March 20, 1945. E. A. HAAGENSEN 2,371,615

HYDRAULIC SIZER FOR SUSPENDED SOLIDS

Filed Sept. 10, 1943 7 Sheets-Sheet 1

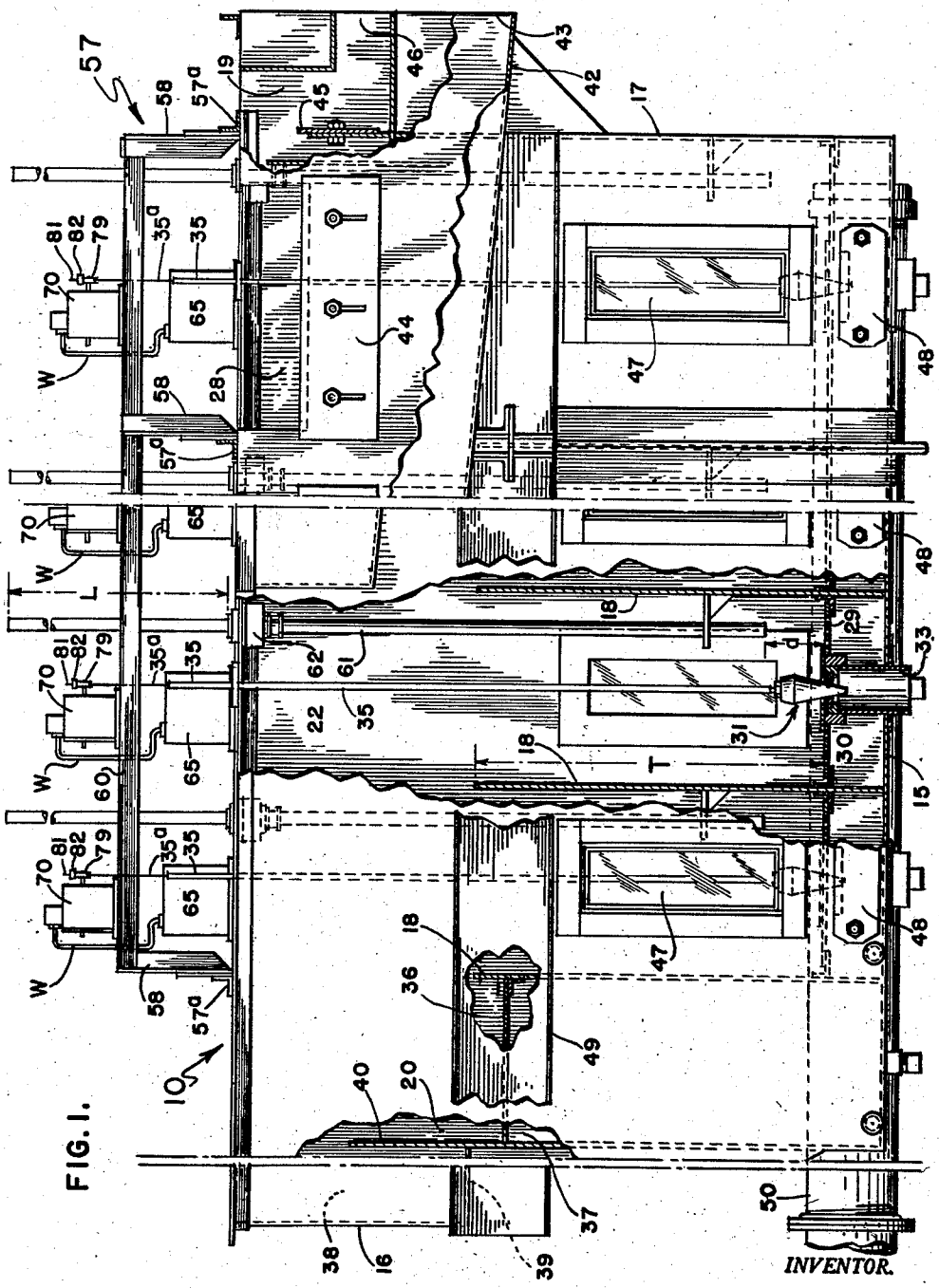


FIG. 1.

INVENTOR.

EDWARD A. HAAGENSEN,

BY

ATTORNEY

March 20, 1945. E. A. HAAGENSEN 2,371,615

HYDRAULIC SIZER FOR SUSPENDED SOLIDS

Filed Sept. 10, 1943 7 Sheets-Sheet 2

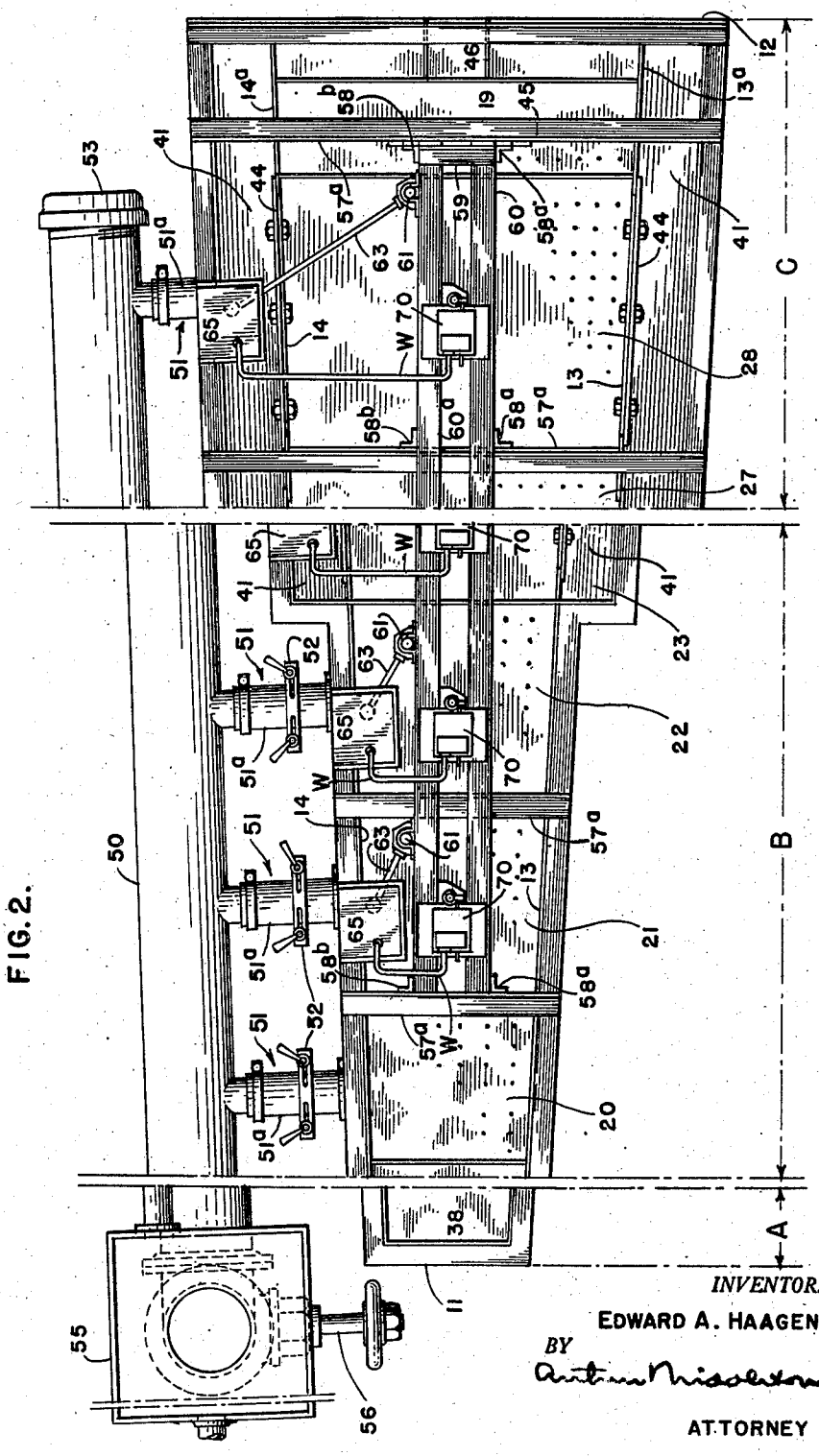


FIG. 2.

INVENTOR.
EDWARD A. HAAGENSEN,
BY
ATTORNEY

March 20, 1945. E. A. HAAGENSEN 2,371,615

HYDRAULIC SIZER FOR SUSPENDED SOLIDS

Filed Sept. 10, 1943 7 Sheets-Sheet 3

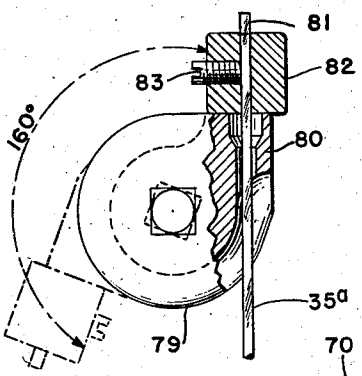


FIG. 4.

