United States Patent [19]

Reinke

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[45] **Date of Patent: Sep. 11, 1984**

[54] **MICROCOMPUTER CONTROLLED DEMAND/SCHEDULED WATER SOFTENER WITH VARIABLE CAPACITY**

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[73] Assignee: **Autotrol Corporation**, Milwaukee, Wis.

[21] Appl. No.: **540,809**

[22] Filed: **Oct. 11, 1983**

[51] **Int. Cl.**[3] **B01J 49/00**

[52] **U.S. Cl.** **210/662**; 210/89; 210/98; 210/140; 210/143; 364/502

[58] **Field of Search** 210/662, 670, 687, 89, 210/98, 102, 103, 109, 140, 143, 190, 191, 269; 364/500, 502

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,104,158	8/1978	Davis	210/662
4,237,538	12/1980	Le Dall	364/500
4,275,448	6/1981	Le Dall	364/500
4,385,357	5/1983	Davis et al.	364/500

FOREIGN PATENT DOCUMENTS

1450222	9/1976	United Kingdom .
2031614A	4/1980	United Kingdom .
1599706	10/1981	United Kingdom .

OTHER PUBLICATIONS

"Comput-A-Save System—Operation and Installation Guide" by Water Refining Company, Inc., Jul. 1, 1978.

Sales Literature—"The Electronic Demand Water Softener with Variable Reserve (The Lindsay Know It All)" by Lindsay Corp., Publication Date Feb. 1982.

Sales Literature—"Water King Solid State 301 & 302" by Water King, Sta-Rite Industries, Publication Date Unknown.

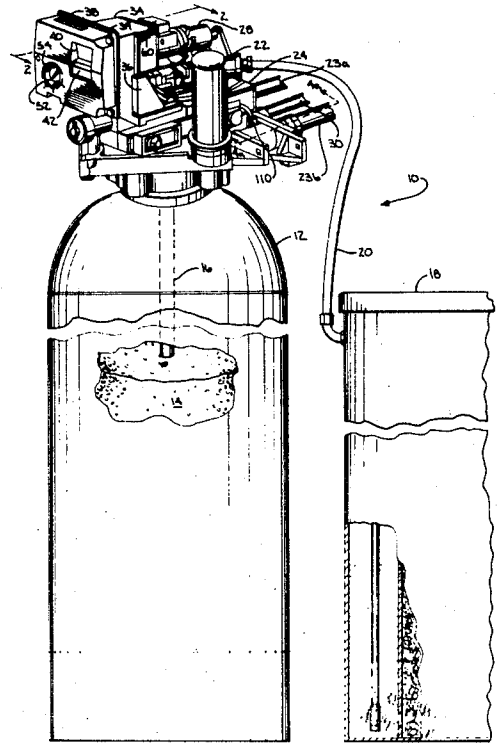
Primary Examiner—Ivars C. Cintins

Attorney, Agent, or Firm—Quarles & Brady

[57] **ABSTRACT**

An improved control for a particle bed water treatment device includes a microcomputer which is supplied with input data from a flowmeter indicative of the quantity of treated water leaving the water treatment device. In accordance with the flow data, the microcomputer determines the amount of water used since the last regeneration and also determines the average daily treated water consumption. The microcomputer is also coupled to a data input device and receives input data indicative of the total particle bed treating capacity resulting in complete particle bed exhaustion. To recognize and account for the additional particle bed capacity that is created when a partially exhausted particle bed is regenerated, the microcomputer advantageously adjusts the total treating bed capacity value received from the data input device in accordance with the remaining particle capacity existing prior to regeneration. At a prescribed hour each day, the microcomputer determines the remaining particle bed treating capacity in accordance with the difference between the adjusted total capacity and the amount of water used since the last regeneration. The remaining particle bed treating capacity is compared to the reserve established as a proportion of the average daily consumption of treated water and regeneration is initiated when the reserve is greater than the remaining particle bed treating capacity.

6 Claims, 9 Drawing Figures



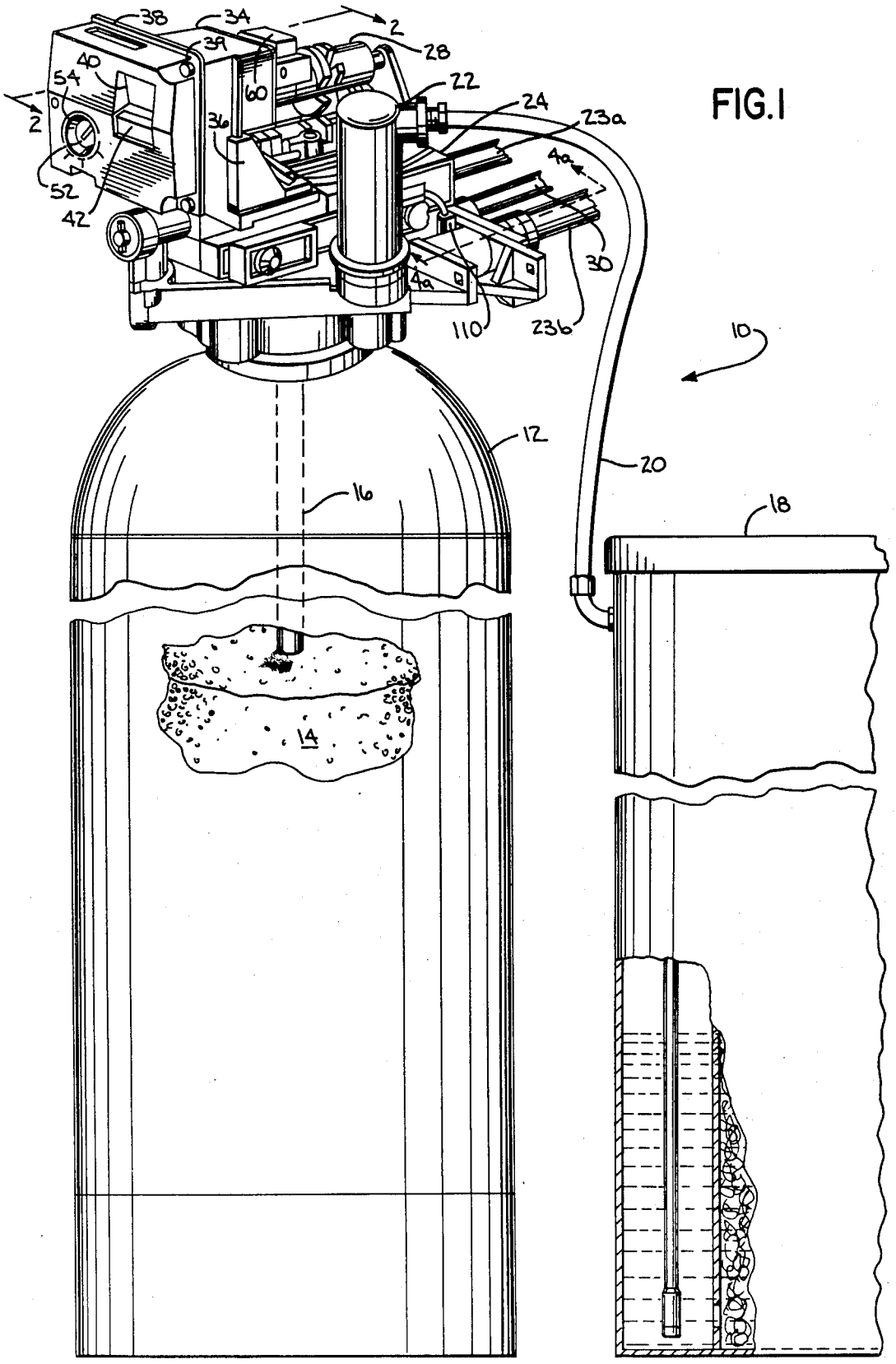
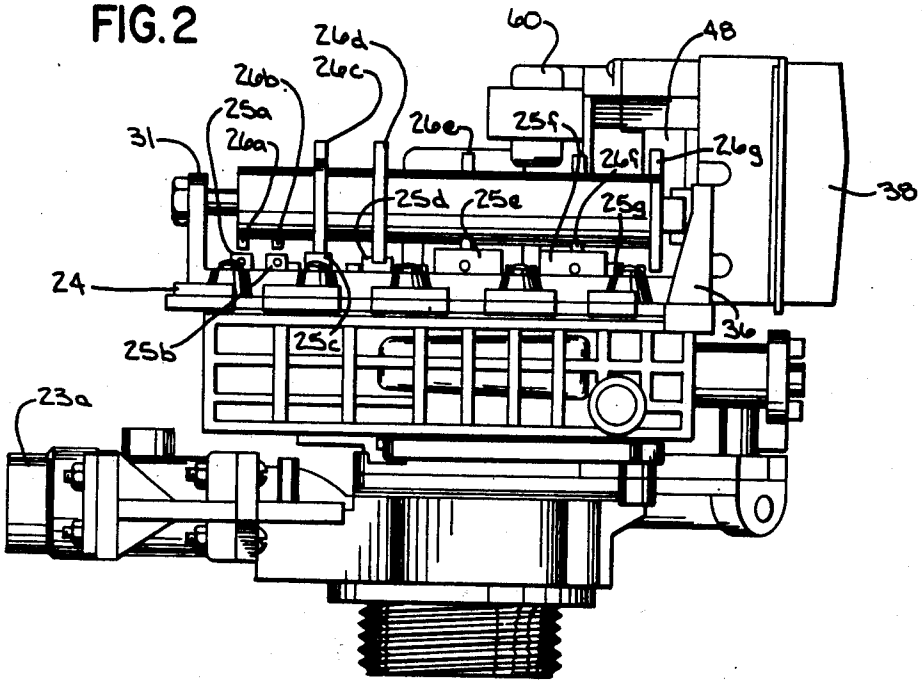

38
34
2
39
28
40
54
60
22
24
23a
2
36
4a
52
42
30
4a
110
236
10
12
20
16
18
14

FIG.1

FIG. 2


60
48
26d
26c
26b
25a
26a
31
26e
25f
26f
26g
38
25d
25e
25g
24
25b
25c
36
23a

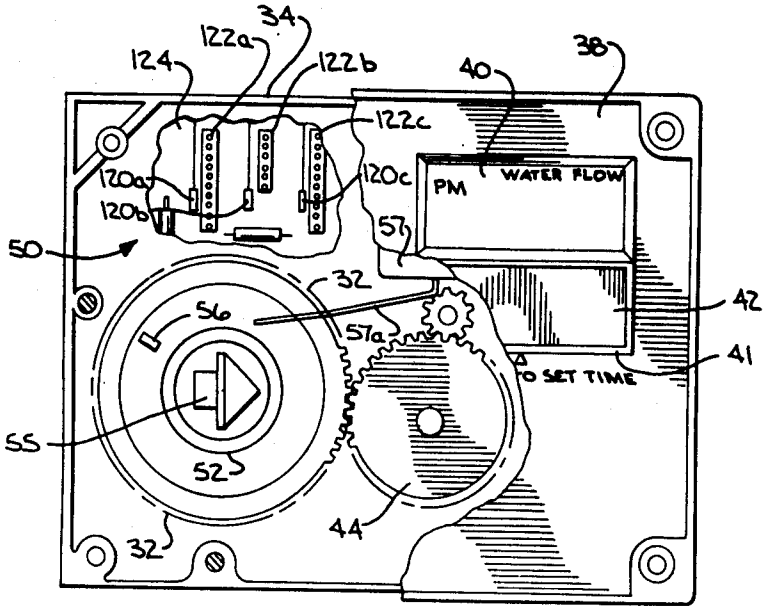

34
122a
124
122b
40
38
122c
120a
120c
PM
WATER FLOW
120b
57b
50
32
42
56
57a
41
TO SET TIME
55
52
44
32

