CORROSION



KEEPING THE SEA CHEST CLEAR

Biofouling, Corrosion and Cooling Reliability in Box Cooler

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1. INTRODUCTION

A harbour tug spends six weeks in a warm coastal port over the summer. Nothing about the vessel changes. Below the waterline, the sea chest keeps exchanging water with a nutrient-rich harbour, and the surfaces inside it are steadily colonised. On the first hot afternoon back at full load, the cooling water temperature runs higher than the chief engineer expects, and the only way to see inside the sea chest is to hire divers or wait for the next docking.

Nothing failed and no component broke. The vessel simply lost the cooling margin it was designed with, and lost it out of sight.

Vessel machinery produces heat continuously, and main engines, auxiliaries, generators and hydraulic systems must stay within defined temperature limits to run efficiently. In a conventional central cooling system, seawater is drawn through a sea chest and pumped through a heat exchanger. In a box cooler system, the heat exchanger sits directly inside the sea chest, removing the need to pump seawater through the cooler at all.[1] That distinction determines where fouling occurs and why the sea chest needs a protection strategy of its own.

WHERE THE SEA CHEST AND BOX COOLER SIT

A sea chest is a recessed compartment in the hull, open to the sea through inlet and outlet gratings, providing a controlled interface between vessel and water. Depending on the design it may feed internal seawater systems, house a box cooler, or both.

An NRF box cooler is a U-shaped tube bundle installed inside the sea chest. The vessel's closed cooling liquid circulates through the tubes while seawater surrounds them, and heat passes through the tube walls from the warmer internal liquid to the colder seawater. As the seawater near the tubes warms up it becomes lighter and rises, cooler water moves in to replace it, and the gratings let that exchange continue.[1] The result is compact cooling with very little seawater-side machinery.

It also places the heat transfer surface in an area permanently exposed to natural seawater. The sea chest is sheltered, contains corners and restricted flow zones, and is hard to reach in service. Those same characteristics make it a good location for biological growth.

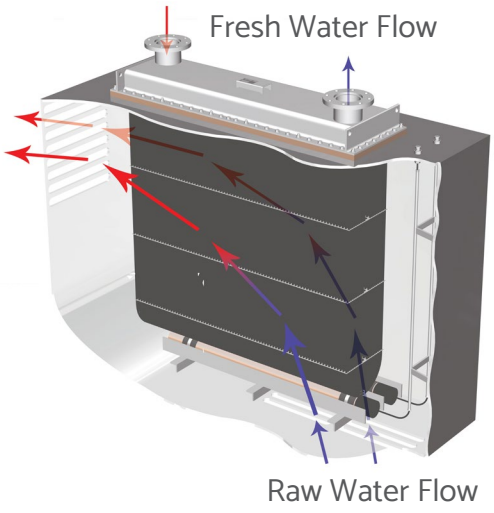


Figure 1. Box Cooler Water Flow in a Sea Chest
Source: NRF

1. INTRODUCTION

WHY THE BOX COOLER EXISTS

NRF invented the box cooler in 1959, when the company was asked to find a simple way of keeping the engines of river boats, cooled with surface water, free of fouling.[1] The product exists because of a fouling problem, and fouling has shaped its engineering ever since. NRF today supplies box coolers, ICAF antifouling and ultrasonic antifouling worldwide, with classification certification available from more than twenty societies and national authorities.[1]

The sections that follow explain the biological process, the operational and corrosion risks, the prevention methods available, and the role of impressed current antifouling in protecting box cooler performance.

No specialist knowledge is assumed, and terms are explained where they first appear and collected in Appendix B.



Figure 2. External View of a Sea Chest with Box Coolers
Source: NRF

2. WHAT IS BIOFOULING?

Biofouling is the accumulation of aquatic organisms on surfaces immersed in water. On a vessel it develops on the hull and, more aggressively, in niche areas such as sea chests, gratings, thruster tunnels, internal seawater pipework and box coolers. The International Maritime Organization (IMO) defines niche areas as submerged parts of a ship more prone to fouling because of structural complexity, variable flow, coating wear or limited antifouling protection.[4] Biofouling is not one type of growth but a biological succession, beginning at a microscopic scale and developing into visible communities of plants and animals.

FROM A CLEAN SURFACE TO ESTABLISHED GROWTH

The process begins the moment a surface goes into the water. Organic molecules form a thin conditioning layer, then bacteria, microscopic algae, fungi and other microorganisms attach and produce a biofilm. The IMO calls this stage microfouling, and it usually appears as slime rather than as recognisable marine growth.[4]

That biofilm changes the surface. It retains nutrients, creates a more complex local environment and makes attachment easier for spores and for the larvae of larger organisms. Macrofouling follows: visible algae, barnacles, tubeworms, mussels, hydroids and other invertebrates.

The sequence is not identical everywhere, since different organisms settle at different temperatures, salinities and seasons. What matters for a cooling system operator is that the process starts long before heavy growth is visible. IMO guidance notes that biofouling can begin within the first hours in the water,[4] and a biofilm too thin to see already adds measurable resistance to heat transfer.

WHY SEA CHESTS ARE VULNERABLE

Sea chests are unusually good places for fouling to start. They are recessed and sheltered, water moves more slowly inside them than across the exposed hull, and they contain edges, corners, gratings, supports and changes of shape. Some areas receive steady water exchange while others sit in local stagnation, and throughout, seawater keeps delivering oxygen, nutrients and organisms into the space. Research on ships' internal seawater systems describes sea chests as places where biofilms and mobile organisms accumulate precisely because they are protected while still receiving a supply of seawater, with curves and corners creating low-flow zones that reduce the effectiveness of passive protection.[7]

A box cooler adds a large amount of submerged surface area to this environment. The tube bundle is designed to maximise heat transfer, so it presents a large wetted surface, and the spaces between tubes must stay open enough for seawater to circulate. Even where the material resists fouling, the installation as a whole is exposed to local water conditions, prolonged inactivity and the fouling pressure of the trading area.

2. WHAT IS BIOFOULING?



Figure 3. Biofouling Accumulation on an Extracted Box Cooler
Source: NRF

FACTORS THAT INFLUENCE FOULING PRESSURE

Fouling risk varies a great deal from vessel to vessel. Five factors do most of the work:

FACTOR	WHAT RAISES THE RISK
Water temperature and season	Warm water supports higher biological activity. A vessel comfortable in winter can struggle in the same port in August.
Location and nutrient load	Ports, estuaries and productive coastal waters carry far more larvae and nutrients than open ocean.
Vessel activity	Time at berth, at anchor or laid up removes the scouring effect of water movement and lets organisms establish.
Sea chest shape and flow	Sheltered corners, narrow openings and poorly circulated zones are both more likely to foul and harder to protect.
Surface condition	Damaged coatings, existing deposits, roughness and corrosion products all give organisms something to grip.

