March 4, 1969 R. C. ABT 3,430,851

AUTOMATIC CENTRIFUGE APPARATUS

Filed Dec. 26, 1967 Sheet 1 of 3

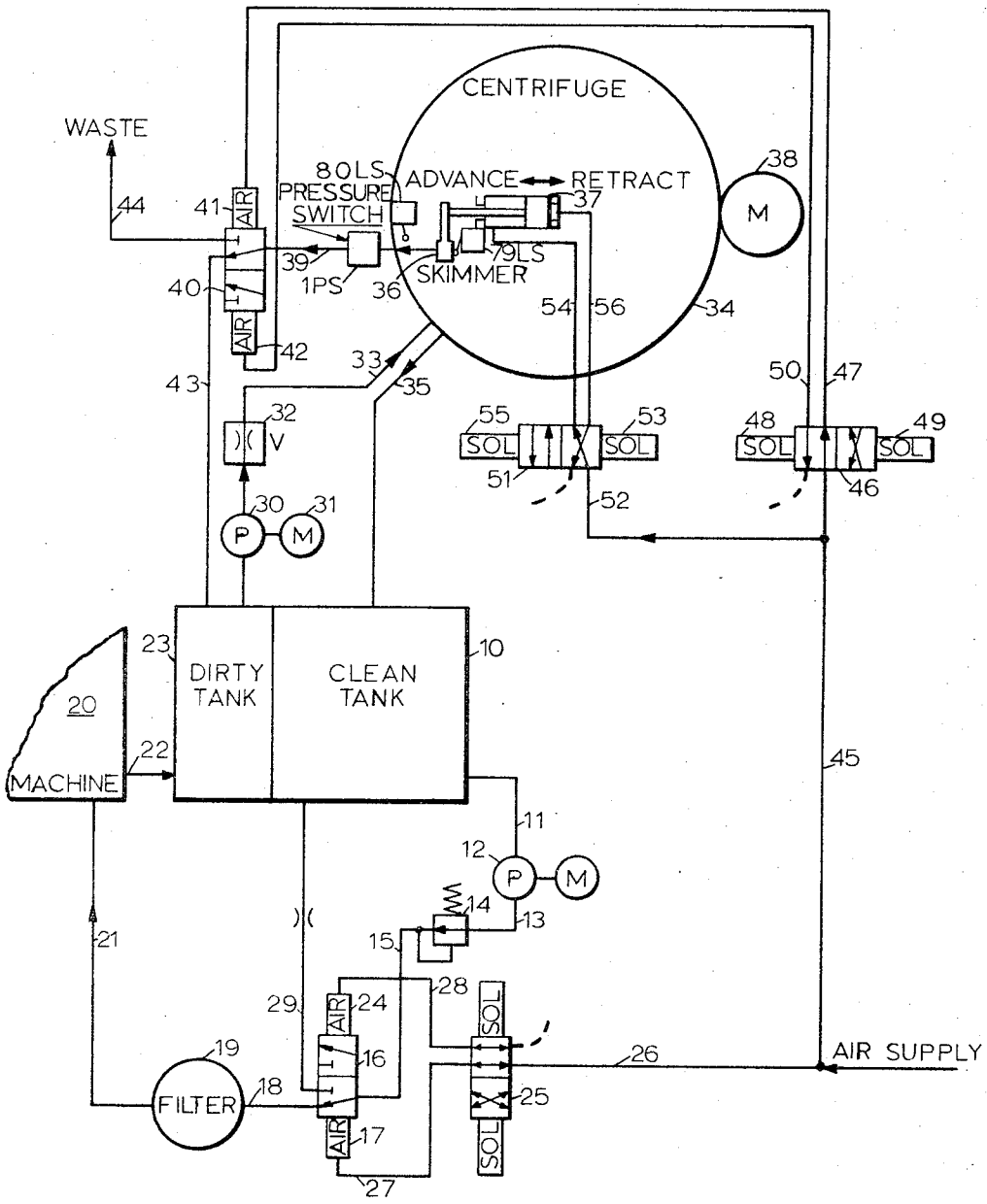


Fig. 1

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AUTOMATIC CENTRIFUGE APPARATUS