FIG. 3

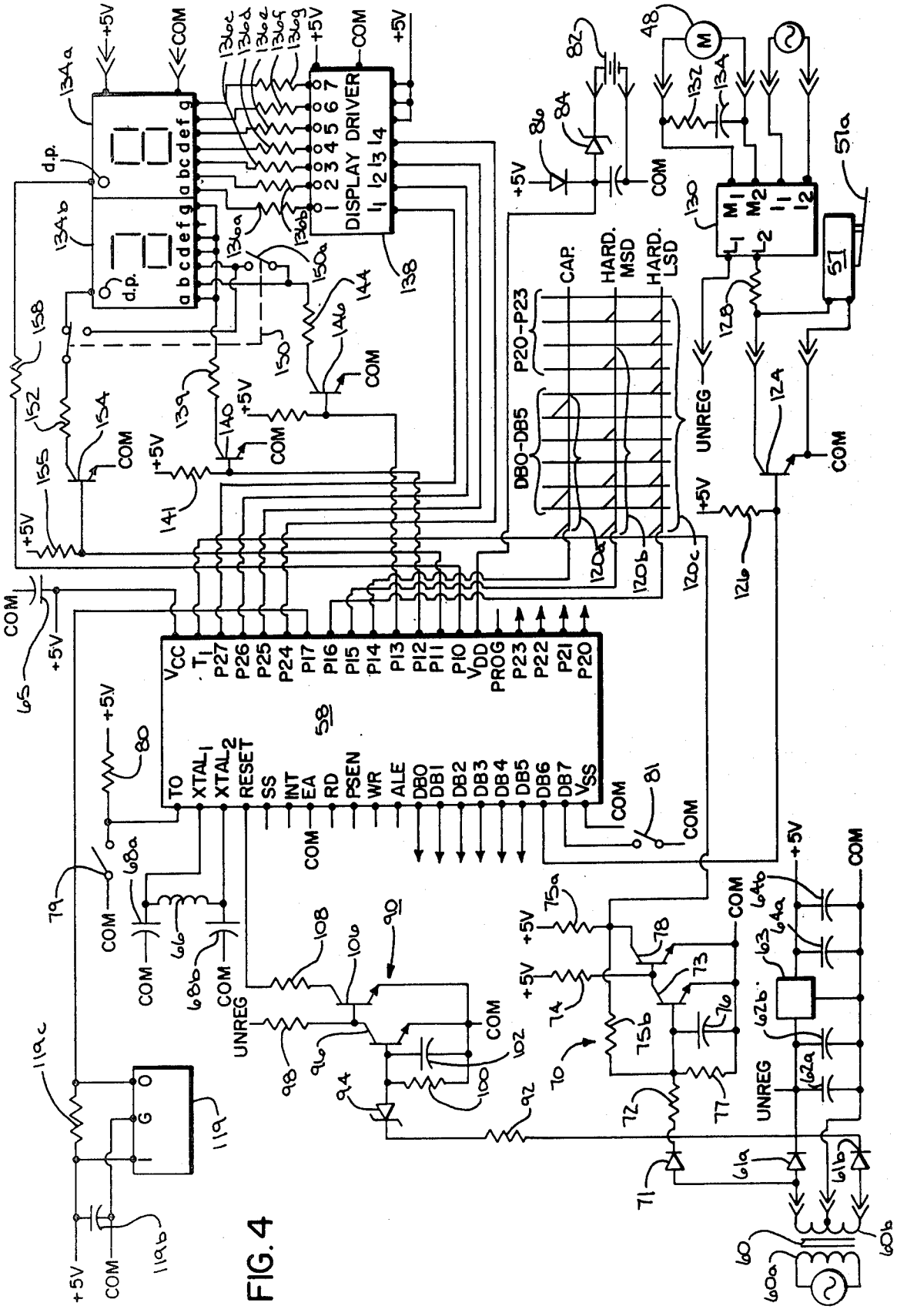

DISPLAY DRIVER
CAP.
HARD. MSD
HARD. LSD
P20-P23
DB0-DB5
UNREG
COM
+5V
VCC
T1
P27
P26
P25
P24
P17
P16
P15
P14
P13
P12
P11
P10
VDD
PROG
P23
P22
P21
P20
TO
XTAL1
XTAL2
RESET
SS
INT
EA
RD
PSEN
WR
ALE
DB0
DB1
DB2
DB3
DB4
DB5
DB6
DB7
VSS
58
M1
M2
I1
I2
L1
L2
d.p.
a b c d e f g

FIG. 4

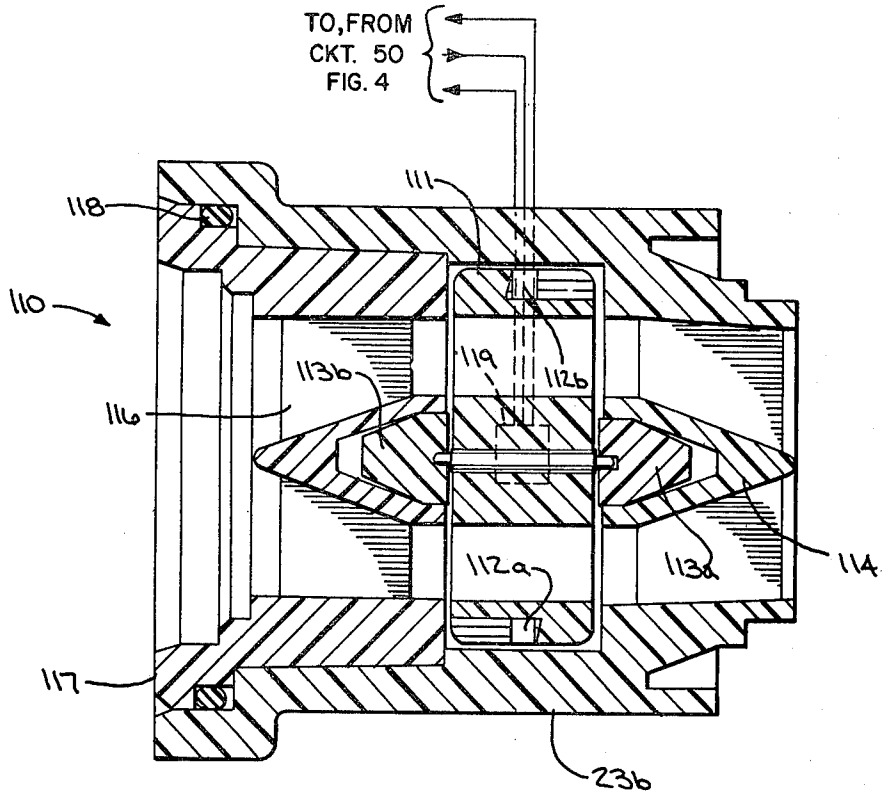
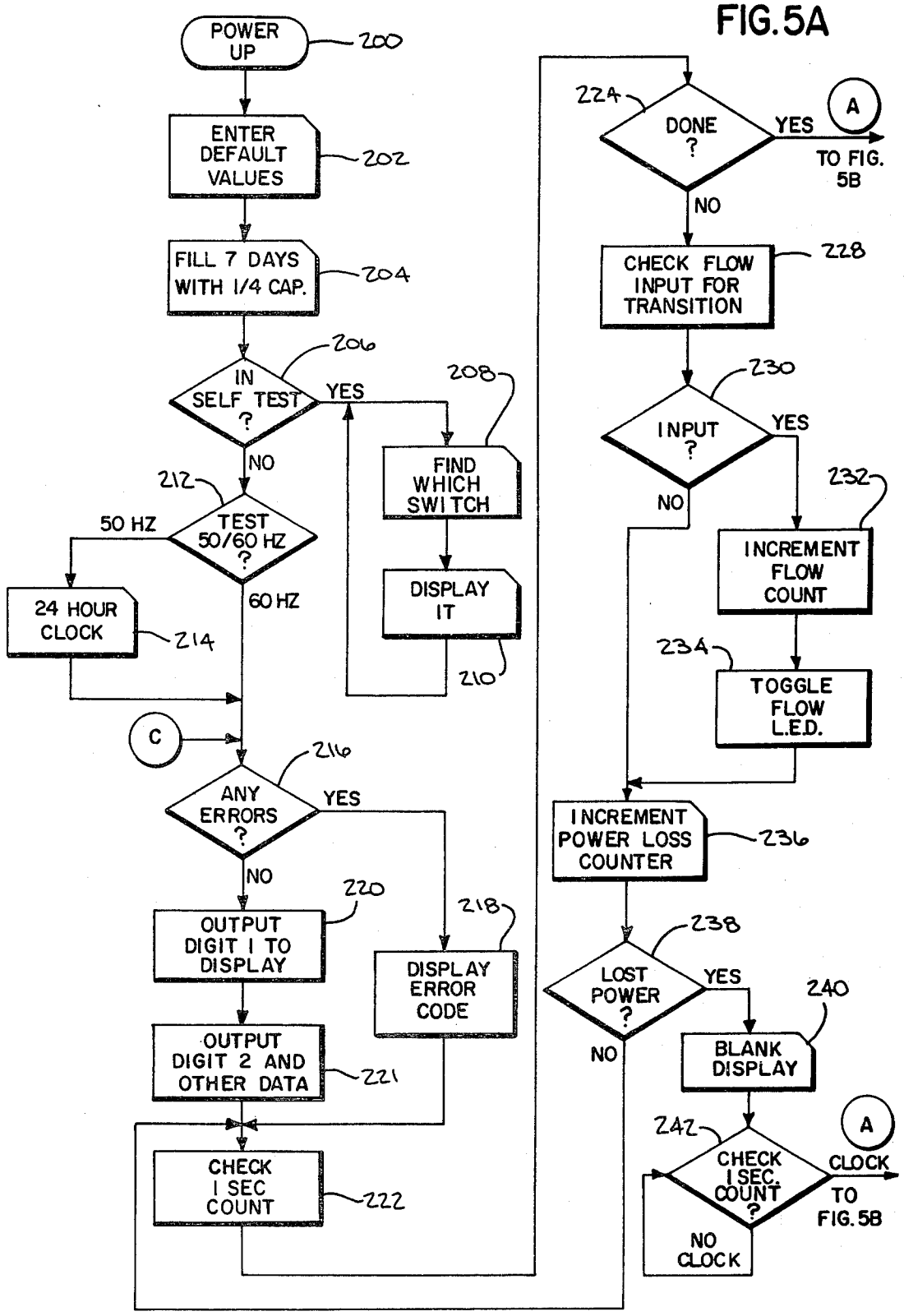

TO,FROM
CKT. 50
FIG. 4
111
118
110
119
112b
113b
116
112a
113a
114
117
236

FIG. 4a

FIG. 5A


POWER UP
200
ENTER DEFAULT VALUES
202
FILL 7 DAYS WITH 1/4 CAP.
204
206
IN SELF TEST ?
YES
208
FIND WHICH SWITCH
DISPLAY IT
210
NO
212
TEST 50/60 HZ ?
50 HZ
60 HZ
24 HOUR CLOCK
214
C
216
ANY ERRORS ?
YES
NO
220
OUTPUT DIGIT 1 TO DISPLAY
218
DISPLAY ERROR CODE
OUTPUT DIGIT 2 AND OTHER DATA
221
CHECK 1 SEC COUNT
222
224
DONE ?
YES
A
TO FIG. 5B
NO
CHECK FLOW INPUT FOR TRANSITION
228
230
INPUT ?
YES
NO
232
INCREMENT FLOW COUNT
234
TOGGLE FLOW L.E.D.
INCREMENT POWER LOSS COUNTER
236
238
LOST POWER ?
YES
NO
240
BLANK DISPLAY
242
CHECK 1 SEC. COUNT ?
A
CLOCK
TO FIG. 5B
NO CLOCK

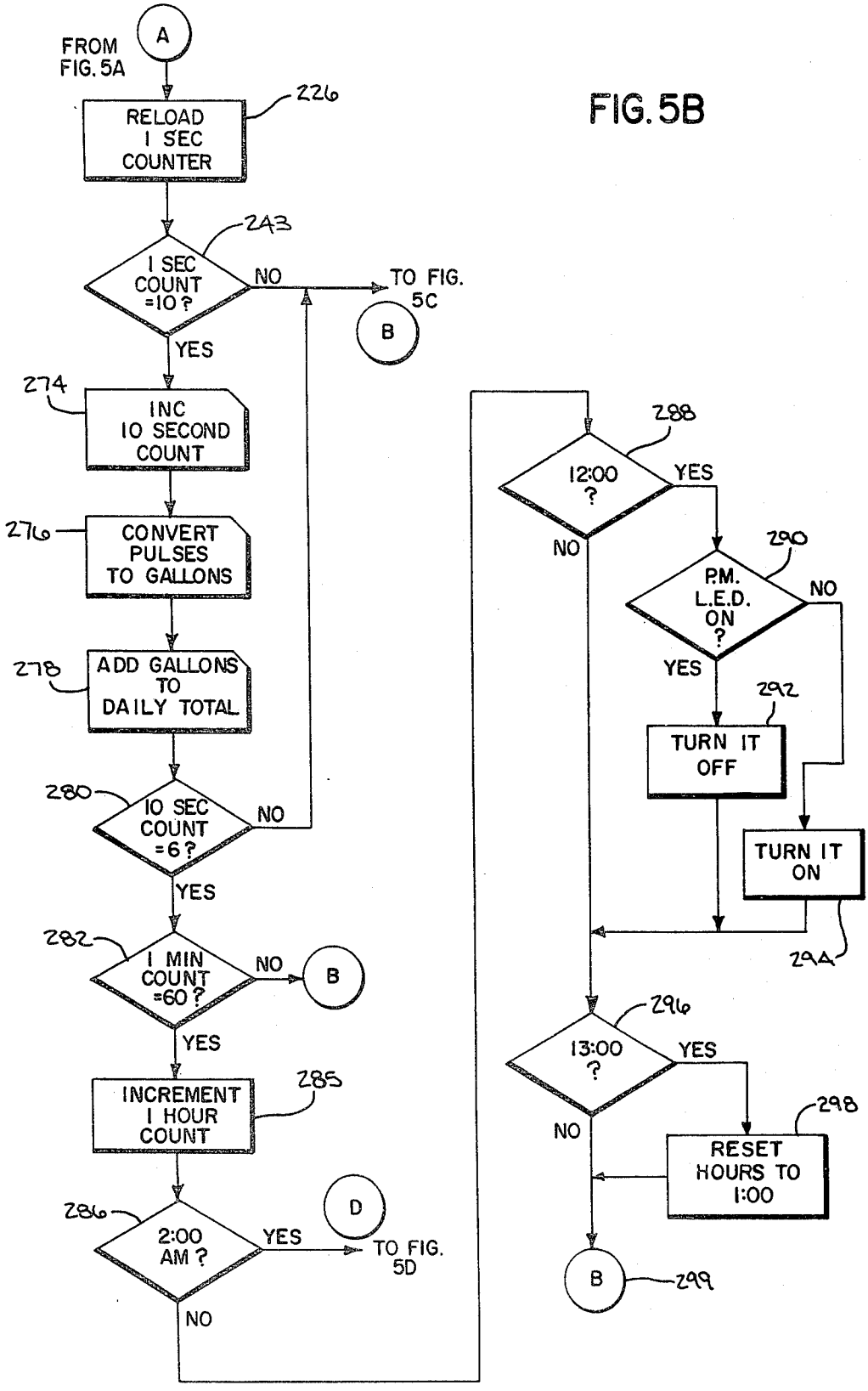

FROM FIG. 5A
A
RELOAD 1 SEC COUNTER
226
1 SEC COUNT =10?
243
NO
TO FIG. 5C
B
YES
INC 10 SECOND COUNT
274
CONVERT PULSES TO GALLONS
276
ADD GALLONS TO DAILY TOTAL
278
10 SEC COUNT =6?
280
NO
YES
1 MIN COUNT =60?
282
NO
B
YES
INCREMENT 1 HOUR COUNT
285
2:00 AM?
286
YES
D
TO FIG. 5D
NO
12:00 ?
288
YES
NO
P.M. L.E.D. ON ?
290
NO
YES
TURN IT OFF
292
TURN IT ON
294
13:00 ?
296
YES
NO
RESET HOURS TO 1:00
298
B
299

