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(72) Inventeurs/Inventors:  
HEI, ROBERT D.P., US;  
GUTZMANN, TIMOTHY A., US;  
LOKKESMOE, KEITH D., US;  
BENNETT, SCOTT P., US;  
PERSON HEI, KIMBERLY L., US

(73) Propriétaire/Owner:  
ECOLAB INC., US

(74) Agent: ROBIC

(54) Titre : PROCEDE AUTOMATISE POUR L'INHIBITION DE LA CROISSANCE MICROBIENNE DANS LES SYSTEMES DE TRANSPORT DE NOURRITURE LIQUIDE

(54) Title: AUTOMATED PROCESS FOR INHIBITION OF MICROBIAL GROWTH IN AQUEOUS FOOD TRANSPORT OR PROCESS STREAMS

(57) Abrégé/Abstract:

The invention is a process for preventing microbial growth in aqueous streams by applying a C<sub>2</sub>-C<sub>12</sub> percarboxylic acid or mixture of such acids to the aqueous stream and to an automated dispensing system for the percarboxylic acids based on a correlation between oxidation-reduction-potential and anti-microbial levels of the aqueous stream. Generally, the process of the invention is applicable to aqueous streams used in any number of applications such as the application of streams for the transport of food products, e.g. fruits or vegetables, into the processing environment and through the various steps of processing.



**ABSTRACT**

The invention is a process for preventing microbial growth in aqueous streams by applying a C<sub>2</sub>-C<sub>12</sub> percarboxylic acid or mixture of such acids to the aqueous stream and to an automated dispensing system for the percarboxylic acids based on a correlation between oxidation-reduction-potential and anti-microbial levels of the aqueous stream. Generally, the process of the invention is applicable to aqueous streams used in any number of applications such as the application of streams for the transport of food products, e.g. fruits or vegetables, into the processing environment and through the various steps of processing.

**AUTOMATED PROCESS FOR INHIBITION OF MICROBIAL  
GROWTH IN AQUEOUS FOOD TRANSPORT OR PROCESS STREAMS**

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**Field of the Invention**

The invention relates to the control of microbial growth in aqueous streams. More specifically, the invention relates to the control of microbial growth in aqueous streams used for transporting or processing food products in processing environments such as fruit, vegetable and food products, for example, mushrooms, poultry, tomatoes, and the like.

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**Background of the Invention**

The advent of food processing has long since revolutionized both the availability of foods as well as the expectation of consumers for a large variety of high quality food products. Initially, food processing techniques included canning, and later, refrigeration, freezing, freeze drying as well as vacuum packaging. The application of various constituent-based and process-based preservation systems have all lead to a wider availability of high quality food stuffs.

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In turn, food pricing and availability is generally subject to various constraints including environmental hazards as well as natural weather cycles, selection and processing considerations, and overall economic and marketing constraints. Given the large volume of food selected and processed on an annual basis, as well as the relative uncontrollability of factors such as the environment and the marketplace, producers strive to economize in the selection and processing of food

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stuffs. One means of processing a large volume of foods, such as, for example, fruits and vegetables, is after selection, to transport these various food stuffs by an aqueous medium to deliver the food stuffs through various processing steps and environments.

For example, in specific applications, fresh fruits and vegetables may be transported through water streams by food handling equipment used at the processing plant.

After picking, fruits and vegetables are introduced into a flume system wherein water acts as a transport medium and a cleaning medium. Water may be used to support and transport the fruits or vegetables from an unloading sight to a final storage or packing or processing location. During the transport, water can take a food item from an initial location through a series of somewhat separate stages to a final station where the produce is removed from the water and packed.

The water within each stage may have a varying degree of organic load in the form of any number of sediments and soluble materials. This water is generally recycled.

Water can also be used in some of the processing stages to further clean, cool, heat, cook, or otherwise modify the food in some fashion prior to packaging. Process water as defined above may sometimes be used once and discarded. However, often times a major portion of this process water is re-used and is, therefore, subject to organic and microbial contamination. In some stages this process water stream is also used to transport the food. In other stages, the process water may be a separate stream and is

recycled apart from the transport water. In either situation, the process water becomes contaminated with organic matter from the food, providing nutrients for microbial growth in the water. Examples of different types of process water are vegetable washers, vegetable cooling baths, poultry chillers, and meat washers.

Given the nature of the food as well as the presence of sediments and soluble materials, the water, flume, and other transport or processing equipment may be subject to the growth of unwanted microorganisms. These microorganisms are generally undesirable to the food, the water, the flume and may cause buildup on all water contact surfaces of slime or biofilm, which requires frequent cleaning to remove. Further, because the transport water, process water and equipment are in contact with food products, the control of unwanted microorganisms presents certain problems created by a food contact environment containing microorganisms.

In the preceding discussion it has been assumed that the transport or process water has contacted the food prior to packaging. There are also aqueous streams used to process certain types of food subsequent to packaging. Some foods are often times heated, cooled, or otherwise processed after being placed into packages made of metal, glass, or plastic containers, for example, bottled beer pasteurizers, can cookers, or can coolers. In all cases, contamination of the aqueous streams by food occurs due to leakage from defective packages or spillage on the outside of the package during the packaging operation. These packaged food process streams also are, therefore, subject to unwanted

microbial growth and high concentrations of organic matter similar to pre-packaged process and transport water.

Ideally, an antimicrobial agent or compound used in such a system will have several important properties in addition to its antimicrobial efficacy. The compound or agent should have no residual antimicrobial activity on the food. Residual activity implies the presence of a film of antimicrobial material which will continue to have antimicrobial effect which may require further rinsing of the food product. The antimicrobial agent preferably should also be odor free to prevent transfer of undesirable odors onto food stuffs. If direct food contact occurs, the antimicrobial agent should also be composed of food additive materials which will not effect food if contamination occurs, nor effect humans should incidental ingestion result. In addition, the antimicrobial agent should preferably be composed of naturally occurring or innocuous ingredients, which are chemically compatible with the environment and cause no concerns for toxic residues within the water.

In the past, transport and process water apparatus have generally been treated with sodium hypochlorite and chlorine dioxide. Generally, these materials are effective in preventing the unwanted growth of microorganisms. However, the use rate of these chlorine-based antimicrobials is very high because they tend to be rapidly consumed by the high organic load included in both the fruits or vegetables and soil. Further, upon consumption, compounds such as chlorine dioxide decompose producing byproducts such as chlorites

and chlorates, while hypochlorite produces trichloromethanes which may be toxic in very low concentrations. Lastly, chlorine dioxide is a toxic gas with an acceptable air concentration limit of 0.1 ppm.

5 Exposure to  $\text{ClO}_2$  often leads to headaches, nausea, and respiratory problems, requiring expensive and intricate safety devices and equipment when it is used.

Iodophor antimicrobial agents have also been used for various antimicrobial applications. However, 10 iodophor compounds tend to decompose or may be lost by evaporation when used in an aqueous medium. Thus, long term activity requires a high iodophor concentration.

Generally the art has taught against the use of percarboxylic acids as antimicrobial agents in aqueous 15 streams due to concerns of compound stability in the presence of high concentrations of organic matter.

As a result, a need exists in the food processing industry to provide a means of food transport and processing which also controls soil and microbial load 20 in the aqueous stream without the use of high concentrations of antimicrobials such as chlorinated compounds and other halogenated constituents.

#### Summary of the Invention

25 The invention is a process for preventing microbial growth in aqueous streams comprising the step of applying a percarboxylic acid or a mixture of percarboxylic acids to the aqueous stream. The application of percarboxylic acids employs an automated 30 dispensing and controlling system.

The method uses an oxidation-reduction-potential (ORP) probe and controller, coupled with a percarboxylic acid dispensing pump and timers, to control the concentration of percarboxylic acid in a produce or packaging flume system. The method involves an initial charging and then control of percarboxylic acid in a flume system using an ORP controller with a low and a high alarm contact set. The invention is based on the finding of a correlation between an "effective anti-microbial" level of residual percarboxylic acid in a flume system and the ORP of that system.

Accordingly the invention is an automated method of controlling microbial growth in an aqueous stream used for transporting or processing food products and packaged foods comprising treating said aqueous stream with an effective antimicrobial amount of a percarboxylic acid, said amount controlled by maintaining said aqueous stream at an oxidation-reduction-potential (ORP) between about 280 to about 460 mv with respect to an Ag/AgCl reference electrode or, preferably between about 310 and 440 mv.

More specifically the invention is an automated method of controlling microbial growth in an aqueous stream used for transporting or processing food products and packaged goods comprising the steps of:

initially charging a percarboxylic acid to said aqueous stream until an oxidation-reduction-potential (ORP) of at least 280 mv with respect to an Ag/AgCl reference electrode is reached, and allowing a continual addition of percarboxylic acid to the aqueous stream wherein the addition is controlled



by an ORP controller set between about 280 and 460 mv with respect to an Ag/AgCl reference electrode.

The process of the invention is unexpectedly effective in preventing the growth of unwanted  
5 microorganisms in food transport and processing apparatus. The consumption of peracetic acid is unexpectedly low in view of the organic loading of both fruits or vegetables and microbial soils within the water.

10 The process of the invention provides an antimicrobial agent useful in water for transporting or processing food products which has a high degree of antimicrobial efficacy and which is safely ingestible by humans while imposing no environmental incompatibility.

15 Differentiation of antimicrobial "-cidal" or "-static" activity, the definitions which describe the degree of efficacy, and the official laboratory protocols for measuring this efficacy are important considerations for understanding the relevance of  
20 antimicrobial agents and compositions. Antimicrobial compositions may effect two kinds of microbial cell damage. The first is a truly lethal, irreversible action resulting in complete microbial cell destruction or incapacitation. The second type of cell damage is  
25 reversible, such that if the organism is rendered free of the agent, it can again multiply. The former is termed bacteriocidal and the latter, bacteriostatic. A sanitizer and a disinfectant are, by definition, agents which provide antibacterial or bacteriocidal activity.  
30 In contrast, a preservative is generally described as an inhibitor or bacteriostatic composition.

