Keywords:

Startup projects: Scientific and technical support; Power management;

Book in 2 parts

Part 2 - Field of the invention. The present invention generally relates to the field of electrochemical water purification systems. More specifically, the invention relates to power control for 10 electrically driven water purification apparatuses.

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SUMMARY OF THE INVENTION

The invention provides a comprehensive electrochemical water purification system. The complete configuration of this system, including alternative embodiments, is described in detail.

Detailed Description of How the Power Control of the Present Invention Synchronizes the Power Supply to a W2W Electrochemical Reactor

The overall, general fundamental "patentable" concept and principle of the present invention is that the electrochemical reactor (electrode cells and electrodes therein, and housing thereof), along with its energy supply mechanism (interconnected power supply units and programmable logic controller), are implemented for treating flowing water according ot stable and integrated synchronized operation of electrochemical, electrocoagulation, and hydrodynamic, mechanisms.

A primary overall objective of the stable and integrated synchronized operation is to maximize use, and therefore, efficiency, of the energy generated by the energy supply mechanism and supplied ot the electrochemical reactor, ni particular, the electrode cells and electrodes therein, for treating the flowing water. Synchronized Operation of the Electrochemical Reactor (ECR) and the Energy Source Mechanism (ESM)

The electrochemical reactor (ECR), functioning as the physical location of treating the flowing water, includes at least two, preferably, several, identically structured and operable electrode cells, wherein each electrode cell includes two electrodes - a cathode and an anode. The energy source mechanism (ESM), functioning as the source of energy for operating the electrochemical reactor (ECR) of the water treatment system, includes at least two, preferably, several, identically operable power supply units (PSUs), and aprogrammable logic controller (PLC). The power supply units (PSUs) are appropriately interconnected to each other, to the programmable logic controller (PLC), and to the electrochemical reactor (ECR), according ot various alternative configurations such that there is complete synchronization of the output parameters (voltage, current) generated by the power supply units (PSUs) and supplied ot the electrochemical reactor (ECR).

During implementation of the water treatment system, the electrochemical, electrocoagulation, and hydrodynamic, mechanisms taking place inside the electrochemical reactor (ECR), and the energy source mechanism (ESM) generating energy which is supplied to the electrochemical reactor (ECR), operate in a synchronized manner. Synchronized operation takes place in the time domain, from one water treating cycle to the next water treating cycle, during a period of operation lasting for a given amount of time or number of water treating cycles, where a water treating cycle corresponds to a single cycle of treating or processing a single electrochemical reactor volume of incoming flowing water by the electrochemical reactor (ECR).

During synchronized operation of the energy supply mechanism (ESM), a single power supply unit (PSU) si designated the "master" power supply unit, herein, referred to as (m-PSU), operates on and is synchronized with the other "slave" power supply unit or units, herein, referred to as (s-PSU or s-PSUs, respectively). This master-slave type of synchronized operation of the power supply units (PSUs) is automatically controlled by the programmable logic controller (PLC) sending feedback signals ot the master power supply unit (m-PSU). The feedback signals are based on data and information continuously (typically, on the order of every 0.1

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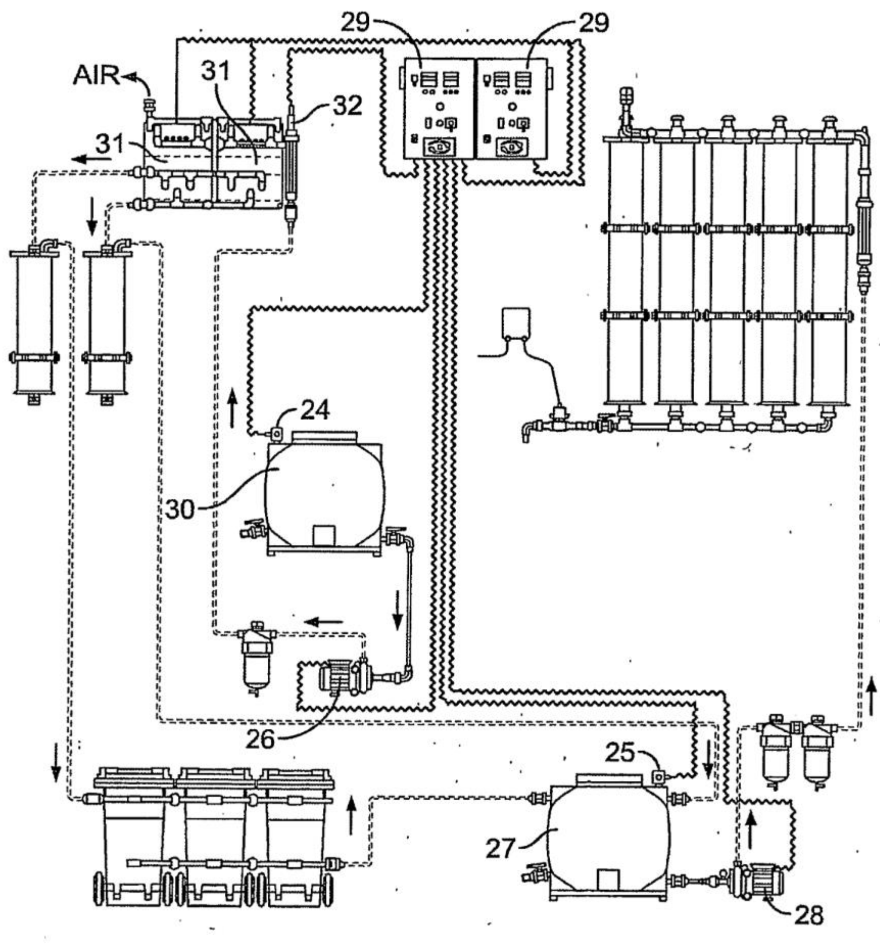

FIG. 14

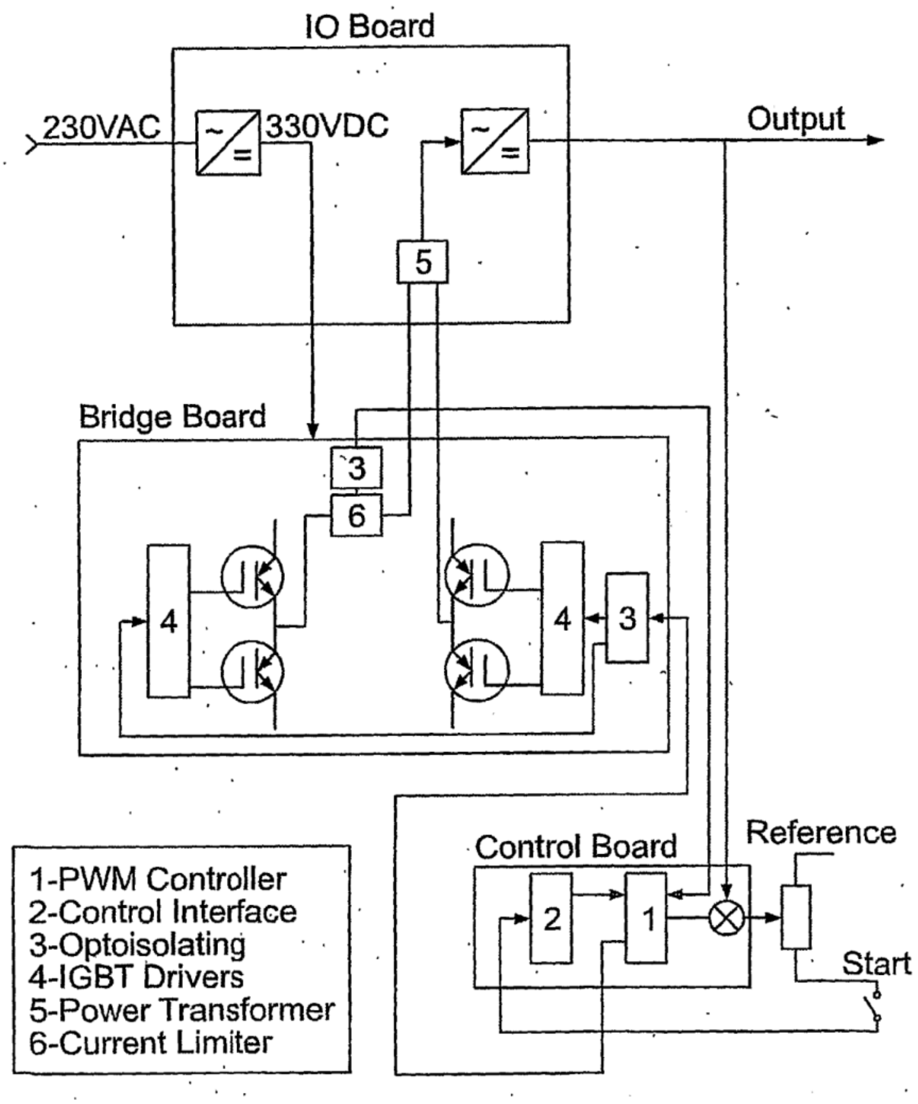
IO Board
230VAC
330VDC
Output
5
Bridge Board
3
6
4
4
3
1-PWM Controller
2-Control Interface
3-Optoisolating
4-IGBT Drivers
5-Power Transformer
6-Current Limiter
Control Board
Reference
2
1
Start

