Title of Innovation:
ElMag: Ultra Low Frequency (ULF)

Category:
Other: ULF Electromagnetic Waves

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Date of Innovation:
January 2011

Brief Summary:
The ElMag system is the latest technology offered to conventional cathodic protection users and it utilizes our own Ultra Low Frequency (ULF) technology for effective corrosion protection. This is done through the passing of a protective current and the formation of a self-regenerating layer of magnetite on the submerged/buried steel structure. The ElMag system is capable of achieving the full Corrosion Protection International Acceptance Criteria of -800mV (potential reading against an Ag/AgCl reference electrode) with the following benefits:
- Simple and cheaper installation/retrofit, operation, and maintenance
- No divers required
- No consumable electrodes used
- Low current drawn by system
- No coatings required due to presence of self-regenerating magnetite layer
- One point monitoring of equipment condition
- Lightweight system
- Environmental friendly
- Effective in both freshwater and seawater applications
Title of Innovation:
ELMag: Ultra Low Frequency (ULF) Electromagnetic Waves for Corrosion Protection at Submerged and Buried Steel Structures in Sea or Freshwater Applications

Full Description:

When and how was it developed?
The ELMag system is developed in January 2011 by our own group of researchers and scientists.

How does it work, in basic terms?
In general, the ELMag system consists of a power unit, direct excitation (Dx), and supplementary (S) emitters. The power unit generates ultra-low frequency (ULF) electromagnetic waves in a specific range. The Dx emitter pair is mounted directly on the steel surface to transmit ULF energy and give direct steel excitation effect, triggering the formation of magnetite (Fe₃O₄). The S. emitters serve as supplementary emitters to enhance the corrosion protection by forming a protective current. Both the Dx and S emitters work together to give the ideal corrosion protection system.

How or why is the innovation unique?
The ELMag system works like a two in one system—it protects the system against corrosion via the protective current generated via the supplementary emitters and at the same time forming a self-regenerating magnetite layer on the structure surface, which acts similar to a coating layer. Magnetite is usually formed under high energy conditions (high temperature, pH, and pressure). However with our patented ultra low frequency (ULF) electromagnetic wave excitation, magnetite formation is promoted and can be formed at low energy level even at normal seawater temperatures and pH conditions. Given sufficient time for energizing, magnetite will form on the submerged steel surface or underneath the coating if the submerged steel is coated. This black magnetite is hard, dense, and strongly adhering to the steel and protects the submerged steel from further corrosion. Critically, magnetite does not exfoliate (expand away) from the steel surface and controls further oxidation of the underlying steel. Besides the formation of magnetite layer, protective calcareous layer may also form on top of magnetite layer if sufficient high protection potential is maintained. ELMag also offers a green solution to corrosion since there are no consumables involved unlike conventional cathodic protection systems where harmful metal or chemicals are being discharged into the water.
What type of corrosion problem does the innovation address?
Electrolytic corrosion—submerged/buried sea structures in sea/freshwater applications.

What is the need that sparked the development of the innovation?
We have observed that related industries that are subscribing to the conventional solutions for electrolytic corrosion have a need for a simpler and cheaper installation process, lower operational/maintenance cost, more safety, and environmentally friendliness.

Are there technological challenges or limitations that the innovation overcomes?
In many large seawater systems, it is not uncommon to use the impressed current cathodic protection systems to widen the disparity of the electrode potentials. However some fall backs that this method encounters in most cases include high electricity consumption, large stray currents causing interference damage to neighboring structures, and a large chance of premature breakdown. In all these, ElMag overcomes these issues through lower power consumption.

What are the potential applications of the innovation?
Potential applications include (not limited to):
- Jetty and loading terminals steel piles
- Steel sheet piles quay walls
- Floating docks and dock gates
- Offshore oil platforms and rigs
- Wind farms foundation steel piles
- Pipeline internal corrosion protections
- Condenser end box protection

How does the innovation provide an improvement over existing methods, techniques, and technologies?
Unlike the traditional cathodic protection method for corrosion control, the ElMag system offers a simpler and cheaper installation process since we do not require any divers or paint coatings for typical installments. In addition, our system weighs only a fraction of the sacrificial anode system. At times of operation, the current drawn by the ElMag system is lower than that of a conventional CP system. With the formation of magnetite, this current drawn will become lower with time and will stay low due to the self-repairing nature of the nonporous layer (hence reducing exposed steel surface area). This too can aid in reducing human exposure to high straying currents generated typically by impressed current systems. Maintenance wise, ElMag does not require any electrode replacements since our materials are all nonconsumable and no touch up of paint coatings are required since our magnetite layer is self-generating.
The ElMag system does not release any metal discharges or ions into the water since we do not work typically like the CP system. This too will make the ElMag system a more environmental friendly product.
The ElMag system is an excellent match and provides the synergy effect to a depleting sacrificial anode system that is coming close for retrofitting or renewal of anodes. As long as the remaining sacrificial anodes is still providing the protection, the ElMag system will prolong the life of the remaining anode for the next period of design life. The remaining sacrificial anode is hibernating and it acts as back up system when the ElMag system is in place.
What type of impact does the innovation have on the industry/industries it serves?
ElMag opens a new chapter in corrosion protection history by using an all-reen working principle and approach. It is able to deliver all the minimum protective protection requirement offered by cathodic protection while yet delivering the abovementioned improvements. We believe ElMag will be able to make a significant contribution to the corrosion industry.

Does the innovation fill a technology gap? If so, please explain the technological need and how it was addressed prior to the development of the innovation.
Yes it does fill a technology gap! As mentioned above, the ElMag system is able to overcome issues such as high electricity consumption, interference damage to neighboring structures caused by large stray currents and premature breakdowns. These are typically some shortcomings caused by the impressed current cathodic protection systems.

Has the innovation been tested in the laboratory or in the field? If so, please describe any tests or field demonstrations and the results that support the capability and feasibility of the innovation.
Yes, this innovation has been tested and proven in our own laboratory and at a local shipyard here in Singapore. The ElMag system is installed at a Finger pier with a total of about 150 piles. These piles are arranged in five groups and all these piles are electrically connected via steel bars. The installation was done in phases with Group 1 being operational in October 2011. Just after about a week of installation, the potential readings for the Group 1 piles (against an Ag/AgCl reference electrode) were all above -800mV, hence achieving the full Corrosion Protection International Acceptance Criteria. Today the installation and commissioning of the ElMag system at the Finger Pier is completed successfully.

Is the innovation commercially available? If yes, how long has it been utilized? If not, what is the next step in making the innovation commercially available?
Yes, this innovation is commercially available. It has been operational since October 2011.

Are you aware of other organizations that have introduced similar innovations? If so, how is this innovation different?
No similar innovations are available in the market.

Are there any patents related to this work? If yes, please provide the patent title, number, and inventor.
Yes. Patent information will be disclosed upon further request.
Supporting Photos:

Fig. 1: This diagram shows how the ElMag system is typically installed in sheet piling applications.

Fig. 2: This diagram shows how the ElMag system is typically installed in Jetty piling applications.
Fig. 3: Under the influence of the ultra low frequency electromagnetic waves, a layer of magnetite will be formed beneath existing layers of red rust.