### Brief Description of the Drawings

Figure 1 is a graphical depiction of the results of Working Example 3.

5 Figures 2 and 3 are graphical depictions of the results of Working Example 4.

Figure 4 is a schematic depiction of a flume system used in conjunction with Working Example 5.

10 Figure 5 is a graphical depiction of certain results obtained from Working Example 5.

Figure 6 is a schematic depiction of the automated dispensing and controlling system.

Figure 7 is a wiring diagram of the components in the control panel of Fig. 6.

### 15 Detailed Description of the Invention

The following describes in more detail the automated dispensing method applying an effective antimicrobial concentration of a percarboxylic acid composition for preventing microbial growth in aqueous  
20 streams.

#### Carboxylic Acid

Among other constituents, the percarboxylic acid composition comprises a carboxylic acid. Generally,  
25 carboxylic acids have the formula R-COOH wherein the R may represent any number of different groups including aliphatic groups, alicyclic groups, aromatic groups, heterocyclic groups, all of which may be saturated or unsaturated as well as substituted or unsubstituted.  
30 Carboxylic acids also occur having one, two, three, or more carboxyl groups.

Carboxylic acids have a tendency to acidify aqueous compositions in which they are present as the hydrogen atom of the carboxyl group is active and may appear as an anion. The carboxylic acid constituent within the present composition when combined with aqueous hydrogen peroxide generally functions as an antimicrobial agent as a result of the presence of the active hydrogen atom.

Moreover, the carboxylic acid constituent within the invention maintains the composition at an acidic pH.

Carboxylic acids which are generally useful in the process of the invention are those which comprise percarboxylic acids. Percarboxylic acids generally have the formula  $R(CO_3H)_n$ , where R is an alkyl, arylalkyl, cycloalkyl, aromatic or heterocyclic group, and n is one, two, or three, and named by prefixing the parent acid with peroxy.

Percarboxylic acids may be made by the direct, acid catalyzed equilibrium action of 30-98 wt.% hydrogen peroxide with the corresponding carboxylic acid, by autoxidation of aldehydes, or from acid chlorides, or carboxylic anhydrides with hydrogen or sodium peroxide.

Percarboxylic acids useful in this invention include  $C_2$ - $C_{12}$  percarboxylic acids such as, for example, peracetic acid, perpropionic acid, perbutyric acid, peroctanoic acid, perglycolic acid, perglutaric acid, persuccinic acid, perlactic acid, percitric acid, perdecanoic acid or mixtures thereof. These percarboxylic acids have been found to provide good antimicrobial action with good stability in aqueous streams.

The process of the invention also uses a combination of peracetic acid with other percarboxylic acids, preferably, those named above and particularly, peroctanoic acid. This combination of percarboxylic acids has been found to provide preferred antimicrobial efficacy and stability in the presence of high organic loads. Generally, within the sanitizer, the concentration of, for example, peroctanoic acid may range from about 10 wt-% to 90 wt-% and preferably from about 10 wt-% to 20 wt-%. The concentration of peracetic acid may range from about 10 wt-% to 90 wt-% and preferably from about 80 wt-% to 90 wt-%.

In its most preferred mode, the process of the invention uses peracetic acid. Peracetic acid may be prepared through any number of means known to those of skill in the art including preparation from acetaldehyde and oxygen in the presence of cobalt acetate. A 50% solution of peracetic acid may be obtained by combining acetic anhydride, hydrogen peroxide and sulfuric acid. Other methods of formulation of peracetic acid include those disclosed in U.S. Patent No. 2,833,813.

#### Hydrogen Peroxide

The antimicrobial composition of the invention may also comprise a hydrogen peroxide constituent. Hydrogen peroxide in combination with the percarboxylic acid provides a surprising level of antimicrobial action against microorganisms despite the presence of high loadings of organic sediment. Additionally, hydrogen peroxide may provide an effervescent action which may irrigate any surface to which it is applied. Hydrogen

peroxide works with a mechanical flushing action once applied which further cleans the surface of application.

An additional advantage of hydrogen peroxide is the food compatibility of this composition upon use and decomposition. For example, combinations of peracetic acid and hydrogen peroxide result in acetic acid, water, and oxygen upon decomposition all of which are food product compatible.

While many oxidizing agents may be used, hydrogen peroxide is generally preferred for a number of reasons.

After application of the H<sub>2</sub>O<sub>2</sub>/peracetic acid germicidal agent, the residue left merely comprises water and an acidic constituent. Deposition of these products on the surface of application such as a flume, will not adversely effect the process or the food products transported therein.

Generally, the concentration of hydrogen peroxide within the composition used in the process of the invention ranges from about 1 weight percent to about 50 weight percent, preferably from about 3 weight percent to about 40 weight percent, and most preferably from about 5 weight percent to about 30 weight percent. This concentration of hydrogen peroxide is most preferred as providing an optimal antimicrobial effect.

These concentrations of hydrogen peroxide may be increased or decreased while still remaining within the scope of the invention.

#### Adjuvants

The antimicrobial composition of the invention may also comprise any number of adjuvants. Specifically, the composition of the invention may comprise

stabilizing agents, wetting agents, as well as pigments or dyes among any number of constituents which may be added to the composition.

Stabilizing agents may be added to the composition of the invention to stabilize the peracid and hydrogen peroxide and prevent the premature oxidation of this constituent within the composition of the invention. Chelating agents or sequestrants generally useful if stabilizing agents in the invention include alkyl diamine polyacetic acid-type chelating agents such as EDTA (ethylene diamine tetraacetate tetrasodium salt), acrylic and polyacrylic acid-type stabilizing agents, phosphonic acid, and phosphonate-type chelating agents among others. Preferable sequestrants include phosphonic acids and phosphonate salts including 1-hydroxy ethylidene-1, 1-diphosphonic acid ( $\text{CH}_3\text{C}(\text{PO}_3\text{H}_2)_2\text{OH}$ ), amino[tri(methylene phosphonic acid)] ( $[\text{CH}_2\text{PO}_3\text{H}_2]_2$ (ethylene diamine[tetra methylene-phosphonic acid])], 2-phosphene butane-1, 2, 4-tricarboxylic acid, as well as the alkyl metal salts, ammonium salts, or alkyloyl amine salts, such as mono, di, or tetra-ethanolamine salts. The stabilizing agent is used in a concentration ranging from about 0 weight percent to about 20 weight percent of the composition, preferably from about 0.1 weight percent to about 10 weight percent of the composition, and most preferably from about 0.2 weight percent to 5 weight percent of the composition.

The composition used in the process of the invention may also contain, if necessary, additional ingredients as necessary to assist in defoaming.

Generally, defoamers which may be used in accordance with the invention include silica and silicones; aliphatic acids or esters; alcohols; sulfates or sulfonates; amines or amides; halogenated compounds such as fluorochlorohydrocarbons; vegetable oils, waxes, mineral oils as well as their sulfated derivatives; fatty acid soaps such as alkali, alkaline earth metal soaps; and phosphates and phosphate esters such as alkyl and alkaline diphosphates, and tributyl phosphates among others; and mixtures thereof.

Especially preferable, are those antifoaming agents or defoamers which are of food grade quality given the application of the process of the invention. To this end, one of the more effective antifoaming agents comprises silicones. Silicones such as dimethyl silicone, glycol polysiloxane, methylphenol polysiloxane, trialkyl or tetraalkyl silanes, hydrophobic silica defoamers and mixtures thereof may all be used in defoaming applications. Commercial defoamers commonly available include silicones such as Ardefoam® from Armour Industrial Chemical Company which is a silicone bound in an organic emulsion; Foam Kill® or Kresseo® available from Krusable Chemical Company which are silicone and non-silicone type defoamers as well as silicone esters; and Anti-Foam A® and DC-200™ from Dow Corning Corporation which are both food grade type silicones among others. These defoamers are generally present at a concentration range from about 0 wt-% to 5 wt-%, preferably from about 0 wt-% to 2 wt-%, and most preferably from about 0 wt-% to about 1 wt-%.

The invention may also contain any number of other constituents as necessitated by the application, which are known to those of skill in the art and which may facilitate the activity of the present invention.

5 The composition used in the invention may comprise:

Composition (Wt-%)

		<u>Useful</u>	<u>Working</u>	<u>Preferred</u>
10	Percarboxylic Acid	2-25	2-20	4-20
	H <sub>2</sub> O <sub>2</sub>	1-45	5-35	7-30
15	Carboxylic Acid	1-70	3-55	5-45
	Water	Balance	Balance	Balance

Initial

Concentration in Transport Water

	<u>Constituent</u>	<u>Useful</u>	<u>Working</u>	<u>Preferred</u>
25	Percarboxylic Acid	5-100 ppm	5-60 ppm	10-50 ppm
	H <sub>2</sub> O <sub>2</sub>	5-500 ppm	5-300 ppm	5-250 ppm

30 Once the antimicrobial of the invention is applied to any given transport or process stream, the antimicrobial will be subjected to a demand resulting from microbes present in the stream as well as other organic or inorganic material present in the stream. As  
 35 a general guideline, not limiting of the invention, the following concentrations of antimicrobial may be found after demand.



Residual Concentration (ppm)  
After Demand

<u>Constituent</u>	<u>Useful</u>	<u>Working</u>	<u>Preferred</u>
Percarboxylic Acid	1-85	1-45	5-30
H <sub>2</sub> O <sub>2</sub>	1-490	1-290	1-240

10 While the demand may reduce the antimicrobial concentration to zero, at least about 5 ppm of peracetic acid (POAA) is generally preferred to provide the intended efficacy.

Generation of Peroxy Acids

The process of the invention may also be initiated through the use of peroxy acid concentrate compositions.