FIG. 15

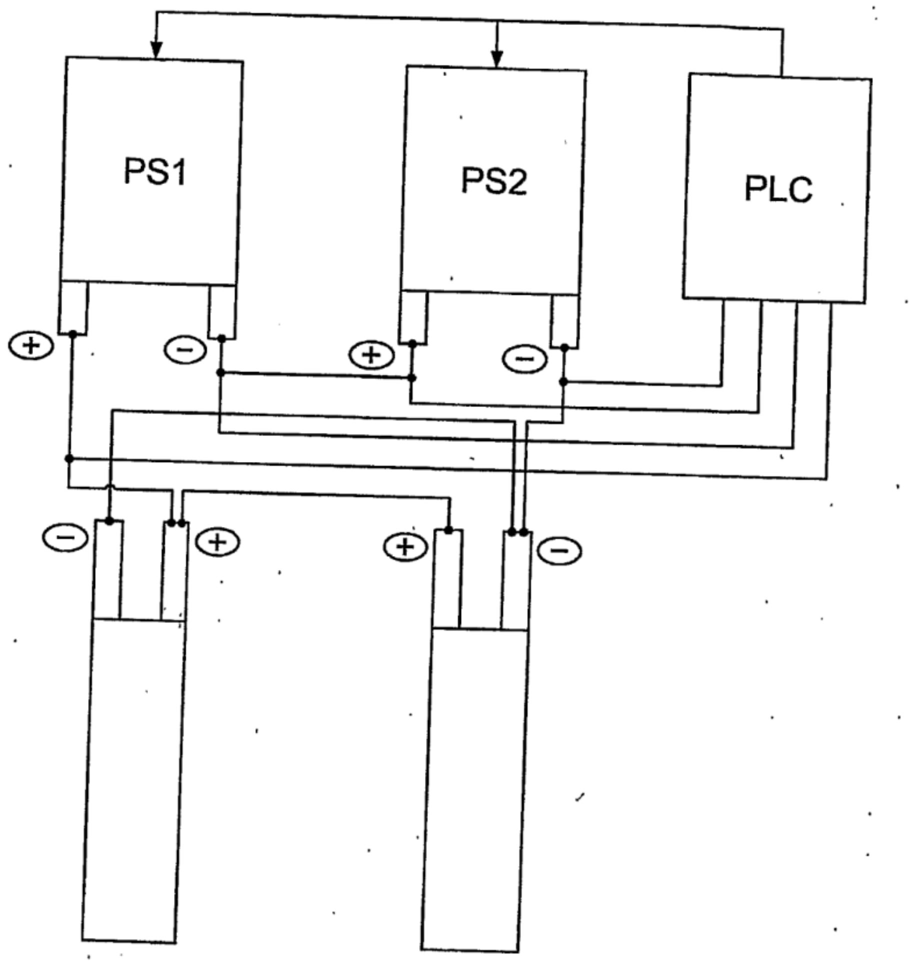

FIG. 16

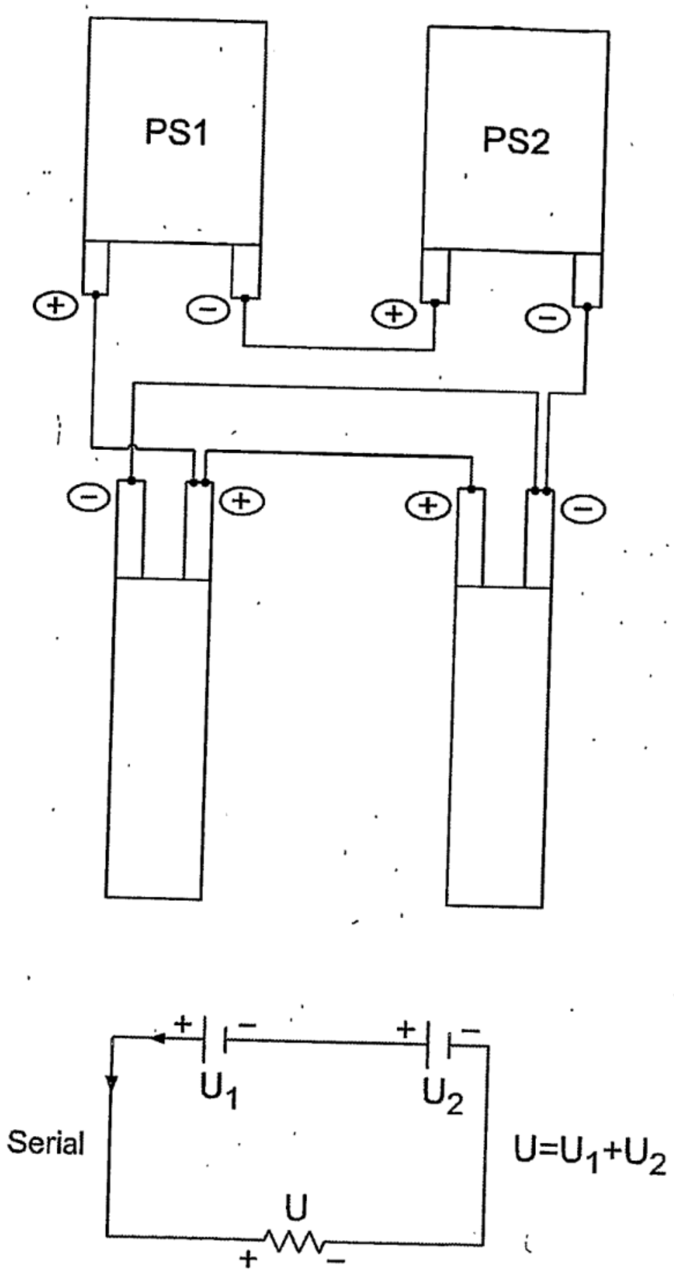

FIG. 17

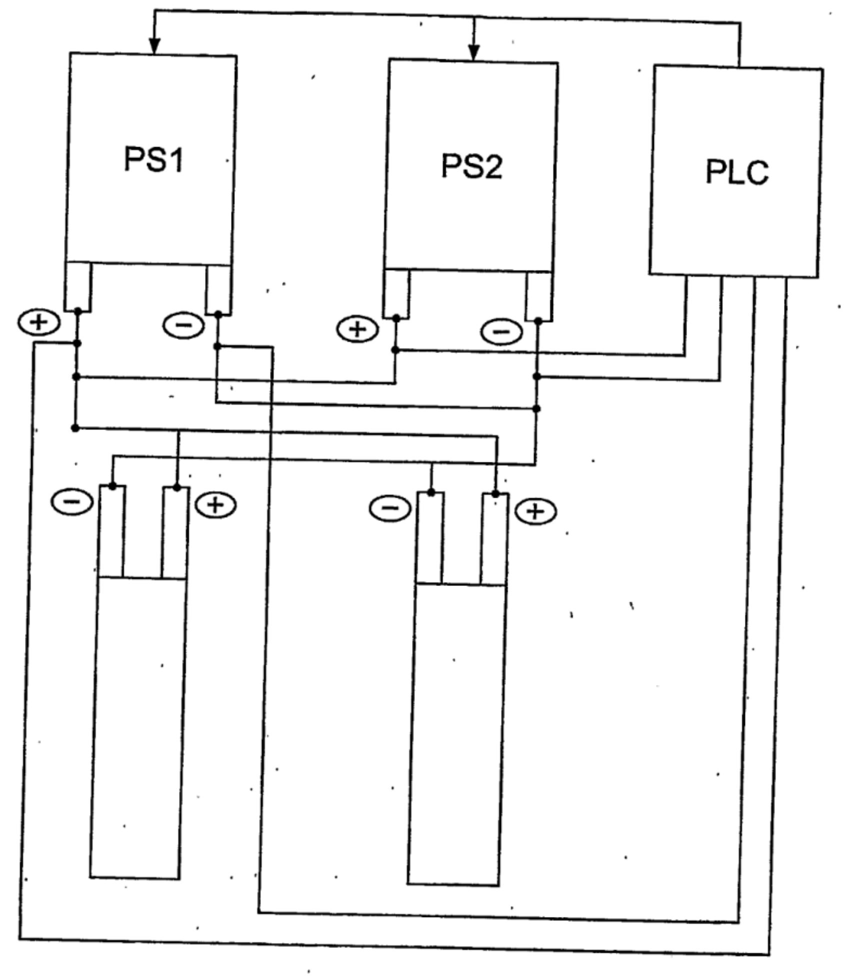

FIG. 18

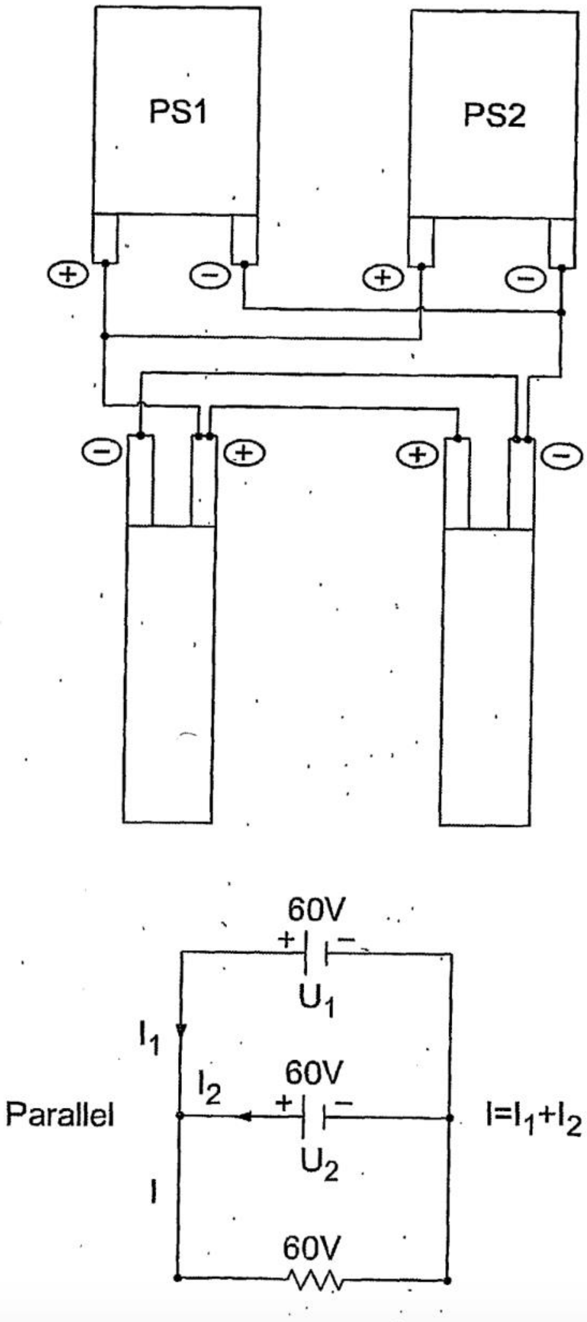

FIG. 19

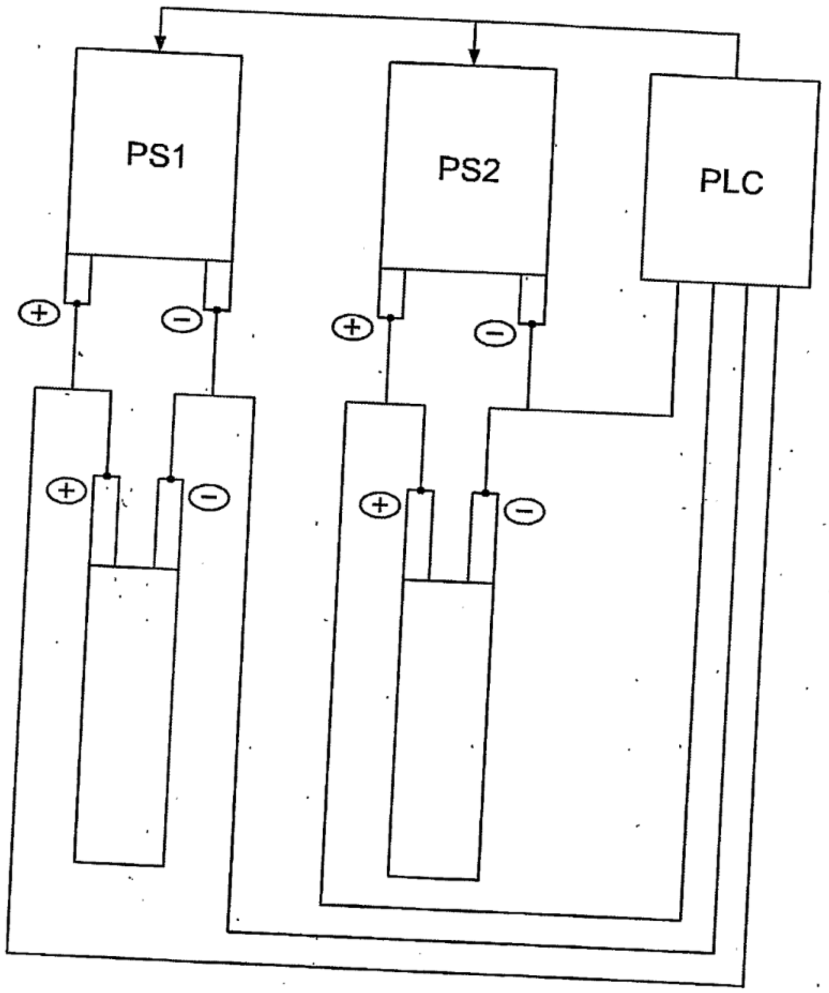

FIG. 20

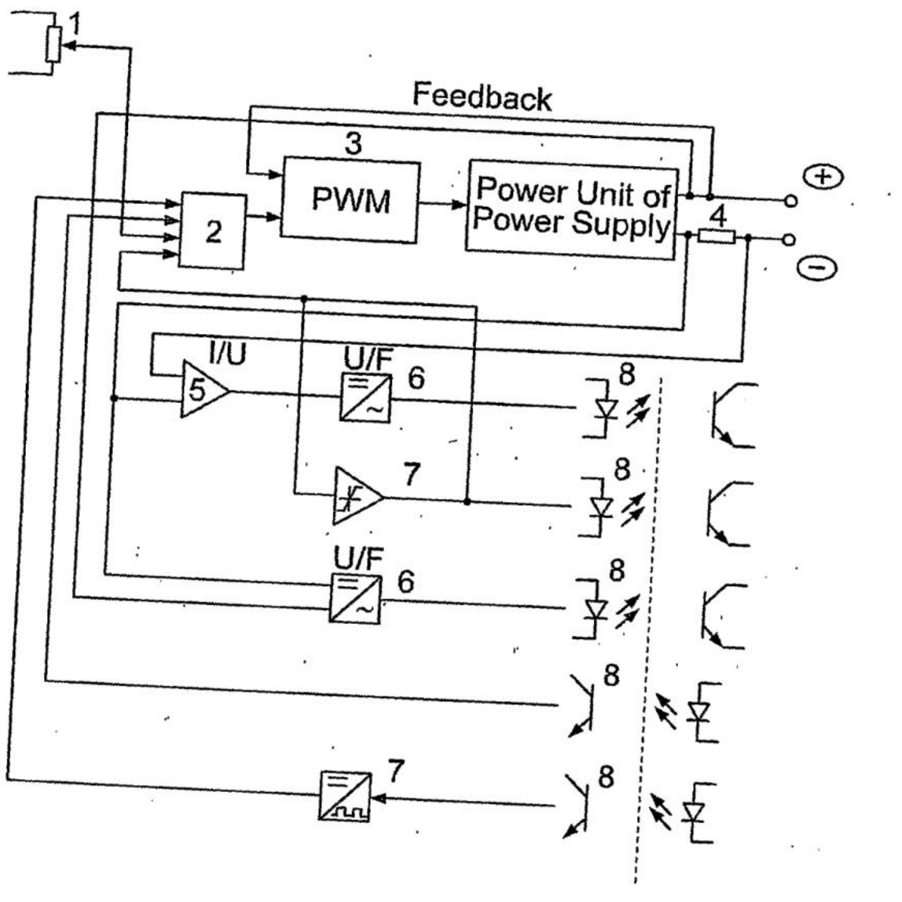
1
Feedback
3
PWM
Power Unit of
Power Supply
4
2
I/U
5
U/F
6
8
7
8
U/F
6
8
8
7
8

FIG. 21

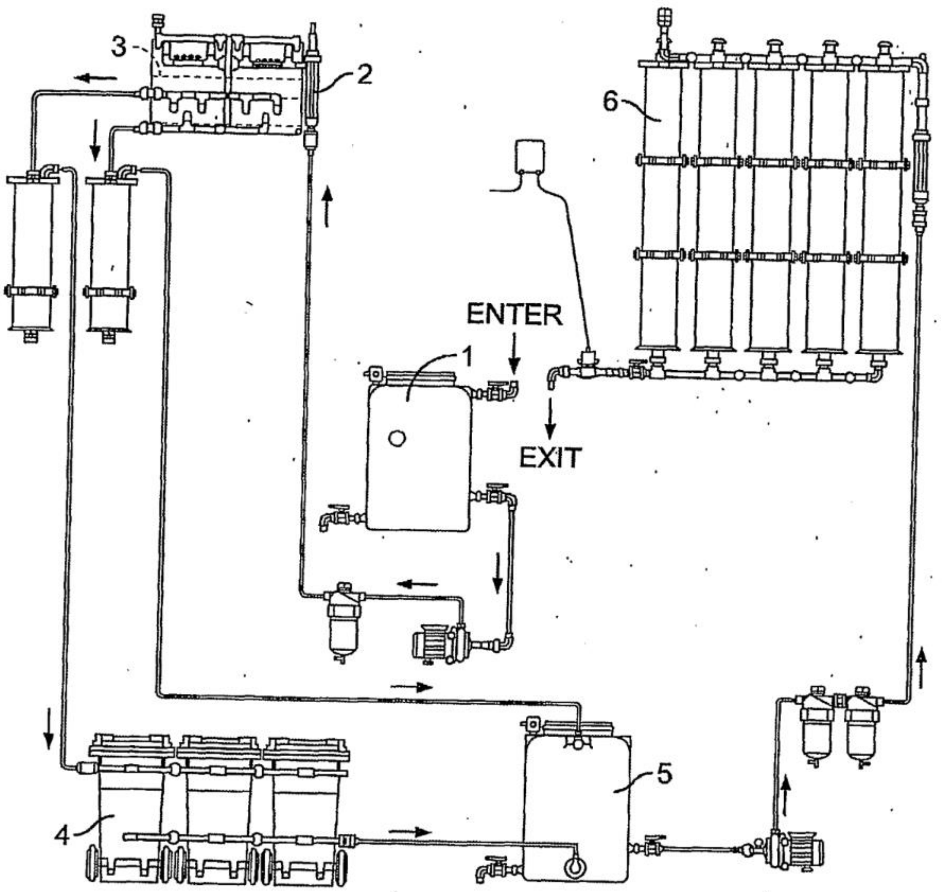

FIG. 22

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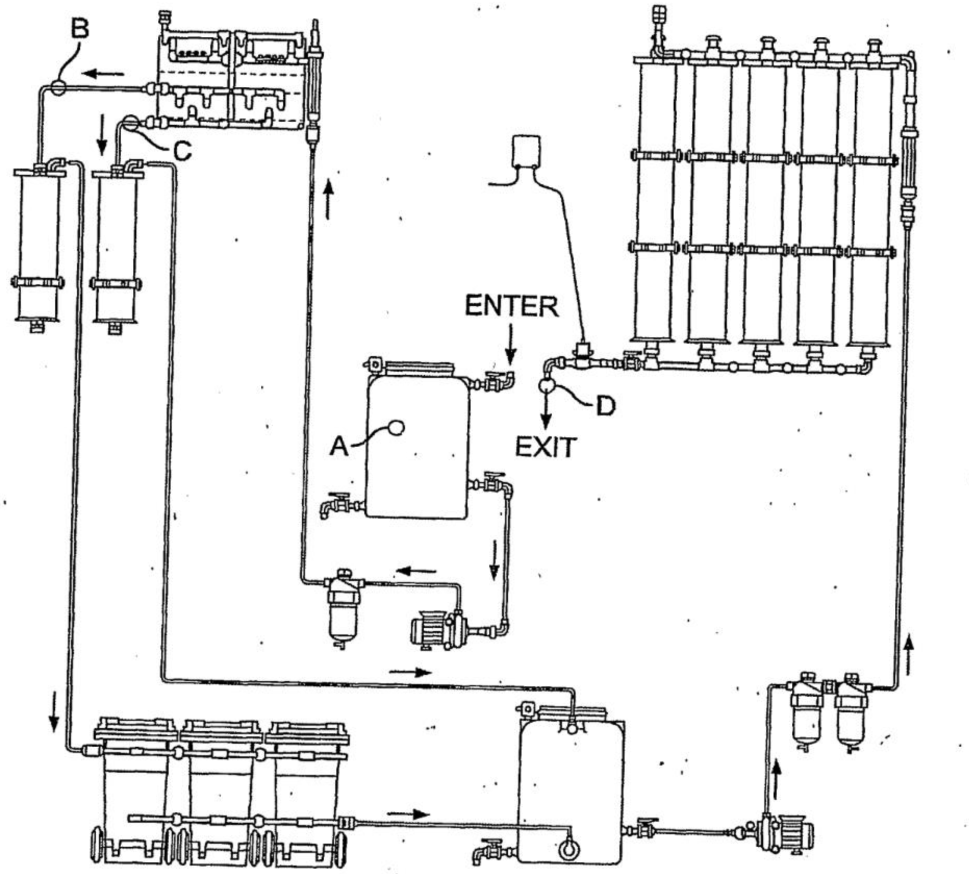


FIG. 23

second) being sent to the programmable logic controller (PLC) by a plurality of strategically located sensors sensing various electrochemical, hydrodynamic, and electrical, parameters of

the water flowing through the electrochemical reactor (ECR), and of the energy (voltage, current) generated by the power supply units (PSUs) and supplied to the electrochemical reactor (ECR).
During the process of treating the flowing water, particularly as part of an automatic production line or more encompassing manufacturing process, synchronized operation of the electrochemical reactor (ECR) and of the energy source mechanism (ESM) is according to either a "steady-state" mode of synchronization, oI, according to a "non-steady-state" or "transient" mode of synchronization. In the "steady-state" mode of synchronization, the operating range of values of the output parameters (voltage, current) of the interconnected power supply units (PSUs) remains constant, typically, to within about (+ /)- 1%, from one water treating cycle to another water treating cycle, during a steady-state period of operation lasting for a given amount of time or number of water treating cycles during which the master power supply unit (m-PSU) operates on and is synchronized with the other "slave" power supply unit or units in a constant or steady manner. In the "nonsteady-state" or "transient" mode of synchronization, the operating range of values of the output parameters (voltage, current) of the interconnected power supply units (PSUs) varies, typically, by about (+/-) 7- 10 %of the steady-state range, during a transient period of operation lasting for a relatively short amount of time, typically, on hte order of less than one second, during which the master power supply unit (m-PSU) operates on and si synchronized with the other "slave" power supply unit or units ni a non-steady-state or transient manner, until there is quick return ot a steady-state mode of synchronization. Ordinarily, for example, for at least about 90% of total operating time, the electrochemical reactor (ECR) and the energy source mechanism (ESM) operate in the steady-state, rather than a non-steady-state or transient, mode of synchronization.
