# Taiwan Customer Event

## Alfa Laval - Sonihull

# Introduction & Agenda

**_Mark Bruce_**
_Global Head of Sales – Sonihull_

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_Regional Business Manager– Sonihull_

- **Regulation updates - How Sonihull are contributing**
- **Ultrasonic Antifouling - The Theory**
- **Sonihull Technology & Applications**
- **Case Studies**
- **Sonihull Installation**
- **Research Projects - In Progress & Future**
- **Choosing the right Biofouling Management partner**
- **Questions & Answers**

# **Alfa Laval – Sonihull:**
# The World’s leading ultrasonic antifouling provider

- Over **17 Years** of ultrasonic antifouling experience
- Over **4,000** installations worldwide
- World’s first **ATEX** approved transducer for zones 0, 1 & 2
- Working across **all** maritime sectors and vessel types
- **Centre of excellence** in Abu Dhabi
- Continuous **Research & Development**
- **Global** sales & service network



**“How we're revolutionizing antifouling with sustainable innovation."**

# The hidden cost of marine fouling….

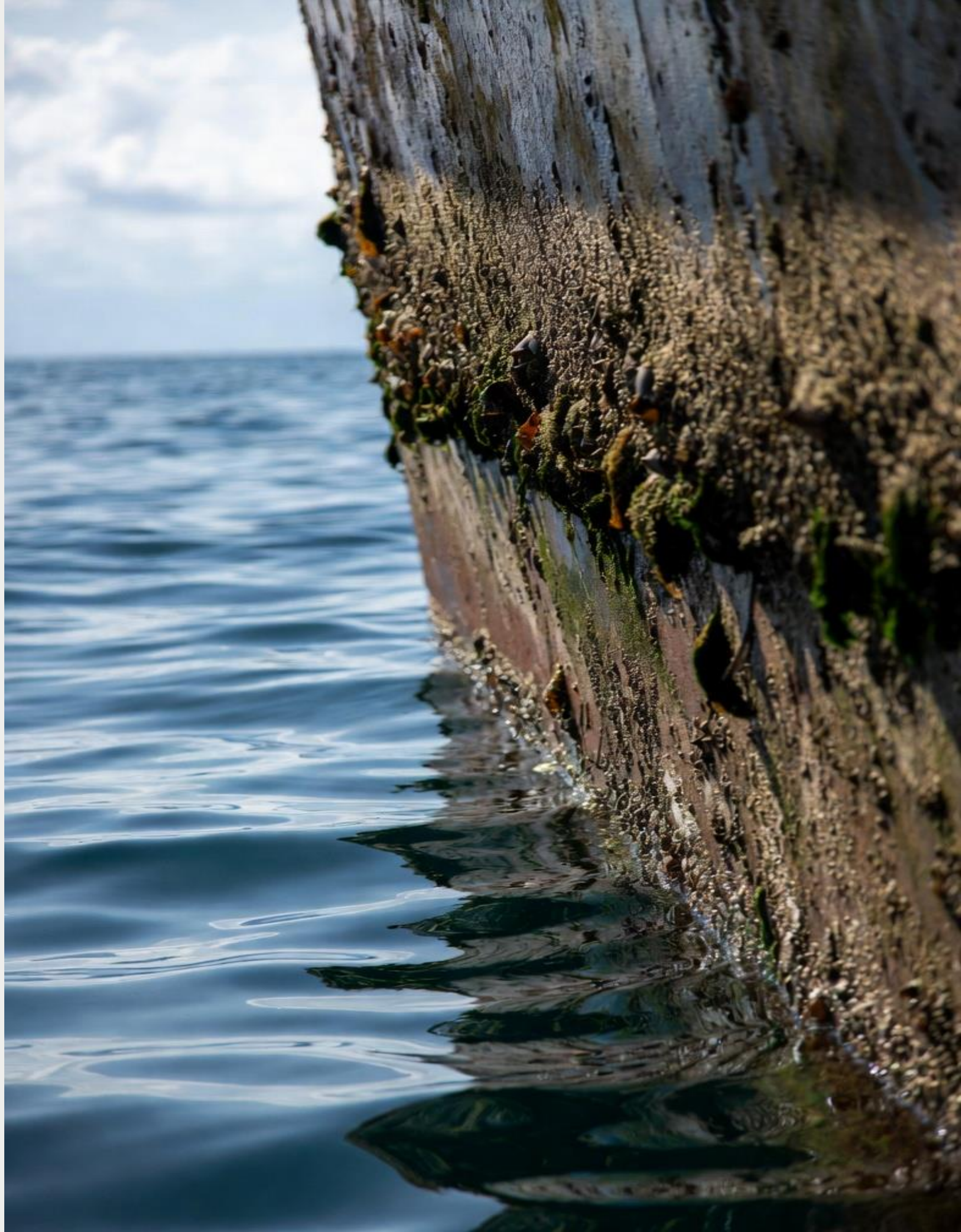
- **Fuel consumption rises dramatically**
  - Light slime → **+25–30 %**
  - Heavily fouled hulls → **+40 %**

- **Annual extra fuel cost per vessel can equate to $200K – $1M+** (depending on size & route)

- **Maintenance & downtime**
  - More frequent dry-docking & cleaning
  - Hull repairs & repainting: **$50K – $500K+** over vessel life
  - Reduced speed → lost revenue & schedule delays

- **Total 5-year impact on a single mid-size vessel can exceed $8M**

**"The hidden costs are bad… the coming regulations will make them unavoidable"**



# Regulation Updates

# **IMO’s biofouling revolution:**
# From guidelines to legally binding law

INTERNATIONAL MARITIME ORGANIZATION

- In April 2025 (MEPC 83) it was agreed to develop a **legally binding framework** for the **control and management of ships' biofouling** to minimize the transfer of invasive aquatic species and in February 2026 (PPR13) it was agreed to develop a new **standalone mandatory instrument.**
- Estimated time for **adopting the framework is 2029** followed by approval and ratification.
- **MEPC 84 (1st May 2026)** concurs with recommendation for a new standalone legally binding IMO instrument on ships’ biofouling
- Builds on 2023 Biofouling Guidelines (MEPC.378(80)) and Guidance on In-Water Cleaning
- Correspondence group established to develop structure, guidelines, and work plan
- The MEPC.378(80) guideline has been implemented by **Brazil** and will be implemented by **Norway** in 2028. **Australia** and **New Zealand** have their own rules on biofouling in force.
  - **1 February 2026 – Brazil – Full enforcement with penalties** of the revised NORMAM-401 hull fouling regime for ships **over 24 m** operating in Brazilian jurisdictional waters, including the requirement to carry a Biofouling Management Plan and Biofouling Record Book and to maintain a **fouling rating of 1 or lower** when transiting between Brazilian marine biogeographic regions, unless cleaned under approved conditions

## **“What can Sonihull do to help?”**

- ***Protects marine biodiversity*** *from invasive species*
- ***Improves fuel efficiency*** *(up to 20–40% potential savings)*
- ***Reduces GHG emissions & underwater noise***
- ***Lowers operational costs and supports sustainable shipping***

**Table 1: Rating scale to assess the extent of fouling on inspection areas**

| Rating | Description | Macrofouling cover of area inspected (visual estimate) | Recommended cleaning |
|---|---|---|---|
| 0 | **No fouling**<br>Surface entirely clean. No visible biofouling on surfaces. | - | - |
| 1 | **Microfouling**<br>Submerged areas partially or entirely covered in microfouling. Metal and painted surface may be visible beneath the fouling. | - | Proactive cleaning may be recommended as further specified in paragraph 9.4. |
| 2 | **Light macrofouling**<br>Presence of microfouling and multiple macrofouling patches. Fouling species cannot be easily wiped off by hand. | 1-15% of surface | Cleaning with capture is recommended as further specified in paragraph 9.9.<br><br>It is recommended to shorten the interval until the next inspection. If the AFS is significantly deteriorated, dry-docking with maintenance and reapplication of the AFS is recommended. |
| 3 | **Medium macrofouling**<br>Presence of microfouling and multiple macrofouling patches. | 16-40% of surface | |
| 4 | **Heavy macrofouling**<br>Large patches or submerged areas entirely covered in macrofouling. | 41-100% of surface | |

# The Theory

01 THE ENERGY CHAIN

# FROM VOLTS TO MICROBUBLES

*The four-stage energy conversion chain that makes the technology work*

1

### Electrical drive

Sonihull driver delivers AC voltage into the transducer. Drive uses a spectrum of frequencies selected for resonance, not the other way around.

2

### Piezoelectric conversion

Bonded piezoceramic converts electrical energy into mechanical strain. Efficiency peaks sharply at series resonance.

3

### Structural propagation

*Bulk longitudinal , primary mode*

Compression waves propagate through the plate . Lamb modes (A0, S0) and shear coexist as consequences of plate boundary conditions but are not the design mechanism.

4

### Radiation into water

*Impedance mismatch governs transfer*

At every wetted surface, displacement couples into the fluid. Impedance mismatch → most energy reflects, the rest forms the boundary-layer pressure field.

# Waves and the Geometry of Propagation

*Why coverage depends on the plate as well as the transducer*

## Wave types in the substrate

**Bulk longitudinal (P-wave): primary working mode**
Thickness-mode transducer drives compression waves through the plate. This is the dominant energy path from transducer to water.

**Lamb waves (A0 + S0)**
Present in any thin substrate as a consequence of plate boundary conditions. A0 (flexural) contributes additional out-of-plane displacement at the wetted surface but is not the design mechanism.

**Rayleigh (surface) waves**
Bulk shear arises from mode conversion at bonds and discontinuities. Rayleigh waves form at free surfaces of thick substrates. Both contribute to the overall field but are not engineered for.

## Propagation realities

**Transmission through plate thickness**
Compression waves cross the steel from dry to wetted face. Plate thickness is typically $<< \lambda$, giving quasi-uniform through-thickness compression.