20 In such a case, the percarboxylic acid may either be generated naturally or through the combination of a hydrogen peroxide concentrate together with a carboxylic acid concentrate at the sight of use such as that process which is disclosed in Lokkesmoe et al, U.S.

Patent No. 5,122,538, issued June 16, 1992. In such a case, the composition may be formed from a hydrogen peroxide concentrate comprising varying levels of hydrogen peroxide and stabilizer as shown in the table below.

Concentration (Wt-%)

<u>Constituent</u>	<u>Useful</u>	<u>Working</u>	<u>Preferred</u>
Hydrogen Peroxide	5-70	15-70	25-60
Stabilizer	0-10	0-5	0.1-3
H <sub>2</sub> O	20-95	25-85	37-75

When combined with a carboxylic acid, the two concentrates result in a peroxy carboxylic acid.

5 Generally, the carboxylic acid concentrate comprises a carboxylic acid in water as shown in the table found below.

		<u>Concentration (Wt-%)</u>		
10	<u>Constituent</u>	<u>Useful</u>	<u>Working</u>	<u>Preferred</u>
	Carboxylic Acid	50-100	65-100	80-100
15	Water	0-50	0-35	0-20

#### AUTOMATED DISPENSING AND CONTROL SYSTEM

20 The automated method of the present invention uses an ORP controller, timers, and pumping sequences to regulate around the effective range (see figure 6). Shown is a basic setup for dispensing product into a produce processing flume. Control panel 1 contains the

25 feed timers, relays, ORP controller, and the air solenoids. A double diaphragm air driven pump 2 is used to meter product from product drum 3 into the produce vessel 4. The vessel 4 could be a flume, tank or produce containment. An ORP probe 5 is mounted into the

30 side of vessel 4 or placed down into the vessel.

Figure 7 represents a wiring diagram of the internal components within the control box. When a prime switch (see operate switch layout 20) is activated, the prime timer 21 which determines the pump

35 stroke rate, the prime run timer 22 which sets the total priming time and the prime cycle timer 23 which

regulates the frequency of charging provide a preset time to feed enough product into a vessel so as to provide a starting concentration. The control panel 1 in Fig. 6 includes an ORP controller 24 shown in Fig. 7.

5 The panel can function with or without high and low concentration ORP control. If the system is to run with ORP control, the high set 25 and low set 26 ORP set points are preset at 460 mv and 280 mv respectively. The ORP controller can control both the initial charge  
10 and the subsequent make up feed of a percarboxylic acid in a flume system. If the system were to attempt to feed longer than the preset alarm timer 27 when the ORP value is below the low set point 26 an alarm condition will occur. The alarm has one normally open (N.O.) 28  
15 contact and one normally closed (N.C.) 29 contact. The normally closed contact is closed during non-alarm conditions.

The percarboxylic acid is fed using a double diaphragm pump 2 (Fig. 6) set up for single or T-stroke  
20 control. The air pulse to stroke the pump is fed through an air solenoid valve 30 which gets a signal from a primary on/off cycle timer 23. The cycle timer will turn on with either a signal from a run timer 31 used to time feed the percarboxylic acid or from the low  
25 level alarm N.O. contacts. The power to the run timer 31 is fed through the N.C. contacts for the high alarm.

During initial charge phase, with the flume background ORP value being typically - 180-300 mv, the low alarm N.O. contacts close directly supplying power  
30 to the primary cycle timer 23 which strokes the double diaphragm pump 2 (Fig. 6) until the low level alarm is

satisfied (e.g., 280 mv); at which time the N.O. contacts open and the run timer 31 controls the power feed. The rate of addition of this initial charge is relatively fast, e.g. about 25 to 1500 ml per minute, since it is used to prime the entire flume system - which might be 2000 gallons or more total process effluent, with percarboxylic acid; i.e., from 0 ppm to ~10 ppm residual percarboxylic acid. If necessary, an alarm (not shown) - audio or visual - can be incorporated off this primary timer to indicate improper charging. This could shut the entire system down and require a product empty check or recharge.

Comparably, the run timer 31 feeds at a rate matched to the flume fresh-water makeup rate and, hence, usually operated at about 5-50 times slower feed rate than the initial charge (e.g., usually 2 to about 150 ml per minute). Thus, after the initial low alarm is reached the pumping system will operate off the run timer 31 and maintain a continual addition of percarboxylic acid to the flume system; to sustain a residual in the percarboxylic acid concentration. This steady-state result is the desired condition. If at any time during the run timer feed the ORP drops below the set low alarm point, due to excess soil/microbial loading or water dilution, this condition would actuate the faster prime timer 21 for a set period of time to boost the flume percarboxylic acid level. This repriming attempt of the system will occur until it rises above the lower limit, or until the alarm condition shuts down the system when defined by the alarm timer 27; i.e., when the ORP controller low alarm

is activated, the alarm timer 27 is also activated and the ORP must rise above the low alarm level - in the set - time or the system shuts down and activates an external alarm (not shown).

5        If the percarboxylic acid level reaches the high alarm level (e.g., 460 mv), the N.C. contacts open, breaking the power feed to the run timer and preventing the percarboxylic acid from feeding. When the percarboxylic acid level drops below the high alarm set  
10 point, the N.C. contacts close again and the secondary cycle timer will control the percarboxylic acid feed rate. This allows for a cycling of peracetic residual around the upper set point.

      This scenario permits the automated maintenance of  
15 an "effective" percarboxylic acid level to control microbial populations in flume process and packaging waters.

#### Working Examples

      The invention will now be described in more detail  
20 by reference to the following examples. The only proper construction of these examples is as non-limiting illustrative examples showing various formulations, stabilities, and applications of the invention.

#### Working Example 1

25        To prepare stock solution of concentrate peracetic acid (or "POAA") formula for use in the flume experiments, the following components were combined.

	<u>Component</u>	<u>Wt-%</u>
	Acetic Acid	43.85
	Hydrogen Peroxide 35%	50.85
5	Dequest 2010 (60% active)	1.5
	1-Hydroxyethylidene-1,1-Diphosphonic Acid	
	H <sub>2</sub> O	3.8

10 The result of this combination was a composition having the following constituency.

		<u>Wt-%</u>
	Acetic Acid	32.0
15	H <sub>2</sub> O <sub>2</sub>	11.1
	Dequest 2010	0.90
	H <sub>2</sub> O	41.0
	Peracetic Acid	15.0

20

#### Working Example 2

In the second working example, the immediate demand of 1% and 3% tomato solutions for POAA was determined. POAA in pure water (control) was compared with similar dilutions in 1% and 3% tomato solutions. The tomato solutions were prepared by grinding fresh tomatoes in a food processor and adding 1% or 3% by weight of the slurry to the water.

	<u>Table 1</u>			
	<u>Control</u> <u>(no tomatoes)</u>	<u>1%</u> <u>Tomato</u>	<u>3%</u> <u>Tomato</u>	
30	Mean POAA conc. (ppm)	111.8	112.25	111.0
	Mean H <sub>2</sub> O <sub>2</sub> conc. (ppm)	65.2	65.3	64.7
35	Number of Trials	3	2	1
	Std Dev. (POAA)	0.61	0.21	--
	Std Dev. (H <sub>2</sub> O <sub>2</sub> )	0.10	0.14	--
	Active Chlorine (ppm) <sup>1</sup>	98.0	34.4	49.8

<sup>1</sup>Made from measured amounts of NaOCl concentrate added to distilled water to achieve concentration of 100 ppm [Cl].

No initial decrease in the POAA concentration was seen. This result was unexpected since POAA has been reported to react significantly with elevated levels of organic matter. For example, Poffe' et al.<sup>2</sup> reported that low levels of POAA are completely decomposed immediately after contact with solutions containing a Biological Oxygen Demand (BOD) of 170 mg. O<sub>2</sub>/liter. A 1% solution of tomatoes in water has a BOD of approximately 300 mg/l, whereas a 3% solution of tomatoes has a BOD of approximately 900 mg/l. Table 1 also shows the large loss of active chlorine when a sodium hypochlorite solution was tested.

#### Working Example 3

The following provided a set of stability experiments expanded to the use of peas, beans, and corn. Tables 2-9 show the stability of a formula which is mostly peracetic acid (with peroctanoic acid being approximately 10 wt-% of the total peracetic and peroctanoic acid content) in 1% solutions of these vegetables prepared as described for tomato solutions in Example 2. The initial concentrations were 70%, 100% and 90% of the control solutions (with no vegetable) for corn, beans, and peas, respectively. After 3 days, 31%, 47% and 32%, respectively, of the initial concentration of peracids such as POAA was left for these vegetables.

The peracids showed surprising stability in solutions comprising a high concentration of organic material.

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<sup>2</sup>"Disinfection of Effluents from Municipal Sewage Treatment Plants with Peroxy Acids", Z61. Bakt. Hyg., I. Abt. Orig. B167, 337-46(1978).