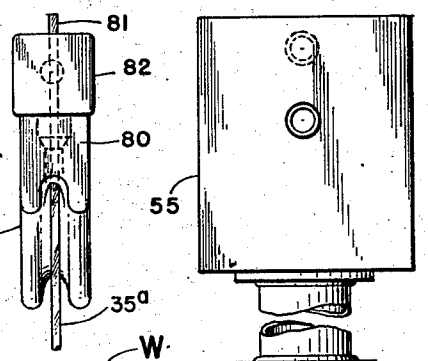


FIG. 5.

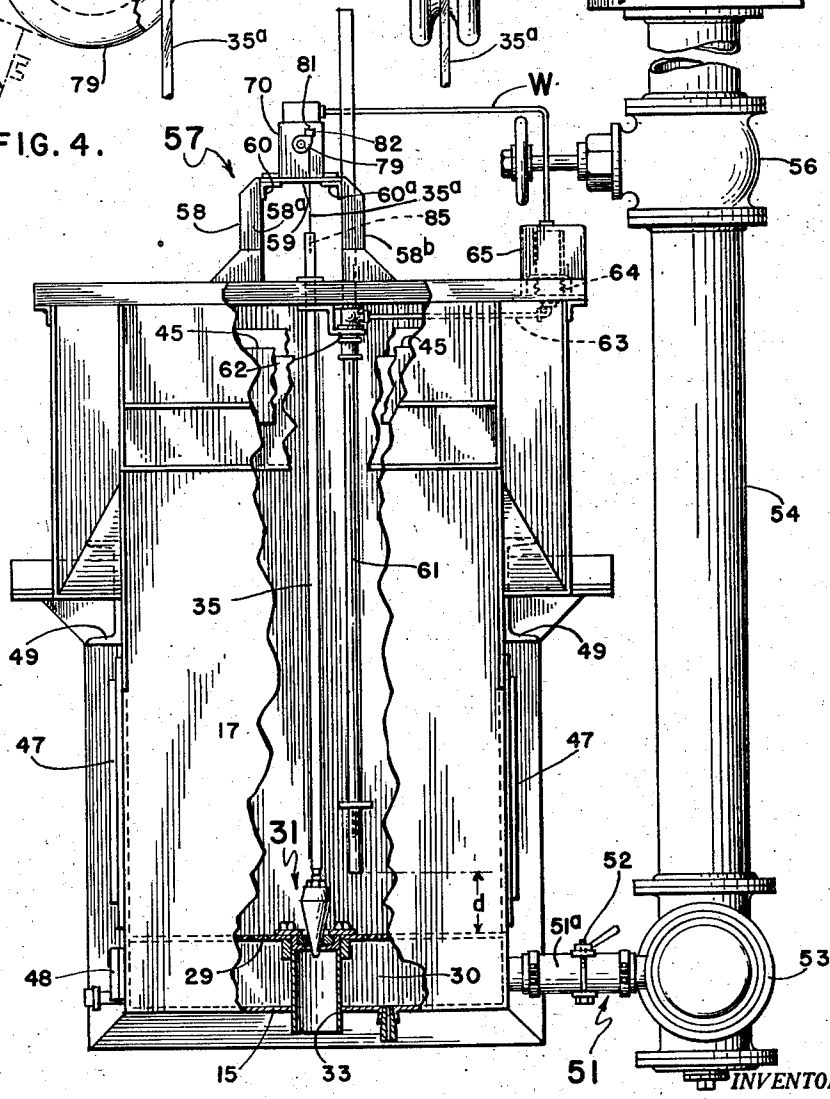


FIG. 3.

INVENTOR.
EDWARD A. HAAGENSEN,
BY
ATTORNEY

March 20, 1945. E. A. HAAGENSEN 2,371,615

HYDRAULIC SIZER FOR SUSPENDED SOLIDS

Filed Sept. 10, 1943 7 Sheets-Sheet 4

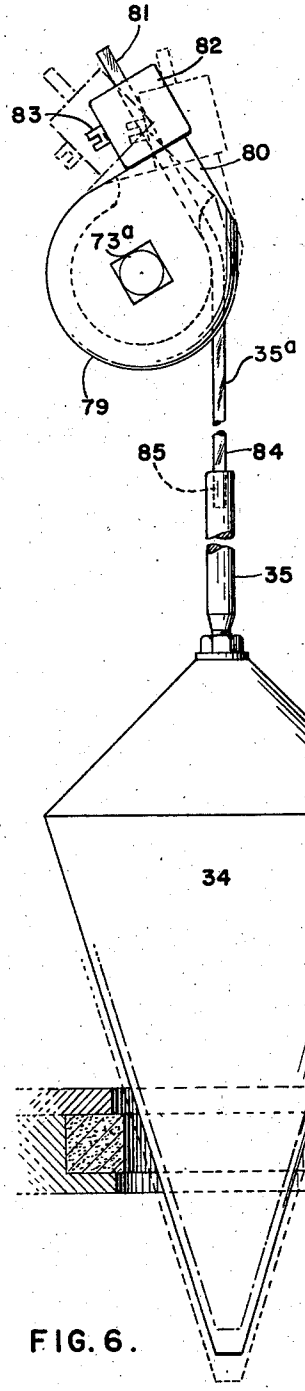


FIG. 6.

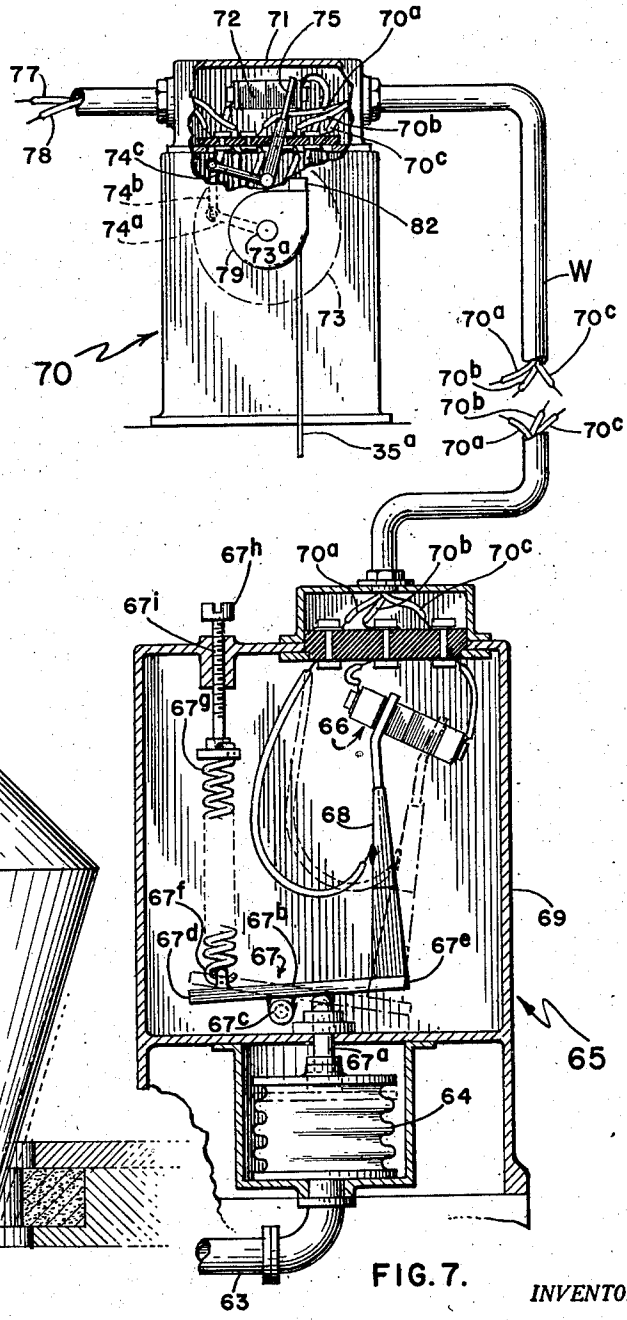


FIG. 7.

