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# MARINE ENGINEERS REVIEW INDIA

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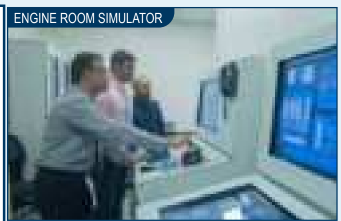
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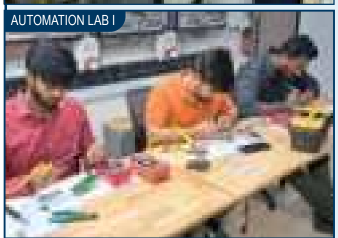
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# EDITORIAL

*Go back and get it. - Sankofa (African)*
*[In sense: Draw from the past and inform the future]*

The India Maritime Week just passed by. Many an MoU have been inked and more plans have been pledged towards the Vikshit Bharat we are working upon. There will be more on this, I hope.

I take this space for another development ... the change of guard at MER. It has been a long innings (>5.5. years) in this MER Engine Control Room since February 2020. Let us look back a bit.

I had envisaged MER to transform from a ‘Trade Magazine’ to a Professional Journal. The spectrum was to be widened. The Review of the Marine Engineers has to be not only on core marine engineering domain but also on allied areas... ocean studies, naval architecture, maritime law and arbitration, maritime heritage and so on. And we aimed to bring up the quality by accommodating knowledge based articles and research studies.

A conscious effort was to migrate to a web based platform with on-line submissions, peer reviewed acceptances of articles, flipbook formats etc. We did host these for a while and on these Research Journal patterns, we had even applied for listing under UGC CARE (University Grants Commission-Consortium for Academic and Research Ethics). [IMU’s support for this application needs a mention here]. For want of better strength in article-management, peer review processes etc., we could not make the cut. Also, UGC was moving away from this model and the timing was not favourable.

Another significant move was to start a newsletter, shift the stock of ‘events and photos’ and the like. Undeniably, this brought in a sobriety to the format. We also brought in new verticals and columns to support contributions:

**Technical Notes:** This was for all the light and medium level discussions on any maritime areas.

**Bol Bada Saab Bol:** This knowledge-box format was for the Competency Exam cohorts. Surprisingly, we had the least contributions under this.

**Spanner in the Works:** This brought in many shipboard problems and was well received also but again suffered a bit from lack of readership and reflection.

**Indicator Cards:** This was created for feedbacks. Ironically, much of the feedbacks we received repeatedly (we seek feedbacks every month) said that there is no column for feedback!

(Maybe that was a feedback just for the halibut).

**Heritage Hourglass:** This was a refreshing column which had quite a bit of contributions and still has scope.

**Going Astern into MER Archives:** We believed (still do) that this column would bring the much needed attention of the veteran marine engineers into the discourses drawing them away from the much trodden digital/social media platforms. We still run the **Students’ Section** to feature somewhat serious efforts, sensible studies, patent works and idea-checks through projects etc., coming in from interested students.

With all humility, I must say there has been moderate successes in the metamorphosis. Looking at this past, We wish to bring the future into focus. Along with my Editorial Team, I place my thanks to all the IMEI teams for their support and all those who appreciated, criticised and contributed.

My appeal to all the readers as always: Read, Reflect and Revert. I sign off with how I started:

**Let noble thoughts come to us from every side (Rig Veda).**

### In this issue

This insightful article by Prabu Duplex explores the predictive power of computational fluid dynamics in estimating ship resistance, specifically through the REVA potential flow solver. Traditionally, towing tanks have dominated hull resistance assessments—

but today, with advanced computing, numerical models like REVA provide faster, cost-effective alternatives. The study focuses on calculating forward resistance for a Series 60 hull using Rankine source panel methods under different Froude numbers.

The author meticulously details the grid convergence process, validating mesh sensitivity and highlighting how computational accuracy can be optimized without excessive resource use. A critical comparison between Dawson and Neumann-Kelvin free-surface linearization models offers practical insight into their performance, especially for fuller versus slender hull forms.

What sets this article apart is its balance of technical depth and applied relevance. It makes a strong case for integrating CFD at early design stages, showing how theoretical simulations now rival traditional experimental methods in accuracy. As hull form optimization becomes increasingly digital, this work reinforces CFD's essential role in shaping the next generation of maritime engineering. Whether you're a researcher or a practicing naval architect, this article offers a robust look into the evolving landscape of resistance prediction—rooted in physics, powered by computation.

In a maritime world increasingly driven by autonomy and offshore renewable energy, this paper cuts to the core of an urgent issue—cybersecurity in converging technologies. Kimberly Tam and co-authors spotlight the vulnerabilities that arise when autonomous vessels and offshore wind farms operate in digitally entangled environments. Through a realistic, multi-layered threat scenario, they reveal how a breach in one system can ripple through others, threatening physical safety and operational control. The article balances technical insight with actionable mitigation strategies—technical, policy, and human-cantered. A timely read for engineers, operators, and policymakers shaping the future of maritime resilience.

In this sharp and timely article, Ulhas S. Kalghatgi unpacks the vital—but often misunderstood—role of classification societies in global maritime governance. With over 90% of the world's cargo-carrying tonnage under their purview, IACS members are not just technical enforcers—they're enablers of policy. Are they silent influencers shaping IMO decisions, or loyal allies translating intent into action? Through clear analysis and real-world insights, this piece navigates the nuanced balance between engineering authority and political neutrality. A must-read for anyone curious about who truly holds the tools—and trust—behind the rules of the sea.

Under Technical Notes, Capt. Gajanan Karanjikar explores the underappreciated menace of metallic corrosion in the maritime world. Rust isn't just surface damage—it's a slow, silent saboteur costing the global economy trillions. In this gripping technical essay, from microbiologically influenced corrosion lurking in ballast tanks to the hidden cost of degraded infrastructure, he reveals how nature quietly reclaims our engineered efforts. Backed by real investigations and global data, this piece is both a wake-up call and a roadmap. If you're in shipping, offshore, or policy—read this and rethink corrosion not as decay, but as a preventable economic crisis with global stakes.

Dr. Shantanu Paul's article on shipowner liabilities (October 2025 issue) received strong praise from senior DGS examiners for its clarity, relevance, and educational value. Articles such the above are an excellent resource, effectively bridging theory and practice with legal precision and practical insight. This sets a benchmark for exam-focused maritime scholarship in MER (I). The editorial team intends to continue publishing more industry-relevant articles to support students preparing for various competency examinations.

The MER Archives from November 1985 has an article on **Variable flow Marine-hydraulic power system** which is ever relevant to all engineers onboard followed another very relevant article on **Propeller Performance and Machinery Applications in WindAssisted Ships.** I consider these are easy reading materials. As the saying goes: "you need to have one eye on windshield and another on the rear-view mirror while driving a vehicle.

**Here is the November 2025 issue for your reading pleasure and intellectual rumination**

**Mani Ganapathi Ramachandran**
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# In This Issue

## ARTICLES



## COLUMNS



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# Ship Resistance Computations Under Potential Flow Theory

Prabu Duplex

## 1. Introduction

Numerical results of ship's forward resistance are presented in this work. The three-dimensional code REVA using Rankine source method is utilised. The numerical results are then compared to the experimental results.

## 2. Prediction of Inviscid Flow with Free Surface

The basic panel methods may be a useful approximation for surface ships in case the wave making is limited. The perturbation caused by a surface wave decay with depth under the water surface, and that the short waves occurring at low Froude numbers are confined to a region close to the surface. Below that region, the velocity field is essentially equal to that without waves. Therefore, in the limit for low Froude numbers the flow field with waves can be supposed to approach that with a flat-water surface, except in few regions along that surface. Therefore, knowledge of the potential flow around the hull under a flat, undisturbed water surface is often practically useful.

The potential flow around the ship hull with a flat-water surface could be computed using an additional panel distribution on the water surface and imposing the boundary conditions there.

> *The potential flow around the ship hull with a flat-water surface could be computed using an additional panel distribution on the water surface and imposing the boundary conditions there*

However, it is more accurate and efficient to represent the water surface by a symmetry plane in the calculation. As **Figure. 1.** illustrates, the flow field of interest is identical to the lower half of the flow around a double model of the underwater body, symmetrical with respect to the undisturbed waterplane. The double body is again a closed body in an infinite fluid, and the double-body flow can thus be computed using any of the Boundary Integral Methods.

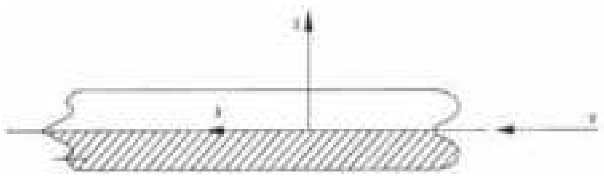

**Figure 1: Double-body flow, representing the flow with a flat-water surface**

Results of such a double-body potential flow computation can be useful in assessing properties of slender hull forms. Specifically, the magnitude of streamline curvature along the hull, flow directions, and pressure maxima and minima can be observed. On the other hand, in the vicinity of the water surface the accuracy will be limited because of the neglect of the wave pattern. Moreover, mirroring of the underwater part of the hull introduces a sharp knuckle at the waterline for flared sections, or a narrow area between a bulbous bow and its mirror image, which locally further invalidate the double-body flow. To compute the wave resistance, wave pattern, and the flow around the hull including the wave-making effect, further steps are needed.

**To compute the flow with wave making data the following assumptions**

**are made: the flow and wave pattern are steady in the coordinate system fixed to the hull; viscous effects be disregarded and a potential flow model used; and that wave breaking and spray will not be modelled.** In addition, surface tension is not modelled, being of little importance for the larger-scale flow behaviour.

The problem again is described by the Laplace equation for the velocity potential, with the following boundary conditions: Body Boundary Condition, Dynamic Free-Surface Condition, Kinematic Free-Surface Condition, Bottom Boundary Condition and Radiation Condition. Now one needs to solve a "nonlinear free-surface problem," where the nonlinearity comes from the boundary conditions. The next steps differ depending on the type of linearization used and few options are:

**Linearization Relative to a Uniform Flow** giving rise to the Kelvin free-surface boundary conditions, methods based on the use of Kelvin or Havelock sources, Neumann-Kelvin theory, and the further simplifications to thin ship, flat ship, and slender-body theories.

