METHOD AND APPARATUS FOR WATER TREATMENT SYSTEM REGENERATION CONTROL

Abstract: A control module activates the regeneration cycle of a water softener based on programmable parameters such as time since last regeneration, set time and day, and other external signals such as an amount of water treated since last regeneration. The control unit's programmable controller allows the same unit to be used in a variety of applications and to be programmed to meet specific operating requirements such as maximum allowable time between regeneration cycles. The control module may also control the duration of chlorine production and provide alarm outputs in the event of system malfunction. It is advantageous that the controller be able to operate solely on battery power.
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Method and Apparatus for Water Treatment System Regeneration Control

Technical Field

The present invention relates generally to fluid treatment and in particular to an improved control system and control device for controlling a water filtration unit, water softening or deionization apparatus.

Background

Water treatment systems such as water filtration units, water softeners, or water deionization units pass untreated water through media or resin that traps undesired materials. In the case of water filtration units, media in a mechanical filter, such as carbon, traps water-borne particles in the spaces between the media. In the case of water softening or deionization units, the resin traps mineral ions such as calcium or magnesium in the untreated water. The softening resin contains ions such as sodium or potassium that can be exchanged with the undesired mineral ions. After a period of treatment, the media becomes clogged with particles or the resin becomes coated with undesired mineral ions to the point that it no longer efficiently removes the undesired constituents in the raw water. Therefore, periodically, it is necessary to backwash filtration media with treated water to flush away the accumulation of removed material or to regenerate softening media by rinsing the media in a brine solution to remove the trapped undesired mineral ions and replenish the surface of the media with ions of the original mineral.

A control valve is included in the water treatment system that uses water pressure to initiate the backwash or regeneration cycle. The control valve initiates the cycle by routing water to a nozzle that directs the water so that it impinges on a turbine. The turbine drives various valve components that operate to place a filtration system in configuration for backwash or regeneration. A control valve for filtration systems is described in U.S. Patent Nos. 3,891,552 and 4,298,025. A control valve for softening or deionization systems is described in U.S. Patent No. 5,022,994. All three of these patents are assigned to the assignee of the present invention and incorporated by reference herein in their entirety for all purposes. During backwash of a filtration system the control valve connects an inlet of the filtration system to a drain and the outlet to a source of filtered water so that the filtered water is passed back through the
filtration media to flush it. During regeneration of a softening or deionization system the control valve connects a source of brine or other chemical solution to the outlet of the resin tank being regenerated and the inlet of the tank is connected to a drain.

Due to the wide variety of conditions in which water treatment systems operate, the specific timing of the regeneration or backwash cycles will vary from application to application. In some instances it is desirable to provide the ability to manually initiate the backwash or regeneration cycle. It may also be advantageous to trigger regeneration or backwash automatically when any of the following occurs: 1) a certain amount of degradation of output water quality is detected; 2) a differential pressure across the unit increases to above a threshold pressure; 3) the elapsing of a set time interval; 4) arrival of a scheduled time and day for backwash or regeneration; or 5) when a predetermined amount of water has been treated. An additional variable in regeneration techniques is that some water softening systems also introduce chlorine into the brine rinse during regeneration to rid the system of any bacterial contamination, and this sanitation may be required by regional ordinance.

**Summary**

A control unit initiates the cleansing cycle of a media or resin filled tanks in a water treatment system based on a variety of parameters. The control unit's controller allows the same unit to be used in a many applications, including water filtration systems to initiate media backwash and water softening systems to initiate resin regeneration. The controller controls, among other things, a mechanically latching cleansing initiation actuator that is movable between a mechanically latched closed position in which no cleansing is initiated and a mechanically latched open position in which a cleansing cycle is initiated. The use of a mechanically latching actuator reduces power consumption and enables the unit to be run on batteries. The programmable controller controls the cleansing initiation actuator by supplying a relatively short duration voltage pulse to the actuator that causes it to travel between the mechanically latched closed and open positions. The controller can trigger a cleansing cycle based on, for example, a time since the last cleansing cycle; a scheduled day and time for cleansing, a differential pressure across a mechanical media filter; and a manual request for cleansing or other external inputs such as signals received from a
volumetric totalizing meter or hardness monitor. The controller may be alerted to the occurrence of a regeneration type cleansing cycle in a softening system by a pressure sensor disposed in the brine line that gives an indication that brine is flowing.

