

**Method and apparatus for providing electric current into an
object or medium.**

FIELD OF INVENTION

The present invention relates to the field of providing and/or inducing electric current into an object or medium. Specifically, the electric current is used to influence, kill, inhibit movement or stun the object or one or more organisms in the medium.

The present invention has many applications, some of which (without limitation) are detailed herein including marine or ship applications, aquaculture industry applications, waste treatment applications and any other applications where the treatment of fluid is required.

In one form, the invention relates to inducing an electric voltage field or current into a medium, such as fluid, for example water, bodily fluids or food and related products.

In another form, the present invention relates a means and/or a method by which an electric voltage field or current can be delivered to a remote object.

In a specific form of application, the present invention relates to what is termed 'bio-fouling', in which pipes and other fluid conduits become constricted or even blocked by organisms present in the medium flowing through the conduits. For example, pipes or water storage (such as ballast) internal of a vessel, ship or submarine may become constricted by organisms present in seawater. The present invention relates to alleviating or preventing bio-fouling and invasive species transport.

In another specific form, the present invention relates to inducing a current into a medium being a relatively 'non-contact' form of delivery of electric voltage field or current into the medium. For example, current is delivered into the medium without the need for electrodes being in direct contact with the medium.

It will be convenient to hereinafter describe the invention in relation to inducing an electric voltage field or current into conduits for the purpose of alleviating bio-fouling, however it should be appreciated that the present invention is not limited to that use only. The term 'BioBlock' is the name given to the method and/or device which is the subject of this specification.

BACKGROUND ART

The inventors have realised that the fouling and subsequent occlusion of ships' pipework by marine organisms such as barnacles and mussels causes failure of seawater cooling and fire-fighting systems. A further, and more global environmental problem caused by shipping is that various organisms can be transported from one country to another in a ship's ballast water. When a ship is being loaded or unloaded, the ship discharges or intakes respectively seawater so as to maintain sea keeping stability. The result of this is transportation of marine organisms and species from port to port and country to country has been found to have potentially devastating effects on the environment and the mariculture industries.

The inventors have realised that there are a variety of ways of dealing with bio-fouling which have been proposed in the past. The idea of using pulsed electric fields or currents to kill biological cells and in particular potential marine biofoulants is not new. For example, there are two papers, namely

1. Amr, A. G. and K. H. Schoenbach (2000). "Biofouling prevention with pulsed electric fields." IEEE Transactions on Plasma Science 28(1): 115-21, and
2. Block, R., F. Leipold, et al. (2001). "Pulsed electric field based antifouling method for salinometers." PPPS-2001 Pulsed Power Plasma Science 2001. 28th IEEE International Conference on Plasma Science and 13th IEEE International Pulsed Power Conference. Digest of Papers (Cat. No.01CH37251). IEEE. Part vol.2, 2001: 1146-9 vol.

The disclosures, however, whilst having been shown to work experimentally, have been found by the inventors to be not practical on a larger scale, such as in application to ships or for other general use applications. For example, electrodes are provided on the pipes through which water flows and are used to make electrical contact with the water and to provide a current flow into the water. The electrodes are spaced some 1.5mm to 1 cm apart and are thus applicable to pipes of only similar small diameters. The voltage imparted across the electrodes is in the order of 8kV/cm. Thus, in order to be applicable to larger pipes, many hundreds of thousands of volts would be need. This creates safety concerns, particularly when such large voltages are used in conjunction with a

conductive medium such as seawater. There are also difficulties in generating and switching such large voltages, as well as electrode degradation and ionic liberation at the electrodes.

Other problems exist in the aquaculture industry. The inventors have realised that the future of the aquaculture industry largely depends on easy access to natural resources, such as space, water and fish meal for animal feed. Other problems pertain to the number of different viral diseases that are causing widespread concern in the European aquaculture industry. For example, Infectious Salmon Anaemia (ISA), which is a devastating disease encountered by Atlantic salmon and has had cases reported in Scotland, Norway and Canada.

Under EU legislation, the disease is regarded as exotic to EU waters. Immediate clearance of fish is required when the disease is confirmed and a raft of controls is put in place when the disease is suspected. Those include movement restrictions on fish, equipment, material and personnel, the disinfection of nets, and fallowing. Zones are created around suspect and confirmed sites and broadly similar controls are applied to non-infected farms located in those zones, depending on the assessment of risk.