**Linearization Relative to Double-Body Flow**, leading to slow-ship linearized methods, among which is Dawson's method.

## 3. About the software REVA

The REVA code is a potential flow program with linear free surface condition, developed at the Hydrodynamic Naval Laboratory (LHN) of Ecole Centrale de Nantes (ECN). Based on Rankine singularities, code REVA solves potential flow with free surface around hull with appendages. The REVA code solves the three-dimensional problem of wave resistance of a ship moving at uniform speed on a free surface at rest upstream. **The fluid is assumed to be perfect and incompressible.** The free surface condition is the linearized by Neumann-Kelvin or Dawson model. The numerical solution is obtained using the singularity method with Rankine sources distributed over the hull and free surface, which are meshed. The forces are obtained by integrating the pressures. The hydrostatic coefficients are linearized. REVA computes ship drag considering free surface deformation (wave resistance) and induced drag from appendages. Typical wave profile due to the ship motion is shown in the **Figure. 2.** Meshes are surfacic **(Figure. 2),** this allows reduced meshing time and reduced computation time. REVA is effective for problems such as efficiency of lifting foil and dynamic trim and sinkage from dynamic pressure field. This code was applied successively to the various hull models.

*The REVA code solves the three-dimensional problem of wave resistance of a ship moving at uniform speed on a free surface at rest upstream*

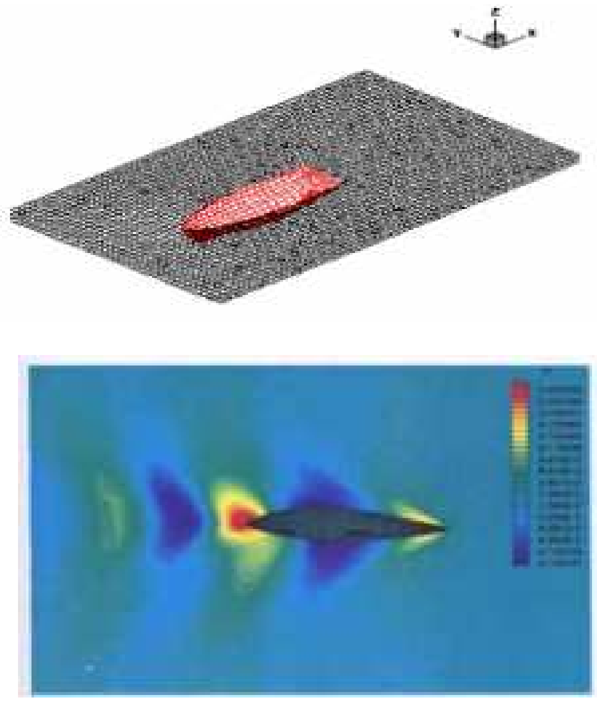

**Figure 2: Meshing of immersed hull part and free surface at rest (L), Wave field around hull (R)**

REVA's main limitations are no viscous effect modelling (no viscous drag), linear free surface model and wave effects on overhangs cannot be completely considered. Therefore, the following effects cannot be considered: Flow separation and vortex in viscous wake, appendages viscous drag and hull-appendage interaction drag, added resistance in waves. Linearity of the free surface condition prevents accurate study of overhangs. The main limitations of REVA are inherent to the linearity of the free surface condition and to the non-viscous potential flow assumption. The non-viscous potential flow assumption can lead to great inaccuracy for the drag generated at the stern of the boat by, for example, immersed transom or asymmetric water line when heeled.

## 4. Forward speed resistance

The forward speed resistance is classically expressed as a drag coefficient (and broken down into a wave-making part (and a friction part () as shown in the equations 1 and 2. The wave-making part scales with the Froude number *(Fr),* while the friction part scales with the Reynolds number *(Re)*. The wave-making part can be computed using a potential-flow 3D Rankine panel method such as REVA. The friction part can be estimated using the ITTC-1957 formula and a suitable form factor *k* as per ITTC recommendations. **Figure. 3.** elaborates the calculations with different notations.

$$C_r = C_w(Fr) + (1 + k)C_f(Re) \tag{1}$$

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$$C_f(Re) = \frac{0.075}{(log_{10}(Re) - 2)^2} \qquad (2)$$

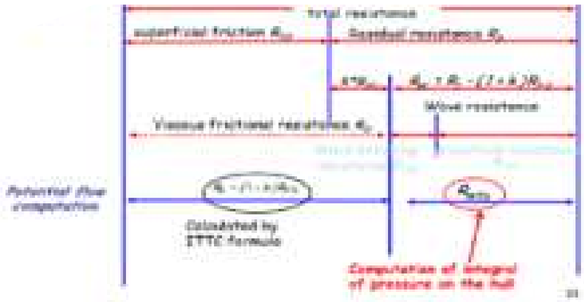


**Figure 3: Total ship resistance estimation in potential flow solver**

## 5. Computations

A fixed series 60 hull at model scale (L=3.048) is tested with two speeds (*Fn*=0.1 and *Fn*=0.3) with various mesh sizes for the grid convergence in order to find the suitable density of mesh necessary to have results (almost, quite) nondependent from grid. Variations of wave coefficient (*Cw*) for different grids of the hull and for the adapted grid density for grids, variations of *Cw* for different mesh of the free surface are tested. When the density converged (very less difference between successive mesh sizes) one can choose that point as the size of mesh to be used and can reduce the computing time. This is the first important criteria to be done in the CFD software prior any calculations. As shown in **Figure. 4.** the *Cw* values converged well for the two forward speeds under consideration. The mesh grid density is chosen for the converged case and used for calculations hence forth. Aspect ratio of 2:1 is set for the mesh, and the maximum grid density refinement one can reach is also identified.

> ***The fuller the hull form and the lower the Froude number, the more the predicted wave resistance is underestimated***

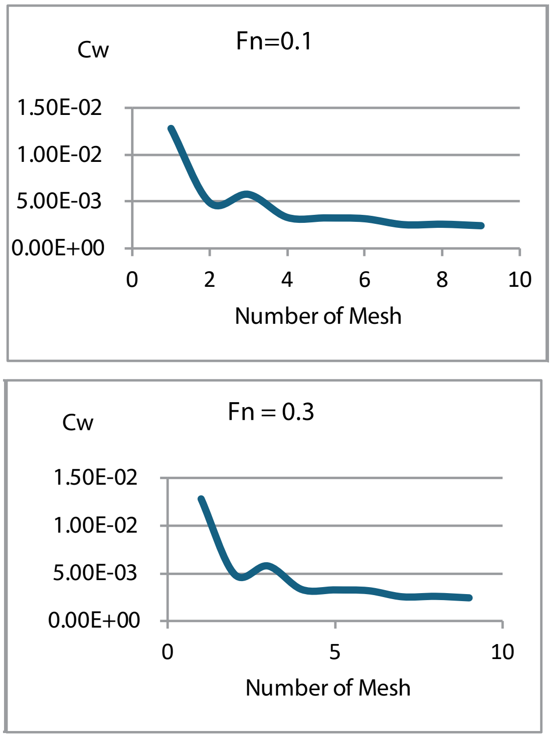


**Figure 4: Mesh convergence analysis**

After mesh convergence the next step is to test the free surface linearization methods available in Reva. For speeds of Froude number between 0.1 - 0.3 a fixed model with the converged mesh is tested to study the influence of the free surface linearization (Dawson vs Newman-Kelvin) and the results are shown in the **Figures. 5** and **6.** The series 60 hull has a large beam to length ratio than Wigley hull. Thus, in the **Figure. 5,** one can see can see the discrepancy at a wide range of the graph. Difference between wave resistances found using the Kelvin condition or Dawson's condition are negligible for slender vessels like Wigley hull. This is obvious from the **Figure. 6.** Neuman Kelvin and Dawson method show reasonable agreements at a low Froude number.

Next, the Series 60 vessel numerical results are compared with the experimental data and the results are shown in the **Figure. 7.** For the range of Froude numbers between 0.1 and 0.35, non-dimensional load coefficients *Ct* (total), *Cf0* (skin friction coefficient) and *Cr* (residual coefficient) are compared with experimental data. The results show deviation to a maximum of 7% and is considered significant (acceptable) in engineering analysis.

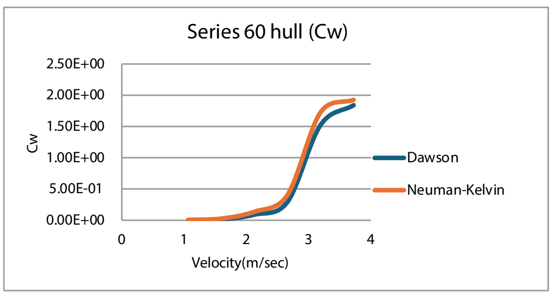


**Figure 5: Dawson vs Neuman-Kelvin analysis**

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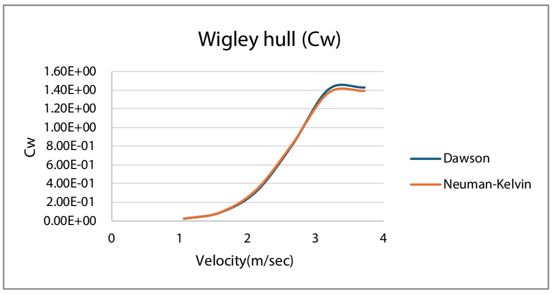



**Figure 6: Dawson vs Neuman-Kelvin analysis**

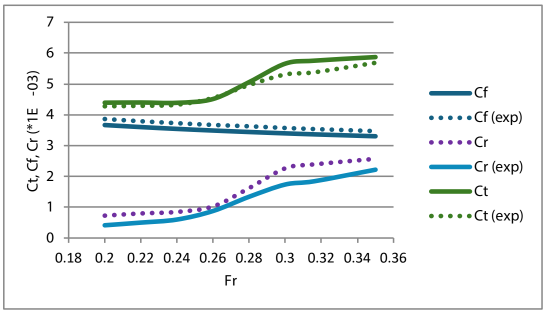
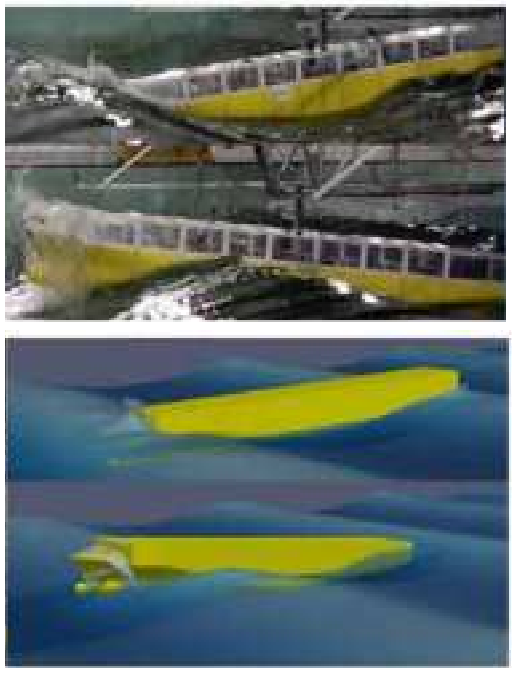