The control unit can also provide chlorination in a water softening system by powering a chlorine probe that is submerged in the brine solution. The chlorine probe is supplied with a constant current regardless of battery voltage, so that proper chlorination level is achieved more reliably.

**Brief Description of Drawings**

Figure 1 is a perspective view of a water softening system that includes a backwash/regeneration controller that is constructed in accordance with an embodiment of the present invention;

Figure 2 is an exploded perspective view of the controller of figure 1;

Figure 3 is a cross section view of the regeneration or backwash initiation control valve of Figure 1;

Figure 4 is a schematic diagram of the water softening system of Figure 1;

Figure 5 is a functional block diagram of the control board shown in Figure 2;

Figures 6A-6B are a flowchart that outlines a method of controlling regeneration and/or backwash that is implemented by the control unit according to one embodiment of the present invention; and

Figure 7 is a flowchart that outlines a method of controlling production of chlorine for sanitization that is implemented by the control unit according to one embodiment of the present invention.

**Description**

Figure 1 is an overview of a water softening system that includes a regeneration control unit 20. The water softening system includes a pair of treatment tanks 13, 14 that are filled with resin that removes unwanted mineral ions from water. A control valve 16 (cross section shown in Figure 3) operates to select which of the treatment tanks is currently treating water and controls the flow water into and out of the treatment tanks. The control valve also includes a regeneration initiation mechanism that begins the regeneration cycle and controls the flow of water and brine throughout the system during regeneration.
Feed water to and treated water from the treatment tanks flows through inlet and outlet pipes 15, 17. Brine solution from a brine tank 12 that is used for regeneration flows through a brine line 21 to the control valve 16. The control unit 20 is disposed in the flow path of the brine line so that an internal pressure sensor can sense pressure levels in the brine line that indicate when the water treatment system is in a regeneration cycle. The control unit has a fluid output 23 that supplies a flow of water to the control valve 16 to turn the regeneration turbine and initiate regeneration. A chlorine probe 25 is also in the flow path of the brine line. The chlorine probe is selectively powered by the control unit to produce chlorine in the brine solution during at least a portion of the regeneration cycle.

Figure 3 is a cross section view that provides further detail on the control valve components that initiate and control regeneration (or backwash in connection with water filtration system shown schematically in Figure 4B). Only an overview of the functioning of the control valve with respect to regeneration is provided here for context. A more complete explanation of the functioning of the control valve can be found in U.S. Patent No. 5,022,994. Currently available water softening systems that employ the control valve 16 shown in Figure 3 can trigger regeneration at any time using an external actuator that is operated at a scheduled time or when water quality has degraded by a certain amount or the actuator may be operated manually at any time by the user. To initiate regeneration, it is necessary to cause regeneration turbine 50 to rotate. This is accomplished by supplying water through a cycle initiation nozzle 60 that impinges on the turbine 50 and to cause rotation. The water then drains through line 24 (also shown in Figure 1). The rotation of the regeneration turbine produces relative motion between control valve components that eventually connect a regeneration passageway 58 to a source of pressurized water. Once the flow of water through passageway 58 commences, the flow through the cycle initiation nozzle 60 is no longer necessary and is discontinued. In this manner, a flow of pressurized water from the passageway impinges upon the turbine and causes it to continue to rotate for the remainder of the regeneration cycle. This flow of water onto the turbine drives the valve components to selectively connect and disconnect water flow passageways at predetermined intervals during the regeneration cycle. The control unit 20 controls the
flow of water to the cycle initiation nozzle 60 as will be described below. Regardless
of whether the control valve is used in conjunction with a softening system or a
filtration system, the regeneration or backwash cycle is initiated by connecting a source
of pressurized treated water to the cycle initiation nozzle. Therefore the control unit 20
can operate with both types of water treatment systems.