FIG. 5B

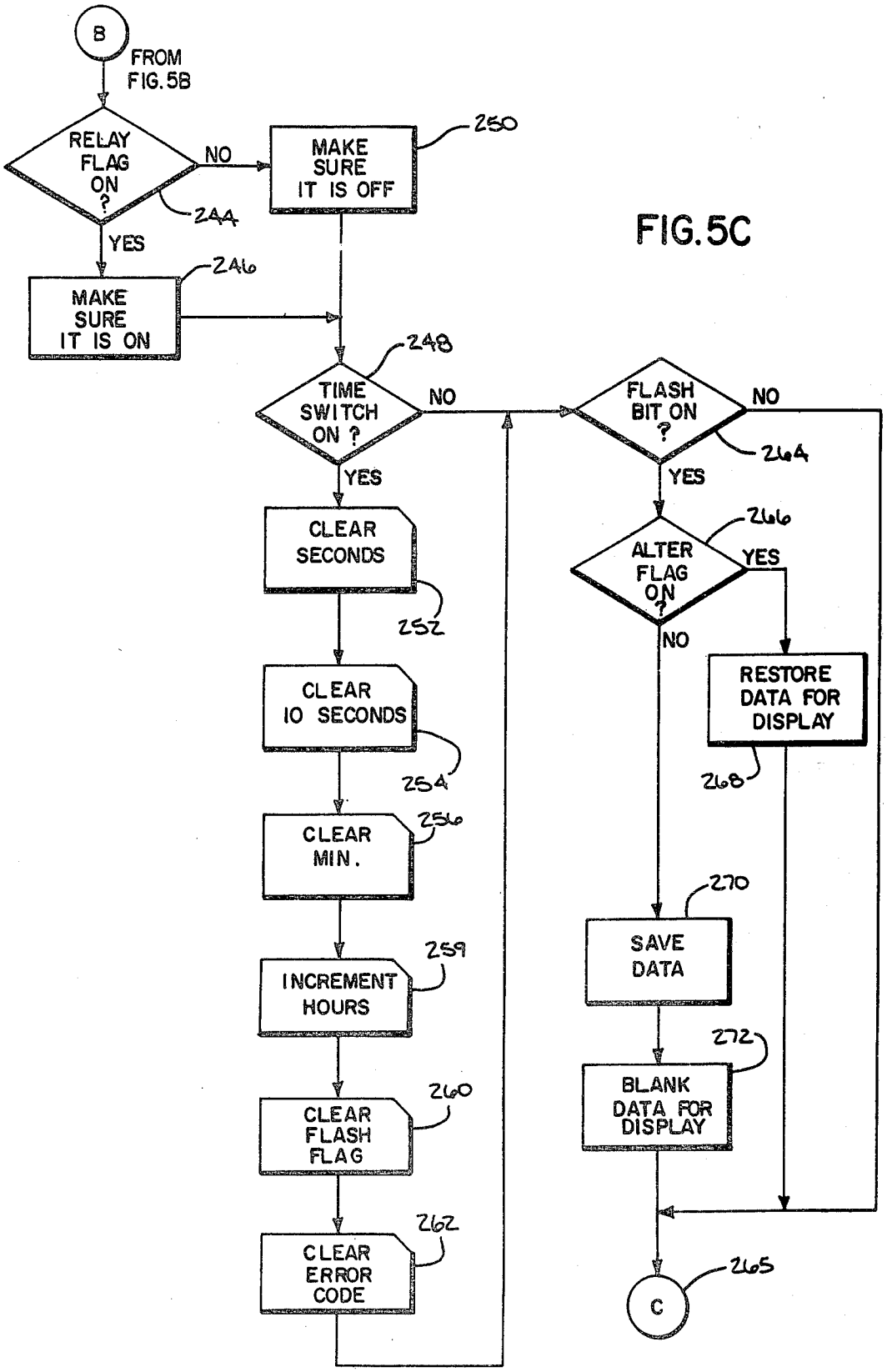
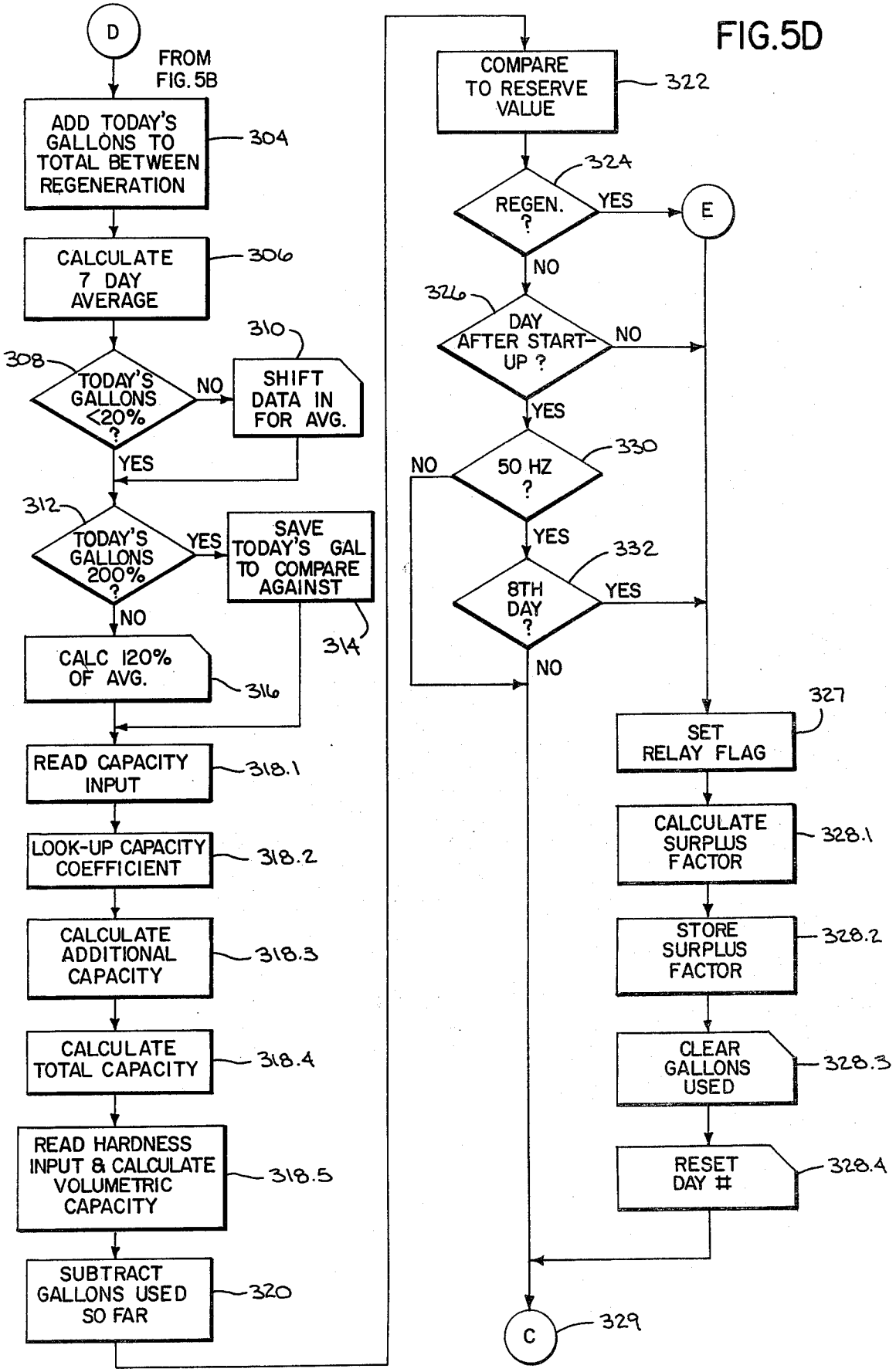

B
FROM FIG. 5B
RELAY FLAG ON ?
244
NO
YES
MAKE SURE IT IS OFF
250
MAKE SURE IT IS ON
246
TIME SWITCH ON ?
248
NO
YES
CLEAR SECONDS
252
CLEAR 10 SECONDS
254
CLEAR MIN.
256
INCREMENT HOURS
259
CLEAR FLASH FLAG
260
CLEAR ERROR CODE
262
FLASH BIT ON ?
264
NO
YES
ALTER FLAG ON ?
266
YES
NO
RESTORE DATA FOR DISPLAY
268
SAVE DATA
270
BLANK DATA FOR DISPLAY
272
C
265

FIG. 5C

FIG.5D


D
FROM FIG. 5B
ADD TODAY'S GALLONS TO TOTAL BETWEEN REGENERATION
304
CALCULATE 7 DAY AVERAGE
306
308
TODAY'S GALLONS <20% ?
NO
310
SHIFT DATA IN FOR AVG.
YES
312
TODAY'S GALLONS 200% ?
YES
SAVE TODAY'S GAL TO COMPARE AGAINST
314
NO
CALC 120% OF AVG.
316
READ CAPACITY INPUT
318.1
LOOK-UP CAPACITY COEFFICIENT
318.2
CALCULATE ADDITIONAL CAPACITY
318.3
CALCULATE TOTAL CAPACITY
318.4
READ HARDNESS INPUT & CALCULATE VOLUMETRIC CAPACITY
318.5
SUBTRACT GALLONS USED SO FAR
320
COMPARE TO RESERVE VALUE
322
324
REGEN. ?
YES
E
NO
326
DAY AFTER START-UP ?
NO
YES
330
50 HZ ?
NO
YES
332
8TH DAY ?
YES
NO
327
SET RELAY FLAG
CALCULATE SURPLUS FACTOR
328.1
STORE SURPLUS FACTOR
328.2
CLEAR GALLONS USED
328.3
RESET DAY #
328.4
C
329

MICROCOMPUTER CONTROLLED DEMAND/SCHEDULED WATER SOFTENER WITH VARIABLE CAPACITY

BACKGROUND OF THE INVENTION

This invention relates generally to a control unit for a resin bed type water softener and more particularly to an improved microcomputer-based control unit for a resin bed water softener which continually monitors the resin bed capacity and adjusts for the additional capacity created when a partially exhausted resin bed is regenerated with the amount of regenerant normally required by a fully exhausted resin bed.

The most common type of water softener is the ion exchange resin-type softener having a vertically disposed tank which holds a bed of resin through which the hard water is passed to remove undesirable minerals and other impurities. The capacity of the resin bed to absorb minerals and impurities is finite and it is thus necessary to periodically recharge or regenerate the resin bed with a regenerant, typically a brine solution, by causing the brine solution to flow from one end of the tank to the other so as to restore the capacity of the resin bed for further water treatment.

The two types of processes commonly employed to regenerate a resin bed water softener are co-current regeneration and counter-current regeneration. Co-current regeneration is accomplished by causing the regenerant fluid (brine solution) to flow in the same direction as the normal or service flow of the incoming water through the resin bed. Typically, the service flow is directed downwardly against the resin bed to keep the resin bed compacted. In contrast, counter current regeneration is achieved by causing the regenerant fluid to flow upwardly, at a low velocity, through the resin bed to maintain the resin bed in a compacted mass. As will be understood by those skilled in the art, the downward and upward flow of regenerant during co-current and counter-current regeneration, respectively, could be reversed if other means were employed to maintain a compacted resin bed.

During the normal or service flow of water through the resin bed, the hard water entering the flow inlet tends to first exhaust the resin nearest the inlet so that the resin within the tank tends to stratify into an exhausted section adjacent to the service inlet and an undiminished or unexhausted section adjacent to the service outlet. The unexhausted portion of the resin bed is separated from the exhausted section by a relatively narrow band of resin comprised of a mixture of exhausted and unexhausted resin particles. During a co-current regeneration, the regenerant, which flows in the same direction as the service flow, first contacts the exhausted resin causing the metallic or hardness ions that were previously exchanged during the service flow of water, to be released from the resin and replaced with the ions of the regenerant. Before the hardness ions may be flushed from the resin tank, the hardness ions must pass through the unexhausted resin adjacent to the outlet. However, as the hardness ions pass through the unexhausted resin, the hardness or metallic ions are exchanged with the unexhausted resin as occurs normally during the softening process. Thus, the previously unexhausted resin becomes exhausted. Therefore, the regenerant fluid contacts only the exhausted resin as it flows toward the outlet and, as a result, there is no difference during a co-current regeneration between

when the resin bed is partially exhausted or when the bed is totally exhausted. The capacity of the resin bed remains the same regardless of whether the bed is partially exhausted or fully exhausted.