Trading pattern sits across all five: a vessel moving between regions meets different biological communities and may carry growth from one environment into another. Biofouling control therefore cannot be based on vessel type alone. It has to reflect the actual operating profile, the sea chest design, the materials present and the interval between inspections.

3. WHY BIOFOULING IS A MAJOR ISSUE FOR MARINE COOLING SYSTEMS

A cooling system is designed around a defined heat load, water temperature and flow. Biofouling changes all three. The effect builds gradually, but the operational consequence arrives suddenly, once the spare capacity has been used up. For a box cooler two risks matter, and they are connected: a deposit on the tube surface adds thermal resistance, while growth between the tubes and around the sea chest changes how water moves through the bundle.

REDUCED HEAT TRANSFER

The box cooler passes heat through the tube wall. Any extra layer between the metal and the seawater acts as a barrier. A thin biofilm already reduces performance. As the layer thickens and mixes with sediment, shells and corrosion products, the barrier gets worse.

The system compensates at first, because it was designed with margin. That is exactly what makes early fouling hard to recognise: temperatures stay acceptable and the vessel keeps operating. As growth progresses the system has less capacity to absorb high engine loads or warm water, so a vessel that runs comfortably in cool conditions starts showing elevated temperatures in a warm port or during a demanding job.

RESTRICTED CIRCULATION, AND HOW FAST IT TURNS

A box cooler depends on seawater reaching the tube surfaces. Macrofouling narrows the spaces within the bundle, obstructs gratings and changes the circulation path. Growth does not have to close an opening completely to cause trouble: uneven growth leaves part of the cooler poorly supplied while other parts carry more flow. That produces local hot spots, unstable temperatures, and wasted heat transfer area that the owner has already paid for.

Evidence from wider internal seawater systems shows that the relationship between obstruction and impact is not proportional. A 2023 study using an engine room simulator and an economic model found a characteristic hockey-stick pattern: engine room systems tolerated blockage of up to roughly 55 per cent at a single node, such as a sea chest, strainer or heat exchanger, with no measurable operational impact, then deteriorated rapidly. Tolerance was substantially lower when several nodes were occluded at once, and impacts varied with seawater temperature. The commercial translation is stark. The required freight rate, meaning the revenue per tonne needed for a voyage to remain profitable, rose by 1 to 26 per cent before blockage forced an automatic slowdown, and by as much as 82 per cent where a slowdown became necessary.[8]

Those figures come from a simulated conventional cooling arrangement rather than a box cooler, and the specific thresholds should not be transferred directly. The transferable lesson is the shape of the curve rather than the numbers on it: fouling that looks manageable can become an operational problem

3. WHY BIOFOULING IS A MAJOR ISSUE FOR MARINE COOLING SYSTEMS

very quickly, particularly when several restrictions act together or when the water warms.

KEY TAKEAWAY

Fouling is invisible while the cooling margin absorbs it, and then it fails fast. By the time cooling temperatures are telling you there is a problem, the system is already past the point where the response is cheap.

WHY NOW: THE REGULATORY DIRECTION

Biofouling has historically been managed as an engineering and cost question. That is changing. The IMO's 2023 Guidelines, resolution MEPC.378(80), replaced the 2011 version with a risk-based, ship-specific approach. They identify sea chests as niche areas whose internal surfaces and inlet gratings should be protected by an anti-fouling system, and they recommend that internal seawater cooling systems be designed to be compatible with an MGPS.[4] A box cooler sits inside the sea chest, so it falls squarely within the area the guidelines address.

Those guidelines are voluntary. In April 2025, however, the Marine Environment Protection Committee approved a new output to develop a legally binding framework for the control and management of ships' biofouling, and approved guidance on in-water cleaning at the same session.[5] DNV's assessment is that biofouling management will become an international requirement in 2029 at the earliest.[6] For anyone specifying cooling equipment now, that timeline is short: a box cooler installed on a newbuild today will still be in the water when the framework takes effect, and a vessel with a documented, functioning marine growth prevention system is in a considerably better position than one relying on reactive cleaning.

OPERATIONAL, RELIABILITY AND BIOSECURITY CONSEQUENCES

When cooling performance falls, the crew reduces machinery load, investigates abnormal temperatures or increases maintenance activity. None of that is simple in a sea chest, where inspection may require divers, remote cameras, temporary blanking or dry docking. Reactive cleaning has its own limits: removed macrofouling becomes debris and can create a secondary blockage, aggressive cleaning damages coatings and tube surfaces, and work in confined space must be planned around vessel safety and environmental controls. The direct cost of cleaning is only part of the picture, since a vessel may lose operating time, miss a schedule or need an earlier docking.

Cooling also supports propulsion and auxiliary machinery, so the problem reaches well beyond the box cooler. Persistent high temperatures accelerate wear, reduce efficiency and can trigger protective shutdowns. Fouling also hides problems: deposits conceal damaged coatings, local corrosion and mechanical defects. That is one of the clearest reasons to manage fouling and corrosion together.

3. WHY BIOFOULING IS A MAJOR ISSUE FOR MARINE COOLING SYSTEMS

Finally, organisms living in sea chests travel with the vessel. The IMO's 2023 Guidelines are built around minimising the transfer of invasive aquatic species, and niche areas are central to that concern.[4] An antifouling system does not by itself make a vessel compliant in every country, but it does reduce the amount of living material carried into a new environment.



Figure 4. Box Cooler Affected by Corrosion and Biofouling
Source: NRF

4. THE RELATIONSHIP BETWEEN BIOFOULING AND CORROSION

Biofouling is living material building up; corrosion is the deterioration of a material through chemical or electrochemical reaction with its environment. In seawater systems they act on the same surfaces and reinforce one another.

A clean metal surface in flowing seawater meets oxygen, salt, temperature and mechanical forces fairly evenly all over. Once a biofilm or deposit forms, that evenness is lost. The water under the deposit is different from the water around it. Oxygen gets used up locally. Acidity and the concentration of aggressive salts shift. Those differences set up small electrical cells on the metal, and corrosion concentrates in one spot instead of spreading thinly.

