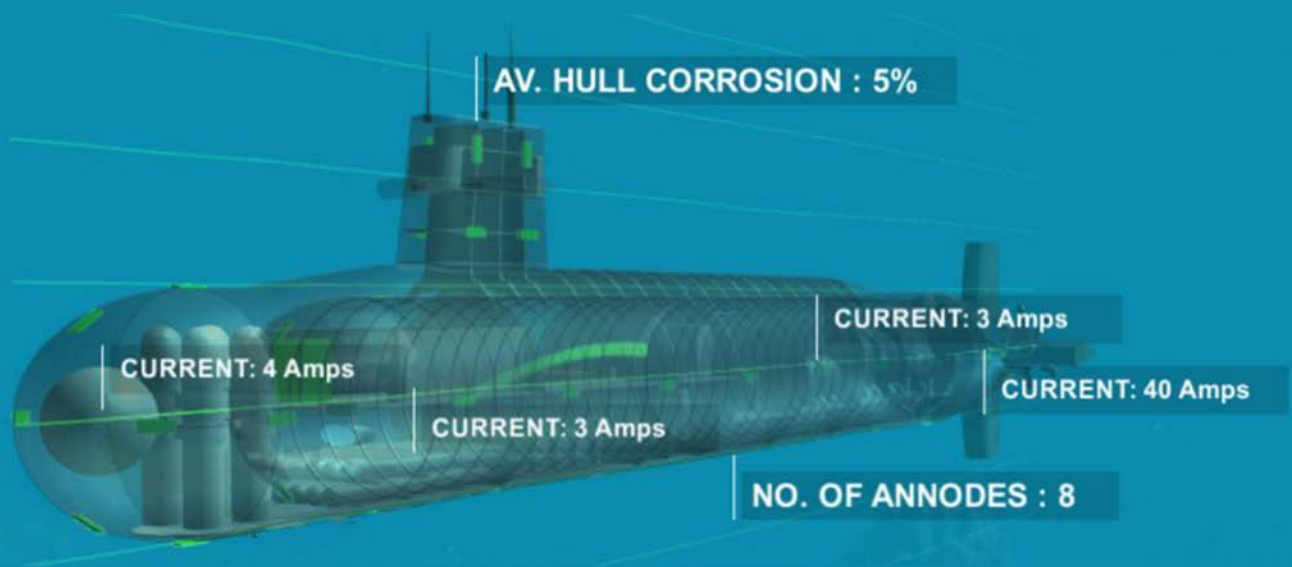


Low Signature Cathodic Protection



THE NEED FOR SILENCE

In the perennial battle for sea power supremacy, big strides in sonar and radar have prompted a countering reduction in acoustic and radar signatures, to the point where both hunter and hunted are claiming hitherto unheard-of (no pun intended) levels of capability in detection and evasion. Like the barely-heard rattle in an otherwise hushed limousine, this reduction in 'traditional' signatures has exposed other emissions that can be detected and classified by sensors as a signature and, therefore, identified as friend or foe. Foremost among these emissions are the products of galvanic corrosion and the systems fitted to combat it.

In this white paper we will outline the case for a managed corrosion protection system for naval vessels that also brings benefits in reduced signature. We will show how each signature element associated with corrosion and its protection system can be tackled by a low signature ICCP system. We will also show that this can be achieved with an added advantage of reduced through-life costs over traditional sacrificial anode corrosion protection.

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THE FIGHT AGAINST CORROSION

Firstly, a basic explanation of why corrosion protection is needed. Corrosion is caused by a galvanic interaction between dissimilar metals in seawater. The sea acts as an electrolyte, allowing an electric current to flow between, for instance, an area of paint-damaged steel hull and a phosphor-bronze hull fitting. This action causes corrosion of the less 'noble' (i.e. less able to resist corrosion) metal, usually the steel hull.