Table 2

(CONTROL)

		TOTAL PERACIDS (AS POAA)	
	<u>DAY</u>	<u>PPM</u>	<u>%REMAIN</u>
5			
10	0	18.85	100%
	1	19.76	100%
	2	18.77	100%
	3	16.80	89%

15

Table 3

(1% CORN)

		TOTAL PERACIDS (AS POAA)	
	<u>DAY</u>	<u>PPM</u>	<u>%REMAIN</u>
20			
	0	13.15	100%
25	1	8.51	65%
	2	6.16	47%
	3	4.03	31%

INITIAL PERCENTAGE OF CONTROL = 70%

30

Table 4

(1% BEANS)

		TOTAL PERACIDS (AS POAA)	
	<u>DAY</u>	<u>PPM</u>	<u>%REMAIN</u>
35			
40	0	21.36	100%
	1	17.48	82%
	2	14.36	67%
	3	9.96	47%

45 INITIAL PERCENTAGE OF CONTROL = 113%



Table 5

(1% PEAS)

		TOTAL PERACIDS (AS POAA)	
	<u>DAY</u>	<u>PPM</u>	<u>%REMAIN</u>
5			
10	0	18.09	100%
	1	12.46	69%
	2	10.41	58%
	3	5.70	32%

15 INITIAL PERCENTAGE OF CONTROL = 96%

Table 6

(CONTROL)

	<u>DAY</u>	<u>H2O2 PPM</u>	<u>%REMAIN</u>
20			
	0	10.30	100%
25	1	10.98	107%
	2	10.91	106%
	3	10.85	105%

Table 7

(1% CORN)

	<u>DAY</u>	<u>H2O2 PPM</u>	<u>%REMAIN</u>
30			
35	0	15.67	100%
	1	7.21	46%
	2	5.71	36%
	3	1.70	11%

40 INITIAL PERCENTAGE OF CONTROL = 152%

Table 8

(1% BEANS)

	<u>DAY</u>	<u>H2O2 PPM</u>	<u>%REMAIN</u>
5	0	8.84	100%
	1	3.09	35%
	2	1.63	18%
	3	1.09	12%

10

INITIAL PERCENTAGE OF CONTROL = 86%

Table 9

(1% PEAS)

	<u>DAY</u>	<u>H2O2 PPM</u>	<u>%REMAIN</u>
15	0	8.57	100%
	1	4.83	56%
	2	3.37	39%
	3	0.78	9%

20

25 INITIAL PERCENTAGE OF CONTROL = 83%

Working Example 4

Experiments testing the efficacy of POAA on molds  
 30 and bacteria showed no microbial growth at  
 concentrations of 5, 10 and 20 ppm POAA in 1% peas  
 solution. As can be seen in Figure 1, later experiments  
 show good control of molds with 10-30 ppm POAA in 1%  
 peas solution and continued rate of kill over a 3 day  
 35 period.

Working Example 5

An analysis of the invention was then undertaken in  
 the context of an actual flume delivery system. As can  
 be seen in Figure 4, a flume system comprising a make-up  
 40 tank 10, a flow line 11, a flume tank 12, an overflow

tank 14 with discharge pipe or drain 13, pumpline 15, pump 16, and recycle line 18 were assembled to model the conditions in food transport flumes used in food processing plants. The make-up water comprised 16  
5 grains/gal of  $\text{CaCO}_3$  and was introduced into the flume at a rate of 343 ml/min. A pea solution was introduced into the make-up tank 10 comprising 10% ground peas in hard water. The pea solution was diluted to 1% in the flume through a flow rate of 42.5 ml/min. Also added to  
10 the make-up water was a dirt solution comprising 3.6% top soil which was diluted to 0.3% in the flume by a flow rate of 35 ml/min. Lastly, a sanitizer was added to the flume assembly and diluted by a factor of 100 through a flow rate of 42 ml/min. The initial  
15 concentration and formulation for the sanitizers analyzed can be seen in Table 10 below.

Table 10

	<u>Working Example</u>	<u>Active/ Concentration</u>	<u>Condition</u>
5	5A	30 ppm POAA	Sterile peas
	Control 1	--	Sterile peas
	5B	NaOCl/110 ppm Cl	--
	5C	NaOCl/30 ppm Cl	--
10	5D	30 ppm POAA	Pulsed feed
	5E	40 ppm POAA	Continuous feed
	5F	3 ppm POOA* / 27 ppm POAA	--
	Control 2	--	--
15	5G	20 ppm ClO <sub>2</sub>	3.7 ml/min flow rate
	5H	1.5 ppm POOA* / 13.5 POAA	--

20 \*POOA is Peroctanoic Acid

The total flow rate in the flume was 425 ml/min with a recycle flow rate created by pump 16 of 3 gallons/min.

25 The total flume volume was 2.25 gallons with overflow discharged out of overflow tank 14 into discharge reservoir 13. Analysis for metals present in the water exiting the flume from a previous experiment gave an average of 13.4 ppm iron (Fe), 0.28 ppm copper (Cu), and 0.52 ppm manganese (Mn).

30 The results of the analysis can be seen in Table 11 and Figure 5. The average residual (col. 2) is the measured antimicrobial agent concentration taken several times per day averaged over the entire 72 hour period. The average demand (col. 3) is the difference between  
35 the dosed (Table 10, col. 2) and the averaged residual concentrations. The pH (col. 4) was also averaged over the 72 hour period, taken once every 24 hours.

The average flume counts, col. 5, were calculated from samples of flume water taken every 12 hours over the entire 72 period, and the units are CFU (colony forming units)/ml for a standard (total) plate count.

5 The average log reduction versus control (col. 6) is calculated by taken the logarithm (base 10) of the flume water counts and subtracting it from the log of the flume water counts for the control experiment. Example 5A is compared to control 1 since both used peas that

10 had been sterilized. The rest of the examples are compared to control 2. The last column, average pea counts, gives the microbial loading (CFU/ml) for the 10% pea solution held in makeup tank 10 from samples taken every 12 hours. This gives an indication of the

15 microbial loading that was being fed to the flume, in addition to the growth occurring in the flume.

Table 11

<u>Working Example</u>	<u>Avg. Residual (ppm)</u>	<u>Avg. Demand (ppm)</u>	<u>Avg. pH</u>	<u>Avg. Flume cts.</u>	<u>Avg. Log Red. vs Control</u>	<u>Avg. Pea cts.</u>
5A	14.9	15.1	7.5	1.7E+03	2.8	5.0E+04
Control 1	--	--	NA	1.0E+06		3.9E+04
5B	41	69	8.4	2.2E+04	2.0	1.2E+06
5C	19	11	8.2	4.9E+04	1.7	1.2E+06
5D	15.7	14.3	7.53	9.5E+03	2.4	2.0E+06
5E	24.1	15.9	7.4	1.5E+04	2.2	7.1E+04
5F	20	10	6.3	9.5E+03	2.4	2.3E+04
Control 2	--	--	NA	2.2E+06	--	1.4E+05
5G	0	17.5	NA	1.4E+04	2.2	1.7E+05
5H	5	10	7.2	4.0E+04	1.7	5.0E+05

Working Example 6

Following the slaughter and degutting and cleaning of poultry, the birds are placed in a chilled aqueous stream (chiller) for at least 30 minutes prior to packaging. Samples of chiller water from a poultry process plant were obtained for comparison testing dosings of peracetic acid, a combination of peracetic acid and peroctanoic acid, sodium hypochlorite and chlorine dioxide. The results are shown in Table 12. The peracetic acid sample was that as prepared from a dilution of the formula described in Working Example 1.

The peracetic acid/peroctanoic acid combination contained 27 parts per million of peracetic acid and approximately 3 parts per million of peroctanoic acid. The active chlorine was obtained from sodium hypochlorite. Treatment of the chiller water using peracetic acid or peracetic/peroctanoic acid combinations performed much better in bacteria kill than treatment of hypochlorite or chlorine dioxide.

20

Table 12

<u>Sample Concentration</u>	(CFU/ml)	<u>Log Red</u>
Untreated (Control)	$1.0 \times 10^2$	--
30 ppm POAA	<1	2.0
30 ppm POAA/POOA	<1	2.0
30 ppm [Cl]	$1.4 \times 10^1$	0.85
20 ppm ClO <sub>2</sub>	3	1.5

Working Example 7

1. Eight different peracids were prepared by mixing the following quantities of the parent acid, a 35% H<sub>2</sub>O<sub>2</sub> solution, and de-ionized water, allowing 8 days for the solution to reach equilibrium and then analyzing for peracid and hydrogen peroxide with a ceric sulfate/sodium thiosulfate titration method. (Note: All of the active peracid concentrations are reported as percent peracetic acid (POAA) to give an equivalent comparison basis and to eliminate confusion as to the distribution of peracid functionalities for the di and tri acids).

Table 13

Peracid	Parent Acid		H <sub>2</sub> O <sub>2</sub> , 35% gms	DI H <sub>2</sub> O gms	Peracid as POAA, wt%	H <sub>2</sub> O <sub>2</sub> wt%
	name, % active	gms				
peracetic	acetic, 100%	55.3	44.7	0.0	12.8	9.8
perpropionic	propionic, 100%	60.4	39.6	0.0	9.8	10.1
perbutyric	butyric, 99%	64.7	35.3	0.0	5.8	10.1
persuccinic	succinic, 99%	5.0	2.0	93.0	0.3	0.9
perglutaric	glutaric, 99%	40.0	14.6	45.4	2.7	4.4
perglycolic	glycolic, 99%	50.0	31.6	18.4	1.9	2.2
perlactic	lactic, 88%	67.8	32.2	0.0	1.4	10.5
percitric	citric, 100%	15.0	3.8	81.2	0.8	1.5

2. A solution of 1% tomatoes in water was prepared as previously described by grinding whole tomatoes in a



food processor and adding 1% by weight of the ground tomatoes to water.

3. This solution was allowed to sit at room temperature for 4 days in order to allow the bacteria to grow to levels typically seen in vegetable plant process or transport water.
4. Measured quantities of the 8 different peracids prepared in step one were added to separate vials containing 500 mls of the 1% tomato solution prepared in step 2 to reach dosed levels of each peracid ranging from 12 to 5 ppm. Each test was done in duplicate.
5. In two of the vials, no peracid was added. These vials were used as no treatment controls.