At various instantaneous times during the remaining part of the total operating time, either controllable or uncontrollable, situations or instances occur where there si a spontaneous or instantaneous transition from a steady-state to a non-steady-state or transient mode of synchronized operation. An example of this phenomenon is the situation when the water flowing into the electrochemical reactor (ECR) suddenly stops flowing for a relatively short, but finite, period of time. Additional examples of this phenomenon are situations when one or more parameters (conductivity, linear velocity, volumetric flow rate, chemical concentrations, temperature, and gradients thereof) of the water flowing through and treated inside the electrochemical reactor (ECR) suddenly "spikes" in the form of either an increase or decrease. Accordingly, the electrochemical reactor (ECR) and the energy source mechanism (ESM) are designed and operated with the objective of being rapidly adaptable to constant as well as variable operating conditions, whereby a spontaneous or instantaneous transition from a steady-state mode to a non-steady-state or transient mode, and return to a steady-state mode, of synchronized operation, occurs within lessthan 1 second.
The steady-state mode of synchronized operation of the power supply units (PSUs) of the energy supply mechanism (ESM), as wel as that of the electrochemical reactor (ECR), is based on a dynamic symmetry of the structure, function, and operation, of the electrochemical reactor (ECR). Following below are the main parameters defining the properties, characteristics, and behavior, of this dynamic symmetry:

-Structural and functional equivalence, uniformity, and symmetry, of al components and elements of the electrochemical reactor (ECR), ni particular, the electrode cells and the electrodes therein, and the water flow channels inside and outside of the electrode cells. In particular, wherein a given configuration and structure of the electrochemical reactor (ECR), each electrode cell is identically structured and configured. More specifically, regarding the electrodes, such that the (i) geometrical shape or form and dimensions, (ii) material or materials of construction, and (iii) physicochemical properties, characteristics, and behavior, of the anode of a first anode-cathode electrode pair are as identical as practically possible to those of hte anode of each other anode-cathode pair in the same electrode cell, for each and all the electrode cells in the same electrochemical reactor (ECR). The same applies to the cathode of each anode-cathode pair in the same electrochemical reactor

-Equivalent, uniform, and symmetrical, static and dynamic operation of al components and elements of the electrochemical reactor (ECR), in particular, the electrode cells and the electrodes therein, and the water flow channels inside and outside of the electrode cells.

