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Calmon

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[45] **Dec. 23, 1975**

[54] **DETECTION DEVICES FOR USE IN SOLUTION PROCESSING SYSTEMS**

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[21] Appl. No.: **534,466**

[52] **U.S. Cl.** **210/96;** 210/139

[51] **Int. Cl.²** **B01D 15/06**

[58] **Field of Search** 210/96, 139, 149

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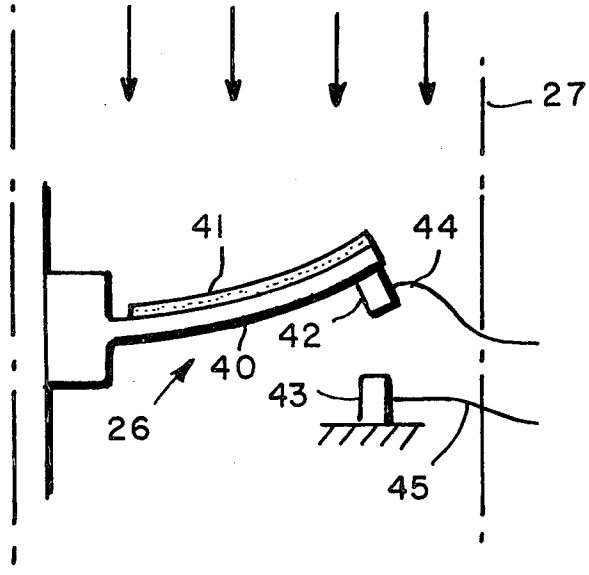
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[57] **ABSTRACT**

A detection device for use in a cyclical solution processing system, such as a water softening system, where an ion-exchange material the dimensions of which vary as a function of the salt concentration of and the valence of ions present in the solution is placed on a flexible, solid substrate material of fixed dimensions. The device is placed in contact with the processed solution at or near the system output so that the dimensional changes of the ion-exchange material causes a flexing of the substrate material, which device is then effectively used as a switch in control circuitry for controlling the operating time of one or more of the sub-cycles of operation required in the overall processing cycle.

13 Claims, 8 Drawing Figures



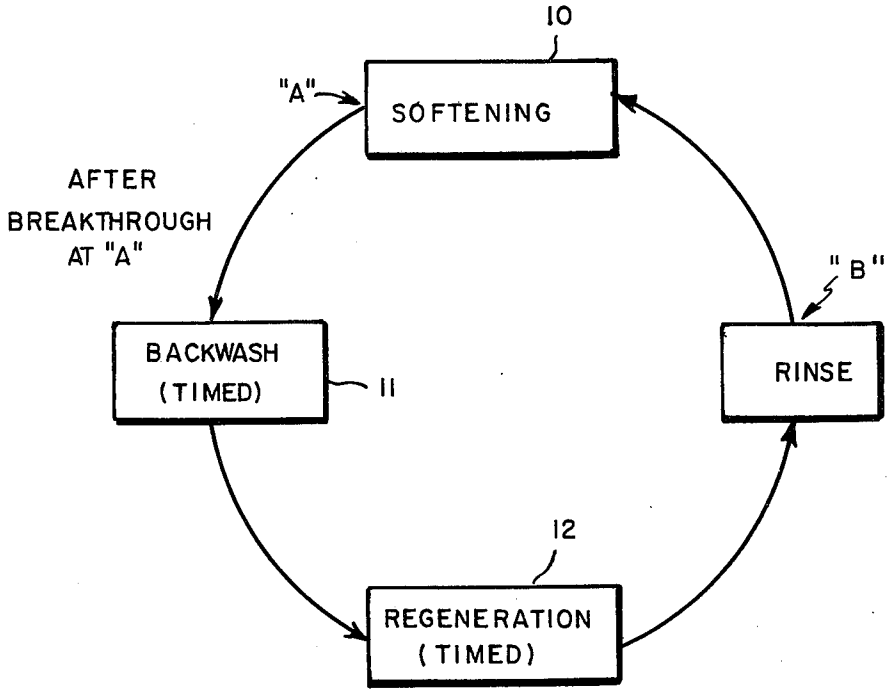

10
"A"
SOFTENING
AFTER
BREAKTHROUGH
AT "A"
"B"
BACKWASH
(TIMED)
11
RINSE
12
REGENERATION
(TIMED)