During a counter-current regeneration, the regenerant flows in a direction opposite to that of the service flow and thus enters the resin bed through what was the service flow outlet and first contacts the unexhausted resin. Since the unexhausted resin contains no metallic or hardness ions, the regenerant generally remains unaffected as it flows through the unexhausted resin until the regenerant passes into the exhausted resin portion where ion exchange does occur, causing the regeneration of the exhausted resin. As a consequence, the released hardness ions pass only through the exhausted resin without further exchange as they are flushed from the resin bed. The counter-flow of regenerant during counter-current regeneration results in an effectively increased amount of regenerant, as measured in pounds, that is available to regenerate the exhausted resin, as measured in cubic feet, of a partially exhausted resin bed in comparison to a completely exhausted resin bed. This may be seen from the following example. Assuming the amount of regenerant used during each regeneration is set at 6 pounds of brine (NaCl) solution and the volume of resin in the tank is 1 cubic foot, then, the regenerant level applied to completely exhausted bed will be given as follows:

$$\text{Regenerant level} = \frac{6 \text{ lb.}}{1 \text{ cubic foot}} = 6 \text{ lb./ft}^3 \quad (1)$$

When the resin bed is only two-thirds exhausted ($\frac{1}{3}$ capacity remaining) then, assuming that the regenerant only acts upon the exhausted portion of the resin bed, the regenerant level applied to the exhausted resin will be given by

$$\text{Regenerant level} = \frac{6 \text{ lb.}}{\frac{2}{3} \text{ cubic foot}} = 9 \text{ lb./ft}^3 \quad (2)$$

Thus, the effective regenerant level applied to the exhausted portion of the resin bed is much greater than the regenerant level applied to the bed where the bed completely exhausted.

It is well known to those skilled in the art that the additional resin bed capacity created upon regeneration of a partially exhausted resin bed is a function of the regenerant level. For example, the resultant capacity-regenerant level relationship for a common resin, such as IONAC type C-253 resin, manufactured by Sybron Corporation, Birmingham, N.J., is illustrated below in Table 1.

TABLE I

Regenerant level (lb. of NaCl/cubic feet)	Capacity (grains of $CaCO_3$/cubic foot)
6	20,000
9	27,500
12	30,000
15	31,500

As may be appreciated from examination of Table I, the capacity does not increase in direct proportion to the regenerant level.

Using the capacity data set forth in Table I, the increase in capacity for the previous example may be calculated in the following manner. If the one cubic

foot resin bed is completely exhausted, and the regenerant level is 6 lbs./ft.^{3}, and the resultant capacity will be given by

$$\text{Resultant Capacity} = 1\ \text{ft.}^3 \times 20{,}000\ \text{grains/ft.}^3 = 20{,}000\ \text{grains} \quad (3)$$

Assuming that $\frac{2}{3}$ of the resin bed is exhausted and $\frac{1}{3}$ remains unexhausted, the capacity of the unexhausted resin bed, assuming that it had been completely regenerated during a previous interval with a regenerant level of 6 lb./ft.^{3}, will be given by

$$\text{Resultant Capacity} = \tfrac{1}{3}\ \text{ft.}^3 \times 20{,}000\ \text{grains/ft.}^3 = 6{,}666\ \text{grains} \quad (4)$$

The resultant capacity of the exhausted resin, when regenerated with an effective regenerant level of 9 lb./ft.^{3} as determined previously by Equation (2) will be given as follows

$$\text{Resultant Capacity} = \tfrac{2}{3}\ \text{ft.}^3 \times 27{,}500\ \text{grains/ft.}^3 = 18{,}333\ \text{grains} \quad (5)$$

The total capacity is the sum of the capacity of the unexhausted $\frac{1}{3}$ portion of the bed (6,666 grains) plus the capacity resulting from regeneration of the $\frac{2}{3}$ portion of the exhausted bed with a regenerant level of 9 lb./ft^3 (18,333 grains) as may be seen from Equation 5 which is

$$\text{Total Capacity} = 6{,}666 + 18{,}333 = 25{,}000\ \text{grains} \quad (6)$$

The capacity increase will be given by

$$\text{Capacity Increase} = 25{,}000 - 20{,}000 = 5{,}000\ \text{grains}$$

As may be appreciated from Equation (6), a 25% capacity increase is obtained. If the hardness of the incoming water is 20 grains per gallon, then the volumetric increase in capacity would be given by

$$\text{Volumetric Increase} = \frac{5{,}000\ \text{grains}}{20\ \text{grains/gallon}} = 250\ \text{gallons.}$$

The foregoing example thus indicates that a significant amount of additional capacity may be obtained merely by recognizing the increased capacity resulting from regeneration of the exhausted portion of the resin bed with a regenerant level which is effectively greater than that employed to regenerate a completely exhausted bed.

Present day water softener controls, and even the advanced microcomputer-based water softener control disclosed in the now allowed U.S. patent application Ser. No. 412,279 now U.S. Pat. No. 4,426,294 for "Microcomputer Controlled Demand/Scheduled Water Softener" filed by J. David Seal on Aug. 27, 1982, and assigned to the assignee of the present invention, do not recognize and evaluate the additional capacity resulting from regeneration of the exhausted portion of the resin bed with the increased regenerant level. If a control could recognize and evaluate the additional capacity, then the number of regenerations would be reduced without increasing the possibility of delivering unsoftened water. By reducing the number of regenerations, a savings of regenerant and water would be effected.

It is an object of the present invention to provide an improved water softener control unit which utilizes a microcomputer to control water softener resin bed regeneration.

It is another object of the present invention to provide an improved microcomputer-based water softener control unit which controls water softener resin bed regeneration in accordance with the remaining capacity of the water softener resin bed to treat water.

It is yet another object of the present invention to provide an improved microcomputer-based water softener control unit which initiates water softener resin bed regeneration when the remaining resin bed capacity as determined from the actual soft water consumption is less than a reserve value calculated in accordance with the actual soft water consumption so that regeneration occurs only when necessary, thereby achieving a savings of regenerant and water.

It is yet another object of the present invention to provide an improved microcomputer-based water softener control which recognizes and adjusts for the increased capacity created when a partly exhausted resin bed is regenerated. The control initiates regeneration based on the additional capacity value so as to achieve an even greater savings of regenerant and water.

BRIEF SUMMARY OF THE INVENTION

Briefly, in accordance with the preferred embodiment of the invention, I have provided a control for a water softener requiring periodic resin bed regeneration comprising a flowmeter for detecting the quantity of softened water leaving the softener. A data input device is also provided for receiving data indicative of the capacity of the resin bed and the hardness of the incoming water. Both the flowmeter and the data input device are coupled to a controller which determines the average daily consumption of soft water from the flowmeter data. The controller reads the hardness and capacity data and adjusts the capacity data in accordance with the capacity remaining before the previous regeneration to account for the additional capacity that may have been created during the previous regeneration if the resin bed was regenerated when partially exhausted. The remaining capacity is determined by subtracting the quantity of water consumed thus far from the adjusted capacity data. Once the remaining resin bed treating capacity is calculated, the controller determines whether or not regeneration should occur by comparing remaining resin bed treating capacity to a reserve value established by the controller in accordance with the actual average consumption of soft water. If the remaining resin bed treating capacity is less than the established reserve value, then regeneration is initiated.

In accordance with another aspect of this invention, I have provided an improved method for controlling water softener resin bed regeneration commencing with the steps of measuring the quantity of water leaving the softener over a given period of time and then determining the actual daily average quantity of soft water consumed and the amount of soft water used since the last regeneration in accordance with the measured amounts of soft water leaving the softener. Thereafter, a reserve quantity of soft water is established from the calculated daily average of soft water consumption. The remaining water softener resin bed treating capacity is calculated by subtracting the quantity of water consumed from a total capacity value which is calculated by first determining the original resin bed treating capacity in accordance with the water hardness and then adjusting the

capacity value to account for the additional capacity that resulted if the resin bed had been regenerated when partially exhausted. Water softener resin bed regeneration is effected when the remaining water softener resin bed treating capacity is less than the established reserve value.

In operation of my improved control, data from the flowmeter is monitored by the microcomputer and at a particular time each day, as determined by the clock, data representing the actual amount of soft water used during the previous 24 hour period is stored in the memory. Typically, seven consecutive values representing the actual daily soft water usage for each of the previous seven days are stored in the memory. After storing the soft water consumption data, the microcomputer first calculates the total amount of soft water used since the last regeneration from the data stored in memory and then determines the actual average daily soft water used by averaging the stored data representing actual soft water usage. Following calculation of the total amount of soft water used since the last regeneration, the microcomputer then calculates the remaining resin bed capacity by subtracting the amount of resin bed capacity depleted, as determined from the total amount of soft water used since the last regeneration, from an adjusted capacity value. The adjusted capacity value is calculated by first reading the input capacity data, representing the total capacity of the water softener prior to complete resin bed exhaustion and then adding a value representing the additional capacity that resulted when the resin bed was regenerated when only partially exhausted. Having now calculated the remaining water softener capacity, this value is then compared to a reserve value established by the microcomputer as a proportion of the determined actual average daily soft water usage.

Typically, the reserve is calculated by multiplying the actual average daily soft water usage by 1.2. If the reserve is greater than the calculated remaining water softener capacity, then water softener regeneration is initiated. Otherwise, the microcomputer only updates the data received from the flowmeter and waits another 24 hours before repeating these calculations to determine whether or not regeneration should occur.

Furthermore, another advantage of the water softener control of the present invention is that the control can account for exceptional variations in soft water usage. If the usage during any one of the previous seven days is less than 20% of the calculated average, then that small value of soft water usage is not entered in memory as the daily usage, but is added to the amount of soft water used since the previous regeneration. Also, should the previous day's consumption exceed 200% of the average daily consumption, then that previous usage will be substituted as the reserve, to assure that sufficient water softener resin bed capacity exists for the increased soft water usage.

Additionally, the control of the present invention provides an additional advantage by recognizing and adjusting for the additional capacity created when a partially exhausted resin bed is regenerated with the normal amount of regenerant. The control recognizes and adjusts for the additional capacity by establishing a surplus factor equal to the ratio of the amount remaining capacity to the total adjusted capacity which initially is set equal to the input capacity. During each subsequent cycle, a new value for the total adjusted capacity is obtained from the product of surplus factor and a capacity coefficient, representing the increased capacity attributed to regeneration with an effectively greater regenerant level. In practice, the capacity coefficient is obtained from a look up table in accordance with the previously calculated surplus value. The capacity coefficient table values are obtained empirically, based on the type of resin and anticipated water conditions.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention, both as to organization and method of operation, together with further objects and advantages thereof may best be understood by reference to the following description taken in conjunction with the accompanying drawings in which:

FIG. **1** is a resin bed type water softener embodying the control of the present invention;

FIG. **2** is a side view of the control of the water softener illustrated in FIG. **1**;

FIG. **3** is a front view of the control of the water softener illustrated in FIG. **1**;

FIG. **4** is an electrical schematic diagram of the circuitry embodied in the control of the water softener illustrated in FIG. **1**; and

FIG. **4***a* is a cut away view of the water softener of FIG. **1** taken along lines **4***a*—**4***a*.

FIGS. **5**A through **5**D illustrate, in flowchart form, the program executed by the water softener control of the present invention during operation.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the Figures, FIG. **1** illustrates a resin bed type water softener **10** which includes a tank **12** containing a resin bed **14**. As incoming hard water enters the tank through an opening (not shown) in the top thereof, the water in the tank is forced through the resin bed and out the draw pipe **16** extending through the center of the resin bed so that water exiting via the draw pipe has been treated by the resin bed to remove minerals and other impurities. The capacity of resin bed **14** to absorb the minerals and impurities of the incoming hard water is finite, and depends on the treating capacity of the resin in the tank as measured in kilograins of hardness as well as the hardness of the incoming water as typically measured in grains per gallon. To regenerate the resin bed, once its treating capacity has been depleted, the resin bed is flushed with a brine solution so that the minerals and other impurities can be released from the resin bed and carried out the tank. In practice, the brine solution is stored in a separate tank **18** and is admitted to the softener tank **12** during regeneration through a tube **20** and a air check valve **22**.

The control of the brine flow into tank **12** from brine tank **18** as well as the control of hard water flowing into the tank via inlet **23***a* and the flow of soft water leaving the tank via outlet **23***b* is accomplished by a valve module **24** threaded on the top of tank **12** so as to be in communication with the tank inlet (not shown) and draw pipe **16**. Valve module **24** typically comprises a control body such as manufactured by Autotrol Corporation, Glendale, Wis. As best illustrated in FIG. **2**, valve module **24** includes seven disc-type valves **25***a* through **25***g*, respectively. In the present valve module, valves **25***e* and **25***f* are designated as the inlet and outlet valves, respectively, as the valves **25***e* and **25***f* each regulate the flow of hard water into tank **12** from inlet **23***a* and the flow of soft water up from draw pipe **16**

(FIG. 1) out through to outlet 23*b*, respectively. Valve 25*g* serves to regulate the flow of brine from brine tank 18 do n the draw pipe 16 and then into tank 12 and is therefore referred to as the brine valve. The valve 25*d* controls water flow in the valve module through a port (not shown) in communication with inlet 23*a* and outlet 23*b* so that when the inlet and outlet valves are closed, water may flow directly through the inlet and out the outlet while valve 25*d* is open. The remaining valves 25*a*, 25*b* and 25*c* serve to control the flow of water and brine from the tank into a drain conduit 30 (FIG. 1).

During a regeneration cycle, each of valves 25*a* through 25*g* is actuated at an appropriate interval by a separate one of the corresponding cams 26*a* through 26*g* carried on a cam shaft 28 when the cam shaft is rotated to bring the corresponding cam into contact with the valve. Cam shaft 28 is journaled at its rear end into a cam shaft support 31 extending upwardly from the valve module. The forward (rightward) end of cam shaft 28 has a forwardly extending shank for engaging the "T" shaped slot in the rearward end of the outwardly extending shaft 32*a* of a gear 32 (FIG. 3). As best illustrated in FIG. 3, gear 32 is journaled for rotation within the cavity 33 of a control housing 34. Returning to FIG. 2, control housing 34 is slidably secured to the forward end of the valve module 24 by a pair of support guides 36 (FIGS. 1 and 2) which each engage complimentary flanges (not shown) on the exterior of the control housing.