15

The results for the two duplicates from each experiment were averaged and are reported in Table 14:

Table 21 continued

Table 14

Experiment	Peracid	Dosed Concn ppm	Residual Concn ppm	1 hour		24 hours		48 hours	
				Avg Micro CFU/ml	Log Red	Avg Micro CFU/ml	Log Red	Avg Micro CFU/ml	Log Red
1	No treatment	0	0	8.60E+06	na	2.76E+07	na	3.47E+07	na
2	peracetic	48	41	<10	5.9	<10	6.4	<10	6.5
3	perpropionic	48	40	<10	5.9	<10	6.4	<10	6.5
4	perbutyric	44	36	<10	5.9	<10	6.4	<10	6.5
5	persuccinic	12	3	9.60E+06	0.0	1.95E+07	0.2	1.36E+07	0.4
6	perglutaric	35	35	3.50E+02	4.4	1.07E+03	4.4	5.20E+04	2.8
7	perglycolic	36	36	5.30E+02	4.2	<10	6.4	<10	6.5
8	perlactic	32	32	1.90E+02	4.7	1.80E+02	5.2	3.50E+02	5.0
9	percitric	50	26	7.00E+01	5.1	<10	6.4	na	na

The dosed concentration (col. 3) is the concentration of each peracid (wt/wt) after addition to the tomato solution. The residual concentration (col. 4) is the measured amount of peracid three minutes after dosing was completed. The measurement technique was again based on a ceric sulfate, sodium thiosulfate titration.

Microbial counts were measured after allowing the peracid to contact the tomato solutions at 70-75°F for 1, 24, and 48 hours. The peracids were neutralized after each time period had expired with a thiosulfate/peptone/catalase solution. The resulting solution, after serial dilutions in phosphate buffered dilution water, was incubated on tryptone glucose extract agar for 48 hours at 35°C. Total colony forming units per ml solution (CFU/ml) were then counted and are reported in col. 5, 7 and 9 in the above table. Log reductions were then calculated by subtracting the log counts of each peracid treated solution (experiments 2-9) for the appropriate time period (cols. 6, 8 and 10) from the logarithm (base 10) of the no treatment microbial counts (experiment 1). Since each test was in duplicate, the results reported are the arithmetic averages for each treatment.

The results (Table 14) show that almost all of the peracids in this study maintained a high degree of residual activity after contacting the 1% tomato solution (except experiment 5, persuccinic, which was dosed at a low initial level). This behavior is similar to that of peracetic acid and again shows the surprising

stability of these peracids in the presence of high amounts of organic matter.

The results also show (Table 14) that perpropionic, perbutyric, perglutaric, perglycolic, perlactic, and percitric acids all gave greater than 4 log reductions in microbial counts after 1 hour contact time with the 1% tomato solution. Furthermore, the level of microbial kill was maintained or increased for 24 hours (and in most cases 48 hours) for the above-mentioned peracids, indicating that residual anti-microbial activity from the peracids was also maintained over this time period.

Perpropionic and perbutyric acid performed equally to peracetic acid, while perglycolic, perlactic, and percitric acids performed almost as well. Persuccinic acid was the only peracid tested to not show high antimicrobial activity under the conditions of this test; however, it was dosed at only 12 ppm. Higher dosages of persuccinic would be expected to give much better results.

Working Example 8Microbial Kill and POAA Residual

5            Tables 15 and 16 show the need to maintain ~2-5 ppm  
residual POAA in process waters to consistently effect  
and maintain substantial ( $\geq 1.0$  log reduction) microbial  
and slime control. Below this minimal level of residual  
POAA only marginal microbial reductions occur, while  
10            substantial kill is found for POAA residuals of 5-10 ppm  
or higher. Above a residual of ~30 ppm POAA the  
economics of the treatment process fall off, so a higher  
level cutoff is necessary. Tables 15 and 16 were  
obtained from commercial flume systems and show that  
15            having a residual of  $\geq 2$  ppm POAA in a vegetable  
processing flume, 5 minutes after addition, yields  
substantial microbial reduction.

Table 15: Stream Flume Experiments

<u>Test</u> <u>Vegetable</u>	<u>Dosed</u> <u>POAA<sup>a</sup></u>	<u>5-Min.</u> <u>Residual</u> <u>POAA</u>	<u>Microbial</u> <u>Log Reductions<sup>b</sup></u>	
			<u>APC</u>	<u>Coliform</u>
corn	63 ppm	42 ppm <sup>1</sup>	3.5 <sup>1</sup>	3.6 <sup>1</sup>
corn	63 ppm	48 ppm <sup>1</sup>	4.5 <sup>1</sup>	3.5 <sup>1</sup>
corn	26 ppm	15 ppm <sup>2</sup>	2.1 <sup>2</sup>	NA
corn	13 ppm	7 ppm <sup>3</sup>	2.2 <sup>3</sup>	NA
potato	33 ppm	<1 ppm <sup>4</sup>	0.7 <sup>4</sup>	NA
potato	67 ppm	<1 ppm <sup>2</sup>	0.4 <sup>2</sup>	NA
potato	90 ppm	10 ppm <sup>3</sup>	1.0 <sup>3</sup>	NA
potato	109 ppm	30 ppm <sup>3</sup>	3.1 <sup>3</sup>	NA

A) POAA = peroxyacetic acid.

b) Versus a control sample with no POAA addition.

1) An average of 6 experimental runs.

2) An average of 3 experimental runs.

3) An average of 2 experimental runs.

4) An average of 4 experimental runs.

NA = Not available

5

10

Table 16: Batch-Flume Experiments

<u>Test</u> <u>Vegetable</u>	<u>Test</u> <u>Flume</u>	<u>Dosed</u> <u>POAA</u>	5-min. Residual <u>POAA</u>	Microbial Log Reductions	
				<u>APC</u>	<u>Coliform</u>
onion	chiller	0 ppm	0 ppm	0.0	0.0
onion	chiller	15 ppm	2 ppm	1.1	0.9
onion	chiller	30 ppm	11 ppm	2.6	2.0
tomato	dump	0 ppm	0 ppm	0.0	NA
tomato	dump	22 ppm	13 ppm	1.7	NA
tomato	secondary	0 ppm	0 ppm	0.0	NA
tomato	secondary	22 ppm	17 ppm	3.1	NA
potato	cutter	0 ppm	0 ppm	0.0	NA
potato	cutter	27 ppm	19 ppm	5.0	NA
potato	cutter	53 ppm	45 ppm	5.0	NA
potato	cyclone	0 ppm	0 ppm	0.0	0.0
potato	cyclone	53 ppm	2 ppm	3.4	4.1
potato	cyclone	80 ppm	10 ppm	4.3	4.1
potato	Trim Room	0 ppm	0 ppm	0.0	0.0
potato	Trim Room	53 ppm	50 ppm	2.8	4.1
potato	ADR flume	0 ppm	0 ppm	0.0	NA
potato	ADR flume	15 ppm	0 ppm	0.1	NA
potato	ADR flume	30 ppm	27 ppm	4.4	NA
potato	ADR flume	60 ppm	2 ppm	1.6	NA
potato	sap	0 ppm	0 ppm	0.0	NA
potato	coater 2	15 ppm	6 ppm	3.4	NA
potato	sap	30 ppm	27 ppm	4.4	NA
potato	coater 2	0 ppm	0 ppm	0.0	NA
potato	post-blancher	15 ppm	<1 ppm	2.4	NA
potato	post-blancher	30 ppm	8 ppm	3.4	NA
potato	post-blancher	60 ppm	42 ppm	4.6	NA
potato	pre-blancher	0 ppm	0 ppm	0.0	NA
potato	pre-blancher	60 ppm	0 ppm	0.0	NA
potato	pre-blancher 1	90 ppm	0 ppm	0.0	NA

Example 9ORP vs. POAA Residual

Without POAA present the background ORP tends to  
5 range from --200 to +300 mv's, depending on the pH and  
temperature of the flume system. Lower water  
temperatures skew the relative active region to a lower  
millivolt starting value; however the limits of the ORP  
controller can be adjusted to fit the new low set-point  
10 range.

It is only when a POAA residual (> 2 ppm) is  
obtained that the ORP climbs above a lower indicating  
limit to an effective - for microbial kill - ORP range  
of ~280-460 mv; i.e., these minimal POAA residuals  
15 requirements (~2-5 ppm) correlate to ~280-460 mv ORP  
units; relative to an Ag/AgCl reference electrode in  
ambient temperature water at pH's ~5-8 (Table 17). The  
unexpected results show the correlation between ORP,  
residual POAA, and microbial kill.

20 Higher ORP values are obtained with increasing POAA  
residuals; however, beyond an overage of ~30 ppm POAA  
(~370-460 mv) the excessive POAA is merely wasted since  
most of the microbial reduction occurs within the first  
30 ppm residual POAA; i.e., there exists an effective,  
25 and economic, ORP range of ~280-460 mv for controlling  
the residual POAA and microbial counts.



Table 17: ORP vs. Residual POAA vs. Micro Reduction

<u>Test Vegetable</u>	<u>Flume</u>	<u>Flume Temp. (°F)</u>	<u>Dosed POAA</u>	<u>Residual POAA</u>	<u>Flume ORP</u>	<u>Micro<sup>1</sup> Log Redn.</u>
tomato	secondary	60 F	0 ppm	0 ppm	240-310 mv	0.0 <sup>2</sup>
tomato	secondary	60 F	26 ppm	8 ppm	410 mv	2.2
tomato	secondary	60 F	30 ppm	7 ppm	420 mv	2.0
tomato	secondary	60 F	45 ppm	11 ppm	430 mv	2.8
tomato	secondary	60 F	60 ppm	41 ppm	430 mv	2.8
tomato	secondary	60 F	90 ppm	61 ppm	490 mv	NA
tomato	secondary	60 F	120 ppm	102 ppm	510 mv	NA
tomato	secondary	60 F	150 ppm	129 ppm	520 mv	NA
potato	heater	145 F	0 ppm	0 ppm	-190 mv	0.0 <sup>3</sup>
potato	heater	145 F	15 ppm	0 ppm	260 mv	0.4
potato	sorter	93 F	0 ppm	0 ppm	220 mv	0.0
potato	sorter	93 F	60 ppm	8 ppm	370 mv	3.2
potato	sorter	93 F	60 ppm	11 ppm	380 mv	3.8
onion	chiller	37 F	0 ppm	0 ppm	20 mv	0.0 <sup>4</sup>
onion	chiller	37 F	15 ppm	3 ppm	310 mv	1.1
onion	chiller	37 F	30 ppm	14 ppm	360 mv	2.6
onion	chiller	37 F	0 ppm	0 ppm	50 mv	NA
onion	chiller	37 F	15 ppm	3 ppm	300 mv	NA
onion	chiller	37 F	30 ppm	12 ppm	320 mv	NA
onion	chiller	37 F	45 ppm	22 ppm	360 mv	NA
onion	chiller	37 F	60 ppm	38 ppm	450 mv	-

1) Results obtained from continuous commercial flume operations, SPC = standard Plate

Count.