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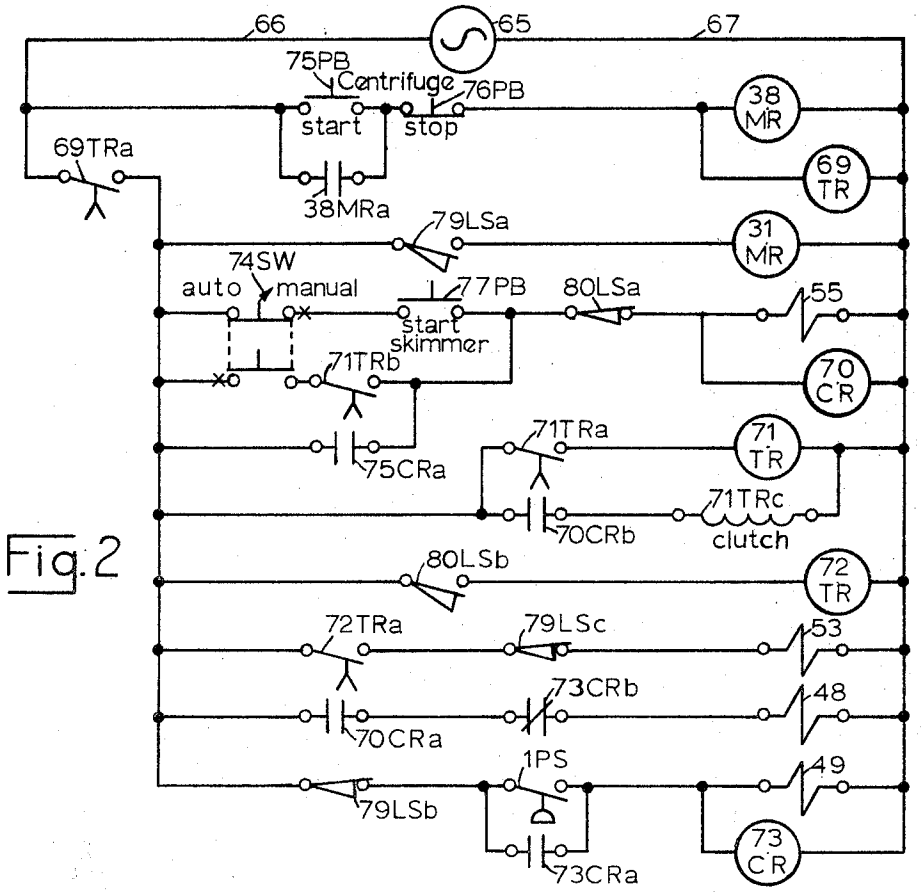