There are generally three methods of countering corrosion:

- Fit blocks of metal in areas vulnerable to corrosion, such that this metal is corroded away (and therefore replaced periodically) rather than the hull element or the hull itself. The block of metal is known as a sacrificial anode.
- Install a system with active anodes which emit a current into the seawater that swamps the galvanic current. The current at the anode is produced by power supplies and managed by a controller, both comprising the inboard end of the system. Feedback is provided by reference cells strategically placed around the hull that measure the output of the anodes. This is known as Impressed Current Cathodic Protection (ICCP) and forms the basis of Aish Technologies' low signature systems.
- Corrosion of the drive shafts is countered with a shaft grounding system. In most cases this is a passive arrangement, but some vessels use an active system similar in its operation to ICCP. There are specific advantages of an active system, as we shall see.

All these systems will provide adequate corrosion protection, with the decision on which to fit calculated on initial and through-life costs for a given vessel and its proposed working profile. However, for naval vessels, vulnerability to detection by enemy assets must also be considered. This is where Aish Technologies' low signature ICCP comes into its own.

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ICCP versus SACRIFICIAL ANODES

Most surface vessels over a certain size, both commercial and naval, use all three systems to fight corrosion: the hull and hull elements are protected with an ICCP system, and sacrificial anodes are fitted in areas such as sea chests and ballast tanks. This has provided the most cost-effective solution; however, things may be changing with the advent of Aish Technologies' Low Voltage ICCP system.

For submarines, the decision on which type of system to fit is made both easier and more difficult:

- Submarines are almost exclusively naval and, by their nature, need to be stealthy. This points towards ICCP systems that offer low inherent signature and allow the signature to be managed in the face of differing threats.
- For nuclear submarines, which have access to abundant power, ICCP is the obvious choice, coupled with active shaft grounding and backed up with sacrificial anodes in ballast tanks, under casings etc (but see our comments below on low voltage ICCP systems as a replacement for sacrificials).
- Conventional submarines, either diesel-electric or powered by one of the Air Independent Propulsion (AIP) power generators, have a limited power budget. Decisions have to be made on how the power is utilized: outright submerged speed may be reduced marginally by running an active ICCP system for instance.

The decision on which system to fit will form part of the initial submarine design modelling.

Aish Technologies can assist in this process with detailed information on power requirements for submarines of varying wetted surface areas and signature management specifications.



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The Case for ICCP

The advantages of ICCP over sacrificial anode protection are well known:

- ICCP eliminates the necessity to dry dock regularly to replace sacrificial anodes. This not only reduces through-life costs, but also increases a vessel's operational availability.
- The introduction of diver-replaceable ICCP anodes has allowed any damaged anodes to be replaced without dry-docking.
- Flush mounted ICCP anodes eliminate both the drag associated with sacrificial anodes and the acoustic signature generated by the turbulence that they cause.
- Low Signature ICCP can reduce and manage the signatures caused by corrosion and its protection system.

Low Voltage ICCP

In ballast tanks and below casings, sacrificial anodes are perceived as the safer option because hydrogen gas generation resulting from their operation is inherently low. Aish has, however, developed a Low Voltage ICCP technology (Patent approved) that will provide the same through-life cost advantages of a conventional ICCP system in these difficult areas without the risk of over-protection and resultant hydrogen generation.

Low Voltage ICCP has the potential also to provide effective management of signatures emanating from these areas, particularly around grillages. The system uses reference cells to monitor and control anode output, optimising the balance between protection and signature.



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KEEPING IT QUIET – SIGNATURE REDUCTION EXPLAINED

All these elements – galvanic currents from corrosion and sacrificial anodes, and protective ICCP currents - create identifiable signatures that can be detected by sensors and matched to specific vessel classes. In the mid 1980's the alternating electric and magnetic signatures associated with conventional ICCP systems were targeted for reduction, and Aish was the first company in the world to equip a submarine class with a system that not only provided automatic corrosion protection, but reduced the Power Frequency ELFE (Extremely Low Frequency Electromagnetic) signature by many orders of magnitude. Three classes of modern submarine (two in the US Navy and one in the UK Royal Navy) have now combined Aish's low signature ICCP systems with active shaft grounding (addressing Shaft Related ELFE), reducing their alternating corrosion-related signatures to negligible levels.

