Office de la Propriété Intellectuelle du Canada
Un organisme d'Industrie Canada

Canadian Intellectual Property Office
An agency of Industry Canada

CA 2382357 A1 2002/01/17

(21) 2 382 357

(12) DEMANDE DE BREVET CANADIEN
CANADIAN PATENT APPLICATION

(13) A1

(86) Date de dépôt PCT/PCT Filing Date: 2001/04/05
(87) Date publication PCT/PCT Publication Date: 2002/01/17
(85) Entrée phase nationale/National Entry: 2002/02/19
(86) N° demande PCT/PCT Application No.: US 2001/011052
(87) N° publication PCT/PCT Publication No.: 2002/004356
(30) Priorité/Priority: 2000/07/10 (09/612,776) US

(51) Cl.Int.^{7}/Int.Cl.^{7} C02F 1/461, C02F 11/12

(71) Demandeur/Applicant:
D-H20 L.L.C., US

(72) Inventeurs/Inventors:
HELD, JEFFRY, US;
CHAUHAN, SATYA P., US

(74) Agent: MACRAE & CO.

(54) Titre : PROCEDE DE DESHUMIDIFICATION DE BOUES ACTIVEES PAR DECHETS, AU MOYEN D'UNE TENSION ELECTRIQUE ELEVEE

(54) Title: METHOD FOR DEWATERING MUNICIPAL WASTE-ACTIVATED SLUDGE USING HIGH ELECTRICAL VOLTAGE

(57) Abrégé/Abstract:

A system that allows the flexibility of primary and secondary treatment of municipal sludge, paper-pulp sludge, animal and plant waste, whereby the treatment thereof via electroporation may be used either as the primary dewatering treatment, secondary dewartering treatment, direct WAS-treatment, and combinations with other conventional dewatering techniques, in order to provide the municipal treatment platn, or the paper-pulp treatment plant, with the most cost-effective and efficient system as possible. The electroporated-treated sludge releases hitherto unreleased biosolids exiting from the PEF-electroporation system, which are returned to aeration tanks. The elelctroporation process causes the release of intracellular dissolved/organic matter, which is used as "food" for the bacteria of the aeration tanks.

WO 02/04356 PCT/US01/11052

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
17 January 2002 (17.01.2002)

PCT

(10) International Publication Number
WO 02/04356 A1

(51) International Patent Classification[7]: C02F 1/461

(21) International Application Number: PCT/US01/11052

(22) International Filing Date: 5 April 2001 (05.04.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/612,776 10 July 2000 (10.07.2000) US

(71) Applicant: **D-H20 L.L.C.** [US/US]; 431 W. Oakdale Avenue, #4A, Chicago, IL 60657 (US).

(72) Inventors: **HELD, Jeffry**; 431 W. Oakdale Avenue, #4A, Chicago, IL 60657 (US). **CHAUHAN, Satya, P.**; 1073 Bluff Point Drive, Columbus, OH 43235 (US).

(74) Agents: **GERSTEIN, Milton, S.** et al.; Hamman & Benn, Suite 3300, 10 S. LaSalle Street, Chicago, IL 60603 (US).

(81) Designated States *(national)*: CA, JP.

(84) Designated States *(regional)*: European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR).

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

WO 02/04356 A1

(54) Title: METHOD FOR DEWATERING MUNICIPAL WASTE-ACTIVATED SLUDGE USING HIGH ELECTRICAL VOLTAGE

(57) Abstract: A system that allows the flexibility of primary and secondary treatment of municipal sludge, paper-pulp sludge, animal and plant waste, whereby the treatment thereof via electroporation may be used either as the primary dewatering treatment, secondary dewartering treatment, direct WAS-treatment, and combinations with other conventional dewatering techniques, in order to provide the municipal treatment platn, or the paper-pulp treatment plant, with the most cost-effective and efficient system as possible. The electroporated-treated sludge releases hitherto unreleased biosolids exiting from the PEF-electroporation system, which are returned to aeration tanks. The elelctroporation process causes the release of intracellular dissolved/organic matter, which is used as "food" for the bacteria of the aeration tanks.

METHOD FOR DEWATERING MUNICIPAL WASTE-ACTIVATED SLUDGE USING HIGH ELECTRICAL VOLTAGE

BACKGROUND OF THE INVENTION

In U.S. Patent No.6,030,538, issued in February 29, 2000 entitled "Method and pparatus for Dewatering Previously-Dewatered Municipal Waste-Water Sludges Using High Electrical Voltages, there is disclosed a system and method for dewatering and treating waste-activated sludge (WAS) emanating from municipal waste, or pulp-waste from a paper mill, as well as treating animal and plant waste. In that patent, the method for breaking down the WAS is to subject the WAS to electroporation, which incorporates nonarcing, cyclical high voltages in the range of between 15 KV and 100 KV, which break down inter-cellular and intracellular molecular bonds, to thus release inter-cellular and intracellular water, whereby the WAS is rendered inactive and greatly reduced in mass.