FIG. 1

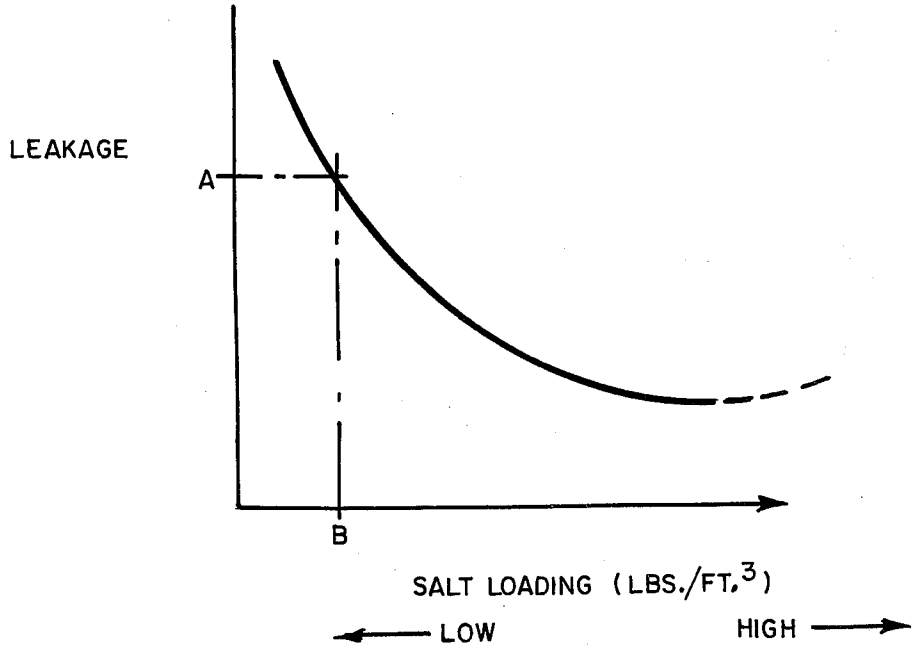

LEAKAGE
A
B
SALT LOADING (LBS./FT.3)
LOW
HIGH

FIG. 6

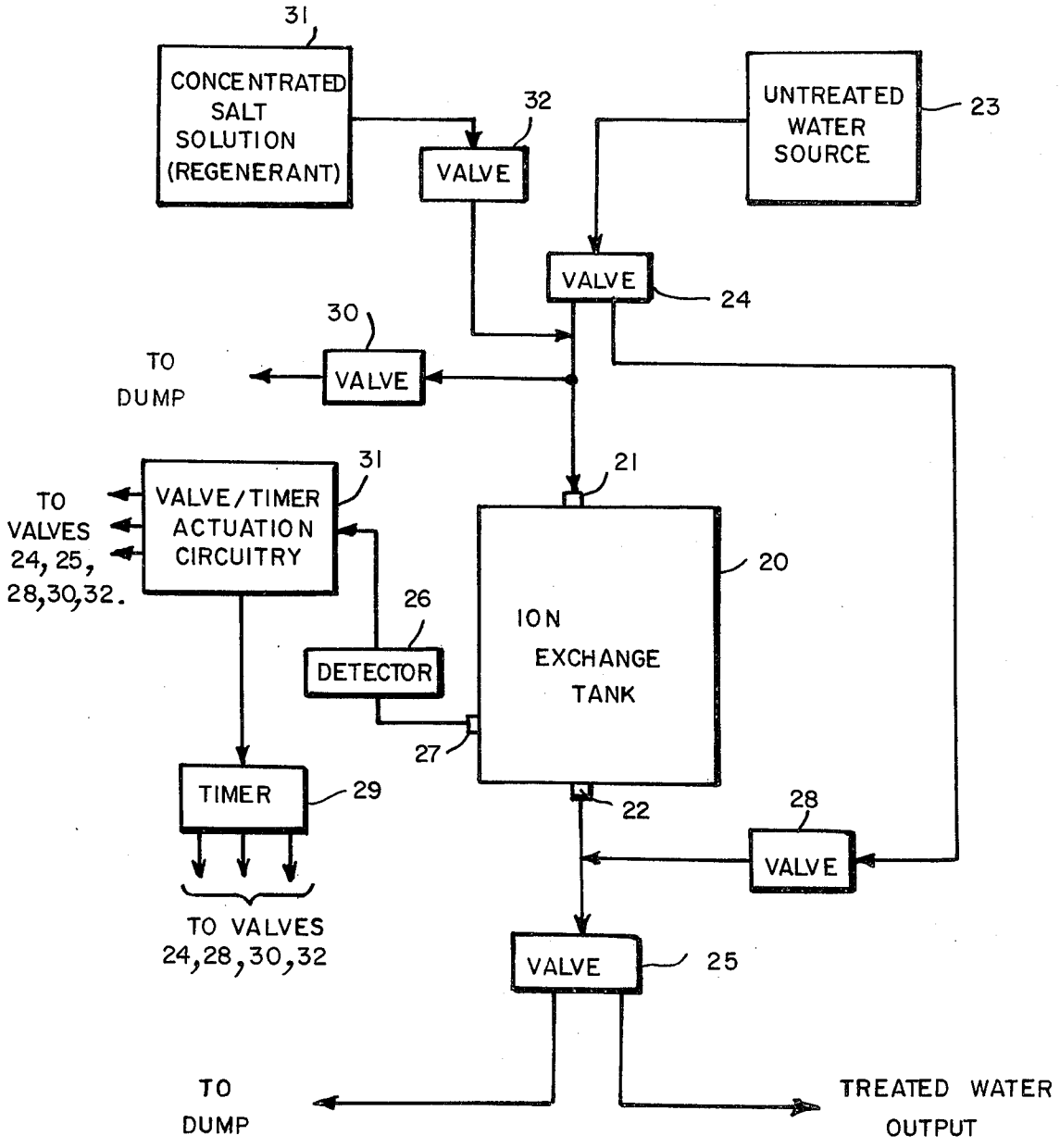

31
CONCENTRATED SALT SOLUTION (REGENERANT)
32
VALVE
UNTREATED WATER SOURCE
23
VALVE
24
30
TO DUMP
VALVE
31
21
TO VALVES 24, 25, 28, 30, 32.
VALVE/TIMER ACTUATION CIRCUITRY
20
ION EXCHANGE TANK
26
DETECTOR
27
TIMER
29
22
28
VALVE
TO VALVES 24, 28, 30, 32
VALVE
25
TO DUMP
TREATED WATER OUTPUT