Signatures can be broadly categorised as alternating or static. Their effects and means of reduction are described in the following paragraphs.

Alternating Signatures

The first corrosion related signatures to be addressed were the Power Frequency ELFE effect resulting from anode power supply ripple, and the Shaft Related ELFE caused by modulation of protection currents at the stern. A combination of Aish Technologies' extremely low ripple anode power supplies and an active shaft grounding system reduces these alternating corrosion-related signatures to negligible levels. Alternating signatures, their threats, causes and remedies are described in more detail below. Note that although the illustrations show a submarine hull form, the signatures apply equally to surface vessel hulls.

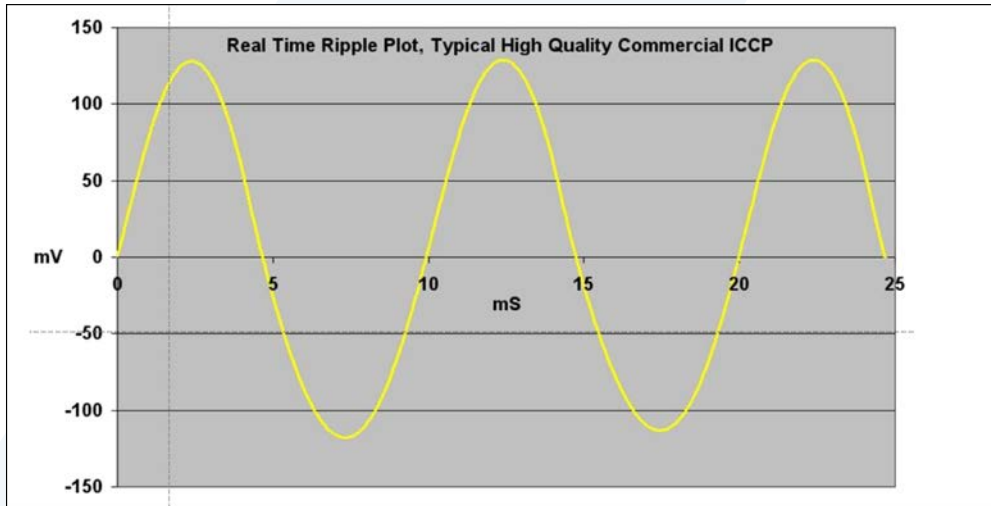


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Power Frequency **ELFE**

Threat: Triggering of mines in littoral waters.

Cause: The outputs to the anodes of a conventional ICCP system may have a ripple superimposed on the DC voltage, a residual effect of the AC supply from which the anode output is derived. This is a fixed frequency, so is easily detectable. The plot shown below is from a typical high- quality commercial ICCP system.



Remedy: Use very low ripple power supplies. Aish Technologies' power supplies are designed to achieve a very low ripple, so that the detectable 50Hz AC component is eliminated, as in the plot below.