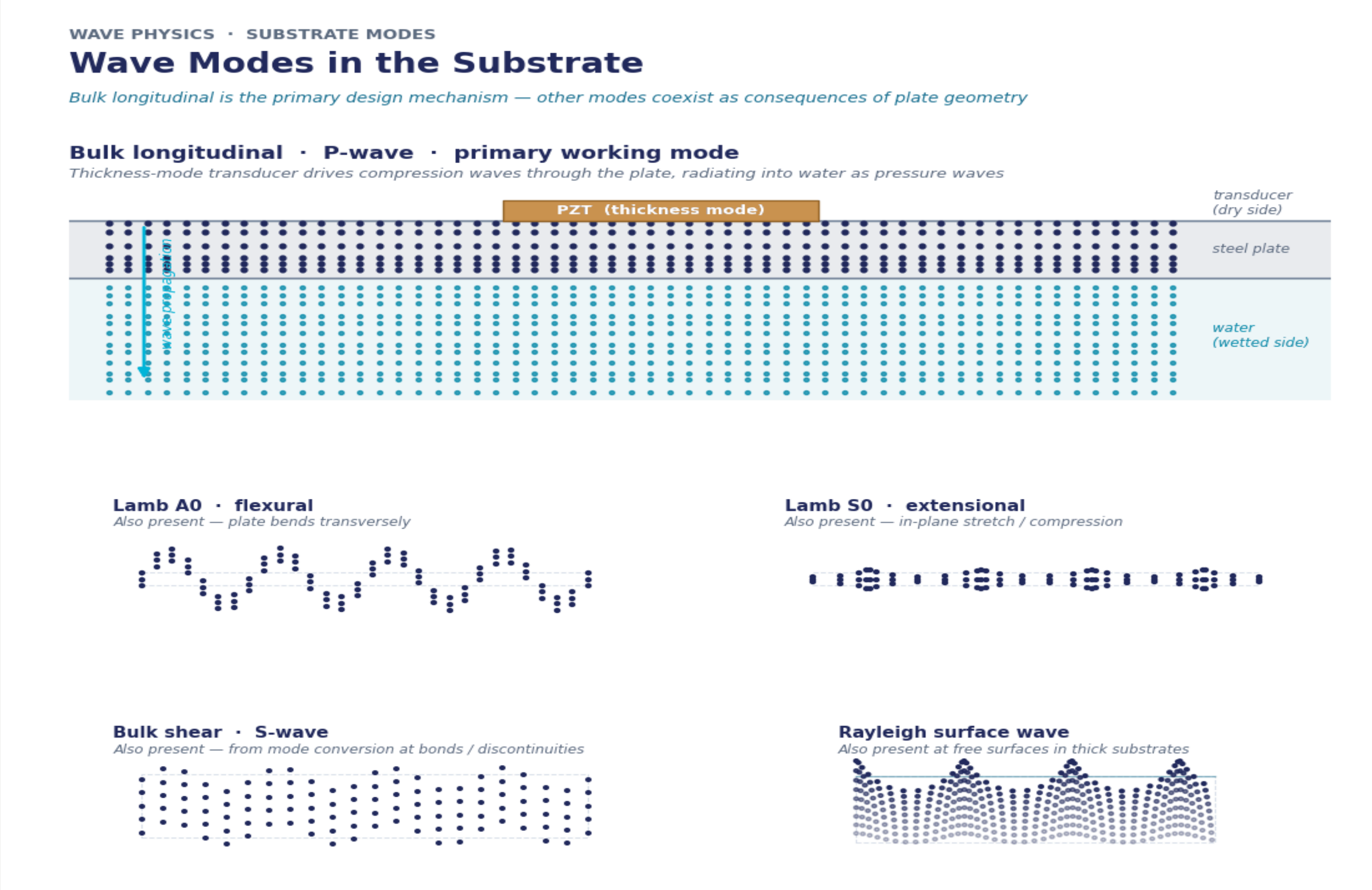
**Coupling at the wetted surface**
Steel-to-water impedance mismatch reflects most energy. Only the small transmitted fraction radiates into the water as a pressure wave.

**Attenuation sources**
Material damping, structural discontinuities (welds, frames, gaskets, ports) and radiation into water. The last is the desirable loss.

**Mode conversion at discontinuities**
Bulk ↔ Lamb ↔ surface conversion occurs at frame edges and welds. Some energy is lost, some redirected, bounding the effective radiating area.

# Waves and the Geometry of Propagation

*Why coverage depends on the plate as well as the transducer and its bond*



03 STRUCTURE-TO-FLUID COUPLING

# Where Structure Meets Fluid

*Acoustic impedance, transmission, and the radiation problem*

### Energy stays trapped in the structure

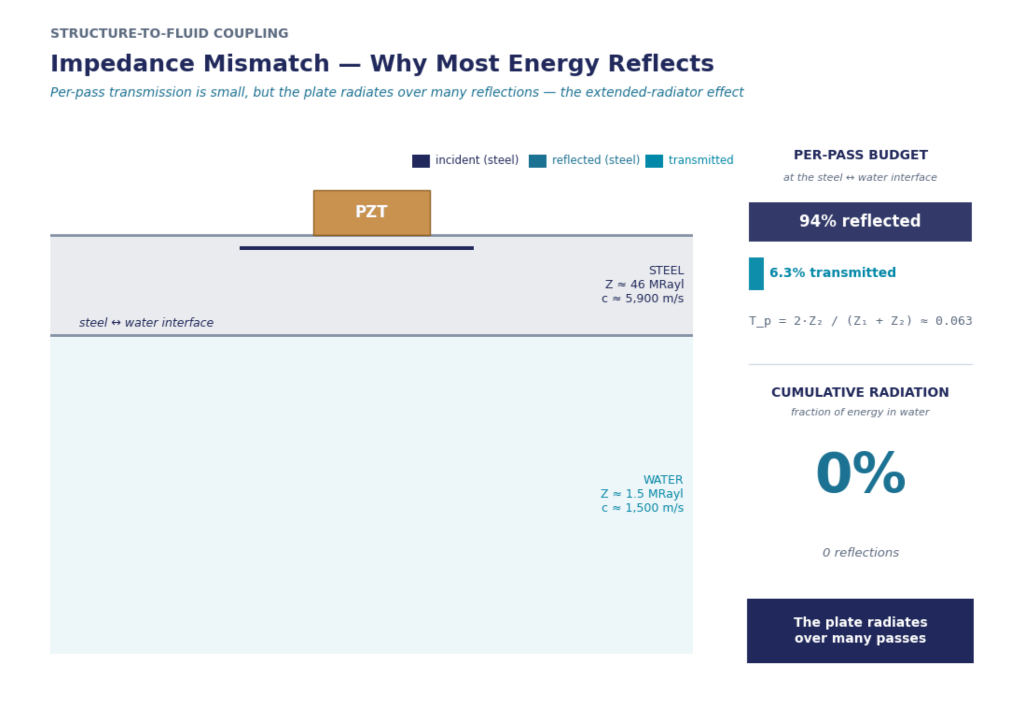
Reflected energy makes repeated passes along the plate, with repeated opportunities to radiate at different positions and angles.

### The plate becomes an extended radiator

Not a point source. The effective radiating area is the continuous plate section bounded by major discontinuities.

### Radiation impedance is frequency-dependent

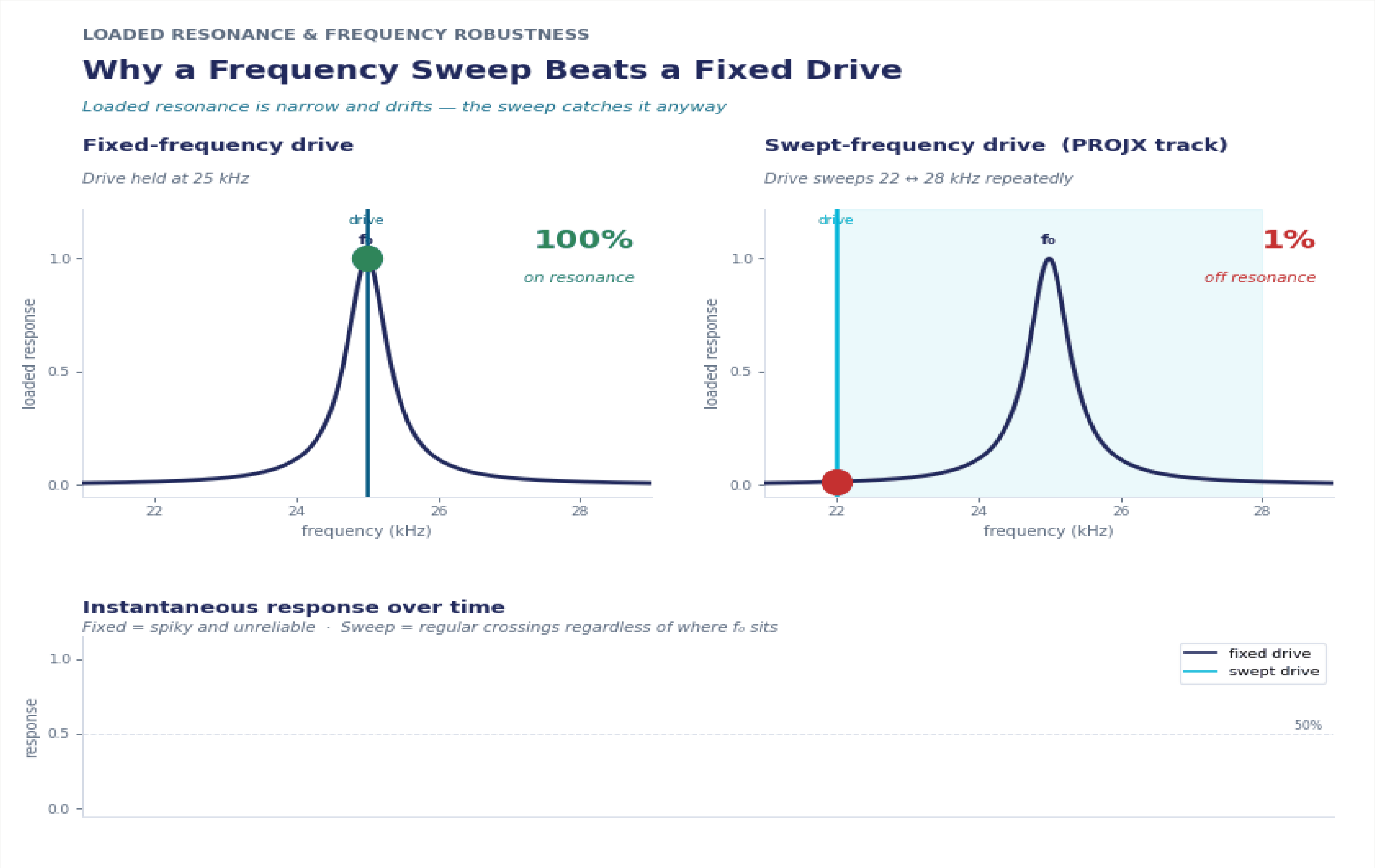
The design challenge is matching the driver to the loaded substrate, not to the bare PZT in air. This is where most field failures originate.



04 LOADED RESONANCE ANDFREQUENCY ROBUSTNESS

# Why Frequency Tracks Beat Fixed Frequency Systems

*The loaded resonance peak is narrow and drifts, the swept drive catches it regardless*



05 PRIMARY MECHANISM

# Non-inertial cavitation: The Primary Antifouling Mechanism

*Nucleation, growth, and collapse in the surface boundary layer*

### Cavitation threshold (Blakes Pressure) [Ref]

Minimum tensile pressure to trigger explosive growth from a nucleus of radius $R_0$. σ = surface tension, $p_0$ = ambient.
Blake Threshold tells you **when** the bubbles will form.

$$p_B = p_o + \frac{4\sigma}{3\sqrt{3}}\sqrt{\frac{3\sigma}{R_o^3(p_o + \frac{2\sigma}{R_o})}}$$

**≈ 0.8 bar**
Degassed water (1 µm nucleus, 20 °C)

**0.1 – 0.3 bar**
Practical seawater (dissolved gas + nuclei)

### Rayleigh-Plesset equation (bubble dynamics)

It describes how the radius of a bubble changes over time in response to external pressure changes: How **Violently** a bubble erupts.

$$R\ddot{R} + \frac{3}{2}\dot{R}^2 = \frac{1}{\rho}\left[(p_g - p_\infty(t)) - \frac{2\sigma}{R} - \frac{4\mu\dot{R}}{R}\right]$$

### Stable Cavitation

Bubble oscillates non-linearly around its equilibrium radius for many acoustic cycles. Generates periodic microstreaming and moderate shear. The dominant regime at antifouling power densities.

