pumps are driven back through their "neutral" zones and then into their "metering" regions wherein the meter-pumps meter fluid out of the cylinders at a rate causing the gate to move downwardly at creeping speed until the gate comes to rest on the aforementioned holding latches. Finally, the slide block control elements of the meter-pumps are driven back toward their "neutral" zones and when they reach positions in the "neutral" zones are stopped and the brake valves closed. Thus the gate will then be in "closed" position resting on holding latches, and the control system readied for operation to "open" the gate. A detailed description of operation of the control system to afford the aforedescribed operation will now be made.

Closure of a "start" switch **65** completes an energizing circuit for pump motor contactor LPCM through closed "stop" switch **64**, slide block limit switches contact LPLSC-4 and LPLSD–1, which will be closed when the slide block control elements are in their "neutral" zones and contacts MCR1–1. Contacts LPCM–4 close to maintain contactor LPCM around switch **65** and limit switch contacts LPLSC–4 and LPLSD–1. Contacts LPCM–1, 2 and 3 close to complete energizing connections from lines L1, L2 and L3 to motor **34** and the brake release winding

34*a* to afford drive of meter-pump 26. Contacts MCR1–1 are normally open but relay MCR1 will then be energized to close them through closed contacts LCRSD2–3 and closed skew limit switch MCRSKE–1. Contacts LCRSD2–3 are normally open contacts but are closed by virtue of energization of relay LCRSD2 through then closed gate position limit switch LGLSB and contact LGLSB–1 and slide block limit switch contacts LPLSC–3 and LPLSD–2.

The aforementioned closure of "start" switch 65 also completes an energizing circuit for a timing relay LTR which is connected in parallel with contactor LPCM. Upon energization relay LTR closes with time delay insuring that the portion of the control system having to do with admission of fluid into and out of the cylinders 9 and 17 cannot operate until the pump driving motors 34 and 35 have come up to full speed.

To initiate gate closing operation a three-position "closing-opening" selector switch MOCS is closed to its "close" contact to complete an energizing circuit for relay MCRC. The latter is energized and closes contacts MCRC–1 to complete an energizing circuit for relay LCRSC through closed contacts LCRO2–2. Relay is maintained around contact MCRC–1 by closure of its contacts LCRSC-1.

Closure of contacts MCRC–2 results in completion of an energizing circuit through the then closed contacts MLR–2 for closing coil MLR–C of a latched relay MLR. Contacts MLR–7 of the latter relay then close to complete an energizing circuit for relay MLRA. Thus an energizing circuit will be completed for relay LCRC through the then closed contacts MCRC–2 and MLRA–1. Thereupon contacts LCRC–2 close to complete an energizing circuit for contactor LPCC through the then closed contacts LCRSKC–1, LCRPD–1 and the then closed interlock contacts LPCO–1.

Contactor LPCC then picks up and closes its contacts LPCC–2, 3 and 4 to energize motor 36 to drive its associated slide block control element 26*a* of meter-pump 26 out of its "neutral" position depicted in Fig. 1 upwardly which may be assumed to afford pumping of fluid into conduit 29. As the slide block continues to move traveling nut 26*b* operates limit switch LPLSD.

Closure of contacts LCRSC–2 by the aforementioned pickup of relay LCRSC results in energization of relay LCRN through then closed contacts LCRPC–4 and LCRPD–4. Pickup of relay LCRN results in closure of contacts LCRN–1 which maintains the relay around contacts LCRPC–4 and LCRPD–4. The aforementioned operation of limit switch LPLSD results in closure of its contacts LPLSD–4 and an energizing circuit is thereby completed for relay LCRBV through limit switch contacts LPLSD–4 and contacts LCRN–3 of relay LCRN. Contacts LCRBV–2 and LCRBV–3 close to complete an energization for operating coil LBV1 of brake valve LBV in conduit 28.

Opening of valve LBV1 permits meter-pump 26 to pump fluid into the upper end of cylinder 9 and as slide block 26*a* is then being moved toward extreme position in the "pumping" region, the rate of fluid flow increases. Consequently piston 8 is caused to accelerate downwardly in cylinder 9 to cause corresponding acceleration of gate in the upward or "closing" direction.

The aforementioned energization of relay LCRC resulted in closure of contact LCRC–3 thereof and closure of the latter results in completion of an energizing circuit for relay LCRHS through the then closed limit switch contact LGLSC–1 and interlock contacts MCRMS–3 of relay MCRMS. Energization of the latter results in closure of contacts LCRHS–3 and the latter contacts together with the then closed limit switch contacts LPLSF–1 provides a maintaining circuit around contacts LCRPD–1 for relay LPCC. The aforementioned operation of limit switch LPLSD results in closure of contacts LPLSD–3 to complete an energizing circuit for relay LCRPD so that its contacts LCRPD–1 open at that time.

The accelerated movement of piston 8 and the gate continues until the traveling nut 26*b* trips limit switch LPLSF to open contacts LPLSF–1 and close contacts LPLSF–2 thereof. Opening of contacts LPLSF–1 results in deenergization of contactor LPCC to deenergize slide block drive motor 36 and brake release winding 36*a*. Movement of slide block 26*a* is then stopped at an extreme position in the pumping direction, and meter-pump 26 then pumps fluid into cylinder 9 at a fixed displacement and piston 8 and gate 7 then move at a uniform rate. LSLSA closes, LGLSB–1 opens and LCRSD2 drops out.

Gate 7 is raised at high speed and at near fully raised position, limit switch contacts LGLSC–2 close. Closure of the latter contacts complete the energizing circuit for relay LCRSD–1 through the then closed contacts LCRSD2–2. Closure of contacts LCRPD–3 of previously energized relay LCRPD and closure of contacts LCRSD2–2 of relay LCRSD2 completes an energizing circuit for relay LCRSD1 through the then closed limit switch contacts LGLSC–2. Simultaneously LGLSC–1 opens to drop out relay LCRHS.

