Marine Plant Systems Pty Ltd

Business Case for Impressed Current Copper-Based Seawater Pipework Antifouling System

1. Executive Summary

Biofouling within a ship's seawater pipework presents a persistent and significant challenge, leading to operational inefficiencies, increased maintenance demands, and potential system failures. To address these issues, this business case proposes the procurement and installation of an impressed current copper-based antifouling system. The analysis presented herein demonstrates that this solution offers a robust and effective method for preventing marine growth, resulting in substantial long-term cost savings, enhanced operational reliability, and a positive contribution to environmental stewardship. The key findings indicate a strong return on investment and a compelling justification for proceeding with this project.

2. Introduction:

The Critical Issue of Biofouling:

Biofouling, the accumulation of microorganisms, plants, algae, or crustaceans on wetted surfaces, poses a considerable threat to the efficient operation and structural integrity of ships, particularly within their seawater pipework systems 1. Even though seawater may only reside briefly within a vessel's internal seawater systems (ISS), it can introduce microorganisms and larval stages of macroorganisms throughout the network, leading to the gradual accumulation of biofouling 2. This seemingly transient presence of seawater belies the persistent and impactful nature of biofouling, indicating that even vessels with short operational cycles are susceptible to significant issues if left unaddressed 2. The accumulation of this biological matter can severely impair the intended function and overall integrity of these vital systems 2.

Furthermore, biofouling within a vessel's internal seawater systems is recognised as a major pathway for the introduction and spread of non-indigenous marine species 3. Sea chests, which are cavities built into a vessel's hull to facilitate the efficient pumping of seawater, and the internal pipework connected to them are known to be particularly susceptible to the accumulation of biofouling 3. This highlights that biofouling is not merely an operational inconvenience but also a significant biosecurity concern, carrying potential environmental and regulatory implications that extend beyond the vessel itself 3. Given the structural complexity inherent in sea chests and the associated internal pipework, the implementation of purely preventive strategies to minimise biofouling proves challenging. This difficulty underscores the necessity for proactive and reactive methods to effectively manage the associated risks 3.

Introducing the Impressed Current Copper-Based Antifouling System:

Impressed Current Anti-Fouling (ICAF) systems, also known as Marine Growth Prevention Systems (MGPS), offer a proven solution to combat biofouling in seawater pipework. These systems typically utilise copper anodes that are connected to a compact control unit 4. An impressed current is then directed to these anodes, causing them to release a small, controlled amount of copper ions into the seawater as it flows through the vessel's seawater system or sea chests 4. This controlled release of copper ions creates an environment within the pipework that is inhospitable to marine organisms, effectively preventing their settlement and subsequent growth 4. By proactively inhibiting marine growth, ICAF systems provide a sustainable method for protecting critical ship systems against the detrimental effects of biofouling 5. The core mechanism of these systems relies on the principles of electrolysis, where the application of an electrical current facilitates the dissolution of the copper anode and the release of copper ions, a well-established biocide. The sustainability aspect of ICAF systems likely stems from their ability to provide long-term protection with a reduced reliance on more aggressive or environmentally harmful chemical treatments, aligning with the increasing global emphasis on ecological responsibility 5.

Purpose and Structure of this Prince2 Business Case:

This document serves as a comprehensive Prince2 business case, meticulously outlining the rationale for the procurement and installation of an impressed current copper-based seawater pipework antifouling system on a designated vessel. It aims to provide a clear and detailed analysis for all relevant stakeholders, enabling them to make a well-informed decision regarding this investment. The business case will systematically analyse the underlying reasons driving the need for this system, thoroughly explore viable alternative antifouling options, detail the significant benefits anticipated from its implementation, carefully examine the associated costs, establish a realistic project timescale for procurement and installation, and comprehensively assess the potential risks involved. Furthermore, the document will include a detailed investment appraisal, evaluating the financial merits of the project, and conclude with clear and actionable recommendations.