In the above-noted U.S. Patent, the apparatus and method disclosed therein, while capable in certain circumstances of being a primary municipal-sludge treatment, its intended and main objective was to use it as a secondary treatment to previously-dewatered municipal waste sludge. It is the goal of the present invention to adapt the method and apparatus of U.S. Patent No. 6,030,538, issued in February 29, 2000 entitled "Method and Apparatus for Dewatering Previously-Dewatered Municipal Waste-Water Sludges Using High Electrical Voltages into a main, primary treatment of municipal waste sludge.

In a previous (Phase I) project, it has been demonstrated the laboratory feasibility of pulsed electric field (PEF) for disrupting the biomass in waste activated sludge (WAS) derived from municipal wastewater treatment. While there was no significant increase in the solids content of dewatered sludge, the quantity of WAS needing disposal was estimated to be significantly reduced.

Encouraged by the Phase I results, a pilot plant for testing at one or two wastewater treatment plants that generate WAS has been developed. It has been decided that a pulsed electric field (PEF) system that could handle 0.5 to 1.0 pgm WAS feed be designed. This requires an 8 kw power supply capable of generating 30 kV and pulse generator capable of handling 50 amp peak, current, bi-polar pulses, square wave, 10 μs pulse width, and 3000 pulses/second (pps).

SUMMARY OF THE INVENTION

It is the primary objective of the present invention to provide a method and apparatus for dewatering municipal waste sludge, paper-pulp waste sludge, animal and plant waste, using electroporation for the primary treatment of the sludge.

It is also a primary objective of the present to provide such a system that will allow flexibility as to the primary and secondary treatment of municipal sludge, paper-pulp sludge, animal and plant waste, whereby the treatment thereof via electroporation may be used either as the primary dewatering treatment, secondary dewatering treatment, direct WAS-treatment, and combinations with other conventional dewatering techniques, in order to provide the municipal treatment plant, or the paper-pulp treatment plant, with the most cost-effective and efficient system as possible.

BRIEF DESCRIPTION OF THE DRAWING

The invention will be more readily understood with reference to be accompanying drawings, wherein:

Figure 1 is a schematic showing the electroporation system as used as a secondary dewatering treatment;

Figure 2 is a schematic showing the electroporation system used in conjunction as a primary dewatering treatment in accordance with the present invention;

Figure 3 is a schematic showing the electroporation sub-system for use in dewatering municipal, paper-pulp, animal and plant waste sludges; and

Figure 4 is a schematic diagram showing the overall apparatus of the present invention incorporating the electroporation sub-system for use as a primary or secondary dewatering treatment.

DETAILED DESCRIPTION OF THE INVENTION

The original concept for the pulsed-electric filed (PEF) effect using electroporation was to dewater the previously-dewatered sludge. However, additional PEF data on a paper plant sludge has indicated that the big PEF effect from electroporation of WAS occurs at higher energy levels (e.g., 100 J/mL; or 400 k Wh/ton (DS) for feed at 6 percent solids), whereby cells are disrupted. The result is inactivation of cells, breakage of cells and release of some intracellular dissolved/organic matter and typically a worsening of flocculation and dewatering. Therefore, a more effective way of using this process is to recycle all of the PEF-treated sludge back to a aerobic bioreactor to utilize the sludge as food; that is, it has been discovered that the PEF-electroporation effect on disrupting the cellular units of the WAS has been to release intracellular dissolved/organic matter. This intracellular dissolved/organic matter is just the type of ideal "food" upon which the aerobic bioreactor flourishes. Thus, returning this released intracellular dissolved/organic matter back to the aerobic bioreactor will increase the BOD load on the bioreactor, and will thus reduce the quantity of WAS by up to about 50 percent. The flow sheet for this scenario is shown in Figure 2. Thus, it is now practical to employ the PEF-electroporation system as not only a secondary system for treating previously-dewatered sludge, but also to employ it as a primary system, as described hereinbelow.

Referring to Fig. 1, there is shown the schematic for using the PEF-electroporation system as a secondary treatment for previously-dewatered sludge, as disclosed in U.S. Patent No. 6,030,538, issued in February 29, 2000 entitled "Method and Apparatus for Dewatering Previously-Dewatered Municipal Waste-Water Sludges Using High Electrical Voltages. In Fig. 1, the wastewater is delivered to the primary treatment, aerobic-reactor tanks 10, and from there to a secondary clarifier 12. From there, the WAS is delivered to the PEF-electroporation system 14 of the invention for deactivating the WAS to make it a Class "B" biomass for easier disposal. The biomass is then sent to a belt press 16 for further processing and disposal.

Referring now to Fig. 2, there is shown the flow chart of the present invention for employing the PEF-electroporation system as part of the primary treatment. In this system, the biosolids exiting from the PEF-electroporation system 14 are returned to the aeration tanks 10, since, as explained above, the PEF process causes the release of intracellular, dissolved organic matter, which is used as "food" for the bacteria of the aeration tanks. This "food" not only is further treated in the aeration tanks via aerobic digestion, but actually causes the aerobic digestion process in the aerobic tank itself to be accelerated for the same amount of oxygen supplied.