BIOFILMS AND MICROBIAL CORROSION

Microorganisms speed up corrosion by changing the chemistry right at the metal surface. This is called microbiologically influenced corrosion, usually shortened to MIC. The organisms do not create a new kind of corrosion. They accelerate reactions that were already possible, or change the route those reactions take. Some use up oxygen. Others produce acids or sulphides. Biofilms also trap corrosion products and create small pockets with their own chemistry. The damage shows up as pitting, or as attack in crevices and under deposits.[9]

MIC should not be diagnosed from the presence of slime alone. The Association for Materials Protection and Performance (AMPP) advises that a credible diagnosis requires biological, chemical, metallurgical and operational evidence together.[9] That matters practically, because corrosion in a sea chest can equally be driven by coating failure, galvanic coupling, flow conditions, deposits or from the wrong material choice.

CORROSION UNDER DEPOSITS

A deposit blocks the exchange of oxygen between the metal and the water. The metal underneath ends up starved of oxygen while the exposed metal nearby has plenty. That difference is itself what drives the attack, and it concentrates the damage under the deposit or at its edge. Because the damage is hidden, a visual inspection from a distance will underestimate the real condition of the metal.

FLOW CAN PROTECT OR DAMAGE

Enough flow limits settlement and brings oxygen-rich water to the metal. Some alloys need that oxygen to keep the thin protective film that gives them their corrosion resistance. Too little flow allows deposits and stagnation. Too much flow, or turbulence in one spot, strips that protective film away and causes erosion damage where the fast water strikes the metal.

This matters most where non-ferrous alloys rely on a stable oxide film: guidance for copper-nickel seawater systems stresses controlled flow velocities, clean commissioning conditions and the avoidance

4. THE RELATIONSHIP BETWEEN BIOFOULING AND CORROSION

of local turbulence.[11] The broader principle holds generally: the right material still performs badly if the water around it behaves in the wrong way.

Biofouling disturbs exactly those conditions. Growth forces water through a smaller opening in one place, raising local velocity, while creating a sheltered stagnant pocket somewhere else, so a single installation can suffer deposit-related attack and high-velocity attack at the same time in different locations.

THE INSTALLATION IS ONE ELECTRICAL SYSTEM

NRF's box cooler construction uses carbon steel covers and welding frames, Muntz metal tube sheets and aluminium brass tube bundles, with epoxy coated variants for seawater and brackish water service to protect against galvanic corrosion.[1] Around them sit hull steel, coatings, support structures, fasteners, anodes and electrical connections. When different metals are electrically connected in seawater, galvanic corrosion follows unless the system is designed and protected as a whole, because coating condition, electrical continuity, cathodic protection, flow, water chemistry and the choice of antifouling anodes all affect each other.

KEY TAKEAWAY

An antifouling system removes one contributor to corrosion by limiting biofilms and deposits. It does not replace material selection, coatings, cathodic protection and inspection. The value comes from designing them together.



Figure 5. Galvanic Marine Sacrificial Anode Installed in a Sea Chest
Source: CORROSION B.V.

5. METHODS USED TO PREVENT BIOFOULING

No single method suits every vessel, sea chest or operating profile. Effective prevention combines design choices, passive protection, active treatment and planned inspection. The IMO recommends choosing antifouling systems to suit the ship's operating profile, and recognises that a combination of coatings and a marine growth prevention system may be right for niche areas.[4] The practical objective is to keep fouling below the level at which it affects function, integrity or biosecurity. Complete sterility is not a realistic target for a marine cooling installation, and no supplier should present it as one.

METHOD	HOW IT WORKS	BEST SUITED TO	MAIN STRENGTH	MAIN LIMITATION
Design for flow and access	Removes sheltered pockets and dead ends; provides inspection points	Newbuild and major conversion	Reduces where growth can establish, permanently and at no running cost	Cannot be retrofitted cheaply; does not reduce fouling pressure
Antifouling coatings	Discourage settlement or give a low-adhesion surface	Hull, sea chest walls, gratings	Broad passive coverage, no power or consumables	Hard to apply to correct thickness in complex geometry; degrades with damage
Inspection and cleaning	Physically removes accumulated growth	All vessels, within any strategy	Direct evidence of actual condition	Access is costly; debris can block gratings; surfaces can be damaged
(Electro) Chlorination	Doses or generates an oxidising biocide	Large circulating seawater systems and pipework	Treats water flowing through pipework and heat exchangers	Needs concentration and contact time control; excess oxidant affects materials and discharge compliance
Copper-based ICAF/MGPS	Impressed current dissolves copper anodes into the protected water	Sea chests and box cooler installations	Continuous local treatment, adjustable output, anode life matched to docking	Preventive not corrective; depends on anode placement and distribution
Ultrasound	High-frequency vibration makes attachment more difficult	Surfaces with good acoustic transmission	No continuous chemical release; low maintenance	Coverage limited by shadow areas, joints and geometry

5. METHODS USED TO PREVENT BIOFOULING

DESIGN, MATERIALS, COATINGS AND CLEANING

The first control measure is good design. Sheltered pockets, dead ends and inaccessible spaces increase deposits and make inspection harder, so gratings, supports and cooler geometry should promote water movement, and the installation should be one that can be inspected, isolated, blanked and serviced safely throughout its life.[4] Materials differ in their resistance to seawater corrosion and biological settlement, and copper-based alloys carry some inherent antifouling character, though resistance to one corrosion mechanism never implies resistance to all conditions.

Antifouling coatings are used on hulls, sea chest walls and gratings, but complex shapes make correct thickness hard to achieve at edges, corners, welds and supports, and damage during service or cleaning creates unprotected areas where corrosion and fouling begin.[4]

Cleaning can be proactive, removing early slime before visible growth, or reactive. Either way the method must suit the tube material and coating, and removed material must be controlled in line with local environment. Cleaning stays necessary in most maintenance strategies, but it is a poor primary control: access is difficult, vessel availability suffers, and detached material can obstruct gratings elsewhere in the system.

WHERE ICAF FITS

Copper dosing and chlorine-based treatment are the two most established approaches for internal seawater service.[10]

For sea chests and box cooler installations specifically, impressed current antifouling is the method most commonly applied, because the treatment is generated inside the protected volume rather than dosed into a flow that has to be routed past every surface.

The remainder of this paper concentrates on ICAF for that reason. It is preventive by design and works best when started with clean surfaces and run consistently, and it should not be treated as a rapid cleaning system for a sea chest that is already heavily fouled.



Figure 6. ICAF Anodes Fitted to a Box Cooler
Source: NRF

6. HOW AN ICAF/MGPS SYSTEM WORKS

MGPS, marine growth prevention system, is the general term for systems that limit marine growth in niche areas and seawater systems. ICAF, impressed current antifouling, is a specific type of MGPS based on controlled electrical current, which drives an electrochemical reaction at one or more anodes so that antifouling material is released into the surrounding seawater at a steady, chosen rate.