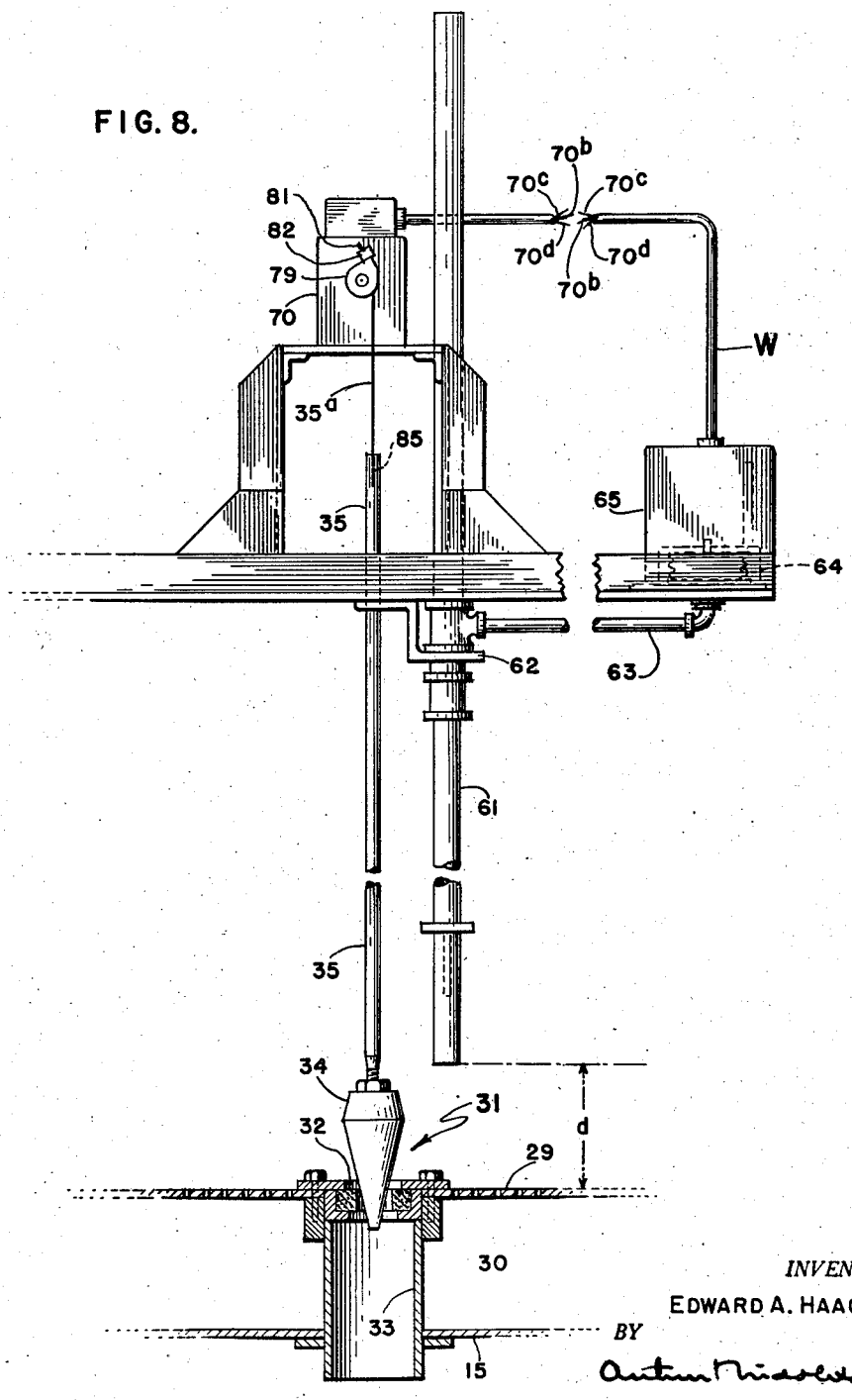
INVENTOR.
EDWARD A. HAAGENSEN,
BY
Arthur Middleton
ATTORNEY

March 20, 1945. E. A. HAAGENSEN 2,371,615

HYDRAULIC SIZER FOR SUSPENDED SOLIDS

Filed Sept. 10, 1943 7 Sheets-Sheet 5

FIG. 8.



INVENTOR.
EDWARD A. HAAGENSEN,
BY
ATTORNEY

March 20, 1945. E. A. HAAGENSEN 2,371,615

HYDRAULIC SIZER FOR SUSPENDED SOLIDS

Filed Sept. 10, 1943 7 Sheets-Sheet 6

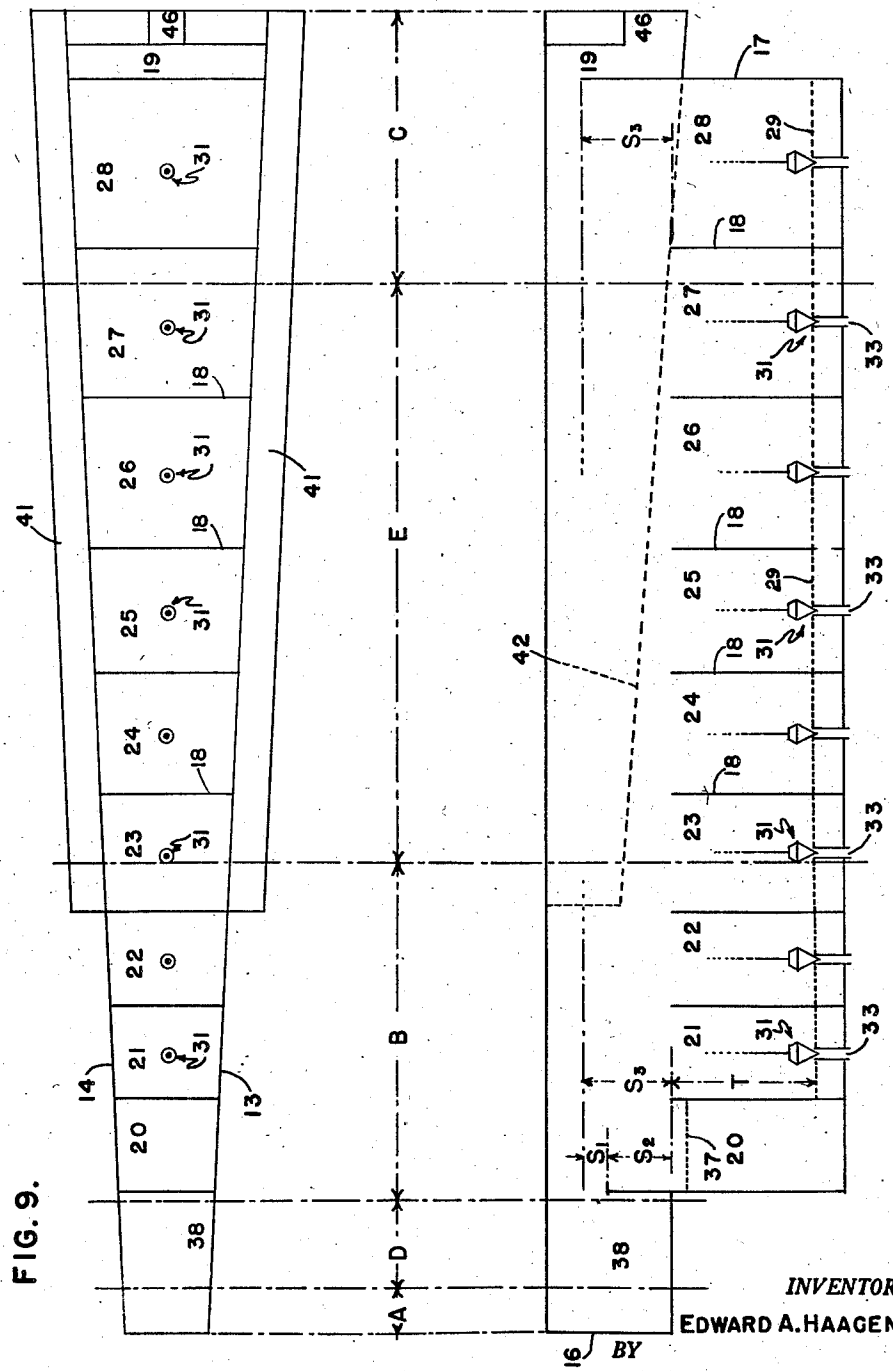


FIG. 9.

FIG. 10.

INVENTOR.
EDWARD A. HAAGENSEN,
BY
ATTORNEY

March 20, 1945. E. A. HAAGENSEN 2,371,615

HYDRAULIC SIZER FOR SUSPENDED SOLIDS

Filed Sept. 10, 1943 7 Sheets-Sheet 7

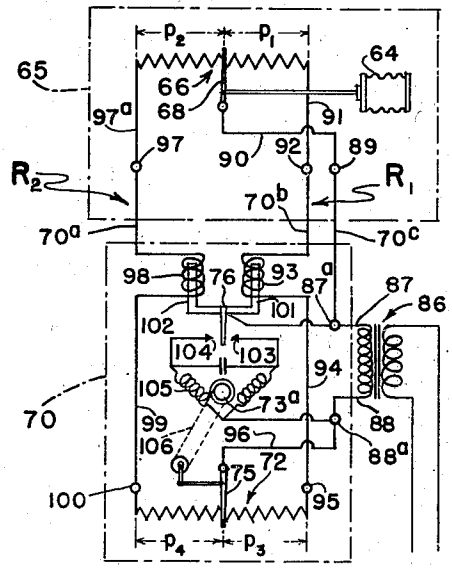


FIG. 11.