**Figure 7: Series 60 hull EFD vs CFD analysis**



## 6. Discussion

Neuman-Kelvin linearization works well for slender hulls such as Wigley hull [4]. The "slow-ship" methods are found also to work well for faster, more slender ships: for increasing slenderness of the hull, the free-surface condition reduces to the normal Kelvin condition, which is not limited to low Froude numbers. So, they are mainly used for optimising the forebody. Wave resistance predictions from Dawson's method are usually fairly good for slender ships at relatively high Froude numbers, such as frigates and sailing yachts, but not for most merchant vessels. The fuller the hull form and the lower the Froude number, the more the predicted wave resistance is underestimated. On the other hand, differences in wave pattern between hull form variations are usually qualitatively well predicted, making the method practically useful for design. Dawson's method and its developments were used intensively in ship hull form design in the period until 1995 approximately; after which they were quickly replaced by nonlinear methods. With their shortcomings, they have proven to be most useful tools for ship design, provided the predictions were considered with care.

## 7. Conclusion

The principal technique used to predict resistance by purely theoretical means is discussed in this work. Theoretical predictions of resistance and flow play an important role in ship design today. Since about 1980, a revolutionary growth of the possibilities for theoretical prediction and optimisation of ship performance has taken place. Major contributing factors to this have been the availability of fast computers, the development of improved numerical techniques, growing insight in an adequate modelling of the principal phenomena, and the development of specialised computation methods for ship hydrodynamic problems.

*The fuller the hull form and the lower the Froude number, the more the predicted wave resistance is underestimated*

Today computations of wave pattern and wave resistance are routinely used in ship hull form design, not only by specialised ship hydrodynamic institutes but also by many shipyards. Such computations have given increased insight in favourable hull form characteristics and have reduced the need for extensive model testing because much of the hull form refinement is done in a computational preoptimisation. Also, viscous flow computations play an increasing role in practical ship design, and a more routine use is developing. In principle, these techniques can bring a level of completeness of the analysis and refinement of the hull form design that in several respects is higher than what a towing tank can offer; on the other hand, ship performance predictions based on CFD gradually reaches the same level of accuracy as model tests.

Alternatively, let us not forget the forward speed resistance estimated using semi-empirical models. Such models are established using regression over a limited set of hull shapes and are suitable for hull shapes close enough to the regression set. The most used model of this type is the Holtrop & Mennen model.

Potential flow with linear free surface method remains a useful, easy to use, tool to study main hull parameters

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*Since about 1980, a revolutionary growth of the possibilities for theoretical prediction and optimisation of ship performance has taken place.*

and appendages efficiency at the predesign state if only minor viscous effect is expected. However, this kind of tool cannot be longer used for high-level optimisation like for example IACC hulls.

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## About the Author

**Prabu Duplex** had sailed as a marine engineer between 2005- 2013. His recent assignment was with the University of Pisa as a research associate. He also has a Professional Doctorate in Engineering (PDEng) degree in maintenance, and a Master's degree in Naval Architecture. Presently, he is looking for a career in design or research activities in naval, wind, offshore or predictive maintenance domains.

**Email:** prabumn@gmail.com

## Understanding Cyber-Risks in Complex Next-Generation Maritime Technologies:

# Autonomy and Offshore Wind Energy Operations

**Kimberly Tam,**
**Avanthika Vineetha Harish,**
**Kevin Jones**

**Abstract -** When developing maritime technology, each new technology is often developed and assessed separately. However, it is likely with the convergence of systems, and greater interconnectivity between systems in the sector, that new technologies will be inter-connected digitally or operationally. Understanding the cyber risks of the larger systems of systems is important. This paper looks at the potential cyber-physical risk of future autonomy and offshore renewable energy solutions co-existing together. A threat scenario is presented using real cyber-vulnerabilities in autonomy and offshore wind systems. This paper discusses potential overall vulnerabilities when combining these two emerging technologies. It concludes with suggested mitigations ranging from technical (e.g., secure communication channels) through policy (e.g., new standards for secure devices on the market) to social (e.g., cybersecurity training for remote operators). This type of multi-solution scenario can be a useful tool for analysing risks in complex circumstances and can be applied to other sectors with multiple emerging technologies.

**Keywords: Maritime technology; Cyber-risk; mitigation; autonomy; offshore wind energy**

## Introduction

New technologies come with their own challenges and risks. Insights on future risks make it easier to mitigate those risks. However, with the convergence of new technologies, gleaning insight of a complex systems-of-systems, becomes harder yet more insightful.

In the maritime sector, there are currently many developments in areas like autonomy and offshore renewable energy. Studies such as [1] [2] look at these solutions in isolation, which often gains valuable insight. This can provide significant solutions and risk mitigations for these systems as they evolve. However, cybersecurity in the big picture is often about the weakest link in the chain, and only focusing on security of one entity does not mean it is unaffected by other entities. In one study [3], it was found that port operations could be vulnerable to a cyber-attack executed on an incoming ship, and efforts to secure ports cannot be limited to only port infrastructure.

In a similar holistic approach, in this paper we focus on autonomy and offshore structures like renewable energy in the maritime sector as emerging, on the horizon, technologies that are being realised now, or will be in the near future. Examples of related works and the state-of-the-art research and practices in these two areas are detailed more in the background section.

New maritime technologies will not exist in a vacuum but will, or must, co-exist in the same physical space. In this case, both autonomy and offshore structures will likely operate in similar coastal areas. Developing ways to discuss the emerging risks from the interactions of solutions may reduce them for the future. Specifically, this paper considers cybersecurity-related risks, however, this scenario can be used to discuss other risks such as safety. These scenarios can be further developed in for educational and team building as a part of mitigation, which will be discussed further in this paper.

One reason why it is useful to assess growing solutions in conjunction, instead of completely separately, is a solution for one challenge in one technology, could create a new risk in another technology. This essentially means problems moving horizontally across the sector and changing, instead of being fully removed. One potential example is maritime systems addressing the challenge of autonomy by increasing remote satellite communications. However, that increased connective increases cyber-risks by increasing the attackable surface area [4] [5].

In another example, demands for decarbonisation have pushed for more digital solutions, such as digital twins and Artificial Intelligence (AI) and third-party solutions. However, many of these solutions generate carbon costs or unintentionally outsource the carbon cost to third parties [6]. Creating scenarios where complex discussions can be explored for complex challenges can help provide meaningful solutions to challenges [7].

## Background

This section covers the essentials of marine autonomous systems (MAS) and offshore wind (OW) as terms of their cyber-physical security. When considering the range of cyber-physical attacks, we define these as cyber-physical security as physical attacks that have a digital impact, but also digital cyber-attacks that have a physical impact.

### *A. Autonomy*

In maritime, there are two main pathways to autonomy in development. First, there are traditionally crewed vessels having increased amounts of autonomy, but there is also an increase in new autonomous Uncrewed Surface Vehicle (USV) that are designed to be autonomous from design.

Typically, these USVs are smaller in physical size than traditional ships but also increasing their tiers of autonomy as defined by the IMO [8]. Because of their size, one of the growing concerns is the physical capture of USVs. Capturing a physical USV could have governance challenges (e.g., stealing another nation's USV during a conflict [9]), as well as cyber-security consequences. During penetration tests of several small autonomous USV in the Cyber-SHIP lab*, it was found some USVs had cyber-physical security vulnerabilities in captured and readable SD cards and communication channels when physical access was possible.

In the middle tiers of autonomy (IMO 2-3) there are additional challenges of human-autonomy teaming (HAT) such as proper hand-offs for control [10]. The highest tier, which represents full autonomy, also has its unique challenges. AI is being used increasingly to solve the challenges around full autonomy and offshore resilience [11], but they also may introduce vulnerabilities if they are not designed or trained with security in mind [12].


As most autonomous vessels will stay near shore for connectivity reasons (e.g., coastal hoppers) or will need to enter/leave a port, it is highly likely that these will need to navigate around, and/or through, the growing number of wind turbines being installed offshore.

### *B. Offshore Wind*

Renewable energy solutions have been around the 1980's, however it was not until recently when the technology became more popular due to concerns over carbon emissions. However, as land-based renewable generators become more popular, therefore public favour began to decrease due to aesthetics and the land they used [13].

To adjust to limited space and how the public viewed large windfarms, efforts have been made to move renewable energy production to oceans where there is more space, turbines are less visible, and for increased access to wind. While this solves the challenge around space on land, this has again created new challenges for offshore windfarms including, but not limited to, floating structures, fixed structures, transferring power back to land, and the complexities of monitoring and maintaining renewable energy infrastructure while it is isolated sea.

One of the power related challenges of remote wind is how to bring power from the turbines, back to shore.

* https://www.plymouth.ac.uk/research/cyber-ship-lab

Doing this with crewed ships would be very costly, and so one of the proposed solutions is to use USVs to monitor, service, and ferry energy to shore. This will likely require digital communication too coordinate joint operations of USV in windfarms, and remotely.

Given how likely and closely physically, and digitally, offshore wind structures will operate with autonomous USVs and vessels in the future, the cybersecurity risks of one could possibly have a huge impact on the cybersecurity risks of the other.

### *C. Maritime cybersecurity*

We define maritime cybersecurity as the field of understanding and mitigating cyber-physical threats (i.e., both digital and physical safety) that effect technologies related to the ocean, such as ships, ports, and offshore structures. This includes autonomous vessels, offshore wind farms, and offshore renewable energy in general.

While there are many papers on specific maritime cybersecurity vulnerabilities, this paper focuses on related state-of-the-art articles that use scenarios to outline the limits of emerging cybersecurity challenges.