FIG. 2

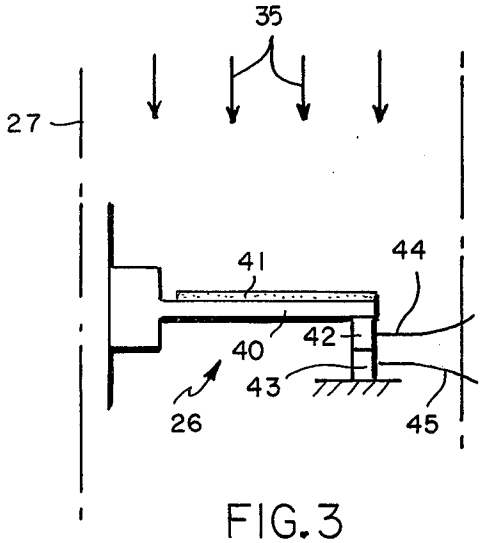


FIG. 3

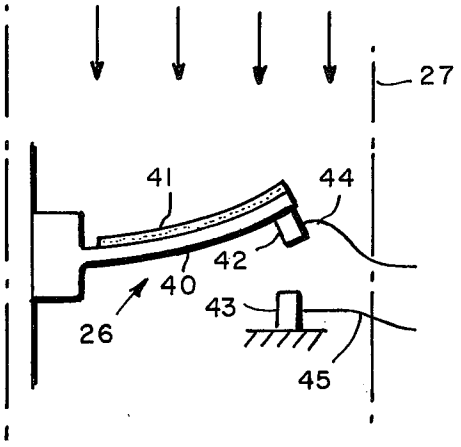


FIG. 3A

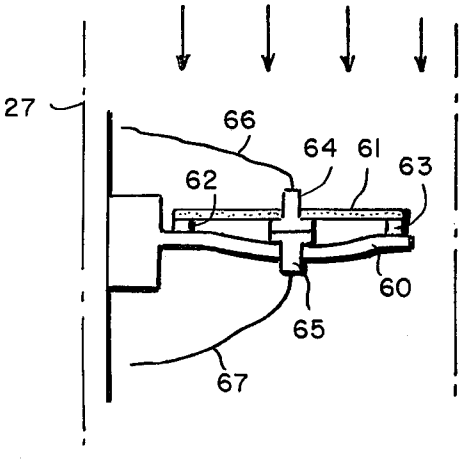


FIG. 5

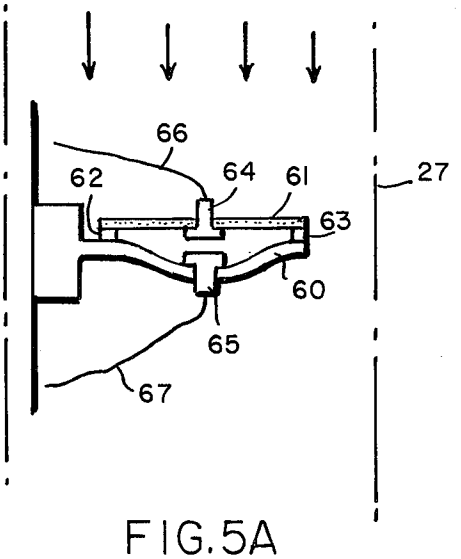


FIG. 5A

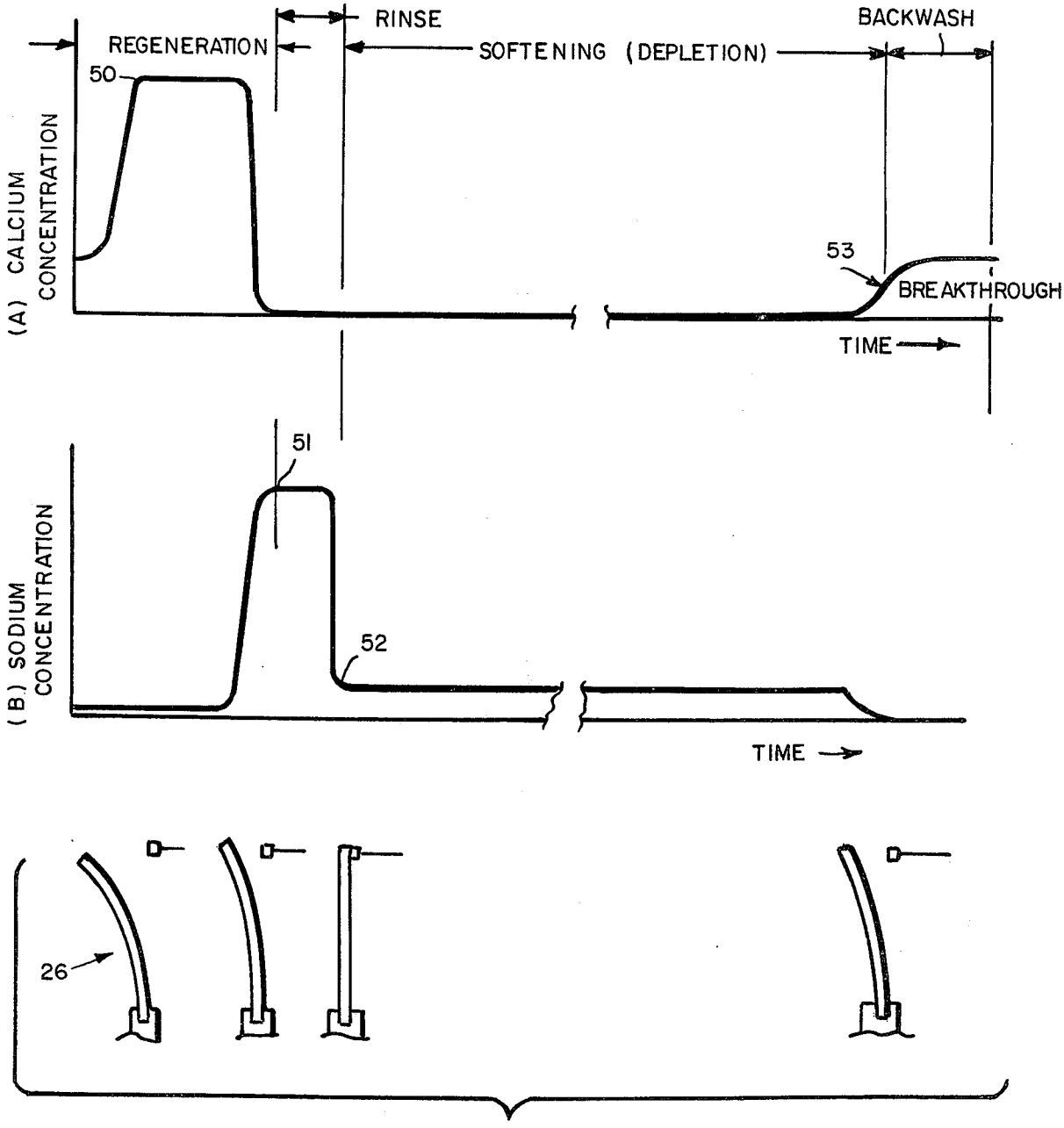

REGENERATION
RINSE
SOFTENING (DEPLETION)
BACKWASH
50
(A) CALCIUM CONCENTRATION
53
BREAKTHROUGH
TIME
51
(B) SODIUM CONCENTRATION
52
TIME
26

FIG.4

DETECTION DEVICES FOR USE IN SOLUTION PROCESSING SYSTEMS

INTRODUCTION

This invention relates generally to devices for detecting certain points in the operating cycle of a water treatment system and more particularly, to a device for detecting the end of the service, or processing, sub-cycle and/or the end of the rinse sub-cycle of a water treatment operating cycle.