Energization of relay LCRSD1 results in closure of its contact LCRSD1–1 completes an energizing circuit for contactor LPCO through the then closed contacts MCRHL1–2, contacts LCRSD1–1 and the previously closed contacts LCRPD–3 and closed interlock contact LPCC–1. Contacts LPCO–2, 3 and 4 close to energize brake release winding 36*a* and motor 36 to afford drive of slide block 26*a* back toward its "neutral" zone. In so doing the output of meter-pump 26 is decreased and the rate of movement of piston 8 and gate 7 thereby reduced.

Ultimately the traveling nut follower 26*a* re-operates limit switch LPLSF and LPLSD and contacts LPLSF–1, LPLSD–2 reclose. Closure of the latter contacts results in completion of an energizing circuit for relay LCRSD2 through the then closed limit switch contacts LGLSC–2. Contacts LCRSD2–1 close to provide a maintaining circuit for relay LCRSD2 around contacts LPLSD–2 and LPLSC–3. Contacts LCRSD2–2 open to deenergize relay LCRSD1.

Deenergization of relay LCRSD1 results in opening of its contacts LCRSD1–1 to deenergize contactor LPCO to momentarily deenergize the brake release winding 36*a* and motor 36. Interlock contacts LPCO–1 recloses, and as a result, the energizing circuit is again completed from contactor LPCC to reenergize brake release winding 36*a* and motor 36 to drive slide block 26*a* out of the "neutral" zone in the "pumping" region. Displacement of the pumping of meter-pump 26 is thereby increased and continues to increase until the traveling nut slide block follower nut 26*b* operates limit switch LPLSD. Contacts LPLSD–3 then close to again energize relay LCRPD. Opening of contacts LCRPD–1 of the latter then results in deenergization of contactor LPCC.

With contactor LPCC again deenergized the brake release winding 36*a* and motor 36 are deenergized to stop movement of slide block 26. As a result meter-pump will then pump fluid at some low fixed displacement into cylinder 9, and piston 8 and gate 7 will then move upwardly at a corresponding slow creeping speed.

As the gate moves just past its upper normal or "latched" position, limit switch LGLSD opens. If contacts LCRSD2–3 are not closed (signifying that "slow down" operation of the slide block has not been completed), the opening of limit switch LGLSD will cause deenergization of relay MCR1. It will be seen that opening of contacts MCR1–1 results in deenergization of contactor LPCM and timing relay LTR to stop the metering pump drive motor and close the brake valve. Thus movement of the gate will be stopped. However, if when such "check point" is reached and contacts LCRSD2–3 have closed (signifying completion of "slow down" operation of the slide block), relay MCR1 will

be maintained energized around the then open limit switch LGLSD by contacts LCRSD2–3 and the gate will continue upwardly at creeping speed.

At this point it may be assumed that holding latches are moved into interferring relation with gate 7 by any preferred means (not shown) and that following completion of movement of the latches a limit switch LLILS–2 re-closes to complete an energizing circuit for relay LCRLI. Contacts LCRLI–2 of the latter thus close to complete an energizing circuit for relay LCRO1 through the then closed contacts LCRSC–5, LPSI and MLRA–2. Opening coil MLR–0 of latched relay MLR, due to contacts MLR–1 then being closed, is also energized in parallel with relay LCRO1 to trip or release latch relay MLR.

As a result of energization of relay LCRO1 contacts LCRO1–5 close to complete an energizing circuit for relay LCRO2. Contacts LCRO2–2 of the latter then open to deenergize relay LCRSC. The aforementioned energization of relay LCRO1 results in closure of its contacts LCRO1–3 to complete an energizing circuit for contactor LPCO through the then closed contacts LCRSKO–1, LCRPC–1 and interlock contacts LPCC–1. Consequently, brake release winding 36*a* and motor 36 are again energized to effect drive of the slide block 26*a* back into and through its "neutral" zone a certain amount in the "metering" range. As slide block moves into the "metering" range fluid is caused to flow back out of cylinder 9 to cause piston 8 to move upwardly and gate 7 to move downwardly at creeping speed.

However, such downward movement of gate 7 is slight before the traveling nut 26*b* operates limit switch LPLSC–1 to close its contact LPLSC–1. Closure of the latter contacts results in completion of an energizing circuit for relay LCRPC. As a result contacts LCRPC–1 open to interrupt the energizing circuit for contactor LPCO and thus slide block 26*a* is stopped in the position then attained. At this point gate 7 is just slightly above the inserted latches and moving downwardly at creeping speed and then ultimately comes to rest on the latches.

When gate 7 comes to rest on the latches pressure of the fluid in cylinder 9 decreases as the latter is metered out above piston 8. Consequently, pressure switch LPS responds to open its contacts LPS1. Opening of contacts LPS1 results in deenergization of relay LCRO1 when it opens its contacts LCRO1–5 to effect deenergization of relay LCRO2. Contacts LCRO1–2 also open to deenergize relay LCRN. Contacts LCRN–3 thereupon open to deenergize relay LCRBV. Opening of contacts LCRBV–2 and 3 of the latter results in deenergization of operating coil LBV1 of brake valve LBV to close the latter to stop flow of fluid in conduit 28.

Deenergization of relay LCRN also results in reclosure of its contacts LCRN–4 and thus completes an energizing circuit for contactor LPCC through the then closed contacts MCRHL1–2, LCRPC–3 and interlock contacts LPCO–1. Consequently slide block 26*a* is then driven back into its "neutral" zone. During such movement the traveling nut follower 26*a* reoperates limit switch LPLSC to open its contact LPLSC–1 which results in deenergization of relay LCRPC. Contacts LCRPC–3 thereupon open to deenergize contactor LPCC when slide block 26*a* has reached some position within its "neutral" zone.

It can be assumed that the right-hand hoisting system will complete "normal closing" operation at approximately the same time, the gate 7 will then rest "level" on the holding latches.