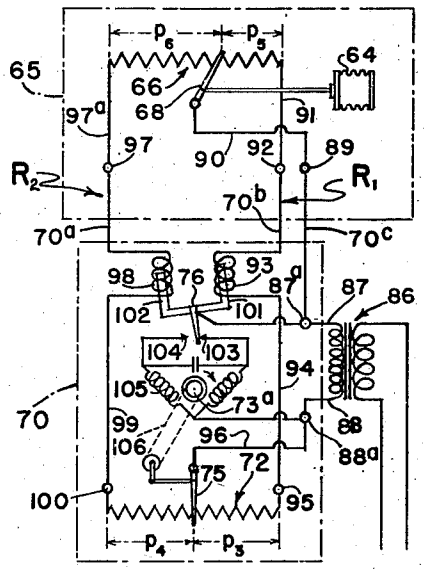


FIG. 12.

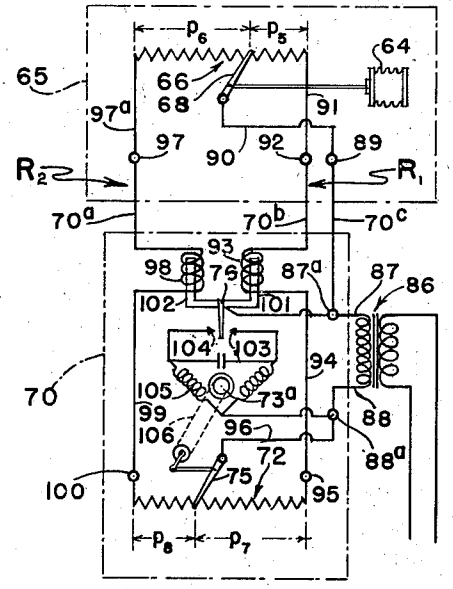


FIG. 13.

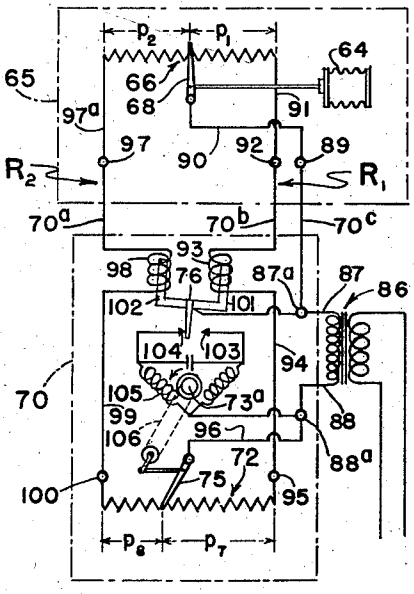


FIG. 14.

INVENTOR.

EDWARD A. HAAGENSEN,

BY

ATTORNEY

Patented Mar. 20, 1945 2,371,615

UNITED STATES PATENT OFFICE

2,371,615

HYDRAULIC SIZER FOR SUSPENDED SOLIDS

Edward A. Haagensen, Westport, Conn., assignor to The Dorr Company, New York, N. Y., a corporation of Delaware

Application September 10, 1943, Serial No. 501,841

11 Claims. (Cl. 209—496)

This invention relates to hydraulic classifiers or sizers of the hindered settling type wherein solids suspended in liquid are supplied to the sizer and the suspended solids are classified according to particle size so that one fraction issues from the sizer containing larger suspended solids or sands while another fraction issues from the sizer containing smaller sized solids, called fines.

The fractionation or size separation takes place in a bath of liquid to which is fed the suspension to be classified. The bath of liquid with its suspended solids is maintained in teeter, namely, thoroughly mobilized or in motion. This type of hydraulic classification is often referred to as "hindered settling." The size separating conditions exhibited by the teetered bath or bed of submerged suspended solids are subject to automatic control. This invention is directed to a type of such control.

In a sizer of this type, the suspended solids such as pulps or slurries, are continually fed to a pool or bath of suspended solids maintained in a pocket having a construction plate in its bottom section through which liquid under hydraulic pressure or head is supplied in an upward direction to the bath. This hydraulic liquid is usually water but may be liquids of greater density, including solutions of salt, calcium chloride and so on. The head under which the hydraulic water is supplied effects the teeter or the mobilizing of the suspended solids of the bath, which is an important condition of operation. The density of the bath, however, effects the size separating qualities of the machine, so the automatic control of this invention operates to control the density of the solids classifying or sizing bath.

A pocket of such a sizer has a valve plug in its bottom section usually passing through a construction plate for controlling the rate of sands discharging therethrough, so this invention is directed to automatic operation of that valve or valve plug, to close or to open it for controlling the density of the bath to be more or less, as the case may be.

Each pocket containing such a bath of suspended solids whose density is important to control, has associated with it (usually in a standpipe) a balancing column of similar liquid, but substantially free of suspended solids. That is, if the bath is made up of water and solids to be classified, the balancing column comprises clean water. Since the bath contains suspended solids and therefore has a greater density than clean water, the balancing column of clean water rises to an elevation higher than that of the surface of the bath, and the difference in height between the liquid level of the bath and liquid level of the clean water in the column is called "superelevation." This super-elevation is an important factor in determining the proper density of the bath.

Thus any change in density of the bath containing the mobilized suspended solids that are in teeter and are in the process of being classified as to size, is indicated by a corresponding change in the liquid level of the clean liquid column that is balanced by the denser bath. The bath and the column stay in equilibrium and therefore fluctuate together, but the liquid column fluctuates much more than does the bath.

Heretofore it has been customary to associate a diaphragm with the teeter bath to indicate variations in the density thereof so that the diaphragm would move in one direction if the density of the bath became too great, and thus would open the valve plug to let out some of the larger solids or sands from the bath, and thus lessen the density of the bath. Conversely, if the density of the bath was too light, the diaphragm would move the other way, the valve plug would close and remain closed until the continuing feed of suspended solids to the bath would raise the density and thus open the valve plug to go on with normal operation.

The principle of the size classifying operation of a machine of this type, known to the trade as the Fahrenwald sizer, is well shown and described in British Patent 268,663, filing date October 4, 1926.

One object of this invention is to provide a very sensitive but dependable control means motivated by change in superelevation of the balancing column of clean liquid to control a valve plug for varying the density of the teeter bath.

Another object of this invention is to inject into the control means between the float or diaphragm operated by the change of level of the balancing column of clear liquid an impulse from an outside source such as electricity, whereby minute fluctuations in liquid level of the clean liquid may be multiplied or amplified so that the relative positioning of the valve plug in the teeter bath may be controlled correspondingly.

Another object is to render less bulky, lighter in weight, more readily mountable and accessible

the automatic control means for the sands discharge valve, and the valve itself.

These objects are attained according to this invention by utilizing the changes of liquid level of the balancing column of clean liquid (caused correspondingly by change of density of the teeter bath or bed) as a primary impulse for actuating a secondary or relay impulse, extraneous reversible power means or prime mover which opens or closes the sands discharge valve in accordance with or substantially in unison with, the extent of the primary impulse.

More specifically, these impulses operate in a manner whereby the power means are started or energized to move the valve in one direction, and stopped or de-energized to end that movement. Similarly, the power means are started in the reverse direction and then stopped if the primary impulse calls for such opposite control effect. The extent of the respective opening or closing movements are substantially in proportion to the extent of the corresponding primary or hydraulic impulses.

The invention possesses other objects and features of advantage, some of which with the foregoing will be set forth in the following description. In the following description and in the claims, parts will be identified by specific names for convenience, but they are intended to be as generic in their application to similar parts as the art will permit. In the accompanying drawings there has been illustrated the best embodiment of the invention known to me, but such embodiment is to be regarded as typical only of many possible embodiments, and the invention is not to be limited thereto.

The novel features considered characteristic of my invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and its method of operation, together with additional objects and advantages thereof, will best be understood from the following description of a specific embodiment when read in connection with the accompanying drawings in which according to one feature, the extent of the primary and hydraulic impulse is electrically translated into a proportional amount of rotation of the armature of a motor, which in turn moves the valve.