### Inertial (Transient) Cavitation

Bubble grows to 2–3× equilibrium radius, then collapses violently. Produces:

- micro-jets at ~100s m/s
- shock waves with local pressures ~100s MPa
- transient bubble-interior temperatures of ~1,000s K (sonochemistry)

***At Sonihull System, most activity is stable cavitation with intermittent inertial events , by design.***

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| Symbol | Name | Description |
|---|---|---|
| pB | Blake Threshold Pressure | The critical pressure value. If the liquid pressure drops below this, the bubble becomes unstable. |
| po | Ambient Pressure | The static pressure of the surrounding fluid (e.g., atmospheric pressure at the sea surface). |
| σ | Surface Tension | The force per unit length acting at the gas-liquid interface. Depends on temperature and salinity. |
| Ro | Nucleus Radius | The initial radius of the tiny gas bubble (the "seed") before it begins to grow or oscillate. |
| 33 | Mathematical Constant | A geometric constant resulting from the derivation of the bubble's potential energy minimum. |

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| Symbol | Definition |
|---|---|
| R | The instantaneous radius of the bubble. |
| R˙ | The velocity of the bubble wall (dtdR). |
| R¨ | The acceleration of the bubble wall (dt2d2R). |
| ρ | The density of the surrounding liquid. |
| pg | The pressure of the gas/vapor inside the bubble. |
| p∞(t) | The pressure in the liquid far away from the bubble (this is where you factor in your ultrasonic acoustic field). |
| σ | Surface tension of the liquid. |
| μ | Dynamic viscosity of the liquid. |

06 SECOND ORDER MECHANISM

# Microstreaming: The Second-Order Mechanism

*Steady-state shear from oscillatory motion; the background effect*

**Rayleigh streaming**
*Outside the viscous boundary layer*
Driven by gradients in wall shear stress. Large-scale circulation cells, lower intensity but bulk-scale reach.

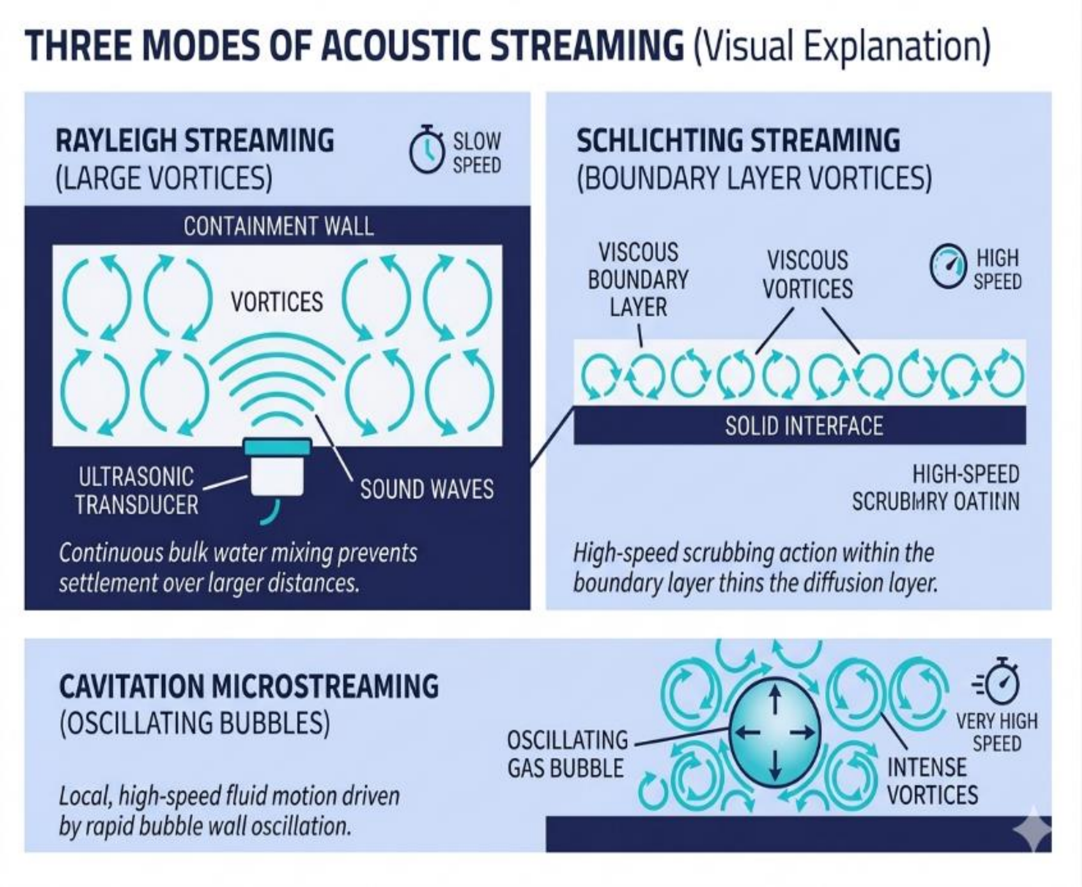
**Schlichting streaming**
*Inside the viscous sublayer*
Strong vorticity confined to the near-wall region. Counter-rotating cells produce concentrated shear at the surface.

**Cavitation microstreaming**
*Around oscillating bubbles*
Intense circulation at μm scale. Co-localized with cavitation activity, dominates locally

Streaming is why the system works in regions where cavitation is only intermittent, it is the mechanism that fills the gaps between hotspots.

The 10–100 μm-thick concentration boundary layer is what microorganisms rely on for nutrient uptake and chemotactic settlement signalling. Streaming continuously thins or disrupts it.

Continuous low-Reynolds shear keeps the conditioning film from stabilizing, even in regions where cavitation thresholds are not exceeded.



07 THE BIOLOGICAL TARGET

# What Ultrasound Actually Does to Biology

*Settlement disruption; not killing, not cleaning*

| Stage | Timeframe | Dominant Organisms | Ecological Role & Impact | Key Scientific Reference(s) |
|---|---|---|---|---|
| I. Biochemical Film | 0 – 24 Hours | Organic molecules (proteins, lipids) | Conditioning: Prepares the net surface for microbial attachment by altering surface energy. | Hellio & Yebra (2009) Maki & Mitchell (2002) |
| II. Primary Biofilm | 1 – 7 Days | Bacteria & Diatoms (Slime) | The Glue: Microorganisms form a sticky matrix (EPS) that provides a food source for larger larvae. | Bloecher et al. (2013) Grzegorczyk et al. (2018) |
| III. Initial Macro-fouling | 1 – 3 Weeks | Filamentous green algae, Brown algae | Water Flow Restriction: These fast-growers use the biofilm to anchor. They significantly reduce dissolved oxygen. | Bannister et al. (2019) Lakra et al. (2020) |
| IV. Secondary Macro-fouling | 4 – 10 Weeks | Hydroids (Ectopleura larynx) | Health Hazard: This is the peak biomass stage in Norway. High-pressure cleaning here causes gill damage. | Bloecher & Guenther (2018) Guenther et al. (2010) |
| V. Tertiary / Climax | 3 – 6+ Months | Tunicates (Ciona intestinalis), Blue Mussels | Structural Load: These heavy, "fleshy" or shelled organisms add massive weight and cause net deformation. | Bloecher et al. (2015/2025) Fitridge et al. (2012) |

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Ultrasound is used to prevent Stage 1 and 2 biofouling by disrupting the biological glue (biofilm) that larvae like mussels and hydroids use to attach.

07 THE BIOLOGICAL TARGET

# What Ultrasound Actually Does to Biology

*Settlement disruption; not killing, not cleaning*

| Organism class | Primary disruption mode | Frequency window |
|---|---|---|
| Bacteria (Pseudomonas, Vibrio) | Membrane shear; biofilm matrix disruption | 30–50 kHz |
| Diatoms | Frustule damage; settlement prevention | 25–40 kHz |
| Algal spores (Ulva spp.) | Chemotaxis disorientation; adhesion prevention | 20–40 kHz |
| Barnacle cyprids | Exploratory disorientation; prevents cementation | 20–30 kHz |
| Mussel byssal threads | Prevents new anchoring (does not detach existing) | 20–30 kHz |

**Different Organisms have different effective frequency classes.** Swept- or multi-band operation broadens organism coverage. No single frequency hits all targets. Sonihull uses multi frequency tracks and covers a broad range.

08 KEY TAKEAWAYS

# Summary of the physics

*Prevention of biological growth*

## 01

### It's a chain of energy conversions

Electrical → mechanical → structural → fluid. Each stage has losses; the system must be designed and matched as a whole.

## 02

### The structure is the radiator

Coverage is governed by plate geometry, frames and discontinuities, not by a spherical field around the transducer.

## 03

### Three coupled mechanisms

Cavitation dominates near the transducer. Microstreaming extends the effective range. Surface vibration denies attachment everywhere in between.

## 04

### It prevents, it does not clean

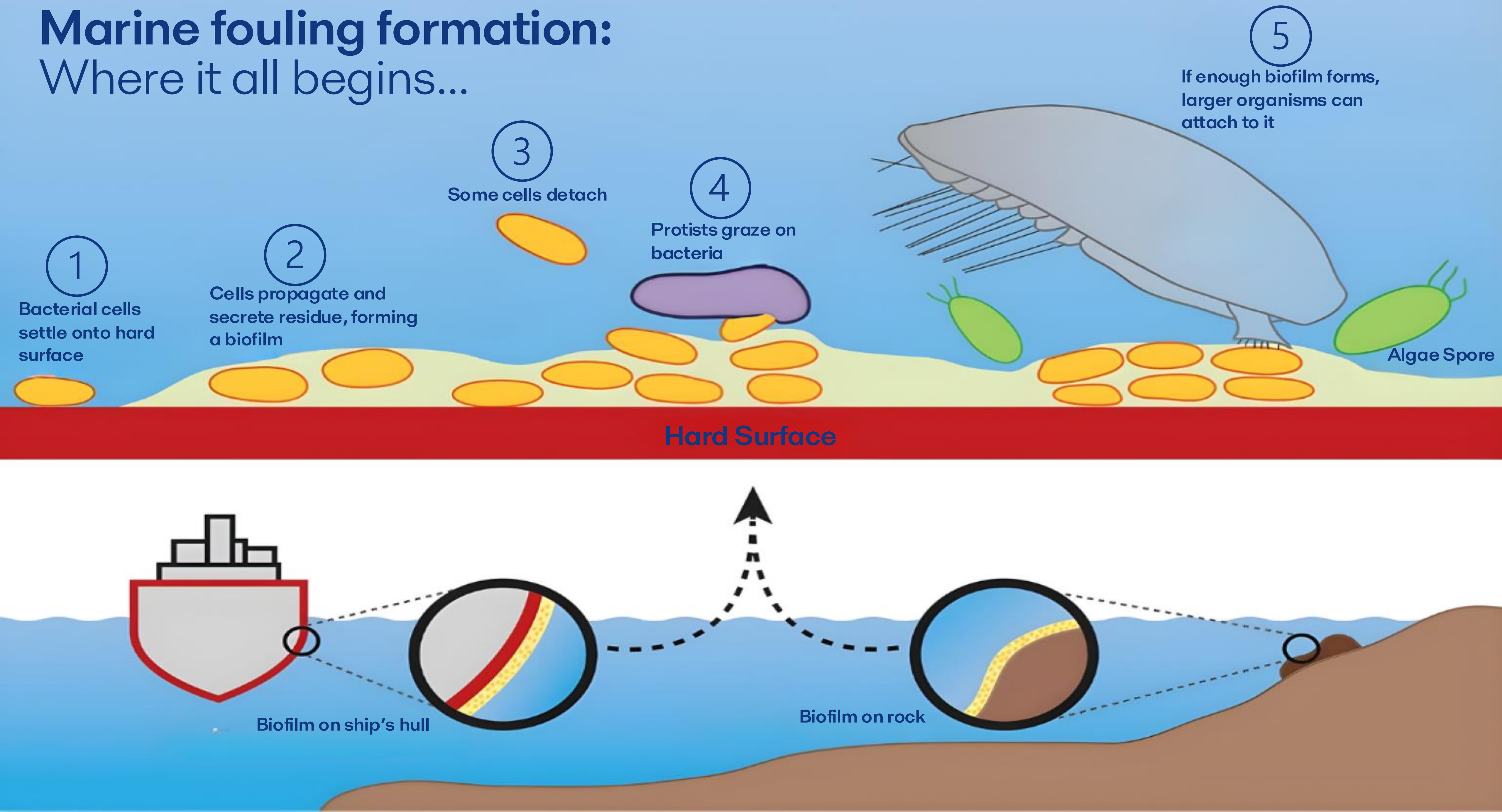
Ultrasonic disrupts settlement stages of fouling. Established macrofouling requires mechanical removal; this technology stops it from coming back.