BACKGROUND OF THE INVENTION

In many sections of the world, water which is available for use contains metallic ions such as calcium, magnesium, iron or other ions which make the water too hard for effective use thereof. In order to soften such water (i.e. remove the undesired ions thereof) ion exchange systems have been utilized wherein the multi-valent metallic ions are exchanged for relatively innocuous mono-valent ions such as sodium.

The normal overall operating cycle of such a system usually includes the following four sub-cycles thereof:

1. the Softening sub-cycle wherein the multi-valent ions of the water to be treated are exchanged for the monovalent ions by the passge of the water to be treated through a fixed bed of ion exchange material in the sodium form;

2. the Backwash sub-cycle wherein the fixed ion exchange bed is counter-washed to remove dirt or other undesired solid particles which may have become caught in the interstices between the ion exchange resin particles or beads;

3. the Regeneration sub-cycle wherein the ion exchange material which has become effectively depleted of its ions for effective exchange purposes during the softening sub-cycle is placed in its original sodium condition by the use of a regenerant solution which is passed through the fixed bed to resupply the mono-valent ions as desired in a regenerating ion exchange process; and

4. the Rinse syb-cycle wherein the regenerated ion exchange material is rinsed free of residual salt which has been used in the regenerant solution and the exchanged ions from the resin.

During such operation, it is desirable to provide the most efficient system so that the end of the softening sub-cycle be detected with accuracy. Such point in the overall operating cycle is often called the "breakthrough" point, that is, the point in a water softening process at which the softened output water begins to become hard again due to the presence of the multivalent metallic ions which can no longer be removed totally once most of the available groups have been utilized. If such point is not accurately detected so that the output water obtained by the softening process can be appropriately shut off and regeneration of the ion exchange material can take place, the undesired metallic ions will be present in the output water which is to be used and their presence will lead to scaling, excessive soap consumption, staining and fouling, etc.

It is also desirable to be able to detect accurately the end of the rinse sub-cycle because, if such end point is not known, the output water at the start of the softening sub-cycle may have an excessively high sodium content which condition is undesirable for reasons of both health and taste.

DESCRIPTION OF THE PRIOR ART

In many presently known water softening processes which utilize ion exchange materials, the operating cycle is usually determined by timing devices which bring each portion of the overall cycle to an end after a predetermined time period which can be set, for example, by an operator. Other systems detect breakthrough for example, by providing devices for monitoring the volume of water which is being treated, the service sub-cycle shutting off after a specified volume has passed through the monitoring device. Such methods may be inefficient or ineffective if the timing or volume is inaccurate. For example, a waste of ion exchange capacity can result if the softening sub-cyle is shut off too soon or untreated or partially treated water will be produced if the softening sub-cycle continues beyond the capacity of the exchanger. If the sub-cycles are not specifically timed, variations in the volume of water used either in home or in plant operation can cause the system to operate at less than its optimum effectiveness. Moreover, if volume is used as a monitoring characteristic, a change in the incoming water composition to be treated will also cause a volume measurement system to operate at less than its optimum effectiveness.

One device for controlling the operation of the softening sub-cycle has been suggested in U.S. Pat. No. 3,250,392 issued to J. R. Luck on May 10, 1966. The device therein utilizes a ribbon type sensor, the length of which changes depending on the type of ion content of the water to which it is exposed. The ribbon is in the form of a thin ion exchange membrane which is mounted so as to be exposed to the water flow. When the water is soft (i.e. treated water containing sodium only) the ribbon is at its maximum length and when the water contains hardness-causing ions (i.e. Ca^{++} or Mg^{++}), the ribbon shrinks by a pre-determined amount depending on the content of multi-valued ions exchanged on it. The ribbon is connected to a switch which opens, or closes, a circuit at the end of the softening sub-cycle (at the breakthrough point) so as to control the time at which energization of the regeneration means occurs.

One of the problems arising from the use of such a thin membrane, or ribbon, structure as in the Luck patent, is that the degree of dimensional sensitivity depends on the cross-linking of the ion exchange material used therein. Thus, the lower the cross-linking the greater the volume, or dimensional, change thereof. However, the lower the cross-linking (i.e. the greater the sensitivity), the weaker the membrane structure, such structures thereby being subject to frequent breakage in use. Accordingly, the reliability thereof and the cost involved in shutting down the entire system for replacement of a damaged membrane makes the use of such a ribbon structure less effective than is desirable. If an attempt is made to strengthen the ribbon by utilizing a rigid inert backing to maintain structural and dimensional integrity, the membrane cannot be utilized since the backing will prevent changes in length thereof.

Moreover, the Luck patent does not suggest any means for effectively determining the end of the rinse sub-cycle, but only deals with the question of detecting the end of the softening sub-cycle so that regeneration can be appropriately actuated.

SUMMARY OF THE INVENTION

This invention avoids the problem of structural weakness inherent in the detection device of the Luck patent and offers a more sensitive and reliable means of detecting not only the end of the softening sub-cycle, but also if desired the end of the rinse sub-cycle of the overall system. In accordance therewith, the detector utilizes an ion exchange material in film, fiber or granular form, such material being placed on one surfce of a relatively rigid but flexible solid material. The cross-linking of the ion exchange materials can be very low provided they are selected so as to be insoluble in solution. The active ion exchange materials are applied to the surface of the solid material in their most expanded form. When the combined detector structure is in contact with a solution containing multi-valent ions (i.e. the solution contains hardness), the ion exchange material shrinks so as to cause the overall structure to deflect, or bend, out of its normal plane, the change in curvature thereof being an indication of a change in valence of the ions forming the counter-ion of the ion exchange material. Such deflection accurately detects the point at which break-through (i.e. the presence of multi-valent ions) occurs at the end of the softening sub-cycle (i.e. at the point where the effective ion-exchange capacity of the ion-exchanger is reduced).

Moreover, the same detector structure can be utilized to determine the end of the rinse sub-cycle. Thus, the ion exchange material is in a deflected condition when in the presence of a solution having a high concentration of mono-valent salt ions (i.e. sodium ions as would occur during the rinse sub-cycle) but is in its extended, or non-deflected, position in the presence of a solution of mono-valent ions of low concentration as would occur at the end of the rinse sub-cycle.