What has been described thus far with respect to the construction and operation of the valve module 24 is well known in the art.

The cavity 33 (FIG. 3) within the forward end of the control housing 34 is closed by a cover 38 which is secured to the forward end of the control housing by screws 39 (illustrated in FIGS. 1 and 3). Referring now to FIG. 3 which is a frontal view of control housing 34 showing portion of cover 38 cut away, cover 38 is generally opaque except for a window 40 which carries the indicia "PM" and "WATER FLOW". As will become clear hereinafter by reference to FIG. 4, window 40 allows a display within the cavity to display certain information. Immediately below window 40 is a passageway 41 through the cover which has a spring biased button 42 protruding outwardly therethrough. As will also become clear by reference to FIG. 4, button 42 is depressed to set the time displayed by the display through window 40.

With a portion of cover 38 broken away in FIG. 3, it can be observed that not only is gear 32 journaled within the cavity 33, but an idler gear 44 is also journaled within cavity 33 and is in meshing engagement with gear 32. Idler gear 44 is driven by a gear 46 which is carried on the forward end of the shaft of motor 48 (FIG. 2); the motor being mounted on the rear of the control housing so that its shaft extends through the control housing 34 and into the cavity to receive gear 46.

Motor 48 of FIG. 2, which is typically a 1 RPM A.C. clock motor, is energized with alternating current by a control circuit 50 of FIG. 4 (described hereinafter) when the control circuit determines, in accordance with a particular algorithm, that regeneration should be effected. Motor 48, when energized from control circuit 50, drives cam shaft 28 through gears 46, 44 and 32 to cause cams 26*a* through 26*g* to actuate a corresponding one of valves 25*a* through 25*f*, respectively. The cams 26*a*–26*f* are shaped such that valves 25*a* through 25*f*, respectively, are actuated in a particular sequence for a particular duration during a single revolution of the cam shaft so that the brining, slow rinse, back wash and brine refill & purge Steps, which are normally required to complete resin bed regeneration, are performed in the desired sequence. Following a single revolution of the cam shaft, the valves return to the service position so as to allow normal water flow through the softener.

Although water softener resin bed regeneration is normally effected when control circuit 50 energizes motor 48, there may be instances when manual regeneration is desired. To enable manual regeneration, gear 32 has a hub 52 extending forwardly of the gear and through an opening 54 (FIG. 1) in cover 38. Gear 32 and hub 52 are spring biased from shaft 32*a* so that when the hub 52 of the gear is pushed inwardly, gear 32 becomes disengaged from idler gear 44 so as to allow the cam shaft to be manually rotated upon rotation of the hub. As the hub is rotated either manually, or upon the gear 32 being driven by the motor 48, an arrow 55 on the hub points to indicia (not shown) on the face of cover 38 representing the various states of water softener operation, to indicate which Step of the regeneration cycle is then being executed, or, whether valves are presently in the service position.

Protruding outwardly from the gear 32 is a member 56 which, as the gear rotates, comes into contact with the spring biased arm 57*a* of a leaf switch 57. Leaf switch 57 is connected to control circuit 50 in a manner described hereinafter. The switch is actuated either by member 56 as the gear is rotated or when the hub is simply depressed since the outward force of the member 56 keeps the spring biased arm 57*a* from normally moving downwardly to actuate the switch. When switch 57 is actuated, the control circuit initiates regeneration. Thus, regeneration can be effected not only by manually rotating hub 52 but by simply depressing the hub to activate switch 57.

The details of control circuit 50 are set forth schematically in FIG. 4. At the heart of control circuit 50 is a data processing unit 58 which, in the presently preferred embodiment, takes the form of a single chip microcomputer, such as a model 8048 microcomputer, as manufactured by Intel Corp., Santa Clara, Calif. Microcomputer 58 includes "on-board" random access memory for storing data and particularly capacity previously entered to the microcomputer as well as the data, such as the adjusted capacity developed during the course of microcomputer operation. Also, the microcomputer 58 includes on-board read only memory in which is stored the operating program to be described in greater detail with respect to FIGS. 5A to 5D. This program controls the operation of the internal microcomputer arithmetic logic unit which performs the necessary calculations and logic determinations, to decide whether regeneration should be effected. The read only memory within the microcomputer 58 also stores a look up table containing capacity coefficient values which, as described hereinafter, enable the microcomputer 58 to recognize and adjust for the additional capacity created when a partially exhausted resin bed is regenerated with a normal regenerant level. Each of the capacity coefficient values stored in the microcomputer 58 read only memory is proportional to the increased capacity attributable to regeneration of a partially exhausted resin bed with a particular regenerant level. In addition to the on-board memory and the arithmetic logic unit, microcomputer 58 also includes an internal

timer which serves as a real time clock. For a further, more complete description of the Model 8048 microcomputer, reference should be had to the "MCS-48 User's Manual," published by Intel Corporation.

A 5 volt regulated d.c. voltage to energize microcomputer **58** is supplied to the microcomputer at its Vcc pin by a power supply **59**, comprised of a transformer **60** whose primary winding **60***a* is coupled to a supply of 110-220 volt, 50-60 Hertz a.c. supply (not shown). Because of the lack of space within the cavity **33** for the transformer, transformer **60** is mounted to the rear of the control housing as shown in FIG. **2**. The low voltage a.c. produced across the center tapped transformer secondary winding **60***b* when the primary winding **60***a* is coupled to the a.c. supply voltage, is rectified by a pair of diodes **61***a* and **61***b* whose anodes are each coupled to one of opposite ends of the transformer secondary winding **60***b*. With the diode cathodes connected together, an unregulated d.c. voltage appears between the junction of the diode cathodes, hereafter referred to as the power supply unregulated voltage (unreg) output terminal, and the transformer center tap, hereinafter referred to as the power supply common (com) terminal.

The unregulated d.c. voltage present between the unregulated voltage and common terminals of power supply is filtered by a pair of parallel coupled capacitors **62***a* and **62***b* before being supplied to a voltage regulator **63**. The 5 volt regulated d.c. voltage produced at the output of the regulator, which is designated as the "+5V" output of the power supply, is filtered by a pair of capacitances **64***a* and **64***b* coupled in parallel between the +5V power supply terminal and the power supply common terminal before being supplied to pin Vcc of the microcomputer. Although the regulated 5 volt d.c. voltage produced by the power supply is well filtered, it is desirable to connect a filter capacitance **65** between microcomputer pin Vcc and the power supply common terminal. A completed circuit between the power supply and the microcomputer **58** is accomplished by connecting the microcomputer ground pin Vss to the power supply common terminal.

Within the microcomputer **58** is a master oscillator (not shown) whose periodic clock signals control the internal microcomputer timer and arithmetic logic unit. The frequency of this oscillator is determined from the reactance appearing across the microcomputer pins $XTAL^1$, and $XTAL^2$. In the presently preferred embodiment, this reactance is established by a inductance **66** coupled across the $XTAL^1$ and $XTAL^2$ pins of microcomputer **58** and a pair of capacitances **68***a* and **68***b* each coupled between a separate one of the microcomputer $XTAL^1$ and $XTAL^2$ pins and the power supply common terminal. The power supply common terminal is also coupled to the microcomputer pin EA to assure that during microcomputer operation, all memory accesses by the internal arithmetic logic unit in response to periodic timing signals from the internal master oscillator are made from the internal random access and read only memories of the microcomputer.

The internal timer of the microcomputer, which, as indicated, serves as a real time clock, is strobed or clocked in accordance with the alternations of the a.c. supply voltage. Since the a.c. supply voltage is accurately maintained either at 50 or 60 Hz, depending on the custom, the frequency of alternations of the a.c. supply voltage can be used as a basis of measuring real time. To strobe the internal microcomputer timer, a clocking circuit **70** is provided for supplying microcomputer at its **T1** pin with a logic level voltage which changes logic states in accordance with the alternations of the a.c. supply voltage. Clocking circuit **70** includes a diode **71** and a resistance **72** serially coupled between the one of the two secondary winding terminals of transformer **60** and the base of a first transistor **73** whose collector-to-emitter portion is coupled in series with a resistance **74** between the +5 V and common terminals of power supply **59**. Transistor **73** is also coupled at its base to the +5 V terminal of the power supply through a pair of serially coupled resistances **75***a* and **75***b*. Each time the a.c. voltage at the secondary **60***b* of transformer **60** undergoes an alternation, the transistor **73** is rendered conductive. A filter comprised of the parallel combination of a capacitance **76** and a resistance **77** filters stray noise to prevent false conduction of transistor **73**.

A second transistor **78** has its base coupled to the junction between resistance **74** and transistor **73** and transistor **78** has its collector-to-emitter portion coupled between the junction resistances **75***a* and **75***b* and the power supply common terminal. The conduction of the transistor is controlled by transistor **73** and when transistor **73** is conductive, transistor **73** shunts current from the base of transistor **78** to keep transistor **78** from conducting. While transistor **73** is nonconductive, transistor **78** is supplied with base current and becomes conductive. In this way transistor **78** acts as a logic inverter so that the logic level voltage appearing across transistor **78**, which is supplied to the microcomputer at pin **T1** to strobe the internal timer, will be logically inverse to the logic level voltage appearing across the collector-to-emitter portion of transistor **73**.

In order for the internal microcomputer timer to keep the correct time, the timer must usually be initially set to the appropriate time. Setting of the timer is accomplished by closing a switch **79** coupled between the microcomputer timing input at pin T_o and the power supply common terminal input to force the voltage at the timing input to a logic low voltage level. In practice, switch **79** is activated by depressing button **42** protruding through the cover **38** (FIG. **3**). While switch **79** is open, the timing input is maintained at a high logic level voltage via a resistance **80** coupled between the pin T_o and the +5 V power supply terminal.

Because the internal microcomputer timer counts time in accordance with the alternations of the a.c. supply voltage as processed by clocking circuit **70**, the microcomputer must be alerted as to whether the a.c. supply voltage frequency is 60 Hz, as is the case in the United States, or 50 Hz., as is the case in many European countries. To alert the microcomputer as to the a.c. supply voltage frequency, a switch **81** is coupled between the second highest order microcomputer data bus line (7) which terminates at pin DB_7 and the power supply common terminal. After determining whether or not that bus is at a ground potential (i.e. whether or not switch **79** is closed) the microcomputer then knows whether the a.c. supply voltage is 50 or 60 Hz., respectively.

Normally, the microcomputer power is provided from power supply **59**, and the timing signal for clocking the internal timer is provided from the clocking circuit **70**. However, should the a.c. supply voltage fail, then not only does the clocking circuit fail to supply periodic pulses, but, more importantly, the internal microcomputer memories which store collected data

may be erased. To keep at least the microcomputer memories from being erased, a battery **82** is coupled at its positive terminal via Zener diode **84** to the standby voltage input pin Vdd of the microcomputer **58**. The negative terminal of the battery is coupled to the power supply common terminal. While there is an a.c. voltage at the input to the power supply **59**, a regulated d.c. voltage is provided to pin Vdd from the power supply via a diode **86**.

Usually, the battery voltage is less than the sum of the break over voltage of the Zener diode **34** and the voltage drop across diode **86**, but is greater than the Zener diode break over voltage. Thus, only when the supply voltage fails will battery **82** render Zener diode **84** conductive and supply voltage to the microcomputer. Note that a capacitance could be substituted as an energy storage device in place of battery **82**. A capacitor **87** is connected between microcomputer pin Vdd and the power supply common terminal to filter any noise.

Once the a.c. supply does fail, resetting of the microcomputer is usually necessary. A reset circuit **90** for accomplishing resetting of microcomputer upon "power up" includes a resistance **92** and a Zener diode **94** coupled in series between the power supply unregulated voltage output terminal and the base of a first transistor **96** whose collector-to-emitter portion is coupled in series with a resistance **98** between the power supply unregulated voltage output terminal and the power supply common terminal. The base-emitter junction of the transistor is shunted by the parallel combination of a resistance **100** and a capacitance **102**.

A second transistor **106** has its base coupled to the junction between resistance **98** and transistor **96**, and transistor **106** has its collector-to-emitter portion coupled in series with resistance **108** between the microcomputer reset input terminating at the RESET pin and the power supply common terminal. During intervals while a.c. is supplied to the power supply, transistor **96** is rendered conductive to divert current from the base of transistor **106** to keep it from conducting, thereby keeping the impedance at the microcomputer reset input high. However, once the a.c. supply voltage fails and then is reapplied to the power supply, transistor **96**, which had become non-conductive once the a.c. supply voltage failed, will not again become conductive until the unregulated output voltage of the power supply **59** reaches the threshold voltage of Zener diode **94**. In the meantime, with transistor **96** temporarily non-conductive, transistor **106** becomes conductive once the power is reapplied to provide a low impedance path between the microcomputer reset input and the power supply common terminal to reset the microcomputer.

As will become better understood by reference to flow chart FIGS. **5A–5D**, microcomputer **58** is programmed to initiate water softener resin bed regeneration when the remaining resin bed treating capacity, as determined from the amount of water used since the previous regeneration and the water hardness, is less than a reserve value calculated as a percentage of the actual average daily soft water consumption.