## 05

### Verify on the loaded system

Bare-transducer specs don't predict real performance. Loaded impedance and measured surface displacement on the installed structure are what matter.

# **Marine fouling formation:**
## Where it all begins...



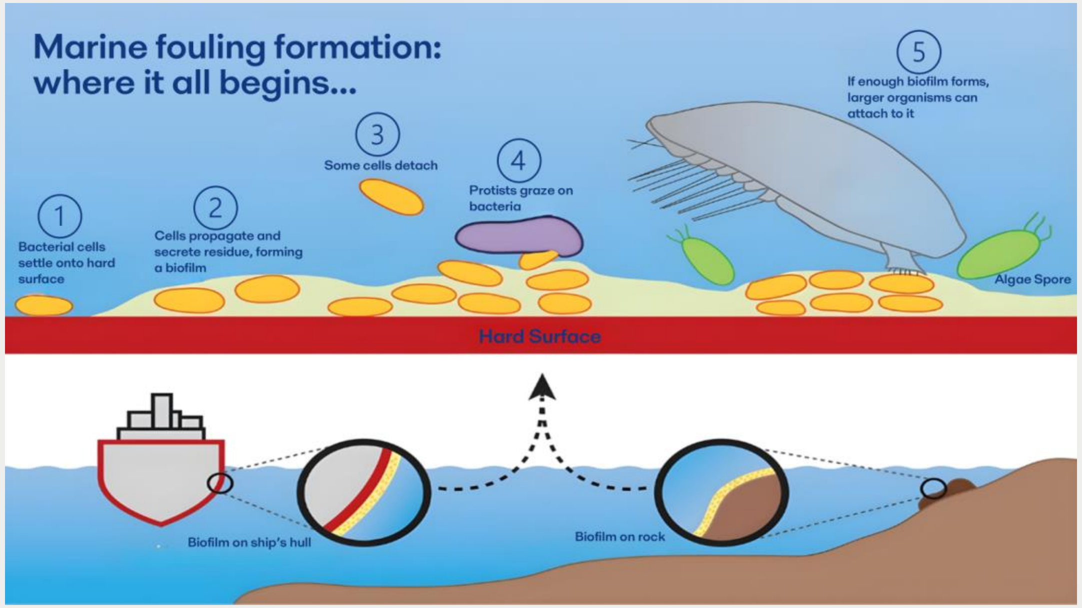
# Marine fouling formation:
## Fouling isn't just a problem for tropical areas

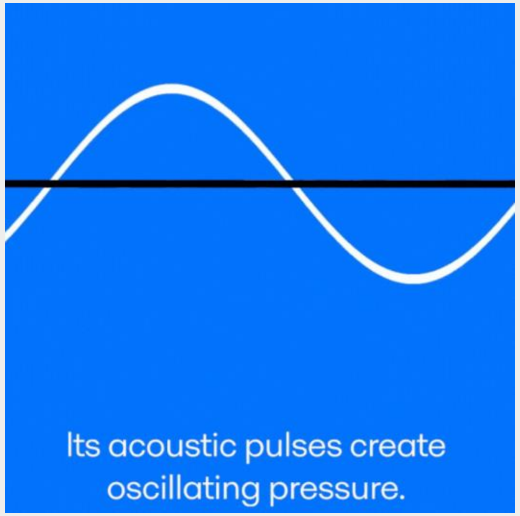
| Stage & dominant organisms | Tropical / Arabian Gulf | Temperate / Cold waters |
|---|---|---|
| – **Biochemical conditioning film**<br>Dissolved organic molecules, proteins and lipids adsorb directly onto the bare metal surface — invisible to the naked eye, but primes the hull for microbial attachment. | DUBAI / SINGAPORE<br>**< 1–2 hours**<br>Near-instant in warm water | NORWAY / UK<br>**Up to 24 hours**<br>Slower in cold water |
| = **Primary biofilm (slime layer)**<br>Bacteria (incl. Vibrio spp.), diatoms and cyanobacteria colonise the conditioning film. Forms a visible slime layer. This is the foundation everything else builds on. | DUBAI / SINGAPORE<br>**1–2 days**<br>Rapid in Gulf temperatures | NORWAY / UK<br>**1–7 days**<br>Variable by season |
| ≡ **Initial macro-fouling**<br>Fast-growing green algae (Ulva spp.) and early Polychaete worms become visible. Hull surface is now biologically active and adhesion is strong. | DUBAI / SINGAPORE<br>**5–10 days**<br>Within first two weeks | NORWAY / UK<br>**1–3 weeks**<br>Onset from week one |
| ≤ **Secondary macro-fouling**<br>Hard foulers arrive: Barnacles (Amphibalanus spp.), Tubeworms and Hydroids. Significant drag penalty begins. Removal now requires mechanical intervention. | DUBAI / SINGAPORE<br>**2–4 weeks**<br>Barnacles visible by week 3 | NORWAY / UK<br>**4–10 weeks**<br>Peak in spring–summer |
| < **Tertiary / Climax community**<br>Oysters, Mussels, large Tunicates and Sponges dominate. Full biofouling community established. Hull drag can increase fuel consumption by 10–40%. | DUBAI / SINGAPORE<br>**2–3 months**<br>Year-round in the Gulf | NORWAY / UK<br>**6–12+ months**<br>Slower seasonal build-up |

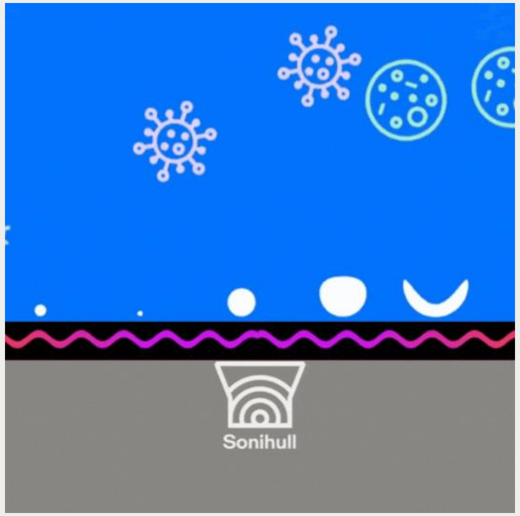
# Sonihull Technology & Applications

# **Sonihull:**
# How does it work?

- The transducers generate acoustic pulses in **targeted** ultrasonic frequencies, transmitted through the material they are attached to.
- The pulses create an oscillating pattern of **decreasing and increasing pressure** on the material surface resulting in a gentle surface agitation.
- This agitation is non-inertial cavitation, a **low-energy** process of **microscopic** bubbles imploding continuously, creating a **washing** effect that **repels** particles of organic matter (the building blocks for biofouling).
- Sonihull operates on **low-power**, **targeted** frequency principles, where energy is distributed evenly and precisely to:
  - **Prevent paint damage**
  - **Avoid surface fatigue**
  - **Eliminate risk of galvanic or stray current corrosion**
  - **Protect integrity of coatings and substrates**



# Sonihull:
# "The OG of ultrasonic antifouling"

- **Nylon plastic mix**
- **3.6 Wh per transducer**
- **Submersible**
- **Ex Zones 0,1&2 (option)**
- **Safe range of frequencies**
- **Surface mounted by Epoxy bonding**
- **Energy transfer enabled by coupling gel**

Sonihull antifouling systems use the **power of ultrasound** to protect the inside and outside of marine vessels and structures from **unwanted marine growth.**


# **Sonihull Xtreme:**
# Enhanced reliability and coverage

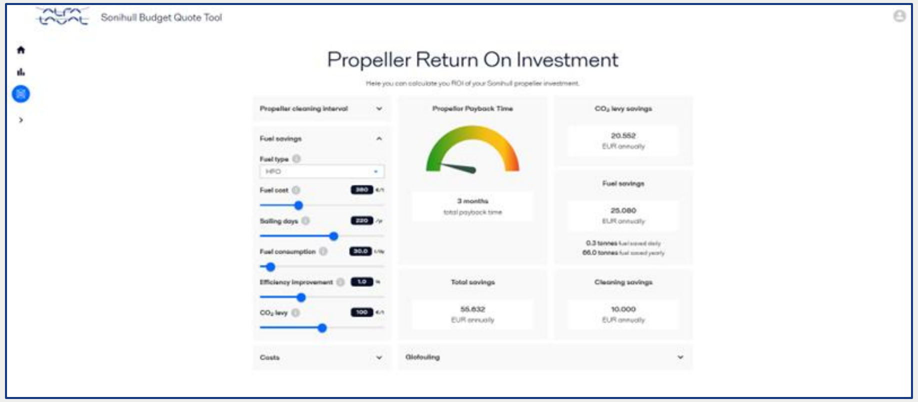
- **Designed for Lifetime Reliability** (drive signal design, continuous per-channel electrical supervision, drive current, case temperature and supply voltage monitored in real-time)
- **Modular** setup allowing **up to 16 transducers** and can be installed on multiple applications
- **Each transducer / group of transducers** can run different ultrasonic tracks behaving like multiple systems
- Time stamped record of full **operational history**
- **Robust** protection system; AC protection, thermal protection and current overload protection (thermal throttling, automatic shutdown and recovery)
- Also includes a **'boost'** feature to deliver a higher intensity of ultrasound that can be routinely timed.