In [14], a human-centered design and scenario-based training was demonstrated for maritime cyber-resilience through crews. While this was not aimed at autonomy or OW, the scenario-based training proved effective for discussion and training. Similarly, the scenario-based maritime cybersecurity training in [15] was proven effective for both novices to maritime cybersecurity, and also those with more experience, and that scenarios stimulated useful discussions about the future of autonomy and maritime cybersecurity challenges.

The strengths of the studies above are the targeted scope allowed for in-depth analysis and discussion of maritime cybersecurity challenges specific to those technologies. However, it is also clear from the context of these studies, solutions to sector challenges do not always remove the issue entirely, and many times shifts the problem to another entity or creates new issues, such as human-computer interactions and cyber-physical security.

## Scenario

The purpose of this scenario is not to deep dive into one technology, autonomy, or offshore wind, and look at the cybersecurity of challenges of one in isolation, but instead to look at a scenario of the two technologies intertwined with each other. This is more likely to be realistic, as mentioned above, these two will likely be well connected digitally and operating in the same bodies of water.


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### A. Scenario technologies

(1) Remote control centre at port (ROC),

(2) Fleet of autonomous USVs,

(3) Windfarm that ROC and fleet of USVs oversee monitoring and servicing.

### B. Scenario vulnerabilities

(1) The windfarm is physically vulnerable and is open enough that ocean craft can often sail through it. The windfarms themselves also obstruct monitoring of some craft sailing through [16]. This windfarm allows vessels to pass through, as it would be nearly impossible to enforce no passage, and because of the placement of the windfarm near busy ocean pathways.

(2) While AI for object recognition is being developed for situational awareness and navigation, adversarial AI can prevent the AI from correctly identifying objects [17].

(3) Hardware vulnerabilities in the USVs means physical access, if captured, can lead to data exfiltration such as swarm/ROC specific data.

(4) Network security is often weaker when considering insider attacks instead of external attackers, with examples in maritime satellite systems being true [5]. A ROC may be protected against external attacks, but if not protected internal, it may be vulnerable to internal threats.

### C. Series of events / attack chain

This is a hypothetical series of events, a scenario, based on the three technologies and four vulnerabilities mentioned previously.

### Events:

(1) An adversary can use a cyber-physical attack on USV AI to confuse a USV in a windfarm.

(2) The initial attack would lead to the physical capture a USV despite ROC control/monitoring.

(3) Physical access to the USV gives the attackers access to the wider network that USV is connected to.

(4) Using more traditional cyber-attacks, attackers can trigger a denial of service (DoS) attack across the wider network.

The potential outcome of this scenario can be multi-fold depending on the audience involved and therefore a useful tool. For example, those in the ROC may be concerned that this DoS could allow the theft of more autonomous USVs. Conversely, those in charge of the wind turbine data could be concerned about stolen information/data to connect with turbines. Those more interested in physical operations could also be concerned with physical damage, such as any connectors (e.g., cables) connecting USV to turbine or shore-based infrastructure.

## Discussion

From this holistic scenario, there are several discussion points and research topics that could improve the sectors' ability to analyse complex scenarios for cyber-physical risks and develop cyber defence and resilience strategies.

### A. Future Work

This scenario can be used in discussion for training, as demonstrated by previous research [14] [15]. This is not only for technical training, but also for promoting more of a more positive cyber-aware culture at all levels within an organisation, such as the board. For those closer to the operations, this includes seeing cyber-security not just as a data challenge, but one that can relate to safety as well [18]. Discussions can also influence local practices, up to local/global policy as these technologies mature [16].

While previous scenario-based training have used tabletops and simulators, these are often difficult to scale due to ship simulator sizes and the need for instructors. Future research in scalable training using digital education tools like virtual reality (VR) is essential for the scalability of maritime cybersecurity education in the future, as well as improving experiences for non-experts more easily.

While scenarios are useful for initial discussion, if scenarios are not based on facts there is a concern that resulting training and policies will not be effective in real life. One of the challenges to validating scenarios, is it is dangerous to do experiments on the real equipment. While simulating and modelling threats is a useful tool, the drawback is that simulations are limited by the developers. When the environment gets more and more complex, such as cyber-physical security in a sea area with remote control over autonomous sea drones within a floating wind farm, the more challenging it becomes to simulate that with high enough fidelity for it to be useful. Alternatives to simulated systems-of-systems for testing are critical.

One way to look at complex systems is with a testbed like Cyber-SHIP [19]. As a first of its kind, both as a configurable testbed and a testbed specifically ship maritime cybersecurity (including autonomy), this testbed demonstrated the need for this level of fidelity for research. However, testbeds like this are expensive and therefore not common. Instead of building a combined autonomy and windfarm testbed for this scenario, it makes more sense to create a windfarm testbed that can connect to existing testbed and simulations for ROC and ship security.

Future work should then include building a windfarm specific cyber-physical testbed and connecting it with other facilities. This will be essential for ensuring realism within scenarios. There is a gap for understanding offshore wind, not just as a floating version of land infrastructure, but the context, other entities, and environment it will sit in, and be influenced by. To some

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## Conclusion

The growth rate of new technological solution for marine and maritime operations has reached new hights. While many have examined the benefits and negatives, including cyber-risks, of new technologies in isolation, once matured, these will not operate in isolation. This paper demonstrated how a scenario for multiple technologies can be created, and how it can be used to further discussions to further knowledge of maritime cyber-physical security.

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## About the Authors

**Dr. Kimberly Tam** is an Associate Professor of Cybersecurity at the University of Plymouth, UK, and Theme Lead for Marine & Maritime at The Alan Turing Institute. Her research focuses on maritime cybersecurity, including ship, port, and autonomous vessel systems.

**Dr. Avanthika Harish** is an Industrial Researcher in Maritime Cyber Security at the University of Plymouth, UK. Her work explores cyber-physical systems, shipboard security, and human-autonomy teaming, combining expertise in computer science and cybersecurity research.

**Professor Kevin D. Jones** is Deputy Vice-Chancellor (Research & Innovation) at the University of Plymouth, UK. A computing science expert, he leads the Maritime Cyber Threats Research Group and advances global research in maritime cyber risk and resilience.

# Classification Society – A Voice of Influence or Just an IMO Ally?

**Ulhas S. Kalghatgi**

*"You can exert no influence if you are not susceptible to influence." — Carl Jung*

**Abstract:** The International Association of Classification Societies (IACS) functions as the principal technical partner of the International Maritime Organization (IMO). It translates regulatory intent into technical rules that ensure uniform global implementation of maritime conventions. Representing twelve leading classification societies covering over 90 percent of the world's cargo-carrying tonnage, IACS supports safe, secure, and environmentally sound shipping. This paper examines whether IACS is an **influencer**, shaping IMO policy, or an **ally**, assisting in its execution. Drawing on practical insights from IMO's Marine Environment Protection Committee (MEPC), it analyses how influence manifests at the IMO, the interaction between governments and non-state actors, and IACS's contribution to global maritime governance.

## 1. Introduction

Shipping remains the backbone of world trade, transporting more than 90 percent of global cargo volume. The reliability of this system rests upon sound engineering standards and consistent enforcement — the realm in which the classification societies, coordinated through IACS, operate.

Since its formation in 1968, IACS has served as a bridge between maritime policy and engineering practice. Its rulebooks govern design, construction, and maintenance for most of the world's merchant fleet. Yet an enduring question persists: does IACS merely assist the IMO in implementing conventions, or does it subtly shape them?

To address this, the paper explores:

1. The IMO's institutional framework and policy objectives;
2. The historical evolution and technical role of IACS;
3. The distinction between influence and alliance in global maritime rulemaking;
4. The real drivers of decision-making within the IMO.

Through this lens, IACS emerges not as a political influencer but as a **technical ally** — indispensable in transforming policy consensus into practical compliance.

## 2. The International Maritime Organization: Structure and Mandate

The IMO was conceived as the **Inter-Governmental Maritime Consultative Organization (IMCO)** in 1948, became a United Nations specialized agency in 1959, and was renamed the IMO in 1982. It currently comprises 174 member states and three associate members.

### 2.1 Institutional Structure

The IMO operates through several governing bodies:

- **The Assembly**, meeting biennially, is the highest authority, setting strategic objectives and approving the budget.
- **The Council**, acting as the executive organ, supervises the Organization's work under the Secretary-General.

- **Five Main Committees** perform policy-making and technical functions:
  o Maritime Safety Committee (**MSC**)
  o Marine Environment Protection Committee (**MEPC**)
  o Legal Committee (**LEG**)
  o Technical Cooperation Committee (**TC**)
  o Facilitation Committee (**FAL**)
- **Seven Sub-Committees** — including III, PPR, CCC, NCSR, SSE, HTW, and SDC — conduct the technical groundwork, developing draft amendments and interpretations.


**Figure 1: Structure of IMO**

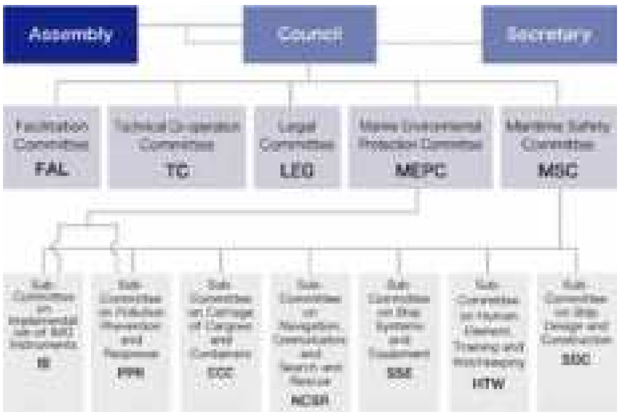


**Figure 2: Structure of IMO**

The above structure ensures that political deliberation, technical expertise, and administrative implementation remain closely aligned.

### 2.2 Mission and Legal Instruments

Article 1(a) of the IMO Convention defines its purpose as providing "machinery for cooperation among Governments" and promoting "the highest practicable standards" in maritime safety, efficiency, and pollution prevention.

Four conventions form the foundation of IMO regulation:

1. **SOLAS (Safety of Life at Sea)** – standards for ship construction, fire protection, and lifesaving appliances.
2. **STCW (Standards of Training, Certification and Watchkeeping)** – competence criteria for seafarers.
3. **MARPOL (Prevention of Pollution from Ships)** – measures to prevent oil, sewage, garbage, and air pollution.
4. **MLC 2006 (Maritime Labour Convention)** – seafarer welfare and employment conditions.