Under EU guidelines, blood and offal water from the infected stock must be treated before discharge. Other virulent diseases include Viral Haemorrhagic Septicaemia and Infectious Pancreatic Necrosis. These diseases tend to be largely found in wild populations of the trout and salmonoids, and generally result in high mortality rates. Maintaining a feedwater supply that is of a very high standard as well as ensuring that no wild stocks enter the farm is therefore an important objective.

The concept of inducing an electrical current in a conducting fluid by magnetic induction was first conceived by the present inventor in the mid 1970s.

Any discussion of documents, devices, acts or knowledge in this specification is included to explain the context of the invention. It should not be taken as an admission that any of the material forms a part of the prior art base or the common general knowledge in the relevant art in Australia or elsewhere on or before the priority date of the disclosure and claims herein.

An object of the present invention is to provide an improved method and device adapted to deliver electrical current into a conducting medium.

A further object of the present invention is to alleviate at least one disadvantage associated with the prior art.

SUMMARY OF INVENTION

The present invention, in one inventive aspect magnetically induces an electric voltage field or current in a conductive medium (such as seawater) without the use of electrodes and without producing any external electric field.

The invention also provides, in another inventive aspect, a method and/or apparatus for inducing, without electrical contact (i.e. with complete galvanic isolation), and preferably without the generation of an external electric field, an electrical current in a conducting fluid.

Furthermore, the invention provides, in a further inventive aspect, a method and apparatus for inducing, without electrical contact (i.e. with galvanic isolation), and (preferably) without the generation of an external electric field, an electrical voltage gradient within a fluid or other medium.

In essence, the present invention provides a method and/or device which is adapted to produce a voltage gradient in a conductive medium so as to influence, kill or stun biological entities in the medium.

Research indicates that some organisms may be affected by the electrical current density within the fluid in which they exist. Other organisms may alternatively be affected by the voltage gradient within their medium. The physical size of the organisms may be an influencing factor on the magnitudes required in order to put the present invention into effect.

To treat a relatively non conducting medium, for example freshwater, the invention in one aspect, provides a method and/or apparatus for applying any desired voltage gradient by manipulation of the applied voltage and the number and distribution of multiple transformer cores. This treatment is considered to be relatively inexpensive as it would involve minimal power loss in the medium.

To treat a relatively conducting medium, for example seawater or blood, the invention provides, in one aspect, a method and/or apparatus for applying any desired current density by manipulation of the applied voltage and the number and distribution of multiple transformer cores. As power usage is proportional to the product of applied voltage and current, the geometry of the invention may also be adjusted to accommodate the electrical capacity of the power electronics.

Other aspects and preferred aspects are disclosed in the specification and/or defined in the appended claims, forming a part of the description of the invention.

Additional inventive aspects concern:

- 5 • the physical construction of the magnetic and electric circuits, particularly having the conductive medium (in a conduit) as the secondary of a transformer,
- the distributed primary windings on distributed magnetic cores to prevent emanating electric or magnetic fields and
- 10 • increasing the effective voltage induced in the medium secondary winding,
- in relation to seawater and conducting fluid applications, a single seawater secondary winding so as to achieve the required electric voltage and current density,
- the electrical symmetry and scalability of the present invention, and
- 15 • the influencing, killing or stunning of an organism as it passes through a fluid conduit with substantially no radiating external electric field.

The device of the present invention, in one application, may be fitted to ships and port infrastructures to sterilise the seawater used for ship cooling, fire-fighting and ballast.

- 20 Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become
- 25 apparent to those skilled in the art from this detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

- Further disclosure, objects, advantages and aspects of the present application may be better understood by those skilled in the relevant art by reference to the following description of preferred embodiments taken in
- 30 conjunction with the accompanying drawings, which are given by way of illustration only, and thus are not limitative of the present invention, and in which:

Figure 1 illustrates prior art, the presence of a magnetic field surrounding an electrical current flow in a wire,

Figure 2 illustrates prior art, the presence of a magnetic field surrounding an electrical current flow in a coil,

5 Figure 3 illustrates prior art, magnetic flux in a magnetic core,

Figure 4 illustrates a prior art transformer,

Figure 5 illustrates prior art, magnetic flux of a transformer under load,

Figure 6 illustrates an example of the components of one embodiment of the present invention,

10 Figure 7 illustrates an embodiment of the present invention,

Figure 8 illustrates another embodiment of the present invention,

Figure 9 illustrates the block diagram of the BioBlock invocation of this invention, and

Figure 10 illustrates the types of voltage/current waveforms applied to the
15 conducting medium to achieve desired efficiencies and efficacies.