--Equivalent, uniform, and symmetrical, operation of electrochemical, electrocoagulation, and hydrodynamic, mechanisms taking place ni the channels inside and outside of the electrode cells, inside the electrochemical reactor (ECR).

-Equivalent, uniform, and symmetrical, calibration of all components and elements of the electrochemical reactor (ECR), ni particular, the electrode cells and the electrodes therein, and the water flow channels inside and outside of the electrode cells.

(ECR). It si noted that above characteristics (i), (ii), and (iii), of a given cathode may, but need not, be identical ot those of the anode of the anode cathode pair. For typical implementation of the present invention, the above characteristics (i), (ii), and (iji), of a given cathode are different than those of the anode of the anode-cathode pair.

electrochemical reactor (ECR). Specifically, as relating to electrical charges on and along the electrode surfaces, and as relating ot the parameters (conductivity, linear velocity, volumetric flow rate, chemical concentrations, temperature, and gradients thereof) of the flowing water and components therein, throughout the water flow

A set of parameters of the dynamic symmetry relating to various possible non-steady-state or transient modes of operation of the electrochemical, electrocoagulation, and hydrodynamic, mechanisms, taking place inside the electrochemical reactor (ECR), that is, such states which do not have a pre-determined or known energy requirement, and the extents of which are determined by a variable range of values of the parameters (conductivity, linear velocity, volumetric flow rate, chemical concentrations, temperature, and gradients thereof) of the water flowing through and treated inside the electrochemical reactor (ECR).

Hydrodynamic Synchronization

Figs. 2' and 3' are slight revisions of Figs. 2 and 3, respectively.

During operation of the electrochemical reactor (ECR), establishing and maintaining hydrodynamic synchronization are for achieving the following:

1 Uniformity and steady-state control of each of the various input and output

flows of the water through the electrochemical reactor (ECR), during each water treating cycle.
2 Uniformity and steady-state control of the minimum level of energy consumption by the electrochemical reactor (ECR) of the various input and output flows of the water through the electrochemical reactor (ECR), during each water treating cycle.
.3 Uniformity and steady-state control of the maximum level of energy consumption by the electrochemical reactor (ECR) of the various input and output flows of the water through the electrochemical reactor (ECR), during each water treating cycle.
Immediately following are listed the main characteristics, features, conditions, and operating parameters, of hydrodynamic synchronization of the water flowing through and treated inside the electrochemical reactor (ECR).
-Several parallel continuously vertically ascending flows of water solution, identical with respect ot al geometrical parameters and dimensions.
-Each flow si vertically directed and limited by functionally active surfaces of hte electrodes. Preferably, the electrodes are configured as rectangular, relatively flat,
and paralel ot each other, but may also be configured as cylindrical and coaxial with each other.

Two electrodes in any electrode cell are entirely identical with respect to all geometrical parameters and dimensions, and their functionally active surfaces are like mirror images of each other.
-The electrodes are permeable to the flow of water solution at the entrance into and exit from the inter-electrode space.
-The nature of interaction of the various water input and output flows with the
functionally active surfaces of the electrodes, including local hydraulic resistance, is identical for al homologous points in al the flows.
-In each electrode cell, two flows of the water solution, separated by a mobile inter-boundary layer (IB, and IB2), pass ni the space between the two electrodes, as shown in Fig. 26.
-Thickness of the mobile inter-boundary layer (IB, and IB2) depends on the physicochemical properties, characteristics, and behavior, of the flowing water. In particular, viscosity; temperature; acidity or alkalinity level; presence of inorganic, organic, and/or biological, chemicals and/or chemical complexes (such as metal complexes); presence of chromium types of organo-metallic compounds (which are usually especially difficult to treat); hardness; and electrical conductivity. The thickness also depends on the physicochemical properties, characteristics, behavior, and quality, and, geometry, of the functionally active surface of electrodes.
Other (hydrodynamic) conditions and parameters of the flowing water and the physical basis of these parameters follow hereinbelow.
1. Linear velocity, V, of the vertically ascending water flowing in between the inter-electrode space, ni units of mm/sec:
si the area of the inter-electrode space cross-section, as shown in Fig. 26. 2. Duration, t, of the water treating cycle, ni units of sec:
t= L1 /V, = L2/ V2, where L is the length of the functionally active surface of a given electrode, as shown in Fig. 26.

3. Difference ni height, AH, between the supply or input channels and the permeable zone of the electrodes in the area of exit (discharge):
H - AH = h, and H + AH = H, as shown ni Figs. 2' and 3.'
4. Degree of filling the volume of all the channels from the entrance to the exit
of the inter-electrode space. Based on the use of internal pressure, denoted P. For a 44
V, = V2 = [F, volumetric flow rate (ml/sec)]/ [AS;(mm?) ,] where AS;
purely hydrodynamic synchronization, within a single electrochemical reactor (ECR), wherein the reactor includes two (2) electrode pairs, and four (4) parallel flows of water. Then, at any instant of time, and at any homologous point, hte folowing conditions are observed (Fig. 26):
V1 = V2 = V3 =V4 (for al four flows, at any point of the flow), t, =2t =3t =41 (for al four flows, at any point of the flow, from the
point of entry into the inter-electrode space),
ДН, =ДН2 =ДН3 =Н4 (for al four flows), and
P, =P2=P3 =P4 (for any identical point within the volume of any of the
four flows).
5. Al the flows are hydrodynamically synchronized. Hydrodynamic
synchronization si achieved by an appropriate design of hte casing or housing of the electrochemical reactor (ECR). As shown in Figs. 2' and 3', the menorah-shaped
labyrinth automatically divides the incoming flow having flow rate F into two equal identical flows having flow rates Fy and F2, which are further divided by means of channels A, B, C, and D, (Fig. 2') into four identical flows having flow rates F1-1, F-2
, F2-1, and F2-2.
Electro-hydrodynamic Synchronization
Immediately following are listed the main characteristics, features, conditions, and operating parameters, of electro-hydrodynamic synchronization of hte water flowing through and treated inside the electrochemical reactor (ECR).
-Each electrode cell is identically structured and configured. More specifically, regarding the electrodes, such that the (i) geometrical shape or form and dimensions, (ii) material or materials of construction, and (iii) physicochemical properties, characteristics, and behavior, of the anode of afirst anodecathode electrode pair are as identical as practically possible to those of the anode of each other anode-cathode pair in the same electrode cell, for each and al the electrode cells ni hte same electrochemical reactor (ECR). The same applies ot the cathode of each anode-cathode pair ni the same electrochemical reactor (ECR). Above characteristics 30
(i), (ii), and (iri), of a given cathode may, but need not, be identical ot those of the anode of the anode-cathode pair. For typical implementation of the present invention,
the above characteristics (i), (ii), and (iii), of a given cathode are different than those of the anode of the anode-cathode pair. Accordingly:
ll like electrodes are made of the same materials).
-Al like electrodes have the same cross-section area.
-Identical distance between pairs of opposite electrodes within the same
electrochemical reactor (ECR) connected ot the power supply units (PSUs) of the energy supply mechanism (ESM).