Input data representing the flow of softened water leaving resin tank **12** of FIG. **1** is supplied from a flowmeter **110** (FIG. **1**) disposed in the outlet **23***b* to the highest order line (**17**) of the first of the two ports of microcomputer **58** terminating at pin P_{17}. Referring now to FIG. **4***a*, which is a cut away view of the inlet **23***b* taken along lines **4***a*—**4***a* of FIG. **1**, flowmeter **110** is comprised of a turbine **111** having a magnet **112***a* embedded in the periphery of the turbine so that the south magnetic pole is facing radially outwardly. A counterweight **112***b* is located in the turbine periphery opposite magnet **112***a* to balance the turbine. The turbine is journaled at its rightward most end by a first bearing **113***a* secured in a bearing strut **114** disposed in the rightward end of the outlet. Turbine **111** is journaled at its leftward most end by a bearing **113***b* carried in a bearing strut **116** that is disposed in the interior bore of a collar **117** which is dimensioned to be received in the leftward most end of the outlet. An O-ring **118** is disposed in sealing engagement between the collar and the outlet to prevent water leakage. As water flows through the outlet, the force of the water drives the turbine **111**, so that the magnet passes a Hall Effect switch **119** disposed in a wall of the outlet adjacent to the turbine.

Returning now to FIG. **4**, Hall Effect switch **119**, which typically comprises a model UGN 3040 T. Hall Effect switch as manufactured by Sprague Electric Co., Concord, N.H., is coupled at its input terminal I and its ground terminal G to the +5 V and common terminal of the power supply. A capacitance **119***b* shunts the I and G input level to filter any stray noise. When energized in this manner, the Hall Effect switch generates a high logic level voltage at its output terminal each time the magnet of the turbine passes the switch. This voltage is supplied to the microcomputer at line **17** of the second microcomputer port terminating at the microcomputer pin P_{17}. By counting the number of voltage level transitions, the microcomputer can determine the turbine velocity, which is directly related to the flow rate of water leaving the softener. A pull up resistance **119***c* couples the microcomputer pin P_{17} to the +5 V power supply terminal to prevent random noise from causing an erroneous flow measurement.

Input data indicative of the total treating or softening capacity of resin bed **14** of FIG. **1** and data indicative of the hardness of the incoming water is entered into the microprocessor through the low order lines (**0–5**) of the microprocessor data bus terminating, at pins DB_0 through DB_5 and through the four lower order lines (**20–23**) of the second microprocessor port which terminate at pins P_{20}–P_{23}. In practice, input data representing the total resin bed treating capacity is entered as a binary number, by connecting the appropriate ones of data bus pins DB_0–DB_5 and port pins P_{20}–P_{23} to the fourth highest line (**14**) of the first microprocessor port terminating at pin P_{14}. The existence of a connection by way of an associated one of jumpers **120***a* between one of data bus pins DB_0–DB_5 and port pins P_{20}–P_{23}, and port pin P_{14} represents a binary 1 digit while the lack of a connection represents a binary zero digit. The most significant digit of the two digit number representing incoming water hardness, as measured in grains, is also entered as a binary number by connecting an associated one of data bus pins DB_0–DB_5 and port pins P_{20}–P_{23} to the third highest line (**15**) of the second microcomputer port terminating at pin P_{15} via one of jumpers **120***b*. The least significant digit of the two digit number representing the incoming water hardness is likewise entered as a binary number by connecting an associated one of data bus pins DB_0–DB_5 and port pins P_{20}–P_{23} to the second highest line (**16**) of the first microprocessor port terminating at pin P_{16} via an associated one of jumpers **120***c*. Since the incoming water hardness is entered as a two digit decimal number varying between 0 and 99, only four binary bits are required to represent each digit. Therefore only the four higher order data bus pins

DB_2–DB_5 or the four port pins P_{20}–P_{23} need be jumpered to one of port pins P_{15} and P_{16} to enter the most significant and least significant digits of the water hardness data. The remaining pins can be jumpered to cause the microcomputer to execute certain self-test instructions.

Referring to FIG. **3**, each of pins DB_0–DB_5 and P_{14}–P_{16} and P_{20}–P_{23} of the microcomputer are connected to a separate one of the terminals of one of connector blocks **122***a*–**122***c* which are carried on the circuit board **124** to which the components of control circuit **50** are mounted. During water softener installation, the installer enters data indicative of the total treating capacity and the incoming water hardness by connecting the appropriate terminals of connector blocks **122***a*–**122***c* together with one or more of the appropriate jumpers **120***a*, **120***b* and **120***c*.

Returning to FIG. **4**, if the microcomputer determines from the input flow meter data and the resin bed treating capacity and water hardness input data that regeneration is required, then the microcomputer outputs a high level logical voltage on the second highest order data bus line (**6**) terminating at pin DB_6. This voltage is supplied to the base of a transistor **124** which is also supplied with a regulated 5 volt d.c. voltage from the power supply via pull up resistance **126**. Transistor **124** has its collector-to-emitter portion coupled in series with a resistance **128** between the power supply common terminal and one of the light emitter input terminals L_2 of an optical triac **130** whose other light emitter input L_1 is coupled to the unregulated voltage output terminal of the power supply. When transistor **124** is rendered conductive by microcomputer **58**, the transistor provides a completed circuit path for current to pass in the light emitter of the optical isolator **130** to render the optical isolator conductive. Optical isolator **130**, when rendered conductive, provides a completed circuit path between each of its input terminals I_1 and I_2, which are supplied with an a.c. voltage, and one of output terminals M_1 and M_2, respectively, which are coupled to motor **48**. Thus, when transistor **124** is rendered conductive, the motor is energized with a.c. current to drive cam shaft **28** of FIGS. **1-3**, thereby initiating resin bed regneration. To filter the voltage switched by optical triac **130**, a resistance **132** is coupled in series with a filter capacitor **134** across terminals M_1 and M_2 of the optical triac.

As will be recalled, a switch **57** (FIG. **3**) is positioned within cavity **33** so that the switch is actuated either upon depression of hub **52** and gear **32** or upon rotation of the gear. Returning to FIG. **4**, switch **57** has its contacts connected to collector and emitter of transistor **124**, respectively. Thus, when switch **57** is actuated, the switch shorts the collector-to-emitter portion of the transistor to energize the optical triac **130**.

In addition to the previously described subcircuitry of the control circuit **50**, the control circuit **50** also includes a display comprised of a pair of 7 segment light emitting diodes (L.E.D.'s) **134***a* and **134***b* for displaying not only the time of day as measured by the number of alternations of the a.c. supply voltage as recorded in the internal microprocessor timer, but also for providing an indication of soft water flow from the tank **12**. Both of L.E.D.'s display **134***a* and **134***b* are coupled to the +5 V and unregulated output voltage terminals of the power supply **59**. Each of the seven segments a–g of L.E.D. **134***a* is connected via a separate one of pull up resistances **136***a* through **136***g*, respectively, to a corresponding one of the outputs **01**–**07** of a display driver circuit **138** which typically comprises a model 74 LS 47 display driver such as manufactured by Texas Instruments, Dallas, Tex. In addition to being coupled to the +5 V and common terminals of power supply **59** so as to receive a regulated 5 volt d.c. voltage therefrom, display driver circuit **138** has its four input terminals I_1–I_4 coupled to a separate one of the four highest lines (24–27) of the second port of microcomputer **58** which terminate at microcomputer pins P_{24}–P_{27} respectively. During execution of its internally stored program, microcomputer **58** outputs a four-bit binary signal at pins P_{24}–P_{27} representing the least significant digit of the hour of the day which is supplied to the display driver **138** which in turn energizes the appropriate segments of L.E.D. display **134***a* to display this least significant digit of the hour of the day.

To enable control circuit **50** of the present invention to be utilized both domestically and internationally, it is desirable that L.E.D.'s **134***a* and **134***b* display the hour of the day either in a 12 hour fashion or a 24 hour fashion. To this end, segments a, d, e, and g of display **134***b* are each coupled to the common terminal of the power supply through resistance **139** in series with a collector-to-emitter portion of a transistor **140**. Transistor **140** is coupled at its base to the power supply +5 V terminal via a pull up resistance **141** and is coupled to the third lowest order line (**12**) of the first port of the microcomputer terminating at pin P_{12} so as to receive a high logic level voltage therefrom at appropriate intervals during execution of the microcomputer program to energize L.E.D. segments a, d, e and g. Segment b of L.E.D. display **134***b* is coupled to the power supply common terminal via a resistance **144** in series with a collector-to-emitter portion of a transistor **146**. Transistor **146** is supplied at its base with a regulated five volt d.c. voltage from the power supply through a pull up resistance **148** and is also supplied in its base with the logic level output signal appearing on the third lowest line (**13**) of the first port of the microcomputer which terminates at microcomputer pin P_{13}. Segment c of L.E.D. display **134***b* is switchably connected by the first contactor **150**A of a double pull, double throw switch **150** to resistance **144**. The second contactor **150***b* of double pull, double throw switch **150** couples one terminal of a resistance **152**, between the decimal point segment d.p. of the L.E.D. display **134***b* and segment c of light emitting diode **134***b*. The other terminal of resistance **152** is coupled by the collector-to-emitter portion of a transistor **154** to the power supply common terminal. Transistor **154** is supplied at its base with the five volt regulated d.c. output voltage of the power supply via pull up resistance **155** and is also supplied at its base with the logic level voltage of the second lowest order line (11) of the first microcomputer port terminating at microcomputer pin P_{11}. When switch **150** is set at the "12 Hr" position so that the decimal point segment d.p. of display **134***b* is coupled to resistance **152** and segment c is coupled in parallel with segment b, then when transistor **154** is rendered conductive as a result of a microcomputer generating a logic high voltage at pin P_{11}, which is the case during the p.m. hours of the day as determined by the internal microcomputer timer, decimal point segment d.p. of light emitting diode display **134***b* is energized. Once energized, the decimal point segment d.p. illuminates the indicia "PM" on the outer face of window **40** of FIG. **3** to indicate the hourly time displayed by L.E.D. displays **134***a* and **134***b* is after

noon. With switch **150** in the "12 Hr" position, a "1" is displayed by L.E.D. display **134***b* when transistor **146** is rendered conductive by the microcomputer. This will occur when the time of day, as determined by the internal microcomputer timer, is between either noon and 1:00 p.m. or midnight and 1:00 a.m.

If, however, switch **150** is set at the "24 Hr" position so that transistor **154** now drives segment c of L.E.D. display **134***b*, then, L.E.D. **134***b* displays a "1" when both transistor **154** and transistors **146** are rendered conductive to energize segments b and c. This will occur when the microcomputer outputs a logical high level voltage at pins P_{13} and P_{11} during the interval when the time of day is between 1200 and 100 hours. During the interval when the time of day, as determined by the internal microcomputer timer, is between 2000 hours and 2400 hours, then the microcomputer outputs a logic high level voltage at both pins P_{13} and pin P_{12} so that segments a, d, e, and g are energized by transistor **140** and segment b is energized by transistor **146** to display a "2" at display **134***b*.

L.E.D. **134***a*, like display **134***b* is also provided with a decimal point segment d.p. which is linked via a resistance **158** to the lowest order line (10) of the first microcomputer port terminating at pin P_{10}. During intervals other than when regeneration is occurring that is, during intervals when soft water is flowing through resin bed **14** of FIG. **1** and out outlet **23***b* of FIG. **2**, then, microcomputer **58** outputs a logic level voltage at pin P_{10} which alternates between a high and low logic level to alternately energize the decimal point segment d.p. of L.E.D. display **134***a*. Decimal point segment d.p. of display **134***b* appears behind the indicia "WATER FLOW" on window **40** of FIG. **3** so that while water is flowing through the softener, the decimal point segment d.p. of L.E.D. **134***a* flashes.

As indicated previously, within the internal memory of microcomputer **58** of FIG. **4** is a program which controls the microcomputer to enable the microcomputer to process the incoming data to determine whether or not motor **48** of FIGS. **2** and **3** should be energized to initiate regeneration as well as to enable the microcomputer to display the time of day on L.E.D. displays **134***a* and **134***b* of FIG. **4**.

PROGRAM START UP—STEPS 200–206

Referring now to FIGS. **5A** through **5C** which illustrate in flow chart form the program executed by the microcomputer and in particular FIG. **5A**, execution of the microcomputer program is commenced (Step **200**) when power is applied to the microcomputer. Following program startup, a default value for the time of day is entered into the register of the internal microcomputer timer for time keeping purposes (Step **202**). Typically, this default value is "12 noon." However, the default value can be incremented while switch **79** of control circuit **50** is actuated so that if the correct hour of the day is other than 12 noon, then the appropriate value can be entered into the timer register. Following entry of the default value into the timer register, seven separate memory locations of the microcomputer internal memory are each filled with a value representing $\frac{1}{4}$ of the total refining capacity of resin bed **14** of FIG. **1**, as measured in gallons (Step **204**). Since the microcomputer of the present invention operates to initiate water softener regeneration when the actual treating capacity of resin bed **14** of FIG. **1** is less than a reserve quantity calculated in accordance with the actual average daily soft water consumption, the entry of finite artificial values for the daily amount of soft water consumed in place of the value 0 enables the microcomputer to better regulate the frequency of water softener regeneration during the first week of operation. Each of the seven artificial values representing the daily consumption of soft water used for a particular day of the week is, however, replaced with the actual value of the daily consumption of soft water as determined from the flow meter during later operation of the water softener control.

Also, during Step **204**, a default value is entered for a variable, designated as the surplus value. As will be seen hereinafter, the surplus value serves to quantify the additional capacity resulting from regeneration of a partially exhausted resin bed. Since the additional capacity is initially zero, the default value for the surplus value is set equal to zero.

