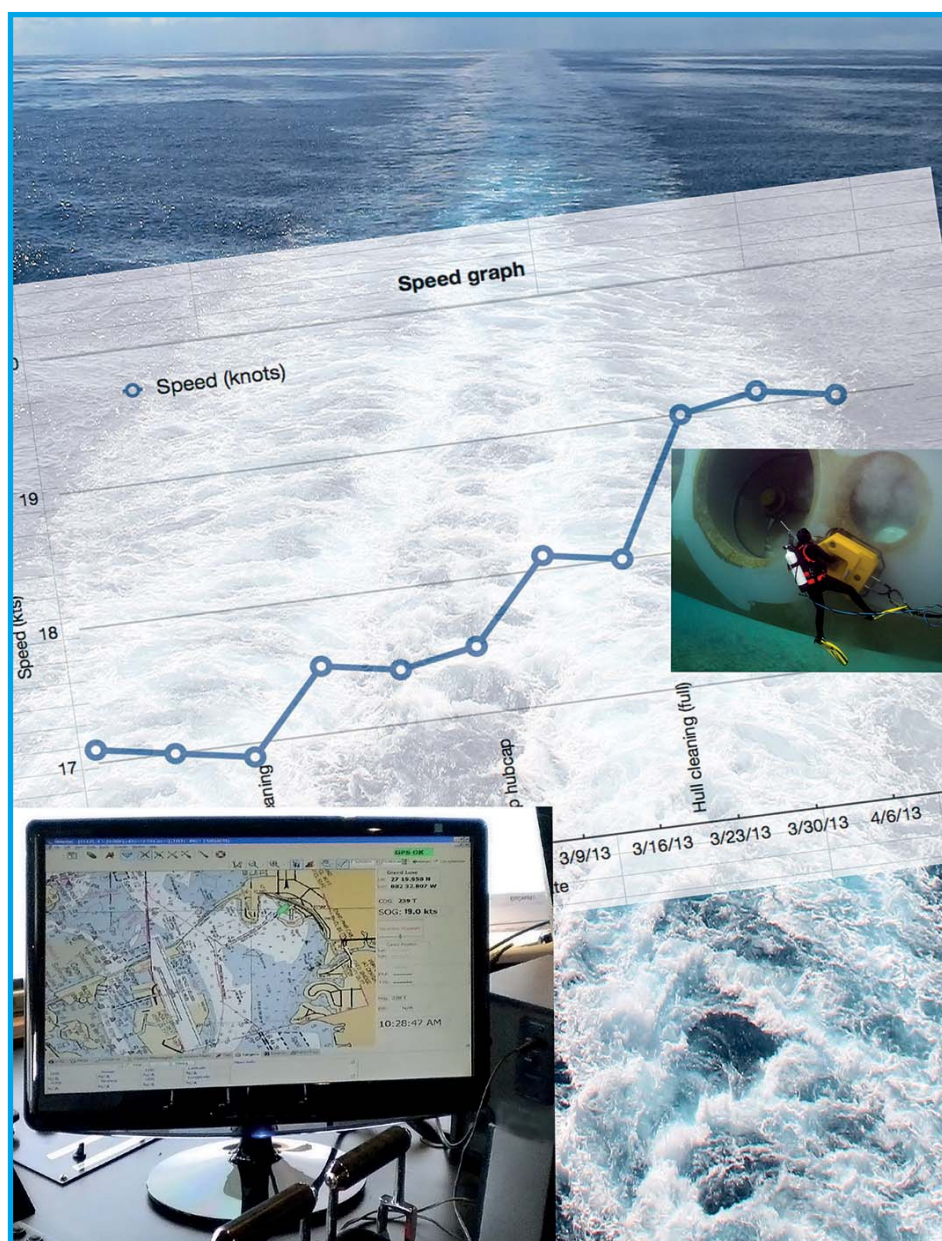


## WHITE PAPER

# Ship-hull Performance Optimization Tool (SPOT) (PILOT)



How to get control of and optimize ship hull and propeller performance

[www.shiphullperformance.org](http://www.shiphullperformance.org)



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# Part I. Introduction

**Recently, the subject of ship hull and propeller performance monitoring has been brought to the attention of the IMO by NGOs, ship paint manufacturers and ship efficiency measurement service providers, and the subject's profile has generally been raised in the media and the shipping industry.**

From some paint manufacturers comes a demand (or at least an urgent plea) for a transparent, uniform measurement of hull and propeller performance and efficiency, ostensibly so that potential customers can confidently choose the best underwater ship hull coating type and brand for their purposes. This plea seems to have been motivated by inter-manufacturer competition.

From the IMO's and particularly MEPC's point of view, improvement in ship hull and propeller performance is needed to contribute to the overall initiative to reduce GHG and other atmospheric pollutants resulting from shipping, an ongoing campaign.

The International Standards Organization (ISO) provides support in the form of developing uniform, global measurements, benchmarks and standards and is interested in doing so for the field of ship hull and propeller performance.

Paint manufacturers providing hull and ship paint are keen to sell as much of their own brand of paint as they can. The hull, although a smaller area than the rest of the ship, is particularly important because the tendency for shipowners is to use the same manufacturer's products for the rest of the ship once they have selected the hull coating

system.

Ship hull and propeller performance measurement companies are interested in providing their services to shipowners/operators, and believe that these services are needed and are the best way for owners and operators to optimize their hull coating and hull and propeller maintenance practices. They work independently of the paint manufacturers and try to advise ship-owners/operators on the effectiveness of their approach to hull and propeller performance improvements.

Shipowners/operators are not concerned with paint brands or paint manufacturers' profits. Nor are they interested in the revenues of ship performance monitoring companies except as these might affect their own profits. They have their own solvency and profitability to consider in a market that is generally slack and where bunker prices are high and rising. Out of necessity, they comply with IMO and local regulations concerning GHG and atmospheric pollutants, harmful antifouling substances and translocation of invasive species. The shipowners are keen to protect the underwater hulls of their ships from corrosion. Operators and owner/operators are anxious to reduce fuel costs by any means, including improvement in hull and propeller efficiency.

Environmental NGOs and the public they represent exist to protect the environment and minimize the effects of shipping on that environment, including GHG and other atmospheric emissions, toxic emissions into the water column and sediments, and the harm to biodiversity and local environments and economies caused by invasive aquatic

alien species transported by ships. These factors all need to be considered together since they are interrelated. Dealing with one at the expense of another is not a sustainable approach.

This is a quick sketch of the various players in the ship hull and propeller performance arena, and the different interests in and viewpoints on the subject of ship hull and propeller efficiency.

The IMO has been addressing these issues for some time. The Second IMO GHG Study of 2009 is an extremely detailed study of the problem of GHG and other atmospheric emissions from ships and proposes a number of ways of reducing these.<sup>1</sup>

The Energy Efficiency Design Index (EEDI) sets requirements for newbuilds aimed at making them more fuel efficient and thus reducing air emissions.

The Ship Energy Efficiency Management Plan (SEEMP) addresses existing shipping with the same general goal.