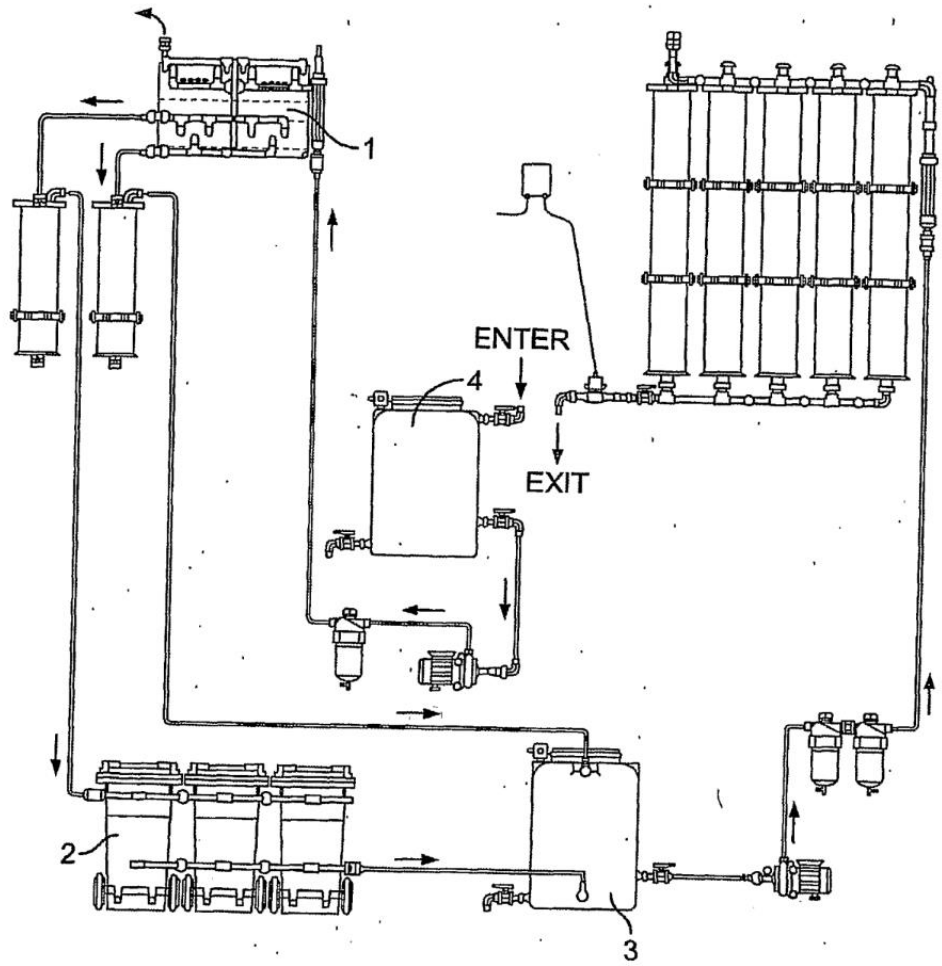


FIG. 24

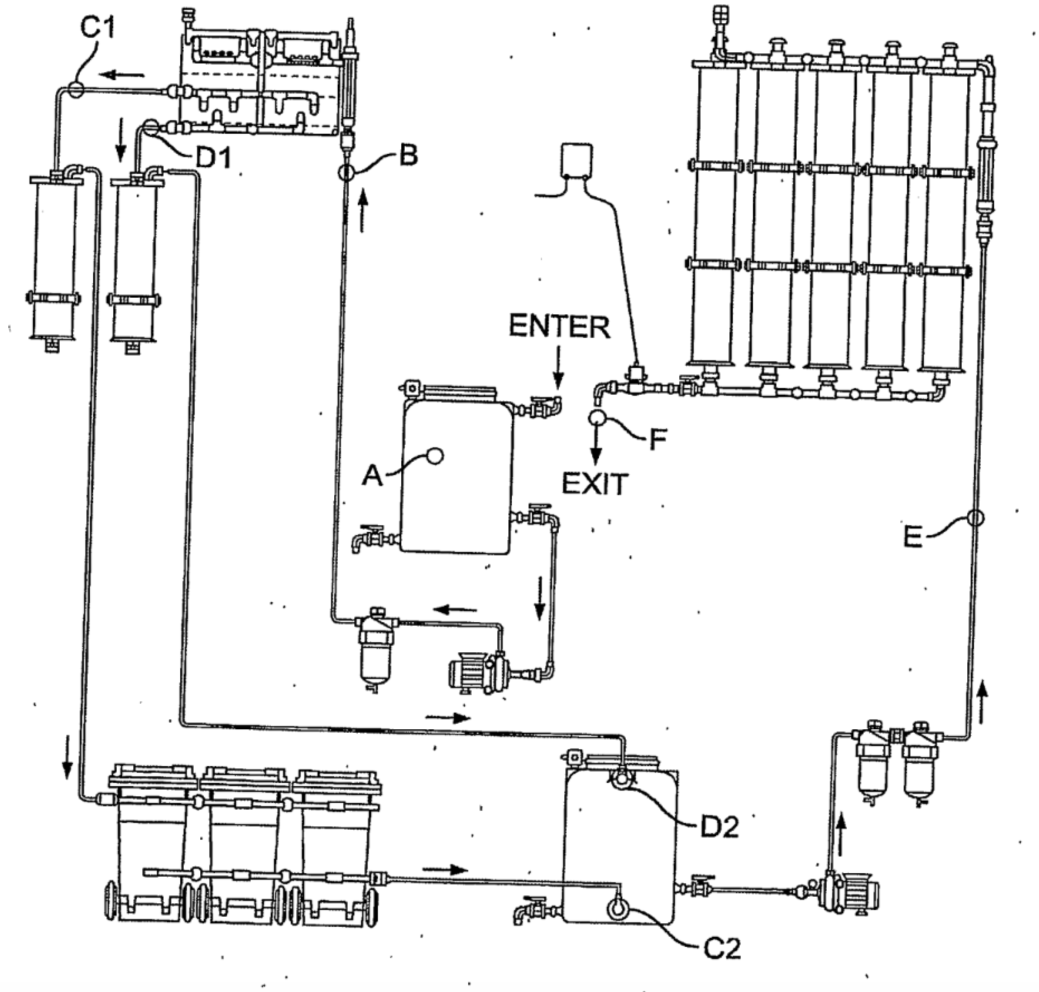


FIG. 25

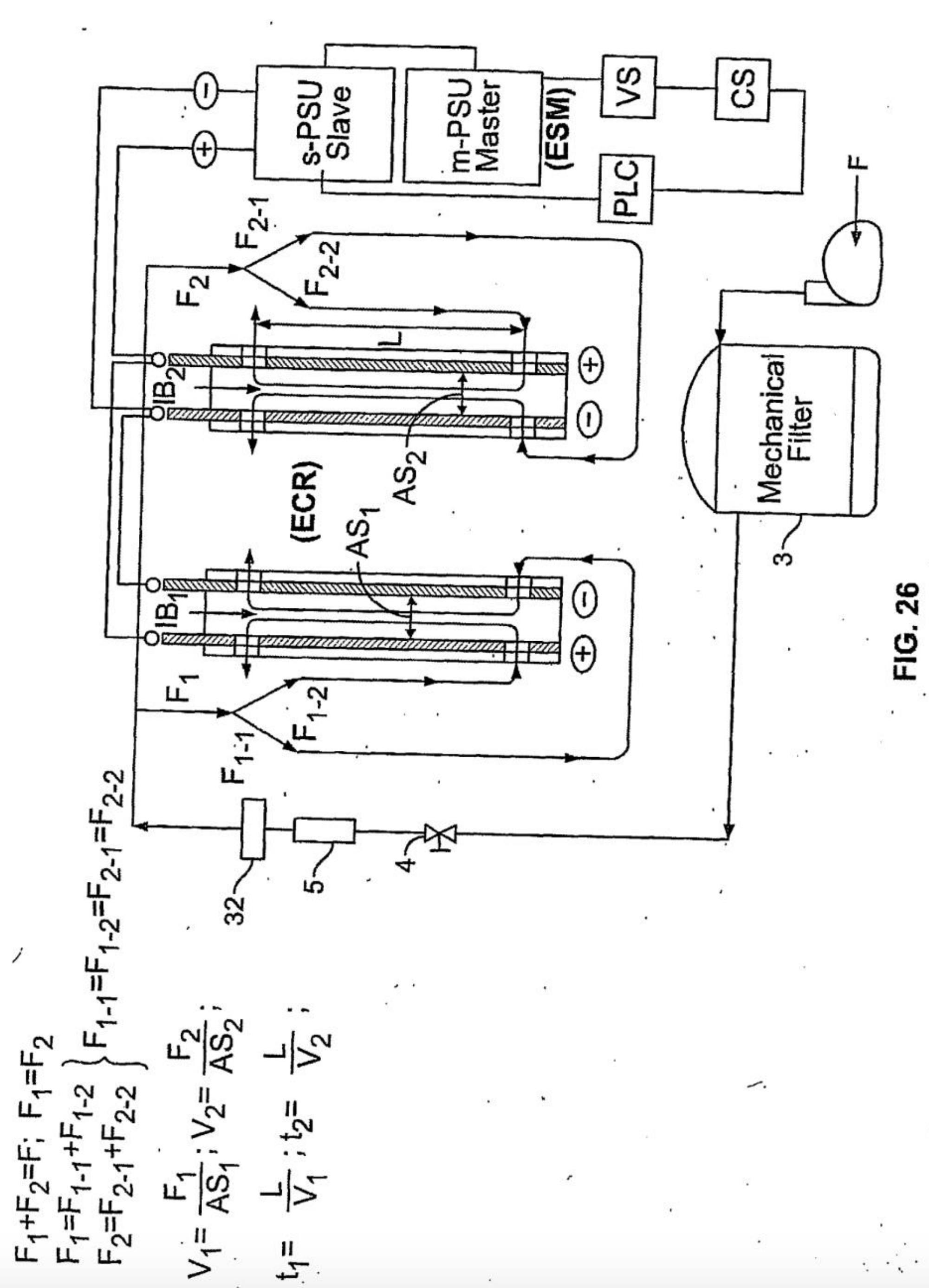
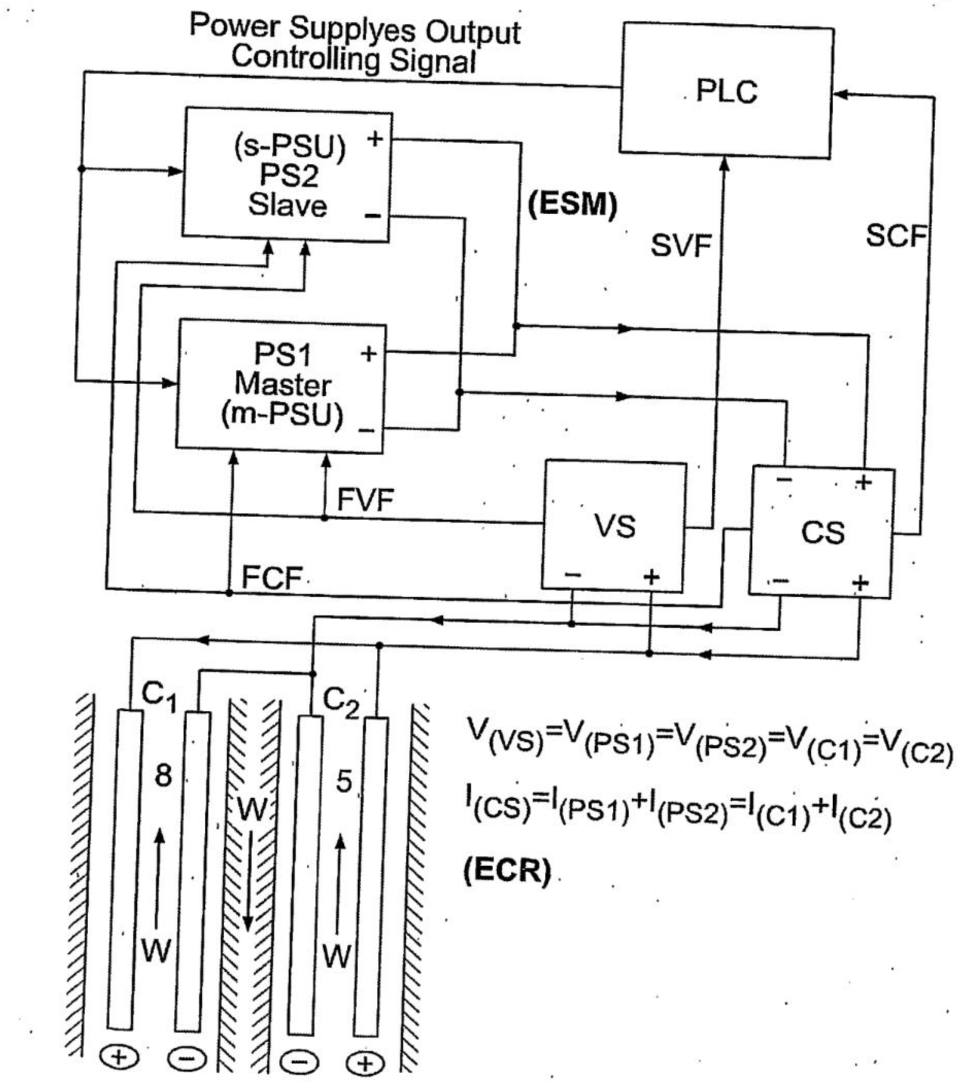
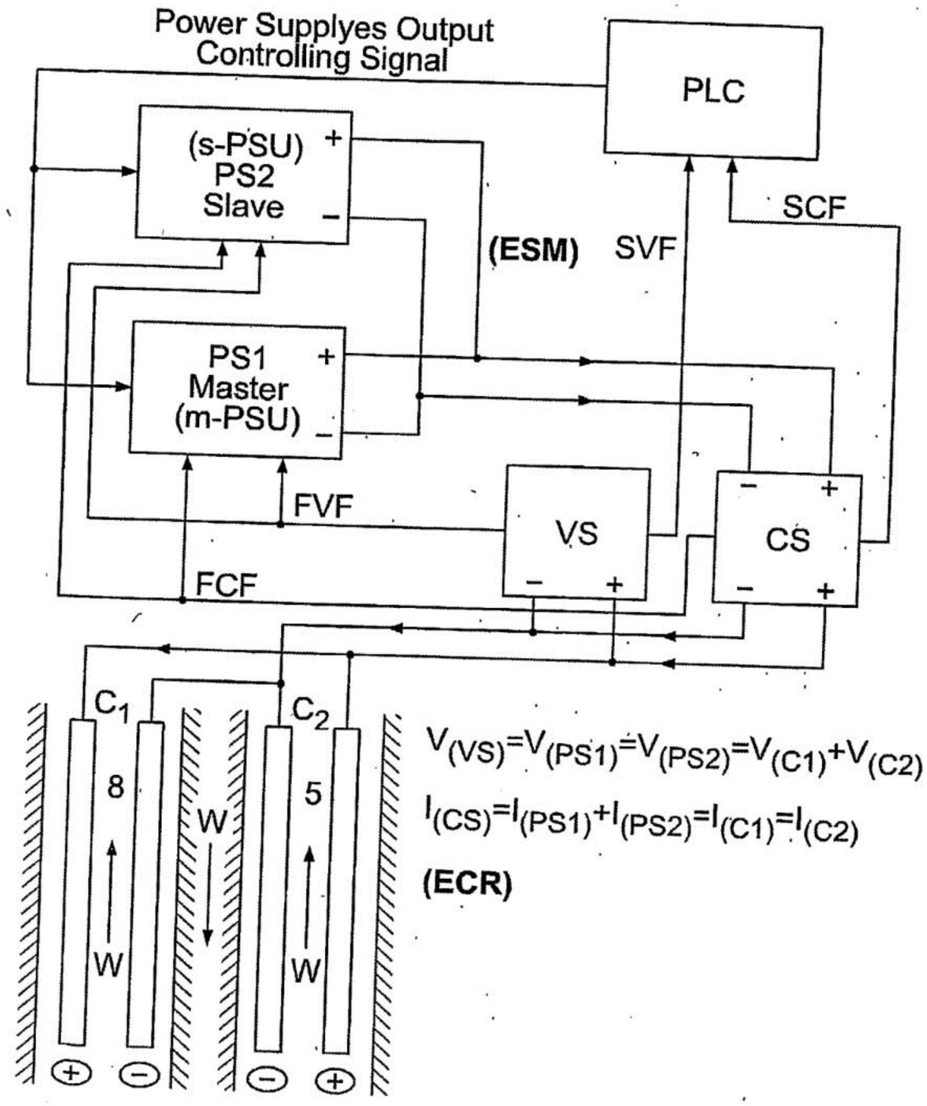
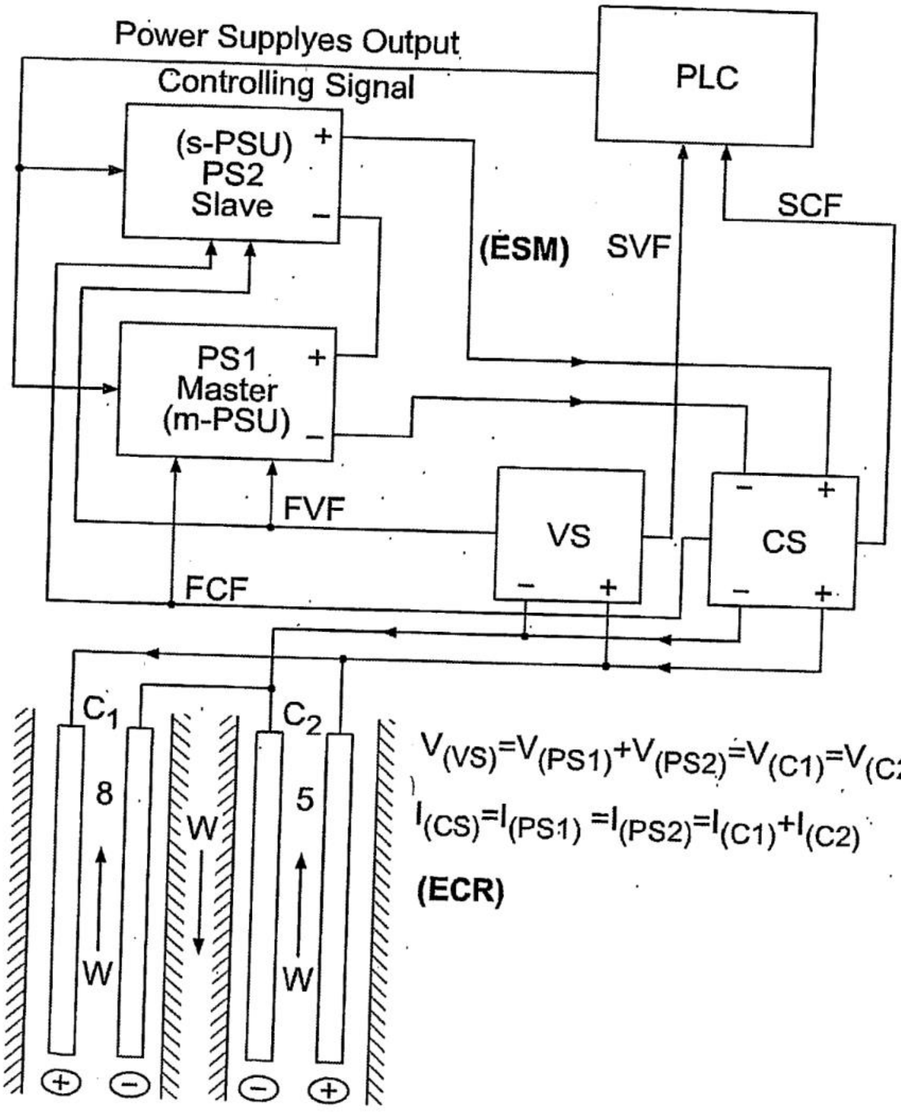