DETAILED DESCRIPTION

By way of background, the present invention has come about by the inventor looking at an alternate solution to the prior art problems. The alternate solution stems from some further developments made to some relatively well
20 known electrical theory.

In this regard, the inventor has realised that, with reference to Figure 1, it is known that there is the presence of a magnetic field surrounding electric current flowing in a wire. The iron filings become magnetically polarised by the magnetic field and align "head to tail" or more appropriately "pole to opposite pole". In
25 performing this alignment, the filings form circular patterns and thus illustrate the presence of the magnetic field surrounding the current.

The inventor has further realised that, with reference to Figure 2, if the wire from Figure 1 were to be formed into a cylindrical coil and threaded through a piece of cardboard as shown in Figure 2, the iron filings would form patterns
30 similar to the dotted lines shown in Figure 2 and which indicate the presence and shape of the magnetic field accompanying an electric coil.

The inventor has still further realised that, with reference to Figure 3, by adding a magnetic core to the coil, as shown in Figure 3, the magnetic flux is

increased considerably. For example, if the magnetic core is made from high permeability steel, the magnetic flux density may be increased by as much as 100,000 times than without the core. The magnetic permeability of a magnetic core represents the increase in magnetic field above that which would be
 5 produced without the core.

The inventor has still further realised that, with reference to Figure 4, by adding a second coil N_2 to the magnetic core, a transformer is formed. A transformer is, in essence, a magnetically coupled set of electric coils, N_1 and N_2 as depicted in Figure 4. If an 'ac' voltage is applied to one coil N_1 , the alternating
 10 magnetic field in the core will induce a voltage, preferably an ac voltage, in the second coil N_2 . Note that there is no electrical connection between the two coils N_1 and N_2 ; the voltage in the second coil N_2 is produced entirely and exclusively by the expanding and collapsing magnetic field caused by the alternating current in the first or primary coil N_1 . If each coil has, for example, five turns of wire each,
 15 and, say, 10 V is applied to the primary coil N_1 , then 10 V will be induced and so measured on the secondary coil N_2 . If the secondary winding N_2 is increased to 10 turns, whilst the first N_1 remains at 5 turns, then there is a 1:2 ratio between the coils N_1 and N_2 and the result will be that 20 volts will be induced and measured on the secondary N_2 .

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$$\text{Thus } \frac{V_1}{V_2} = \frac{N_1}{N_2} \quad \text{or } V_2 = \frac{N_2}{N_1} V_1$$

The inventor has still further realised that, with reference to Figure 5, by adding a load R_L to the secondary coil N_2 causes a current I_2 to flow through the
 25 load R_L and the secondary coil N_2 which produces a magnetic flux (secondary flux) in opposition to that caused by the primary current (primary flux).

The present inventor has made a further advance in that by making the primary coil from wire but making the secondary coil from a circuit of an electrically conducting medium, such as seawater (in application of the present
 30 invention to ships, for example) which medium then acts as both as the secondary coil as well as the load, electrical current can be induced into the conducting medium without the need for direct electrical contact with the conducting medium.

The present inventor has made still a further advance by forming the secondary from a limited number of turns of the secondary winding. Preferably, the secondary includes a single winding of the non-conductive pipe (conduit) carrying the conductive medium. The medium itself, inside the insulating pipe
5 forms the 'load' into which the electric voltage field/current is induced. Thus, in application to marine environments, the water may be seawater, which is conductive. In other applications, the medium may be another fluid.

Figure 6, illustrates one component embodiment of this advance. The primary winding, or windings, 1 are provided around a core 2. The secondary
10 winding 3 is shown in cross section where it passes through the core. An example of the secondary 'winding' is shown in the piping configuration 4.

Figure 7 further illustrates this embodiment of invention. The pipe providing a flow path 5 for the conductive medium 6 passes as a secondary winding 3 proximate the core 2. A first primary 7 and a second primary 8 are
15 provided in opposing configuration. In this way, external electric fields generated by the windings cancel each other as they are arranged in opposing fashion.