# **Hull Protection:**
# Maximize your savings

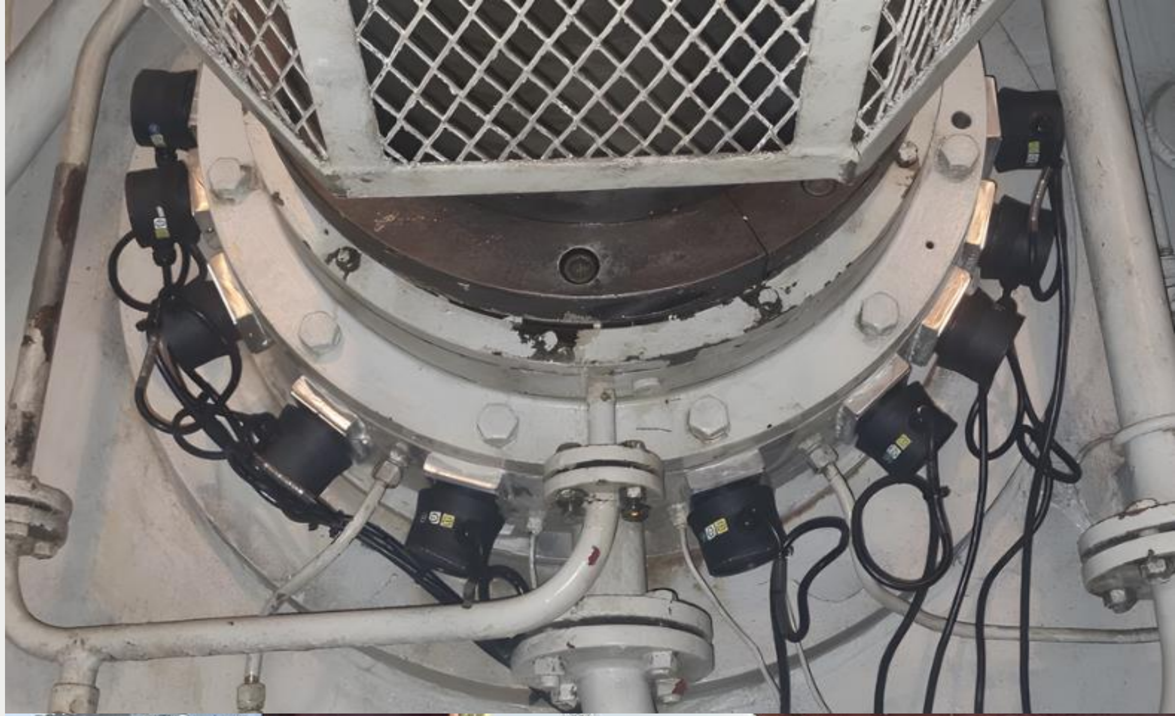
- **Continuous** protection of the hull especially when the vessel is stationary as a preventative measure, keeping the surface clean from marine growth
- Maintain hull form **efficiencies** to original design intent,
- **Minimizes** power loss from biofouling induced **drag**
- **Reduces** fuel burn and emissions
- **Extends** cleaning intervals

# **Propeller:**
# Short return of investment

- Maintain propulsion **efficiency** according to original design intent
- Fuel **savings** and carbon emission **reduction**
- Minimize surface damage of blades by **reduced** polishing intervals
- Save on **OPEX** cost for propeller polishing by prolonging intervals
- Prevent propeller imbalance complication, **extend** lifespan of gearboxes, bearings and shafts



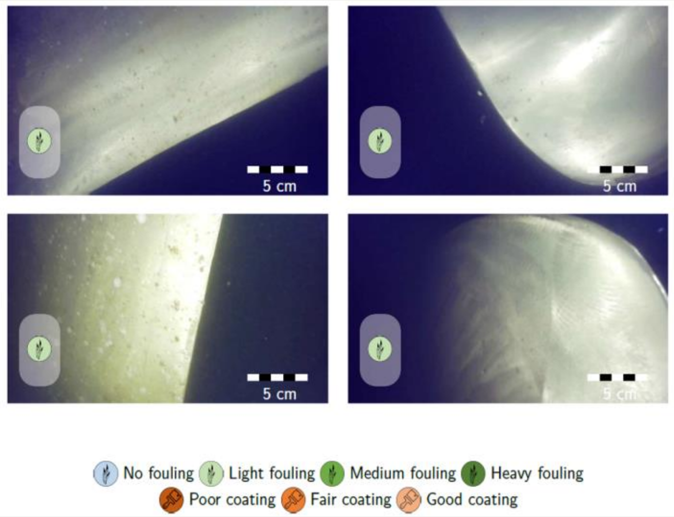

## **"Request an ROI calculation for your vessel today"**



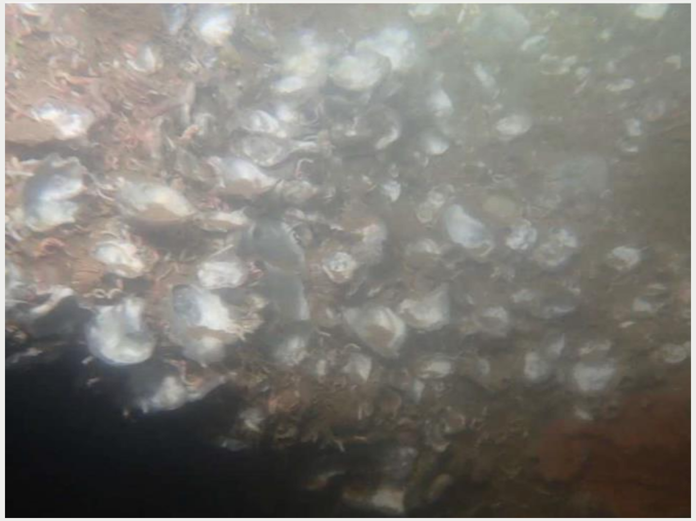
# Propeller:
What to expect



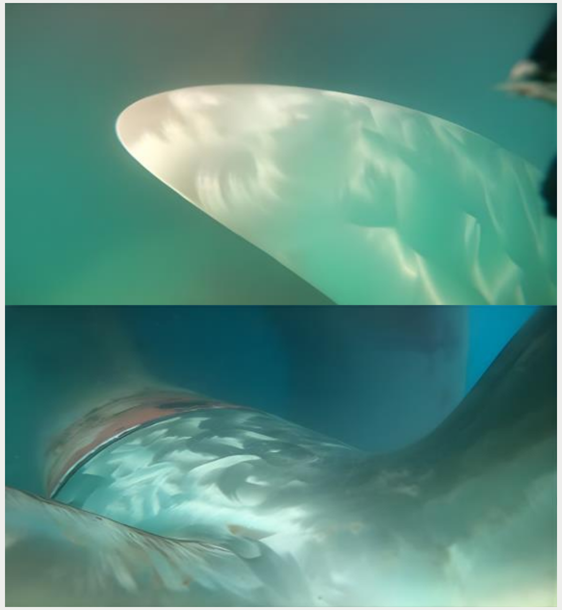
- **Propeller surface condition:** Maintained surface cleanliness (with limited hard-fouling). Expect some light slime and oxidisation on the surface.
- **Propeller Polishing:** Measurable reduction in necessary propeller polishing.
- **Fouling resistance:** Reduced biofilm/hard fouling attachment frequency and severity compared to similar vessels in the fleet.
- **Operational impact:** No adverse effects on vessel operations or increased maintenance burden.




Sonihull protected Propeller
(12 months after polishing)



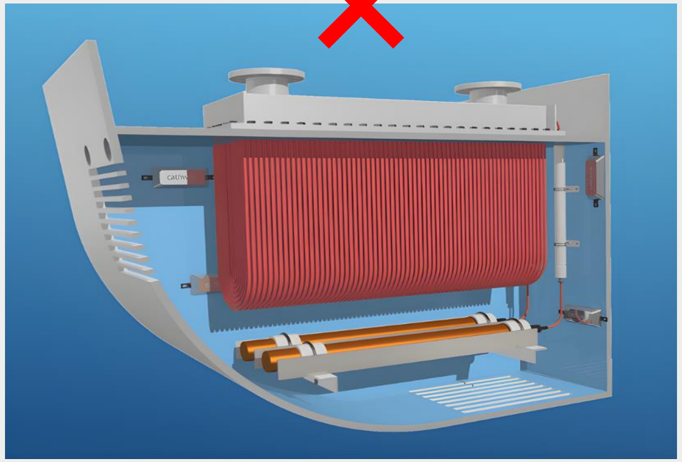
Unprotected Propeller
(6 months after polishing)



Sonihull protected Propeller
(6 months after polishing)

Sonihull protected Propeller
(12 months after polishing)

# **Sea Chests:**
# Replace your ICAF (Impressed Current Anti-Fouling) with Sonihull



- ✗ Harmful to the environment from the anodes emitting toxic biocides into the ocean.
- ✗ Expensive ICAF anodes needs to be replaced increasing OPEX
- ✗ ICAF does not protect gratings

- ✓ 100% green technology
- ✓ Zero harmful chemicals to environment
- ✓ Protects the inlet gratings of sea chest
- ✓ Sonihull is classed as a MGPS system
- ✓ Designed to last minimum 10 years with no expensive consumables to save on OPEX cost

Protected Grating

Unprotected Grating

# **Box Coolers:**
# Prevent unplanned dockings

Unprotected

- **Reduced cooling efficiency / performance** leading to higher engine temperatures, potential overheating, reduced power output, and in extreme cases, main engine shutdowns or failures.
- **Overheating of critical equipment** risking breakdowns, reduced vessel speed/power, or complete loss of propulsion in severe scenarios.
- **Higher operational costs and downtime** which leads to unscheduled interventions, extra drydocking's, fuel inefficiency and potential lost revenue. It shortens component lifespan and can force premature replacements.

Sonihull Protected

- **Maintained / optimized cooling efficiency** helping to keep heat exchanger surfaces cleaner for longer optimizing heat transfer efficiency.
- **Prevents overheating** of critical equipment ensuring systems stay properly cooled, eliminating risks of breakdowns, and preventing any loss of propulsion due to cooling issues.
- **Lower operational costs and reduced downtime** extending maintenance intervals significantly minimizes or eliminates unscheduled interventions/diver cleanings, avoids extra drydocking's, supports optimal engine efficiency for lower fuel consumption, prevents lost revenue from downtime, extends component lifespan, and avoids premature replacements.

# LT Coolers:
## Optimize cooling systems

- Optimized equipment performance
- Improved energy efficiency
- Up to 30% reduction in cooler maintenance cost
- Extended lifetime of your existing cooler

# Seawater pipework & strainers:
## Optimize cooling systems


❌ Unprotected
(After 4 months)

✔ Sonihull Protected
(After 14 months)

- Optimized equipment performance
- Improved energy efficiency
- Reduction in chemical cleaning

# Case Studies

# **Hull:** The three sisters case study

| Speed band (kn, SOG) | Vessel 1 (Sonihull) | Vessel 2 (No Sonihull) | Vessel 1 improvement vs Vessel 2 | Vessel 3 (No Sonihull) | Vessel 1 improvement vs Vessel 3 |
|---|---|---|---|---|---|
| 8-<10 | 0.09015 | 0.10575 | 14.8% | 0.09742 | 7.5% |
| 10-<12 | 0.09585 | 0.10049 | 4.6% | 0.10045 | 4.6% |
| 12-<14 | 0.08735 | 0.09925 | 12% | 0.10421 | 16.2% |
| All at sea (weighted) | 0.09178 | 0.09573 | 4.1% | 0.0968 | 5.2% |

**Fuel per nm by speed band (MT/nm) and implied fuel efficiency improvement (%)**

**Background:** Three sister vessels operate on comparable voyage profiles along the Eastern Australian coast. Vessel 1 underwent dry-dock installation of a full-scope ultrasonic antifouling system (Sonihull) covering the propeller, hull, and sea chests, with a capital expenditure of **$132,000**. Vessels 2 and 3 received no such treatment and serve as direct comparators.