SELF TEST MODE STEPS 206–210

Following entry of each of the seven artificial values which initially represent the amount of soft water used for each of the seven days of a week, the microcomputer **58** then checks whether it is operating in a self test mode (Step **206**). During installation as well as during intervals when the operation of microcomputer **58** is to be evaluated, the microcomputer is placed in a self test mode by jumpering certain of the microcomputer data bus pins DB_0–DB_5 and port pins P_{20}–P_{23} to one of port pins P_{14} and P_{15}. If the microcomputer is operating in the self test mode, then the microcomputer checks to see which of any of the switches connected thereto, such as switches **150** and switch **136**, have been actuated (Step **208**). Should a particular switch be actuated, then a particular code representing the switch is displayed (Step **210**).

DISPLAY OF TIME OF DAY—STEPS 212–222

Once the microcomputer **58** has determined that it is not operating in the self test mode, the microcomputer examines the conduction state of switch **81** to determine whether or not the incoming a.c. supply to the primary of transformer **60** is at 50 or 60 hertz (Step **212**). The frequency of the a.c. input voltage is 50 hertz, then, microcomputer **58** a.c. supply voltage is important since the internal timer of microcomputer **58** is clocked in response to the alternations of the a.c. power supply voltage. If frequency of the operates light emitting diode displays **134***a* and **134***b* (FIG. **4**) as a 24 hour clock (Step **214**), assuming that switch **150** has been set to the "24 hour" position. In a location where the frequency of the a.c. supply voltage is 50 hertz, time is usually measured in 24 hour fashion rather than a 12 hour fashion. Following either a determination that the a.c. supply voltage is 60 hertz, or following the operation of the L.E.D. **134***a* and **134***b* (FIG. **4**) in a 24 hour clock mode, microcomputer **58** checks to see whether or not there are any errors (Step **216**), such as a failure to establish values for the total resin bed treating capacity and the incoming water hardness. Detection of an error results in a code indicative of the error being displayed on L.E.D's displays **134***a* and **134***b* (Step **218**). Otherwise, if no errors are detected, then the microcomputer causes L.E.D. **134***b* to display the least significant digit of the hour of the day (Step **220**) and causes L.E.D. display **134***a* to display the most significant hour of the day (Step **221**).

TIME KEEPING AND FLOW DETECTION—STEPS 222-234

After displaying either the time of day, assuming that no errors exist, or after displaying the error code, the microcomputer then checks the one second count recorded by the internal microcomputer timer (Step **224**). When the microcomputer has completed this task, that is to say that the lapse of one second has been recorded by the one second register then, the microcomputer branches to program block A and reloads the one second register (Step **226**) as indicated in FIG. **5B**. Otherwise, while the microcomputer is waiting for one second to elapse, the microcomputer checks the flow meter (Step **228**) by inputting the logic level output voltage of the flow meter. The output logic level voltage of the flow meter is compared to a reference level stored in memory (Step **230**). A determination that the logic level voltage produced by the flow meter equals the stored reference value is indicative of the passage of water through the flow meter. In response an internal microcomputer counter storing a count representative of a passage of a certain quantity of water through the flow meter during a given interval is incremented (Step **232**) and thereafter, the decimal point segment d.p. of light emitting diode display **134***a* (FIG. **4**) is energized or toggled (Step **234**) to indicate water flow through the softener.

POWER LOSS DECTION—STEPS 236-242

Following a determination that the output logic level voltage of the flow meter has not changed states, or following toggling of the L.E.D. display decimal point segment, an internal microcomputer register designated as a "power loss" counter is incremented (Step **236**). This register is referred to as a power loss counter because its count continues to be incremented during the period while the microcomputer is awaiting its internal timer to record the lapse of one second. Failure of the power loss counter to be incremented indicates failure of the internal microcomputer timer to record the passage of one second, thus indicating a loss of a.c. power. By checking the count of the power loss counter, (Step **238**) a power loss can be detected. If the count of the power loss counter has not been incremented, as determined during Step **238**, a power failure has occurred and the microcomputer then blanks the display of light emitting diodes **134***a* and **134***b* of FIG. **4** (Step **240**) to conserve on power.

After the display has been blanked, the microcomputer checks whether the internal microcomputer timer has resumed counting (Step **242**) and continues to check until the internal microcomputer timer records the passage of one second as will normally occur once power is reapplied to the microcomputer. Upon a determination that one second has elapsed, the microcomputer branches to program block A (FIG. **5B**) and the one second register is reloaded (Step **226**). However, after checking the power loss counter (Step **238**), if no power loss has been detected, then the microcomputer branches to Step **222** to recheck the one second register to determine whether or not one second has elapsed.

TIME SETTING—STEPS 244-265

Referring to FIG. **5B**, following completion of checking the one second register (Step **224**) and reloading of the register (Step **226**), the microcomputer determines whether or not the internal microcomputer timer ten second register has counted out the passage of ten seconds (Step **243**) after the one second register has been reloaded. If ten seconds have not elapsed, the microcomputer branches to block B and determines whether or not the relay flag has been set (Step **244**) as illustrated in FIG. **5C**. As will become better understood by reference to the remaining Steps of the program, once the microcomputer determines that regeneration should occur, microcomputer **58** sets a relay flag causing a high logic voltage to appear at microcomputer data bus pin DB_7 in response to which, transistor **124** of FIG. **4** is rendered conductive to energize the optical triac **130** of FIG. **4**. The optical triac then energizes motor **48** (FIG. **2**) to drive cam shaft **28** (FIGS. **1** and **2**) to initiate regeneration. After regeneration is initiated by setting of the relay flag, the relay flag remains set for ten minutes to assure that the optical triac keeps motor **48** of FIG. **2** energized. Once the motor has been energized to drive the cam shaft **28** of FIGS. **1** and **2** via gears **46**, **44** and **32**, the switch **57** is kept closed by the rotation of the gears to keep the motor energized well after the 10 minutes has elapsed so that the entire regeneration cycle, which usually takes between 1-2 hours will be completed.

Returning to FIG. **5C**, if the relay flag has been set, or is "on" the microcomputer makes sure that the relay flag has been set (Step **246**) before determining whether or not switch **79** of FIG. **4** has been closed (Step **248**) to set the time displayed by light emitting diodes **134***a* and **134***b* of FIG. **4**. Alternatively, the microcomputer makes sure that after having not detected a set relay flag, that no flag was in fact set (Step **250**) before checking to see whether switch **79** is closed to alter the displayed time (Step **248**).

Following the determination that switch **79** has been closed to set the time display by the light emitting diodes **134***a* and **134***b* of FIG. **4**, the microcomputer then clears the internal microcomputer timer one second registers recording the number of elapsed seconds (Step **252**). Thereafter the microcomputer then clears the timer ten second register recording the number of ten second intervals that have elapsed (Step **254**). Next, the microcomputer clears the register recording the number of 60 second or one minute intervals that have elapsed (Step **256**) before the microcomputer increments the register of the internal microcomputer timer which records the passage of hours (Step **258**).

Upon incrementation of the hour-register of the internal microcomputer timer, a "flash" flag is reset (Step **260**) before clearing the register storing the error codes (Step **262**). The purpose of the flash flag will be explained below. After, either the microcomputer has cleared the error code register (Step **262**) or after the computer has determined that the time switch **79** of FIG. **4** has not been closed (Step **248**), the microcomputer determines whether the flash flag has been set (Step **264**). During execution of the presently described program, an internal flag within the microcomputer referred to as the "flash flag" is alternately set and reset every second. As will become clear immediately hereinafter, the alternation of the state of the flash flag causes the display of light emitting diodes **134***a* and **134***b* to flash on and off during alternate seconds. A determination that the flash flag was unset when checked during Step **264**, causes the microcomputer **58** to execute a jump instruction (Step **265**) to branch to program block C so that Step **216** is re-executed after which either the appropriate error code is displayed (Step **218**) or if no

error exists, then the time of day is displayed on L.E.D. **134***a* and **134***b* of FIG. **4** (Steps **220** and **221**). However a determination that the flash flag is set, causes the microcomputer **58** to check to see whether another flag, referred to as the "alter flag", has been set (Step **266**). This flag is set each time the time of day data to be displayed by the light emitting diodes has been altered or changed as will occur when the hour of the day has changed. When the alter flag has been set, then the altered time of day data to be displayed, is stored in microcomputer memory in place of the previous time of day data (Step **268**) and jump Step **265** is then executed so that program control branches to Step **216**. If the alter flag has not been set, then the time of day data is stored (Step **270**) in a section of memory other than that associated with the data to be displayed on the light emitting diode display and data representing a blank display is moved into the memory location where the time of day to be displayed is usually stored (Step **272**) before jump Step **265** is executed. When data represented a blank is stored in this memory location of the microcomputer memory, and when steps **220** and **222** are executed, neither of light emittng diode displays **134***a* and **134***b* are energized, so as to effectively display a blank.

WATER FLOW CALCULATION AND TIME UPDATE—STEPS 274–298

Returning now to FIG. **5B**, when the internal microcomputer timer has in fact counted ten seconds, then the program branches to Step **274** after the ten second register has counted out rather than to Step **244** as was described previously. Upon execution of Step **274**, the microcomputer increments the ten second register. Following incrementation of the ten second register, the previously stored count representing the number of transitions of the logic level of the flowmeter output voltage is converted into gallons (Step **276**). This is accomplished by multiplying the flowmeter output voltage transition count by a constant. The constant is actually a conversion factor which equals the number of gallons flowing past the flowmeter during the interval between each transition of the flowmeter output voltage. The calculated amount of soft water that left the softener during the 10 second interval is added to the previously calculated daily volume of soft water already stored in memory (Step **278**) to keep an ongoing record of the amount of soft water passing through the softener for that day. Thereafter, the microcomputer checks whether the ten second counter has counted out six times thus indicating the passage of a minute (Step **280**). If the ten second timer has not counted out six times, then the microcomputer jumps to program block B to re-execute Step **244** and those following it described previously to make sure that the relay flag is set or not set and then to cause the time of day to be flashed on the L.E.D.'s **134***a* and **134***b* of FIG. **4**.

When, however, the ten second register of the internal microcomputer timer has in fact counted out six times indicating the passage of a minute, then the microcomputer checks the 60 minute register to determine whether or not the number of minutes that have been counted equals sixty (Step **282**) indicating the passage of an hour. The microcomputer will execute a jump instruction (Step **283**) to branch to block B of the program if an hour has not elapsed so that the microcomputer commences re-execution of Step **244**. Otherwise, if the number of minutes counted does equal sixty, then the hour register which counts the number of hours that have elapsed is incremented by one (Step **285**).

Following incrementation of the hour register the microcomputer then determines whether or not the particular time of day as determined by the count of the hour counter is 2:00 a.m. (Step **286**) so that the microcomputer can determine whether or not regeneration should occur at this off-hour. Should the time not be 2:00 a.m., then the microcomputer checkes the count of the hour register to determine whether or not the count of the hour register is twelve which would indicate a time of either 12:00 noon or 12:00 midnight (Step **288**). Upon a determination that the count of the hour counter was 12, the microcomputer then checks whether or not the decimal point segment d.p. of light emitting diode **134***a* of FIG. **4** was previously energized (Step **290**). If, at the time the count of the hour register equals 12 the microcomputer has determined that the decimal point segment d.p. of L.E.D. **134***a* of FIG. **4** was previously on, indicating that the time of day was after 11:00 p.m. but before 12:00 midnight, then the decimal point segment d.p. is turned off (Step **292**) indicating that the time is now after midnight and before noon. However, if the decimal point segment d.p. of the light emitting diode **134***a* had previously been off or deenergized before the count of the hour register reached twelve, then after the hour counter has counted twelve, the decimal point segment d.p. of light emitting diode display **134***a* is turned on (Step **294**) to indicate that the time is now post meridian rather than antemeridian.

When the microcomputer has determined that the hour register has not counted twelve during Step **288**, then, the hour register is checked to determine whether or not the number of hours counted equals thirteen (Step **296**). A count of 13 requires that the number of hours counted by the hour register be reset to one (Step **298**) before the program executes jump instruction **299** to branch to program block B to re-execute Step **244**. Otherwise if the count of the hour register is other than thirteen, then the program executes jump instruction **299** to branch to Step **244** directly without resetting of the hours register.

DECIDE IF REGENERATION IS REQUIRED—STEPS 286–332

Should the microcomputer determine during execution of Step **286** that the time of day is 2:00 a.m. or such other off-hour time as designated for regeneration, then the microcomputer proceeds to determine whether or not regeneration should occur by branching to block D and executing the following Steps illustrated in flow chart form in FIG. **5D**. First, the total number of gallons used during elapsed 24 hour period, as determined during execution of Steps **260–264**, are added to the total number of gallons used since previous regeneration (Step **304**). Thereafter, the average daily amount of soft water used over the past seven days (excluding the just elapsed day) is calculated (Step **306**) by summing the seven separate values which each represent the soft water consumption for each of the past seven days and then dividing the total sum by seven. Once the average of the daily comsumption of soft water is calculated, this average value is compared to the previous day's total consumption (Step **308**). If the previous day's consumption is greater than 20% of the average daily consumption, then the previous day's usage is stored in memory as the amount of water consumed for that day

causing each of the daily stored values of the water consumption to be shifted in memory to now represent one earlier day's usage (Step **310**) before proceeding to the next Step. Note that the earliest day's usage will be erased. However, when the previous day's usage is less than 20% of the average daily consumption, then the amount of water used during the previous day is stored to enable it to be added to the total amount of water used between regenerations during the next execution of the program, but the previous day's consumption is not stored in memory as the amount of soft water consumed during that day so that no data shifting occurs. In this way, an unusually low daily consumption of soft water is ignored to avoid a zero average daily consumption of soft water such as might occur during intervals of non usage such as during vacations.