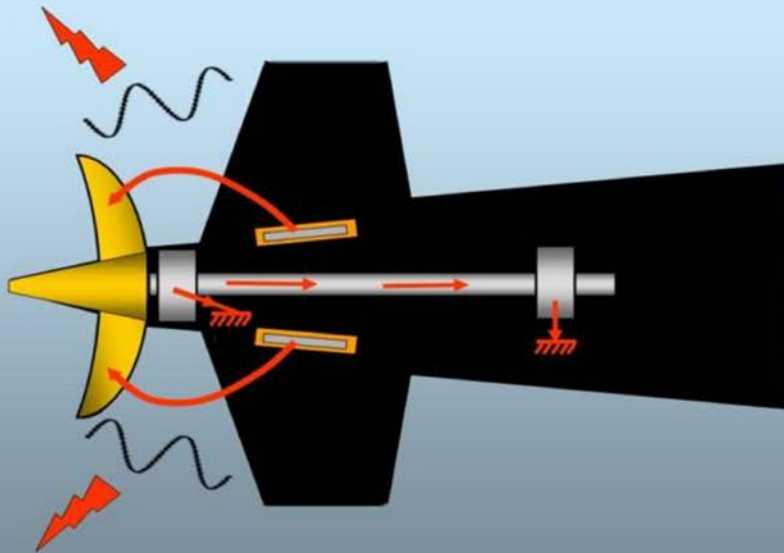


INNOVATION IN ACTION

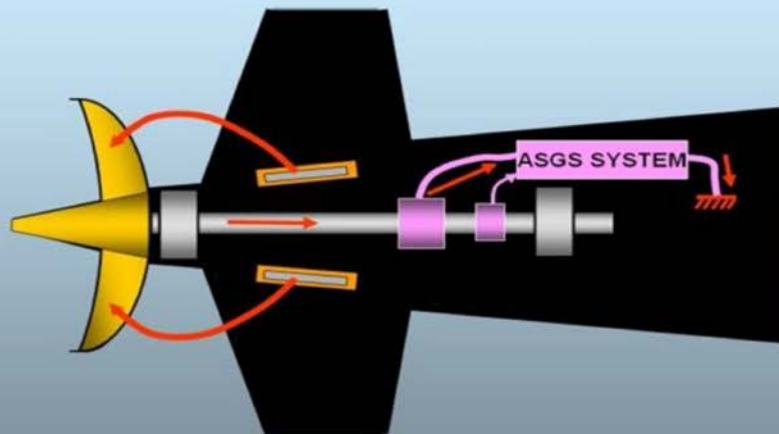
Shaft Related **ELFE**

Threat: Triggering of mines in littoral waters.

Cause: Anode currents protecting the stern may be modulated by variation in the resistance between shaft and hull as the shaft rotates. The modulation has a limited frequency range related directly to shaft rotation speed, so is easily detectable. The image below illustrates the interaction between shaft and hull.



Remedy: Ensure that the resistance between shaft and hull is maintained at a constant very low level using an active shaft grounding system (ASGS). The image below shows the basic elements of an ASG system.



Active Shaft Grounding

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Static Signatures

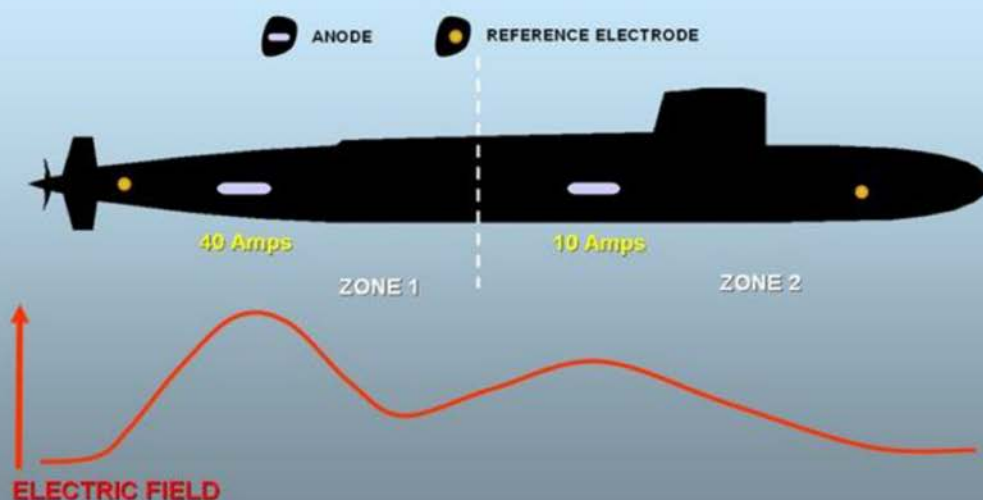
Reduction of static corrosion-related signatures (Underwater Electric Potential and Corrosion Related Magnetic) is known as 'de-amping'. This needs to be considered very early in the design of any class of vessel in order to optimise the layout of anodes and reference electrodes for signature reduction and corrosion protection, while being compatible with other important facilities both inside and outside the hull (e.g. fuel tank and sonar locations). Aish can work with computer modelling and/or physical scale modelling facilities around the world to achieve this.