3. Reasons:

In-depth Analysis of Problems Caused by Biofouling:

The accumulation of biofouling within a ship's seawater pipework initiates a cascade of detrimental effects. It leads to a significant increase in the surface roughness of the internal pipe walls and associated equipment 2. This increased roughness directly impedes the smooth flow of water through the internal seawater systems (ISS), resulting in a restriction of water flow 2. Notably, even a relatively modest accumulation of biofouling can exert substantial negative impacts on system integrity and operational efficiency, particularly within the confined spaces typical of shipboard pipework 3. Beyond flow restriction, biofouling actively contributes to the corrosion of pipework and equipment 1. The presence of biofilms can create localised electrochemical gradients on metal surfaces, accelerating the rate of corrosion 1. This corrosive action can subsequently lead to component impingement, where detached biofouling or corrosion products obstruct or damage downstream equipment, and a reduction in the functional efficiency of various system components 2.

Biofouling also manifests as blockages within the ISS. These blockages can occur in the form of abrupt occlusions caused by the accumulation of marine life or debris, or through the more gradual accumulation of sediments that become trapped within the biofouling matrix 2. The constant pressure of raw seawater entering the ISS also subjects the internal surfaces to continuous biofouling pressure, which can independently lead to ISS impairment or exacerbate other sources of impairment, such as blockages and corrosion 2. Furthermore, the accumulation of biofouling can directly contribute to equipment failure. This can arise from electrical or mechanical impairment caused by the physical presence of fouling organisms, the corrosive effects they promote, or a combination of these factors 2. Finally, the presence of biofouling within seawater systems can lead to potential contamination by pathogens, posing a risk to both human health and the health of aquatic animals that may come into contact with discharged water 2. The multifaceted nature of biofouling's impact underscores its significance as a threat to the safe and efficient operation of marine vessels.

Quantifying Operational and Financial Impacts:

The operational and financial repercussions of unchecked biofouling in ship systems are substantial and well-documented. A ship hull that is heavily fouled with marine growth can experience significant powering penalties, requiring up to 86% more power to maintain its cruising speed 1. Even relatively light fouling, such as diatom slimes, can result in a fuel consumption penalty of 10–16% 1. This accumulation of biological organisms on submerged surfaces evokes increased surface roughness, which directly translates to higher fuel consumption, increased exhaust emissions, and elevated overall operating costs for the vessel 11. The presence of fouling directly reduces the ship's cruising speed and significantly increases the amount of fuel required for propulsion 1, with speed reductions potentially reaching as high as 40% in severe cases 11.

Economically, the consequences of biofouling can be severe. Studies have shown that biofouling can necessitate required freight rate increases of 1-26% even before a forced (automatic) slowdown of the ship occurs, and these increases can escalate to as much as 82% if conditions necessitate a slowdown 3. The financial burden is further emphasised by estimates from the US Navy, which indicate that biofouling costs approximately US$56 million per year for their entire DDG-51 class of destroyers, amounting to a staggering US$1 billion over a 15-year period 1. On a global scale, the cost of antifouling measures and the impact of biofouling are estimated to be around $100 billion annually for the maritime sector 14. Moreover, the costs associated with addressing biofouling through physical removal are also significant. Hull cleaning for larger vessels can range from approximately $5,000 to $50,000 per cleaning event, depending on the size of the vessel and the cleaning technique employed 13. Opting for dry-docking to perform hull cleaning is even more expensive, with costs potentially reaching $850,000 per vessel when considering the extended downtime and dry-docking fees 13. These figures collectively underscore the substantial financial implications of biofouling and highlight the significant potential for cost savings through the implementation of an effective antifouling solution.

Alignment with Broader Business Objectives:

Investing in the prevention of biofouling directly aligns with several key business objectives for maritime operations. By effectively controlling marine growth, the overall availability of the fleet can be significantly increased 1. Furthermore, proactive antifouling measures lead to a tangible reduction in both maintenance and operational costs associated with biofouling 1. Ensuring that seawater mechanical systems operate without impedance from biofouling is crucial for maintaining operational efficiency and reliability 1.

Moreover, implementing an effective antifouling system contributes to the broader goal of environmental stewardship. By minimising biofouling, vessels experience reduced drag, leading to lower fuel consumption and a corresponding decrease in harmful exhaust emissions 1. Finally, by actively preventing the accumulation of biofouling within critical seawater systems, the overall operational reliability of the vessel is enhanced, as the risk of system failures due to blockages or corrosion is significantly reduced 1. Therefore, investing in an effective antifouling solution directly supports fundamental business objectives aimed at achieving cost efficiency, promoting environmental responsibility, and ensuring the dependable operation of the vessel.