At MEPC 63 under agenda item 4, the Clean Shipping Coalition (CSC) provided new data indicating that

1. While underwater hull and propeller performance has already been recognized by MEPC as important in the Organization's drive to reduce the industry's GHG emissions, new data suggests that the impact of hull and propeller performance on individual vessel efficiency and world fleet GHG emissions is somewhat higher than indicated in the Second IMO GHG Study 2009.

2. For a typical vessel in a typical trade, deterioration in hull and propeller performance is now estimated to result in a

15 to 20 per cent loss in vessel efficiency on average over a typical sailing interval for the entire world fleet (approximately 50 months). This corresponds to a 15 to 20 per cent increase in bunker consumption and GHG emissions if the vessel maintains its speed. Given that a share of the bunkers consumed is used for purposes other than propulsion, and given that speed is not always maintained, the deterioration in hull and propeller performance is broadly estimated to account for 9 to 12 per cent of current world fleet GHG emissions.<sup>2</sup>

The paper from CSC goes on to state the case for a transparent, reliable hull and propeller performance standard.

In conjunction with one of the main ship paint manufacturers, an NGO organized a workshop to which some of the players in the ship hull and propeller performance field were invited. The workshop discussed the topic of a hull and propeller performance standard.

The summary of the workshop includes the following statements:

The most basic purpose would be to enable assessment of the success of any improvements made to a ship's hull and/or propeller.

...

Workshop participants stressed that the purpose of this standard would be to establish a reliable method of measuring ships against themselves. It is not intended to create ranking of ships within classes, nor to be a precursor for regulations by governments or international treaties.<sup>3</sup>

*The most basic purpose would be to enable assessment of the success of any improvements made to a ship's hull and/or propeller.*

<sup>1</sup> IMO, "Second IMO GHG Study, 2009."

<sup>2</sup> Clean Shipping Coalition, "Air Pollution and Energy Efficiency – A transparent and reliable hull and propeller performance standard," IMO, MEPC 63/4/8, (23 December 2011).

<sup>3</sup> Summary of the Oslo Workshop, [www.bellona.org/filearchive/fil\\_Workshop\\_Summary-final.pdf](http://www.bellona.org/filearchive/fil_Workshop_Summary-final.pdf), accessed 5 April 2013.

Disregarding any vested interests in the subject, the underlying requirement is quite simple: Shipowners and operators need to be able to monitor the hull and propeller performance of any given ship and, if possible, of their fleet, so that they can implement and fine tune the hull and propeller related products and practices which will result in optimum performance of that ship with due regard for all environmental factors.

This monitoring could be simple or complex but it would be ideal if it could be carried out by existing ship officers and personnel without additional cost or equipment, thus placing the control firmly in the hands of those directly responsible for the ship's day-to-day performance. If external help is used, it should be acceptable to the ship's officers and crew and should help them control the fuel efficiency of their own ship, not wrest the ship's fuel efficiency management from their control.

The benefits of such monitoring would include

- bringing about optimum hull and propeller performance
- reducing the ship's carbon footprint as much as possible from hull and propeller standpoint
- minimizing any harmful environmental effects of hull and propeller efficiency measures taken

- the most cost-efficient running of the ship from a hull and propeller standpoint over that ship's full service life.

This White Paper proposes a simple, effective method by which a ship's officers and crew can accurately monitor the performance of their ship's hull and propeller, isolate changes which improve or worsen this performance, over time invariably arrive at the optimum hull and propeller performance for their ship and maintain that optimum performance from then on.

This method has been christened the Ship Performance Optimization Tool, acronym SPOT. It enables the ship's officers to spot the best hull and propeller coating system and maintenance approach, to spot the vessel's optimum performance over its service life (which is usually higher than that attained at initial speed trials), and requires that the officers involved spot various changes which lead to that optimum performance.

SPOT can be considered to be a pilot project which needs to be tested on a number of different ships and fleets under varying conditions. The editors of this White Paper would appreciate any and all feedback, comments and results obtained from using this approach.

## **Part II. Problems with measuring ship hull and propeller performance**

### **Long term paint degradation (LPD)**

Perhaps the first question that must be asked when someone says, “We need a transparent standard for measuring hull and propeller performance,” is, “When? Over what period of time?”

There is the performance at the time the ship is launched when the hull coating is new. This is best measured in a lab and will vary with different types of coating, with the preparation of the hull and with the application of the coating chosen. But this is unlikely to be more than about 3 - 7% difference between any coatings currently in use and any quality of application currently found. It is a factor in hull and propeller performance but certainly not the main factor.

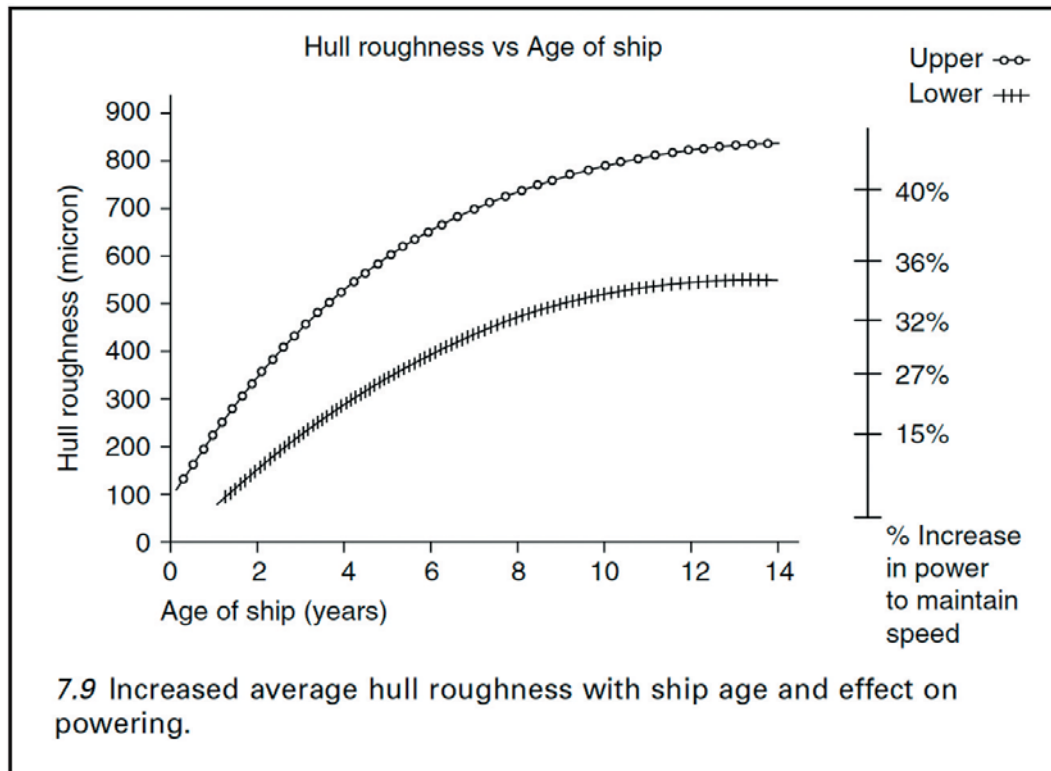
A second time period to consider is the interval between launch or outdocking and when the first underwater hull cleaning is performed. This varies with type of coating and with the ship operator’s maintenance practices. In some cases no cleaning at all is carried out between drydockings.