Together, these "four pillars" define the modern framework for safe, secure, and sustainable shipping.

### 2.3 IMO and the Global Decarbonization Agenda

Beyond safety, the IMO increasingly focuses on **greenhouse-gas (GHG) reduction**. The **Initial GHG Strategy (2018)** and its **Revised Strategy (2023, MEPC 80)** commit international shipping to:

- Reduce carbon-intensity by **40 percent by 2030** (relative to 2008).
- Reduce total GHG emissions by **70–80 percent by 2040**.
- Achieve **net-zero GHG emissions by 2050**, or earlier.

These ambitions align with the United Nations' Sustainable Development Goals (**SDG 13** – Climate Action; **SDG 14** – Life Below Water). Implementation, however, demands rigorous technical solutions — areas where IACS's contribution is crucial.

### 2.4 Cooperation and Global Governance

IMO maintains formal partnerships with 64 inter-governmental organizations and consultative status for 81 non-governmental organizations. These collaborations extend to the European Union, the World Bank, the Global Environment Facility, and numerous industry bodies.

Through instruments such as the **Hong Kong Convention on Ship Recycling** and engagement in the **Biodiversity Beyond National Jurisdiction (BBNJ)** treaty, IMO supports broader ocean governance initiatives.

Yet enforcement remains decentralized: once a state ratifies an IMO convention, it must transpose it into national legislation and ensure compliance through flag and port-state control mechanisms.

## 3. The International Association of Classification Societies (IACS)

### 3.1 Definition and Scope

A **classification society** is an independent, non-commercial organization that:

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4. Operates without ownership or financial ties to shipowners or builders.
5. Is authorized by flag administrations under SOLAS XI-1 / Regulation 1 and listed in IMO's **Global Integrated Shipping Information System (GISIS)**.

Its principal task is to verify the structural integrity and functional reliability of hull, propulsion, electrical, and auxiliary systems — ensuring vessels remain seaworthy throughout their operational life.

> *IACS is not the voice that drafts policy but the hand that steadies its execution — the technical conscience of the maritime world*

### 3.2 Historical Background

Classification emerged in eighteenth-century London when marine insurers met at **Lloyd's Coffee House** to assess ship condition for underwriting. The early "A–E–I–O–U" and "G–M–B" rating systems evolved into the now-familiar "A1" standard. As maritime trade expanded, similar societies formed worldwide, leading to greater uniformity in construction standards and surveys.

### 3.3 Formation and Recognition of IACS

Prompted by the **1930 International Load Line Convention**, which called for harmonized strength standards, seven classification societies convened in 1939 to coordinate technical rules. This cooperation formalized in 1968 as the **International Association of Classification Societies (IACS)**. In 1969, IACS was granted **consultative status** with the IMO — the only non-governmental organization authorized to develop and apply technical rules globally.

### 3.4 Technical Deliverables

IACS's principal instruments include:

- **Unified Requirements (URs):** Baseline standards adopted by all members.
- **Unified Interpretations (UIs):** Clarifications of IMO regulations ensuring consistent implementation.
- **Procedural Requirements (PRs):** Internal procedures harmonizing survey and certification activities.
- **Recommendations and Position Papers:** Guidance on new technologies, risk assessment, and safety practices.

### 3.5 Recognized Organizations (ROs)

Under SOLAS II-1/Regulation 3-1, ships must comply with the structural, mechanical, and electrical rules of a recognized classification society. Flag administrations may delegate survey and certification functions to these

**Recognized Organizations**. To qualify, a society must meet IMO criteria defined in **Resolutions A.739(18)** and **A.789(19)** — now consolidated into the **Code for Recognized Organizations (RO Code)** adopted in 2013 (MEPC 237(65) / MSC 349(92)). All IACS members comply with the RO Code, ensuring competence, independence, and consistent quality across the global fleet.

## 4. IACS as Ally or Voice of Influence

The relationship between IACS and IMO reflects technical interdependence rather than political alignment. IACS provides the engineering realism necessary to operationalize IMO conventions.

### 4.1 Historical and Contemporary Collaboration

Notable examples include:

- **Implementation of IMO Codes:** IACS played a pivotal role in enforcing the **ISM Code (1998)**, **ISPS Code (2004)**, and **Maritime Labour Convention (MLC 2006)**, ensuring consistent verification and compliance.
- **Technical Initiatives:** Collaborative work on **cyber-risk management**, **goal-based ship construction standards (GBS)**, and redevelopment of IMO's **Global Integrated Shipping Information System (GISIS)** for casualty data.

Although IACS did not draft these instruments, its involvement guaranteed technical viability and uniform application — establishing its reputation as the IMO's most reliable **implementation partner**.

### 4.2 Engineering Neutrality

IACS deliberately refrains from policy advocacy. Its mandate is confined to interpretation, verification, and harmonization — not persuasion. By maintaining neutrality, IACS preserves credibility among governments and industry stakeholders alike.

Its influence, therefore, lies not in *shaping* policy but in *enabling* it. The distinction underscores its role as an

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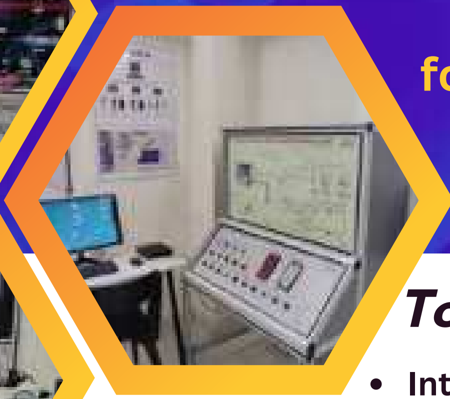

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**ally** in execution rather than a **voice** directing political debate.

## 5. Influence Dynamics at the IMO

### 5.1 Participants and Process

The IMO's decision-making ecosystem involves both member states and observers. Currently, 81 NGOs and 64 IGOs hold consultative status. Prominent among them are ICS, BIMCO, INTERCARGO, INTERTANKO, CESA, IMAREST, RINA, and IACS.

Influence at the IMO depends less on delegation size and more on technical credibility, quality of submissions, and participation in working groups. Large delegations can attend multiple parallel discussions, but even small, expert groups can shape debate through evidence-based interventions.

### 5.2 Policy Challenges and Lobbying

Climate change and GHG regulation have tested IMO consensus. The adoption of measures such as the **Energy Efficiency Design Index (EEDI)** and **Ship Energy Efficiency Management Plan (SEEMP)** faced resistance from some states and industry bodies citing cost and technical feasibility. Developed nations pressed for ambitious timelines; developing nations invoked **Common But Differentiated Responsibilities and Respective Capabilities (CBDR-RC)** to ensure equitable treatment.

> *Maritime governance thrives on the balance between political consensus and technical integrity. The IMO offers the legislative architecture; IACS ensures that architecture stands on solid engineering foundations*

Trade associations, using their observer status, occasionally lobbied to delay implementation, while open-registry states leveraged economic influence to protect national interests. Despite these pressures, IACS maintained a consistent position of technical impartiality, providing clarifications that helped bridge divergent views.

### 5.3 Factors that Shape Influence

Drawing on MEPC proceedings, the author identifies three principal determinants of influence:

1. **Delegation composition and expertise** – technical proficiency outweighs numerical strength.
2. **Frequency and relevance of submissions** – regular, well-researched papers earn credibility.
3. **Active engagement** – contributions to intersessional and correspondence groups sustain visibility.

Even so, technical allies like IACS influence outcomes indirectly — by enhancing clarity, feasibility, and confidence in regulatory implementation.

## 6. The Ally–Influencer Continuum

### 6.1 Conceptual Distinction

An **ally** supports the implementation of decisions; an **influencer** determines their direction. The two roles can overlap, yet their motives differ. IACS's charter commits it to neutrality and cooperation, aligning more closely with the ally archetype.

### 6.2 Functional Contribution

IACS's practical influence manifests through:

- Interpretation of ambiguous SOLAS or MARPOL clauses;
- Advising shipowners and equipment manufacturers on compliance pathways;
- Coordinating with flag states for certification and audit;
- Sharing data and research to inform IMO discussions.

### 6.3 Response to Emerging Challenges

Modern classification societies face new demands — digitalization, autonomous ships, cyber threats, and alternative fuels such as LNG, methanol, and ammonia. IACS's ongoing research, including safety frameworks for low-flashpoint fuels, demonstrates its ability to adapt without straying into political advocacy.

During the **COVID-19 pandemic**, class societies played a crucial role in maintaining statutory compliance despite global travel restrictions — further evidence of their operational resilience and supportive role to IMO member states.

## 7. Discussion and Observations

1. **Consensus Decision-Making:** Most IMO resolutions are adopted by consensus, not by vote, reflecting equitable participation and legitimacy.
2. **Limited Core Influencers:** A small group of technologically advanced or economically strong states (such as Japan, Korea, China, the United States, and some EU members) often set the agenda.
3. **IACS's Apolitical Posture:** By avoiding lobbying, IACS sustains trust among diverse stakeholders.
4. **Technical Authority:** Its credibility arises from sound engineering practice, independent audit, and transparent rule-making.

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5. **Implementation Bridge:** IACS translates regulatory ambition into shipyard and onboard procedures, ensuring safe, uniform execution.
6. **European Union's Stance:** Despite potential leverage, the EU typically works through consensus within IMO frameworks rather than unilateral influence.

Collectively, these observations confirm that the IMO–IACS relationship is symbiotic — the former sets the direction; the latter provides the tools.

## 8. Conclusion

Maritime governance thrives on the balance between political consensus and technical integrity. The IMO offers the legislative architecture; IACS ensures that architecture stands on solid engineering foundations.

While certain states and trade blocs wield disproportionate policy influence, IACS's strength lies in **credibility, neutrality, and implementation capacity**. Its role as an ally complement, rather than competes with, the policymaking process.

As the industry confronts twin transitions — **decarbonization** and **digitalization** — the importance of this partnership will only grow. Safe and sustainable shipping depends on continued collaboration between rule-makers and rule-interpreters.

In the final analysis, IACS is not the voice that drafts policy but the hand that steadies its execution — the **technical conscience of the maritime world**.