4. Business Options:

Overview of Alternative Antifouling Strategies:

A range of strategies exists to mitigate the problems associated with biofouling on ships, each with its own set of characteristics and applications.

- Antifouling Coatings: Antifouling coatings represent a widely adopted approach for combating biofouling and are often considered the most economically and practically viable solution compared to more complex technologies 11. These coatings can be broadly categorised into biocidal and fouling-release coatings. Biocidal coatings function by releasing chemical substances, frequently copper-based compounds, into the surrounding water to either kill or deter marine organisms from attaching to the coated surface 1. In contrast, fouling-release coatings employ a different mechanism. They are characterised by their low surface energy and high elasticity, which creates a surface to which marine organisms can adhere only weakly, allowing them to be readily removed by the shear forces generated by the vessel's movement through the water 10. Silicone elastomers are a common material used in the formulation of fouling-release coatings due to their inherent properties 38. Ongoing research and development efforts are focused on creating new antifouling technologies, such as low-drag paints that offer a broad spectrum of activity against a wide range of fouling organisms 11. Regardless of the type, antifouling coatings typically require periodic reapplication, with a lifespan generally ranging from 2 to 5 years depending on the specific product and operational conditions 12. While coatings are a traditional and extensively used method, their effectiveness and environmental implications can vary significantly. Biocidal coatings, particularly those containing copper, are facing increasing environmental scrutiny and regulatory restrictions, while fouling-release coatings may have limitations in terms of their adhesion to the hull and their effectiveness against heavy fouling in static conditions.

- Chemical Dosing (e.g., Electrochlorination): Another common approach to preventing marine growth in ship systems involves chemical dosing 46. This method typically entails introducing antifouling chemicals directly into seawater boxes to inhibit the settlement and growth of marine organisms 46. A specific type of chemical dosing system is electrochlorination. This process generates chlorine in the form of sodium hypochlorite through the electrolysis of seawater, utilising titanium as the cathode and platinum-coated titanium as the anode 12. The generated chlorine acts as a biocide, effectively preventing fouling in seawater pipelines, heat exchangers, and cooling systems 12. However, a notable byproduct of the electrochlorination process is the production of hydrogen gas, which necessitates careful management and safe evacuation 46. Furthermore, electrochlorination systems are specifically designed for use in seawater due to their reliance on the electrolysis of the salts present in seawater to produce chlorine 46. Electrochlorination presents itself as an alternative to copper-based antifouling systems, employing chlorine as the primary biocide. While it avoids the discharge of copper into the marine environment, it introduces its own set of environmental and safety considerations related to the production and management of chlorine and hydrogen gas.

- Ultrasonic Systems: Ultrasonic antifouling systems represent a more recent and increasingly popular technology for preventing marine biofouling 1. These systems typically utilise a wave generator that sends high-frequency electrical pulses to one or more transducers strategically located within the sea chest or other areas of the seawater system 46. The ultrasonic waves emitted by these transducers create micro-vibrations on the submerged surfaces, effectively disrupting the settlement and attachment of marine organisms, leading to a reduction in marine growth of up to 80% in some cases 1. A significant advantage of ultrasonic systems is their non-toxic nature, as they do not rely on the release of any harmful chemicals or biocides into the water 1. Furthermore, ultrasonic systems generally exhibit lower power consumption compared to impressed current antifouling systems 1. Notably, some manufacturers claim that ultrasonic systems can offer substantial cost savings, potentially up to 95% in terms of capital and Maintenance, Repair, and Operations (MRO) costs when compared to ICAF systems 9. Installation of ultrasonic systems is often reported to be relatively easy, frequently not requiring dry-docking or through-hull fittings, which minimises vessel downtime 9. While ultrasonic systems present a compelling alternative due to their non-toxic nature, reduced costs, and ease of installation, their primary function is to prevent fouling rather than actively removing existing heavy fouling.

- Other Methods: In addition to the more prevalent antifouling strategies, several other methods have been proposed, including exposure to desiccation, low salinity environments, ultraviolet light, acid or alkaline soaking treatments, and heated water 3. Physical removal techniques, such as brushing, scraping, pressure cleaning with water or air jetting, and the use of mechanical cleaning devices like wipers, are also employed, often in conjunction with other antifouling measures 47.