The specific structure and use of the detection device of the invention is described in more detail with the help of the attached drawings wherein

FIG. **1** shows a simplified diagrammatic representation of the overall operating cycle of the system;

FIG. **2** shows a diagrammatic representation of an appropriate water softening system utilizing a tank containing a fixed bed ion exchanger which system uses the detection device of the invention;

FIGS. **3** and **3A** show a more detailed diagrammatic representation of one embodiment of the detection element of the detection device of the invention;

FIG. **4** shows the configuration of the detector device at various points in the overall operating cycle of the system shown in FIG. **1**;

FIGS. **5** and **5A** show a more detailed diagrammatic representation of another embodiment of the detection element of the detection device of the invention; and

FIG. **6** shows a graphical relationship between leakage and salt loading in the regenerant solution.

FIG. **1** depicts the overall operating cycle of a typical water softening system. As can be seen therein, in the softening portion **10** of the cycle, untreated water containing hardness-causing ions is changed to treated water containing non-hardness-causing ions by ion exchange, the ion-exchange material being effectively depleted or exhausted at the end thereof (Point "A"). Following the softening portion of the cycle, the dirt and other materials which may be present in the bed of ion exchange material is cleansed in a backwash, or counter-wash, portion **11** of the cycle which can be arranged to extend for a pre-determined time period at a given flow rate through suitable timing means. After the backwash portion of the cycle, the depleted ion exchange material is regenerated (portion **12** of the cycle) with a salt solution of a given strength at a prearranged flow rate so as to regenerate the ion exchange material and to place it in the condition required for the exchange operation in the next softening sub-cycle. After the timed regeneration sub-cycle, the bed is rinsed free of the excess regenerant salt solution, as well as some of the exchanged hardness-causing ions which still diffuse out of the ion exchange particles. At the end of the rinse process (Point "B"), the ion exchange material is then ready for use in softening the untreated water.

The detection device of the invention is utilized to determine both the end of the softening portion of the cycle (Point A) and the end of the rinse portion thereof (Point B) or to determine each of such points individually.

A diagrammatic representation of a typical apparatus useful for an ion exchange water softening process is shown in FIG. **2** wherein a fixed bed of ion exchange material in the form of ion exchange beads, or particles, is contained within a tank **20** into one end of which, identified as the "input" end **21**, a liquid material to be treated, such as "hard" water, is introduced, the treated liquid which has passed through the ion exchange bed being obtained at the output end **22.**

Thus, during the softening portion of the operating cycle of the system, untreated water from a source is introduced into the input end of ion exchange tank **20** through an appropriate valve **24.** As the untreated water initially moves through the ion exchange bed, the contaminant ions (e.g. Ca^{++} ions) therein are exchanged with the counter ions (e.g. Na^{+} ions) in the ion exchanger in a relatively narrow zone near the top of the bed. The exchange zone effectively travels through the tank at a much slower rate than the input water, thereby leaving depleted exchange resin particles behind. Accordingly, treated water, in which the hard ions have been removed, is available at the output end **22** and can be supplied via valve **25.** The treated water is continuously supplied until the exchange zone reaches close to the bottom of the bed at which time the ion exchange material is depleted for complete softening and the break-through of hardness causing ions takes place.

A detector **26** of the type described in more detail, for example, with reference to the embodiments of FIGS. **3** and **4** is appropriately positioned outside the tank and a sample of the treated water is supplied thereto. For example, an outlet pipe may be used to obtain the sample and the detector is placed in the outlet pipe, so as to come into contact with the sampled water, as explained more fully below. At the end of the softening portion of the cycle a break-through appears, that is, the ion exchange material of the bed in tank **20** becomes substantially depleted. Accordingly, the multi-valent ions in the untreated water appear in the water sample supplied at the outlet pipe **27** of tank **20.** Such break-through point is detected by detector **26** which causes valve **24** to be actuated so as to divert the supply of further untreated water from the input of ion exchange tank **20** to a valve **28** for purposes described below.

At the same time, timer **29** is activated and in turn activates valve **28** so that the untreated water supplied thereto from source **23** via valve **24** is fed to the output

end 22 of tank 20. Such untreated water is thereby forced through the ion exchange bed in a reverse direction so as to clean out dirt or other foreign solids, which may be present in the bed. The back-wash water is then appropriately dumped via valve 30 which has been activated by valve activation circuitry 31.

At the end of the back-wash sub-cycle, as determined by the setting of timer 29, regeneration of the ion exchange bed must begin. Accordingly, valves 24, 28 and 30 are appropriately actuated so as to end the back-wash portion of the cycle. Simultaneously, timer 29 activates a valve 32 so that a concentrated salt solution from a supply 31 thereof (i.e. the regenerant solution) is supplied to the input 21 of ion exchange tank 20. The sodium ions therein are exchanged for the multi-valent ions in the depleted ion exchange bed so as to resupply the latter with sodium ions and place it in condition for the softening portion of the cycle. The waste regenerant leaving ion exchange 20 is thereupon dumped via valve 25.

At the completion of the regeneration sub-cycle as appropriately timed by timer 29, valve 32 is activated so as to stop the feeding of salt solution to the tank. At the same time, valve 24 is actuated so as to supply untreated water once again from source 23 to the input of ion exchange tank 20 at the beginning of the rinse portion of the operating cycle. During the rinse sub-cycle, the regenerated ion exchange bed is cleansed of the residual salt and the exchanged hardness ions which diffuse out of the ion exchange particles by the rinse which is discharged from the tank via valve 25. At the end of the rinse sub-cycle, when the salt concentration of the solution of the sample fed to the detector is extremely low, valve 25 is actuated so that untreated water from source 23 again is fed to the input 21 of ion exchange tank 20 for softening to supply treated water at tank output 22 as discussed above.