A practical problem with the system of Figure 2 is that the PEF throughput needs to be of the same order of magnitude as the WAS disposal rate in order to see a noticeable effect of PEF on WAS reduction. For this reason a 1.8 ton (DS)/day PEF system has been chosen as a pilot plant. With such a system, a WAS reduction of 0.9 ton/day on a dry basis or 7.5 tons/day on a filter press cake (at 12 percent solids) basis may be achieved. In terms of thickened sludge (at 2 percent solids) basis, this translate to elimination of 45 tons/day needing to be flocculated and dewatered. This will require PEF treatment of 15 gpm WAS at 2 percent solids.

One way to reduce the cost of the pilot plant, which is driven by the PEF power supply and pulser cost, is to pre-thicken the WAS. Therefore, a 15 gpm rental centrifuge 18 is used for pilot testing. It is estimated that this will produce a 5 gpm feed for the PEF reactor at a solids content of 6 percent. Such a feed can be handled by a Moyno pump. The feed streams to the centrifuge and the PEF units are represented as Stream Nos. 10 and 11, respectively in Figure 2. However, in practical application such as centrifuge may not be necessary.

PEF POWER SUPPLY AND PULSER DESIGN

The conceptual design of the power supply and the pulse generator (pulser) for the system of Fig. 2 is shown in Figure 3. This figure shows four chambers 20 in series, although two chambers also can be used if the pulse rate is increased. The specifications for the two-chamber design are shown in Table 1. The design requires a 35 kW input power supply 22 (32 kW continuous output) delivering 30 kV. The pulse generator 24 is 200 amp maximum current and a pulse rate of 4,000 hz. (maximum).

Table 1. Pilot Plant PEF Power Supply, Reactor, and Pulser

Chambers	
Gap Distance D (cm)	1.2
Chamber	1
Number of chambers in use	2
Flow Conditions	
Flow rate (ml/s)	315
PEF Parameters	
Voltage to apply (kV)	30
Rep-rate (pps)	3342.254
Pulse duration (μs)	4
Physical Properties	
Conductivity (S/m)	0.2
Density (g/cm^3)	1
Specific Heat ([J/(g . ^{o}C)]	4.18
Viscosity (Pa . s)	0.0100
Dosage Level	
Electric Field Strength (kV/cm)	25
Total Treatment Time (μs)	80
Number of pulses per chamber	10
Temperature Change	
Temperature increase per pair of chamber (°C)	11.962
Related Information	
Residence Time (s)	0.00299
Flow Speed (cm/s)	401.070
Energy Consumption (J/ml)	100
Estimated Power requirement (W)	31500
Reynolds Number	4010.705
Pulse Generator Current	78.5

The actual sludge handling system and the associated instrumentation is shown in Figure 4. A detailed list of specifications is provided in Table 2. Tank T1 holds up to 100 gallons of untreated feed material, delivered through valve V1 from the centrifuge 18. A mixer is provided for blending infeed material. A bottom drain allows disposal to sewer at the end of a test run. Valve V4 is provided for withdrawing a sample for analysis. Material leaves T1 through V2 and a strainer to a variable-speed progressing cavity pump, which can flow from 0.5 to 5.0 gallons per minute. The tank, pump mixer and associated valves are mounted to one 42-inch square skid for transport purposes. The feed leaving P1 passes through quick-connect fittings to a reinforced hose to the reactor.

The PEF-electroporation reactor subsystem includes a power supply, pulse generator and pairs of treatment chambers as described above with reference to Fig. 3. These would be mounted to a skid , along with associated valves V5, 6 and 7. Quick-connect fittings and hose convey the treated material to valves on the outlet tank skid. Valves V12 and 13 permit the treated material to be recycled back to T1. Valve V8 permits the treated material to enter tank T2, of 100-gallon capacity. As with T1, a mixer, a sample port and a bottom drain are provided. Tank T2, pump P2, mixer M2 and associated valves are mounted to another skid. Treated material leaving through V10 leads to transfer pump P2. Valve V18 is a globe style for adjusting the flow rate through V14 to tank T3. Valve V13 allows treated material from T2 to return to T1, assisted by P2, to increase treatment time.

The P2 pump is used to return the treated sludge to the biotreatment plant, aerobic tanks 10, when the PEF-electroporation system is used as a primary system, or optionally to filter press 16, if desired, when the PEF-electroporation system is used as a secondary treatment.

Safety logic has been incorporated as follows. Level control L1 will close V1 to prevent overfilling T1, with subsequent spillage. Level control L2 will shut down P1 and the power supply when the liquid level becomes too low. Level control L3 and T2 will shut down P1 and the power supply when tank T3 becomes full, to prevent spillage.