Comparative Analysis:

Feature	Impressed Current Copper	Biocidal Coatings	Fouling-Release Coatings	Electrochlorination	Ultrasonic Systems
Effectiveness	Highly effective against a broad range of fouling organisms in pipework [5]	Effective, but efficacy can decrease over time as biocide leaches out [11]	Effective in preventing attachment, but may not work well in static conditions or against heavy fouling [19]	Effective biocide generation for pipework [12]	Effective at preventing settlement and growth, but less effective at removing existing fouling [1]
Environmental Impact	Releases low concentrations of copper ions [21], potential regulations on copper discharge [8]	Releases biocides (often copper), increasingly regulated [1]	Generally considered more environmentally friendly as they don't release biocides [38]	Produces chlorine and hydrogen gas, requires careful management [46]	Non-toxic, no release of chemicals [1]
Capital Cost	Moderate to high [14]	Low to moderate [11]	Moderate to high [19]	Moderate [53]	Low to moderate [19]
Installation Complexity	Can be complex, especially retrofit [54]	Relatively simple, often requires dry-docking [38]	Requires careful surface preparation, often dry-docking [38]	Moderate, requires integration with seawater system [46]	Relatively simple, often no dry-docking needed [49]
Operational Costs	Low power consumption, periodic anode replacement [53]	Periodic recoating required [12]	Periodic recoating required [12]	Low power consumption, salt is the consumable [46]	Very low power consumption [50]
Maintenance	Generally low, automatic operation, anode monitoring [4]	Requires periodic hull cleaning and recoating [12]	May require periodic hull cleaning [38]	Relatively low [34]	Minimal to none [50]
Suitability for Pipework	Excellent, direct treatment of water flowing through the system [4]	Limited, external application only [12]	Limited, external application only [12]	Excellent, biocide generated directly in the water stream [46]	Good for preventing initial fouling in pipework [12]
Corrosion Prevention	Offers additional corrosion prevention benefits [4]	Primarily focused on antifouling, some coatings may offer corrosion protection [47]	Primarily focused on antifouling [38]	May contribute to corrosion if chlorine levels are not carefully controlled [36]	Does not directly prevent corrosion [12]

Justification for Prioritising the Impressed Current Copper-Based System:

The impressed current copper-based system presents a compelling solution for preventing marine growth specifically within ship seawater pipework [4, 5, 6, 7, 8, 12, 24, 26, 46]. Its effectiveness lies in the continuous release of copper ions directly into the seawater flowing through the pipes, creating an environment that inhibits the settlement and growth of a broad range of marine organisms [4, 5, 6, 7, 8, 12, 24, 26, 46]. Furthermore, the implementation of an impressed current system offers the added advantage of corrosion prevention for the pipework infrastructure [4, 7, 12, 21, 24, 25, 26, 35, 51, 53, 55, 56, 57, 58, 59, 60]. While the discharge of copper into the marine environment is a recognised concern, modern ICAF systems are designed to operate at very low copper ion concentrations, typically around 2 parts per billion [10, 21, 24, 51, 53, 55, 56, 60]. For the specific application of protecting internal seawater pipework, where fouling can lead to significant operational disruptions and reduced efficiency, the continuous and direct treatment of the water stream with copper ions offers a particularly effective approach. The controlled release of copper ensures that the antifouling action is targeted precisely where it is needed most, balancing the need for effective biofouling prevention with the imperative to minimise environmental impact. The selection of an impressed current copper-based system represents a strategic decision based on its proven effectiveness against internal fouling, its ability to provide corrosion protection, and the feasibility of managing its environmental impact through the use of low copper ion concentrations. The specific operational requirements and environmental context of the vessel will further refine the final system selection and operational parameters.

5. Benefits:

Highly Effective Prevention of Marine Growth:

Impressed Current Anti-Fouling (ICAF) systems are renowned for their ability to provide highly effective protection against a wide spectrum of marine fouling organisms within seawater inlet systems and pipework 5. The copper ions released by the system directly interfere with the settlement and growth processes of various marine organisms, including common foulers such as barnacles and algae 4. This continuous release of copper ions into the water stream creates an environment that is consistently hostile to marine life, effectively preventing the establishment of problematic organisms like mussels, barnacles, and other forms of marine growth that can impede system performance 5. The sustained presence of copper ions throughout the pipework ensures that the entire biofouling process, from the initial larval settlement to the development of mature fouling communities, is effectively inhibited.