Turning now to Figure 2, an exploded view of the control unit 20 is shown. An
enclosure mid-wall 53 serves as central structure for mounting control unit components
and back and front covers 28, 29. The control unit is capable of running solely on four
AA type batteries that are housed in a battery pack 27. A control board 26 includes a
microprocessor that stores and performs operating instructions for the water treatment
system components. A latching, DC, bi-stable solenoid valve 51 is mounted within the
control unit 20. The bi-stable solenoid is selectively actuated by the control board to
serve as the regeneration actuator and initiate regeneration by routing pressurized water
to the nozzle 60. The bi-stable solenoid reduces power consumption because it changes
state in response to voltage pulses and remains mechanically latched in either position
in the absence of power. The bi-stable solenoid transitions between a closed position in
which no water is supplied to the nozzle 60 and an open position in which water is
supplied to the nozzle via line 23 (Figure 1) to squirt water on the regeneration turbine
to initiate a regeneration cycle. For the purposes of this description, a bi-stable latching
solenoid is used to control the supply of water to the nozzle, however it will be
apparent to one of skill in the art that other actuating means may be used. When used
in softening or deionization systems, the control unit 20 also controls the operation of
the chlorine probe 25 as will be described in more detail with reference to Figure 7.

Figure 4A is a schematic illustration of a water softening system that includes a
bi-stable solenoid to control the flow of water to the cycle initiation nozzle 60. The
control valve 16 is shown schematically between the inlet pipe 15 and outlet pipe 17.
The brine line 21 that is connected to the brine tank 12 supplies brine solution to the
treatment tanks during regeneration. A pressure switch “A” on the brine line senses the
vacuum caused by the flow of brine through the line during regeneration. In this
manner, the sensed pressure signal sends a signal to alert the control unit that a
regeneration cycle has begun. The control unit may alter the timing of subsequent
scheduled regeneration cycles based on the sensed occurrence of a regeneration cycle. In response to this signal, the control unit also supplies current to the chlorine probe 25 that flows between the contacts of the probe to generate chlorine in the brine solution for sanitization. The duration of chlorine production is a programmable parameter. A chlorine probe 25 is located in proximity to the control unit 20 and is inserted in the brine line.

Figure 4B is a schematic illustration of a water filtration system that includes a bi-stable solenoid to control the flow of water to the cycle initiation nozzle 60. The control valve 16 is shown schematically between the inlet pipe 15 and outlet pipe 17. A differential pressure switch 31 measures the pressure drop across the water filtration system. As the media collects materials filtered from the water, the pressure drop increases. When the pressure drop increases to a preset threshold, regeneration is initiated. The bi-stable solenoid 51 is actuated by the control unit to selectively route treated water to the control valve 16 to the nozzle 60 (Figure 3) when the control unit determines that a backwash cycle should be initiated.

Figure 5 is a functional block diagram of the control board 26. The control board can be powered by the battery pack 27 or by an external 12 Volt DC power supply. The control board includes operator interface button bank 45 by which means the operator can set the present day ("Day" button) and time ("Time" button) and the desired regeneration/backwash day (dip switches 34), regeneration/backwash time ("Regen" button), and program various regeneration parameters such as time between cycles, the duration of chlorine production ("Chlor" button), and the length of time the bi-stable solenoid valve remains open during regeneration initiation ("Kick" button). In addition, combinations of buttons can be actuated simultaneously to allow a user to call for regeneration at any time.

When used with a filtration system, the control unit inputs a pressure signal 31 from the differential pressure switch B which gives a an indication as to the efficiency with which the filtration system is operating. This signal can be used to trigger a backwash cycle when the pressure drop indicates that the filtration media is becoming clogged. When used with a softening system, the control unit inputs a signal 33 from the pressure switch "A" that indicates that a regeneration cycle is occurring. The
control unit uses this information to trigger chlorine production by supplying current to the chlorine probe and also to reset the countdown timer which cancels soon-to-occur scheduled regeneration cycles. To conserve power consumption and assure proper chlorine levels, the current source on the control unit is a constant current source whose current supply does not vary within an operating range as a function of battery voltage. The method used by the control unit to operate the bi-stable solenoid and the chlorine probe are described below. In addition one or more external contact closures 37 can be operated by other external means, such as a manual initiation feature, volumetric totalizing meter or a water quality monitor, to provide an input to the control board to cause the board to actuate the bi-stable solenoid 51 to initiate regeneration or backwash.

Regeneration or backwash triggering events are specified by the user. The water treatment system can operate in two modes, a weekly day timer mode in which the user can select certain days/times of the week for regeneration or backwash to occur or in a countdown mode that initiates a regeneration or backwash cycle at preset time intervals. In both modes, regeneration or backwash can be manually triggered by actuating two buttons on the control board. In filtration systems, backwash can be triggered by a sensed pressure drop across the filtration system exceeding a preset threshold for a given period of time, such as fifteen minutes, which can indicate that the media has become clogged. In softening systems, regeneration can be triggered by an external contact for five seconds on the "regen" input.