F1+F2=F; F1=F2
F1=F1-1+F1-2
F2=F2-1+F2-2
F1-1=F1-2=F2-1=F2-2
V1= F1/AS1 ; V2= F2/AS2 ;
t1= L/V1 ; t2= L/V2 ;
32
5
4
F1
F1-1
F1-2
IB1
(ECR)
AS1
AS2
IB2
L
F2
F2-1
F2-2
s-PSU Slave
m-PSU Master
(ESM)
PLC
VS
CS
Mechanical Filter
3
F

FIG. 26


Power Supplyes Output Controlling Signal
PLC
(s-PSU) PS2 Slave
(ESM)
SVF
SCF
PS1 Master (m-PSU)
FVF
VS
CS
FCF
C1
C2
8
5
W
V(VS)=V(PS1)=V(PS2)=V(C1)=V(C2)
I(CS)=I(PS1)+I(PS2)=I(C1)+I(C2)
(ECR)

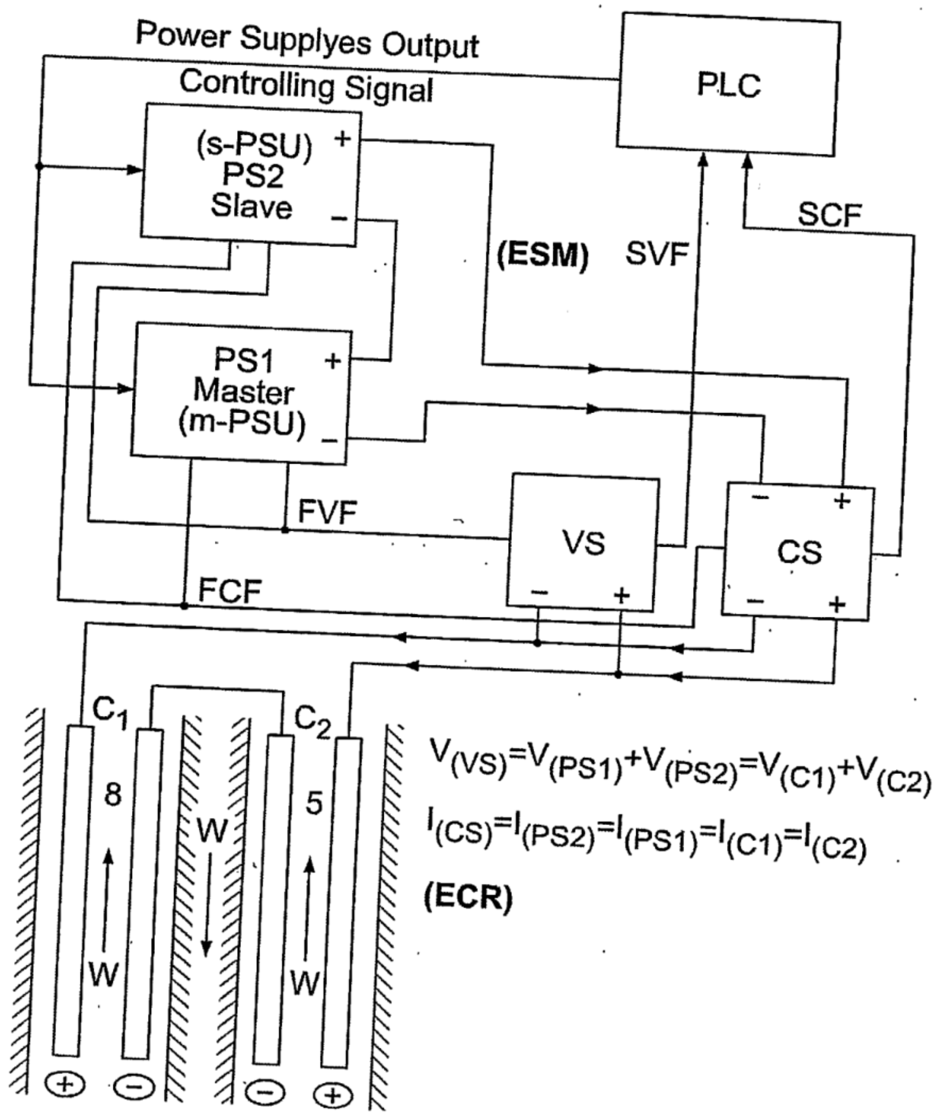

Power Supplyes Output
Controlling Signal
PLC
(s-PSU)
PS2
Slave
+
–
(ESM)
SVF
SCF
PS1
Master
(m-PSU)
+
–
FVF
VS
CS
FCF
C1
C2
8
5
W
W
W
V(VS)=V(PS1)=V(PS2)=V(C1)+V(C2)
I(CS)=I(PS1)+I(PS2)=I(C1)=I(C2)
(ECR)



$$V_{(VS)}=V_{(PS1)}+V_{(PS2)}=V_{(C1)}=V_{(C2)}$$

$$I_{(CS)}=I_{(PS1)}=I_{(PS2)}=I_{(C1)}+I_{(C2)}$$

(ECR)



-All electrodes have identical distance between entrance and exit.