Fig. 2

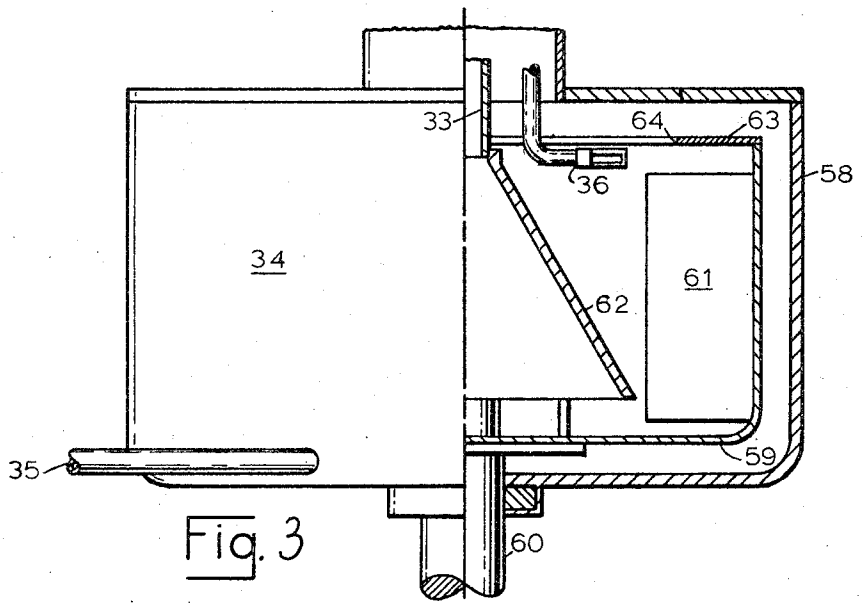


Fig. 3

AUTOMATIC CENTRIFUGE APPARATUS

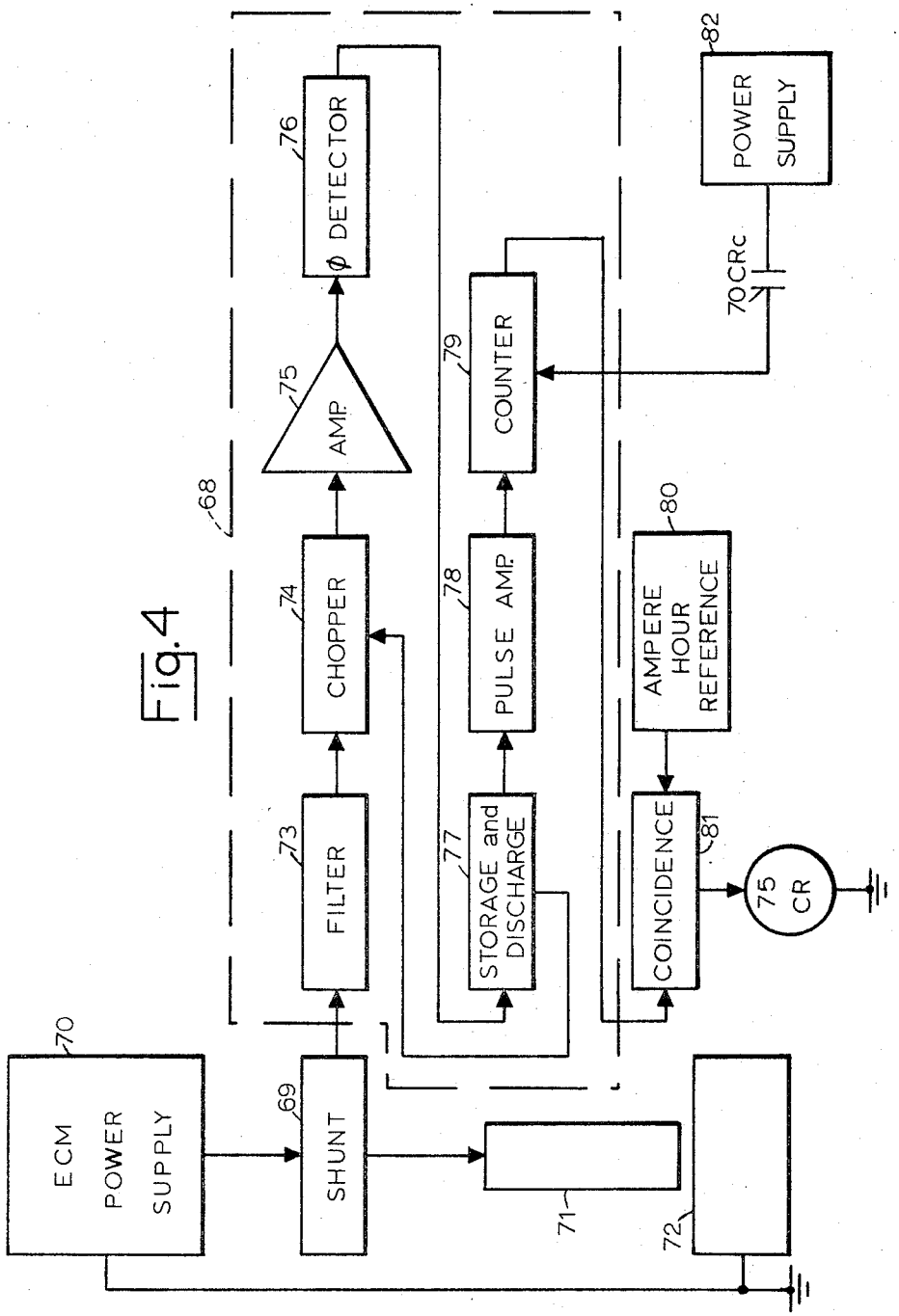


Fig. 4

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AUTOMATIC CENTRIFUGE APPARATUS

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U.S. Cl. 233—19 10 Claims
Int. Cl. B04b 9/00

ABSTRACT OF THE DISCLOSURE

There is shown and described a clarifying system in combination with an electro-chemical metal cutting machine. The system includes a centrifuge and automatic controls for producing an automated cycle of use. The control system responds to the density of the discharge from the centrifuge waste skimmer to direct the discharge either for recirculation to the centrifuge or for collection at a waste station. The waste skimmer is caused to move through its cycle in response to either the lapse of a predetermined period of time or to the consumption of a predetermined amount of energy in the metal cutting machine.

BACKGROUND

This invention is specifically an improvement of the apparatus disclosed and claimed in U.S. patent application Ser. No. 540,955, now Patent No. 3,366,319, assigned to the same assignee as the present application and copending herewith.

In the cited application, the centrifuge apparatus is operated in an automatic mode and responds to the change in density of the material within the centrifuge as it is encountered by the waste skimmer to effect alternately a change in the transport of material collected by the skimmer to a destination for recirculation or to a waste station. The apparatus of the cited invention has been found to perform satisfactorily in most instances although the effectiveness is not as good as is desired where high volumes are involved. This is due in large part to a reduced sensitivity of the system caused by the flywheel effect of the large mass of the centrifuge mechanism and its contents. In the system of the cited application, the change of density encountered by the skimmer therein is reflected as a change in the resistance to rotation of the centrifuge and causes an increase in the centrifuge motor load. Since the centrifuge acts as a flywheel, there is a slight time lag before the change is felt and therefore a small amount of high density sludge is returned for recirculation and this of course necessitates more frequent centrifuge cycles to maintain a given volume of material in a specific state of clarity.

It is an object of this invention to reduce the amount of high density sludge returned for recirculation by improving the sensitivity of the automatic system to passage of high density material into the waste skimmer.