Normal opening operation

Assuming that fluid meter pumps are being driven, operation of the master "opening-closing" switch to opening position will result in energization of the slide block driving motors to drive the slide blocks out of their "neutral" zones in the direction affording "pumping" at a slow rate. The brake valves are then opened and fluid is pumped into the upper end of the cylinders to raise the gate at slow or creeping speed. The holding latches are then withdrawn and when they reach withdrawn position, the control system functions to reverse the direction of drive of the slide blocks back through their "neutral" zones on into their "metering" regions. The upward movement of the gate is momentarily halted, and then moves downwardly under its own weight at an increasing rate as the slide blocks move farther into their "metering" region. The slide blocks continue to move into their "metering" region until predetermined positions are reached wherein they are stopped and metering of fluid from the upper to the lower cylinder chambers then continues at a corresponding fixed rate or displacement to afford lowering of the gate at high speed. When the gate is lowered to within a given distance of its bumpers, the slide block of the meter-pumps are driven back toward the "neutral" zone to positions affording slow down of fluid metering and hence the rate of gate lowering is reduced to creeping speed. As the gate passes a second position below the aforementioned predetermined position and the gate has not slowed down to creeping speed, it will automatically be stopped at that position. However, if it has slowed down to creeping speed when it reaches the second position it continues on down until it rests on the bumpers. When the weight of the gate is relieved from the cables, the brake valves close and the slide blocks then return to their "neutral" zones. A detailed description of operation of the control system to afford the aforedescribed operation will now be made.

To initiate gate "opening" operations the three-position selector switch MOCS is closed to its "open" contact to complete an enengizing circuit for relay MCRO1 through the then closed contacts LCRSC–6 and MCRC–4. Contacts MCRO2–3 thereupon close to energize relay LCRSO through the then closed contacts MCRC1–3 and LCRO2–1. Contacts LCRSO–1 then close to maintain relay LCRSO around contacts MCRO2–3 and contacts LCRSO–3 close to complete an energizing circuit for closing coil MLR–C of latched relay MLR through the then closed contacts LLOLS–1 and MLR–2. Latched relay MLR then operates and contacts MLR–7 close to complete an energizing circuit for relay MLRA.

Contacts MLRA–1 close to complete an energizing circuit for relay LCRC through the then closed contacts LCRSO–3 and limit switch contacts LLOLS–1 and contacts MLRA–1. As a result contacts LCRC–2 close to complete an energizing circuit for contactor LPCC through the then closed contacts LCRSKC–1, LCRPD–1 and interlock contacts LPCO–1. Brake 36*a* is thereby released and motor 36 drives slide block 26*a* out of its "neutral" zone into the "pumping" direction. Closure of contacts LCRSO–2 results from the last mentioned energization of relay LCRSO and such closure completes an energizing circuit for relay LCRN through the then closed contacts LCRPC–4 and LCRPD–4. Closure of contacts LCRN–1 maintains relay LCRN. As the slide block moves into its "pumping" region it operates limit switch LPLSD to close its contacts LPLSD–4 which then results in completion of an energizing circuit for relay LCRBV through the then closed contacts LCRN–3. Relay LCRBV is maintained around contacts LPLSD–4 and LPLSC–2 by closure of its contacts LCRBV–1. Closure of contacts LCRBV–2 and 3 results in energization of coil LBV1 of brake valve LBV, whereupon fluid is then pumped into the upper chamber of the cylinder to raise the gate off of its holding latches.

As the slide block 26*a* moves into its "pumping" region it operates limit switch LPLSD to close its contacts LPLSD–3 to complete an energizing circuit for relay LCRPD. Contacts LCRPD–1 thereupon open to deenergize contactor LPCC which results in deenergization of motor 36 and setting of the brake 36*a* to stop slide block 26*a* in a position affording pumping into the cylinder at

a displacement or rate providing raising of the gate at creeping speed.

As the gate is raised off its holding latches the same may be assumed to be withdrawn, and upon initiation of their withdrawal limit switch LILS is reset to reopen its contacts LILS–1 and consequently, relay LCRLI becomes deenergized. When the latches reach fully withdrawn positions limit switch LLOLS is tripped to open its contacts LLOLS–1 to deenergize relay LCRC and to close its contacts LLOLS–2 to complete an energizing circuit for relay LCRLO.

Energization of relay LCRLO results in closure of its contacts LCRLO–4 to complete an energizing circuit for opening coil MLR–0 of latched relay MLR through the then closed contacts LCRSO–5, LPS1 and MLR–1. Relay MLR operates and opening of its then closed contacts MLR–1 deenergizes coil MLR–0. Contacts MLR–7 also open to deenergize relay MLRA and as a result contacts MLRA–2 close to energize relay LCRO1. Contacts LCRO1–5 then close to complete an energizing circuit for relay LCRO2.

Energization of relay LCRO1 results in closure of its contacts LCRO1–3 to complete an energizing circuit for contactor LPCO through the then closed contacts LCRSKO–1, LCRPC–1 and interlock contacts LPCC–1. The aforementioned energization of relay LCRO1 and closing of contacts LCRO1–4 resulted in completion of an energizing circuit for relay LCRHS through the then closed contacts LCRLI–4 and LGLSB–2, and thus contacts LCRHS–1 provide a maintaining circuit, in conjunction with the then closed contacts LPLSA–2 of limit switch LPLSA, for contactor LPCO. Contacts LPCO–2, 3 and 4 close to energize motor 36 to drive it in the direction to move slide block 26*a* through its "neutral" zone and beyond into the "metering" direction. Consequently, the gate's upward movement is stopped and then begins to move downwardly as the slide block moves into its "metering" region. As the slide block moves farther into its "metering" region the rate of fluid metering increases and the gate accelerates downwardly.

Before slide block 26*a* moves into the "neutral" zone from its "pumping" region limit switch LPLSD operates and contacts LPLSD–3 open to deenergize relay LCRPD, and as the slide block moves out of the "neutral" zone into the "metering" region limit switch LPLSC operates and closure of its contacts LPLSC–1 completes an energizing circuit for relay LCRPC. The slide block continues to move father into the "metering" region and the rate of movement of gate downwardly increases until limit switch LPLSA is operated to open its contacts LPLSA–2 which results in deenergization of contactor LPCO and stopping of movement of the slide block in a given position in its "metering" region. The gate thereafter continues to move downwardly at a uniform high speed.