- 5 2) a baseline average micro count of  $3.2 \times 10^6$  counts/ml.  
 3) a baseline average micro count of  $1.4 \times 10^6$  counts/ml.  
 4) a baseline average micro count of  $2.3 \times 10^6$  counts/ml.  
 NA = not available

**Working Example 10**

Table 18 shows an example where using a batch sample of vegetable flume effluent and spiking with percarboxylic acid, the ORP and residual percarboxylic acid initially rise and then fall over time; simulating what would occur in an automated percarboxylic acid dosing system. However, in practice, we would not allow the final ORP - or POAA residual - to return to the background level, but would restart the run timer once the ORP reached the set lower level of the ORP controller.

Table 18: ORP and Residual POAA Decay

	Test Vegetable	Batch Dosed POAA	Residence Time	Sample ORP	Residual POAA
Test I.	tomato flume 1	0 ppm	0 (background)	240 mv	0 ppm
	tomato	22 ppm	0.1 min.	480 mv	22 ppm
	tomato	"	10 min.	460 mv	16 ppm
	tomato	"	20 min.	450 mv	15 ppm
	tomato	"	90 min.	440 mv	5 ppm
	tomato	"	140 min.	260 mv	0 ppm
Test II	tomato flume 2	0 ppm	0 (background)	290 mv	0 ppm
	tomato	22 ppm	0.1 min.	430 mv	14 ppm
	tomato	"	5 min.	430 mv	13 ppm
	tomato	"	10 min.	420 mv	12 ppm
	tomato	"	30 min.	290 mv	0 ppm
Test III	tomato flume 2	0 ppm	0 (background)	290 mv	0 ppm
	tomato	7 ppm	0.1 min.	400 mv	6 ppm
	tomato	"	5 min.	370 mv	3 ppm
	tomato	"	10 min.	360 mv	2 ppm
	tomato	"	20 min.	310 mv	0 ppm
Test IV	potato flume 1	0 ppm	0 (background)	180 mv	0 ppm
	potato	30 ppm	0.1 min.	390 mv	6 ppm
	potato	"	1 min.	370 mv	4 ppm
	potato	"	3 min.	330 mv	1 ppm
	potato	"	5 min.	220 mv	0 ppm
Test V.	potato flume 1	0 ppm	0 (background)	160 mv	0 ppm
	potato	60 ppm	0.1 min.	400 mv	38 ppm
	potato	"	1 min.	380 mv	22 ppm
	potato	"	5 min.	370 mv	6 ppm
	potato	"	10 min.	240 mv	0 ppm
Test VI	onion flume 1	0 ppm	0 (background)	300 mv	0 ppm
	onion	60 ppm	0.1 min.	460 mv	28 ppm
	onion	"	5 min.	380 mv	15 ppm
	onion	"	10 min.	310 mv	5 ppm

Working Example 11

Table 19 shows actual field test data accumulated - at a potato production plant - over a series of test periods using the disclosed ORP dispensing system. The system was run continuously for the treatment times shown, with microbial testing of 4 to 8 samples taken per day. The data shows the ability to continuously reduce the microbial populations in the flume waters substantially over the control test. The tests also verify the ORP dispenser to work under actual field conditions where millions of pounds of produce are being run.

**Table 19: Field Trial of the ORP System**

E X P #	Treatment Time & Temp. (hours & °F)	Treatment Tests	Approximate Treated Produce Amount (lbs/ experiment)	Peroxyacetic Acid Levels (ppm)		Process Water Microbial Levels (log- reductions <sup>1</sup> )	
				Dosed	Residual	APC <sup>2</sup>	Coliform
1	55 h., 90°F	non (control) <sup>3</sup>	2.4 MM lbs fries	0 <sub>(control)</sub> <sup>3,4</sup>	0 <sub>(control)</sub> <sup>3,4</sup>	0 <sup>4</sup>	0 <sup>4</sup>
2	2h., 90°F	POAA	1.6 MM lbs fries	11.5 ml/min	12 ppm	4.5	4.4
3	24h., 90°F	POAA	1.6 MM lbs fries	NA ml/min	30 ppm	4.0	3.9
4	12h., 90°F	POAA	1.6 MM lbs skins	20.0 ml/min	60 ppm	6.0	5.2
5	31h., 90°F	POAA	1.6 MM lbs fries	10.0 ml/min	4 ppm	0.9	0.2

- 15 1) An average over the experiment run time using 4-8 daily microbial samplings.  
 2) APC = Aerobic Plate Count.  
 3) Control experiment with no additives.  
 4) The actual background (control) plate counts were SPC=9.9 x 10<sup>7</sup> and  
 20 coliform=1.5 x 10<sup>5</sup>.  
 NA = not available.

## WE CLAIM:

1. An automated method of controlling microbial growth in an aqueous stream used for transporting or processing food products and packaged foods comprising  
5 treating said aqueous stream with an effective antimicrobial amount of percarboxylic acid, said amount controlled by maintaining said aqueous stream at an oxidation-reduction-potential (ORP) between about 280 to about 460 mv with respect to an Ag/AgCl reference  
10 electrode.
2. The method of claim 1, wherein said percarboxylic acid in said aqueous stream is maintained at a residual concentration of at least about 2 ppm.  
15
3. The method of claim 1, wherein said percarboxylic acid comprises a C<sub>2</sub>-C<sub>12</sub> percarboxylic acid.
4. The method of claim 1, wherein said carboxylic  
20 acid comprises peracetic acid.
5. The method of claim 1 additionally comprising hydrogen peroxide.
- 25 6. The method of claim 5 wherein the hydrogen peroxide is present in an initial concentration ranging from about 5 ppm to 50 ppm and the percarboxylic acid is present in an initial concentration ranging from about 2 ppm to 100 ppm in the aqueous stream.  
30
7. The method of claim 1 comprising the steps of:

initially charging a percarboxylic acid to said aqueous stream until an oxidation-reduction-potential (ORP) of at least 280 mv with respect to an Ag/AgCl reference electrode is reached, and

5 allowing a continual addition of percarboxylic acid to the aqueous stream wherein the addition is controlled by an ORP controller set between about 280 and 460 mv with respect to an Ag/AgCl reference electrode.