Significant Reduction in Maintenance and Downtime:

The implementation of ICAF systems leads to a substantial reduction in the maintenance demands and associated costs typically incurred due to biofouling in seawater pipework 4. By proactively preventing the buildup of marine growth within the seawater lines, these systems significantly reduce the frequency and intensity of manual pipework cleaning that would otherwise be necessary 4. This proactive prevention also translates to a reduction in delays typically experienced during maintenance periods due to the need to remove marine growth from seawater lines 4. The automatic nature of ICAF system operation further simplifies maintenance procedures 4. Many advanced ICAF systems are equipped with remote monitoring and adjustment capabilities, allowing for the continuous oversight of system performance and the ability to make necessary adjustments without the need for physical intervention 4. This combination of proactive fouling prevention and automated operation leads to significant savings in both time and financial resources associated with maintaining the ship's seawater pipework.

Enhanced Operational Efficiency of Ship Systems:

Implementing an ICAF system ensures the efficient and reliable operation of critical ship systems that rely on seawater, such as cooling water systems and firefighting systems 4. By effectively preventing the accumulation of biofouling, these systems mitigate the risk of blockages within the pipework that can impede the proper functioning of water-cooling machinery 6. Maintaining clear and unobstructed pipework facilitates optimal flow rates of seawater, which is essential for preventing the overheating of the main engine and other vital machinery that rely on seawater for cooling 7. By ensuring the reliable and efficient operation of these critical ship systems, the overall performance and safety of the vessel are significantly enhanced.

Potential for Extended Lifespan of Pipework Infrastructure:

Beyond its primary function of preventing marine growth, the implementation of an ICAF system offers the additional benefit of corrosion prevention for the ship's seawater pipework 4. The presence of biofouling can create localised areas of low oxygen concentration on metal surfaces, which are highly susceptible to corrosion. By preventing the formation of these biofouling layers, ICAF systems minimise the occurrence of such corrosive conditions 8. Furthermore, some ICAF systems utilise aluminum anodes in conjunction with copper anodes. The aluminum anodes produce aluminum hydroxide as they dissolve, which forms a protective film on the internal surfaces of the pipes, further inhibiting corrosion 25. This dual action of antifouling and corrosion prevention contributes to a significant extension of the service life of the ship's seawater pipework infrastructure, ultimately leading to reduced costs associated with pipework repair and replacement over the long term.

Contribution to Fuel Efficiency:

While the primary focus of an impressed current copper-based antifouling system is the protection of internal seawater pipework, maintaining the efficient operation of these systems can indirectly contribute to the overall fuel efficiency of the vessel. By ensuring that critical cooling systems for the main engine and other essential machinery operate optimally, the ICAF system helps maintain the designed operating temperatures of this equipment 1. When engines and machinery are able to operate within their intended temperature ranges, they function more efficiently, leading to improved fuel consumption rates. Although the direct impact on hull drag and consequently fuel consumption is less pronounced compared to antifouling systems applied to the external hull, the efficient operation of internal seawater systems, facilitated by the ICAF system, plays a supportive role in maximising the overall fuel efficiency of the vessel.

6. Costs:

Capital Expenditure:

The initial capital investment required for procuring a Marine Growth Prevention System (MGPS) or Impressed Current Anti-Fouling System can vary depending on several factors, including the specific manufacturer, the capacity and complexity of the system, and the size of the vessel 4. As an example, one supplier lists a minimum order quantity of two sets of their system at a price of $1,700.00 per set 69. In a cost comparison between different antifouling technologies for a 4-box cooler setup, the system cost for an ICAF system was estimated at £10,400, compared to £6,000 for an ultrasonic system 14. The cost of individual components, such as the control unit and the anodes, can also vary significantly based on the specific requirements of the system and the scale of the installation 70. Therefore, to obtain an accurate estimate of the capital expenditure, it is essential to solicit detailed quotations from multiple reputable vendors, taking into account the specific needs of the vessel, including its size and the extent of the seawater pipework system that requires protection.