The next time period to consider is the performance average over the interval (averaging 50 months or so) before the ship is returned to drydock. Some types of coatings, particularly soft coatings, get rougher with use. Biocidal antifouling (AF) coatings are designed to gradually dissolve or leach away.

Foul-release (FR) coatings get damaged rather easily. All coating types accumulate

fouling, some more than others. Some coatings can be cleaned in the water while others are not suited to this type of maintenance, particularly if the cleaning is aggressive as is needed to remove heavier fouling, and will become rougher with in-water cleaning. Over the sailing interval between drydocking, the difference in performance between various coating systems and maintenance approaches will really start to show.

However, there is a longer period to consider. A ship will usually go through several drydockings in which the coating system is spot repaired, patched up and the topcoat (AF or FR) reapplied. It is very rare for a ship’s hull to be entirely blasted back to white or near-white steel and the full coating system reapplied every time a ship goes to drydock. The normal practice is to clean the hull, repair any damaged undercoat locally (spot blasting and spot repair) before applying a full coat or coats of antifouling or fouling release topcoats. Each time this is done the hull becomes considerably rougher than when the ship was first launched. This of course shows up in reduced hull efficiency. Eventually after 10, 12 or 15 years, the hull has become so cratered, pitted and rough that the only answer is to blast off all the paint (this can be 15 layers in places) and reapply the full coating system to the entire hull. This will restore the ship’s hull to its original or near original efficiency.



(Source: International Marine Coatings Akzo Nobel, Propeller Issue 15, January 2003, p 7, as used in Chapter 7 of *Advances in marine antifouling coatings and technologies*, edited by Claire Hellio and Diego Yebra, page 161.)

MEPC 63/4/8, many of the presentations at the Oslo Workshop mentioned above and several of the recent articles on the subject of hull and propeller efficiency include a basic incorrect assumption. They assume when a ship is drydocked, the hull cleaned and the coating repaired and renewed, that the hull is restored to its original efficiency level and the cycle started again – that the clock is reset to zero, the slate cleaned, and the process begun again from that point. In other words, they consider the hull efficiency over the 50 months or so of sailing interval (period between drydocking) and then imply or state that the hull will revert to its original efficiency after drydocking. This is almost never the case. It is a basic false assumption which throws off all calculations of hull efficiency. It ignores long-term paint degra-

dation as described above. LPD is a major cause of reduced hull efficiency and it occurs gradually over the entire life of the coating from first application to final full removal and replacement of the entire coating system, which is almost always a much longer period than the 50 months or so in between drydockings.

It is well known in the shipping and coatings industries that a hull blasted back to bare steel and recoated entirely after 10 - 15 years will produce a dramatic increase in efficiency or reduction of fuel penalty, estimated at between 25 and 40%, regardless of the type of coating used. This phenomenon is well documented and summarized in Hydrex White Paper No. 9, "Hull Coating Degradation – the Hidden Cost."<sup>4</sup>

AF, FR and some other coating types

***LPD [Long-term Paint Degradation] is a major cause of reduced hull efficiency and it occurs gradually over the entire life of the coating from first application to final full removal and replacement of the entire coating system.***

deteriorate over time and with each dry-docking in which they are spot repaired or patched up. Thus, considering the performance of the hull for a sailing interval of 3 - 5 years only will inevitably give a false picture of the efficiency of the hull coating and hull and propeller maintenance plan. It does not lead to a useful comparison of different coating types and brands or of different approaches to hull and propeller maintenance. Nor will it lead to optimal hull coating and maintenance practices.

The following graph is a hypothetical representation of the cycle of hull coating degradation undergone by the AF and FR coatings in current use.

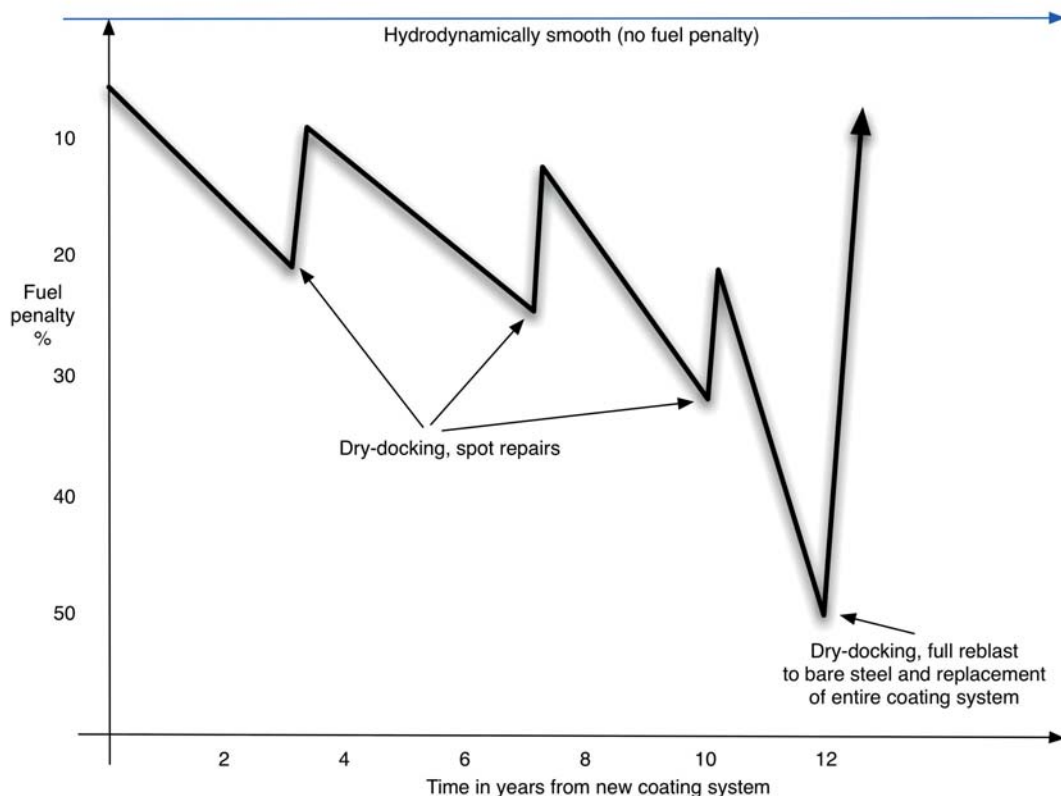
What then is the period of time over which the performance and efficiency of a ship's underwater hull coating system and hull and propeller maintenance plan can

validly be judged?

It is not the time immediately following initial application and launch. Nor is it the time in between cleanings nor even the 50-month or so sailing period in between drydockings.

*The only period that will produce a valid comparison is the time between newly applying the full coating system, and fully reblasting the hull back to bare steel and reapplying the full coating system.* Better still one should consider the full service life of the ship. But at the very least, the period between the full application of the entire coating system and a new full application on bare steel must be used for optimization and for comparison.