**[This Paper was presented in the WMTC 2024; 4-6 Dec 2024, Chennai]**

### About the Author

**Ulhas S Kalghatgi** joined Indian Register of Shipping (IRS) in 1988 after 12 years at sea with Shipping Corporation of India, rising to Chief Engineer. Served 33 years in IRS, retiring as Chief Surveyor and Sr. VP, later Technical Advisor to the Chairman. Represented IRS at IACS and IMO. Holds Extra 1st Class CoC, MS (Quality Management, BITS Pilani) and Executive Management (SP Jain). Authored 25+ acclaimed technical papers internationally.

**Email:** ulhassk@gmail.com

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# Ashes to Ashes, Rust to Rust: The Inevitable Toll of Metallic Corrosion on the Global Economy

**Gajanan Karanjikar**

It began with a whisper of decay — a faint flake of reddish-brown dust on a tanker bulkhead, a line of pitted indentations on the belly of an offshore pipeline. In the grand theatre of natural processes, corrosion plays the unrelenting villain: silent, persistent, and ruinously expensive. To a maritime investigator, corrosion is not merely a chemical reaction but a slow unravelling of infrastructure, capital, and confidence.

The phrase ***"Ashes to ashes, rust to rust"*** carries a scientific inevitability. Just as all organic matter returns to dust, refined metal will, if left unprotected, return to its base state. Corrosion is nature reclaiming what industry has refined — the slow reversal of metallurgy, an electrochemical journey back toward entropy.

## The Science Behind Rust

Corrosion is an electrochemical reaction between a metal and its environment. When iron reacts with oxygen and water, it forms iron oxide — rust. Other metals such as aluminium, copper and zinc also corrode, forming oxides or carbonates that may either protect or further degrade the surface.

This decay takes many forms:

- **Galvanic corrosion** – when two dissimilar metals are electrically coupled in a conductive medium, the less noble metal becomes the anode and corrodes faster.
- **Pitting corrosion** – a localised attack that penetrates deeply while leaving adjacent areas untouched; a single pit can trigger catastrophic failure.
- **Crevice corrosion** – occurs in stagnant micro-environments beneath gaskets or deposits.
- **Stress corrosion cracking (SCC)** – results from the combined action of tensile stress and a corrosive environment, causing brittle fractures without warning.
- **Microbiologically influenced corrosion (MIC)** – driven by microbial activity, particularly sulphate-reducing bacteria (SRB) that generate hydrogen sulphide and acidify their surroundings.

In marine systems these modes often overlap. During one bulk-carrier investigation, metallurgical sampling of ballast tanks revealed SRB colonies thriving in anaerobic zones; their acidic by-products had undermined protective coatings, producing deep localised wastage invisible to routine inspection.

## Corrosion and the Maritime Industry

The maritime sector is uniquely exposed. Ships, offshore platforms, and subsea assets endure continuous contact with salt water, humidity, mechanical vibration, and thermal cycling. A single unprotected weld can become a nucleation point for corrosion that spreads unseen.

From hull plates to cargo hold fittings, anchor chains to propeller shafts, the effects are pervasive. Regular dry-dockings, coatings, and cathodic-protection renewals cost shipowners millions. When corrosion is ignored, consequences multiply.

In one investigation, a crude-oil tanker suffered corrosion through a slop-tank partition, leading to cargo cross-contamination. The incident rendered the shipment unsellable and caused losses exceeding **USD 4 million**, excluding penalties and downtime. Such events highlight that corrosion control is not simply a maintenance issue — it is a matter of commercial survival.

Figure1- Real money burner

## The Global Cost of Corrosion

The numbers are staggering. Studies by NACE International (now AMPP) estimate the global annual cost of corrosion at **USD 2.5 trillion**, roughly **3.4 percent of global GDP**.

Approximate sectoral losses include:

- **Oil and gas:** > USD 100 billion annually in maintenance and failure.
- **Shipping and marine infrastructure:** ~ USD 50 billion in dry-docking and repair.
- **Transportation infrastructure:** In the United States alone, bridge corrosion exceeds USD 8 billion per year.
- **Utilities and water networks:** Global losses surpass USD 75 billion.

Yet between 30 and 40 percent of this cost is preventable through proactive design, improved coatings, and timely inspection. Corrosion control is one of the few industrial expenditures that demonstrably pays for itself.

## MIC – The Invisible Accelerant

Among the least understood but most destructive mechanisms is **Microbiologically Influenced Corrosion**. MIC arises when microorganisms — chiefly SRB, acid-producing, or iron-oxidizing bacteria — create microscopic environments hostile to metal.

Within ballast tanks, sewage lines, and offshore risers, MIC can remove **0.3–0.5 mm of steel per year**, several times faster than atmospheric corrosion. The danger lies in its invisibility: activity occurs beneath biofilms or sludge where oxygen is scarce but bacterial metabolism thrives.

On one FPSO unit, internal corrosion of a seawater-injection line caused a rupture after only four years of service. Laboratory analysis confirmed a dense SRB colony had reduced a **20 mm** wall to near-failure thickness. The resultant downtime and repair logistics cost tens of millions — a vivid reminder that biology and metallurgy often conspire in silence.

## Prevention: Cost Now, Savings Later

Corrosion prevention must be treated as an investment, not an expense. Effective strategies include:

- **Cathodic protection:** Impressed-current or sacrificial-anode systems divert corrosion currents away from critical structures.
- **Coating systems:** Advanced epoxy, polyurethane, and ceramic coatings form durable moisture barriers.
- **Material selection:** Using duplex stainless steels or corrosion-resistant alloys (CRAs) can extend service life manyfold.
- **Inspection and monitoring:** Non-destructive testing, ultrasonic scanning, and microbial sampling identify early degradation before failure.

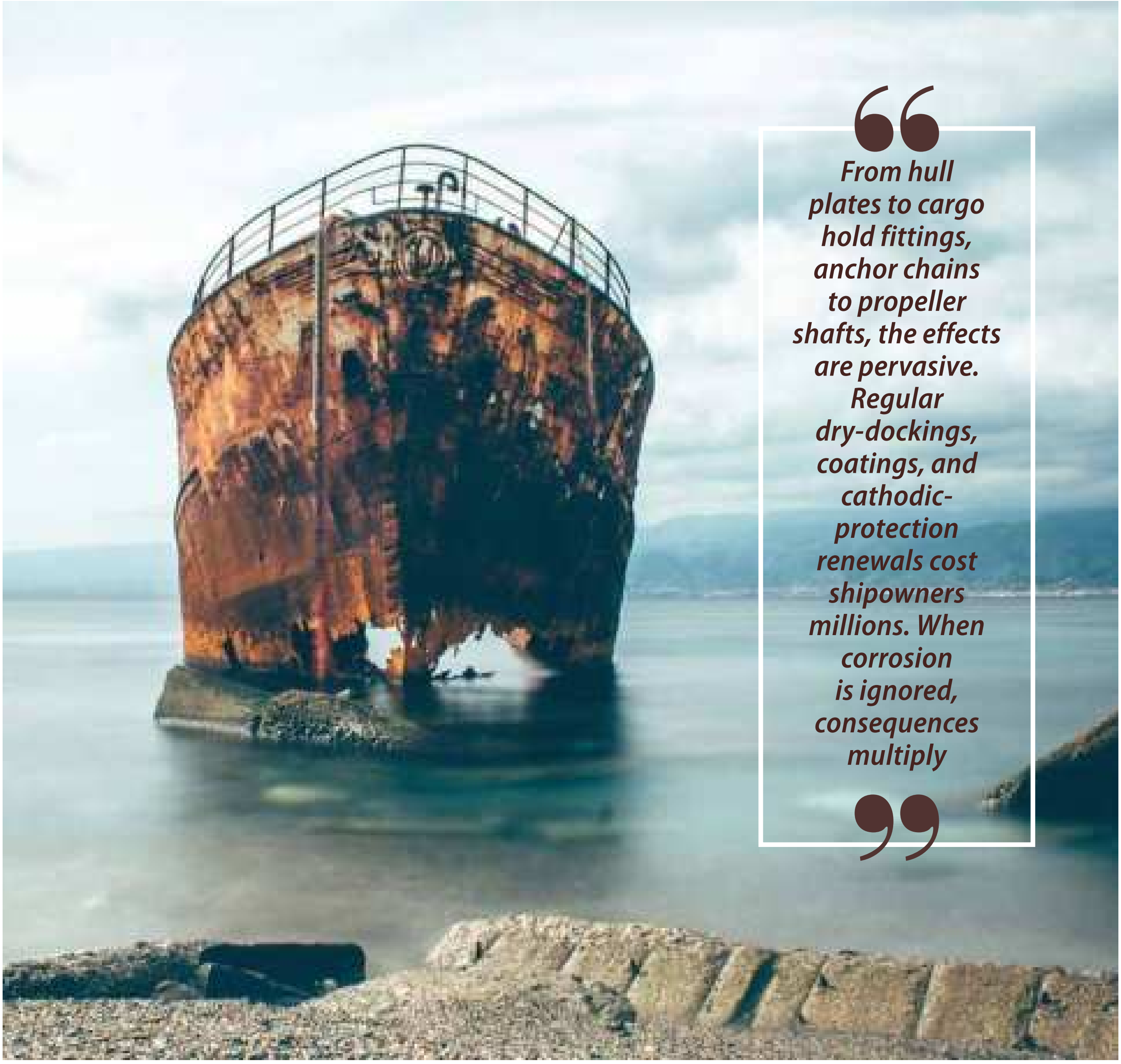
The **U.S. Department of Defence** reported saving over **USD 10 billion** in a decade through organised corrosion-prevention programs — proof that planned protection yields measurable economic returns.

## Toward a Rust-Conscious World

The reality remains: corrosion cannot be eliminated, only delayed. *"Ashes to ashes, rust to rust"* is both a scientific truth and a philosophical reminder of material impermanence. Metals yearn to revert to their natural states; human ingenuity merely postpones that journey.

For maritime professionals, this means embedding corrosion awareness into every phase of design, construction, and operation. Class societies, flag administrations, and shipowners must collaborate to

Figure 2 – Extensive wastage and loss to industry



> *From hull plates to cargo hold fittings, anchor chains to propeller shafts, the effects are pervasive. Regular dry-dockings, coatings, and cathodic-protection renewals cost shipowners millions. When corrosion is ignored, consequences multiply*

create maintenance cultures that value early detection as highly as efficiency.

For policymakers, corrosion control deserves elevation from maintenance overhead to strategic infrastructure protection. Every dollar spent on prevention saves multiple in repairs, environmental damage, and lost productivity.