IMPRESSED CURRENT, AND WHY THE DISTINCTION MATTERS

Many marine growth prevention systems use sacrificial anodes. These dissolve at whatever rate the surrounding water and the connected metals dictate. An impressed current system is different. It applies a controlled direct current between copper anodes and a cathode, which in NRF's arrangement is an integrated steel plate.[2] The operator controls the output.

That control has two consequences. Protection can be matched to the actual duty, rather than to whatever the water happens to be doing. And no more copper is released than the design requires, which both limits what enters the environment and makes the anodes last longer. NRF's ICAF system includes control functions intended to release the minimum quantity of copper necessary for protection, with the output set against the vessel's design duty at commissioning and adjustable in service.[1]

CONTROLLED DISSOLUTION OF COPPER

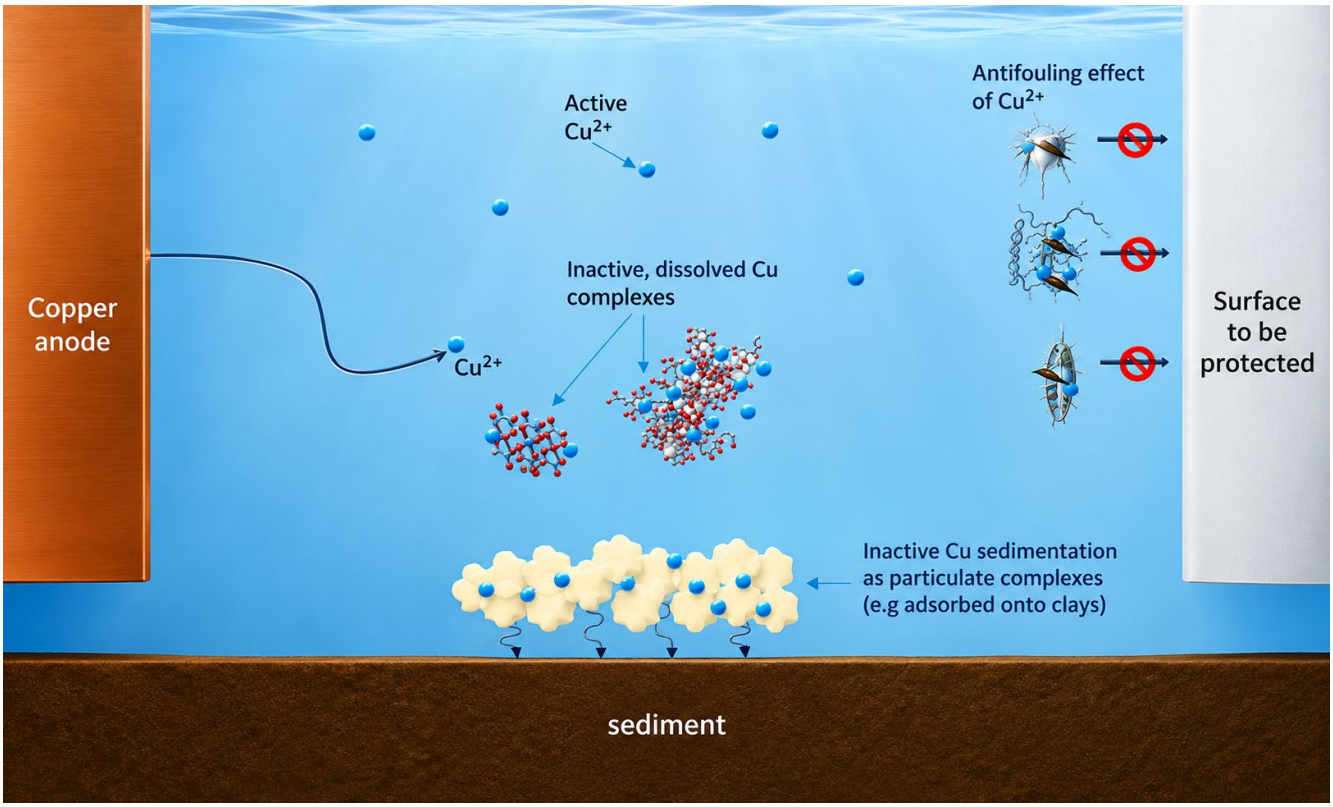


Figure 7. Copper transformations and antifouling activity in seawater
Source: CORROSION B.V.

6. HOW AN ICAF/MGPS SYSTEM WORKS

When the current is applied, copper atoms leave the anode and enter the seawater. Once there, copper does not stay in one form. It exists as free ions, as ions bound to other substances, as tiny particles and as solid compounds. Which form dominates, and how easily organisms can take it up, changes with acidity, salt content, organic matter and time.[2]

The antifouling effect comes specifically from the free cupric ions, chemically written as Cu^{2+}. This is the most active antifouling form of dissolved copper. It blocks the sites that fouling organisms use to take up the nutrients they need to survive and grow. Organisms at the earliest stage of settlement cannot establish, so surfaces stay clean. The free copper ion is highly reactive and loses its effect once it binds to other substances or settles out as a solid. On NRF's account, that is why the effect is concentrated near the protected area rather than spread across the wider environment.[2]

DISTRIBUTION IS AS IMPORTANT AS GENERATION

Producing copper at the anode is only half the job, because the treatment has to reach the surfaces that need protecting. The shape of the sea chest, water exchange, temperature, salinity, suspended solids and the position of the cooler all influence distribution and residence time.

Poorly circulated corners receive less treatment, while strong local flow can carry released material away before it has had sufficient contact with the intended area. Anode placement and output therefore have to be based on the specific sea chest rather than a general rule, with cooler dimensions, sea chest volume, inlet and outlet arrangement, expected vessel speed and idle periods all feeding into the antifouling duty. This is the strongest argument for treating the box cooler and its antifouling system as one designed installation rather than as a cooler with equipment added to it.

THE ROLE OF ALUMINIUM AND IRON ANODES

The same principle can be used to dissolve aluminium or iron anodes alongside the copper, for corrosion reasons rather than fouling reasons. The right choice depends on the main materials in the seawater circuit.[2]

Where the pipework is steel, aluminium anodes are commonly installed together with the copper. The dissolved aluminium forms soft, gel-like particles that combine with copper reaction products and gradually settle on internal surfaces. These particles have a very large surface area, so they hold onto copper ions and carry them further through the system. In practice they improve how well the antifouling copper is distributed.[2]

Iron anodes are generally preferred where copper alloys are present. Those alloys rely on a thin, naturally formed protective film. Under fast-flowing seawater that film can be worn away or destabilised.

6. HOW AN ICAF/MGPS SYSTEM WORKS

Extra iron in the water helps the film form again and stay intact,[2] an effect that independent copper-nickel guidance also recognises.[11]

These combinations should not be generalised. An anode arrangement that suits one set of materials can be unsuitable for another.