In fact, monitoring ship hull and propeller efficiency so as to optimize these by choice of the best possible underwater hull coating



and the best in-water and drydock hull and propeller maintenance plan is a continuous activity over the service life of the ship. It will take time, experience and accurate observation to reach that optimum efficiency. Then it will require continuous monitoring to make sure that that optimum efficiency is maintained.

The good news is that the observation and monitoring are relatively simple activities which can be carried out by a ship's officer, chief engineer or other person assigned this duty on a ship so that this optimum is inevitably arrived at.

The even better news is that the potential savings from such a program is in the order of magnitude of millions or tens of millions of dollars per ship.

### **All environmental factors considered**

Ship hull and propeller efficiency are economic and environmental concerns. The more efficient the hull and the propeller, the lower the ship's fuel bill. Optimum hull and propeller performance will contribute to optimum fuel efficiency for the ship and are in fact major contributors.

Hand in hand with the economic benefits of optimum hull and propeller performance is the environmental benefit of reduced atmospheric emissions such as CO<sub>2</sub>, SO<sub>x</sub>, NO<sub>x</sub> and particulate matter (PM), all key to the reduction of the environmental impact of shipping on the environment. This is a major concern to the IMO and the reason MEPC is involved in the subject of ship hull and propeller performance in the first place.

However, it can be a serious error from an environmental point of view to isolate a single impact and not consider it in the

context of all environmental impacts. TBT was a perfect example of this error. While TBT based self-polishing copolymers (SPCs) were very efficient in preventing fouling and keeping a ship's hull relatively smooth for an extended period of time, TBT was devastating to the marine environment in terms of pollution and contamination. The effects of this disaster are still very much alive and will continue to be so, with whole areas of the seabed and waterways undredgable due to the risk of resuspending and spreading the contamination caused by organotins.

This demonstrates clearly the havoc that can be wrought by a one-track mind approach on ship hull efficiency.

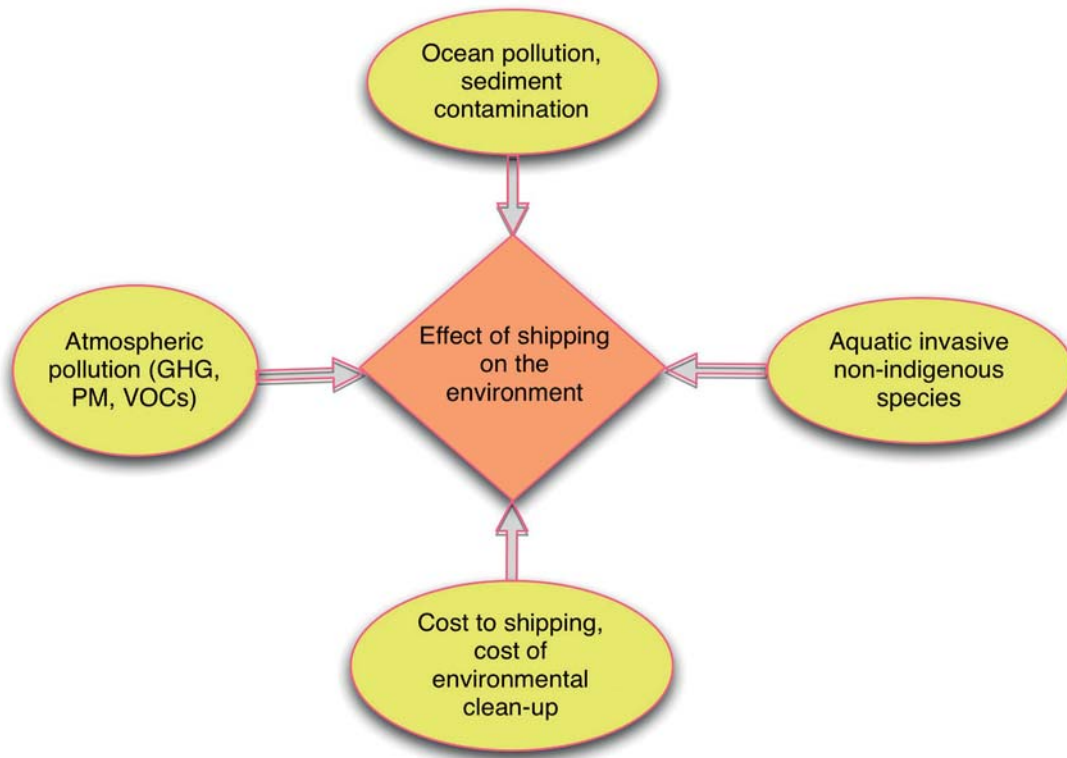
In viewing the effects of measures taken to reduce the environmental impact of shipping, several factors must all be taken into consideration together. (Only those factors affected by the condition of the hull and the propeller with regard to roughness and fouling and the measures taken to deal with these are considered here.)

For example, using a combination of different, powerful biocides may prevent biofouling from attaching to the hull or kill it when it does, but they do this at the cost of widespread marine pollution, sediment contamination and damage to many non-target species, the food chain and human health.

At the other extreme, use of an entirely non-toxic coating without in-water cleaning, may avoid the emission of heavy metals and other toxicants but at the expense of spreading NIS and incurring a large fuel penalty with the associated high CO<sub>2</sub> and other emissions.

In-water cleaning of a toxic antifouling paint or a fouling release coating may

*...it can be a serious error from an environmental point of view to isolate a single impact and not consider it in the context of all environmental impacts.*



remove potential NIS at their source point and prevent their spread but the cleaning is likely to damage the coating and result in increased emission of toxicants.

Insisting on drydocking a vessel several times a year for thorough cleaning of the hull would be helpful in preventing the spread of NIS and reduction of emissions by minimizing hull drag and improving fuel efficiency, but the cost in terms of interrupted service and drydocking fees is prohibitive.

Thus all these environmental and economic factors need to be balanced and an approach arrived at which considers them all:

- improving fuel efficiency, thus reducing noxious air emissions
- avoiding toxic pollution of water column and sediment contamination
- preventing the spread of hull-borne NIS

- doing all of the above in a way that is economical and cost-effective to the shipping industry so as to reduce the overall cost of shipping, and to the taxpayer in terms of clean-up costs.

That is quite a challenge, but any solution, in order to be workable, popular and enforceable, has to balance up all these factors. The test of any approach is how little one has to compromise with any of these points.

This applies very much to any approach recommended or adopted for improving hull and propeller efficiency. One could recommend returning to TBT-based SPCs as the best way to make ship hulls more efficient. It would accomplish that. But at what cost? This applies equally to any other approach recommended such as in-water cleaning of biocidal antifouling paint which

is hazardous to the environment. All the environmental factors must be considered, as well as cost.

### **Summary of problems with existing proposals**

Thus the two main problems with the current arguments and proposals for a transparent, reliable standard for hull and propeller performance are

1. They include a false basic assumption that the hull will be restored to its original efficiency each time the ship goes to drydock and the hull coating is repaired
2. They do not take into account all environmental factors, concentrating only on the reduction of atmospheric pollution in the form of GHG and PM.