When the treatment system is in weekly day timer mode, the treatment system performs a regeneration or backwash cycle at a specific time on preset days of the week. If an external contact or pressure drop regeneration occurs as triggered by the external contact on the "regen" input or the differential pressure input, regeneration or backwash can be initiated immediately or may be delayed at the user's request until the specified time of day. If a regeneration or backwash cycle is triggered manually the regeneration cycle is initiated immediately.

When the system is in the countdown timer mode, a regeneration will be initiated each time the timer counts down from the preset number of hours, usually 48 or 96 hours. If a manual, external contact, or pressure drop trigger initiates a regeneration or backwash cycle, the countdown timer is reset at that point and the
countdown begins again. Also, if a "reset" input is received, caused by the control valve's normal regeneration for manually initiating a regeneration by the user on the control valve, then the countdown timer is reset.

Figures 6A-6C illustrate one solenoid operating method 100 that can be stored and executed by the control board to selectively actuate the bi-stable solenoid to initiate a regeneration when the user specified triggering events occur. In each method cycle, a determination is made as to which of these modes of operation has been selected at 110. If the system is in countdown timer mode, at 115, the current value of the timer is compared to the set countdown time and if it is time to initiate regeneration,

regeneration is initiated at 175 (as will be described later). If the system is in day mode, the current time is compared to the set regeneration time at 125. At 130 the status of a delayed regeneration request flag is checked to determine if regeneration has been called for by some other trigger but whose occurrence is to be delayed until the preset regeneration time. If the flag is set, the flag is reset at 135 and regeneration is initiated at 175. If the delayed regeneration request flag is not set, the current day is checked against the set regeneration day at 140 and if it is the scheduled regeneration day, regeneration is initiated at 175.

At 150 and 155, the pressure drop input and manual regeneration input are checked to see if either of these inputs is calling for regeneration. If one or both of them is calling for regeneration, the delay response mode setting is checked at 160. If the delay response mode indicates that delayed regeneration has not been requested, regeneration will be immediately initiated at 175. If the system is in day mode and delayed regeneration has been requested, the delayed regeneration request flag is set at 165 so that regeneration will be delayed until the set time unless the user is manually overriding the delay at 170, in which case regeneration is initiated at 175.

At 175, the method begins the process of actuating the solenoid to start regeneration. Prior to actuating the solenoid the battery voltage is checked by attempting to moved the valve to the closed position (its present state) to insure that the remaining voltage is sufficient to move the solenoid to the open and closed position to avoid having the solenoid stuck in the open position due to low power. At 180 the solenoid is actuated to open the valve and a counter begins counting down toward the
preset "kickstart" time during which water should be supplied to the nozzle. After regeneration or backwash has been initiated for any reason, the countdown timer is reset at 183. At 185 if the open time is equal to the kickstart time, at 188 the counter is reset and at 192 the solenoid is actuated to close the valve. If the kickstart time has not yet expired at 190 a manual regeneration termination input is checked and if it has occurred the valve is closed prior to expiration of the kickstart time.

In some applications, it is desired that chlorine be injected into the system during regeneration to sanitize the system. In this case, the control board executes a method such as the chlorine probe control method 200 that is outlined in Figure 7. At 210 a "reset" input is monitored. The reset input is set when the pressure sensor A indicates that regeneration is occurring. Once regeneration has been ongoing for one minute, meaning that the brine line should be full of solution around the probe, at 220 the countdown time is reset and a constant current, usually around 137 mA, is supplied to the chlorine probe for the preset time. At 230 the chlorine probe voltage is checked and if it is out of specification, an alarm light is turned on at 235 and the chlorine probe is turned off at 243. At 240 if the preset time has expired or if regeneration has terminated at 243 the chlorine probe is turned off. At 245, the reset input is checked to ensure that it has been at least two minutes since the last regeneration and if so, the routine returns and waits for the next regeneration.

According to a feature of the invention, there is a lockout timer 250 (Figure 6C) which prevents a regeneration from occurring from the beginning of the last regeneration for a set period of time, such as five hours. During this lockout period, requests for regeneration from the various methods previously described, will be remembered and a regeneration will be initiated at the end of the lockout period.