WHAT AN ICAF SYSTEM IS DESIGNED TO DO, AND WHAT IT IS NOT

An ICAF system is designed to prevent fouling organisms from settling and establishing. It is not designed to sterilise a sea chest, and it will not repair damaged coatings, correct unsuitable flow conditions or remove established shells and heavy deposits. It cannot protect an area that does not receive adequate treatment because of poor anode placement, a failed electrical component or an operating pattern outside the design basis.

The distinction matters for compliance as well as engineering: where a vessel must meet a specific biosecurity standard, that should be confirmed against the relevant national requirement rather than inferred from the presence of an antifouling system.

KEY TAKEAWAY

ICAF works by keeping the cupric ion concentration high enough, in the right place, continuously. Generation is the easy part. Placement, distribution and consistent operation determine whether the system performs.



Figure 8. ICAF Anode
Source: NRF

7. BENEFITS OF USING AN ANTIFOULING SYSTEM IN MARINE COOLING SYSTEMS

An antifouling system creates value by protecting the cooling function across the vessel's real operating cycle. The benefits are best expressed in terms of performance stability, maintenance planning, equipment condition and compliance readiness.

COOLING PERFORMANCE STAYS WHERE IT WAS DESIGNED TO BE

Keeping tube surfaces and flow passages clear preserves the heat transfer area the cooler was sized for and supports even circulation around the bundle. The system holds its temperatures during high load and warm-water operation, which is precisely when a fouled system fails.

In terms of the evidence in section 3, an antifouling system keeps the installation on the flat part of the curve, well away from the point where performance drops away. That is a commercial outcome as much as a technical one.

MAINTENANCE BECOMES SCHEDULED RATHER THAN DISCOVERED

This is the benefit that changes how a vessel is run.

Heavy fouling produces unplanned work: underwater cleaning at short notice, reduced load, or a docking earlier than the plan allowed. Prevention moves that work into the maintenance schedule. Anode life can be chosen to match the vessel's docking period,[1] so replacing anodes becomes a planned dry-dock task rather than something triggered by a temperature alarm.

The financial comparison is not cleaning cost against equipment cost, but a scheduled replacement at a known date against an unscheduled intervention at an unknown one, with the vessel's earning days attached to it.

	FOULING MANAGED REACTIVELY	FOULING PREVENTED
Cooling performance	Degrades invisibly, then fails under high load or warm water	Held close to design condition across the docking interval
Inspection burden	Diver surveys or early docking driven by symptoms	Planned inspection against a known baseline
Timing of work	Determined by the growth, at short notice	Determined by the maintenance plan
Surface condition	Repeated aggressive cleaning damages coatings and soft alloys	Light growth, gentler cleaning, longer coating life
Compliance evidence	Condition demonstrated only at inspection	Continuous operating record of the installed system

7. BENEFITS OF USING AN ANTIFOULING SYSTEM IN MARINE COOLING SYSTEMS

LESS CLEANING, AND LESS DAMAGE FROM CLEANING

Cleaning is easier when growth is light. Dense macrofouling needs more force and produces more debris, and repeated aggressive cleaning damages coatings and soft alloy surfaces, which raises future fouling and corrosion risk. By limiting settlement and early growth, an active antifouling system reduces both the frequency and the severity of cleaning.

THE BOX COOLER CONCEPT IS PROTECTED

A box cooler is chosen because it delivers compact cooling with very little seawater-side machinery, no seawater pumps and no seawater piping to maintain.[1] Fouling inside the sea chest undermines that advantage if it creates frequent cleaning needs or unreliable cooling. Integrating antifouling into the installation protects the reason the cooler was specified: a cooling concept expected to run reliably between scheduled dockings.



Figure 9. 3D Rendering of a Box Cooler
Source: NRF

VISIBILITY OF SYSTEM CONDITION, AND READINESS FOR REGULATION

A controlled system produces data. Current, voltage, anode consumption, cooling temperatures and inspection findings can all be reviewed over time. That supports much better decisions than simply noting the absence of alarms. A trend shows a problem developing while there is still time to act cheaply.

With the IMO having approved work on a legally binding biofouling framework,[5] which DNV expects to become an international requirement in 2029 at the earliest,[6] and the 2023 Guidelines already treating sea chests as niche areas that need managing,[4] a vessel with an installed, operating and documented system is in a materially stronger position than one relying on inspection alone. The IMO's model Biofouling Record Book already includes entries for system operation, downtime, malfunction and maintenance,[4] so a system that is monitored also generates the record that future requirements are likely to ask for.

These benefits depend on correct selection, installation and operation. The strongest business case is built from the individual vessel's fouling pressure, downtime cost, access constraints and docking strategy. Section 9 sets out how to get those decisions right.

8. NRF ANTIFOULING SYSTEMS

NRF has manufactured cooling products for close to a century and invented the box cooler in 1959, specifically to keep engines cooled with surface water free of fouling.[1,3] Antifouling is not an accessory line for NRF. It is the problem the core product was created to solve.

AN ANTIFOULING SYSTEM DESIGNED AROUND THE COOLER

The NRF ICAF arrangement places copper anodes below the box cooler. Current from the power supply dissolves them gradually, and natural and forced water movement distributes the copper through the sea chest and tube bundle.1 The electrochemical arrangement uses a controlled voltage difference between the copper anodes and integrated steel plate cathodes.[2]

Because the anodes are positioned in relation to a cooler whose shape NRF designed, the distribution problem described in section 6 is addressed at the design stage rather than at installation. NRF supplies box coolers in top-build and bottom-build configurations, and in stepped, extended and multi-circuit variants developed to follow the shape of a difficult sea chest.[1] Those configurations matter for antifouling as well as for heat transfer, because the shape of a sea chest drives both fouling risk and treatment coverage.

COMPONENT	WHAT IT DOES FOR THE OPERATOR
Copper anodes	Generate the cupric ion concentration that prevents settlement, positioned for the specific cooler and sea chest
Power and control unit, 50/60 Hz, single or three phase	Regulates current so that no more copper is released than the design requires, which limits consumption and extends anode life
Anode life matched to the docking period	Turns anode replacement into a planned dry-dock task instead of an unscheduled intervention
Seawater-resistant cable, hull feedthrough and junction box	Keeps the electrical path intact in the environment least forgiving of a weak connection
Optional aluminium or iron anodes	Selected against the materials in the circuit, for distribution support or protective film regeneration

NRF also supplies ultrasonic antifouling, which uses transducers to make initial attachment more difficult and requires no continuous chemical release.[1] Having both technologies in the range means the selection conversation can start from the vessel rather than from the product.