FIG. 1

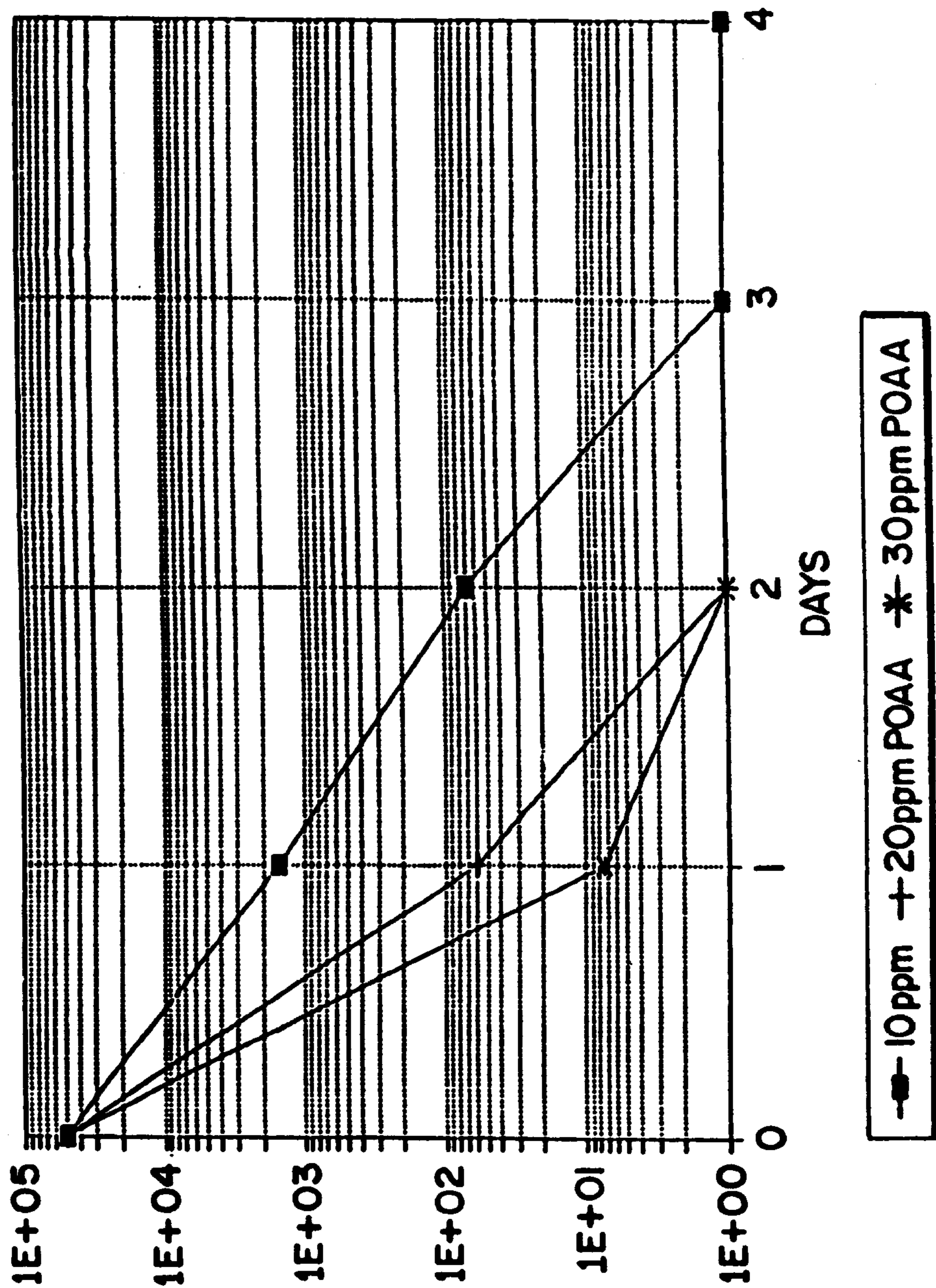
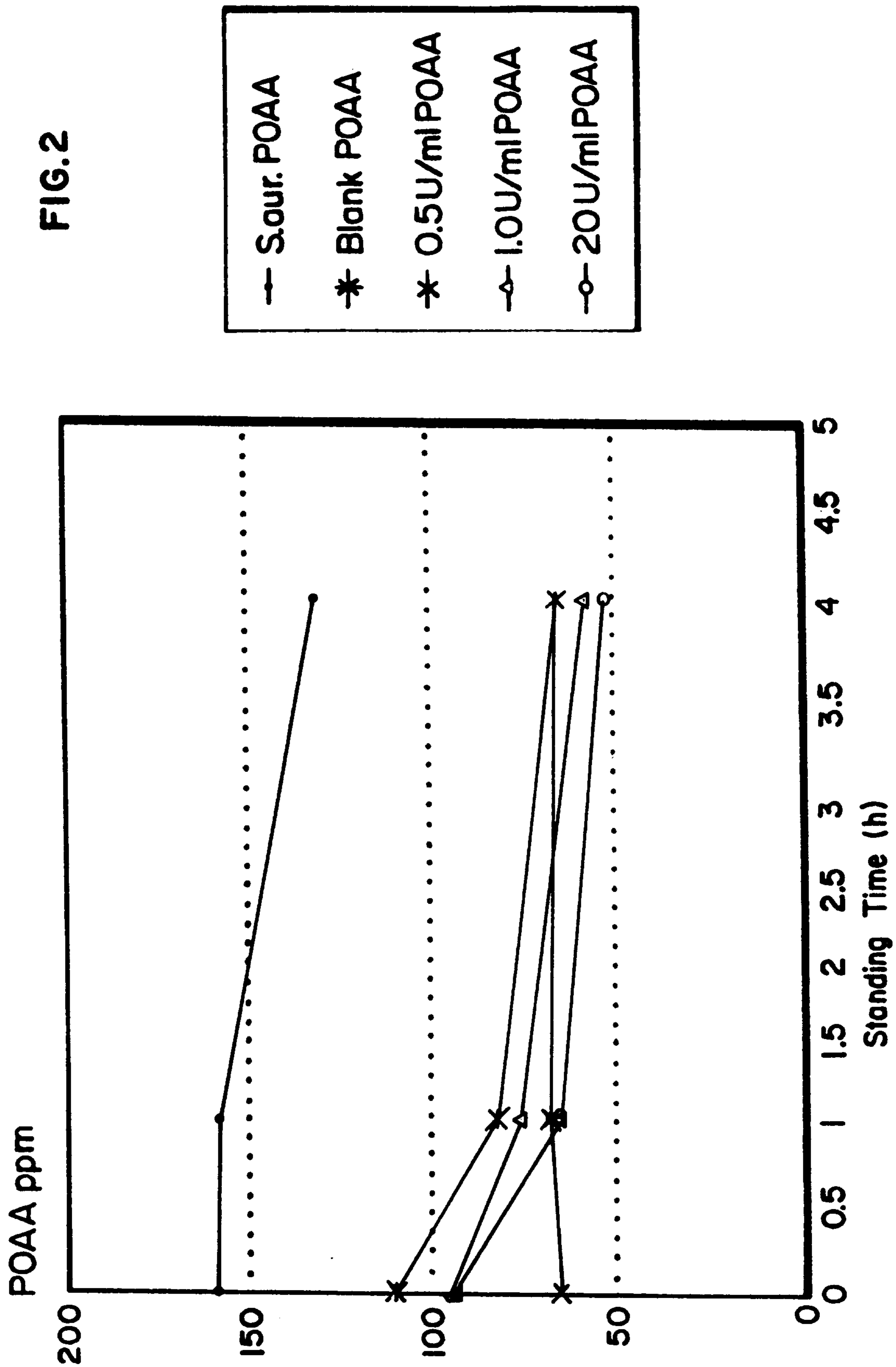
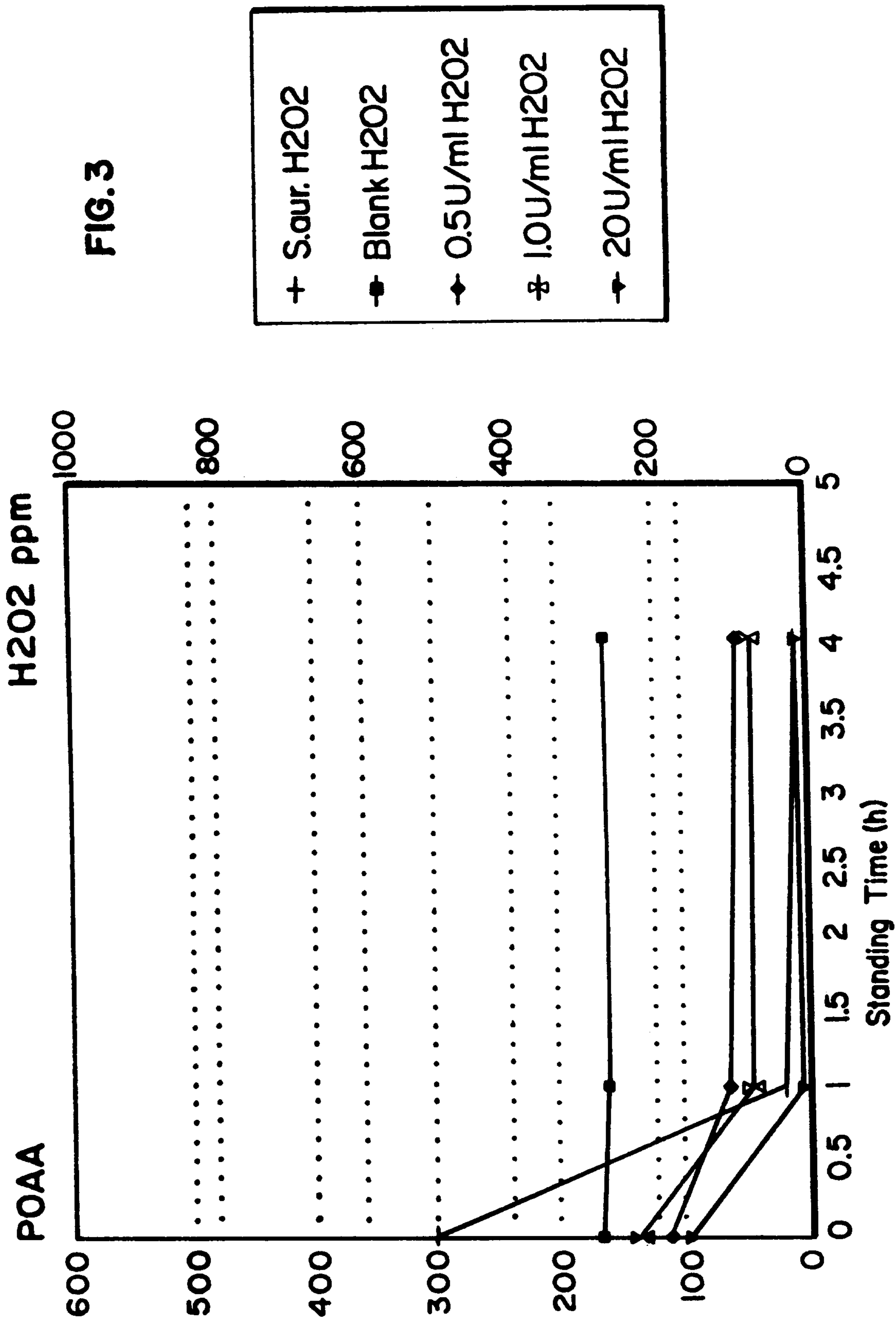