This lockout feature can be overridden by pressing and holding the "TIME" and "REGEN" buttons for twenty seconds. Also, the lockout time remaining can be observed by pressing and holding the "REGEN" and "KICK" pushbuttons for five seconds.

While the present invention has been described with a degree of particularity, it is the intent that the invention includes all modifications and alterations from the disclosed design falling with the spirit or scope of the appended claims.
Claims

1. For use with a water treatment system that treats feed water by passing it through a tank containing media that is periodically cleansed; wherein the water treatment system includes a control valve that selectively places the water treatment system in configuration for a cleansing cycle in which the media filled tank is flushed with a cleansing solution; and wherein the control valve uses a supply of water that flows through a nozzle to initiate the cleansing cycle, a control valve control unit comprising:

   a mechanically latching cleansing initiation actuator that is disposed in a flow path between a source of water and the nozzle wherein the cleansing initiation actuator interrupts the flow of water to the nozzle when in a mechanically latched closed position and moves out of the flow path to allow water to flow to the nozzle when in a mechanically latched open position; and

   a programmable controller that controls the cleansing initiation actuator by supplying a relatively short duration voltage pulse to the actuator that causes it to travel between the mechanically latched closed and open positions.

2. The control unit of claim 1 including controller power source that accepts one or more D.C. batteries.

3. The control unit of claim 1 including a controller power source that is a 12 V DC adaptor.

4. The control unit of claim 1 wherein the water treatment unit is a filtration system that includes a tank filled with mechanical filter media.

5. The control unit of claim 4 wherein the media is carbon.

6. The control unit of claim 4 including a differential pressure sensor that senses a difference in water pressure upstream of the tank and downstream of the tank
and wherein the programmable controller actuates the cleansing initiation actuator based on the differential pressure.

7. The control unit of claim 6 wherein the programmable controller actuates the cleansing initiation actuator to move to the open position when the differential pressure exceeds a threshold.

8. The control unit of claim 1 wherein the water treatment system is a water softening system that and wherein the media is a chemically active resin that removes mineral ions from the feed water and wherein the cleansing solution is a brine solution that replaces removed mineral ions on the surface of the media with ions from the brine solution to regenerate the resin.

9. The control unit of claim 8 comprising a brine line pressure sensor disposed within a brine line that connects a brine storage tank with the water treatment system and wherein the controller receives signals from the brine line pressure sensor that indicate that cleansing solution is flowing through the brine line.

10. The control unit of claim 8 comprising a chlorine probe having probes that are disposed in the brine solution and wherein the controller includes a constant current source that can supply a constant current to the chlorine probe such that the current flows between the probes and produces chlorine in the brine solution to sanitize the tank during cleansing.

11. The control unit of claim 1 wherein the controller includes a countdown timer that can be set to a desired time between cleansing cycles and wherein the controller initiates a cleansing cycle when the timer has counted down the time between cycles.
12. The control unit of claim 1 wherein the controller includes a manual cleansing cycle input capable of receiving a signal that causes the controller to initiate a cleansing cycle.

13. The apparatus of claim 1 wherein the cleansing initiation actuator is a latching bi-stable solenoid.

14. A method that initiates a flow of water to trigger a cleansing cycle in a water treatment system comprising:
   monitoring water treatment system functioning to detect the occurrence of one or more trigger events; and
   actuating a latching cleansing initiation actuator when one or more trigger events has occurred.

15. The control unit of claim 1 wherein the controller includes a lockout timer that inhibits a cleansing cycle for a predetermined period of time.

16. The control unit of claim 8 wherein the controller includes a lockout timer wherein regeneration of the resin is inhibited for a predetermined period of time.

17. The control unit of claim 15 wherein said lockout timer can be overridden by a user input.
START

IS "RESET" INPUT ON FOR 1 MINUTE?

REPEAT COUNTDOWN TIME AND TURN ON CHLORINE PROBE FOR SETTABLE ON TIME (1 TO 20 MINUTES)

IS CHLORINE PROBE VOLTAGE WITHIN SPECIFICATIONS?

IS CHLORINE TIME FINISHED OR IS "RESET" INPUT OFF?

TURN OFF CHLORINE PROBE

IS "RESET" INPUT OFF FOR 2 CONTINUOUS MINUTES?

Fig. 7