As the gate approaches the bumpers limit switch LGLSB is operated and closure of its contacts LGLSB–1 completes an energizing circuit for relay LCRSD1 through the then closed contacts LCRSD2–2 of relay LCRSD2. Contacts LCRSD1–1 then close to complete an energizing circuit for contactor LPCC through the then closed contacts MCRHL1–2, LCRPC–3 and LPCO–1. Thus the slide blocks are driven back toward the "neutral" zone to reduce the metering rate of the meter-pump and hence the rate of lowering of the gate. As the slide blocks move back toward the "neutral" zone limit switch LPLSA is reset to reclose its contacts LPLSA–2 and just before it reaches its "neutral" zone limit switch LPLSC is reset to reopen its contacts LPLSC–1 to deenergize relay LCRPC. Then contacts LCRPC–3 reopen and deenergize contactor LPCC and stop the slide blocks momentarily in the "neutral" zone.

The last mentioned reset of limit switch LPLSC also results in closure of its contacts LPLSC–3 to complete an energizing circuit through their closed limit switch contacts LGLSB–1 and contacts LPLSD–2 for relay LCRSD2. Closure of contacts LCRSD2–1 maintains relay LCRSD2 around contacts LPLSC–3 and LPLSD–2. Contacts LCRSD2–2 open to deenergize relay LCRSD1. The aforementioned reset of limit switch LGLSB also reopened its contacts LGLSB–2 to deenergize relay LCRHS to open its contacts LCRHS–2 and close its contact LCRHS–5.

The last mentioned deenergization of contactor LPCC results in reclosure of its contacts LPCC–1 to complete an energizing circuit through closed contacts LCRO1–3, LCRSKO–1 and LCRPC–1 for contactor LPCO. The slide block moves back out of the "neutral" zone into the "metering" region and limit switch LPLSC is tripped. Contacts LPLSC–1 thereupon close to complete an energizing circuit for relay LCRPC. Contacts LCRPC–1 of the latter relay then open to deenergize contactor LPCO to the slide block in a position in the "metering" region affording creeping speed lowering of the gate.

With the meter-pump metering rate reduced, the gate then slows down to approach the bumpers at creeping speed. As it continues to lower a "check" point is reached when limit switch LGLSA is opened. If contacts LCRSD2–3 are not closed (signifying that "slow down" operation of the slide block last described has not been completed), the opening of limit switch LGLSA will cause deenergization of relay MCR1. It will be seen that opening of contacts MCR1–1 will result in deenergization of contactor LPCM and timing relay LTR to stop the metering pump drive motor and close the brake valve. On such occurrence lowering of the gate will be stopped. However, if when such "check" point is reached and contacts LCRSD2–3 have closed (signifying completion of "slow down" operation of the slide block), energization of relay MCR1 will be maintained by contacts LCRSD2–3 around the then open limit switch LGLSA and the gate will continue downwardly toward the bumpers.

When the bottom of the left side of the gate comes to rest on the bumpers the weight is relieved from the cables and pistons and consequently, pressure switch contacts LPS–1 open to deenergize relay LCRO1. From here on the reclosing of the brake valve and drive of the slide block 26*a* of meter pump 26 back to its "neutral" zone will be exactly the same as that described in detail in connection with completion of "Normal Closing Operation." It may be assumed that the right side hoisting system will complete its "Normal Opening" operation at approximately the same time and thus the entire gate will rest on the bumpers in substantially a "level" condition.

Automatic skew correction

When the gate is traveling at constant raising or lowering speed if the upper or lower side of one end of the gate should lead, or be out-of-level, with respect to the other end beyond certain limits, the differential synchro receiver serves to operate a limit switch to cause the slide block control element of the meter-pump of the leading side to be stepped back toward its "neutral" zone a predetermined amount to cause slow down of that end of the gate. If such slow down is sufficient to permit the other end to catch up and the gate made substantially level, then the slide block of the previously leading side is returned to its previous operating position. The differential synchro receiver also functions to provide skew correction when the gate is accelerating in the raising or lowering direction but then the slide block associated with the leading end is stopped in its movement until the other end comes within the aforementioned degree of level therewith and then continues on to its normal position for the speed selected. The independent hoisting systems associated with the respective gate ends are thus coordinated to minimize the amount of skew that can occur. A detailed description of the control system to afford such operation will now be made.

Let it be assumed that the gate is to be raised at high

speed as aforedescribed under "Normal Closing Operation." Under such conditions the slide block control element 26*a* will be in its farthest extreme position in the "pumping" region and limit switch LPLSD and LPLSF will be tripped. If the left upper end of the gate leads the right upper end by a small amount, skew limit switch MDSRSKA closes to complete an energizing circuit for relay MCRSKA which then closes its contacts MCRSKA–4. If such lead or skew exceeds a given amount, say one and one-half inches, skew limit switch MDSRSKC then closes to complete an energizing circuit for relay MCRSKC which is then maintained through closed contacts MCRSKA–4 and MCRSKC–5.

Contacts MCRSKC–1 close to complete an energizing circuit for relay LCRSKC through the then closed contacts MLRA–6. Contacts LCRSKC–2 thereupon close to complete an energizing circuit for contactor LPCO through closed contacts LCRHS–4, LPLSF–2 and interlock contacts LPCC–1. The slide block 26*a* is then driven back toward its "neutral" zone until limit switch LPLSF resets to open its contacts LPLSF–2 which deenergizes contactors LPCO to stop movement of the slide block. Thus as the slide block has been stepped back a small fixed amount toward its "neutral" zone, the displacement or output of meter-pump 26 will be decreased by a corresponding amount to slow down the rate of upward movement of the left end of the gate.

Now assuming that slow down of the left end of the gate permits the right end to catch up and decrease the skew below one and one-half inches, limit switch MDSRSKC will reopen. At a point, just prior to the ends of the gate coming into exact level, limit switch MDSRSKA reopens to deenergize relay MCRSKA. Contacts MCRSKA–4 of the latter then reopen to deenergize relay MCRSKC and contacts MCRSKC–1 reopen to deenergize relay LCRSKC. Contacts LCRSKC–2 reopen and contacts LCRSKC–1 reclose to complete an energizing circuit for contactor LPCC through the then closed contacts LCRC–2, LCRHS–3 and LPLSF–1 and interlock contacts LPCO–1. The slide block is then driven back toward the position affording high speed raising of the left end of the gate until limit switch LPLSF is tripped to open contacts LPSF–1 to deenergize contactor LPCC which stops the slide block in the position affording high speed raising of the left end of the gate.