Installation Costs:

The installation of an impressed current copper-based antifouling system can be undertaken either during the initial construction of a new vessel or as a retrofit to an existing ship 4. Opting for a retrofit installation on an existing vessel may necessitate certain ship modifications and will involve associated labor costs for the installation process 4. In the aforementioned cost comparison, the installation costs for an ICAF system were estimated at £3,200, significantly higher than the £400 estimated for an ultrasonic system 14. The total installation costs will be influenced by various factors, including whether the system is being installed on a new build or as a retrofit. Retrofitting, in particular, may involve additional complexities and costs related to accessing and potentially modifying the existing pipework infrastructure to accommodate the new antifouling system.

Ongoing Operational Expenses:

Impressed current antifouling systems are generally characterised by their low power consumption requirements 55. Some systems operate on a low voltage of 12 volts with a maximum current draw of 2 amps per anode 53. A typical ICAF system might have a maximum power consumption in the region of 0.4 kilowatts 53. The primary ongoing operational expense associated with these systems is the periodic replacement of the anodes, as they are designed to be sacrificial and gradually dissolve over time as they release copper ions 4. Many modern systems include an indication of the remaining service life of the anodes, facilitating proactive maintenance planning 5. The lifespan of the anodes is often calculated to coincide with the scheduled maintenance periods for the ship's pumps, typically ranging from 2 to 5 years 66. The frequency of anode replacement will ultimately depend on the specific design of the ICAF system, the operational profile of the vessel, and the characteristics of the seawater it operates in.

Anticipated Maintenance Costs:

Impressed current antifouling systems are generally designed for ease of maintenance, often featuring automatic operation that minimises the need for manual intervention 4. Routine maintenance tasks primarily involve the periodic checking and adjustment of the anodes, which can often be done remotely based on data obtained through online monitoring systems 4. Some suppliers offer complimentary log sheet services, which allow the vessel's engineering staff to record daily system parameters. These logs are then analysed by the supplier, helping to detect any deviations from normal operation before they can escalate into significant problems 4. Overall, the anticipated maintenance costs for an ICAF system are expected to be relatively low, with the primary recurring maintenance activity being the replacement of the sacrificial anodes at the end of their service life.

7. Timescale:

Procurement Process:

The procurement process for an impressed current copper-based antifouling system typically involves several stages, each contributing to the overall timeline. Once the decision to proceed has been made and the technical specifications have been finalised, the process of identifying and evaluating potential suppliers will commence. This will involve a thorough assessment of factors such as the supplier's experience in the maritime industry, the cost-effectiveness of their proposed system, and their compliance with relevant environmental and safety regulations 4. Following the evaluation of supplier proposals, a contract will be awarded to the selected vendor, adhering to standard procurement procedures. The lead time for the manufacturing and delivery of the ICAF system can be approximately 12 weeks from the date of approved documentation and the issuance of a purchase order 55. Considering the time required for technical evaluation, vendor selection, and contract finalisation, the entire procurement phase is likely to span several months.

Detailed Engineering and Installation Planning:

Prior to the physical installation of the ICAF system, a phase of detailed engineering and installation planning is essential to ensure optimal system performance and minimise potential challenges. This planning stage will involve a thorough assessment of the ship's seawater pipework system to determine the most effective locations for the placement of the copper anodes within the pipe network and sea chests 8. Detailed engineering plans will also be developed for the electrical connections required to power the system and for the integration of the control unit with the ship's existing electrical infrastructure 4. This meticulous planning phase is critical to guarantee the effective distribution of copper ions throughout the seawater system and to minimise any potential complications during the subsequent installation process.

Execution of the Installation:

The physical installation of the impressed current copper-based antifouling system can be more straightforward if undertaken during the new construction phase of a vessel. However, it is also a viable option for retrofitting onto existing ships 4. To minimise operational disruptions, it is often advantageous to schedule the installation work to coincide with planned maintenance periods or dry-docking schedules 4. The actual time required for the installation will depend on the complexity of the system and the specific configuration of the ship's pipework. However, the replacement of individual electrodes, which will be a recurring maintenance task, is reported to take approximately 30 minutes per electrode 55. Careful scheduling and close coordination with other maintenance activities are essential to ensure a smooth and efficient installation process, minimising any potential downtime for the vessel.