**Objective:** Demonstrate measurable reductions in fouling accumulation on hull compared to sister vessels over a period of 12 months.

**Key Results:**

- Annual fuel savings on Vessel 1 approximately 403 metric tonnes, equivalent to **~$ 242,000** per year.
- Fuel efficiency advantage (total fuel per nautical mile):
  - In the primary operating band (12–14 knots, distance-weighted): Vessel 1 is **~12% more efficient** than Vessel 2 and **~16% more efficient** than Vessel 3.
  - Across all at-sea speeds (distance-weighted): Vessel 1 is **~4% more efficient** than Vessel 2 and **~5% more efficient** than Vessel 3.

**These gains are consistent with sustained cleaner hydrodynamic condition throughout the year due to combined protection of hull, propeller, and sea chests.**

# Propeller:
## Bulk carrier case study

| Period | Vessel 1 (Sonihull) | Vessel 2 (No Sonihull) | Vessel 3 (No Sonihull) |
|---|---|---|---|
| Q1 (Jan–Mar) | 3.29% | 4.71% | 8.52% |
| Q2 (Apr–Jun) | 3.44% | 4.89% | 9.03% |
| Q3 (Jul–Sep) | 3.38% | 5.21% | 9.77% |
| Q4 (Oct–Dec) | 3.52% | 5.36% | 10.42% |

**Propeller Slip Trend** (Median slip_apparent %, 'At Sea' Only)

**Background:** Three sister vessels operate on comparable voyage profiles. Vessel 1 underwent dry-dock installation of a Sonihull ultrasonic antifouling system for the propeller. Vessels 2 and 3 received no such treatment and serve as direct comparators.

**Objective:** Demonstrate measurable reductions in fouling accumulation on propeller compared to sister vessels over a period of 12 months.

**Key Results:** Propeller Slip measures the efficiency loss between theoretical and actual propeller advance; higher values indicate increasing fouling/roughness penalties.

Vessel 1: 3.41% (stable, low baseline).
Vessel 2: 9.25% (rising trend; reached 15.51%).
Vessel 3: 5.04% (rising trend; reached 9.87%).

**The clear upward slip gradient on the unprotected vessels confirms progressive fouling accumulation, while Vessel 1 maintains a materially cleaner propeller condition.**

***Vessel 1(with Sonihull):***
*pictured after 15 months*
*with no interventions*

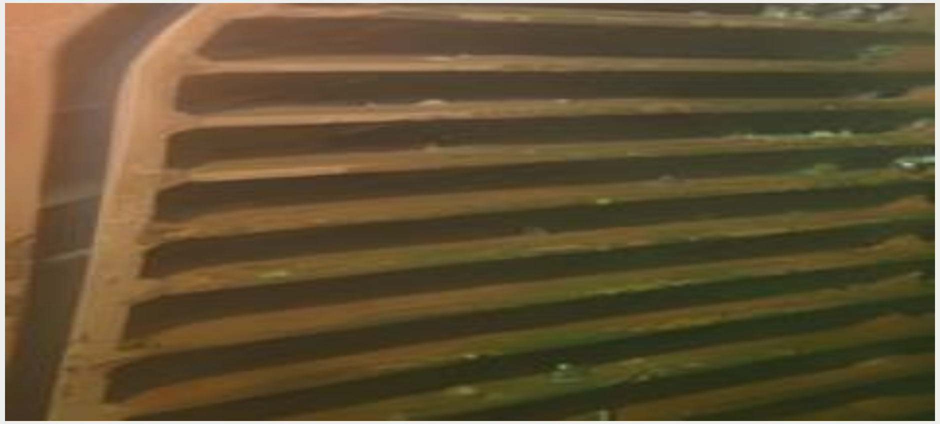
# **Sea Chests:**
# Bulk carrier case study

**Route:** China – Brazil

**Objective:** Demonstrate measurable reductions in fouling accumulation on Sea chest gratings. Port side protected with Sonihull and Starboard side left unprotected.

**Key Results:**

- Vessel carried out underwater inspection following six months sailing.
- Port sea chest grating (Picture A) - Inlet remained clean – no visible organism accumulation. Starboard sea chest grating (Picture B) - Clear organism buildup and fouling at the inlet.
- Critical cooling water systems were kept free from biofouling with Sonihull protection.

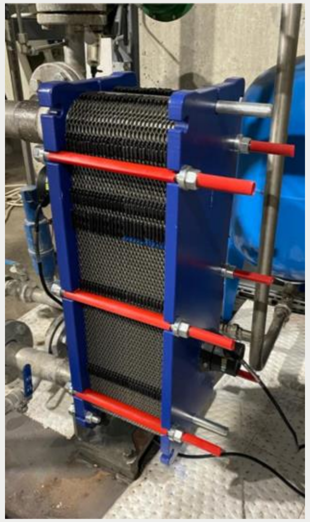


***Picture A – With Sonihull***

***Picture B – Without Sonihull***

# **Coolers:**
# LT Coolers Case Study

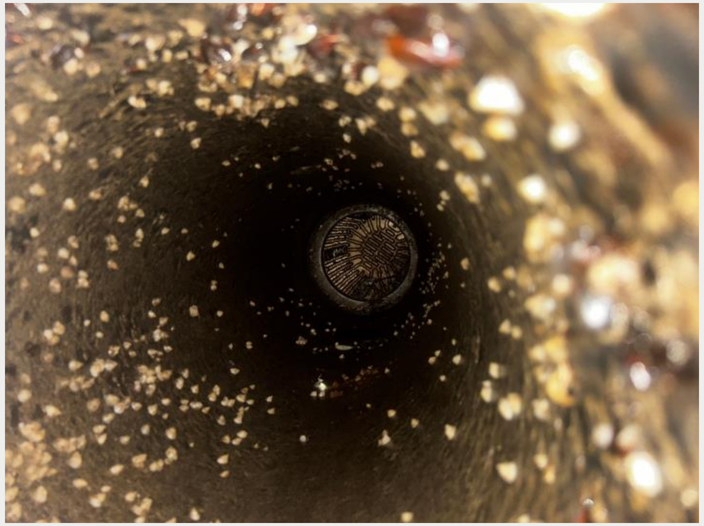
**Client / Vessel:** Arkas / MV Bernard A

**Objective:** Demonstrate measurable reductions in fouling accumulation, improved heat transfer efficiency, and reduced maintenance frequency

**Key Results:**

- As demonstrated in Table A the 3°C lower outlet temperature on the protected cooler indicates better heat transfer efficiency, reduced thermal resistance from fouling, and maintained cooler performance.
- Forward LT Cooler (Picture A)- Inlet remained clean – no visible organism accumulation. Aft LT Cooler (Picture B) - Clear organism buildup and fouling at the inlet.



*Picture A – With Sonihull (no visible organisms)*

*Picture B – Without Sonihull (clear organism buildup)*

| Parameter | Forward LT Cooler (With Sonihull) | Aft LT Cooler (Without Sonihull) | Difference |
|---|---|---|---|
| Seawater inlet temperature | 23°C | 23°C | 0°C |
| Cooler L/T inlet temperature | 30°C | 31°C | -1°C |
| Cooler L/T outlet temperature | 26°C | 29°C | **-3°C** |

*Table A - Thermal Performance (Temperature Delta) Under identical load and conditions*

# **Box Coolers:**
# Coastguard case study

**Vessel Type: Coastguard Patrol Vessel**

**Area:** Northern Europe

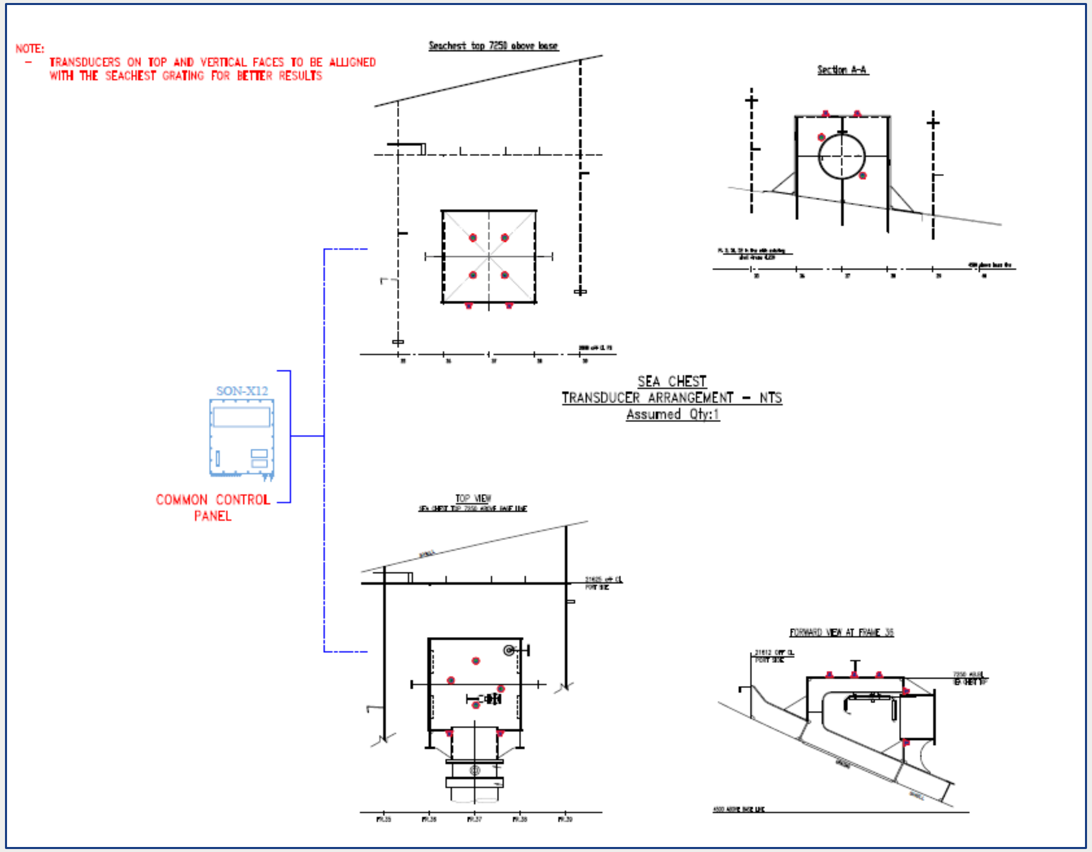
**Objective:** Demonstrate measurable reductions in fouling accumulation on tube stacks. Right side protected with Sonihull and left side unprotected.