According to another feature, the means for electrically translating the extent of primary or hydraulic impulse into a proportional extent of valve movement, comprises the "Modutrol" motor of the Minneapolis-Honeywell Regulator Company, as shown and described in their bulletin Form No. 95–1057A entitled "Type M904E Modutrol motor," in conjunction with a control circuit as shown and described in the Bulletin entitled "Series 90 control circuit" by the same company.

Hence, the hydraulic or primary impulse in one direction causes a proportionate change in the setting of a first or controlled potentiometer which therefore energizes a double-throw solenoid actuated switch to start the valve actuating motor. The motor rotates until it has changed the setting of a second or motor balancing potentiometer sufficiently to restore the switch to its neutral or normal electrically balanced condition whereby it stops the motor. A primary impulse in the opposite direction will produce an amount of rotation of the motor in reverse. The amount of rotational movement of the motor armature and the corresponding extent of the valve setting movement are substantially proportionate to the extent of the primary or hydraulic impulse because of the respective proportionate settings effected on both the potentiometers.

Fig. 1 is a side view of a hindered settling multiple pocket classifier with part of the tank wall broken away to expose in one pocket the arrangement of the novel sands discharge valve and actuating means, the tank for the purpose of this showing being foreshortened by the omission of some of the intermediate pockets, as well as by the omission of a tank portion near the feed end.

Fig. 2 is a plan view of the classifier shown in Fig. 1.

Fig. 3 is an end view of the classifier tank, taken on the direction 3—3 in Fig. 1, with the end wall partially broken away to expose the sands discharge valve.

Fig. 4 is an enlarged detail view of the elements operatively connecting the motor shaft with the valve stem, in extreme end operating positions.

Fig. 5 is a view in the direction 5—5 upon Fig. 4.

Fig. 6 is a view of the actuating elements shown in Fig. 4, further completed by the showing of the sands discharge valve connected therewith.

Fig. 7 is an enlarged detail showing of the devices for automatically actuating the sands discharge valve, to effect automatic density control.

Fig. 8 shows a detached sub-assembly including the arrangement of the sands discharge valve and of the electrical control means therefor, as well as the arrangement of an associated clear water pipe for transmitting the primary or hydraulic impulse to the electrical control means.

Fig. 9 is a key diagram of a plan view of the classifier tank complete, to identify those portions of the tank that are shown in Figs. 1 and 2 as well as those omitted therein.

Fig. 10 is a key diagram of the classifier tank representing the side view.

Figs. 11, 12, 13 and 14 are wiring diagrams illustrating the operating cycle of the electrical control means which actuate the sands discharge valve for effecting automatic density control.

The hindered settling type of hydraulic classifier herein shown to illustrate the invention comprises a tank 10 resembling a deep trough having a narrow feed inlet end 11 and a wider liquid outlet or overflow end 12. That is to say, the tank 10 comprises side walls 13 and 14 diverging from the inlet towards the overflow end, a horizontal bottom 15, a narrow end wall 16, and a wide end wall 17.

The tank is subdivided into a series of pockets by transverse submerged partitions such as represented for instance by partitions 18 (Fig. 1). The actual disposition of the pockets is indicated in the key diagrams of Figs. 9 and 10 showing eight pockets 21 to 28, equipped with the novel automatic sands discharge and density control devices. The key diagram (Figs. 9 and 10) indicates parts A, B and C of the tank as being those which are shown in Figs. 1 and 2, while indicating at D and E the parts that have been omitted or broken away in Figs. 1 and 2.

A pocket 20 closest to the narrow inlet end of the tank differs from the others in that it lacks the control devices.

Each of the pockets 21 to 28 has a perforated false bottom or perforated flow constriction plate 29, forming between it and the tank bottom 15

a pressure chamber 30 to receive liquid under hydraulic pressure herein also called teeter liquid for the purpose to be further explained. The constriction plate 29 also defines the floor of a classifying pocket in which during operation there is established a hindered settling classifying zone or pool that comprises a bath or teeter bed approximately of a depth "T," as hydraulic liquid from the pressure chamber 30 is forced upwardly through the constriction plate whereby the sands in the slurry passing through the tank are graded in a manner further to be described.

Each of the pockets 21 to 28 also has a sands discharge valve 31 comprising a valve seat 32, a sands outlet passage 33 leading from the valve seat through the pressure chamber 30 and through the tank bottom 15 out of the tank to discharge, and a valve body 34 provided with a valve stem 35.

The pocket 20 is relatively shallow as compared with the other pockets 21 to 28, in that it has a flow constriction plate 36 disposed but slightly below the top edge of the partitions 18, and forming with the tank bottom a relatively deep pressure chamber 37. The extreme narrow end portion of the tank forms a shallow pan-like feed receiving section 38 having but a solid bottom 39, and a transverse weir portion 40 which extends to a point well above the top edge of the partitions 18, and over which the feed suspension enters the first or valve-less classifying pocket 20. The sands-carrying liquid feed passes from the pocket 20 in a continually widening stream over the pockets 21 to 28, the depth of this stream above the top edge of the partitions 18 being determined by the height of overflow means for discharging the carrying liquid from which various sizes of sand particles have been removed by the classifying action of the pockets 21 to 28, and which overflow means will be presently described.

The tank 10 is provided with overflow discharge means for discharging the carrier liquid of the feed suspension or slurry, which remains after various grades of particle sizes or sands have been abstracted therefrom due to the classifying action of the hindered settling pockets over which the horizontal stream of the liquid or slurry has passed. These overflow discharge means comprise an overflow receiving trough or launder 41 at each side of the tank and are shown to extend along that section of the tank that is occupied by all but the pockets 20, 21 and 22. These overflow launders are shown to have a sloping bottom 42 and an outlet 43 at the extreme wide end of the tank. Consequently, that section of the tank that corresponds to the pockets 23 to 28 is provided with adjustable overflow weir members 44, one at each side of each pocket (see Figs. 1 and 2). The last or widest classifying pocket 28 has an additional overflow weir member 45 adjustably mounted upon the end wall 17 of the tank. This last mentioned weir member allows overflow liquid to be discharged into a transverse trough or launder 19 extending between extensions 13a and 14a of the side walls 13 and 14 of the tank and having an outlet 46 intermediate its ends.

Each of the classifying pockets 21 to 28 has at each side the familiar transparent wall portion or window 47 through which the hindered settling or teeter condition within the pocket can be observed. The pressure chamber 30 underlying each of the pockets 20 to 28 is provided at one side with the familiar hand hole cover 48.

To each side wall of the tank 10 there is secured about halfway between the top and the bottom thereof a horizontally extending channel iron 49 serving as reinforcement members and as a bracket means for thereby supporting the entire tank unit upon a suitable supporting structure herein not shown.

In order to supply the hydraulic liquid or water for the classifying operation to each of the classifying pockets 20 to 28, the tank is provided with a familiar horizontally extending distribution header 50 having lateral branch connections 51 leading to the respective pressure chambers 30. The connection proper is here represented by a hose portion 51a. The flow rate of hydraulic water through each branch connection 51 is controllable as by adjustable clamps 52 pinching the hose connections 51a.

At one end the header 50 is closed as by a screw cap 53; at the other end it connects with a vertical pipe or standpipe 54 leading into and being fed from a constant level water container 55 supplying the pressure water under a corresponding static hydraulic head. A control valve 56 is provided in the standpipe 54.

Mounted upon and extending over the top of the tank 10 is a bracket construction or framework 57 for the purpose of supporting thereon automatic sands discharge and density control devices for each of the pockets 21 to 28. This framework is shown to comprise a series of parallel transverse members 57a extending across the tank, brackets 58 rising from some of the transverse members 57a, each such bracket comprising a pair of rising standards 58a and 58b interconnected at the top by a crosspiece 59. The brackets 58 in turn are interconnected at the top by a pair of rails or angle irons 60 and 60a extending horizontally and longitudinally of the tank and substantially over a length corresponding to the combined length of the pockets 23 to 28.

The framework 57 also serves for mounting and supporting a vertical open ended clear liquid-containing standpipe 61 for each of the pockets 21 to 28 as by means of a bracket 62. The lower end of the standpipe 61 terminates a distance *d* above the constriction plate 29. Each standpipe 61 comprises a length L of its upper end portion of transparent material such as leucite to permit observation of the level of the clean liquid column in the pipe since that level is indicative of the "super-elevation" reached by the clean liquid column above the level of the suspended solids bath or column in the classifying pocket into which the standpipe 61 extends.

The fluctuations of this super-elevation of the clean liquid column in pipe 61 furnishes the primary and hydraulically controlled impulse for effecting the automatic control of the sands discharge valve and thereby automatic density control for the grading of the sands fractions in the various classifying pockets, all as will be more clearly described below.