In a typical operation, the service or processing portion of the cycle, i.e. the "softening" process in a water softening apparatus, for example, is often arranged so as to provide daily regenerations of the ion exchange bed, such duration being effectively controlled by the size of the bed and the rate of flow of the water through it. If costs are minimized the service time can be reduced to shorter time periods, e.g. four to eight hours, so that smaller equipment and a smaller volume of resin is needed. Continuous operation can be obtained by switching operation to another column, for example. The back-wash process is carried out for about 15 to 30 minutes in a typical installation, the reserve flow being at such a rate that the ion exchange bed tends to expand by 50 to 100 percent of its original volume. The flow rate is controlled to be low enough so that resin particles are not carried out of the tank. At the end of the back-wash, the bed settles so a substantially uniform packing and any channelling formed during the preceding service portion of the cycle is removed. The regeneration period depends on various parameters, but basically it should be slow enough to assure that adequate exchange takes place. Thus, regeneration may typically take 20 to 60 minutes for a 24 hour service run.

While regeneration is described above as occurring in a downward direction, the regenerant solution could alternatively be fed upwardly through the bed, such a regeneration process being referred to as counter-current regeneration.

The rinse sub-cycle can often be arranged to provide for an initial slow rinse wherein the rinse water is passed slowly through the bed to displace the residual regenerant solution which may be collected for recycling, if desirable. The slow rinse is followed by a relatively fast rinse to clear out any remaining residue of regenerant solution until the rinse sub-cycle is ended.

In order to detect the points at which the softening and the rinse sub-cycle end, the detector 26 must be made sensitive to the presence of ions of different valences and also to the concentration of salt in the solution to which it comes into contact.

As can be seen for example in Table I below, an ion exchange material shows a volume reduction in the presence of a salt solution as a function of the concentration thereof, the salt in effect acting as a dehydrating agent which shrinks the ion exchange material. The degree of shrinkage depends not only on the concentration of the salt solution with which it is in contact but also on the cross-linking of the exchanger. The table specifically shows the percentage of volume reducton of a cation exchanger comprising a sulfonated copolymer of styrene cross-linked with a 1 percent divinyl benzene when it is in contact with sodium chloride solutions of varying concentrations.

TABLE I

Concentration of Salt Solution	Volume Reduction of Exchanger
0.00%	0%
0.03	4
0.06	7
0.1	13
0.3	25
0.6	33
1.4	44
2.9	51
5.8	57
11.7	65

Table II below shows the effect on the volume of an ion exchange material in the presence of counter ions having different valences. Thus, the cation exchanger of the type discussed with reference to Table I shows a reduction in volume in the presence of an ion exchange resin having cations of different valences from sodium ions having a valence of one to thorium ions having a valence of four.

TABLE II

Valence of Cation	Ratio of Volume of Ion Exchanger (Compared to Sodium State)
1 (e.g., Na^{+})	1.0
2 (e.g., $Mg^{++}Ca^{++}$)	0.5
3 (e.g., Cr^{+++})	0.25
4 (e.g., Th^{++++})	0.10

The detection device of the invention is fabricated to react to the shrinkage in volume in such a way as to indicate both the end of the softening portion of the cycle (at which break-through and the presence of multi-valent ions occurs) and the end of the rinse portion of the cycle at which the concentration of salt solution changes from a relatively high concentration to a relatively low concentration. FIG. 3 shows one embodiment of the detector 26 of the invention which includes a substrate 40 which is a relatively rigid, but flexible, strip of solid backing material fixedly mounted in an outlet pipe 27 (as shown in phantom) of ion exchange tank 20. The outlet pipe can be appropriately

opened to sample the liquid which is passing through tank **20**, so that the sampled liquid comes into contact with detector **26**. An ion exchange material **41** in a film, fiber or granular form is applied to one surface of substrate **40**. The active ion exchange material **41** is applied to the substrate **40** in its most expanded form so that, in the embodiment of FIG. **3**, the substrate **40** is projected at its full length into the flowing path of the liquid shown by arrows **35**. When the liquid in contact with the detector has a relatively low concentration of salt and contains mono-valent ions such as sodium, the ion exchange material and substrate remain in their extended position. A contact member **42** is attached to the free, extreme end of substrate **40** at the surface opposite to the surface on which the active ion exchange material is applied. A second contact **43** is fixedly mounted in pipe **27** adjacent to and in contact with contact **42** when the detector is so extended. A contact wire **44** is connected to contact **42** and similarly a wire **45** is connected to contact **43** and appropriately made available externally to the pipe via suitably fluid-sealed openings therein. Such wires are connected in the valve actuation circuitry **30** as explained below more fully. When detector **26** is in its fully extended position, the circuit within which wires **44** and **45** are connected is completed through contacts **42** and **43**.

When the character of the solution which comes into contact with detector **26** changes, i.e. when the mono-valent ions contained therein are replaced by multi-valent ions, or when the relatively low concentration of salt changes to a relatively high concentration of salt, the volume of the active ion exchange material **41** is reduced and causes a deflection of substrate **41** so that contact **42** is raised from its contact with contact **43** and the circuit to which wires **44, 45** are connected is appropriately opened as shown in FIG. **3A**.

Accordingly, the operation of detector **26** can be utilized to detect the end of the softening portion or the end of the rinse portion of the operating cycle. In the first case, the solution with which the detector comes into contact changes from one having mono-valent to one having multi-valent ions and in the second case the solution changes from one having a relatively high salt concentration to one having a relatively low salt concentration. Such operation is shown in FIG. **4**.

As shown in FIG. **4**, graph (A) depicts a curve as a function of time of multi-valent ion concentration in the liquid which comes into contact with detector **26** (in the case shown for a water softening process, the calcium (Ca) concentration is shown) and graph (B) depicts a curve as a function of time of sodium concentration in such liquid. The state of the detector **26** is depicted diagrammatically below the curves (A) and (B) at key points in the overall cycle time.

Thus, at the beginning of the regenerating portion of the cycle, the Ca^{++} ion concentration at the point at which the detector water sample is taken increases rapidly to a maximum level **50** during which time the presence of sufficient Ca^{++} causes detector **26** to be in its open position. At the same time, the concentration of sodium ions is very low.