### **Other problems in monitoring and optimizing ship hull and propeller performance**

The simplest way to define a ship's hull and propeller efficiency at any given time is the ratio of the engine rpm to the speed of the ship. For example, at 180 rpm the ship averages 18 knots. This is the simplicity (over-simplicity) of what's needed. It will be covered in detail below.

This is not the full picture of the ship's overall propulsive fuel efficiency. There are many factors which influence this:

- load
- draft
- trim
- engine condition
- fuel quality
- currents
- weather
- ship speed

- sea state
- route taken
- hull condition
- propeller condition.

These and other factors can make the picture seem very complicated which in turn leads to very complex systems of measurement and analysis involving an array of instruments and computer programs. These complexities and variables have led ship-owners, operators, officers and crew to believe that it is very difficult to monitor hull and propeller efficiency and to get a good idea of the effectiveness of the steps taken to improve this efficiency.

However, we are only considering the measurement of hull and propeller efficiency for the service life of the ship so that we can choose the best underwater hull coating system and implement the optimum hull and propeller maintenance procedures and schedule for that ship.

Fortunately, there is a system of rough measurement and analysis based on observation and common sense which will invariably and inevitably lead to optimization of hull and propeller efficiency and permit the monitoring of each of these (hull and propeller) separately and together. This rough system may not meet the precise criteria of engineers and scientists working in labs to come up with 100% accurate measurements. However, due to all the variables involved, a precise and meaningful calculation is close to impossible. After all, we are dealing here with ships at sea under infinitely varying conditions, and the officers and crew who operate them and try to get maximum efficiency out of them under real operating conditions, not technicians and engineers working in labs or with hypothetical com-

puter modeling under carefully controlled conditions. One can get so involved in minute calculations that one completely loses sight of the ship and its crew and what one is trying to accomplish, and can come up with answers which are disconnected from the real world. On the other hand, a monitoring system which is fairly accurate *and which will lead inevitably to hull and propeller efficiency optimization* is not only possible, but is relatively easy to implement and maintain.

This is the method which is described in this White Paper.

In fact, this same system can easily be used to monitor and improve other key factors affecting a ship's overall fuel efficiency. But this White Paper is limited to the practical measurement and optimization of a ship's hull and propeller efficiency with due regard for the environmental factors involved.

## Part III. Simple approach – overview

**While detailed instructions will be given later in this White Paper, an overview of the proposed simple approach to monitoring and optimizing ship hull and propeller efficiency will introduce the purpose and main elements of this procedure.**

Using this method will help identify over time the most suitable coating type and the ideal underwater hull and propeller maintenance routine for a ship or fleet.

There are two variations of this simple approach. The first one uses the average speed of the ship under comparable conditions. The second one is based on the time it takes to complete a set course that is repeated. Both work but one will be more applicable to a particular vessel than the other. In the end they both measure the same thing.

### Observation and recording of speed or time

#### Using the ship's speed

1. Observe and record the ship's speed at regular intervals and after changes are made that will affect that speed. The speed should be gauged under generally similar conditions for purposes of comparison.
2. Keep the speed notations on a graph which simply has the date and time on the x axis and the speed on the y axis.
3. Keep a change log in which any changes to the running of the ship which will

affect its engine rpm to speed ratio are noted with the date and time.

4. Add these changes to the speed graph in 2.
5. Keep the speed observations and the change log current for the entire service life of the vessel.

That is the simplicity of the monitoring.

The graph can then be analyzed so as to isolate the changes which improve the hull and propeller's efficiency. Once those changes have been isolated (e.g. propeller cleaning increased the speed by 1 knot, all other factors being relatively equal) then they can be repeated. Inevitably if this is kept up over time, the graph will reach the optimum efficiency for that ship's hull and propeller. This will be the maximum speed that can be attained for that vessel as a result of choice of hull coating system and hull and propeller maintenance. Then it is a matter of continuing to monitor the efficiency in the same way with a view to keeping it at optimum.

#### Using a set course

In the case of a ship that regularly travels the same course (for example a ferry, a cruise ship or a cargo vessel on a regular ocean crossing) there is an alternative system that can be used. Steps 1 and 2 become:

1. Observe and record the time it takes for the ship to travel a set distance which it repeats regularly.
2. Keep the time notations on a graph which simply shows the date along the x axis

and the time of travel for the set course of the y axis.

Otherwise the steps remain the same.

### **The observation – more information**

Some judgment and common sense are required on the part of the observer. The measurement of the ship's speed or the duration of the ship's course need to be carried out under similar conditions.

The speed one needs is speed over the ground (GPS speed) corrected for current.

The conditions that should be similar when the speed is noted include:

- engine rpm
- draft
- weather conditions
- sea state
- currents
- hull condition
- propeller condition

These conditions, except for the engine rpm, do not need to be exactly the same as this is not intended to be a system of precise measurement.

**Inaccuracies will average out:** the inaccuracies will average out and take care of themselves over time and one will soon be able to tell what changes to the hull and propeller affect the ship's fuel efficiency. One is not looking for minor changes but for significant ones. But the conditions need to be similar. There is no point comparing the speed of the ship in ballast at 175 rpm to the speed of the ship when fully laden. The load in each case should be similar. Likewise to record the speed at given engine rpm with similar cargo conditions when there is a 60

mph head wind and record it when there is a 40 mph tail wind and record it in a dead calm is not going to give a useful comparison. Thus the person assigned to record the ship's speed should make sure that conditions such as draft and weather are reasonably similar and that the engine rpm are the same. Then the comparison, even though not 100% accurate, will clearly show the effect that different changes have on the ship's fuel efficiency.

This also applies to use of the second method, the length of time it takes to travel a set course. Comparing the length of time it takes to go from point A to point B with a ship in ballast in perfect weather to the length of time it takes to go the same route fully laden in foul weather conditions will not be a useful comparison for monitoring hull and propeller efficiency. This is a matter of common sense. The comparison must include similarity of conditions so that it is relatively accurate.

### **The changes log – details**

The changes which should be logged include the following (the log should be detailed enough so that there is no question as to what was done and so that it can be repeated if successful):

- drydock (with a list of all changes made that could affect the ship's speed, such as hull blasting, coating repair or replacement or a different coating system applied, propeller cleaning or polishing, engine maintenance)
- hull cleaning in drydock (how much of the hull's surface? how thoroughly?)
- underwater hull cleaning
- propeller cleaning or polishing in drydock

- underwater propeller cleaning or polishing
- change of fuel type or quality
- change in cathodic protection system
- change of propeller type
- change of rudder type
- changes to the ship's engines
- any other change to the underwater hull (e.g. anode removal)

## Analysis and optimization

Over time it will become obvious what changes to hull and propeller improve the ship's efficiency. By noting the average speed before and after propeller cleaning, the effect on the ship's speed will be observable. Perhaps it will take two or three cleanings to get a reliable average but the story will be told right there on the graph.

Noting little difference in speed before and after a drydocking in which the hull coating was repaired would lead one to question a) the type of coating and b) the quality of the repair. With soft coatings such as AF or FR the effects of long term paint degradation will become obvious when one looks at the graph for a period of years which include drydocking and coating repair and most significantly if the time period includes full reblasting and reapplication.