Voltage is applied to the first and second primary 7, 8, and a current is induced into the conductive medium 6 as it passes through the secondary winding 3. The voltage, and resulting current is preferably pulsed, and timed in a
20 manner that each 'section' or volume of conductive medium passing through the secondary winding is induced with the current created. Voltage and timing is applied in the present invention and induced current is created sufficient to influence, stun or kill organisms in the conductive medium.

It has also been advantageously found that in using the present invention,
25 it may be sufficient to simply influence and / or stun an organism so that, for example, it is unable to attach itself to the interior of piping in the time it takes the organism to travel through the piping and be exhausted. For applications such as food sterilisation, however, it will be necessary to attain a level of effective killing of organisms.

30 Obviously, various currents, voltages and timings can be used depending on the result to be obtained. For example, in a marine application, it is desirable to kill or stun barnacles and the like. For this, a particular voltage may be applied

to the primary, resulting in a particular voltage gradient and hence a particular current density induced into the seawater.

Together with this, the inventor has made yet a further advance in providing multiple primary windings in association with the single secondary winding. The electric current in the seawater which, when sufficiently high, kills the biofoulants is limited by the resistance of the seawater loop. The secondary voltage is effectively increased by the multiple primary and single secondary winding, providing a form of step-up configuration.

Figure 8 illustrates a preferred form of the present invention which includes a number of primaries. This embodiment may be used on, for example, the cooling conduits used to provide cooling fluid to a ship's engine. As the seawater or conductive medium enters the present invention, its path is split, with some of the seawater passing the first primaries 7 and some other seawater passing the second of the primaries 8. The region 3 and the entire water loop secondary forms the secondary loading of the invention to which current is induced.

The piping of the secondary is preferably electrically non-conductive, such as PVC tubing.

Figure 9 illustrates a driver circuit according to one embodiment of the present invention. An AC power supply 9 provides power to a High Voltage supply 10. The voltage supply may be of the order of 1000V to 2000V for a marine application. A pulse former 11 of suitable circuitry, together with a timer 12 and driver circuitry 13 is employed to deliver a pulse of energy to the primary 7 and 8. The conductive medium 3 & 6 in the pipe forms the secondary.

Figure 10 illustrates a preferred timing pulse for the present embodiment. A number of pulses 14 of approximately, depending on the application of the invention, preferably 700 nanoseconds duration is used in the marine application. One or more pulses may be used depending on the degree of current that is to be induced into the conductive fluid. For example, a delay of 8 to 10 milliseconds may be provided between pulse(s), or pulse trains, depending on the rate of flow of fluid in the pipe, and the application of the invention. Many researchers have examined the effect of electrical pulses on various forms of aquatic and other biological species. It is well-known and supported by the literature that electrical pulses of the correct magnitude will kill several forms of marine life which are

representative of biofouling organisms. Suitable pulses may be induced into the conductive medium depending upon the application to which the present invention is applied.

The magnetic core of the present invention may be made of various materials, such as: steel, metallic alloys, ferrite or amorphous alloys (glassy metal).

The applications of the present invention are many, including, without limitation:

- Inducing current into a medium, such as fluid, for example water or food and related products,
- 10 • The favourable processing or sterilisation of food in which organisms are influenced, killed or stunned by the current delivered by the present invention,
- The treatment of water, such as drinking water and/or water used in industrial processes, such as use in relation to cooling towers, and the like,
- 15 • where (otherwise) Legionella bacteria and other similar organisms may grow,
- A means and/or a method by which current can be delivered to a remote object, such as in relation to tasers, used in delivering electric current to living organisms, such as animals and humans,
- 20 • Various medical applications, in which the delivery of current is used in surgery and other medical treatments,
- In pipes or water storage (such as ballast) internal of a vessel, ship or submarine may become constricted by organisms present in seawater. The present invention relates to alleviating or preventing bio-fouling and species transport,
- 25 • In the treatment of fluid storage vessels and sites, such as containers, tanks, dams, irrigation systems and the like. The present invention may be used in conjunction with a fluid transfer system in which water from a dam or storage container having algae or other unwanted organisms is treated
- 30 • either prior to delivery of the water to another dam or container, or returned to the original container or dam.
- Sterilization of drinking water from diseases such as cholera.