**Key Results:**
- Vessel carried out underwater inspection following twelve months sailing.
- Right side tube stack remained clean – no visible organism accumulation. Left side tube stack had clear organism buildup and fouling.
- Critical cooling water systems were kept free from biofouling with Sonihull protection.

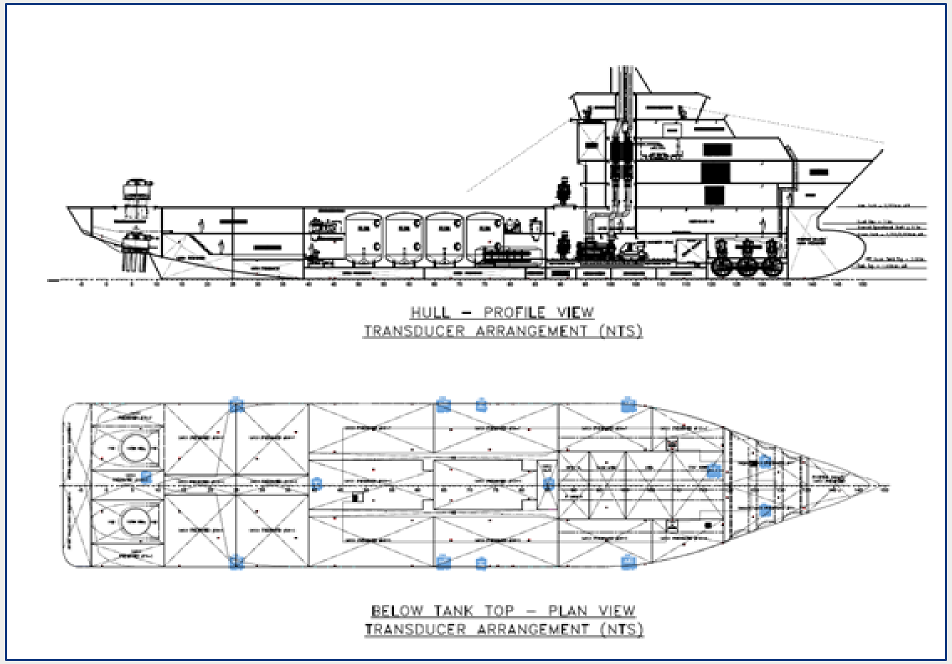
# Sonihull Installation

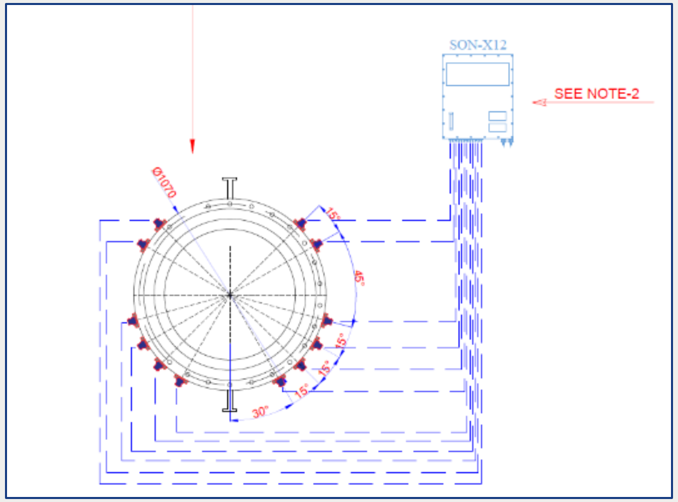
# **New Build Specification:** Get ready for 2029

- **Sonihull engineering team can support with detailed analysis of marine growth protection optimisation for your vessel.**
- **Drawing and location of transducers**
- **Specification wording for design**