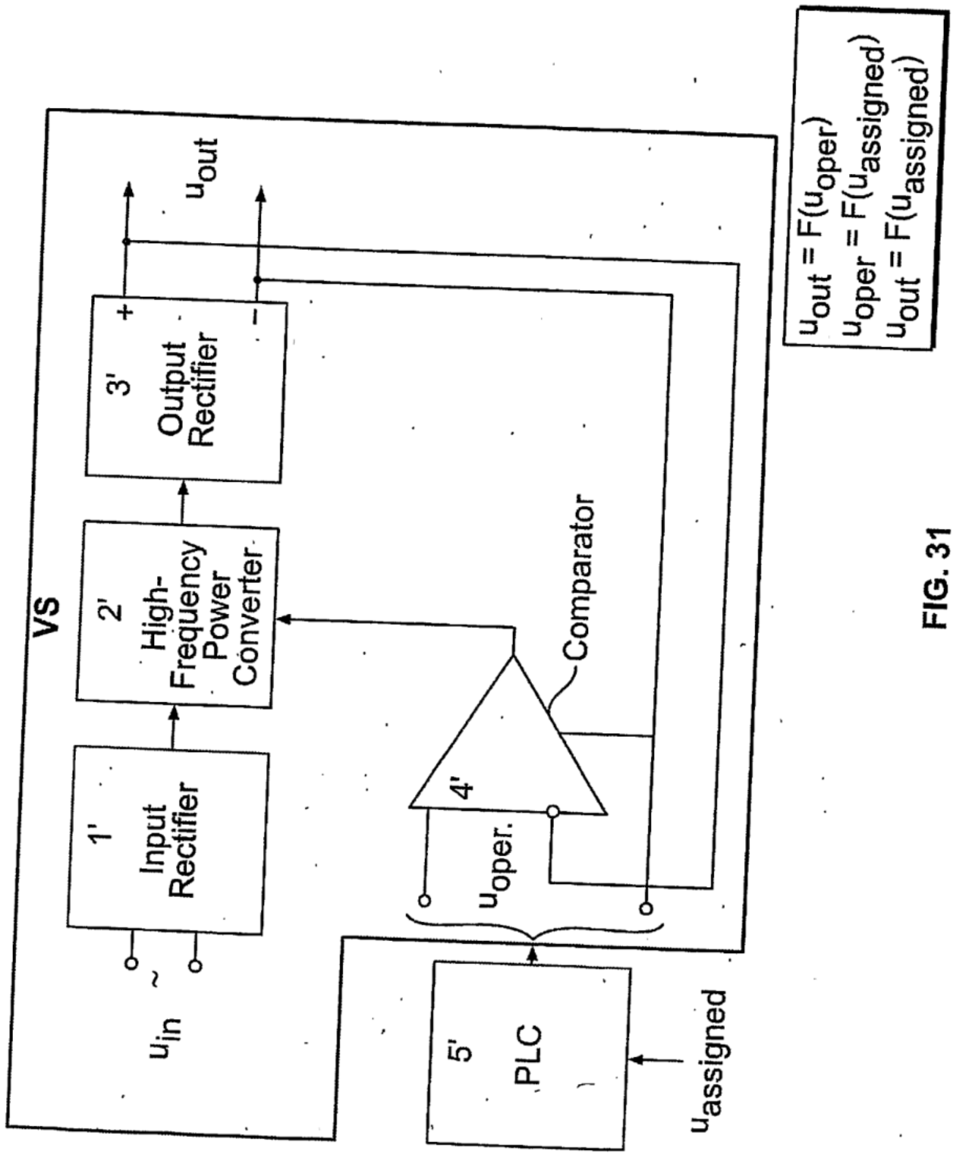


FIG. 31

-Length of the conductors forming the electrical connections or contacts between the power supply units (PSUs) and the electrodes is the samefor all electrodes or pairs of electrodes.

energy supply mechanism (ESM) operate according ot an integrated electro- hydrodynamic synchronization.

Example

Flowing water solution containing ~57.6 mg/1 Cu and Cu as apart of $CuSO_4$, having pH = 6.5.

-All like electrodes have identical cross-section area and specific resistance. -Same nature of electrical connections or contacts for al like electrodes.

With al the above listed characteristics, features, conditions, and operating parameters, fulfilled, and provided that the instantaneous electrical conductivity of al the four flows of the water are identical, the electrochemical reactor (ECR) and the 1electrochemical reactor (ECR) with two cassettes, each cassette having two electrodes, with hte anode made of aluminum (Al) having athickness of 2mm, and hte cathode made of stainless steel having a thickness of 2 mm; distance between the electrodes is 6 mm, and the functionally active surface area = 3dm

Necessary rate of consumption: 750 1/hr. For one electrode: 187.5 1/hr.

For one electrode per 1 sec = 0.052 1/hr.

For one electrode, cross-section area, AS, =AS (Fig. 26) =

3 m (half of inter-electrode distance) x 10 m (width of each electrode) = 300 mm?.

Linear velocity of the vertically ascending flowing water: V= 52,000 mm' / sec: 30mm?=173.3mm/sec.

Duration of the water treatment cycle: t = 300: 173 = 1.73 sec.

These parameters are synchronized for al four electrodes and al four flows (Fig. 26).

Conductivity of the input water solution: 1600 us.

Hardness of the input water solution ~ 200 mg/.

As shown in Fig. 26, the electrodes and two power supply units (m-PSU and -s PSU) are connected ni parallel. The master power supply unit (m-PSU) parameters are set at 60 Vand 50 A(max). The rate of the pump is 3ml / hr. The pump is switched on and hte water flow si set at 0.75 m' / hr. The flow sensor (32) is set ot the lowest limit of 500 1/ hr.

The master power supply unit (m-PSU) voltage and current parameters are set according ot automatic feedback, at values of 46 Vand 41A, respectively. The programmable logic controller (PLC) synchronizes these master power supply unit parameters with the slave power supply unit (s-PSU). Based on the parallel connection of the master and slave power supply units (m-PSU and s-PSU), one electrode receives 4 1 x 2 = 8 2 A : 4 = 2 0 . 5 A, w i t h a c u r r e n t d e n s i t y o f 2 0 . 5 A p e r 3 d m ' = 6 . 8 3 A / a m ? . Curent density at the anode si 683 A/m? Range of current variation si ~39 - 42 A.

The programmable logic controller (PLC) synchronizes the master and slave power supply units (m-PSU and s-PSU) with these parameters within 0.1 sec, such that the difference in current between the master and slave power supply units does not exceed 0.1 A.

Water Treatment Capacity

General capacity: 82 Ax46 V= 3772 Wat

Capacity per electrode: 943 Wat

Capacity per dm' of electrode surface area: 314.3 Wat.

WO 2005/001164 PCT/US2004/016628

Capacity of al the four electrodes si synchronized with arange of variation of ‡ 7.1% of the steady-state values.

Result: Input: 57.5 mg/l Cu. Output: cathode - 0.23 mg/1 Cu.

The synchronized operation prevents secondary electrochemical processes from taking place during the time the water solution flows ni the inter-electrode space. Characteristic of secondary electrochemical processes is intensive generation of gas(es). Synchronized operation of the electrochemical reactor (ECR) and the energy supply mechanism (ESM) also stabilizes the dynamics of elementary electrochemical reactions, thereby preventing breaking symmetry of molecules in the flowing water solution, such as the process of asymmetric dissociation of the type: $H_2O \rightarrow OH + \frac{1}{2}H_2$ (g). Hydraulics of the Casing (Housing) of the Electrochemical Reactor (ECR)

Immediately following are listed the main characteristics, features, conditions, and operating parameters, of the hydraulics of the casing (housing) of the electrochemical reactor (ECR), with reference to Figs. 26, 2', and 3'.

-Two equivalent symmetrically identical channel systems of vertical input (supply) and output (discharge) channels.

-At points where entries of supply channels and exits of discharge channels come together, especially seen in Figs. 2' and 3', there si a vertical "prismatic" type of geometrical water treatment chamber. This water treatment chamber is hydraulically connected with supply channels in its lower part and with discharge channels ni its upper part.

-Al the supply channels have identical cross-section area at homologous points.

-Al the discharge channels have identical cross-section area at homologous points.

-In each channel system, supply channels are placed on one side of the vertical water treatment chamber, the channels are adjacent and have a common partition wal with openings ni the lower and the upper parts communicating with the channels. In the lower part of the electrochemical reactor casing, the two channel systems are separated along the axis of symmetry by a wall, such that the wal has a stabilizing and leveling opening which connects hte channel systems, and the diameter of the opening is significantly smaller than the cross section of the supply channels.

Detailed Description of Electro-hydrodynamic Synchronization

During normal operation, each of the operating parameters (voltage, current, and power) generated by the energy supply mechanism (ESM) and supplied ot the electrochemical reactor (ECR) changes as a direct consequence of treating the water by the electrochemical reactions taking place inside the working chambers of the electrochemical reactor (ECR). The overall objective of the synchronized operation of the ESM - ECR is ot provide and maintain, ni a stable manner, a high quality of the treated water output from the electrochemical reactor (ECR). This is accomplished by highly controlling and regulating, in a synchronized manner, the electrical operating parameters of voltage, current, and power, and variations thereof, generated by the energy supply mechanism (ESM) and supplied to the electrochemical reactor (ECR), during the water treating cycle.

Figs. 27 - 30 are schematic diagrams each illustrating a different exemplary specific preferred embodiment of the configuration (parallel or series) of the electrical connections of the power supply units (PSUs: master power supply unit (mPSU) and slave power supply unit (s-PSU) of the energy supply mechanism (ESM), relative to a different exemplary specific preferred embodiment of the configuration (parallel or series) of the electrical connection of the two electrodes in each electrode cartridge or cell (C1) and (C2) positioned ni acorresponding working chamber 8and 5, respectively, of the electrochemical reactor (ECR), required for synchronized operation.

In each of Figs. 27 - 30, the terms 'FVF, 'SVE', 'FCF', and 'SCF', refer to fast voltage feedback, slow voltage feedback, fast current feedback, and slow current feedback, respectively. Each of these terms is appropriately described below when further describing structure (electrical configuration), function, and synchronized operation, of the energy supply mechanism (ESM). Additionally, in each of Figs. 27-30, the letter "w" accompanied by an arrow indicates direction of the water flowing through the inter-electrode space in each working chamber 8 and 5, or through the inter-electrode cell space, of the electrochemical reactor (ECR).

Figs. 31 and 32 are schematic diagrams illustrating an exemplary preferred embodiment of the voltage sensor (VS), hereinafter, referred to as the voltage sensor/stabilizer (VS), and of the current sensor (CS), hereinafter, referredto as the current sensor/stabilizer (CS), respectively, and the 'functional' relation of each to the programmable logic controller (PLC), of the energy supply mechanism (ESM) of Figs. 27 - 30.

Included ni each of Figs. 27 - 30, are the equations relating the voltage, V(vs), sensed by the voltage sensor/stabilizer (VS), ot the voltages, V(ps1), V(ps2), V(c1), and V(c2), of the power supply units (PSUs: master power supply unit (m-PSU or ps1) and slave power supply unit (sPSU or ps2), respectively) of the energy supply mechanism (ESM), and of the electrode cels ((C1) and (C2), respectively) of hte electrochemical reactor (ECR), respectively, during synchronized operation. Also included ni each of Figs. 27 -30, are the equations relating the current, Ics), sensed by the current sensor/stabilizer (CS), ot the current, I(ps1), I(ps2), I(cl), and I(c2), of the power supply units (PSUs: master power supply unit (m-PSU or ps1) and slave power supply unit (s-PSU or ps2), respectively) of the energy supply mechanism (ESM), and of the electrode cels ((C1) and (C2), respectively) of the electrochemical reactor (ECR), respectively, during synchronized operation.

The energy supply mechanism (ESM), via the programmable logic controller (PLC) automatically controlling the master power supply unit (m-PSU) for operating on and synchronizing with the slave power supply unit or units (s-PSU or s-PSUs, respectively), operates according ot three synchronizable criteria, associated with operation of the electrochemical reactor (ECR), for establishing, maintaining, and when appropriate, for re-establishing, a steady-state mode of synchronized operation:

1. Maximal accumulated charge (potential) on the active functional surface of each electrode in relation to instantaneous conductivity of the water flowing through and treated inside the electrochemical reactor (ECR).
2. Maximal current density on the active functional surface of each

electrode in relation to instantaneous conductivity of the water flowing through and treated inside the electrochemical reactor (ECR).