During regeneration, the highly concentrated sodium solution is fed to tank **20** to replenish the sodium ions in the ion exchange bed via exchange with the calcium ions. Near the end of regeneration the sample at detector **26** changes in character to one having a low concentration of calcium in the solution, while the concentration of sodium in the solution increases rapidly to a high level **51**, as shown. Due to the latter relatively high sodium solution concentration, the detector **26** remains open as shown.

During the rinse portion of the overall operating cycle, the sodium solution and sodium particles are washed away and the sodium concentration of the liquid sample is rapidly reduced by the end of the rinse process as shown at **52**. Because of the relatively low sodium solution concentration, the detector changes to its fully extended position so that its contacts are closed as shown.

The softening portion of the cycle then proceeds with a low concentration of calcium and sodium in the detected liquid sample substantially throughout. During the softening process, depletion of the ion exchange bed continues until the break-through point occurs at which the presence of calcium (Ca^{++}) ions reaches a level **53** in the detected sample at which point the detector opens and the softening process is ended. The sodium concentration of the sampled solution also is reduced even further.

At the latter time, the back-wash portion of the cycle begins and, throughout such process, the calcium concentration continues to rise at a relatively slow rate and the sodium concentration remains very low. Following the timed back-wash process, the regeneration process is again begun, as discussed above.

Accordingly, the detector **26** is used to identify both the end point of the softening process at the break-through point **53**, where the detector state changes from a closed to an open condition, and the end point **52** of the rinse process, when the detector state changes from an open to a closed condition.

An alternative embodiment of the detector switch of FIGS. **3** and **3A** is shown in FIGS. **5** and **5A**. A solid substrate **60** is attached fixedly at one end for example to the pipe **27** and projects into the flow path of the liquid at the output thereof. An active ion exchange material **61** in the form of a fiber, for example, is attached to substrate **60** at its end points **62** and **63** via an appropriate adhesive. When the active ion exchange material **61** is in its fully extended position, a contact **64** at the center thereof is adjacent to and in contact with a contact **65** fixedly positioned substantially at the center of substrate **60** so that the circuit to which wires **66** and **67**, respectively, are attached, is completed. When the ion exchange material is in contact with a liquid solution having multi-valent ions or having a high salt concentration, the ion exchange material **61** shrinks in volume so that the substrate **60** is deflected outwardly from its center and the contact made by contact elements **64** and **65** is opened as shown in FIG. **5A**. The detector acts as an appropriate switch in a manner similar to that discussed in reference to FIG. **3**. Since the electrical resistance of the liquid separating the two metal contacts when they are in their separated condition in either FIGS. **3A** or **5A** is extremely high, the detection device as shown therein provides a very sensitive indication of the dimensional change of the ion exchange material. The force needed to deflect the inert backing material is relatively small and, accordingly, the shrinkage required from the ion exchange material in order to open the electrical contacts is also very small. Such shrinkage is much smaller, for example, than would be required if an ion exchange membrane or ribbon is directly connected to a micro-switch contact, as described in the aforesaid Luck patent.

Thus, the inventive structure provides a relatively strong and reliable ion exchange detection device available for determining both the end of the softening portion and the rinse portion of the overall operating cycle of a water softening system.

One aspect of ion exchange water processing systems which represents a relatively significant part of the overall costs of operation thereof lies in the cost of the regenerant solutions when such solutions are heavily loaded with salt. In order to reduce such costs, water softening processes have recently tended to limit the dosages of regenerant salt solutions used therein so that the quantity of salt available for regeneration is reduced considerably. If the salt loading is so reduced in the system of the invention, the amount of salt available at the outlet pipe **27** near the bottom of the tank **20** for regenerating the sensor can be insufficient for the sensor to regenerate to its original state. Accordingly, not all of the ions of calcium, magnesium, etc. (Ca^{++}, Mg^{++}, etc.), on the sensor are exchanged for the sodium ions in the regenerant salt solution during the regeneration sub-cycle.

Further, when relatively low dosages of regenerant salt solution are used, traces of hardness-causing ions may be present in the water during the softening sub-cycle. Such "leakage" of hardness-causing ions must be held to acceptable levels and depends upon the density, i.e. the loading, of the salt in the regenerant solution. As graphically shown in FIG. **6**, leakage varies as a function of salt loading (expressed, for example, in lbs./ft.^{3}), so that at relatively low salt loadings, the leakage is extremely high, such leakage reducing to a minimal level as the loading is increased. In a specific water processing system, for example, the minimum salt dosage that can be used will be determined by the amount of leakage which is acceptable in a particular application for which the process is being used. For example, if an acceptable leakage level is selected as being at Point A a salt loading level, as shown in Point B can be used.

Furthermore, if iron is present in the water being processed, such iron can be released during the regeneration sub-cycle and, thereupon, a portion thereof may be deposited on the sensor element and, accordingly, foul the sensor and adversely affect its operation.

Hence, if a relatively low loading of salt is used in the regenerant solution to save costs, some modification in the operation of the sensor is required in order to provide effective operation thereof.

In one such modification, the sensor can be arranged to operate intermittently, i.e. the sensor operation is controlled so that it samples the output of the tank at outlet **27** at separate intervals during certain portions of the overall processing cycle. As shown in FIG. **4**, the sensor element can be arranged so that it is exposed to the effluent at outlet **27** near the bottom of the tank **20** on an intermittent basis beginning at a selectable point in time relatively near to the end of the service sub-cycle as shown for example at point "T_1" prior to the break-through point at the end of such sub-cycle. During the earlier portion of the service sub-cycle, i.e. from the point at the end of the rinse sub-cycle to a point T_1 the system operation is arranged so that the sensor is not exposed to the effluent at all. After break-through is reached at the end of the softening sub-cycle, the sensor is deflected, the amount of such deflection depending upon the hardness of the effluent. Accordingly, the system can be arranged so that when the sensor reaches a certain predetermined deflection position, the effluent is again diverted from the outlet **27** and the sensor is thereby prevented from exposure thereto.

At the end of the back-wash sub-cycle, the system is arranged so that the regenerant solution is directed to the sensor directly from the source thereof. Thus, regeneration of the sensor is not dependent on the characteristics of regenerant solution which is present at outlet **27.** During the regeneration sub-cycle, the sensor is thereby directly exposed to regenerant solution, and is not exposed to the effluent at outlet **27.**

At the start of the rinse sub-cycle the sensor is still not exposed to the effluent and remains in such state until a point "T_2" near the end of the rinse sub-cycle, at which point the sensor has a predetermined deflection. At T_2 the detector is again exposed to the effluent on an intermittent basis during the rinse sub-cycle.