Figure 10. Ultrasonic Antifouling Transducer
Source: Shipsonic

8. NRF ANTIFOULING SYSTEMS

CORROSION IS TREATED AS PART OF THE ANTIFOULING DESIGN

NRF links the choice of additional anodes directly to the materials present. Aluminium anodes are used where the pipework is steel, because the particles they form help spread the copper further. Iron anodes are used where copper alloys are present, because the extra iron helps their protective film regenerate.[2]

Box cooler construction reflects the same thinking. Epoxy coated aluminium brass bundles are specified for seagoing and brackish water service, to protect against galvanic corrosion. Bare bundles are used where stable inland conditions do not require the coating.[1]

Copper release limits biological settlement, but the complete installation still needs compatible materials, suitable coatings, controlled flow and a defined corrosion protection strategy, designed together.

CERTIFICATION, COVERAGE AND LIFECYCLE SUPPORT

NRF box coolers can be delivered with the classification certificates required by more than twenty societies and national authorities, including Bureau Veritas, DNV, Lloyd's Register, the American Bureau of Shipping, RINA, Nippon Kaiji Kyokai, the China Classification Society and the United States Coast Guard.[1]

Support does not stop at delivery. NRF operates an agent network across thirteen territories covering Europe, the Americas, the Middle East, Asia-Pacific and Africa, together with service partners in the Netherlands and Belgium, the United Kingdom and Ireland, Italy, Malta and Monaco, and Norway with coverage extending across Scandinavia, the Gulf, Africa, South-East Asia and Australasia. Those partners handle cleaning, re-coating, and repair using original parts, and custom spare parts.[1] They are equipped to respond rapidly and efficiently, helping vessel operators minimize dock time, as every additional hour in port can result in significant costs.

That continuity has practical value, because cooling performance, antifouling output and physical condition are easier to manage when the supplier understands the cooler, the installation method and the intended docking plan.

TALK TO NRF

To discuss box cooler sizing and antifouling specification for a particular vessel or newbuild project, contact the team at marine@nrf.eu or +31 (0) 485 476 458.

9. SYSTEM SELECTION, OPERATION, AND MAINTENANCE

A reliable ICAF installation starts from a clear design basis. The question is not whether the vessel operates in seawater, but whether the system matches the fouling pressure, sea chest, box cooler, materials and maintenance plan of this particular vessel. The IMO's guidance uses the vessel's operating profile as the basis for selecting antifouling systems, identifying temperature, salinity, speed and periods of inactivity as the relevant conditions.[4] Each of those alters fouling pressure, copper chemistry, water exchange or coverage. The full list of inputs needed for specification is in Appendix A.

ENGINEERING THE ANODE ARRANGEMENT

Anodes should be positioned so that treatment reaches the box cooler and the other intended surfaces, taking account of natural circulation, flow created by vessel movement, the position of the gratings and the location of sheltered zones. The quantity and size of anodes determine available output and service life, while the current setting determines the rate of consumption, so the two must be calculated together. Oversized anodes do not correct poor placement, and higher current does not compensate for poor distribution. The selection of copper, aluminium and iron anodes must be coordinated with the materials present and reviewed alongside any cathodic protection, so that the electrical systems do not interact in unintended ways.

COMMISSIONING, OPERATION AND MONITORING

Commissioning should begin with clean, inspectable surfaces, because an ICAF system prevents establishment and starting it after heavy fouling is present limits what can reasonably be expected. The commissioning checks are listed in Appendix A. Beyond the equipment itself, crew should know the normal readings, the alarm conditions and the action required after a power interruption.

In service, continuous operation is generally required to maintain protection, and it matters most during periods of low vessel movement, when settlement risk is highest and the temptation to shut equipment down is greatest. No single reading proves that all surfaces are clean: stable electrical readings do not confirm that treatment reaches a sheltered corner, and stable cooling temperatures can hide gradual fouling while ambient water stays cool. Electrical monitoring and physical inspection have to support each other, and trends over time are stronger evidence than any individual measurement. The vessel should also record periods when the system is unavailable, which is exactly what the IMO's model Biofouling Record Book asks for.[4]

RESPONDING TO ABNORMAL CONDITIONS

If fouling is found despite normal electrical readings, investigate coverage as well as output. Likely causes include unexpected flow patterns, changed water chemistry, incorrect anode placement, depleted or passivated anodes, electrical faults, extended inactivity, or growth already present at commissioning. If corrosion is found, do not assign the cause automatically to the antifouling system or to MIC: review

9. SYSTEM SELECTION, OPERATION, AND MAINTENANCE

FIVE QUESTIONS TO ASK BEFORE SPECIFYING AN ANTIFOULING SYSTEM

1. What exact surfaces and water volume must the system protect?
2. How will treatment reach those surfaces in every relevant operating condition?
3. Are the anodes and current settings compatible with the wetted materials and the corrosion strategy?
4. How will the crew confirm that the system is operating and that the sea chest remains acceptably clean?
5. Will the anodes and critical components remain serviceable until the planned inspection or docking?

A design that answers these five questions clearly is easier to operate, easier to maintain and easier to defend technically than one selected from a standard equipment list.