Table 2. Sludge Handling System Specifications

Description Supplier	Qty
Inlet Tank T1	
100-Gal carbon steel jacketed mixing tank Buckeye Fab.	1
2-inch PVC, Schedule 80 90-Deg. elbow, 806-020 (bypass in) Harrington	1
Mixer, C-Clamp mount direct drive, ¼ HP, 400-250-DD-ED Harrington	1
Union ball valve, 2-inch socket, 1001020 Harrington	2
Strainer, 2-inch clear PVC, RVAT108 Harrington	1
Replacement screen, PVC Harrington	1
2-inch PVC, Schedule 80 pipe, 800-020, 20 feet length Harrington	1
2-inch PVC, Schedule 80 90-Deg elbow, 806-020 Harrington	2
Quick disconnect, Part F, 2-inch, polypro., FPP-020 Harrington	2
Quick disconnect, Part C, 2-inch, polypro., CPP-020 Harrington	2
Hose, PVC standard duty, 2-inch, 110P-020 Harrington	100 ft
Hose clamps, 3-inch, H-44SS Harrington	10/pack
Bulkhead fitting, ½-inch PVC BF10050SXT Harrington	1

Ball valve, ½-inch socket, 107005 Harrington	1
Elbow, 90-degree, ½-inch Sch 80 PVC, 806-005 Harrington	1
Level control, high to shut feed valve, LV751 Omega	1
Level control, low to shut off pump P1 and Powr supply, LV751 Omega	1
Solid state relay for feed valve, SSR240AC10 Omega	1
Solid state relay for pump and power supply, SSR240AC25 Omega	1
Feed Valve V1	
Quick disconnect, Part F, 2-inch, polypro., FPP-020 Harrington	1
Quick disconnect, Part C, 2-inch, polypro., CPP-020 Harrington	1
Union ball valve, 2-inch, 1001020 Harrington	1
Electric actuator, 2085020 Harrington	1
Process Pump P1	
Pump, 5.0 down to 0.5 GPM, 35 psi, Moyno Buckeye Pump	1
Direct Current control for pump, NEMA 4 enclosure Buckeye Pump	1
Hose nipples, polypro., 2-inch, HNPP-020 Harrington	2
2-inch PVC, Schedule 80 tee, 801-020 Harrington	2
2-inch PVC, Schedule 80 pipe, 800-020, 20 feet length Harrington	1
2-inch PVC, Schedule 80 90-Deg elbow, 806-020 Harrington	2
Reactor Connections	
Quick disconnect, Part F, 2-inch, polypro., FPP-020 Harrington	2
Quick disconnect, Part C, 2-inch, polypro., CPP-020 Harrington	2
Union ball valve, 2-inch socket, 1001020 Harrington	1
2-inch PVC, Schedule 80 socket tee, 801-020 Harrington	2

Table 2. Sludge Handling System Specifications (Continued)

Description Supplier	Qty
Reducing bushing, 2-inch by ½-inch thread, 838-247 Harrington	2
½-inch by 1-1/2-inch long PVC Schedule 80 nipple, 882-015 Harrington	2
Union ball valve, ½-inch threaded, 1001005 Harrington	2
½-inch PVC Schedule 80 threaded tee, 805-005 Harrington	1
Reducing bushing ½-inch to ¼-inch threaded, 839-072 Harrington	2
Pressure gauge with guard, 0-60 psig, GGME060-PP Harrington	1
Tube adapter, ¼-inch MPT to ¼-inch tube, 4MSC4N-B Parker	2
Outlet Tank T2	
100-Gal jacketed carbon steel tank with legs, 2-in outlet Buckeye Fab.	1
2-inch PVC, Schedule 80 90-Deg elbow, 806-020 (inlet) Harrington	1
Union ball valve, 2-inch socket 1001020 Harrington	5
Quick disconnect, Part F, 2-inch, polypro., FPP-020 Harrington	3
Quick disconnect, Part C, 2-inch, polypro., CPP-020 Harrington	3
2-inch PVC, Schedule 80 90-Deg elbow, 806-020 Harrington	4
2-inch PVC, Schedule 80 socket tee, 801-020 Harrington	2
2-inch PVC, Schedule 80 threaded tee, 805-020 Harrington	3
2-inch by 6-inch PVC, Schedule 80 nipple Harrington	2
Mixer, C-Clamp mount direct drive, ¼ HP, 400-250-DD-ED Harrington	1
½-inch by 2-inch PVC, Schedule 80 Harrington	1
Ball valve, ½ inch socket, 107005 Harrington	1
Elbow 90-degree, ½-inch Sch 80 PVC, 806-005 Harrington	1

Level control, low to shut off pump P1 and Powr supply, LV751 Omega	1
Solid state relay for pump and power supply, SSR240AC25 Omega	1
Outlet Tank Pump	
Pump, 5 GPM 20 feet of head, centrifugal Buckeye Pump	1
Motor starter, NEMA 4 with thermal unit C.E.D.	1
Hose nipples, polypro., 2-inch, HNPP-020 Harrington	4
Glove valve, threaded, PVC, 2-inch, 1261020 Harrington	1
Product Pump P2	
Pump, 5 GPM 20 feet of head, centrifugal Buckeye Pump	1
Motor starter, NEMA 4 with thermal unit C.E.D.	1
Sealtite, ½-inch C.E.D.	lot
Wires, cords C.E.D.	lot
Skids	
42-inch square, metal, fork lift entry four sides	

Table 2. Sludge Handling System Specifications (Continued)