Noting the huge difference that will occur on an aging hull when it is blasted back to white or near-white steel and a full new coating system applied would lead the owner/operator to consider replacing the system with a hard coating which does not degrade over time and which can be cleaned regularly, such as an STC.

The effect of in-water hull cleaning will become clear. On soft coatings the cleaning may produce a short term improvement in speed followed by a rapid decline to lower

speeds than before the cleaning, as the cleaning will damage the coating and make it more prone to fouling. On a hard coating the cleaning will create a predictable improvement in performance and it will be a matter of working out how frequently to clean so as to keep the hull at or near optimum.

If one cleans the propeller separately from the hull and observes the ship's speed before and after each, one will have an accurate idea of how much each will influence the ship's fuel efficiency.

## Fleet-wide improvements

Observations on one ship can be used to improve the performance of sister vessels or on a fleet or part of a fleet which has similar hull and propeller requirements.

Thus the information graphed for each ship should also be made available to fleet managers for comparison purposes.

Trends and successful practices will become obvious just from studying the graphs of the various ships.

An overall improvement in fuel efficiency across several ships following a change of coating type will enable the fleet manager to make the best choice of hull coating for all the fleet's ships that have a similar requirement.

The biggest changes to the fuel efficiency of the ship and the fleet, as discovered in the preliminary SPOT experiments and developments, will come from:

1. choosing the best underwater hull coating for that ship or fleet
2. regular in-water hull cleaning (on an appropriate coating type)
3. regular in-water propeller cleaning or polishing.

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- 3. regular in-water propeller cleaning or polishing.*

## **World fleet**

Information from many different ships and fleets can be correlated in such a way that the optimum hull coating and hull and propeller maintenance practices can be established for the entire world fleet. These can then be published as best available technology and practices. Thus the IMO's goal of greatly reducing GHG emissions from shipping can be realized without causing other environmental problems in the process.

## **Maintaining optimum performance**

Once optimum performance for a particular ship or fleet has been reached, the task becomes maintaining that optimum performance.

Coating type is very important here. A soft coating will, by its very nature, deteriorate and degrade over time as has been described. This becomes particularly noticeable after several drydockings and spot repairs, but in fact the decline is continuous over the entire life of that coating system, from the point when it is first applied until the time when it is entirely blasted off down to bare steel and a new coating system applied. This is not true of all hard coatings, however. An STC will actually become smoother over time and at the end of 10 or 15 years will be more fuel efficient than when it was first applied, assuming that it has been properly maintained with in-water cleaning, and any minor mechanical damage repaired in drydock.

The maintenance program can be fine-tuned so that both propeller and hull are cleaned at the optimum interval. The frequency depends on operating conditions and pattern but can be quite frequent. Again, the graph will show the economic soundness of frequent cleaning of hull and propeller as the savings thus obtained will be far greater than any costs incurred.

Once the correct hull coating has been established and the best maintenance routine evolved, the change log and speed/time graph are used to watch for changes which might worsen the ship's fuel efficiency. If a drop in speed is noted, it can be compared to the log and to earlier graphs and logs. The change may be an omission (less frequent propeller cleaning for example). This would only show up if one compared the current graph to an earlier one when the speed averaged higher. Answering the question, "What were we doing then that we are not doing now?" would help isolate the fact, for example, that only the vertical sides were cleaned recently and not the flat bottom, or that the propeller cleaning had been skipped. This could then be reverted and one would return the vessel to optimum performance.

That is the broad view of this approach to monitoring and optimizing hull and propeller performance and efficiency.

It needs to be stressed again that detailed precision of measurement taking into account all possible variables is not needed for this system to achieve its purpose.

## Part IV. Step by step instructions

**F**ollowing are the main steps to follow. Each one of these will then be described in detail below.

1. Assign two people on the ship to implement this procedure. One person to be in charge and a second person to keep up monitoring when the person in charge is not available, on leave, etc. It might be wise to have a third officer or crew member also able to use this system.
2. Those assigned should study this White Paper all the way through and make sure they understand all parts of SPOT.
3. Make up a changes log.
4. Set up a spreadsheet or logbook and graph for recording and graphing ship speed. This is simple to do using a spreadsheet application on a PC, notebook or tablet. But it is also easy to accomplish on paper using a logbook and graph paper and keeping this current.
5. Begin the changes log with the current state of hull and propeller, the coating type, when applied originally to bare steel, when repaired and to what extent, when cleaned, and when the last propeller cleaning or polishing was done. This will then provide a basis to which further changes can be related.
6. Keep the changes log up to date with any new changes.
7. Measure and record the ship's speed at

given engine rpm and under generally similar conditions each time. The observation and measurement could be once a week but interim observations could be made before and after any significant change.

8. Keep up the graph and the changes log accurately and without fail.
9. Analyze the data from time to time or have it available for analysis and report it to operations and management so that decisions can be made about underwater ship hull coating application and hull and propeller maintenance.

### 1. Assign personnel

This will vary from ship to ship, fleet to fleet. Ideally the people chosen should be familiar with the sailing of the ship, the state of the hull and propeller and a good understanding of the factors which lead to fuel efficiency. The Chief Officer, the Chief Engineer or one or more of their subordinates would be good candidates.

### 2. Study this White Paper

At time of writing, this is the only known description of the SPOT approach to fuel efficiency. Anyone intending to employ this method should be fully conversant with this entire White Paper before starting. Think of it as the full instruction manual and user guide. There is a plan to create an app for desktop or laptop computers or mobile devices which will simplify the creation of the graphs and tables involved but until these become available, the manual system described here

will serve adequately.

### 3. Make up a Changes Log

The changes log is a very simple thing. It can be in the form of a spreadsheet on a computer or a hard copy logbook. It has a column for date, a column for time, a column for the change and a column for any additional notes.

A spreadsheet on a computer would look like this:

Date	Time	Change	Notes
Feb 15, 2013	9:00 AM	Full propeller cleaning finished	
Mar 4, 2013	10:00 PM	Propeller hubcap installation completed	
Mar 22, 2013	1:00 PM	Hull cleaning completed, vertical sides and bottom, full hull cleaning	

with spreadsheets. But the changes log and the speed notations can just as well be kept on separate sheets.

All of this can just as easily be accomplished using a paper-based system. The principles and procedure are the same.