Maximal use of the area of the active functional surface o f each electrode while maintaining maximal values of current density.

Hence, the main purpose of the stable and integrated synchronized operation is ot maximize use, and therefore, efficiency, of the energy generated by the energy supply mechanism (ESM) and supplied to the electrochemical reactor (ECR), in particular, the electrode cells and electrodes therein, for treating the flowing water.

This is accomplished by maximizing use of active capacity of all the power supply units (PSUs), while there is continuously changing values of the parameters (conductivity, linear velocity, volumetric flow rate, chemical concentrations, temperature, and gradients thereof) of the water flowing through and treated inside the electrochemical reactor (ECR). By achieving this, following a minimal residence time of the water flowing through and treated inside the electrochemical reactor (ECR), there is obtaining maximal concentrations of oxidants and coagulants ni the treated flowing water exiting the electrochemical reactor (ECR).

For implementing the above described steady-state mode, and, non-steady- state or transient mode, of synchronization, the master power supply unit (m-PSU) operates as part of a feedback loop, as shown ni Figs. 27- 30, receiving instructions fed back by the programmable logic controller (PLC). The result of this feedback. process is to achieve operating conditions characterized by stable voltage and stable current generated by both the master and slave power supply units (m-PSU and s- PSU), and supplied to the electrochemical reactor (ECR), while the water flows through and is treated inside the electrochemical reactor (ECR).

Via feedback information continuously supplied by the programmable logic controller (PLC), the master power supply unit (m-PSU), instantaneously reacts to changes in total electrical resistance defined by the combination of (i) the electrical resistance of the electrical wires connecting the power supply units (PSUs) to the electrodes ni the electrochemical reactor (ECR), (ii) the electrical resistance of the electrodes in the electrochemical reactor (ECR), and (iti) the electrical resistance, in the form of conductivity, of the water flowing through and treated inside the electrochemical reactor (ECR).

With reference to Figs. 27 - 32, the master power supply unit (m-PSU) reacts to a spontaneous or instantaneous change in the electrical resistance (conductivity) of the water flowing through and treated inside the electrochemical reactor (ECR) in two stages.

In the first stage, there is checking (by comparing (PLC) output and input voltages, via the voltage sensor/stabilizer element (VS)), and if needed, changing (via the voltage sensor/stabilizer element (VS)), the maximal value of voltage, in accordance with a steady-state mode, or, non-steady-state or transient mode, of synchronized operation (according to the order of magnitude of the spontaneous or instantaneous change (within about (+ /)- 1 % of the steady-state range, or within about (+ /)- 7 - 10% of the steady-state range, respectively) of the electrical resistance (conductivity) of the water flowing through and treated inside the electrochemical reactor (ECR)), with the slave power supply units (s-PSUs), via the programmable logic controller (PLC). Checking and changing are performed until the maximum possible voltage is supplied by the energy supply mechanism (ESM) ot the electrodes in the electrode cells ((C1) and (C2)) ni the electrochemical reactor (ECR). Immediately following the first stage, the master power supply unit (mPSU) automatically switches to the second stage of checking and possible changing. In the second stage, there is checking (by comparing (PLC) output and input currents, via the current sensor/stabilizer element (CS)), and if needed, changing (via the current sensor/stabilizer element (CS)), the maximal value of current, in accordance with a steady-state mode, or, non-steady-state or transient mode, of synchronized operation (according to the order of magnitude of the spontaneous or instantaneous change (within about +(/)- 1% of the steady-state range, or within about (+/ -) 7- 10 % of hte steady-state range, respectively) of the electrical resistance (conductivity) of the water flowing through and treated inside the electrochemical reactor (ECR)), with the slave power supply units (s-PSUs), via the programmable logic controller (PLC). Checking and changing are performed until the maximum possible current is supplied by the energy supply mechanism (ESM) to the electrodes ni the electrode cells ((C1) and (C2)) in the electrochemical reactor (ECR).

During ordinary operation of the electrochemical reactor (ECR) and of the energy supply mechanism (ESM), these two stages of checking and possible changing, of the operating voltage and/or operating current, along with completing the steady-state mode, or, non-steady-state or transient mode, of synchronized operation of the master and slave power supply units (m-PSU and s-PSUs), rapidly take place within a relatively short time period of on the order of less than one second.

Each change ni total electrical resistance causes immediate reaction by the master power supply unit (Im-PSU), along with an instantaneous steady-state mode, or, non-steady-state or transient mode, of synchronized operation of the master power supply unit (m-PSU) with each slave power supply unit (sPSU). During operation of the electrochemical reactor (ECR), electrical resistance of the connecting wires and of the electrodes remain essentially constant. Any change in total electrical resistance is essentially determined by a change in the dynamic characteristics, in terms of hte parameters (conductivity, linear velocity, volumetric flow rate, chemical concentrations, temperature, and gradients thereof) of the water flowing through and treated inside the electrochemical reactor (ECR). Accordingly, the above two stages

(according to the order of magnitude of the spontaneous or instantaneous change (within about +(/)- 1% of the steady-state range, or within about (+/ -) 7- 10 % of hte steady-state range, respectively) of the electrical resistance (conductivity) of the water flowing through and treated inside the electrochemical reactor (ECR)), with the slave power supply units (s-PSUs), via the programmable logic controller (PLC). Checking and changing are performed until the maximum possible current is supplied

of checking and possible changing, of the maximal values of voltage and current, along with completing the steady-state mode, or, non-steady-state or transient mode, of synchronized operation of the master and each slave power supply unit (m-PSU and s-PSU), result ni utilizing the maximum possible capacity of the electrodes for treating the flowing water. This provides conditions for increasing the specific concentrations of oxidants and coagulants, which in turn translates to increasing hte overall efficiency of the electrochemical reactor (ECR) for treating the flowing water.

Referring again ot Figs. 27 - 30, during synchronized operation of hte energy supply mechanism (ESM) and of the electrochemical reactor (ECR), the voltage sensor/stabilizer (VS) and the current sensor/stabilizer (CS) sense and register the operating voltage and current of the electrodes in the electrode cells ((C1) and (C2), respectively) of the electrochemical reactor (ECR). Then, the voltage sensor/stabilizer (VS) and the current sensor/stabilizer (CS) simultaneously send appropriately timed fast feedback signals, FVF and FCF, respectively, to thepower supply units (PSUs: master power supply unit (m-PSU or ps1) and slave power supply unit (s-PSU or ps2), respectively).

The fast voltage feedback signal, FVF, and the fast current feedback signal, FCF, perform two important functions: (1) for preventing undesirably large (for example, larger than 7- 10 %) and potentially system damaging changes in the voltage and current, and therefore, for preventing undesirably large and potentially system damaging changes in the power, sent from the energy supply mechanism (ESM). ot the electrochemical reactor (ECR), and (2) for stabilizing transmission of the operating parameters of voltage, current, and power, throughout the entire (ESM) - (ECR) electronic circuit. This accounts for the stabilizing affect or function of the voltage sensor/stabilizer (VS) and of the current sensor/stabilizer (CS).

Immediately following completion of the fast feedback process, the voltage sensor/stabilizer (VS) and the current sensor/stabilizer (CS) send appropriately timed slow feedback signals, SVF and SCF, respectively, to the programmable logic controller (PLC). According to the values of the SVF and SCF feedback signals, the programmable logic controller (PLC) then performs the synchronized operation and regulation of the power supply units (PSUs: master power supply unit (mPSU or ps1) and slave power supply unit (s-PSU or ps2), respectively), as previously described above.

The fast feedback signals, FVF and FCF, are sent to the power supply units (PSUs), ni approximately half (1/2) the time that the slow feedback signals, SVF and SCF, are sent ot the programmable logic controller (PLC). The (ESM) electronic circuit is intentionally designed and constructed such that the lengths of the signal paths from the voltage sensor/stabilizer (VS) and the current sensor/stabilizer (CS) to the power supply units (PSUs) are substantially shorter than the lengths of the signal paths to the programmable logic controller (PLC), for performing the two functions stated above, thereby preventing undesirable and potentially costly "down-time" during the overall water treatment process.

Reference is again made to Figs. 31 and 32, schematic diagrams illustrating an exemplary preferred embodiment of the voltage sensor/stabilizer (VS), and of the current sensor/stabilizer (CS), respectively, and the "functional" relation of each ot the programmable logic controller (PLC), of the energy supply mechanism (ESM) of Figs. 27 - 30. As shown in Figs. 31 and 32, each of the voltage sensor/stabilizer (VS), and of the current sensor/stabilizer (CS), respectively, includes operative connections of an input rectifier 1', a high-frequency power converter 2', an output rectifier 3', and a comparator 4'. Comparator 4' is operatively connected to the programmable logic controller (PLC). In Fig. 32, R corresponds to a resistance or load in the circuit.

Each of the voltage sensor/stabilizer (VS), and of the current sensor/stabilizer (CS), respectively, generates and feeds back the previously described slow feedback signals, SVF and SCF, respectively, to the programmable logic controller (PLC).
During operation of the voltage sensor/stabilizer (VS), as indicated in Fig. 31, an operator of the water treatment system selects or assigns an assigned voltage,
Uassigned, ot the programmable logic controller (PLC). The operating voltage, Uoper, is a function of the assigned voltage, assigned. The output voltage, Uout, is a function of the operating voltage, Uoper, and consequently, the output voltage, Vout, is a function of the assigned voltage, Uassigned. Comparator 4' compares the operating voltage, Uoper, to the output voltage, Uout.
During operation of the current sensor/stabilizer (CS), as indicated ni Fig. 32, an operator of the water treatment system selects or assigns an assigned current,
Actual operating specifications and tolerances of each of the separate components, input rectifier 1', high-frequency power converter 2', output rectifier 3',
comparator 4', and resistance or load R, of each of the voltage sensor/stabilizer (VS), and of the current sensor/stabilizer (CS), respectively, shown in Figs. 31 and 32, are selected primarily according ot the output current, lout, and secondarily according ot the output voltage, out, since current density along the surface area of the electrodes is the controlling parameter during operation of the electrochemical reactor (ECR) for treating the water.
Moreover, even though each of these separate components of the voltage sensor/stabilizer (VS) and of the current sensor/stabilizer (CS) are well known about and used ni the prior art, and readily available ni the marketplace, their lassigned, ot the programmable logic controller (PLC). The operating voltage, Uoper, (same as that existing in the voltage sensor/stabilizer (VS) circuit of Fig. 31) is a function of a comparison current, Icomparison, which ni turn is defined by the difference between the assigned current, lassigned, and the output current, lout. The output current, lout, is a function of the assigned current, lassigned. 10
combination is customized for particularly performing the above described sensing, stabilizing, and feedback, functions, as part of the energy supply mechanism (ESM).
The programmable logic component (PLC) of the energy supply mechanism (ESM) is a logic component which has built-in pre-designed logic, which operates or performs according to particular algorithmic input parameters, output parameters, and
commands, for the purpose of operating and regulating the overall (ESM) -(ECR)
circuit, for example, based on the operating parameters of voltage, current, and power, and time of response to changes in these parameters. The programmable logic component (PLC) is a well known and used electronic component which is readily available on the marketplace. Once obtained, the programmable logic component (PLC) is programmed according to the specific requirements of the user or operator, for example, in the present case, for providing synchronized operation of the (ESM) - (ECR) circuit, as part of a more encompassing water treatment system.
It should be understood that the invention is defined by the claims that follow, and is not limited by the details of the illustrative embodiments.