Description Supplier	Qty
Instrumentation	
Oscilloscope, storage, two inputs, 100 MHz, printer interface Tektronix	1
Current sensor, 0.01 Volt/Ampere, 100 Amp. max. Pearson Electr.	1
Clamp-on flowmeter, 2 to 12-inch pipe, 4 – 20 ma output Controlotron	1
Voltage sensor, 60 Kilovolt, 1000v/1V, Type PVM-1 North Star Resch	1
Printer, Epsom jet Model 740, Part No. C257001 parallel port ADS Systems	1

Centronics-type paraller printer port cost, Epsom F2E020-06 ADS Systems	1
Type K thermocouple readout, Omega DP45KF + SB45 Omega	1 ea.
Type K thermocouple, 304SS sheath, 1/8-in. dia., KQSS-18G-12 Omega	2
Conductivity and pH meter, 0-200 μS, 0-14pH, P-19651-20 Cole-Parmer	1
Conductivity and pH flow-through cell, P-19502-42 Cole-Parmer	2

Alternative clamp-on flow meter, Omron FD-303 + FD-5 sensor for ¼-in. to ¾-in. pipe + FD-5000 sensor for ¾-in. to 12-in. pipes.

While a specific embodiment of the invention has been shown and described, it is to be understood that numerous changes and modifications may be made therein without departing from the scope and spirit of the invention as set forth in the appended claims.

WHAT WE CLAIM IS:

CLAIM 1. A method of dewatering paper-pulp sludge, municipal waste sludge, animal waste sludge containing intra-cellular water molecules contained in molecular cellular units of the waste sludge, or plant and animal waste sludge, comprising:

(a) pumping the waste sludge into a dewatering apparatus;

(b) destroying in the dewatering apparatus at least most of the individual cellular units of the waste sludge in order to release the intra-cellular water molecules contained therein; and

said step (b) causing massive disruption of the cellular matter, allowing for the release of bound as well as intra-cellular liquids and intracellular dissolved/organic matter, which may be used as food for the bacteria of aeration tanks;

(c) directing the released intracellular dissolved/organic matter to an aeration tank for supplying food to bacteria of said aeration tank.

CLAIM 2. The method according to claim 1, wherein said step (b) comprises electroporating said sludge.

CLAIM 3. The method according to claim 2, wherein said electroporation is performed with voltages between 15 KV. and 100,00 KV.

CLAIM 4. A method of treating sludge, such as paper-pulp sludge, municipal sludge, plant and animal waste, in which the sludge is treated in an aeration tank for performing aerobic digestion, comprising:

(a) treating the sludge to a dewatering process that releases intracellular dissolved/organic matter;

(b) directing the sludge treated in said step (a) to an aeration tank for performing aerobic digestion thereon

whereby the intracellular, dissolved organic matter is used as food for the bacteria of the aeration tanks, whereby the aerobic digestion process is accelerated thereby for the same amount of supplied oxygen.

CLAIM 5. The method according to claim 4, wherein said step (a) comprises electroporating the sludge.

CLAIM 6. The method according to claim 4, further comprising alternatively directing the sludge directly to a further dewatering process.

CLAIM 7. A method of treating sludge, such as paper-pulp sludge, municipal sludge, plant and animal waste,

(a) treating the sludge to a dewatering process that releases intracellular, dissolved organic matter;

(b) directing the sludge treated in said step (a) to one of: an aeration tank for performing aerobic digestion thereon, or to a different, dewatering process.

CLAIM 8. The method according to claim 7, wherein said step (b) comprises alternatively directing the sludge to further dewatering process consisting of a filter press.

CLAIM 9. The method according to claim 7, wherein said (b) comprises directing the sludge to an aeration tank, where said intracellular, dissolved organic matter is used as food for the bacteria of the aeration tanks, whereby the aerobic digestion process is accelerated thereby for the same amount of supplied oxygen.