It is also an object of this invention to provide a centrifuge in an electro-chemical machining apparatus that is responsive to the cutting process for operation of the waste skimmer so that the cycle can vary with the actual rate of metal removal and sludge generation.

Other objects and advantages of the present invention should be readily apparent by reference to the detailed description following herein, considered in conjunction with the accompanying drawings forming a part thereof, and it is to be understood that modifications may be made in the exact structural details of the described structure, within the scope of the appended claims, without departing from or exceeding the spirit of the invention.

SUMMARY OF INVENTION

The inventor has observed that the progress of high density sludge through the waste skimmer discharge system is accompanied by a simultaneous increase in pressure as the high density sludge front passes any point in the system. Therefore, this invention utilizes a pressure sensitive switch device in the waste discharge system to detect the entry of waste material therein. In the preferred form, this switch is located between the skimmer and a control valve that is operable to change the discharge from a recirculation destination to a waste collection station. The switch is spaced from the valve a sufficient distance to account for the valve operation time before the sludge front reaches the valve so that no high density sludge is returned to the recirculation destination. Therefore, less frequent skimmer cycles are required and better clarity of fluid is achieved and maintained. This is especially important in apparatus such as an electro-chemical metal cutting machine.

The apparatus of the present invention is also provided with a device that maintains a record of the amount of electrical energy consumed in the electro-chemical machining process. This is directly proportional to the amount of sludge generated and therefore means are provided to initiate the skimmer cycle in response to a preset amount of electrical energy consumed to relate centrifuge operation directly to the machining process.

THE DRAWINGS

FIG. 1 is a schematic diagram of the electrolyte system in an electro-chemical machining apparatus, including the fluid control valves operable within the system.

FIG. 2 is a wiring diagram showing the electrical circuits used in automatic operation of the valves in the system of FIG. 1.

FIG. 3 is a simplified showing of a centrifuge mechanism useful in the system of FIG. 1.

FIG. 4 is a functional block diagram of a control circuit using conventional elements uniquely combined for providing an alternate control feature in the present invention.

DETAILED DESCRIPTION

In the electro-chemical machining system shown in FIG. 1, clean electrolyte is stored in a supply tank **10** from which it is drawn for use through a pipe **11** by a pump **12**. Fluid under pressure is discharged from the pump **12** to a pipe **13** connecting with a pressure reducing valve **14** from which the fluid is passed by way of a pipe **15** to an air piston operated control valve **16**. Assuming that a machining operation is taking place, a cylinder **17** of the valve **16** would be under pressure and therefore the pipe **15** is connected as shown to a pipe **18** that carries the fluid to a cartridge type filter **19** and from there, the fluid is supplied to the electro-chemical process machine **20** by a pipe **21**. After use in the machine, the fluid, which is now contaminated with swarf, is passed through a gravity drain pipe **22** to a dirty fluid supply tank **23** where the ditry fluid is accumulated prior to centrifuging. Electro-chemical machining is an example of a process which generates a variable amount of heavier material in a slurry form since the amount of heavier solids depends upon electrolyte composition, size or shape of hole being formed, material being eroded and rate of erosion. These vary from job to job and often vary from time to time in any single job.

The connection of air under pressure to the cylinder **17** of the valve **16** and to another cylinder **24** at the opposite end of the valve **16** is controlled by an electrical solenoid operated valve **25**. This valve **25** is placed in the condition shown by conventional control circuitry (not shown) to connect air from a supply line **26** to a

control line 27 connecting with the cylinder 17. When machining is stopped, the condition of the valve 25 is reversed by the control circuitry and air under pressure is connected from the line 26 to a control line 28 that connects with the cylinder 24 to reverse the position of the valve 16. In this reversed position, the pipe 15 is connected to a restricted pipe 29 that returns the electrolyte directly to the clean fluid supply tank 10 thereby bypassing the machine 20 and any centrifuging since the clean electrolyte has not been used.

A pump 30, driven by a motor 31 is provided to draw dirty electrolyte from the tank 23 where it is accumulated and to force it through a rate control valve 32 and discharge pipe 33 into a centrifuge mechanism 34. Electrolyte that is thoroughly cleaned and separated in the centrifuge 34 is returned through a gravity return pipe 35 to the clean tank 10.

The centrifuge 34 is equipped with a sludge skimmer 36 which is shifted radially in the centrifuge by a pneumatic piston and the cylinder motor 37 to scoop up sludge during the centrifuge cleaning cycle. The centrifuge 34 is powered by an electric motor 38 which operates to rotate the mass of fluid within the centrifuge at at constant rotational velocity during this cycle. Fluid which is picked up by the skimmer 36 passes through a flexible conduit or hose 39 to a flow control valve 40 which is operable from one position to another by operation of pneumatic cylinders 41, 42 at opposite ends thereof. When air is connected to the cylinder 41, the valve 40 is in the control condition shown and the hose 39 is connected to a pipe 43 that returns fluid to the dirty fluid tank 23 for recirculation through the centrifuge 34. When air is connected to the cylinder 42, the fluid picked up by the skimmer 36 is discharged to a pipe 44 which carries it away as waste to either a sewer or to a waste recptacle.