Since the invention proper resides in an improved device for the automatic density and sands discharge control, such device is more clearly illustrated in Fig. 8 showing the arrangement of a sub-assembly comprising the control devices proper and environmental parts directly associated therewith. This sub-assembly appears in Fig. 8 in a somewhat enlarged scale, showing the train of component parts constituting the control device as being detached from the environment of the tank structure shown in Fig. 3.

The function of the control devices is further

illustrated by way of wiring diagrams (see Figs. 11, 12, 13, 14) presenting the complete operating cycle or train of events whereby the automatic correction of density and of sands discharge in the respective classifying pockets is effected.

Referring to Fig. 8, the automatic control device according to this invention as applied to one classifying pocket comprises a train of component parts, in which the clear liquid pipe 61 represents the initial element through which and from which the primary corrective impulse emanates to set the corrective operating cycle going. The pipe 61 has a hydraulic operating connection by way of a branch pipe 63 leading to the interior of a bellows 64 which in turn constitutes the controlling part of a primary potentiometer unit 65 comprising further mainly a primary potentiometer resistance coil 66, and movement transmitting means 67 for translating any expansion or contraction of the bellows 64 into movements of a contact arm 68 slidable upon the potentiometer resistance coil 66 (see Fig. 7) all parts of the unit 65 being contained in a housing 69. It will be understood that the changes in the shape of the bellows 64, that is, contraction or expansion, are caused by variations in hydraulic pressure from the clean liquid column or super-elevation in the pipe 61.

The movement transmitting means 67 in the primary potentiometer unit 65 (see Fig. 7) comprise a stem 67^a coaxial with and fixed to the free end of the bellows 64 and extending slidably through the wall of housing 69 and into contact with a double-armed lever 67^b fulcrumed as at 67^c, and having a relatively shorter arm 67^d and a longer arm 67^e, the latter arm being engaged by the stem 67^a from below. The extreme end of the longer arm 67^e is rigidly connected with the aforementioned contact arm 68 extending at right angles therefrom, while the opposite end portion of the shorter arm 67^d has anchored thereon as at 67^f a tension coil spring 67^g, the opposite end of that spring being fastened to a coaxial screw 67^h threaded as at 67^i into the wall of the housing 69 for adjusting the tension of the spring 67^g. The tension of the spring insures operating contact with the stem 67^a. Also, by adjusting the spring tension it is possible to influence or adjust or time the degree of response of the control devices relative to the primary impulse as represented by the hydraulically induced changes of the bellows 64.

Changes in the condition of the potentiometer unit 65, induced by changes in the position of the contact arm 68, affect in turn the condition of a secondary or controller potentiometer unit 70 by way of an electrical three-wire connection W comprising individual wires or leads 70^a, 70^b and 70^c.

The unit 70 comprises a housing 71 in which are contained a secondary potentiometer resistance coil 72, a motor 73 having an armature shaft 73^a operatively connected with the valve stem 35 by a wire or flexible linear element 35^a, movement transmitting means 74 such as the arm 74^a fixed on the armature shaft, the link 74^b, and arm 74^c, for translating rotation of the armature shaft 73^a into movement of a contact arm 75 slidable upon the secondary potentiometer resistance coil 72, and finally a solenoid controlled double throw switch 76 not visible in the Fig. 7 showing of the unit 70, but adequately shown in the wiring diagrams in Figs. 11 to 14.

Wires 77 and 78 leading into the unit 70 furnish extraneous electrical power to the control system as represented by the units 65 and 70, so that the control circuits may be operated in the manner to be further described.

The operative connection between the armature shaft 73^a and the valve stem 35 is illustrated in Figs. 6, 7, 5, 4. It comprises winding member 79 partially resembling a pulley having at its circumference a hollow lug portion 80 through which extends the flexible member or wire 35^a the free end portion 81 of which is adjustably fixed in a terminal or anchoring block 82 by means of a set screw 83. The other end portion 84 of the wire extends coaxially into the free end portion of the valve stem 35 and is shown to be embedded therein as at 85 and thus be fixedly connected therewith.

Due to this flexible wire connection 35^a a rotation of the armature shaft 73^a for instance through an angle of 160° as shown in Fig. 4 will accordingly lift or lower the valve to the extent that the wire is wound up on or unwound from the member 79.

The functioning of the control devices as represented by the units 65 and 70 will be understood from, and described by reference to the wiring diagrams in Figs. 11 to 14. It will be noted that identical parts shown in Fig. 7 on the one hand and in Figs. 11 to 14 on the other hand, are designated by identical numerals. Also, for the purpose of readily identifying and correlating parts of the wiring diagram to the mechanical showing of the control devices in Fig. 7, respective parts of the diagram have been boxed in by dot-and-dash lines, and the boxed-in portions designated by the same numerals as the corresponding control units shown in Fig. 8, namely, by the numerals 65 and 70 respectively.

The electrical control system embodied in the wiring diagram Fig. 11, and its principle of operation or its operating cycle as illustrated in Figs. 12, 13, 14, will now be described.

The system comprises a source of electrical power as represented by the transformer 86 from which conductors 87 and 88 lead into the control system proper, namely to the respective terminals 87^a and 88^a, where they split to form two parallel circuits, namely a potentiometer circuit involving the potentiometer resistance coils 66 and 72, and a motor circuit for stopping and starting the motor 73.

The potentiometer circuit comprises the conductor 70^c leading from terminal 87^a in unit 70 to terminal 89 in unit 65, a conductor 90 leading within unit 65 from terminal 89 to contact arm 68 engaging the primary potentiometer resistance coil 66 at a point intermediate the ends thereof in this instance.

By way of this contact arm 68 the circuit splits into two parallel branches R_1 and R_2. The one branch R_1 comprises the portion p_1 of the resistance coil 66, a conductor 91, leading therefrom to a terminal 92 within the unit 65, the conductor 70^b leading from terminal 92 in unit 65 to the unit 70 where it connects up with one end of a solenoid coil 93, a conductor 94 within the unit 70 leading from the other end of the solenoid coil 93 to the terminal 95 of the resistance coil 72, and the portion p_3 of the resistance coil 72 terminating at the contact arm 75 from which the circuit is completed by way of a conductor 96 leading to terminal 88^a. The other branch R_2 of the potentiometer circuit leading from the contact arm 68 comprises the complementary portion p_2 of the resistance coil 66, leading through conductor 97^a to a terminal 97 within the unit

65, the conductor 70a leading from the terminal 97 to the unit 70 to connect up with one end of a solenoid coil 98, a conductor 99 leading from the other end of the solenoid coil 98 within the unit 70 to a terminal 100 of the resistance coil 72, and finally through the complementary portion p_4 of the secondary resistance coil 72 to the contact arm 75.

The two solenoid coils 93 and 98 have cores 101 and 102 respectively, which cores constitute part of the double throw switch member 76.

In Fig. 11 both solenoid coils 93 and 98 appear equally energized due to the balanced condition of the two branches R_1 and R_2 of the potentiometer circuit, exerting equal force upon both cores 101 and 102 and thus holding the switch member 76 balanced in a neutral or open position with respect to contact terminals 103 and 104.

In Fig. 12 a change in the position of the contact arm 68 has taken place due to a contraction of the bellows 64 whereby unequal resistance portions p_5 and p_6 of the resistance coil 66 are established. Thence, the solenoid coil 93 becomes more strongly energized than the coil 98, unbalancing the cores 101 and 102 and causing the switch member 76 to be thrown into a circuit closing position by contact with the terminal 103, starting the motor to rotate in a corresponding direction. The motor circuit thus established leads from power terminal 87a through switch member 76, then by way of terminal 103, motor winding 105, to power terminal 88a.

Since the rotation of the armature shaft 73a thus induced is coupled with and mechanically translated into movement of the contact arm 75, the latter continues to be moved until it will have reached the Fig. 13 position whereby it establishes unequal portions p_7 and p_8 of the resistance coil 72. This re-establishes the balanced condition of both branches R_1 and R_2 of the potentiometer circuit, causing both solenoid coils 93 and 98 to be equally energized and thus to restore the balanced condition of the cores 101 and 102, and the balanced or neutral position of the switch member 76. While in the unit 70 in Fig. 7 the motion transmitting means 74 are shown in the form of linkage, they are shown in Figs. 11 to 14 in the form of a chain and sprocket drive 106 for the purpose of diagrammatic expediency. Thus the switch member 76 assumes the intermediate or neutral Fig. 11 position interrupting the motor circuit and stopping the movement of the armature shaft 73a.