Now let it be assumed that the gate is being lowered at high speed as aforedescribed under "Normal Opening Operation." Under such conditions the slide block control element 26*a* will be in its extreme position in the "metering" region. If the left lower end of the gate leads the right lower end by a small amount, skew limit switch MDSRSKB closes to complete an energizing circuit for relay MCRSKB and contacts MCRSKB–4 of the latter close.

If the left lower end of the gate is skewed or leading by an amount in excess of one and one-half inches over the right lower end, skew limit switch MDSRSKD closes to complete an energizing circuit for relay MCRSKD which is then maintained through closed contacts MCRSKB–4 and MCRSKD–5. Closure of contacts MCRSKD–1 completes an energizing circuit for relay LCRSKO through the then closed contacts MLRA–5. Contacts LCRSKO–2 close to complete an energizing circuit for contactor LPCC through closed contacts LCRO1–3 and LCRHS–2, limit switch contacts LPLSA–1 and interlock contacts LPCO–1. Thus the slide block will be driven toward its "neutral" zone a small amount until limit switch LPLSA is reset to open its contacts LPLSA–1 to deenergize contactor LPCC. Thus as the slide block is stepped back this small amount the metering output of the meter-pump 26 will be decreased a proportionate amount to slow down the rate of downward movement of the left end of the gate.

If the latst mentioned slow down of the left end of the gate permits the right end of the gate to catch up and decrease the skew below one and one-half inches, limit switch MDSRSKD will reopen. If the skew decreases to a point where the left and right ends are substantially in level, limit switch MDSRSKB will reopen to deenergize relay MCRSKB and contacts MCRSKB–4 of the latter then reopen to deenergize relay MCRSKD. Contacts MCRSKD–1 reopen to deenergize relay LCRSKO and contacts LCRSKO–2 open and contacts LCRSKO–1 reclose to complete an energizing circuit for contactor LPCO through closed contacts LCRO1–3, LCRHS–1, limit switch contacts LPLSA–2 and interlock contacts LPCC–1. The slide block is then driven back toward its extreme position in the "metering" region and limit switch LPLSA is tripped to open its contacts which deenergize contactor LPCO to stop the slide block in the last mentioned extreme position wherein the left end of the gate is again lowered at high speed.

The aforementioned skew correction can, of course, take place repeatedly during closing and opening operations. Skew correction is also afforded when the gate is accelerating to high speed either during closing or opening operation as will now be described.

Assume that the gate is at rest on the bumpers in fully open position and that closing operation is initiated as aforedescribed in connection with "Normal Closing Operation," that the slide block control elements have moved from their "neutral" zone into their "pumping" region toward high speed positions. As the gate accelerates upwardly assume that the upper left end of the gate leads the upper right end an amount sufficient to close limit switch MDSRSKA, which thereby completes an energizing circuit for relay MCRSKA to in turn close its contacts MCRSKA–4. If such lead or skew of the upper left end exceeds one and one-half inches, limit switch MDSRSKC will close to energize relay MCRSKC which then closes contacts MCRSKC–5 to maintain itself. Contacts MCRSKC–1 also close to complete an energizing circuit for relay LCRSKC through closed contacts MLRA–6. As a result contacts LCRSKC–1 open to deenergize contacts LPCC which stop the slide block then attained in the pumping region. The meter-pump 26 then pumps at a corresponding rate while meter pump 27 may be assumed to increase its pumping rate to continue acceleration of the right end of the gate upwardly.

Let it be assumed that the right end catches up and skew is reduced below one and one-half inches. Limit switch MDSRSKC will then open. When the skew is reduced to a point where the ends of the gate are substantially level, limit switch MDSRSKA opens to deenergize relay MCRSKA. Contacts MCRSKA–4 open to deenergize relay MCRSKC and opening of contacts MCRSKC–1 of the latter results in deenergization of relay LCRSKC. Consequently, contacts LCRSKC–1 reclose to complete an energizing circuit for contactor LPCC and thus the slide block 26*a* is then again driven toward its extreme position in its "pumping" region to again accelerate the left end of the gate upwardly to attain high speed uniform movement of the latter.

Assume that the holding latches have been withdrawn and the slide blocks associated with meter-pumps 26 and 27 are being driven from their "neutral" zones toward their extreme position in the metering region to accelerate movement of the gate downwardly. Let it be assumed that during such movement of the slide blocks the left lower end of the gate becomes low by a small amount. Limit switch MDSRSKB will then close to complete an energizing circuit for relay MCRSKB which then closes its contacts MCRSKB–4. If such skew increases beyond one and one-half inches then limit switch MDSRSKD will close to complete an energizing circuit for relay MCRSKD which is then maintained through closed contacts MCRSKB–4 and MCRSKD–5.

Contacts MCRSKD–1 also close to complete an energizing circuit for relay LCRSKO through the closed contacts MLRA–5. Contacts LCRSKO–1 then open to deenergize contactor LPCO to stop slide block 26*a* in

the position then attained and hold the lowering speed of the left end of the gate at the speed then attained while the right end continues to increase its speed downwardly.

If such corrective action decreases the skew below one and one-half inches, limit switch MDSRSKD will then open. When the skew is reduced to a point where the ends of the gate are substantially level, limit switch MDSRSKB opens to deenergize relay MCRSKB and the opening of contacts MCRSKB–4 open to deenergize relay MCRSKD and the opening of contacts MCRSKD–1 of the latter results in deenergization of relay LCRSKO and reclosure of its contacts LCRSKO–1 to again complete the energizing circuit for contactor LPCO through the closed contacts LCRO1–3, LCRHS–1 and LPLSA–2 and interlock contacts LPCC–1. Slide block 26*a* is then again driven toward its extreme position in its "metering" region to increase the speed of the left end of the gate in its downward "opening" movement.