### 5. Begin the Changes Log

Whenever this monitoring system is implemented, it is vital to begin the log with

### 4. Set up a spreadsheet for recording and graphing ship speed

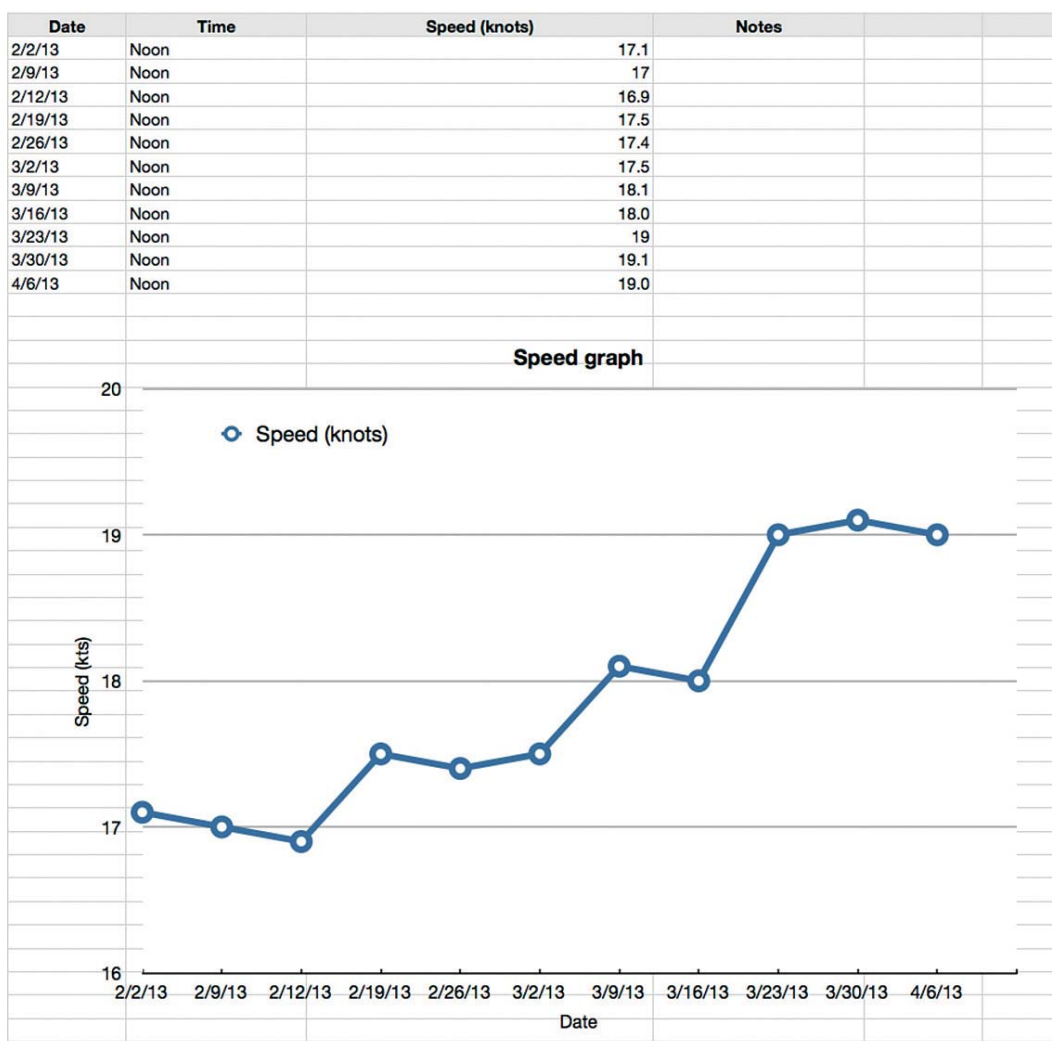
The spreadsheet for recording and graphing the ship's speed on a given date at a given time is also very simple. On the graph, along the bottom, the x axis, one has the date with a unit of perhaps weeks. On the left hand side on the y axis one has the speed in knots, maybe 3 knots less and 3 knots more than the expected speed at the usual engine rpm at which the ship steams. The actual range will be handled automatically if you are using a spreadsheet program such as Microsoft Excel or Apple Numbers. Here is a sample spreadsheet and graph. It is, as you can see, very simple.

Note: Some might prefer to set up a single spreadsheet which combines changes log and ship speed notations. There is no reason not to do this if you are sufficiently conversant

the current state of hull and propeller, the coating type, when applied originally to bare steel, when repaired and to what extent, when cleaned, last propeller cleaning or polishing and whether in drydock or under water. This will then provide a basis from which further changes can be reflected.

More specifically, these factors should be recorded at the very beginning of the changes log:

- type and brand of underwater hull coating in use
- when first applied
- when last fully reapplied to bare steel (for an older ship)
- when repaired and reapplied (possibly more than once, depending on how many times the ship has been drydocked since the coating was first applied



- the extent of the last coating repair/reapplication
- when hull last cleaned, whether in dry-dock or underwater, and to what extent
- when was the propeller last cleaned or polished, whether in drydock or underwater
- any other details regarding underwater hull coating and hull and propeller maintenance.

This is quite a lot of information to gather and record, but it is necessary so that the change log is meaningful and there is

something to compare future changes to.

## 6. Keep the changes log up to date with any new changes

Any of the following or similar changes should be recorded with the date and time that the change is completed:

- drydock (with a list of all changes made that could affect the ship's speed, such as hull blasting, coating repair or replacement or a different coating system applied, propeller cleaning or polishing, engine maintenance)

- hull cleaning (drydock or in-water? how much of the hull's surface? how thoroughly?)
- propeller cleaning or polishing (dry-dock or in-water?)
- change of fuel type or quality
- change in cathodic protection system
- change of propeller type
- change of rudder type
- changes to the ship's engines.

### **7. Measure and record the ship's speed at given engine rpm and under generally similar conditions**

This has already been covered. The speed can be measured once a week. It could be more or less frequently. Experience will show what works best.

The speed one needs to record is the speed over ground (GPS log) corrected for current.

The ship must be steaming in roughly similar conditions. The engine rpm must be the same. If you record the speed at 175 rpm at noon on Saturday March 9<sup>th</sup> then you should record it again at 175 rpm at noon on Saturday March 16<sup>th</sup> as long as conditions are fairly similar. The conditions that should be similar include

- draft
- weather conditions
- sea state
- ballast.

Note that the conditions need only be roughly similar. This is not something to worry about too much. But if the external factors are very different it might give a false picture. This needs to be taken into account. To note the speed on one day in a calm sea with no wind and to compare that to another day in the

middle of a storm with a heavy sea and strong headwind is going to throw the results off. It is better to wait and note the speed on a later day when conditions are similar.

As far as the graph is concerned, it is particularly important to note and record the speed before and after any change that might affect the ship's fuel efficiency.

For example, say the Chief Officer is the one keeping up these records. He has chosen to make observations every Wednesday at noon. He keeps this up as long as the conditions are similar as covered above. But one Wednesday at noon the conditions are very different and don't return to normal for a couple of days. He simply waits for a couple of days until he judges conditions to be similar to other times he has made his observations. He then notes this on the graph as the speed for that week.

Over a period of time, this will even out. After a few propeller cleanings, hull cleanings, drydockings and other changes, it will become abundantly clear what actions and changes improve the hull and propeller efficiency and generally how much these changes improve that efficiency. It will also show what changes worsen that efficiency and increase fuel consumption for given engine rpm.

If one knows there are going to be more than one change implemented within the week (or other period chosen for regular speed notations) then one should take additional readings before and after each change if possible so that the effect of the different changes can be gauged separately.