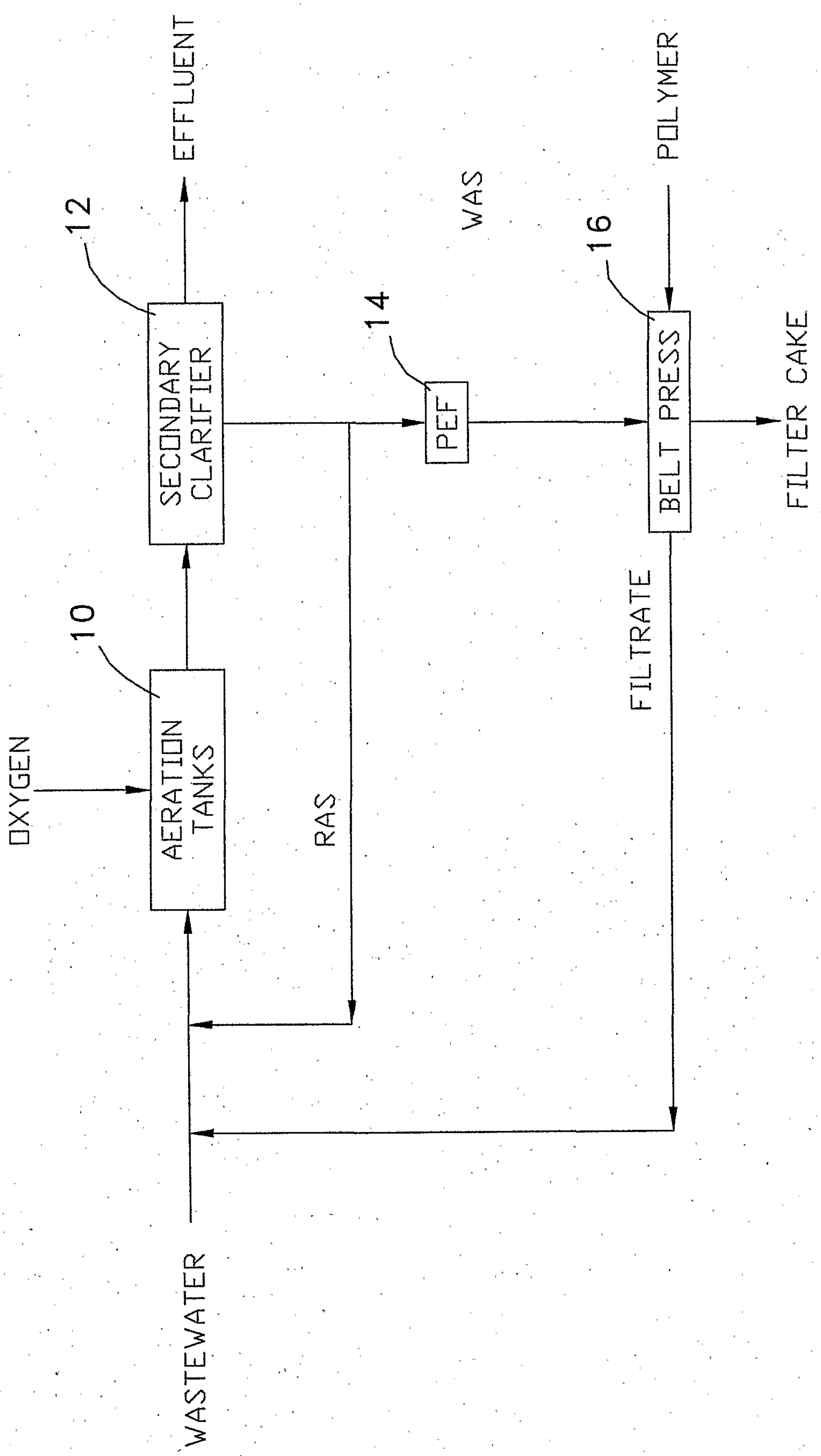
EFFLUENT
12
SECONDARY CLARIFIER
WAS
14
PEF
POLYMER
16
BELT PRESS
FILTER CAKE
FILTRATE
10
AERATION TANKS
OXYGEN
RAS
WASTEWATER

FIG 1

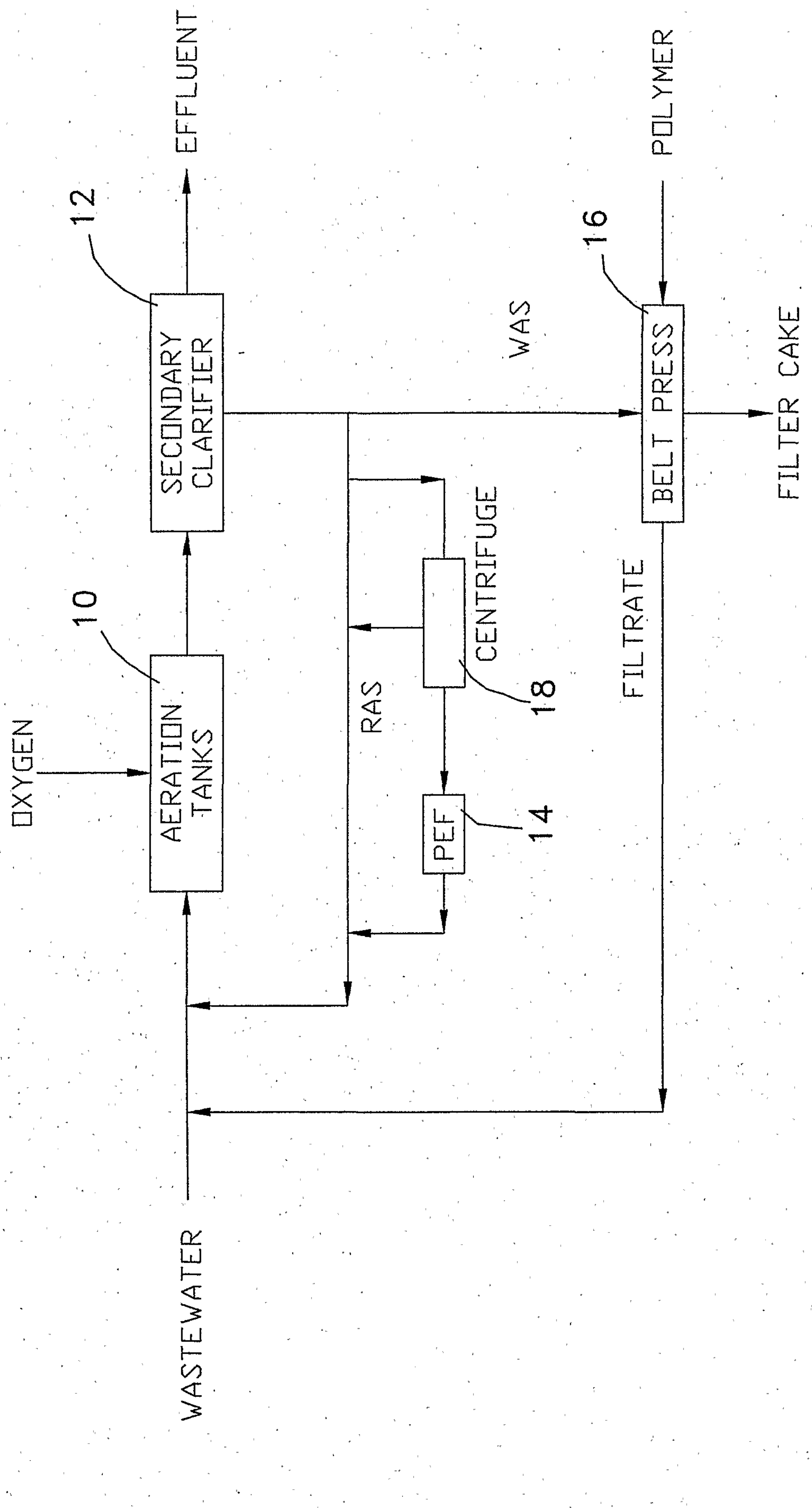
WASTEWATER
OXYGEN
10
AERATION TANKS
12
SECONDARY CLARIFIER
EFFLUENT
RAS
CENTRIFUGE
18
PEF
14
WAS
16
BELT PRESS
POLYMER
FILTER CAKE
FILTRATE