In Fig. 14 the contact arm 68 is shown to have been restored to the Fig. 11 position due to expansion of the bellows 64. This again unbalances the conditions in the branches R_1 and R_2 of the potentiometer circuit with respect to one another, sending a greater current through the branch R_2 engaging the solenoid coil 98 more strongly, causing the switch member 76 to be thrown into a circuit closing position opposite to that shown in Fig. 12 by contact with the terminal 104. This causes the armature shaft 73a to turn in a direction opposite to that mentioned in connection with the Fig. 12 condition of the system. The motor circuit thus established leads from power terminal 87a through the switch member 76, and by way of terminal 104, motor windings 105, to power terminal 88a.

Again by way of motion transmitting means 106 the rotation of the armature shaft 73a is translated into a corresponding amount of movement of the contact arm 75 whereby the arm will have been returned to the Fig. 11 position, restoring the portion p_3 and p_4 of the resistance coil 66, and thus the balanced condition of the potentiometer branch circuits R_1 and R_2.

It will be understood that the control cycle just described by reference to the diagrams in Figs. 11 to 14 effects the positioning or corrective adjustment of the sands discharge valve, resulting in density control, since the valve stem 35 is operatively connected with and moved by the rotation of the armature shaft 73a, and since the operation of the armature shaft 73a is in turn the result of primary hydraulically induced impulses from the classifier pocket causing contraction or expansion of the bellows 64.

The aforementioned circuit R_1 (in Fig. 11) consists of the portion P_1 of resistance coil 66, the conductor 91, terminal 92, conductor 70b, solenoid coil 93, conductor 94, terminal 95, and the portion p_3 of the resistance coil 72.

The circuit R_2 (in Fig. 11) consists of the portion p_2 of resistance coil 66, terminal 97, conductor 70a, solenoid coil 98, conductor 99, terminal 100, and the portion p_4 of the resistance coil 72. The circuits R_1 and R_2 in this phase are in balanced condition relative to one another. In Fig. 12 the respective portions of the resistance coil 66 are shown to have changed to uneven portions p_5 and p_6, while the portions p_3 and p_4 of the resistance coil 72 have remained the same as in Fig. 11. The circuits R_1 and R_2 are in unbalanced condition relative to one another.

In Fig. 13 the portions p_5 and p_6 of resistance coil 66 have remained the same as in Fig. 12, but the portions of resistance coil 72 have changed to p_7 and p_8 respectively. The circuits R_1 and R_2 are again in balanced condition relative to one another.

In Fig. 14 the portions of the resistance coil 66 have again reverted to the Fig. 11 condition, while the portions of the resistance coil 72 have remained the same as in Fig. 13. That is, the circuits R_1 and R_2 have again been thrown out of balance relative to one another.

While the double-throw switch 76 is shown (see Figs. 11 to 14) to be included in the structural unit that is represented by the unit 70, it may be instead incorporated in the unit 65 by a corresponding relocation of the wiring.

Operation

The sizing operation in principle functions as follows:

The feed material which may be a liquid suspension of liquid and sands or other granular material to be sized, is received in the feed compartment 38 which acts as a quieting or disseminating chamber for the next following compartment or pocket 20. A stream of the feed suspension or slurry thus flows across the submerged wall or partition 40, and on across the shallow pocket 20 to form a pool or bath therein, into which rises hydraulic liquid through the perforated bottom 36 from the liquid pressure chamber or compartment 37, to effect a preliminary teetering and mobilizing of solids suspended in the bath. The stream of feed suspension then passes on in a gradually widening bed (see Figs. 9 and 10) over the classifying pockets 21 to 28 proper. Assuming that the overflow edge of the weir portion 45 defines the depth of the stream of slurry flowing across the classifying pockets, it will be noted that the depth of the feed stream relative to the top edge of the partition 40 is S_1, and the depth relative to the top

edge of the partition 18 of the classifying pockets is S_3, the differential S_3—S_1 being designated as S_2.

The function of the classifying pockets in intercepting and grading the sands from the feed suspension flowing over them, is well known in principle. Each pocket has maintained in it a different upflow velocity of hydraulic or teeter liquid, the velocity in the initial and narrowest pocket 21 being the highest and in the last and widest pocket 28 the lowest. Teeter conditions are maintained in the pool or bath in each pocket corresponding to a depth "T," each pocket representing a classification zone over which the stream of the suspension must pass. The teeter condition in each pool or bath of the classification pockets is so controlled that substantially only a certain grade or size fraction from the entire size range of the sand will gravitate to the bottom of the pocket, where it is removed by way of the automatically controlled valve 31 and outlet passage 33.

The automatic discharge control by way of the valve 31, in effect, represents a means for automatically maintaining a certain density condition in the teeter bath or bed, and an individual automatic valve control device for this purpose is provided for each pocket. Such a device will correctively respond to vary the setting or position of the valve body 34 to accelerate or retard the discharge of the sands fraction from the pocket. Corrective action takes place for instance when for any reason, for instance due to a fluctuation in the quantity or character of the feed suspension, there occurs an undue accumulation of solids in the bath, the density of the bath increases which offers increased resistance to the incoming hydraulic water. This all in turn causes a corresponding increase of height of a clear liquid column in the stand-pipe communicating with and balanced by the teeter bath or bed. A relatively small change of density in the teeter bed of the pocket will thus manifest itself in an appreciable change in the height of the clear liquid column which change in turn is utilized to cause changes in the setting of the sands discharge valve.

In as much as the present invention resides more specifically in improvements in devices for effecting the automatic corrective control or setting of the discharge valve in response to fluctuations or changes in density conditions in the teeter bed of a pocket, the operation of the improved device will now be described:

While feed suspensions of a certain uniform composition and flowing at a certain uniform rate enter the narrow feed end of the tank, there will maintain a corresponding open-position setting of the valve body 34 allowing a fraction of the sands of a certain size to pass out of the pocket at a steady rate. As long as all these conditions remain uniform, the teeter and density conditions effecting this particular grading also will remain substantially uniform. This position of the valve body 34 is maintained by the sustained pressure from the then super-elevation of the clear liquid column in standpipe 61 acting through the branch pipe 63 upon the bellows 64 within the housing of unit 65, and by the corresponding position of the armature shaft 73a connected with the valve stem 35. This condition (see Fig. 11) is maintained due to the then electrically balanced condition of the primary unit 65 and the secondary unit 70 relative to one another, or else due to the balanced condition of the parallel circuits R_1 and R_2 relative to one another, whereby the switch 76 is held in balanced or neutral position due to the solenoids 93 and 98 being equally energized.

If a change in the feed condition or else a change in the pressure of the hydraulic liquid or teeter water causes decrease in the density of the teeter bed, this will be accompanied by an equivalent drop of the clear liquid column in pipe 61, to establish hydraulic balance. The resultant lower super-elevation of clear liquid effects a corresponding compression or shortening of the bellows 64 which is transmitted to the contact member 68, moving it to the Fig. 12 position, and thereby upsetting the balance of the system. The amount of dislocation of the contact member 68 thus produced is in proportion to the amount of change in super-elevation caused by the density change in the teeter bed. This causes the switch actuating solenoids 93 and 98 to be unequally energized and to close the motor switch 76.

The armature shaft consequently rotates for a time interval causing a compensatory movement of the contact member 75, equivalent to the movement which the contact member 68 has already performed. Thus, when the contact member 75 reaches the position shown in Fig. 13, the equilibrium condition of the electrical system will have been restored, as the solenoids 93 and 98 again become equally energized, causing the switch member 76 to revert to its balanced or neutral position, whereby the armature shaft is again stopped leaving the valve 31 in a somewhat further lowered position, namely, sufficiently nearer its seat to discharge sands at a decreased rate whereby the desired density of the teeter bed and thus the desired classifying effect thereof is again restored. In this way, the valve 31 will have been lowered correctively in proportion and in response to the amount of change in super-elevation that was caused by the density decrease in the teeter bed. This condition will maintain as long as the condition of the slurry feed and of the supply pressure of the teeter water remains unchanged.

In Fig. 14 it is assumed that the density in the teeter bed has increased to an extent whereby there will be effected increase in the clean water super-elevation, that will cause the bellows 64 to expand, restoring the contact member 68 to the position which it is also shown to assume in Fig. 11. This again causes unbalancing and unequal energization of the solenoids 93 and 98, causing the switch member 76 to close, although in a direction opposite to that shown in Fig. 12.

Consequently, the armature shaft 73a will be caused to rotate in a direction opposite to that in Fig. 12 until it will have brought the contact member 75 back to the position shown in Fig. 11, thereby restoring the balanced condition which energizes the solenoids 93 and 98 to an equal degree. This restores the switch member 76 to neutral, which stops the armature shaft 73a and leaves the position of valve 31 somewhat higher off-seat, to increase the discharge of sands sufficiently to restore the desired density condition of the teeter bed.