Following execution of Step **310**, or following execution of Step **308** if the consumption for a given day is less than 20% of the average daily consumption, the microcomputer then checks whether or not the previous day's consumption was greater than 200% of the average daily consumption (Step **312**). Should the previous day's consumption of soft water be 200% greater than the seven day average consumption of soft water due to a sudden increase in water consumption which may result from the arrival of weekend guests for example, then this previous day's usage is stored in memory as a reserve value (Step **314**). This reserve value represents the total amount of soft water likely to be consumed during the next 24 hour interval before the microcomputer will again make a determination as to whether or not regeneration is necessary. Otherwise the reserve value is determined as a percentage of the calculated seven day average (Step **316**). Typically, if the previous day's consumption is less than 200% of the calculated average, the reserve calculated during Step **312** is obtained by multiplying the seven day average by 1.2.

After the reserve is established, either during execution of Step **314** or Step **316**, depending whether the previous day's consumption was greater than or less than 200% of the calculated seven day average, respectively, then the microcomputer **58** proceeds to calculate the total treating capacity of the resin bed **14** in gallons by executing Steps **318.1–318.5**. First, the input resin bed treating capacity, as measured in grains, is read (Step **318.1**). As will be recalled from the discussion of the control circuit **50** of FIG. **4**, the capacity data is input to the microcomputer **58** by connecting the jumper from the microcomputer port pin P_{16} to one or more of the data bus pins DB_0–DB_5 and port pins P_{20}–P_{23}. The input capacity value is equal to the resin bed capacity when the resin bed is totally exhausted and then regenerated. To account for the additional capacity resulting from the regeneration of a partially exhausted resin bed, an additional amount of capacity, proportional to the variable referred to as the surplus factor, is added to the input capacity value. The surplus factor is defined as the ratio of the remaining capacity (in gallons) when a regeneration is initiated to the total adjusted resin bed capacity. As will become better understood following a complete description of the flow chart of FIG. **5D**, each time a regeneration is initiated, a new value for the surplus factor is calculated and stored for future use so that the most current value of the surplus factor is proportional to the current additional capacity created upon regeneration of a partially exhausted resin bed.

Following execution to Step **318.1**, the surplus factor is utilized to look up a capacity coefficient value stored in tabulated form in the microcomputer **58** read only memory (Step **318.2**). As described previously, each capacity coefficient value is proportional to the increased capacity attributed to regeneration of a partially exhausted resin bed with a particular regnerant level. The capacity coefficient values are nonlinear and are determined empirically based on the type of resin employed and the water conditions. Next, the additional capacity is calculated (Step **318.3**) by multiplying the input capacity obtained during Step **318.1** by the capacity coefficient value obtained during Step **318.2**. After calculating the additional capacity (Step **318.3**) the total capacity is calculated (Step **318.4**) by adding the additional capacity calculated during Step **318.3** to the input capacity obtained in Step **318.1**. The total capacity value calculated during Step **318.4**, which is measured in grains, must be converted into gallons in order to enable the remaining capacity to be calculated. To convert the capacity value calculated during Step **318.4** into gallons, the water hardness, as measured in grains/gallons is first read (Step **318.5**). As will be recalled, the water hardness is input to the microcomputer **58** by connecting each of the jumpers from the microcomputer port pins P_{15} and P_{16} to a selected one of the data bus pins DB_0–DB_5 and port pins P_{20}–P_{23}. Once the water hardness is read by the microcomputer, the total adjusted capacity value calculated during Step **318.4** is divided by the water hardness to yield the total adjusted capacity, as measured in gallons.

After the adjusted total water softener resin bed treating capacity has been calculated (Step **318.5**), the quantity of water consumed since the last regeneration is subtracted from the adjusted total resin bed treating capacity (Step **320**) to yield a value representing the remaining water softener resin bed treating capacity. The value representing the remaining water softener treating capacity is then compared (Step **322**) to the reserve value previously calculated during Step **314** or Step **316**. Following comparison of the reserve value to the calculated value representing the remaining water softener resin bed treating capacity, the microcomputer **58** then determines whether or not regeneration should occur (Step **324**). If the reserve value, as previously calculated during either Step **314** or Step **316**, is greater than the remaining water softener resin bed capacity, so that it is highly improbable that the water softener resin bed would have sufficient capacity to treat the amount of water likely to be consumed during the next 24 hour interval, then regeneration is effected by following branch E to Step **327** to cause the relay flag to be set and motor **48** of FIGS. **1** and **2** to be energized. Otherwise, the remaining water softener resin bed treating capacity calculated during Step **320** is greater than the reserve calculated during either of Steps **314** or **316** and thus no regeneration need be effected. Then, the microcomputer **58** checks whether or not the particular day of the week is the first day following a start up after a power failure (Step **326**). If the day happens to be the first day following start up after a power failure, then the microcomputer **58** follows branch E to Step **327** to set the relay flag which causes the energization of motors **48** of FIGS. **1** and **2**. This way, regeneration always occurs after the first day after a power failure to assure that soft water always leaves a softener which may not otherwise occur if a large quantity of soft water is consumed during the power failure.

Following execution of Step **327** and setting of the relay flag, the microcomputer **58** calculates a new value for the surplus factor (Step **328.1**). To calculate the new value for the surplus factor, the microcomputer **58** divides the remaining capacity, previously calculated during Step **320** by the total volume metric capacity (previously calculated during Step **318.5**). Following calculation of the new value for the surplus factor, the newly calculated value is stored in memory (Step **328.2**) at the location where the previously calculated surplus factor was stored to overwrite the old value thus replacing any previously stored value including the default value of zero placed in the memory during Step **204**. Following Step **328.2**, the memory location within the internal memory of microcomputer **58** storing the data representing the number of gallons used since the previous regeneration is cleared (Step **328.3**). Once this memory location has been cleared, the microcomputer **58** resets the register which records the number of days between the regeneration intervals (Step **328.4**). Thereafter, the microcomputer **58** executes jump instruction **329** to follow branch C to Step **216** of FIG. **5A**.

If, however, more than one day has elapsed since the start up of the microcomputer **58** following a power failure, then the microcomputer **58** branches to Step **330** during which the microcomputer checks whether the frquency of the incoming power is 50 Hz. If the frequency of the incoming power is 50 Hz, then the microcomputer **58** checks whether 8 days have elapsed since the last regeneration (Step **322**). Should the count of the register recording the number of days since regeneration be 8 or greater, indicating that 8 or more days have elapsed since the previous regeneration, then the microcomputer follows branch E to Step **327** which, when executed initiates water softener resin bed regeneration. In this way, regeneration is automatically effected every 8 days if no previous regenerations have occurred as is sometimes required by the health laws of countries foreign to the United States.

When the microcomputer **58** has determined that the frequency of the incoming power is not 50 Hz, or that if the power frequency is 50 Hz but 8 days have not yet elapsed since the previous regeneration, then the microcomputer **58** executes jump instruction **329** to follow branch C to Step **216**.

Execution of the above described program occurs continuously during operation of the water softener without any need for manual intervention. Once the initial data of the water softener resin bed refining capacity (in kilograins) and the incoming water hardness (in grains per gallon) is entered into the microcomputer **58** memory, no further adjustments need to be made. Even a power outage will not totally prevent execution of the internal microcomputer **58** program controlling the water softener although it is necessary for power to be resumed in order for the control circuit **50** to effectively control water softener regeneration.

Although the control circuit of the present invention has been described for use with a resin bed water softener, it is equally useful for controlling other types of water treatment devices having a filter bed requiring periodic regeneration.

The foregoing describes an improved control circuit for a water softener for controlling regeneration of a water softener resin bed in accordance with the actual average daily consumption so as to prevent the water softener from regenerating too often or not often enough.

While only certain preferred features of the invention have been shown by way of illustration, many modifications and changes will occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as will fall within the true spirit of the invention.

What is claimed is:

1. A control for a water treatment device having a particle bed requiring periodic regeneration and including a flowmeter for measuring the quantity of treated water leaving the particle bed and a data entry device for entering input capacity data indicative of the amount of water treatable by the particle bed until the particle bed is completely exhausted, the improvement comprising:

a controller for controlling regeneration of the particle bed, the controller including:

memory means for storing said input capacity data and for storing remaining capacity data indicative of the remaining particle bed treating capacity prior to regeneration;

calculating means for calculating

(i) a reserve value representing the anticipated volume of soft water likely to be used prior to the next regeneration interval, said reserve value calculated in accordance with the treated water consumed as measured by said flowmeter,

(ii) the total adjusted treating capacity of the particle bed, said total adjusted treating capacity calculated in accordance with the input capacity data and said remaining capacity data,

(iii) the remaining particle bed capacity in accordance with the difference between the total adjusted treating capacity value and the quantity of treated water leaving the particle bed since the previous regeneration, as measured by said flowmeter, said remaining capacity value stored in said memory and overwriting the previously stored remaining capacity data; and

logic means for initiating regeneration of the water treatment device particle bed at a predetermined time each day if the reserve calculated by said controller calculating means exceeds the remaining capacity value calculated by said controller calculating means.

2. The invention according to claim **1** wherein said controller means comprises a microcomputer.

3. A method for controlling a water treatment device having a particle bed requiring periodic regeneration comprising the steps of:

(a) measuring the quantity of water leaving the water treatment device particle bed over a period of time;

(b) periodically determining the actual quantity of treated water consumed and establishing a reserve value representative of the amount of water likely to be consumed prior to the next regeneration in accordance with the amount of treated water leaving the water treatment device during the period;

(c) determining a total capacity value representative of the quantity of water treatable by the water treatment device until the water treatment device particle bed becomes completely exhausted;

(d) adjusting the total capacity value to account for the increased capacity created when a partially exhausted particle bed is regenerated;

(e) calculating the remaining water treatment device particle bed treating capacity in accordance with the difference between the total capacity value, as adjusted for the increased capacity created when a partially exhausted particle bed is regenerated, and the quantity of water that has left the softener since the previous regeneration; and

(f) initiating regeneration of the particle bed at a predetermined time if the calculated remaining treated capacity is less than the established reserve value.

4. The method according to claim **3** wherein the Step of adjusting the total capacity value to account for the increased capacity created if a partially exhausted resin bed is regenerated comprises the steps of:

(a) calculating the increased capacity created when a partially exhausted particle bed is regenerated, said calculation being made in accordance with the remaining particle bed treating capacity prior to regeneration; and

(b) adding the calculated additional water treatment device particle bed capacity created when a partially exhausted particle bed is regenerated to the total capacity value representing the quantity of water treatable by the particle bed until the particle bed becomes fully exhausted.

5. The method according to claim **4** wherein said Step of calculating the additional particle bed treating capacity created when a partially exhausted particle bed is regenerated comprises the Steps of:

calculating a surplus factor value in accordance with the ratio

$$\text{Surplus factor value} = \frac{\text{Remaining capacity}}{\text{Adjusted total capacity}};$$

(b) obtaining a capacity coefficient value which is proportional to the increased capacity created when a partially exhausted resin bed is regenerated with a particular regenerant level, said capacity coefficient value being obtained in accordance with the said surplus factor value; and

(c) determining the additional particle bed treating capacity created when a partially exhausted particle bed is regenerated in accordance with the product of the capacity coefficient value and the input capacity value.

6. A control for a water treatment device having a particle bed requiring periodic regeneration including a flowmeter for measuring the volume of flow of treated water leaving the water treatment device and a data entry device for entering input capacity data indicative of the total quantity of water treatable by the water treatment device until the particle bed is completely exhausted, the improvement comprising:

a controller for controlling the water softener to initiate regeneration, said controller including:

a timer for measuring time;

a memory for storing data indicative of the quantity of treated water consumed over a period of time in accordance with the flow measured by said flowmeter and for storing a table of coefficient values, each coefficient value being proportional to the additional particle bed treating capacity created when a partially exhausted particle bed is regenerated with a particular regenerant level; and

a central processor coupled to said timer and said memory for determining the actual average daily quantity of soft water used over a period of several days and establishing a soft water reserve value indicative of the amount of soft water likely to be consumed prior to the next possible regeneration in proportion to the actual average daily quantity of soft water consumed, said central processor coupled to said data input device for reading the input capacity data and for adjusting the input capacity data in accordance with a selected one of said coefficient capacity values selected in accordance with the previously calculated remaining particle bed treating capacity, said central processor calculating and storing a new value for the remaining resin bed capacity in accordance with the difference between the adjusted total capacity value and the quantity of water consumed since the previous regeneration and said controller initiating regeneration of the particle bed with the newly calculated remaining particle bed treating capacity less than the established reserve quantity.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 4,470,911

DATED : September 11, 1984

INVENTOR(S) : John F. Reinke

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Col. 11, line 11, "Zener diode 34" should be --Zener diode 84--.

Col. 17, line 30 "DECTION" should be --DETECTION--.

Col. 18, line 24, "1-2 hours" should be --1-2 hours,--.

Col. 19, line 19, "day to be" should be --day data to be--.

Col. 19, line 23, "emittng" should be --emitting--.

Col. 20, line 9, "checkes" should be --checks--.

Col. 22, line 7, "regnerant" should be --regenerant--.

Col. 23, line 27, "frquency" should be --frequency--.

Col. 25, line 33, "calculating a surplus" should read --(a) calculating a surplus--.

Signed and Sealed this

Twenty-seventh Day of *August 1985*

[SEAL]

Attest:

DONALD J. QUIGG

Attesting Officer *Acting Commissioner of Patents and Trademarks*