FIG 2

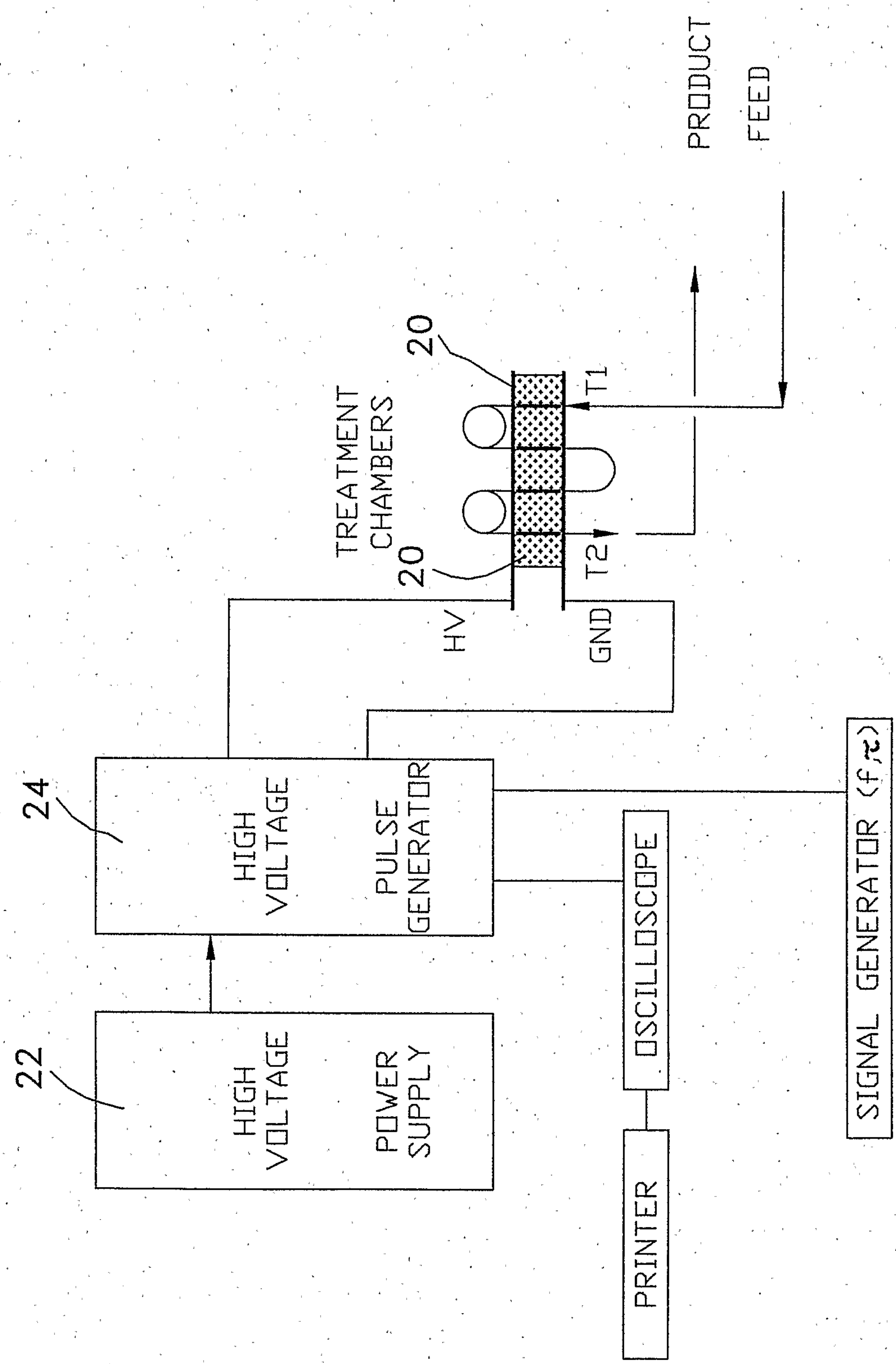
PRODUCT FEED
TREATMENT CHAMBERS
20
T1
T2
20
HV
GND
24
HIGH VOLTAGE PULSE GENERATOR
22
HIGH VOLTAGE POWER SUPPLY
OSCILLOSCOPE
PRINTER
SIGNAL GENERATOR (f,τ)