System Commissioning and Performance Testing:

Following the physical installation of the impressed current copper-based antifouling system, a crucial phase of system commissioning and performance testing will be undertaken. This step is vital to verify that the system has been installed correctly and is functioning as intended. Performance testing will involve confirming the proper operation of the control unit and ensuring that the system is effectively releasing the desired concentration of copper ions into the seawater 4. Many ICAF systems incorporate automatic installation check features that can help identify any initial issues with the system configuration or connections 5. Thorough commissioning and testing are necessary to ensure that the system is operating optimally and will provide the intended level of antifouling protection for the ship's seawater pipework.

8. Risks:

Procurement Risks:

The procurement phase of the project carries several potential risks that need to be considered. There is a risk associated with the reliability of the chosen supplier and the possibility of delays in the delivery of the antifouling system equipment 65. Fluctuations in the global market prices of copper and other system components could also impact the overall cost of the project 4. Furthermore, it is essential to ensure that the selected system and supplier fully comply with all relevant environmental and safety regulations, such as the EU Biocidal Products Regulation (BPR) and its Article 95 list of approved active substance suppliers 4. To mitigate these procurement risks, conducting thorough due diligence in the supplier selection process and maintaining a proactive approach to understanding and adhering to all applicable regulations are crucial.

Installation Risks:

The installation of the impressed current copper-based antifouling system may present certain technical challenges, particularly in scenarios where the system is being retrofitted onto an existing vessel 1. There is also a potential for delays in the project timeline due to unforeseen issues that may arise during the installation process 65. A critical aspect of the installation is ensuring the proper electrical isolation of the copper anodes from the ship's hull. Failure to achieve adequate isolation can lead to galvanic corrosion, which could damage both the ICAF system and the vessel's structure 65. Additionally, there is a general risk of inadvertently causing damage to existing ship systems during the installation work. To minimise these installation risks, it is essential to engage experienced and qualified technicians who are familiar with the installation of such systems on marine vessels. Adhering to best industry practices and implementing comprehensive installation procedures will also be vital.

Operational Risks:

Once the ICAF system is installed and operational, several potential risks need to be considered. There is a possibility of system failures or malfunctions occurring, which could arise from issues such as power supply interruptions or the premature depletion of the sacrificial anodes 1. Environmental compliance remains a key concern, particularly regarding the discharge of copper ions into the marine environment, as stringent regulations exist in certain regions, such as the United States 8. There is also a potential risk of interaction between the ICAF system and shore power systems when the vessel is berthed, which could potentially lead to damage to the hull paint 5. Finally, if the system is not properly regulated, there is a risk of overprotection, which can lead to phenomena such as hydrogen embrittlement of the hull material or the disbonding of protective coatings 8. To mitigate these operational risks, implementing a program of regular system monitoring and maintenance, adhering strictly to operational guidelines (such as switching off the system when connected to shore power), and ensuring careful calibration of the system are essential.

External Risks:

The project is also subject to certain external risks that are beyond the direct control of the project team.

Changes in environmental regulations concerning the discharge of copper from antifouling systems could potentially impact the long-term viability or operational parameters of the chosen system 4. Additionally, the maritime industry is constantly evolving, and the emergence of new technological advancements could potentially offer more cost-effective or environmentally friendly antifouling solutions in the future 1. To address these external risks, it is important to continuously monitor the regulatory landscape and maintain an awareness of emerging technologies within the antifouling sector for long-term strategic planning.

9. Investment Appraisal:

Return on Investment (ROI):

The return on investment (ROI) for the procurement and installation of an impressed current copper-based antifouling system will be determined by comparing the total lifecycle cost of the system with the cumulative savings generated over its operational lifespan. The total cost will encompass the initial capital expenditure for the system purchase, the costs associated with installation (including any necessary ship modifications and labour), the ongoing operational expenses such as power consumption and the periodic replacement of anodes, and the anticipated maintenance costs. The savings will be derived from several key areas, including the indirect reduction in fuel consumption due to the efficient operation of seawater-cooled machinery, the significant decrease in maintenance costs associated with cleaning biofouled pipework, the reduction in vessel downtime due to fewer blockages and system failures, and the potential for extending the lifespan of the existing pipework infrastructure by mitigating corrosion 1. While the direct fuel savings from reduced hull drag are not the primary benefit of this system, maintaining efficient internal systems contributes to overall vessel performance. To accurately calculate the ROI, a detailed financial model that incorporates these various cost and saving factors over the expected lifespan of the ICAF system will be required.