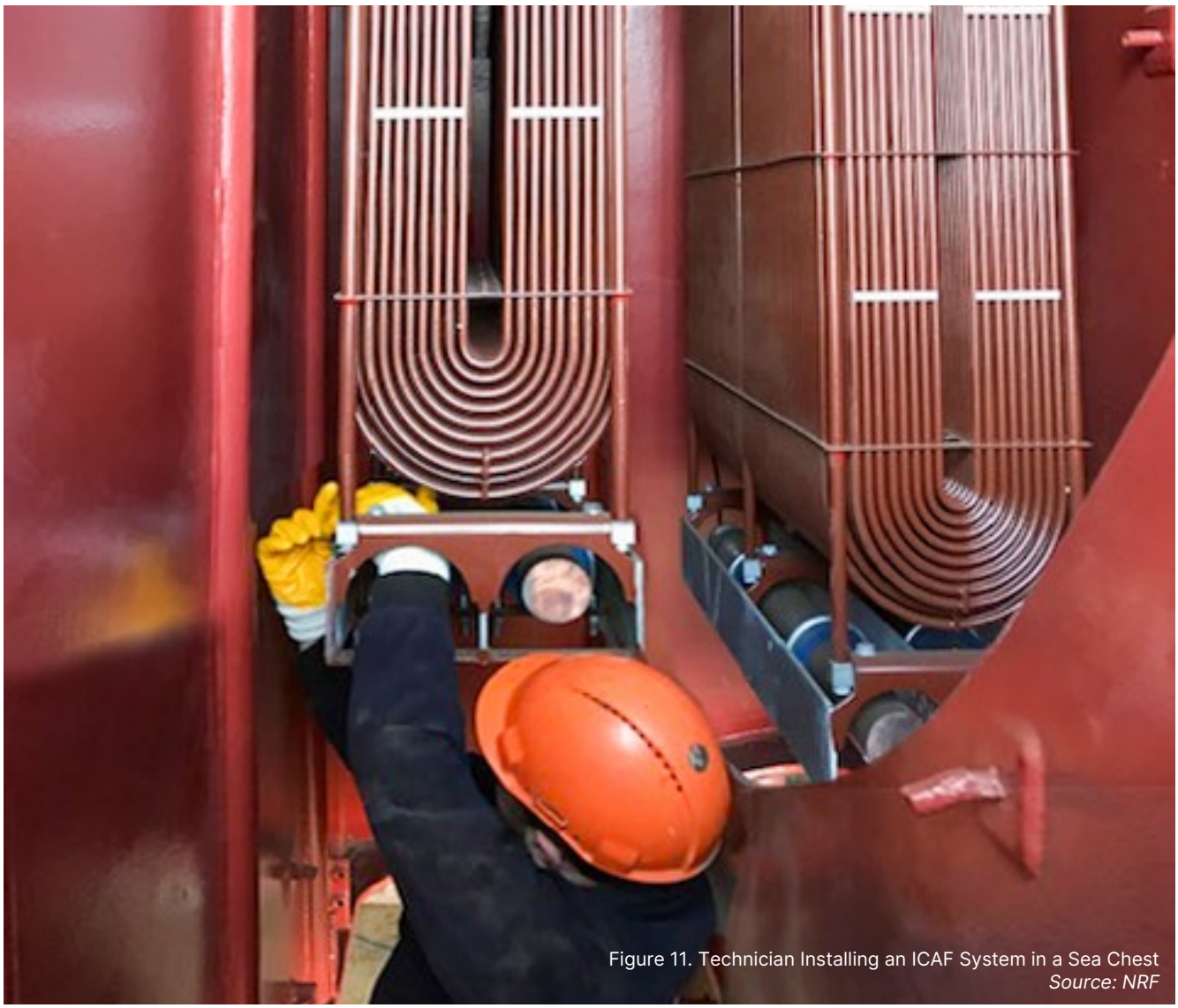


Figure 11. Technician Installing an ICAF System in a Sea Chest
Source: NRF

10. CONCLUSION

Box coolers transfer heat from a vessel's closed cooling circuit to the surrounding seawater in a compact arrangement with very little seawater-side machinery. Their performance depends on two things: clean heat transfer surfaces and free water movement inside the sea chest.

Biofouling attacks both. Microfouling adds thermal resistance and lays the foundation for larger growth; macrofouling restricts the spaces around the tube bundle, obstructs gratings and disturbs natural circulation. The effect stays hidden while cooling margin remains, then becomes critical during warm-water or high-load operation, and the published evidence on internal seawater systems shows how sharp that transition can be.[8] Corrosion compounds the problem, since biofilms and deposits change local surface chemistry, conceal material loss and contribute to under-deposit corrosion and MIC, while altered flow damages the protective films that non-ferrous alloys depend on.

ICAF gives box cooler sea chests a preventive option that works where the problem starts. Controlled current dissolves copper anodes and maintains conditions in which fouling organisms cannot settle and establish, with aluminium or iron anodes added for defined material and corrosion purposes. Success depends on anode placement, distribution, current control, material compatibility, monitoring and maintenance, all of which are decisions taken before the vessel enters service.

NRF invented the box cooler in 1959 to solve a cooling problem, designs the antifouling around its own coolers, certifies to more than twenty classification societies and national authorities and supports the installation through a global service network. For an owner, that means cooling performance, antifouling duty and the docking plan are handled as one engineering conversation rather than three.