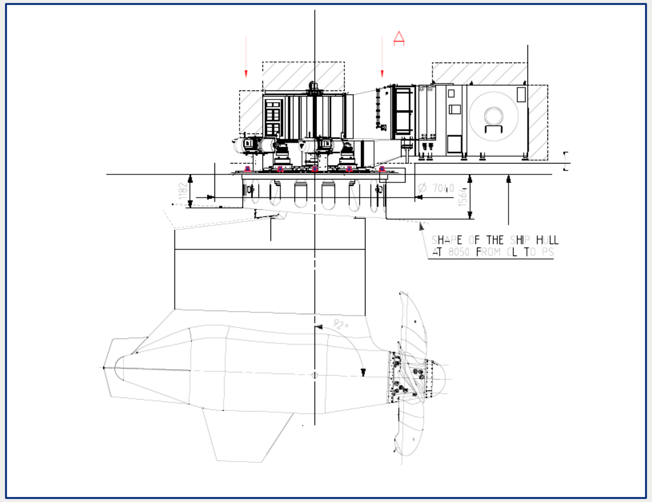


# Engineered Solutions (retrofit):
## Naval architecture expertise

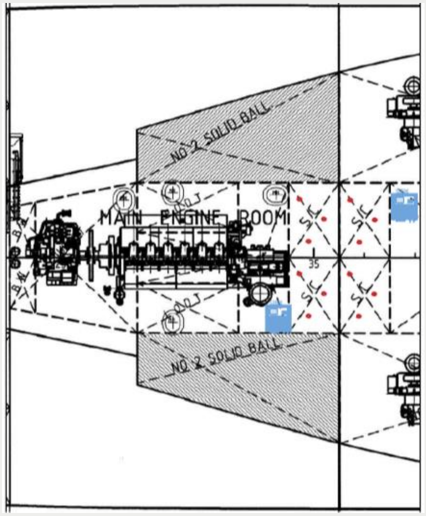


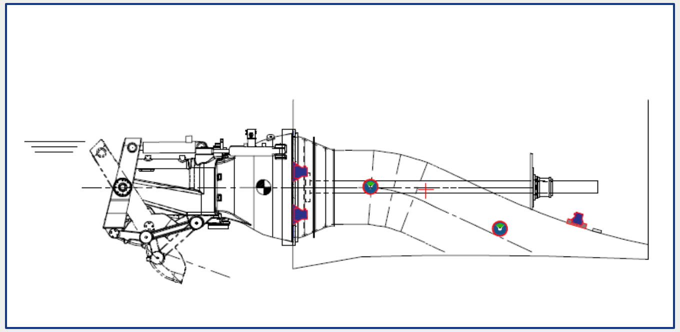

Propeller Protection



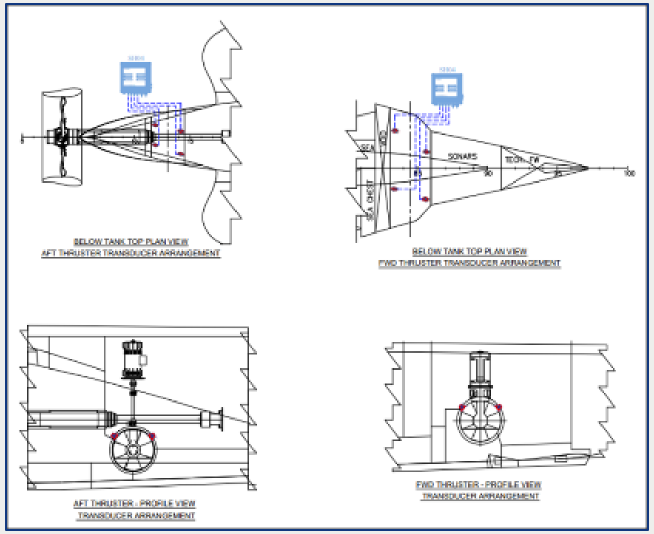
Azimuth Protection




Hull Protection

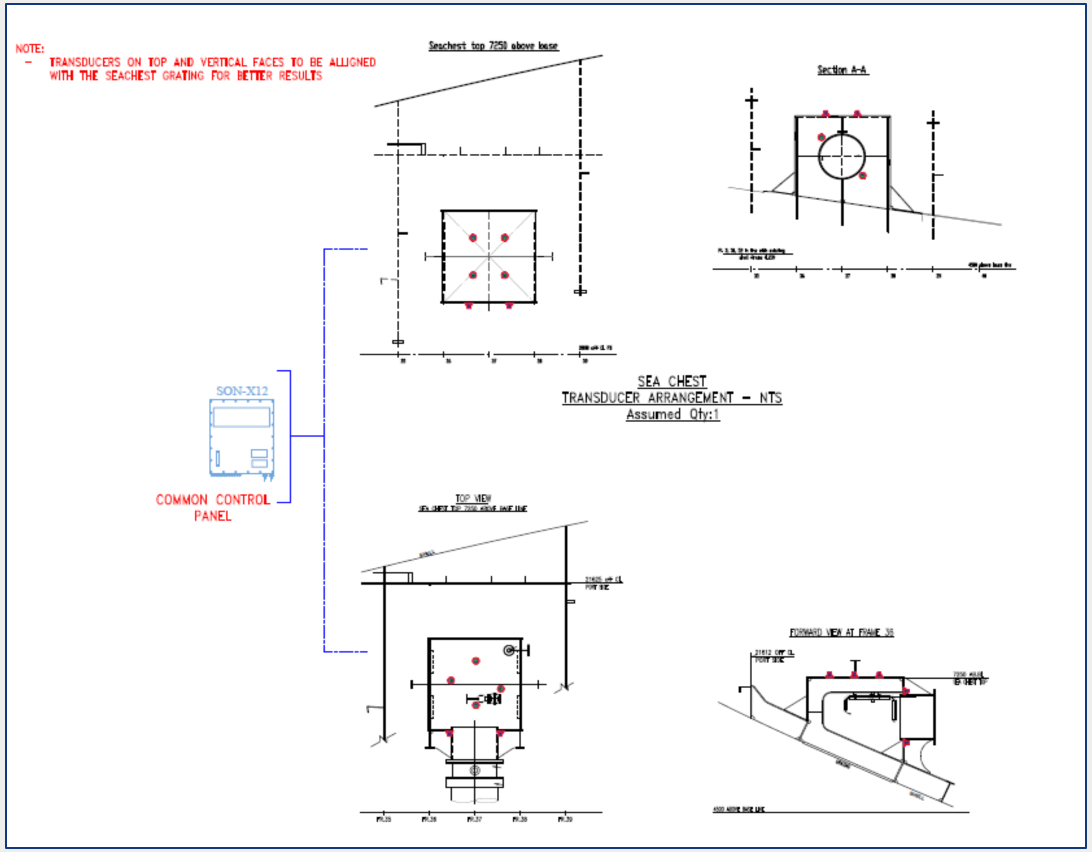


Waterjet Protection

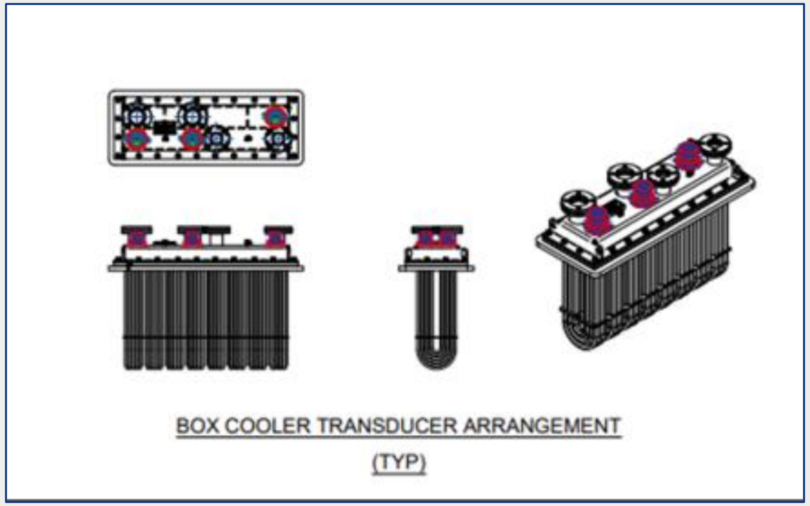


Bow Thruster

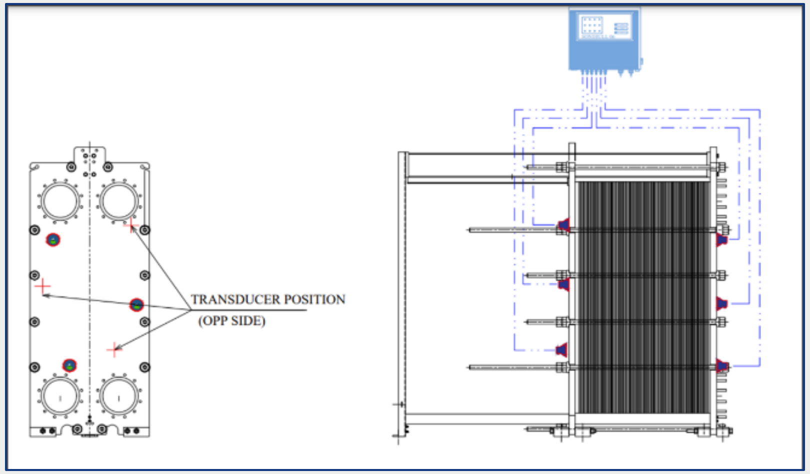
# Engineered Solutions (retrofit):
## Naval architecture expertise




Sea Chest Protection



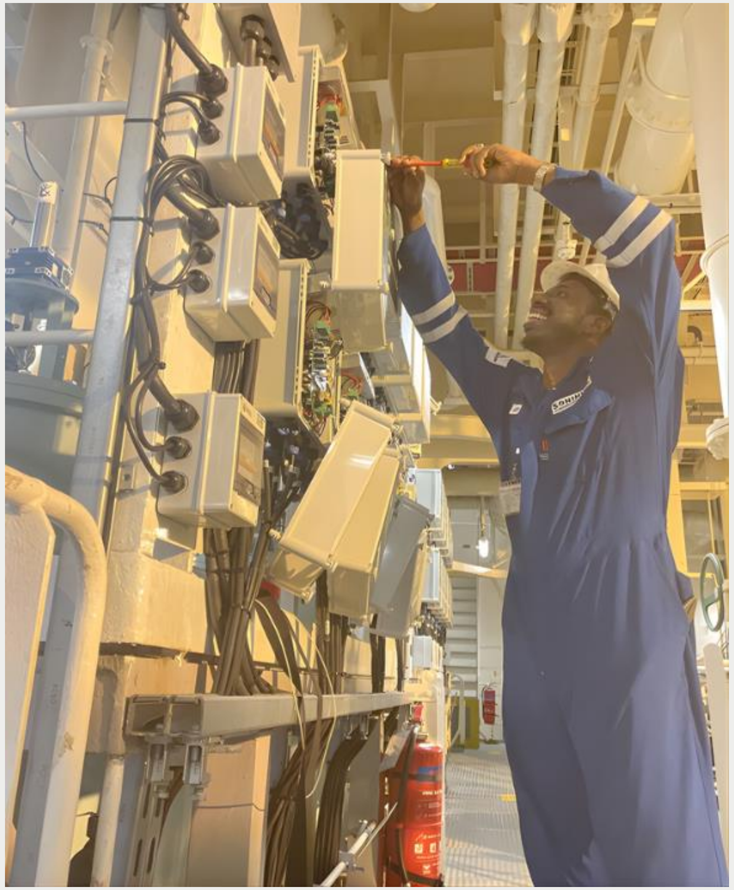

Box Cooler Protection




Cooler Protection

# **Sonihull Installation:**
# Vessel pre-works for commissioning

- **Location of control panel**
- **Power Supply to control panel**
- **Mounting plate for control panel(s)**
- **Cable routing (if required)**
- **Pre-installation checklist completed**

# **Sonihull Installation:**
# Vessel pre-works for commissioning

- **Surface mounted by Epoxy bonding**
- **Energy transfer enabled by coupling gel**

# Sonihull Post Installation Care:
## Visual checks & transducer gel maintenance

### WEEKLY

| | ITEM TO CHECK |
|---|---|
| 1. | Is the unit powered on continuously (24/7)? |
| 2. | Is the 'System OK' status LED active and showing green? |
| 3. | Are all control panel switches, indicators, and cable connections intact and undamaged? |

VISUAL CHECK

### MONTHLY

| | ITEM TO CHECK |
|---|---|
| 1. | Are all transducers securely mounted?<br>*If loosened, hand-tighten carefully. Do not overtighten — this may damage adapter threads or cause misalignment.* |
| 2. | Is each transducer face clean and free of debris or contamination? |
| 3. | Do the adapters and grub screws show any signs of wear, cracks, or damage? |
| 4. | Are all transducer cables in good condition, without cuts, abrasion, or kinks? |
| 5. | Are all transducer glands and connectors properly secured and confirmed watertight? |

VISUAL CHECK

### EVERY 6 MONTHS

| | ITEM TO CHECK |
|---|---|
| 1. | Remove the grub screw from the transducer completely. |
| 2. | Unscrew the transducer from the mounting ring or adaptor by rotating counterclockwise. |
| 3. | Thoroughly clean the transducer contact face and inner ring surface using contact cleaning spray and a microfibre cloth. Remove all old gel, dirt, and contaminants.<br>*→ If the transducer uses a contact disc, clean both sides of the disc as well.* |
| 4. | Apply half a sachet (≈5 g) of transducer coupling gel to the transducer contact face. Spread a thin, even layer across the face and place a marble-sized amount in the centre. |
| 5. | Screw the transducer back into the mounting ring or adaptor. Excess gel squeezed out through the grub screw hole is normal — wipe away excess, replace grub screw, and secure any loose cabling. |

ADD TO PLANNED MAINTENANCE SYSTEM (PMS)

# Choosing the Right Partner

# Technical & Commercial risks
## Validate claims

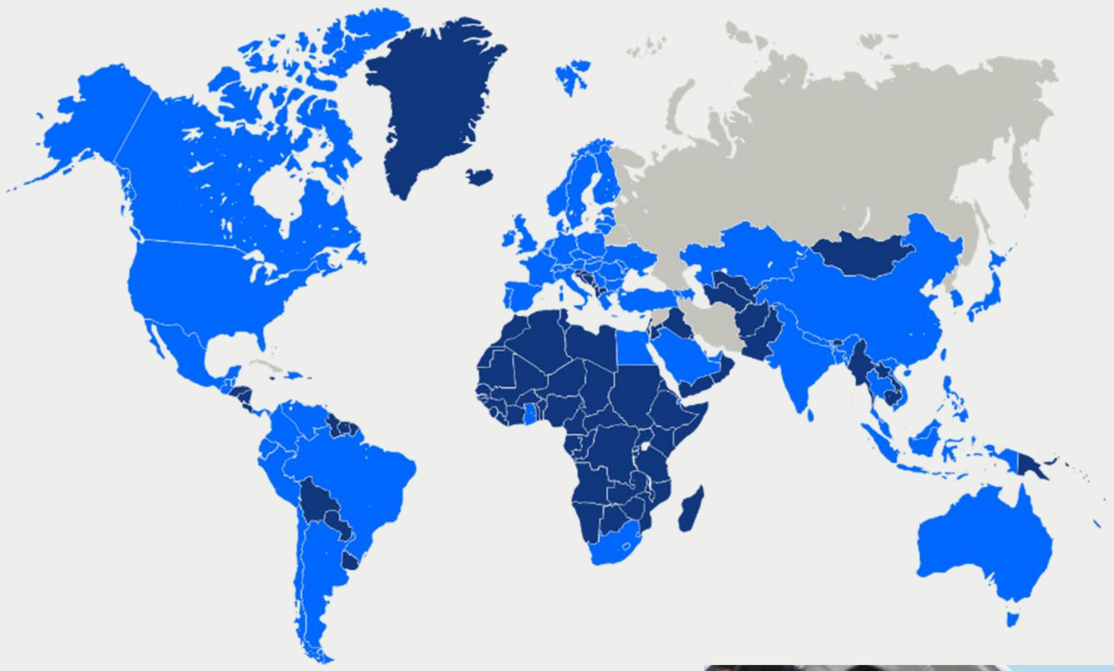
***Many new ultrasonic antifouling providers have emerged in the last 12-24 months. Choose your partner carefully, challenge their claims on experience and performance with validated research and proof. Look for a partner that will support you in the long term (20+ years) throughout your vessel's lifecycle.***

***Complications & risks with new providers:***

- **Guided Wave Reality:** Severe attenuation at frames/stiffeners (3–9.5 dB per crossing). Effective range likely 5–18 m (not 25 m) on real commercial vessels.
- **High Hidden Costs:** Cofferdams, dry-docking, equal-length cabling, mandatory engineer visits, recalibration.
- **Owner Lock-in:** No field tuning, monthly reporting to provider, warranty tied to paid service.
- **Limited experience**: Only narrowboat, superyacht, cable ferry, and tank tests — no robust commercial vessel data with typical framing & operations.

# Why choose us?

- Market leaders in ultrasonic antifouling
- Trusted biofouling management partner to shipowners and shipyards
- Engineered solutions
- Trained technicians worldwide for installation and service
- Dedicated project delivery teams
- Proven technology for all onboard applications
- Continuous product development from dedicated R&D teams



- Countries without Alfa Laval representation
- Listed countries: No new orders allowed
- Alfa Laval sales companies and service centres

# Next steps:
# Let’s protect your fleet

### Environmentally Friendly

It delivers effective biofouling control with zero release of poisonous substances or persistent pollutants into the ocean, helping preserve marine ecosystems and comply with stricter environmental regulations.

### Easy Installation

The system installs quickly and non-invasively—either while the vessel is in service or during dry docking—with no need for through-hull fittings, major modifications, or expensive impressed-current copper anode replacements.

### Lower Operating Costs

It can reduce capital expenditure and maintenance, repair, and overhaul (MRO) costs significantly compared to conventional impressed-current antifouling systems.

### Less Downtime

By eliminating the need for frequent manual cleaning in hard-to-reach areas, it extends maintenance intervals significantly, minimizes vessel downtime, and lowers overall running costs.

### No Disturbance

The ultrasonic frequencies are completely inaudible to humans and marine life, and cause no interference with sonar, navigation, or other electronic equipment on board.

### Lower Fuel Consumption

A clean hull and propeller dramatically reduce drag, delivering substantial fuel savings—especially when Sonihull protects both the hull and propeller. This translates to lower emissions and faster payback through improved energy efficiency.

***Look no further, choose Alfa Laval Sonihull!***

# Questions & Answers

# Thank you