The corrective operating cycle will automatically perform and repeat itself for the pool or bath in each classifying pocket, so that a desired average uniform density condition and uniform size grading is automatically maintained in the operation of each pocket.

I claim:

1. Control apparatus of the class described for association with a pool of suspended solids to be classified by hindered settling to which such solids are continually fed and from which fractions of solids are continually discharged by one path from the bottom of the pool and by another path from the top of the pool, a column of clean liquid balanced by the density of the pool to a super-elevation above the top of the pool which varies with the density thereof, a vertically movable valve controlling the rate of discharge of the solids fraction through a valve seat in the bottom of the pool, and automatic means for stabilizing the density of the pool at a predetermined normal to ensure accurate size classification of solids therein which comprises a reversible electric motor in a power circuit adapted to raise and lower the valve to adjusted positions while off its seat, means movable upwardly by rise of the super-elevation incident to increased density above normal of the pool and movable downwardly as the risen super-elevation begins to fall; and conjoint means operated by movement of the movable means for controlling the motor to (1) raise with its power from the outside source the unseated valve a distance proportional to the rise of super-elevation for thus effecting a proportional increase in the rate of release of solids from the pool for lowering the density of the pool and consequently the risen super-elevation, (2) to arrest the valve when the risen super-elevation begins to fall, and (3) to lower the raised valve a distance less than to valve-seating position, but proportional with the fall of elevation from the level at which the rising valve was arrested to the level of the super-elevation at which the valve is again arrested for decreasing the release of solids from the pool and increasing the density thereof.

2. Apparatus according to claim 1, in which the armature shaft of the motor has a flexible connection with said valve and unwinds relative to said shaft in accordance with the degree of rotation of the motor.

3. Apparatus according to claim 1, in which the armature shaft of the motor has a motion translating connection with said valve comprising a pulley fixed on said armature shaft, and a wire element having one end anchored upon said pulley and the other end connected with said valve.

4. Apparatus according to claim 1, in which there is provided a motion translating connection between the armature shaft of the motor and said valve comprising a pulley fixed on said shaft, a wire element connecting the valve with said pulley, and means for anchoring the wire element upon said pulley including a lug at the periphery of said pulley and having a hole for the passage of said wire element therethrough, and an anchoring member adjustably fastened to the free end of said wire element emerging from said lug.

5. Apparatus according to claim 1, with the addition of settable actuating means for the motor having a potentiometer circuit, and including a first and a second resistance coil, a pair of solenoids in said circuit, a double throw switch controlled by said solenoids for operating the motor in two directions, a contact arm movable on said first resistance coil that is settable by said impulse transmitting means, a contact arm movable on said second resistance coil and settable by movement of the motor armature, the structural arrangement being such that said first resistance coil and the associated contact arm are combined in one component unit associated with said impulse transmitting means controlled by said super-elevation, while the motor and the second resistance coil are combined in another component unit associated with the valve, both component units being electrically interconnected by way of said solenoids and said motor switch.

6. Apparatus for sizing suspended solids, which comprises means for establishing and maintaining a pool of suspended solids to be classified by hindered settling, means for continually feeding suspended solids thereto, means for continually discharging fractionated larger solids or sands from the bottom of the pool, means for continually overflowing from the upper section of such pool another fraction of smaller solids or fines, means for continually supplying liquid under hydraulic pressure to mobilize solids in such pool, means for establishing and maintaining a column of clean liquid balanced by the density of the pool to a super-elevation above the top of the pool which super-elevation varies with the density of the pool, a vertically movable valve controlling the rate of discharge of the solids fraction through a valve seat in the bottom of the pool, and automatic means for stabilizing the density of the pool at a predetermined normal to ensure accurate size classification of solids therein characterized by a reversible prime mover operated from an outside source of power adapted to raise and lower the valve to adjusted positions while off its seat, means movable upwardly by rise of the super-elevation incident to increased density above normal of the pool and movable downwardly as the risen super-elevation begins to fall; and conjoint means operated by movement of the movable means for controlling the prime mover to (1) raise with its power from the outside source the unseated valve a distance proportional to the rise of super-elevation for thus effecting a proportional increase in the rate of release of solids from the pool for lowering the density of the pool and consequently the risen super-elevation, (2) to arrest the valve when the risen super-elevation reaches a predetermined height, and (3) to lower the raised valve a distance less than to valve-seating position, but proportional to the fall of elevation from the level of the super-elevation at which the rising valve was arrested to the level of the super-elevation at which the valve is again arrested for decreasing the release of solids from the pool and increasing the density thereof.

7. Apparatus according to claim 6 with the addition of means for adjusting the degree of responsiveness of the movable means to changes of super-elevation.

8. Apparatus according to claim 6 with the addition that the prime mover raises the unseated valve a distance proportional to but less than the rise of super-elevation.

9. Apparatus of the class described having a basin adapted to hold a varying density pool of suspended solids to be classified by hindered settling to which such solids are continually fed and from which fractions of solids are continually discharged by one path from the bottom of the pool and by another path from the top of the pool, a column of clean liquid extending to a super-elevation above the top of the pool and balanced by the density of the pool for thus indicating in magnification changes in density of the pool, a vertically movable valve controlling the rate of discharge of the solids fraction through a valve seat in the bottom section of the basin, and auto-

matic means for stabilizing the density of the pool at a predetermined normal to ensure accurate size classification of solids therein which comprises a reversible prime mover operated from an outside source of power adapted to raise and lower as well as stop the valve while off its seat; means (1) movable in one direction by rise of the superelevation beyond a predetermined minimum distance incident to increased density above normal of the pool, (2) automatically stoppable thereafter, and (3) movable in the opposite direction as risen super-elevation falls beyond a predetermined minimum distance; and conjoint means operated by the movable means for controlling the prime mover to arrest the moving valve whereby the valve will have been moved a distance less than the distance moved by the level of the super-elevation, and to restart movement of the valve at a constant rate in the same direction as the super-elevation but only after the super-elevation shall have moved in that direction a predetermined minimum distance from the elevation of the valve-arresting change of direction.

10. Apparatus of the class described for association with a basin adapted to hold a varying density pool of suspended solids to be classified by hindered settling to which such solids are continually fed and from which fractions of solids are continually discharged by one path from the bottom of the pool and by another path from the top of the pool, a column of clean liquid balanced by and changing with the density of the pool to a super-elevation above the top of the pool, a vertically movable valve controlling the rate of discharge of the solids fraction through a valve seat in the bottom of the pool but movable a distance less than the change of height of the super-elevation, and automatic means for stabilizing the density of the pool at a predetermined normal to ensure accurate size classification of solids therein which comprises a reversible prime mover operated from an outside source of power adapted to raise and lower the valve to adjusted positions while off its seat, pressure-responsive means movable in one direction by rise of the super-elevation incident to increased density of the pool above normal and movable in the opposite direction as the risen super-elevation begins to fall; and means operated by movement of the pressure-responsive means for selectively controlling the prime mover (1) to raise the unseated valve after such time as rise of super-elevation reaches a predetermined minimum extent of rise for thus effecting increase in the rate of release of solids from the pool for lowering the density of the pool and consequently the risen super-elevation, (2) to arrest the valve thereafter, and (3) to lower the arrested valve after such time as falling super-elevation reaches a predetermined minimum of fall until the super-elevation again rises for decreasing the release of solids from the pool and increasing the density thereof.

11. Apparatus of the class described for association with a basin adapted to hold a varying density pool of suspended solids to be classified by hindered settling to which such solids are continually fed and from which fractions of solids are continually discharged by one path from the bottom of the pool and by another path from the top of the pool, a column of clean liquid balanced by and changing with the density of the pool to a super-elevation above the top of the pool, a vertically movable valve controlling the rate of discharge of the solids fraction through a valve seat in the bottom of the pool but movable a distance less than the change of height of the super-elevation, and automatic means for stabilizing the density of the pool at a predetermined normal to ensure accurate size classification of solids therein which comprises a reversible prime mover operated from an outside source of power adapted to raise and lower the valve to adjusted positions while off its seat, pressure-responsive means movable in one direction by rise of the super-elevation incident to increased density of the pool above normal and movable in the opposite direction as the risen super-elevation begins to fall; means operated by movement of the pressure-responsive means in one direction to operate the prime mover to raise the unseated valve after such time as rise of super-elevation reaches a predetermined minimum extent of rise and for arresting movement of the valve thereafter, means operated by movement of the pressure-responsive means in the opposite direction to operate the prime mover to apply power in reverse to lower the unseated valve after such time as falling super-elevation reaches a predetermined minimum fall and for arresting movement of the valve thereafter, and means for controlling the sensitiveness of the response of the prime mover operating means to the pressure-responsive means.

EDWARD A. HAAGENSEN.