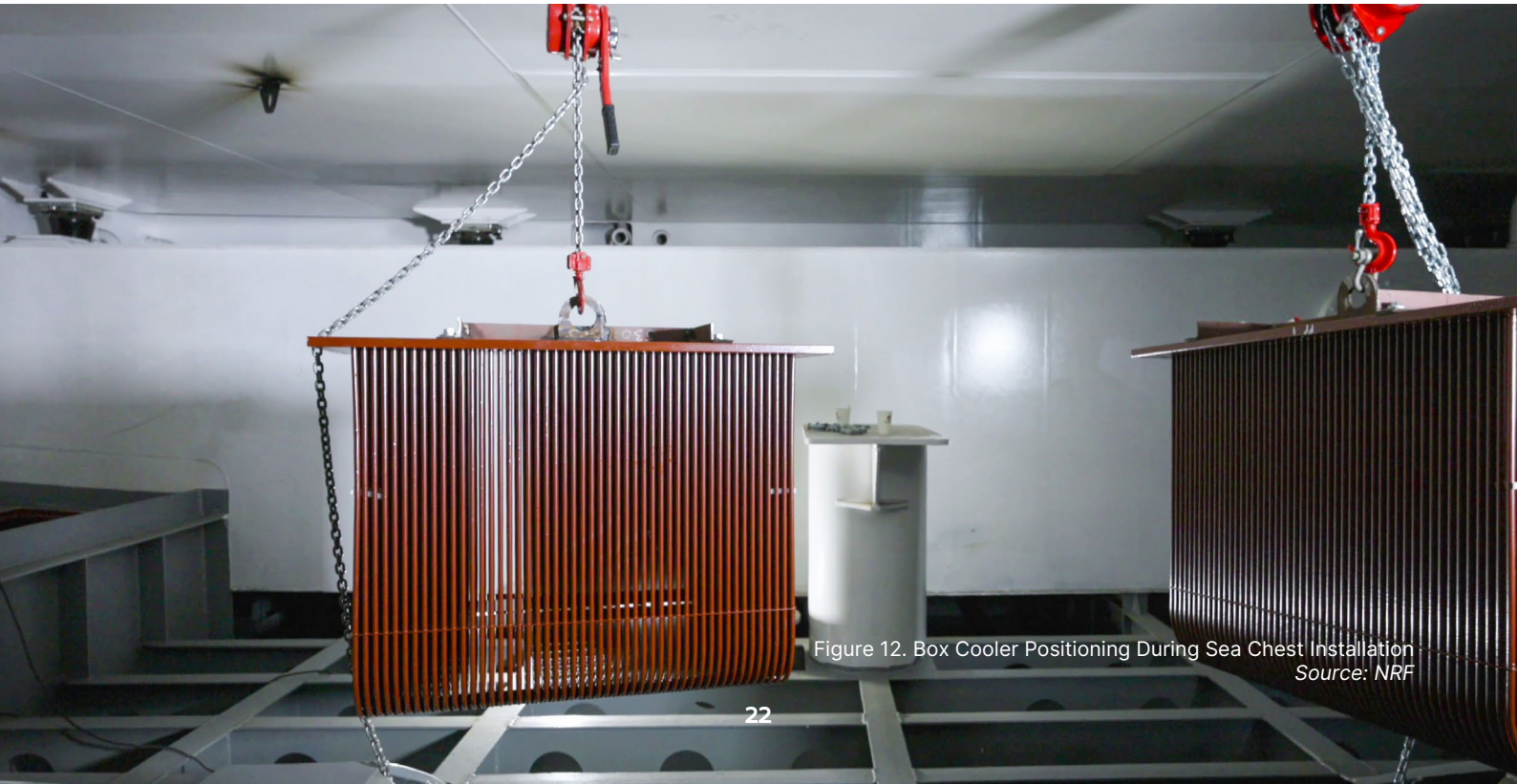


Figure 12. Box Cooler Positioning During Sea Chest Installation
Source: NRF

APPENDICES

APPENDIX A: SPECIFICATION, COMMISSIONING AND MAINTENANCE CHECKLIST

A1. INFORMATION REQUIRED BEFORE THE SYSTEM IS SPECIFIED

- Vessel type and duty cycle, including typical engine load and cooling demand.
- Trading areas, water temperature, salinity and seasonal conditions.
- Expected periods at berth, at anchor or in lay-up.
- Sea chest dimensions, inlet and outlet arrangement, gratings and internal obstructions.
- Box cooler type, dimensions, tube material and installation method.
- Hull, sea chest, pipework and other wetted materials.
- Coatings, cathodic protection and existing corrosion control measures.
- Planned docking interval and access for anode replacement.
- Available electrical supply and cable routing.
- Applicable class, flag, port, environmental and biosecurity requirements, including the biocidal product status of the anode supply in the waters concerned.

A2. COMMISSIONING CHECKS

- Correct anode type, position and electrical connection.
- Cable integrity and watertight hull feedthroughs.
- Power supply input and control unit operation; current and voltage confirmed for each circuit.
- Initial settings verified against the approved design basis.
- Cooling system temperatures and other baseline performance data recorded.
- Anode dimensions or mass documented for future consumption checks.
- Crew briefed on normal readings, alarm conditions and the response to a power interruption.

A3. ROUTINE INSPECTION AND MAINTENANCE

- Check power and control unit condition, alarms and calibration.
- Inspect cables, terminals, junction boxes and hull feedthroughs.
- Measure or estimate anode consumption against the expected rate, and confirm anodes have not become passivated, damaged or obstructed.
- Inspect the sea chest, gratings and box cooler for fouling, deposits, coating damage and corrosion.
- Clean surfaces using methods compatible with the tube material and coating.
- Replace anodes before the remaining life becomes insufficient for the next operating period.
- Review current settings after any major change in route, water conditions or vessel activity.

Inspection frequency should reflect risk. A vessel operating continuously in cool open water needs a different regime from one with long idle periods in warm coastal ports.

APPENDIX B: GLOSSARY

TERM	MEANING
Biofouling	The accumulation of aquatic organisms on surfaces immersed in water.
Microfouling	The early stage: a conditioning film and biofilm of bacteria and microorganisms, usually seen as slime.
Macrofouling	Visible growth such as algae, barnacles, tubeworms, mussels and hydroids.
Niche area	A submerged part of a ship more prone to fouling because of structural complexity, variable flow, coating wear or limited protection. Sea chests are niche areas; a box cooler installed inside one sits within that area.
Sea chest	A recessed compartment in the hull, open to the sea through gratings, providing a controlled water interface.
Box cooler	A tube bundle heat exchanger installed inside the sea chest, cooling a closed circuit directly against seawater.
MGPS	Marine growth prevention system. The general term for systems that limit growth in seawater systems and niche areas.
ICAF	Impressed current antifouling. An MGPS using controlled electrical current to dissolve copper anodes.
Cupric ion Cu^{2+}	The free hydrated copper ion, the most active antifouling fraction of dissolved copper.
Occlusion	Partial or complete blockage of a flow path by growth or debris.
MIC	Microbiologically influenced corrosion. Corrosion accelerated or redirected by microbial activity.
Passive film	The thin, naturally forming oxide layer that gives some alloys their corrosion resistance.
BFMP / BFRB	Biofouling Management Plan and Biofouling Record Book, the ship-specific documents recommended by the IMO's 2023 Guidelines.

REFERENCES

REFERENCES

Superscript numerals in the text refer to the sources below.

NRF PRODUCT DOCUMENTATION

1. NRF. Marine Catalog & Services, 6th edition.
2. NRF. Antifouling System. Technical note.
3. NRF. “Marine cooling solutions” and “ICAF system”, www.nrf.eu, accessed 3 August 2026.

STANDARDS, GUIDANCE AND REGULATION

4. International Maritime Organization. 2023 Guidelines for the Control and Management of Ships’ Biofouling to Minimize the Transfer of Invasive Aquatic Species. Resolution MEPC.378(80), adopted 7 July 2023.
5. International Maritime Organization. Outcome of MEPC 83, April 2025: approval of Guidance on in-water cleaning of ships’ biofouling (MEPC.1/Circ.918) and of a new output to develop a legally binding framework for the control and management of ships’ biofouling.
6. DNV. “Improve environmental performance with a ship-specific biofouling management plan.” 2025.

INDEPENDENT RESEARCH AND TECHNICAL SOURCES

7. Davidson, I., Cahill, P., Hinz, A., Kluza, D., Scianni, C. and Georgiades, E. “A Review of Biofouling of Ships’ Internal Seawater Systems.” Frontiers in Marine Science, vol. 8, 2021, article 761531.
8. Davidson, I., Cahill, P., Hinz, A., Major, R., Kluza, D., Scianni, C. and Georgiades, E. “Biofouling occlusion of ships’ internal seawater systems: operational, economic, and biosecurity consequences.” Biofouling, vol. 39, no. 4, 2023, pp. 410-426.
9. Association for Materials Protection and Performance. “Microbiologically Influenced Corrosion (MIC).” Accessed 3 August 2026.
10. Grandison, C., Piola, R. and Fletcher, L. A Review of Marine Growth Protection System (MGPS) Options for the Royal Australian Navy. DSTO-TR-2631, Defence Science and Technology Organisation, 2011.
11. Copper Development Association. “Copper-Nickel: Seawater System Design Guidelines.” Accessed 3 August 2026.



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