The skimmer motor 37 and the control valve 40 in the centrifuge system are pneumatically actuated by air from the main supply line 26. An air line 45 is connected with the line 26 to direct compressed air to a solenoid operated valve 46 which connects air through a line 47 to the cylinder 41 when it is held in the position shown by the energization of the solenoid 48. When this solenoid 48 is deenergized and the solenoid 49 is energized, compressed air is connected through a line 50 to the cylinder 42 to reverse the valve 40 from the condition shown.

A second solenoid valve 51 is provided in the centrifuge system to control the operation of the motor 37. Compressed air from the line 45 is passed through a line 52 to the valve 51 which is held in the condition shown by a solenoid 53. Air from the line 52 is connected to a control line 54 that connects to the left end (as viewed in FIG. 1) of the motor 37 to hold the skimmer retracted in the centrifuge 34 where it will not pick up any fluid. When the solenoid 55 is energized and the solenoid 53 is deenergized, the valve 51 is shifted to connect compressed air from the line 52 to a control line 56 and this reverses the pressure differential in the motor 37 and effects a feeding of the skimmer 36 from the retracted position to an advanced position during which the skimmer 36 passes first through relatively clean fluid and then into the heavy sludge. After the arrival of the skimmer 36 at the advanced position, the solenoid 55 is deenergized and the solenoid 53 is energized to cause a return of the valve 51 to the state shown whereby the skimmer motor 37 is revised and the skimmer 36 is returned through a retraction stroke to its retracted position.

A simplified, typical centrifuge mechanism is shown in FIG. 3 and their brief reference to it will assist in the understanding of the basic centrifuging process. The mechanism includes a stationary tub 58 from which the gravity drain pipe 35 extends. A rotating tub 59 is contained within the stationary tub 58 and is rotated at a relatively high angular velocity by an input drive through a shaft 60. A series of paddle members 61 are spaced around and fixed to the inside of the rotating tub 59 to form pockets therearound which prevent turbulent movement of the fluid therein during a centrifuging process. Dirty fluid is input to the rotating tub 59 from the pipe 33 which directs the fluid first to the inside of a cone member 62 that rotates with the tube 59. The centrifugal forces cause the fluid entering the cone 62 to be moved outward and therefore downward to the bottom of the tub 59 and then radially outward to the periphery. As a result of the feed of new fluid at the bottom of the tub 59, the flow at the periphery of the tub 59 is upward and at the same time the heavier portions tend to concentrate at the outer endge of the tub 59. The upward migration of fluid causes fluid to be moved against the top 63 of the tub 59 and the less dense portion is forced radially inward to the inside edge 64 of the top, this edge sometimes is termed the curb of the centrifuge, where it is flung outward to the stationary tub and caught. This fluid that escapes from the tub 59 over the curb 64 is the clean fluid and is returned to the clean tank 10 by the pipe 35.

The skimmer 36 is moved radially outward through the fluid which accumulates at the top of the tub 59 above the paddle members 61. Due to the general upward migration of fluid and the centrifugal forces which cause the heavier solids to move radially outward the sludge will tend to be concentrated at the radial extremes of the area in which the skimmer 36 is moved. Therefore, in moving radially outward, the skimmer will pass through some electrolyte which has a low sludge concentration before engaging the heavy sludge that is to be discharged by way of the waste pipe 44, FIG. 1.

The separation of the relatively thick heavy sludge in a centrifuge used with an electro-chemical machining process, as described, is relatively sharply defined and as a result, when the skimmer 36 encounters the thick sludge a front of this waste material enters and moves through the conduit 39. The entry of the sludge in the conduit results in a higher fluid pressure behind the front than ahead of it as it moves along the conduit 39. This is observable in the flexible hose connected to the skimmer 36 which will be stressed to suddenly increase in diameter a small amount and will in effect show the instant that the sludge enters by a small, but sudden, motion. Mechanical sensors can be applied to the conduit to detect this or other devices used in fluid control circuits communicating directly with the pressurized fluid inside the conduit 39 and can be used to detect the time of entry of the sludge.

In the described embodiment, a pressure switch 1PS of conventional form employing a diaphragm subject to the pressure within the conduit 39 is used. The switch includes electrical contacts, FIG. 2, which are closed upon the increase of pressure within the conduit 39 to a level adequate to cause movement of the sludge front therethrough. The switch device 1PS is located between the skimmer 36 and the valve 40, but is spaced from the valve 40 so that in normal operation, the sludge front will not move on past the switch 1PS to the valve 40 before the control circuit will respond and cause the valve 40 to be operated. Therefore, all of the heavy sludge will be diverted to the waste line 44 and none will be returned through the line 43 for recirculation.