While this invention has been described in connection with specific embodiments thereof, it will be understood that it is capable of further modification(s). This application is intended to cover any variations uses or adaptations of the invention following in general, the principles of the invention and including such departures from the present disclosure as come within known or customary practice within the art to which the invention pertains and as may be applied to the essential features hereinbefore set forth.

As the present invention may be embodied in several forms without departing from the spirit of the essential characteristics of the invention, it should be understood that the above described embodiments are not to limit the present invention unless otherwise specified, but rather should be construed broadly within the spirit and scope of the invention as defined in the appended claims. Various modifications and equivalent arrangements are intended to be included within the spirit and scope of the invention and appended claims. Therefore, the specific embodiments are to be understood to be illustrative of the many ways in which the principles of the present invention may be practiced. In the following claims, means-plus-function clauses are intended to cover structures as performing the defined function and not only structural equivalents, but also equivalent structures. For example, although a nail and a screw may not be structural equivalents in that a nail employs a cylindrical surface to secure wooden parts together, whereas a screw employs a helical surface to secure wooden parts together, in the environment of fastening wooden parts, a nail and a screw are equivalent structures.

"Comprises/comprising" when used in this specification is taken to specify the presence of stated features, integers, steps or components but does not preclude the presence or addition of one or more other features, integers, steps, components or groups thereof."

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A transformer configuration including:
 - a primary winding
 - 5 a secondary winding
 - a magnetic corewherein the secondary winding is a conductive medium within a non-conductive conduit.
- 10 2. A configuration as claimed in claim 1, wherein the conductive medium is a fluid or a multiphase slurry.
3. A configuration as claimed in claim 1 or 2, wherein there are a plurality of primary windings.
- 15 4. A configuration as claimed in claim 1, 2 or 3, wherein there is only one secondary winding
5. A configuration as claimed in claim 1, 2 or 3, wherein at least 2 secondary
20 windings are provide in parallel.
6. A configuration as claimed in claim 4 or 5, wherein the number of turns in the secondary winding is only one.
7. A configuration as claimed in claim 4 or 5, wherein there are a plurality of
25 turns in the secondary winding.
8. A configuration as claimed in any one of claims 1 to 7, wherein the windings are disposed to substantially reduce or provide negligible radiating external electric field.
- 30 9. A configuration as claimed in any one of claims 1 to 7, wherein the windings are disposed to substantially provide a relatively high radiating external electric field.

10. A transformer including the configuration of any one of claims 1 to 9.
11. Apparatus adapted to apply electrical current to organisms in a conductive medium, the apparatus including:
- 5 the configuration as claimed in claim any one of claims 1 to 9,
a conduit adapted to provide a medium operative as the secondary winding, and
electrical supply means adapted to deliver electrical energy to the primary winding.
- 10 12. Apparatus as claimed in claim 11, wherein the medium is a conductive medium.
13. Apparatus as claimed in claim 11 or 12, wherein the electrical energy is
15 delivered in galvanic isolation of the conductive medium.
14. Apparatus as claimed in claim 11, 12 or 13, wherein the apparatus provides a voltage gradient to the medium.
- 20 15. Apparatus as claimed in any one of claims 11 to 14, wherein the apparatus provides an electric current to the medium.
16. Fluid treatment apparatus including an apparatus as claimed in any one of claims 11 to 15.
- 25 17. A boat or ship including the apparatus as claimed in claim 16.
18. Apparatus as claimed in claim 16, being for the treatment of fluid in the aquaculture industry.
- 30 19. A method of configuring a transformer to applying electrical current to organisms in a conductive medium, the method including the steps of:
providing a primary winding
providing, as a secondary winding, the conductive medium.

20. A method of applying electrical energy to organisms within a conductive medium, the method including the steps of:

providing a transformer configuration as disclosed herein,

5 inducing into the conductive medium, at least one pulse of electrical energy by applying electrical energy to the primary of the transformer.

21. A method as claimed in claim 13, wherein the method is used to influence or stun organisms.

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15. A method as claimed in claim 13, wherein the method is used to kill organisms.

16. A method as herein disclosed.

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17. An apparatus and/or device as herein disclosed.