## Conclusion

Corrosion may begin as a stain on steel, but it ends as a stain on the balance sheet of nations. Its reach extends from pipelines to ports, from naval fleets to municipal bridges. Combating it demands an alliance of science, engineering, and policy.

Nature will always seek equilibrium; iron will always seek oxygen. Our task is not to stop rust, but to understand it, anticipate it, and slow its advance.

Because in the world of metal, **rust waits for no one**.

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## About the Author

**Capt. Gajanan Karanjikar**

U.S.-based Marine Surveyor, Accident Investigator and Maritime Consultant.

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## Basic Training for Oil and Chemical Tanker Cargo Operations

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This course is principally intended for candidates for certification for basic training for oil and Chemical tanker cargo operations as specified in section A-V/1-1 para 1 of the STCW Code as amended.

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Course Date: **15th – 20th December 2025**

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***Indicator Cards is a forum for letters from readers on technical matters, published articles and discussions.***

# "A Study on Shipowners' Protections and Liabilities in Maritime Accidents"

**Shantanu Paul**

## Overview

Following publication, the author circulated the article among eleven senior professionals directly associated with the Directorate General of Shipping (DGS), including serving and former Chief Surveyors, Principal Officers of MMDs, and Class-1 examiners (written + oral). The intent was to evaluate whether such analytical articles could serve as reference material for MEO Class-1 candidates.

## Consolidated Feedback

| Theme | Summary of Comments |
|---|---|
| **Relevance & Clarity** | The article was unanimously praised as **pertinent**, **well-structured**, and **written in accessible language**, simplifying a complex legal subject. |
| **Educational Utility** | Multiple examiners confirmed that the piece is **highly suitable for MEO Class-1 preparation**, bridging the academic–practical gap. One examiner even noted that it provided ideas for framing new oral questions. |
| **Technical Depth vs. Pedagogic Approach** | While the conceptual depth was appreciated, a senior examiner suggested a **tiered approach** — starting with "basic building-block" articles for junior candidates before advancing to complex case applications. |
| **Pedagogical Value** | Examiners highlighted that **integrating practical examples and case-based explanations** makes the conventions' application clearer, aiding retention and understanding. |
| **Encouragement & Continuity** | Every respondent encouraged continued contributions, calling the effort "a very good exercise," "pertinent," and "highly useful." Several urged the author to write **a series of similar exam-focused articles**. |

## Representative Remarks

1. *"Explained owner's liabilities in simple and clear text — very informative for MEO Class I candidates. Continue to write such articles."*
2. *"A good write-up on a complicated topic. They don't need more than this."*
3. *"Articles like these with practical examples help students grasp minute applications of conventions in varying scenarios."*
4. *"This will also help me prepare some oral questions!"*
5. *"To maximize impact, begin with basics before advancing to complex examples."*

## Context & Author's Note

This article continues the author's initiative to publish examination-relevant, legally precise papers aligned with MEO CoC syllabi. Earlier pieces include:

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- **July 2024:** *[Regulatory interpretation]*
- **March 2025:** *"MV DALI Allision: A Legal Snapshot of Brahmastra"*
- **October 2025***: A study on shipowners Protections & Liabilities in Maritime Accidents*

All were developed independently or under guidance of **World Maritime University (WMU), Malmö** professors, ensuring academic rigor and international perspective.

A limited survey among young Indian marine engineers indicated strong preference for **exam-relevant, case-driven legal and technical content**, which enhances both professional competence and interest in MER (I).

## Editorial Recommendation

Based on these results, future MER (I) issues may consider:

1. A **dedicated "MEO Exam Corner"** featuring such analytical yet accessible papers.
2. Short "*Concept → Convention → Case*" articles that move from fundamentals to applied examples.
3. Integration of examiner insights as a recurring "Expert's Note" sidebar accompanying each article.

## Conclusion

The October 2025 article has been **strongly endorsed by senior DGS examiners** for its clarity, depth, and pedagogical contribution. It demonstrates how high-quality, exam-aligned scholarship can strengthen MER (I)'s relevance to the next generation of Indian marine engineers.

### About the Author

**Dr. Shantanu Paul** is a First-Class Marine Engineer, WMU (Shipping Management) and PhD (Management).

**Email:** wmuspsci@gmail.com

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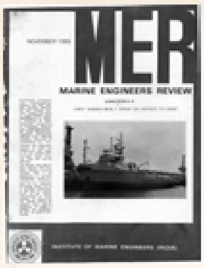
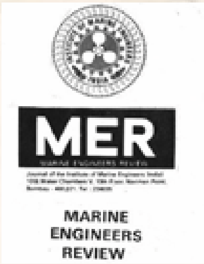
# Going Astern into MER Archives…




The editorial emphasises leveraging technology to drive future value-based discoveries and innovations, rather than focusing on uncovering only the past. It highlights advancements such as undersea robots, sonar mapping systems, high-speed magnetometers and remote-controlled underwater cameras. The discussion advocates for using these technologies to build a better future, cautioning against materialism by referencing the decline of the Spanish empire due to its pursuit of material wealth.

There is discussion on the glories of Naval Dockyard in Mumbai stands as a landmark of maritime heritage, with a legacy spanning over 250 years. Established in 1735 by the East India Company, the dockyard's early success was shaped by the expertise of Lowji Nusserwanji Wadia, a master shipbuilder from Surat. Under his stewardship and that of his descendants, the dockyard became renowned for its craftsmanship, constructing 170 ships for the East India Company, 34 warships for the Royal Navy, and 87 merchant vessels. Notably, ships such as HMS Ceylon, HMS Asia, HMS Cornwallis, and HMS Minden—on which the lyrics to "The Star-Spangled Banner" were built here, earning international acclaim for their quality and durability.

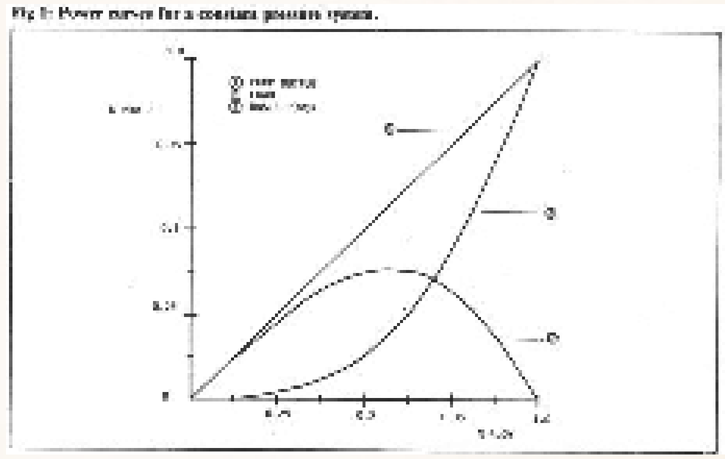
The dockyard's strategic location and advanced shipbuilding capabilities contributed significantly to British naval dominance in the region and played a pivotal role in the development of Mumbai as a premier maritime city. The Wadia family's legacy of integrity and technical excellence left an indelible mark on Indian maritime history, with nine generations serving as master builders.

Today, the Naval Dockyard continues to serve as a vital facility for the Indian Navy, focusing on refitting and repairing vessels to ensure operational readiness. Its ongoing contributions underscore its historical importance as both a custodian of India's maritime legacy and a cornerstone of national defence.

### Variable flow Marine-hydraulic power systems:

This article provides a good discussion on selection principles fo variable-flow marine hydraulic power systems. This is easy read for the readers.

The author talks providing advanced solutions for transmitting medium power in marine applications. They offer high power-to-weight ratios, precise control, and efficient energy usage. These systems use variable-flow pumps to adjust speed and direction based on pump output, minimising power loss compared to constant-pressure systems. They are ideal for applications requiring high torque at low speeds, accurate control, and flexibility in layout. Variable-flow systems are particularly efficient for high-power applications, achieving up to 75% overall system efficiency. They are commonly used in propulsion systems, deck machinery, and specialised applications like minesweepers and stabilising structures for VTOL aircraft.



The article compares two types of hydraulic systems: **constant-pressure oil supply with speed and direction control** and **variable-flow transmission** where speed and direction depend on pump output.

1. **Constant-Pressure Oil Supply**:
    - o Uses a pressure-compensated pump to maintain a constant oil pressure.
    - o Speed and direction are controlled by introducing a valve into the system.
    - o This method results in power loss due to throttling, as the valve creates a restriction in the system.
    - o At partial loading, the pump produces excess power, which is destroyed by throttling, leading to inefficiency.
    - o The pump produces up to 40% more power than required by the load at partial loading.
2. **Variable-Flow Transmission**:
    - o Speed and direction are directly controlled by the pump output.

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**Days**

★**Course Id - 5121**

## Basic Training for Liquefied Gas Tanker Cargo Operations

**Entry Criteria:** Any seafarer who has successfully completed approved Basic Safety Training Course as per STCW Section A-VI/1, para 2.3, Tables A-VI/1-1, A-VI/1-2, A – VI/1-3, A-VI/1-4

- This Course will familiarize with the equipment, instrumentation and controls used for cargo handling on a Gas tanker. It will enhance the awareness to apply proper and safe procedures at all times when carrying out the various operations on board tanker
- The trainee will be able to identify operational problems and assist in solving them and will be able to co-ordinate actions during emergencies and follow safety practices and protect the marine environment.


**Course Date: 11th – 15th Nov 2025/ 9th – 13th 2025**

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- o The pump provides only the required output speed, and pressure rises only to meet the output torque demand.
- o This system minimises power loss, as there is no throttling involved.
- o It achieves higher efficiency, with an overall system efficiency of up to 75%.
- o Variable-flow systems are more energy-efficient and cost-effective in terms of life cycle costs.

The article highlights that while constant-pressure systems are cheaper for multiple drives with a single pump, variable-flow systems are favored for higher power applications due to their efficiency and energy-saving benefits.

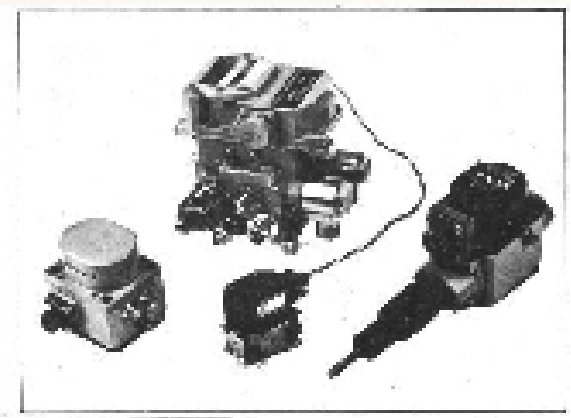

Fig. 2: Typical servo valves.