The aforedescribed corrective action takes place within predetermined limits of skew, for example one and one-half inches to three inches. If such skew correction is not effective and the skew increases beyond the larger limit automatic shut down occurs as will hereinafter be described.

Extreme skew shut down

If the aforedescribed skew correction is not effective and the skew continues to increase beyond another limit, for example three inches, another skew limit switch associated with the synchro receiver is operated to initiate complete shut down of the gate hoisting system by deenergizing the meter-pump driving motors and setting of the brake valves. The slide blocks of the meter-pumps are then driven back to their "neutral" zones and stopped. A detailed description of the system to afford such action follows.

Assume that the gate is being raised, that the automatic skew correction is unable to decrease or halt the skew or lead of the left upper end and that such skew ultimately exceeds three inches. Extreme skew limit switch MDSRSKE will then open to deenergize relay MCRSKE which opens its contacts MCRSKE–1 to deenergize relay MCR1. Contacts MCR1–1 then open to deenergize contactor LPCM which deenergizes motor 34 driving meter-pump 26, and timing relay LTR. Contacts LTR–1 of timing relay LTR open to deenergize all circuits therebelow which results in setting of the brake valves. The gate is then stopped and hangs on the cables in the positions then attained. Relay LCRN is deenergized and recloses its contacts LCRN–4 to complete an energizing circuit for contactor LPCO through the closed contacts MCRHL1–2, LCRPD–3 and interlock contacts LPCC–1. Thus the slide block will be driven back toward its "neutral" zone. As it moves into the "neutral" zone, limit switch LPLSD is reset to reopen its contacts LPLSD–3 which deenergizes relay LCRPD. Contacts LCRPD–3 of the latter open to deenergize contactor LPCO to stop slide block 26*a* in its "neutral" zone.

Let it be assumed that the gate is being lowered and the skew or lead of the lower left end exceeds three inches. Extreme skew limit switch MDSRSKE will then open to effect deenergization of relay MCR1. Contacts MCR1–1 then open to effect deenergization of contactor LPCM and timing relay LTR to shut down the hydraulic system and hold the gate on the cables in the position then attained as aforedescribed.

Reclosure of contacts LCRN–4 completes an energizing circuit for contactor LPCC through the then closed contacts MCRHL1–2, LCRPC–3 and interlock contacts LPCO–1 to afford drive of slide block 26*a* out of the metering region into the "neutral" zone. As it passes into the "neutral" zone limit switch LPLSC is reset to reopen its contacts LPLSC–1 which deenergizes relay LCRPC to open contacts LCRPC–3 of the latter which deenergizes contactor LPCC to stop the slide block 26*a* in the "neutral" zone.

Manually initiated automatic leveling from extreme skew shut down condition

Upon restart of drive of the meter-pump and operation of a master leveling switch the control system will function to return the leading end of the gate into level with the trailing end and stop the hydraulic system to permit initiation of normal closing or opening operation of the gate as desired. The system takes into account whether the gate was being moved in the upward-closing or the downward-opening direction at the time extreme skew shut down occurs. Thus, if it occurred on "closing" then the leading end of the gate is lowered into level with the trailing end and if it occurred on "opening" the leading end of the gate is raised into level with the trailing end. A detailed description of the control system operation to afford such action follows:

Let it be assumed that at the time extreme skew shut down occurred that the gate was moving upwardly and that the upper left end was leading. Pushbutton switch LPB1 is then operated to close its contacts LPB1–2 to complete an energizing circuit for relay LCRHLV through stop switch 64, contact LPB1–2 and LCRN–2. Contacts LCRHLV–2 close to complete an energizing circuit for relay MCR1 through the closed limit switch contacts LGLSA. Contacts MCR1–1 then close to complete an energizing circuit for contactor LPCM and timing relay LTR which are then maintained by closure of contacts LPCM–4. Relay LCRHLV is maintained around switch LPB1 through the then closed contacts LCRHLV–1 and the latter switch then may be released. At this point the drive motors for the meter-pump will be energized.

Leveling operation is initiated by operation of hand leveling master switch MHLVS to close its contacts MHLVS3–4 which completes energizing circuit for relays MCRHL1 through their closed contacts LTR–1, LCRHLV–3 and MCRSKA–3. Relay MCRHL1 is then maintained by closure of contacts MCRHL1–1. Contacts MCRHL1–6 close to energize contactor LPCO through contacts MCRSKA–1, MLRA–3, LCRPC–1 and interlock contacts LPCC–1. Slide block 26*a* is then driven out of its "neutral" zone into its "metering" region and in so doing limit switch LPLSC is tripped to close its contacts LPLSC–1 and LPLSC–2.

Closure of contacts LPLSC–1 completes an energizing circuit for relay LCRPC and closure of contacts LPLSC–2 completes an energizing circuit for relay LCRBV through their closed contacts MCRHL1–3. Closure of contacts LCRBV–1 maintains relay LCRBV around limit switch contacts LPLSC–2 and LPLSD–4 contacts LCRBV–2 and LCRBV–3 close to complete an energizing circuit for coil LBV1 of brake valve LBV to open the latter. Fluid is then metered out of the upper end of cylinder 9 and the left side of the gate commences to lower. The last mentioned energization of relay LCRPC opens its contacts LCRPC–1 which results in deenergization of contactors LPCO just as the slide block reaches creeping speed metering position. Metering, and consequently lowering of the left end of the gate, then proceeds at creeping speed until the skew between gate ends decreases below three inches at which point extreme skew limit switch MDSRSKE recloses to energize relay MCRSKE. Contacts MCRSKE–1 then close.

The left end of the gate continues to be lowered and when the skew decreases below one and one-half inches limit switch MDSRSKC reopens, and the lowering of the gate continues until the gate ends are substantially in level when limit switch MDSRSKA reopens to deenergize relay MCRSKA. Contacts MCRSKA–3 open to deenergize relay MCRHL1.