Once the optimum layout has been achieved, Aish's three families of ICCP system (AishC3P, Series 300 and Series 3000) can be used for open-loop de-amping, whereby the minimum signature achieved at new build can be maintained by adjustment at periodic rangings. The computer-controlled AishC3P and Series 3000 families can also be used for closed-loop de-amping, where data such as seawater conductivity and ship's speed can be combined with the ICCP data to provide a prediction of present signature and allow automatic adjustment of it. The control algorithm for this process can have a classified nature; therefore Aish's software is arranged so that a locally generated algorithm can be 'bolted in' in the country of use.

Underwater Electric Potential

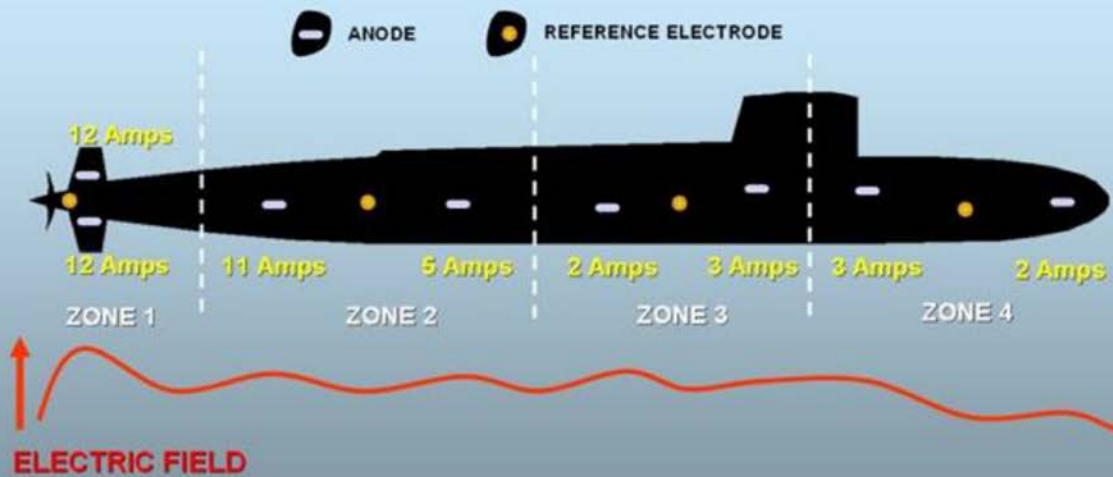
Threat: Detection; triggering of mines in littoral waters.

Cause: Underwater electric potential gradients exist wherever electric currents are flowing in seawater, whether from galvanic action or the output of an ICCP system. The illustration below shows large variations in potential caused by the necessarily high anode output needed to protect the hull with few anodes.