The centrifuging process is operated by the fluid control circuit of FIG. 1 and the associated electrical circuit shown in FIG. 2. A source of power 65 provides a potential across supply lines 66 and 67 for the ladder-type electrical circuit shown. The closing of a switch 75PB results in the energization of a motor start relay 38MR which switches on the power to the motor 38 that drives the centrifuge 34. A set of latch contacts 39MR*a* also are closed to bypass the switch 75PB to maintain the centrifuge motor in operation until such time as a switch 76PB, the master stop, is opened to deenergize the relay 38MR.

A timer 69TR is in parallel with the relay 38MR and has contacts 69TR*a* which close to cause energization of the pump 31 after a delay sufficient to allow the centrifuge 34 to accelerate the normal operating velocity. The contacts 69TR*a* close and apply power across a set of limit switch contacts 79LS*a* which are closed when the skimmer 36 is in a retracted position. Thereafter, the relay 31MR is energized to operate the pump 30 to fill the centrifuge 34. The pump 30 will not operate during a skim cycle when the skimmer 36 is moved from the retracted position.

To initiate operation in a skim cycle, the circuit includes a manual-automatic selector switch 74SW shown in the manual mode position. To begin a skim cycle in the manual mode, a switch 77PB is closed to energize the solenoid 55 along with a control relay 70CR. Energization of the solenoid 55 shifts the valve 51 to connect air under pressure to the motor 37 to cause movement of the skimmer 36 radially outward in the centrifuge 34. When the control relay 70CR is energized, its contacts 70CR*a* close and complete an energizing circuit, including normal closed contacts 73CR*b* of another relay 73CR, to energize the solenoid 48. The solenoid 48, being energized, shifts the valve 46 to the position shown which in turn causes the air from line 45 to be connected to the cylinder 41. The valves 46 and 51 are detented valves and will remain in this described condition even though the machine operator does not continue to hold the switch 77PB closed. The valve 40 is positioned as shown by this operation and the skimmer discharge 39 is connected to the recirculation line 43. Therefore, as the skimmer 36 advances at the start of a cleaning or skim cycle, the first material picked up will be returned for recirculation. This first material will be relatively clean.

After the skimmer 36 has advanced some distance, it will encounter the heavy sludge and this will begin to move through the line 39. As the heavy sludge passes the pressure switch 1PS, the hydraulic pressure in the line 39 at that location will be substantially increased to a level sufficiently high to cause the pressure switch 1PS to react and close its electrical contacts. The level of pressure at which the switch is adjusted to operate is predetermined from the particular fluid and impurities being handled and the concentrations of these which are normally found to produce satisfactory fluid cleaning. Once this has been determined and the switch 1PS adjusted, the system will automatically and repeatedly react at the desired sludge concentration.

When the switch 1PS closes its electrical contacts, the solenoid 49 is energized along with the control relay 73CR. The contacts 73CR*b* are opened and the solenoid 48 is deenergized. This reverses the valve 46 which in turn causes reversal of the flow control valve 40 and the line 39 is connected to the waste line 44. Contacts 73CR*a* of the relay 73CR are also closed to latch the solenoid 49 and the relay 73CR in the energized condition even though a subsequent drop in pressure might cause the pressure switch 1PS to open. A set of normally closed limit switch contacts 79LS*b* are included in the serial circuit of the solenoid 49 and relay 73CR which are closed except when the skimmer 36 is in the retracted position where the limit switch 79LS is operated. Therefore, until the skimmer 36 is retracted, the line 39 will be connected to the waste line 44 once the switch 1PS has operated.

At the end of its advance stroke, the skimmer 36 operates a limit switch 80LS and its contacts 80LS*a* are opened to deenergize the relay 70CR and solenoid 55. The contacts 80LS*b* are closed to energize a timer 72TR that operates for a brief time to produce a dwell period at the end of the advance stroke. At the end of the dwell period, the timer contacts 72TR*a* momentarily close and since the skimmer is advanced to allow the contacts 79LS*c* to be closed, the solenoid 53 is energized. The valve 51 is shifted back to the condition shown and the motor 37 is operated to retract the skimmer 36.

The skimmer 36 is shifted back to be fully retracted, the limit switch 79LS is again operated and the solenoid 49 and relay 73CR are deenergized. This conditions the solenoid 48 for energizing by allowing the contacts 73CR*b* to close to their normal condition, but the relay 70CR is not energized. The detented valve 46 will not change position. Operation of the limit switch 79LS will close the contacts 79LS*a* and the pump motor start relay 31MR will be energized and dirty fluid from the tank 23 will be transported to the centrifuge 34. The limit switch contacts 79LS*c* are also opened at this time to hold the solenoid 53 deenergized, but since the valve 51 is detented and the solenoid 55 is not energized, the motor 37 will continue to urge the skimmer toward its retracted position and hold it there.