Contacts MCRHL1–2 reclose to complete an energizing circuit for contactor LPCC through the closed contacts LCRN–4, LCRPC–3 and interlock contacts LPCO–

1. Thus slide block 26*a* is driven back to the "neutral" zone and in so doing limit switch LPLSC is reset thereby opening its contacts LPLSC–1 which effects deenergization of relay LCRPC. Contacts LCRPC–3 open and deenergize contactor LPCC to stop slide block 26*a* in the "neutral" zone.

Contacts MCRHL1–3 are open concurrently with contacts MCRHL1–1 to deenergize relay LCRBV. Contacts LCRBV–2 and 3 then open to deenergize coil LBV1 of brake valve LBV to close the latter. Hence leveling will be completely halted with the gate hanging on the cables with the opposite ends in level.

Similar action is afforded when the gate is being lowered and its left end is low prior to extreme skew shut down. The system functions the same up to the point the hand leveling master switch MHLVS is operated and relay MCRHL1 is energized and maintained as aforedescribed. Closure of contacts MCRHL1–6 completes an energizing circuit for contactor LPCC through the closed contacts MCRSKB–1, MLRA–4, LCRPD–1 and interlock contacts LPCO–1. Slide block 26*a* is then driven out of its "neutral" zone into its "pumping" region, and in so doing limit switch LPLSD is tripped to close its contacts LPLSD–3 and LPLSD–4. Closure of contacts LPLSD–3 completes an energizing circuit for relay LCRPD and closure of contact LPLSD–4 completes an energizing circuit for relay LCRBV through the closed contacts MCRHL1–3. Closure of contacts LCRBV–1 maintains relay LCRBV around contacts LPLSD–4. Contacts LCRBV–2 and 3 close to complete an energizing circuit for LBV1 of brake valve LBV to open the latter. Fluid then commences to be pumped into the upper end of cylinder 9 to raise the left end of the gate. The energization of relay LCRPD effects opening of contacts LCRPD–1 to deenergize contactor LPCC just as slide block 26*a* reaches minimum speed pumping position. Raising of the left end of the gate then proceeds at creeping speed until the skew decreases below three inches at which point extreme skew limit switch MDSRSKE recloses to energize relay MCRSKE. Contacts MCRSKE–1 then close.

The left end of the gate continues to be raised and when the skew decreases below one and one-half inches, limit switch MDSRSKD reopens, but raising of the left end continues until the gate ends are substantially in level whereupon limit switch MDSRSKB reopens to deenergize relay MCRSKB. Contacts MCRSKB–4 open to deenergize relay MCRSKD and contacts MCRSKB–3 open to deenergize relay MCRHL1.

Contacts MCRHL1–2 reclose to complete an energizing circuit for contactor LPCO through the closed contacts LCRN–4, LCRPD–3 and interlock contacts LPCC–1. Thus slide block 26*a* is driven back to the "neutral" zone and in so doing limit switch LPLSD is reset thereby reopening contacts LPLSD–3 which effects deenergization of relay LCRPD. Contacts LCRPD–3 open to deenergize contactor LPCO to stop slide block 26*a* in the "neutral" zone.

Contacts MCRHL1–3 are opened concurrently with contacts MCRHL1–1 to deenergize relay LCRBV which results in closing of brake valve LBV when the left end of the gate has been brought back substantially in exact level with right end.

Medium speed operation

With the addition of two slide block position limit switches for each hoisting system, namely, limit switches LPLSB and LPLSE for the left side hoisting system and RPLSB and RPLSE for the right-hand hoisting system, as shown in Fig. 6, acting in cooperation with certain switches and relays hereafter to be described in connection with Figs. 5*b* and 5*c*, medium speed opening and closing operation of the gate is afforded.

Such medium speed operation affords greater gate lifting force although the pump driving motors operate at constant speed. Medium speed operation is advantageous for raising the gate under extreme load condition, such as where water may be flowing thereover from the upper pool into the lock for supplemental filling or the like.

The control to afford medium speed operation additionally comprises a manual switch MS, a relay MCRMS having normally open contacts MCRMS–2 and normally closed contacts MCRMS–3, and a relay LCRMS having normally open contacts LCRMS–1 through LCRMS–4 and normally closed contacts LCRMS–5 and LCRMS–6. With switch MS open, the control system will function as aforedescribed in connection with normal closing and opening operation. When switch MS is closed relay MCRMS is energized thereby closing contacts MCRMS–2 and opening contacts MCRMS–3. Accordingly, when opening and closing switch MOCS is thereafter closed either to its "open" or "closed" contact, relay LCRMS will thereafter be energized in place of relay LCRHS.

Energization of relay LCRMS results in closure of each of its contacts LCRMS–1 through LCRMS–4 and opening of its contacts LCRMS–5 and LCRMS–6. It will be noted that contact MCRMS–2 is connected in series with relay LCRMS and together therewith in parallel with the contacts MCRMS–3 and relay LCRHS. Thus, whenever switch MS is closed to energize relay MCRMS, relay LCRHS will be effectively excluded from circuit under all operating conditions and relay LCRMS readied for operation in its stead in exactly the same manner as aforedescribed.

Contacts LCRMS–1 and LPLSB–2 are connected in series and together in parallel with contacts LCRHS–1 and LPLSA–2 thus to render limit switch contacts LPLB–2 effective in place of limit switch contacts LPLSA–2. Similarly, contacts LCRMS–4 and LPLSE–2 are connected in series and together in parallel with contacts LCRHS–4 and LPLSF–2 thus to render limit switch contacts LPLB–2 effective in place of limit switch contacts LPLSA–2. Contacts LCRMS–3 and LPLSF–1 are connected in series and together in parallel with contacts LCRHS–3 and LPLSF–1, and contacts LCRMS–2 and LPLSB–1 are connected in series and together in parallel with contacts LCRHS–2 and LPLSA–1, thus to render contacts LPLSE–1 effective in place of contacts LPLSF–1 and to render contacts LPLSN–1 effective in place of contacts LPLSA–1.

Accordingly, the control system will function exactly the same upon operation of switch MCOS to its "close" and "open" contacts as aforedescribed under "Normal Closing" and "Normal Opening" operation, except that the slide block control element 26*b* will be halted in intermediate positions in the "pumping" and "metering" region to afford decreased output of fluid from pump 26, but at increased output pressure or back pressure as the case might be, to raise and lower gate 7 at half speed, but at increased raising force or retarded lowering force.