INNOVATION IN ACTION

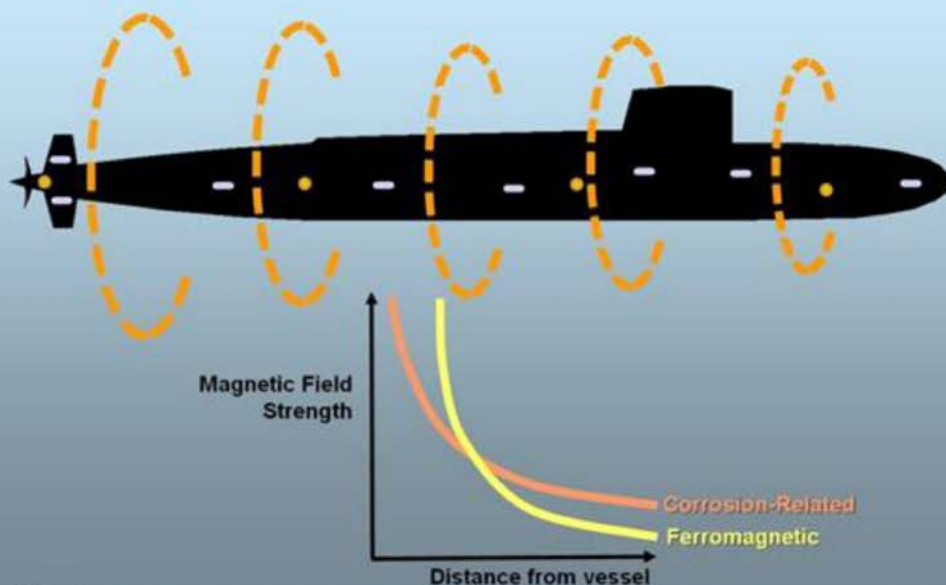
Remedy: Install multiple anodes at lower voltages to achieve corrosion protection with minimum anode output; optimise anode layout using modelling. The following illustration shows how the variation is reduced.



Better Protection – Reduced Signature

Corrosion Related Magnetic

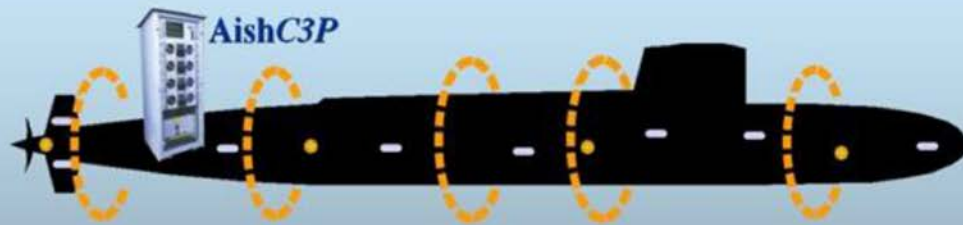
Threat: Submerged submarines can be tracked from the air using Magnetic Anomaly Detection equipment.



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Cause: Electric currents cause a magnetic field around the vessel. This field can be greater than that caused by the ferromagnetic field (e.g. from a magnetised steel hull) at distance, as illustrated below:

Remedy: Optimise anode layout by modelling and install computer-controlled ICCP such as Aish Technologies' C3P or Series 3000 system to manage the signature (de-amping).



Far Field Deamping (Open or Closed Loop)

Conclusion

It can be deduced from the above that the only way to manage and reduce these signatures is by fitting a low signature ICCP system plus active shaft grounding.

Modelling

Optimising the quantity and position of hull-mounted ICCP components is critical for both corrosion protection and signature reduction. The most cost effective time to do this is early in the hull design, by computer modelling or scale modelling. Aish Technologies can provide modelling services or can work with the customer's trusted modelling partner to provide a complete ICCP design service.

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LATEST LOW SIGNATURE ICCP SYSTEM FROM AISH TECHNOLOGIES

Aish Technologies' new ATL Series 3000 computer controlled Low Signature ICCP system breaks new ground in affordability, versatility and applicability. It will provide exemplary corrosion protection, extending hull life. It will also improve survivability by managing electrical and magnetic signatures that can be read by enemy assets.

Based on Aish's proven C3P, the world's leading in-service low signature ICCP System, ATL Series 3000 provides most of the features of that system in a cost effective package. This makes it eminently suitable for applications where comprehensive but affordable corrosion and signature control are needed.

The initial implementation of Series 3000 is in the Royal Navy's new tankers, which form part of the RN's Maritime Afloat Reach and Sustainability (MARS) programme. This implementation gives a strong indication that ships traditionally considered as auxiliary, and therefore held out of harm's way, are now key to operational success and increasingly obliged to enter hostile waters, where they are vulnerable to detection.

It is also an indication that an Aish Technologies Low Signature ICCP system can be considered a cost-effective solution for an inherently low-cost vessel.