At the end of the rinse sub-cycle, the system is arranged to divert the effluent again from the outlet **27** so as to prevent exposure of the detector thereto from the beginning of the service sub-cycle until the selected point T_1 near the end thereof.

The above operation of the detector, wherein it is only intermittently exposed to the effluent at outlet **27** and wherein the regenerant solution is applied directly to the sensor permits the sensor to become completely regenerated and avoids exposure thereof to hardness-causing ions present because of leakage during the service sub-cycle. Moreover, since the detector is not exposed to the effluent during regeneration, none of the iron released in the regeneration sub-cycle can be deposited on the sensor.

While the detection device of the invention has been described with reference to its use in a water softening process, it can be used in other processes where detection of an ion exchange depletion or a change in salt concentration is required, either in different processes or in the same overall process.

For example, the detector may be used in metal plating applications involving the purification of chromic acid plating and anodizing baths. In such applications, an additional step is used wherein the feed solution is drained down to the top of the resin bed in the tank after completion of the service portion of the cycle and before the back-wash process is begun. The feed solution in the bed is then slowly displaced with treated water and the treated water is then treated again in the following cycle. Such a procedure minimizes the amount of chromic acid sent to waste with the rinse water. The detector of the invention may also be used in other applications using dual-bed and mixed bed operations often used in de-ionizing water.

Accordingly, the invention is not to be deemed as limited to the specific configuration and uses shown herein except as defined by the appended claims.

What is claimed is:

1. A detection device for use in a solution processing system, said device comprising

a sensing element including

a first ion-exchange material the dimensions of which vary as a function of the salt concentration of said solution and as a function of the valence of ions present in said solution when said element is in contact with said solution, said first material having maximum dimensions when it is in contact with a solution having mono-valent ions whereby said sensing element is in its unflexed state and having

reduced dimensions when it is in contact with a solution having multi-valent ions whereby said sensing element is in its flexed state and said first material further having its maximum dimensions when it is in contact with a salt solution having a relatively low salt concentration whereby said sensing element is in its unflexed state and having reduced dimensions when it is in contact with a salt solution having a relatively high salt concentration whereby said sensing element is in its flexed state;

a second, substantially flexible, solid material having substantially fixed dimensions which are retained in the presence of said solution independently of the salt concentration thereof and the valence of ions therein;

said first material being in contact with a surface of said flexible, solid material,

whereby dimensional changes of said first material which occur when said first material is in contact with said solution cause a flexing of said sensing element due to the flexing of said second material.

2. A detection device in accordance with claim **1** for use in a solution processing system having a system input for feeding a solution to be processed and a system output for supplying a processed solution, and further including

means for positioning said sensing element at a location such that during the processing of said solution said detection device is in contact with said solution near said system output; and

means responsive to the flexing of said second material for indicating a change in the characteristics of said solution with respect to the salt concentration thereof and the valence of ions therein.

3. A detection device in accordance with claim **2** wherein said indicating means include

first electrical contact means mounted on said sensing element;

second electrical contact means mounted in a fixed spatial relationship with respect to said first contact means, said first and second electrical contact means forming a part of an electrical circuit;

whereby said flexing of said sensing element causes an opening or closing of said electrical circuit.

4. A detection device in accordance with claim **3** for use in a solution processing system having an overall operating cycle which includes an ion-exchange processing sub-cycle, an ion-exchange regeneration sub-cycle and a rinse sub-cycle.

said sensing element of said detection device changing from its unflexed state to its flexed state substantially at the end of said ion-exchange processing sub-cycle, remaining in its flexed state during said ion-exchange regeneration sub-cycle and changing from its flexed state to its unflexed state substantially at the end of said rinse sub-cycle.

5. A detection device in accordance with claim **3** wherein

said second material of said sensing element is formed as a band fixedly mounted at one end thereof and having said first electrical contact means mounted thereon at a position remote from said one end;

said first material is applied to one surface of said second material; and

said second electrical contact means is fixedly mounted to be in contact with said first electrical contact means when said sensing element is in its unflexed state and to be out of contact with said first contact means when said sending element is in its flexed state.

6. A detection device in accordance with claim **3** wherein

said second material of said sensing element is formed as a band fixedly mounted at one end thereof and having said first electrical contact means mounted thereon at a position remote from said one end;

said first material is applied to one surface of said second material; and

said second electrical contact means is fixedly mounted to be out of contact with said first contact means when said sensing element is in its unflexed state and to be in contact with said first contact means when said sending element is in its flexed state.

7. A sensing device in accordance with claim **5** wherein said first electrical contact means is positioned at the other end of said band of said second material.

8. A sensing device in accordance with claim **6** wherein said first electrical contact means is positioned at the other end of said band of said second material.

9. A sensing device in accordance with claim **3** wherein

said second material of said sensing element is fixedly mounted at one end thereof and said first electrical contact means being attached thereto between the ends thereof; and

said first material is fixedly mounted at its ends to said second material, said second electrical contact means being attached thereto between the ends thereof so that said first electrical contact means is in contact with said second electrical contact means when said sensing element is in its unflexed state and is out of contact with said second electrical contact means when said sensing element is in its flexed state.

10. A sensing device in accordance with claim **9** wherein said first and said second electrical contact means are each positioned substantially at the centers of said second and first materials, respectively, between the ends thereof.

11. A detection device in accordance with claim **4** wherein said detection device is out of contact with the solution at the output of said system during a portion of said ion-exchange processing sub-cycle and is intermittently in contact with the solution at the output of said system during the remaining portion of said ion-exchange processing sub-cycle.

12. A detection device in accordance with claim **11** and further wherein said detection device is out of contact with the solution at the output of said system during said regeneration sub-cycle and is in direct contact with a regenerant solution during said regeneration sub-cycle.

13. A detection device in accordance with claim **12** and further wherein said detection device is out of contact with the solution at the output of said system during said rinse sub-cycle.

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