The cycle described thus far has been the manually initiated, automatically progressing cycle. The apparatus also contains a circuit to automatically initiate the cleaning or skimmer cycle either at a preselected frequency or after a preselected volume of sludge is formed. A timer 71TR is provided which can be set to operate two sets of contacts 71TR*a* and 71TR*b*. Operation of these contacts will initiate the skimmer cycle at the preselected frequency. The switch 74SW will be placed in the automatic position to open its upper contacts and to close its lower contacts (as positioned on FIG. 2). This disables the switch 77PB and makes the cycle dependent upon operation of the timer contacts 71TR*b* for initiation. As soon as the timer contacts 69TR*a* close, in the automatic mode, the timer 71TR is energized through the normally closed contacts 71TR*a*. These contacts time open after a preset period and contacts 71TR*b* close at the same time. The relay 70CR is energized as is the solenoid 55. The skimmer cycle now progresses in the same manner as in the manual mode described.

The energization of the relay 70CR closes contacts 70CR*b* in series with the timer reset clutch 71TR*c* and this causes a resetting of the timer 71TR. The contacts 71TR*a* and 71TR*b* are returned to the condition shown while the skimmer cycle continues to completion. Since the control valves 46 and 51 are detented, it is necessary only to momentarily energize their solenoid to selectively position them and relay 70CR along with the solenoids 55 and 48 need only be momentarily energized. The timer 71TR is a long term timer having a cycling time that is preset to operate over a longer cycle than the skimmer operation so that between each automatic cleaning cycle sufficient time elapses to permit new sludge to accumulate in the centrifuge 34. The timer 71TR will periodically and automatically operate to initiate the skimmer on clean cycle as long as the master stop switch 76PB is not closed and the switch 74SW is in the automatic position.

For the most efficient mode of operation, the skimmer of centrifuge system should be controlled directly in response to sludge generation in the electrical machining process. Therefore, there is shown in FIG. 4 a control system whereby the centrifuge can be controlled in response to the ampere hours of energy consumed in the machining process which is directly proportional to the amount of metal removed and sludge produced. The figure shows an ampere hour meter and recording circuit 68 which takes a signal from a conventional meter circuit 69 in the circuit between the machining power supply 70 and the anode tool 71, which effects metal removal from the workpiece 72. This meter circuit 68 can be one such as the "Lectrocount III" voltage to pulse rate converter circuit adopted for ampere hour counting and obtainable as a packaged unit from the Royson Engineering Company, Hatboro, Pa. 19040.

A functional block diagram of the circuit 68 is shown in FIG. 4 to illustrate its basic operation. An input filter 73 passes a D.C. signal to a chopper circuit 74 that produces an A.C. output which is amplified by the circuit 75. The A.C. signal is applied to a phase detector 76 which recognizes the phase sense of the A.C. signal and provides a high value D.C. signal corresponding to it.

This D.C. is applied to a capacitive storage circuit **77** which is discharged periodically by a flashing type circuit such as a thyratron. The D.C. signal input to the storage circuit **77** is also fed back to the chopper circuit **74** which makes a comparison between this signal fed back and the input from the shunt **69**. The A.C. output of the chopper **74** is dependent upon the difference. A pulse amplifier **78** receives a pulse signal corresponding to the frequency of discharge of the circuit **77** and the amplified pulse signal is applied to a conventional counter circuit **79** which records the pulses in a decimally coded representation. The circuit components are selected and the system is calibrated so that the count recorded in the circuit **79** reflects ampere hurs of energy supplied to the process through the tool **71**.

A manually set control circuit **80** is provided that permits the machine set-up man to select and store a reference energy level. This circuit **80** will produce an electrical output signal in a form corresponding to the electrical output of a signal from the counter **79**. This circuit may be, for example, a digital switching network having a decimally related set of output signals corresponding in form to the outputs of a decimal counter such as used in the circuit **79** for operator convenience. A conventinal coincidence testing and operator circuit **81** receives the outputs from both the control circuit **80** and the counter **79** and when these two coincide, a relay **75**CR is energized. A set of relay contacts **75**CR*a* in parallel with the timer contacts **71**TR*b* of FIG. 2 are closed when the relay **75**CR is energized, and these contacts will effect a skimmer cycle in the same manner as described for the closing of the timer contacts **71**TR*b*. Thus, the centrifuge is caused to be responsive to the energy consumed in the machining process which is directly proportional to sludge production.

To cause a clearing of the amount of energy previously recorded and resetting of the ampere hour counter **79** to zero, a set of normally open contacts **70**CR*a* are provided to apply a reset signal from a power supply **82** to that counter. This reset occurs with each skimmer cycle since the relay **70**CR energizes in every described mode of skimmer cycle control and these contacts close each time the relay **70**CR energizes. The timer **71**TR is simultaneously reset by the closing of contacts **70**CR*b* as previously described.