ATL Series 3000 Power and Control Cabinet

ATL Series 3000 Highlights

- Automatic operation for reduced crew workload: closed loop monitoring of anode output via silver/silver chloride reference electrodes. The system allows automatic output control of individual anodes; manual override is included as standard.
- Scalable, with the capability of up to 64 zones from each controller.
- Modular: the system can be packaged in a number of ways to allow for versatile positioning of controller and power supplies within the hull.
- Can accept third party algorithms that allow the vessel to modify the output of individual ICCP anodes in order to manage the vessel's signature.
- Automatic data logging, removing the need to manually record anode outputs – the first indication of damaged hull protective coating. The data can be output to external terminals such as an integrated platform management system.
- Simplified power and cable management, reducing training and making the system quick and easy to maintain.

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AISH TECHNOLOGIES ICCP SYSTEMS

Including the simple-but-effective Series 300, ATL Series 3000 brings Aish's low signature ICCP offering to three distinct ranges. The following table lists the attributes and advantages available from each system.

SYSTEM ATTRIBUTE	SERIES 300	ATL SERIES 3000	C3P
Wide range of low ripple anode power supplies	Yes	Yes	Yes
User-friendly Interface with easy visibility of all parameters	Mimic Panel	LCD Display	LCD Display
Control to ± 1 mV at controlling electrode	Yes	Yes	Yes
Zone capability from one controller	5 Zones 16 Anodes 10 Reference Cells	64 Zones 64 Anodes 64 Reference Cells	50+ Zones 100+ Anodes 100+ Reference Cells
Automatic data logging	Optional	Yes	Yes
Individual anode control	Yes	Yes	Yes
Manual control override	Yes	Yes	Yes
Compatible with wide range of anodes	Yes	Yes	Yes
Control from high quality silver/silver chloride reference electrodes	Yes	Yes	Yes
Interface with third party software for signature optimisation	Limited	Yes	Yes
Automatic reference electrode changeover on electrode failure	Yes	Yes	Yes
System is modularised and can be split up to fit available compartment spaces	Yes	Yes	Yes
Individual back-EMF measurements (to check state of anodes)	Yes	Yes	Yes
Immediate trip if overprotection is detected (to avoid hydrogen embrittlement) and cathodic disbondment of the hull coating	Yes	Yes	Yes
Environmental Qualification to Mil Stds			Yes
Environmental Qualification to Def Stans	Yes	Yes	



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COST COMPARISONS – SACRIFICIAL AND ICCP

In the words of Shakespeare, 'comparisons are odorous'. It is notoriously difficult to compare accurately the costs of a passive sacrificial system with an active ICCP system, depending as they do on usage and the life of a vessel. Naval vessels are increasingly being asked to continue in service way beyond their design life, and this favours the reduced maintenance costs of an ICCP system. Conversely, power generation required for an ICCP system has a cost, which is particularly relevant to the limited power budget of conventional submarines. We firmly believe that, over a certain hull volume and complexity, ICCP provides major savings through the life of the vessel.

However, the real comparison is between a vessel that emits a detectable signature and one that does not, and that depends on so many factors: mission profile; necessity to operate in littoral (and possibly mined) waters; likely improvement in detection techniques over the service life of the vessel that could leave a non ICCP-equipped vessel vulnerable.

To assist in validating customers' decisions, Aish Technologies can provide cost details for ICCP systems with various capabilities to suit their signature management requirements.

IN SUMMARY....

Aish Technologies' Low Signature ICCP systems can play a major part in reducing a vessel's vulnerability both on open water and in the littoral, and enable increased operability in mined areas. And all this, of course, while automatically keeping corrosion at bay.

For more information on Aish Technologies' capability in Low Signature Cathodic Protection, please contact:

Tony Holmes - Business Development Director

Aish Technologies Ltd, Broom Road, Poole, Dorset BH12 4NL, England

Tel +44 (0)1202 307158

Mobile +44 (0)7384 258974

Email: tonyh@aisstechnologies.com

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