Controls in variable-flow systems adjust the pump's swash-plate angle to vary speed and direction. They can be mechanical, hydraulic, or electrical, with modern systems favoring electrical controls for integration with ship systems.

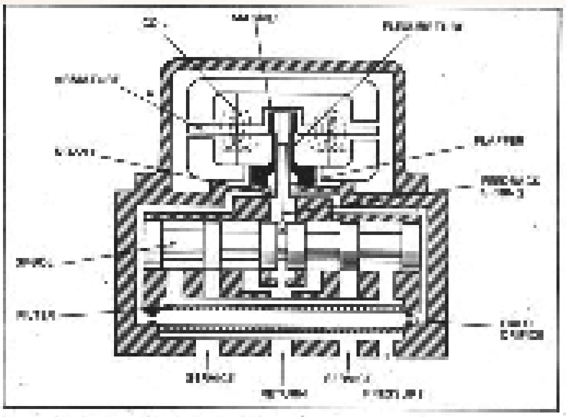

Fig 3: Servo valve operating principle.

Servo valves, a key component, convert error signals into hydraulic energy for precise control. They use a torque motor and hydraulic bridge circuit to ensure proportional spool displacement, enabling accurate and rapid response for critical applications like propulsion systems.

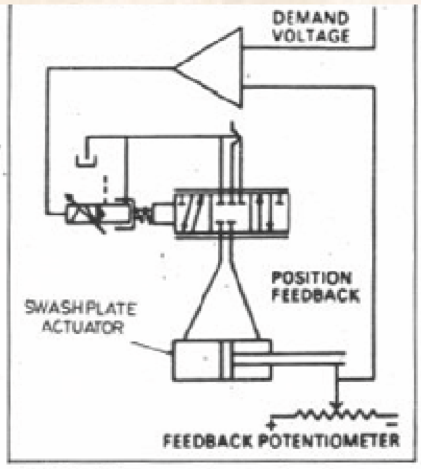


Fig 4: Typical servo valve control system.

Figure 4 illustrates a typical closed-loop system used for position control. In this system, a servo valve receives an electrical signal proportional to the error between the set position and the actual position. The servo valve then adjusts the hydraulic flow to correct the position. This setup ensures precise control and allows for safeguards and interlocks to handle failures, such as loss of pressure or electrical supply, by returning the pump to neutral or maintaining the last position.

***"An Investigation of Propeller Performance and Machinery Applications in WindAssisted Ships"*** **(1985)** by Dr A F Molland MRINA & Dr C J Hawksley FIMarEng

## Key points

1. **Context / motivation**
    - o The study addresses the scenario of ships which utilise some form of windassisted propulsion (so the propeller and engine system are not in conventional mode).
    - o With windassisted drive, the thrust contribution of the wind propulsor (e.g., sails or rotors) reduces the load on the main propeller/engine system; this in turn changes the operating point of the propeller and machinery.
2. **Propeller performance under altered operating point**
    - o The authors examine how the propeller's effective wake, loading, revolutions, and efficiency vary when the ship is assisted by wind (therefore the main engine may run at reduced power or the ship may maintain speed with less fuel/engine load).
    - o They point out that when a ship is windassisted, the propeller may operate off its "best design condition" (e.g., different advance ratio, different wake fraction) and thus suffer a loss in propulsive efficiency, or require changes in revolutions/power to maintain service speed.

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3. READING AND TRACING THE HYDRAULIC SCHEMATIC DIAGRAMS
4. MAINTENANCE / TROUBLE SHOOTING OF INDIVIDUAL COMPONENTS: D.C.V.S, HYDRAULIC CYLINDERS, HYDRAULIC PUMPS (SWASH PLATE, VANE, GEAR), COUNTER BALANCE VALVES, PRESSURE RELIEF VALVES, NON-RETURN VALVES,BI-DIRECTIONAL MOTORS, PROPORTIONAL VALVES, ELECTRO-HYDRAULIC SERVO VALVES, CARTRIDGE VALVES
5. FLOW CONTROL VALVES - METER IN, METER OUT, BLEED OFF CIRCUITS
6. CONTROLLING THE POWERPACK ELECTRIC MOTOR SPEED THROUGH V.F.D. FOR HYDRAULIC PUMP SPEED CONTROL
7. WORKING OF DIFFERENT TYPES OF ACCUMULATORS (BLADDER, DIAPHRAGM & PISTON), H.P.U.
8. WORKING OF REGENERATIVE AND SEQUENTIAL LOGIC CIRCUITS, SPEED CONTROL OF LINEAR ACTUATORS
9. DESIGN OF P.L.C. CIRCUIT BASED CONTROL FOR DOUBLE ACTING HYDRAULIC CYLINDERS
10. DEMONSTRATE, UNDERSTAND AND CARRY OUT TROUBLE-SHOOTING OF HYDRAULIC MARINE STEERING SYSTEM, HYDRAULIC CRANES, GRABS, HATCH COVERS
11. STUDY OF ASSOCIATED ELECTRICAL & ELECTRONIC CIRCUITS, INCLUDING 440V , 3 PHASE MOTORS FOR H.P.U., D.C. POWER SUPPLY, PROXIMITY SENSORS, PRESSURE SENSORS
12. HYDRAULIC SYSTEM PREVENTIVE MAINTENANCE & CHECKS TO BE CARRIED OUT - PRIOR OPERATION OF THE EQUIPMENT

### PNEUMATIC SYSTEMS:

1. UNDERSTANDINGPNEUMATIC SYMBOLS, AS PER ISO 1219-1: 2012 STANDARDS
2. READING AND DECIPHERING PNEUMATIC SCHEMATIC DIAGRAMS
3. LEARNING THE WORKING, MAINTENANCE AND OVERHAULING OF PNEUMATIC EQUIPMENT: 5/2 WAY, 3/2 WAY, 4/3 WAY SOLENOID / LEVER OPERATED VALVES, AIR CYLINDERS, ACTUATORS, MANIFOLDS, AIR FILTER REGULATORS, AIR DRYERS, GAUGES, PIPINGS
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3. **Machinery matching and power/ gearbox considerations**

   o Because the load on the engine/ gearbox/propeller system changes with the windassist component, the paper looks at alternative propeller/ engine/gearbox arrangements: fixedpitch vs controllablepitch, different gearbox ratios, variable speed engines, etc.

   o The authors discuss practical operating regions: e.g., the machine must still be able to supply full power when windassist is absent, and the margins (e.g., power margins, revolutions margins) must be considered. They also examine how the fuel consumption (specific fuelconsumption) may change when the engine is operated at nonoptimum loads.

4. **Different operational modes**

   Two broad modes are considered:

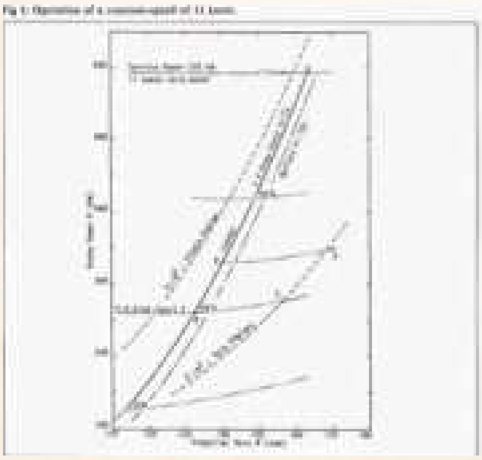
   (a) constant shipspeed mode (where windassist reduces required engine load) and

   (b) constant enginepower mode (where the windassist enables higher speed for the same engine power).

   The propeller/machinery must be evaluated differently for each mode.

   o The choice of mode influences the required revolutions and hence the propeller efficiency and machinery performance.

Fig 1: Operation at a constant speed of 11 knots



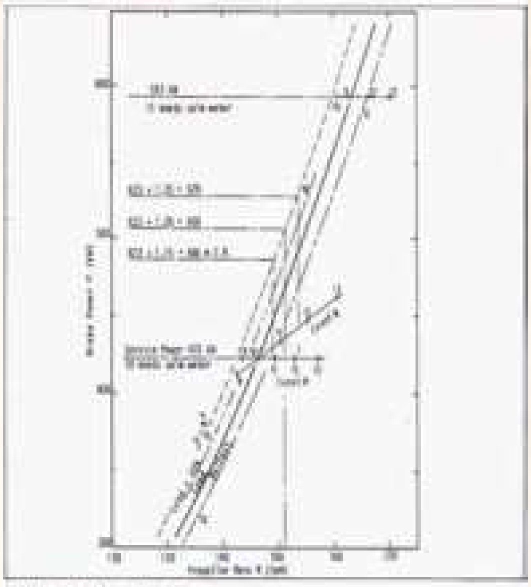


Fig 2: Operation at constant power

5. **Implications & recommendations**

   o One implication is that simply adding a windassist system without rethinking the propeller/engine/gearbox match can undermine the overall benefit (because the propeller might be loaded differently and efficiency may drop).

   o The paper suggests that, for windassisted ships, it may be worthwhile to consider controllablepitch propellers (CPPs) especially when windassist becomes large (i.e., a significant portion of propulsion). For more modest windassist, fixedpitch may suffice.

   o The authors argue that the design and selection of machinery for windassisted ships must incorporate the altered load cases and offdesign conditions arising from wind contribution.

6. **Limitations / caveats**

   o The paper acknowledges that the offdesign behaviour is more complex than a "normal" dieselpropeller system: e.g., changes in advance ratio, wake fraction, cavitation margins, gearbox loads.

   o It also points out that the data for windassisted ships are sparse (in 1985) and that the usual assumptions for propeller design may not hold.

## Summary

In short, the paper examines how the interaction of propeller and engine/machinery must be reconsidered when a windassist system is employed. Rather than simply adding windassist as a "bolton" to a standard propulsion train, one must evaluate how the propeller's loading, speed and efficiency change under windassisted conditions and match the engine/gearbox accordingly. Otherwise, one may lose part of the potential benefit. The authors present analyses of different operational modes (constant speed vs constant power) and offer guidance on when a controllablepitch propeller may be more advantageous.

***We invite observations, discussion threads from readers, taking cues from these sepia-soaked MER pages. – Hon.Ed***

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