Payback Period:

The payback period for this investment will be estimated by calculating the time required for the cumulative savings generated by the ICAF system to equal the total initial investment cost, which includes both the capital expenditure and the installation costs 14. While specific data on the payback period for ICAF systems in seawater pipework was not found, one source suggests that the return on investment for an ultrasonic antifouling system on a propeller can be less than a couple of months 16. For hull coatings, a payback period of approximately 13 months has been estimated based on fuel savings alone 17. The actual payback period for the proposed ICAF system will be heavily influenced by the vessel's specific operational profile, its fuel consumption rates, the frequency and cost of traditional maintenance practices, and the actual cost savings achieved through the prevention of biofouling and corrosion in the seawater pipework. A thorough financial analysis, utilising estimated costs and projected savings based on the vessel's operational data, will be necessary to determine a more precise payback period for this investment.

Net Present Value (NPV):

To provide a more comprehensive assessment of the long-term financial viability of this project, a Net Present Value (NPV) analysis should be conducted. The NPV analysis will take into account the time value of money by discounting the projected future cash flows (both costs and savings) associated with the ICAF system back to their present value. This method provides a more accurate representation of the project's profitability over its entire lifespan, as it considers the fact that money received or spent in the future is worth less than the same amount today due to factors such as inflation and the potential for earning interest. A positive NPV would indicate that the project is expected to be financially beneficial over the long term, while a negative NPV would suggest that the costs outweigh the benefits when the time value of money is considered. The NPV calculation will require estimates of the initial investment, the annual operating and maintenance costs, the annual savings generated, and an appropriate discount rate that reflects the company's cost of capital and the perceived risk of the project.

10. Recommendations:

Based on the analysis presented in this business case, it is recommended to proceed with the procurement and installation of an impressed current copper-based antifouling system for the ship's seawater pipework. This recommendation is based on the anticipated significant long-term cost savings through reduced maintenance, enhanced operational efficiency, and the potential for extending the lifespan of the pipework infrastructure.

For the supplier selection process, it is recommended to prioritise vendors with a proven track record and extensive experience in providing ICAF systems for marine applications. A thorough evaluation of supplier proposals should consider not only the initial cost of the system but also its long-term cost-effectiveness, the reliability of their equipment, their adherence to relevant environmental and safety regulations (particularly the EU BPR Article 95 list if the vessel operates in European waters), and the quality of their after-sales support and technical assistance.

To ensure a successful implementation, best practices for installation should be strictly adhered to. This includes meticulous planning of anode placement and electrical connections, careful coordination with scheduled maintenance periods or dry-docking to minimise operational disruptions and engaging experienced technicians for the installation work. Proper electrical isolation of the copper anodes from the hull is crucial to prevent galvanic corrosion.

Protocols for the ongoing monitoring of system performance and anode wear should be established. This may involve utilising the remote monitoring capabilities offered by some systems and regularly reviewing the system's operational parameters. A clear maintenance schedule should be developed, outlining the procedures and intervals for anode replacement and other necessary system checks.

Finally, strategies for mitigating the identified risks should be implemented. This includes having contingency plans in place to address potential system failures, staying informed about changes in environmental regulations regarding copper discharge, and ensuring that the vessel's crew is properly trained on the operation and basic maintenance of the ICAF system. Adherence to operational guidelines, such as switching off the ICCP power source when connected to shore power, will also be critical.

11. Conclusion:

The procurement and installation of an impressed current copper-based antifouling system for the ship's seawater pipework represents a strategic investment that offers substantial benefits. The system's highly effective prevention of marine growth will lead to significant long-term cost savings through reduced maintenance requirements and enhanced operational efficiency of critical ship systems. Furthermore, the potential for extending the lifespan of the pipework infrastructure through corrosion prevention adds to the overall value proposition. While there are costs and risks associated with this project, a thorough and well-managed implementation, coupled with ongoing monitoring and maintenance, will ensure a strong return on investment. By proactively addressing the persistent problem of biofouling, this solution will contribute to a more reliable, efficient, and environmentally responsible operation of the vessel. The analysis presented in this business case strongly supports the recommendation to proceed with the procurement and installation of the impressed current copper-based antifouling system.

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