FIG. 3

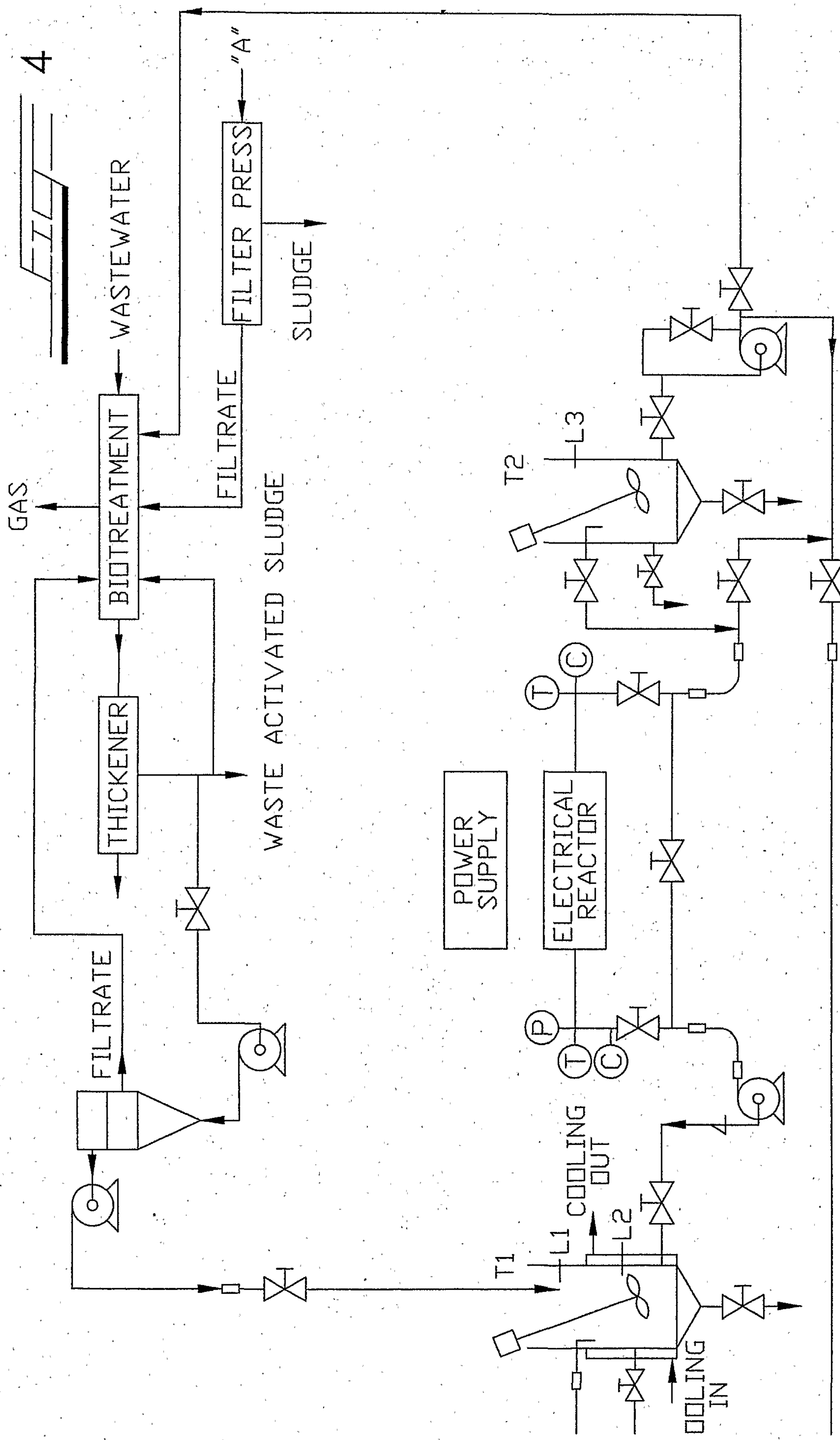
FIG 4
WASTEWATER
"A"
FILTER PRESS
SLUDGE
FILTRATE
GAS
BIOTREATMENT
WASTE ACTIVATED SLUDGE
THICKENER
FILTRATE
POWER SUPPLY
ELECTRICAL REACTOR
T
C
P
T
C
T1
L1
L2
COOLING OUT
OOLING IN
T2
L3