FIG.2







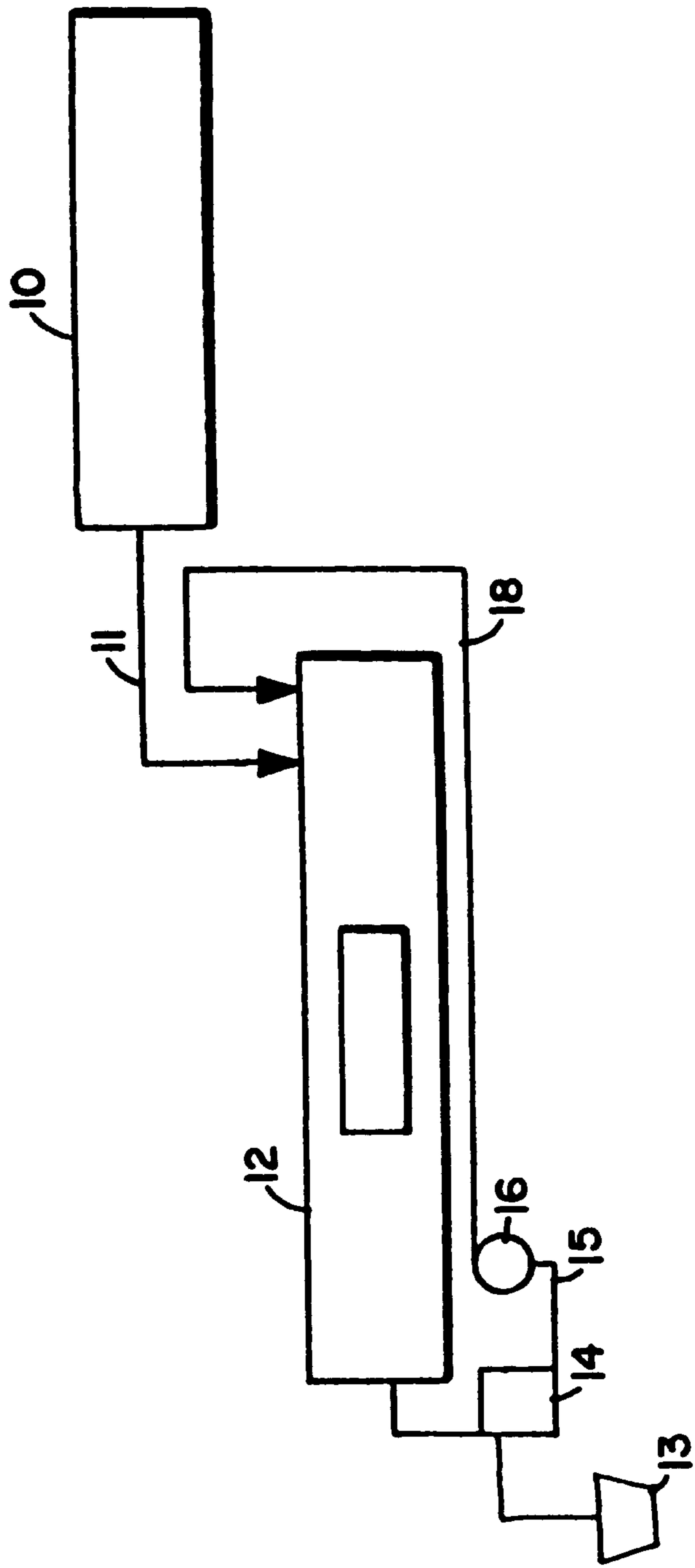


FIG. 4



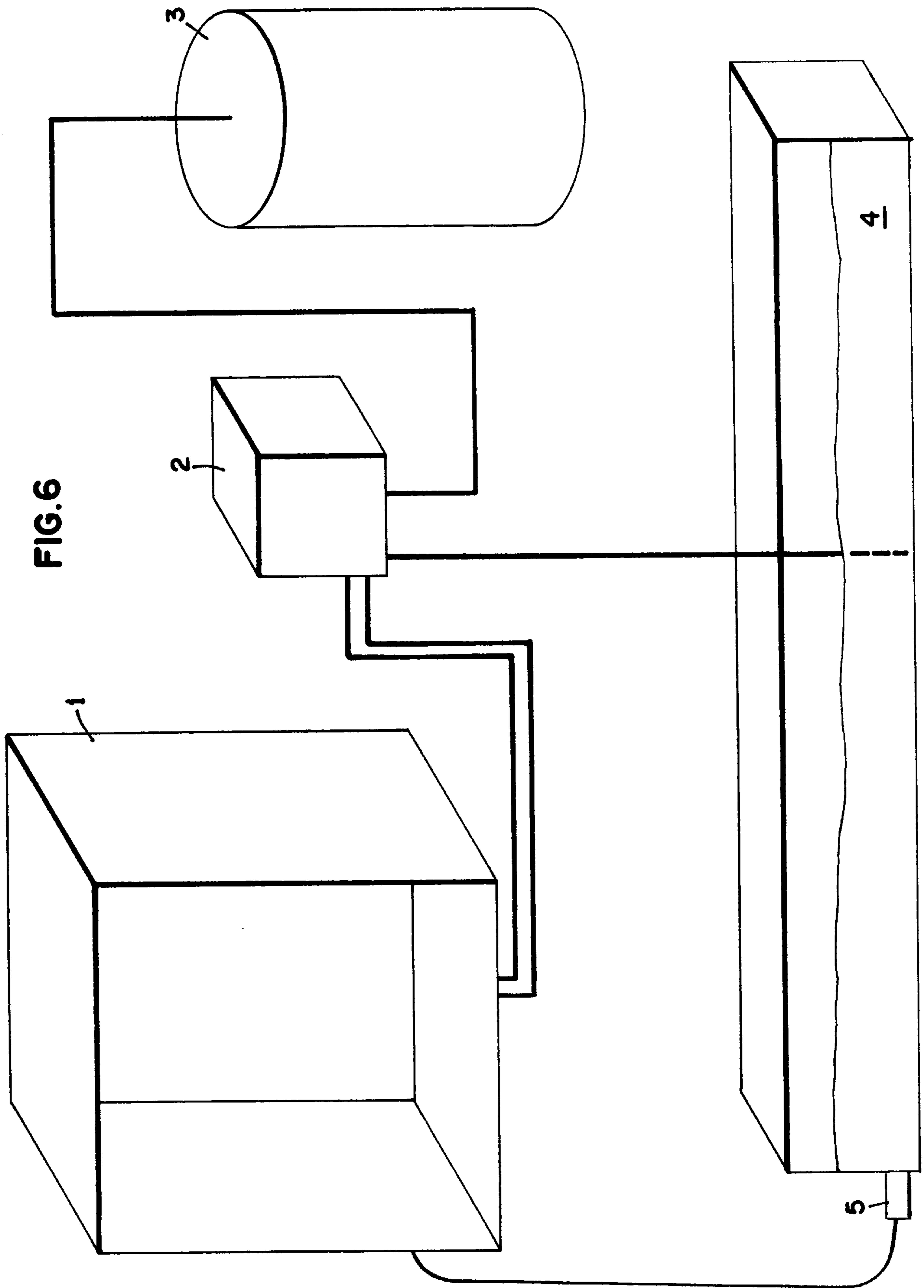


FIG. 6

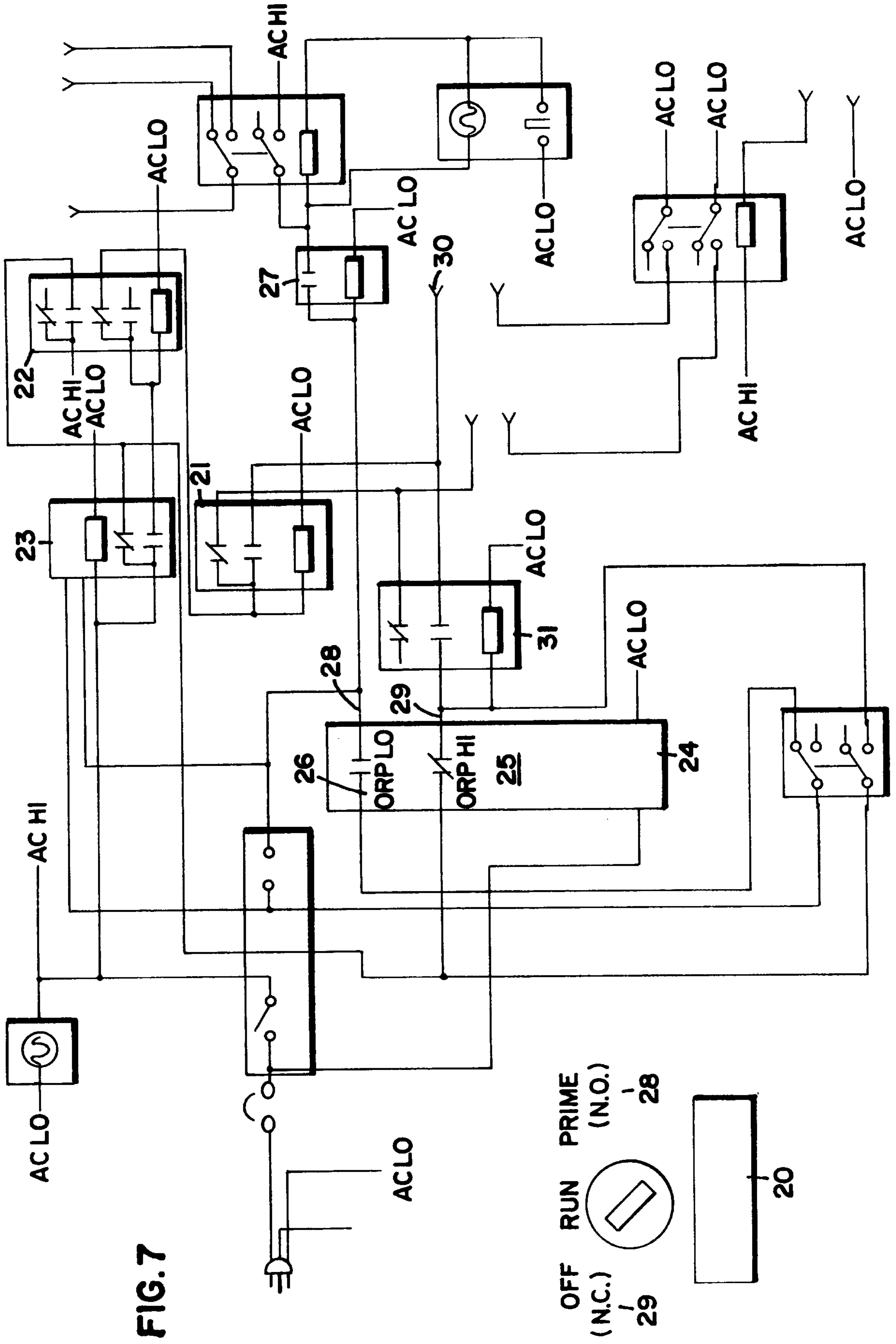


FIG. 7

OFF RUN PRIME  
(N.C.) 29 (N.O.) 28