### **8. Keep up the graph and the changes log accurately and without fail**

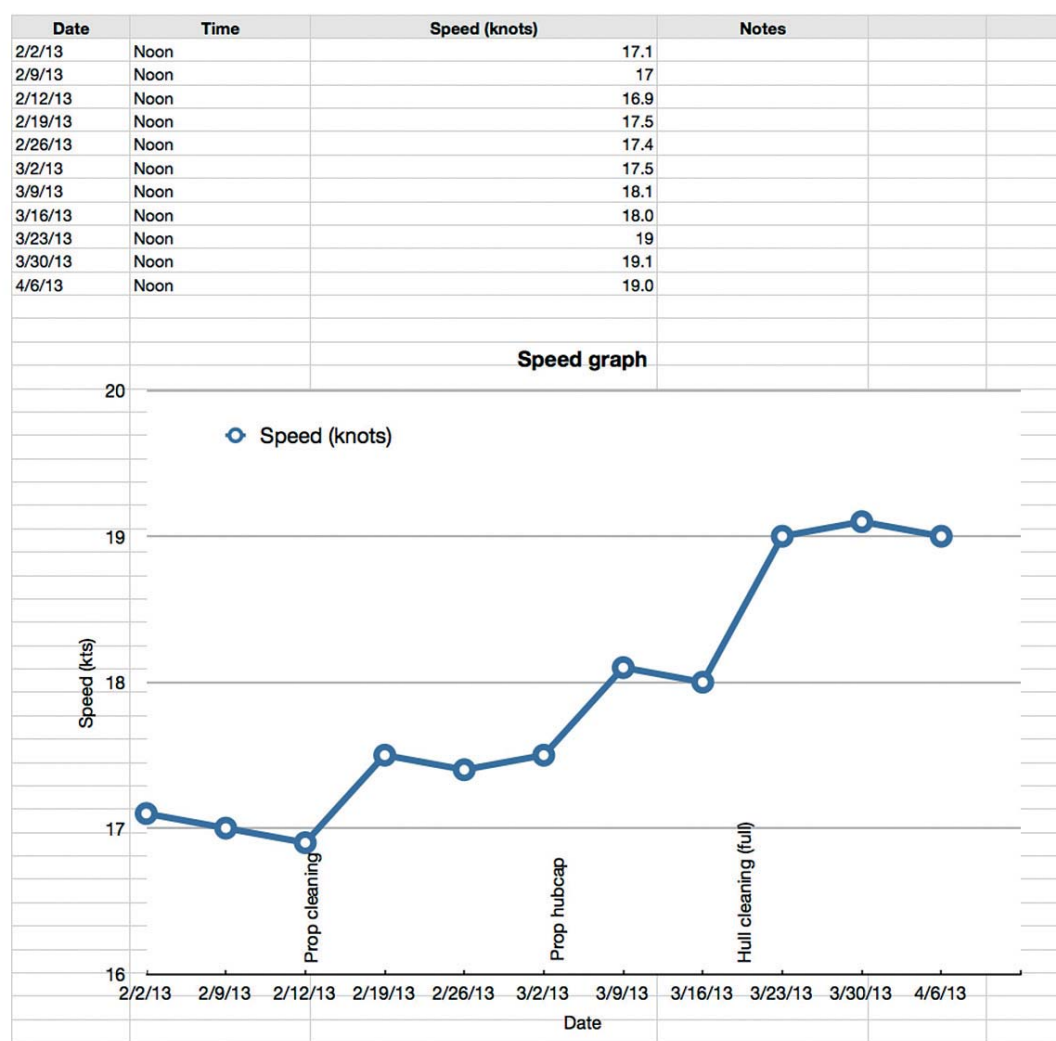
This system works very well with sensible observations accurately noted over time. In

order for analyses to be correct, they must be based on correct data. Thus the accurate recording of changes that might affect propulsive fuel efficiency in the changes log, and correct, regular notations of speed for given engine rpm under relatively similar conditions are the key factors in the success of the approach. Whoever is put in charge of this function needs to be steady and reliable, must “get behind” this program and take care

towards achieving optimum fuel efficiency for his/her ship. Common sense is a key ingredient.

The changes noted in the changes log should be added to the speed graph for easy correlation. It need only be a brief notation and the changes log itself can be consulted for full details of a particular change.

Thus in the case of the graph above in Step 4, it would look like this:



to observe and record the data accurately. It need not become a “crusade” but the person should have a strong interest in working

As explained in step 7 above, it may be necessary to record the speed more frequently at times. If more than one significant

change is scheduled and one wants to see what effect each change has on the ship's fuel efficiency, it would be necessary to record the speed before and after each of the changes. Then one can see what change was responsible for what percentage of the improved fuel efficiency (or lack of it). The fact of some irregular intervals between notations is not important.

### **9. Analyze the data**

The analysis of the data is also quite simple as long as one realizes that he is looking for large changes, not tiny details. The propeller is cleaned. Next speed reading shows a speed increase of 0.75 knots. The cause is obvious. Ignore the fact that there is a slight variation in speed readings for the next couple of weeks. The average speed clearly shows that there has been a speed increase of about 0.75 knots after a propeller cleaning. The propeller blades are damaged. The speed drops by 0.5 knots. The vessel goes to drydock and the coating is spot repaired. It comes out of drydock and the speed soon drops by 1 knot on average. This is due to the spot repair in drydock and the effects of long term paint degradation (LPD) on the efficiency of the hull. The person doing the

analysis needs to have a good idea of what sort of things can cause improved or worsened fuel efficiency and not assign changes to the wrong cause.

The information thus analyzed, steps can be taken to keep improving the ship's fuel efficiency until it reaches the optimum for that ship. This may take years to achieve, but the information can also be used for the rest of the fleet and can help determine a shipping company's policies and procedures with regard to underwater hull coating and hull and propeller maintenance.

This White Paper doesn't go into details on the types of changes which can be implemented in order to improve the efficiency of the hull and propeller. These are covered in exhaustive detail in the previous White Papers in this series and in the book *Surface Treated Composites White Book*.<sup>5</sup>

But, if this method of fuel efficiency monitoring is kept up, the results analyzed, and the analysis sensibly used to make decisions about underwater hull coating type used and hull and propeller maintenance scheme employed, it will inevitably lead to the optimum hull and propeller efficiency for any ship.

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5 Boud Van Rompay, *Surface Treated Composites White Book*, Tahoka Press (2013).

## Part V. Conclusions

**M**onitoring underwater hull and propeller efficiency is a relatively simple activity which can be accomplished successfully by a ship's officers and crew with minimal equipment, time or expense.

Long-term observations are needed in order to truly optimize hull and propeller efficiency.

The observations and measurement can be fairly rough and the system will still lead inevitably and unerringly to the optimum hull coating system and hull and propeller maintenance plan for any given ship or fleet.

The system consists simply of a changes log, a ship speed graph, all changes that affect the ship's propulsive fuel efficiency logged, and speed notations at regular intervals. These data can then be analyzed and the optimum measure for the ship's best possible hull and propeller efficiency determined.

This system is capable of generating huge savings for any shipowner/operator using it. It will have a tremendous influence on ships' performance in general and will greatly contribute to the economics of transport by sea.



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