The machine operator will normally select an ampere hour setting that is compatible with the volume of sludge produced by the cutting process which he intends the machine to perform. However, in processes where a very small volume of metal is to be removed, it is good to skim the centrifuge at a period of time not exceeding the time at which the sludge is compacted in the centrifuge to a solid mass that is relatively impenetrable by the skimmer and unflowable therethrough. Therefore, the timer **71**TR will be set to operate at some time before this compaction occurs even when operating with the ampere hour control. The parallel circuit arrangement of the timer contacts **71**TR*b* and relay contacts **75**CR*a* permits either of these to override the other and therefore the timer will cause the skim cycle to occur at least as frequently as required to avoid excessive compaction of the sludge even though the preset amount of energy is not consumed in the cut.

What is claimed is:

1. In a centrifuge system having a rotating member, a skimmer movable transversely therein between a retracted position and an advanced position to pick up a fluid mass rotating therewith, a conduit for carrying fluid away from the skimmer and a valve in said conduit having alternate control states to direct fluid selectively from the conduit to one and the other of two discharge pipes connected to the valve, the combination comprising:

(a) means responsive to changes of pressure of fluid passing through the conduit for producing a signal when the pressure therein exceeds a preset level, and

(b) means for operating the valve to change the state thereof from one condition to the other in response to said signal.

2. The apparatus of claim **1** wherein:

(a) said means for producing a signal is a pressure sensitive device in the conduit,

(b) said device is connected in a control circuit and operates to change from one condition to another condition when the fluid pressure in the conduit exceeds a predetermined level, and

(c) said means for operating is actuated by the control circuit and responds to changes in condition of said device.

3. The apparatus of claim **2** wherein:

(a) the control circuit responds to a change in condition of said device for changing the valve from the one state to the other, and

(b) said control circuit includes means independent of said device for operating the valve to return it from the other state to the one state thereof.

4. In combination with an electro-chemical machining apparatus including a power circuit supplying direct current electrical energy through a tool electrode and workpiece separated by an electrolyte filled gap and a centrifuge having a skimmer movable transversely therein between a retracted position and an advanced position to pick up a fluid mass therein, a conduit for carrying fluid away from the skimmer and a valve in said conduit having alternate control states to direct fluid selectively from the conduit to one and the other of two discharge pipes connected to the valve, the combination comprising:

(a) metering means for recording the amount of energy furnished by the power circuit,

(b) control means for storing a predetermined energy level as a reference,

(c) operator means responsive to coincidence between the energy recorded by said metering means and said predetermined energy level for initiating movement of the skimmer from the retracted position,

(d) means responsive to changes in pressure of fluid passing through the conduit for producing a signal when the pressure therein exceeds a preset level, and

(e) means for operating the valve to change the state thereof from one condition to the other in response to said signal.

5. The apparatus of claim **4** wherein:

(a) said metering means is an ampere hour recorder, and

(b) said control means is presettable to a predetermined ampere hour indication.

6. The apparatus of claim **4** wherein:

(a) a timer is provided and is operable to indicate the lapse of a predetermined period of time,

(b) said operator means is responsive to said timer to start movement of the skimmer when the predetermined period of time lapses before the coincidence of the predetermined energy level and the energy recorded by said metering means, and

(c) means are provided for clearing and resetting both said metering means and said timer when movement of the skimmer is initiated.

7. The apparatus of claim **4** wherein:

(a) said means for producing a signal is a pressure sensitive switch in the conduit,

(b) said switch is connected in a control circuit and operates to change from one condition to another condition when the fluid pressure in the conduit exceeds a predetermined level, and

(c) said means for operating is actuated by the control circuit and responds to changes in condition of said switch.

8. In combination with an electro-chemical machining apparatus including a power circuit outputing direct current electrical energy through a tool electrode and a workpiece separated by an electrolyte filled gap and an elec-

trolyte centrifuge system including a movable cleaning skimmer, the combination comprising:

(a) means for recording the amount of energy furnished by the power circuit,

(b) means for storing a predetermined energy level as a reference, and

(c) means responsive to coincidence between the energy recorded by said means for recording and the predetermined energy level in said means for storing for initiating movement of the skimmer.

9. The apparatus of claim 8 wherein:

(a) said means for recording is an ampere hour meter connected to the power circuit, and

(b) said means for storing is presettable to a predetermined ampere hour indication.

10. The apparatus of claim 8 wherein:

(a) a presettable timing mechanism is provided and is operable to repetitively time a predetermined interval,

(b) said means for initiating movement of the skimmer includes additional means for initiating skimmer movement in response to operation of said timer after each predetermined interval occurring before coincidence of the energy recorded and the predetermined energy level, and

(c) means for simultaneously clearing and resetting both said means for recording and said timing mechanism when movement of the skimmer is initiated.

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ROBERT W. JENKINS, *Primary Examiner.*