Similarly, the control system will function the same as aforedescribed under the heading, "Automatic Skew Correction" except that any corrective action to slow down or stop travel of a gate end will be from half speed rather than from high speed.

I claim:

1. In combination, a vertically movable structure, like hoisting systems for each end of the structure each comprising a hydraulic motor, a variable displacement fluid pump connected to said motor and having a control element operable in reverse directions from a neutral position to effect pumping of fluid into or metering it out of its connected motor and a reversible electric motor for operating said control element in said reverse directions, and control means including selectively operable means to energize said electric motors to position said control elements in a plurality of corresponding positions in said reverse directions to afford corresponding pumping and metering rates for said hydraulic motors to raise and lower said structure.

2. The combination according to claim 1 wherein said selectively operable means includes means operable to position said control elements to afford full and intermediate speed normal pumping and metering rates selectively at constant pump speeds.

3. The combination according to claim 1 wherein said control means includes means operable upon approach of said structure within predetermined distances of upper and lower extreme positions to effect positioning of said control elements at corresponding positions affording reduced raising and lowering speeds of said structure.

4. The combination according to claim 3 together with holding latches which are movable into interfering relation with the structure when the latter is moved to its upper extreme position, and wherein said control means further includes means responsive to movement of said latches into interfering relation with said structure to first cause movement of said control elements to positions corresponding to, but on the opposite side of their neutral position to that last mentioned to afford lowering of the structure onto the latches and thereafter return said control elements to their neutral positions and stop operation of said hoisting systems.

5. The combination according to claim 4 wherein when said structure is in its upper latched position and said control means is operated to select lowering operation said control elements first move to corresponding positions affording reduced speed raising of the structure to its upper extreme position, and thereafter in response to withdrawal of the latches are moved to corresponding positions on the other side of their neutral positions affording normal speed lowering operation of said hoisting systems.

6. The combination according to claim 3 wherein said control means also includes means operable upon said structure moving within a given shorter distance of its extreme positions and the rate of movement of said structure has not been reduced to said lower speed to stop said hoisting systems and cause return of said control elements to their neutral positions.

7. The combination according to claim 1 wherein said control means includes means responsive to a given difference in level between the ends of said structure during raising or lowering of the latter to adjust the control element of one or the other of said pumps a predetermined amount to change the rate of movement of one end of the structure with respect to the other.

8. The combination according to claim 7 wherein said means responsive to a given difference in level between the ends of said structure responds to adjust the control element of the pump of the hoisting system connected to the leading end of the structure said predetermined amount to slow down the leading end of the structure.

9. The combination according to claim 8 wherein the last specified means is also responsive to decrease in difference in level between the ends of said structure below said given difference to readjust the control element of the pump of the hoisting system of the leading end of the structure back to its normal position for the selected direction of movement of the structure.

10. The combination according to claim 7 wherein the last recited means when said given difference in level occurs and either of said control elements are being moved toward any of said predetermined positions stops the movement of one or the other of said control elements until the ends of the structure are substantially in level.

11. The combination according to claim 7 wherein said control means further include means responsive to another greater difference in level of the ends of the structure during raising or lowering to stop admission of fluid into or exhaustion of the same from said piston motors to stop and hold the structure in the position then attained.

12. The combination according to claim 11 wherein said selectively operable means includes means operable following the last mentioned stopping of said structure to operate one or the other of said motors individually to operate its control element to one or the other of said predetermined positions on opposite sides of its neutral position to raise or lower the connected end of said structure until brought into level with the other end thereof.

13. The combination with a vertically movable gate for a navigation lock or the like, of like hoisting systems for each end of the gate, each of which comprises a hydraulic piston motor, an electrically driven variable displacement fluid pump connected to said motor and having a control element operable in reverse directions from a neutral position to afford pumping of fluid into said motor to cause said piston to raise its connected gate end and to meter said fluid from said motor to permit said gate end to lower under its own weight, an electroresponsive valve in the fluid circuit between said pump and said piston motor which is energizable to open said fluid circuit, and a reversible electric motor for operating said control element in said reverse directions, and electrical control means including switches selectively operable to energize said valves and said electric motors to position said control elements in a plurality of corresponding positions to afford corresponding pumping and metering rates for said piston motors for raising and lowering said gate.

14. The combination according to claim 13 together with electroresponsive brakes for each of the aforementioned electric motors which are energizable and deenergizable concurrently with their respective motors to release and set the motor shafts.

15. The combination according to claim 13 wherein said control means includes a plurality of limit switches and differential synchro control means for said switches to operate certain of the latter upon occurrence of a given difference in level between the ends of said gate during raising or lowering to effect adjustment of the control element of one or the other of said pumps a predetermined amount to correspondingly change the rate of movement of one end of the gate with respect to the other.

16. The combination according to claim 15 wherein operation of said certain of said limit switches causes the control element of the pump of the hoisting system connected to the leading end of the gate to be moved back toward its neutral position a predetermined amount to slow down the rate of movement of the leading end of the gate, and wherein the last mentioned limit switches thereafter respond upon decrease in difference in level below said given amount to reposition such control element back to its normal position for the selected direction of gate travel.

17. The combination according to claim 15 wherein operation of said certain of said limit switches when either of said control elements is being moved toward a predetermined position stops movement of one or the other of said control elements until such limit switches reset upon the ends of the gate being returned to substantially in-level condition.

18. The combination according to claim 15 wherein upon occurrence of another greater difference in level between the gate ends other of said limit switches operate to deenergize said valves and the pump driving motors and return the control elements to their neutral positions to stop movement of said gate.

19. The combination according to claim 18 wherein said control means includes an electric switch which when operated following the last mentioned stopping initiates operation of the control system to operate one or the other of the control element driving motors individually to one or the other of predetermined positions on opposite sides of its neutral position and energize the

associated one of said valves to raise or lower the associated end of said gate until brought substantially in level with the other end thereof.

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