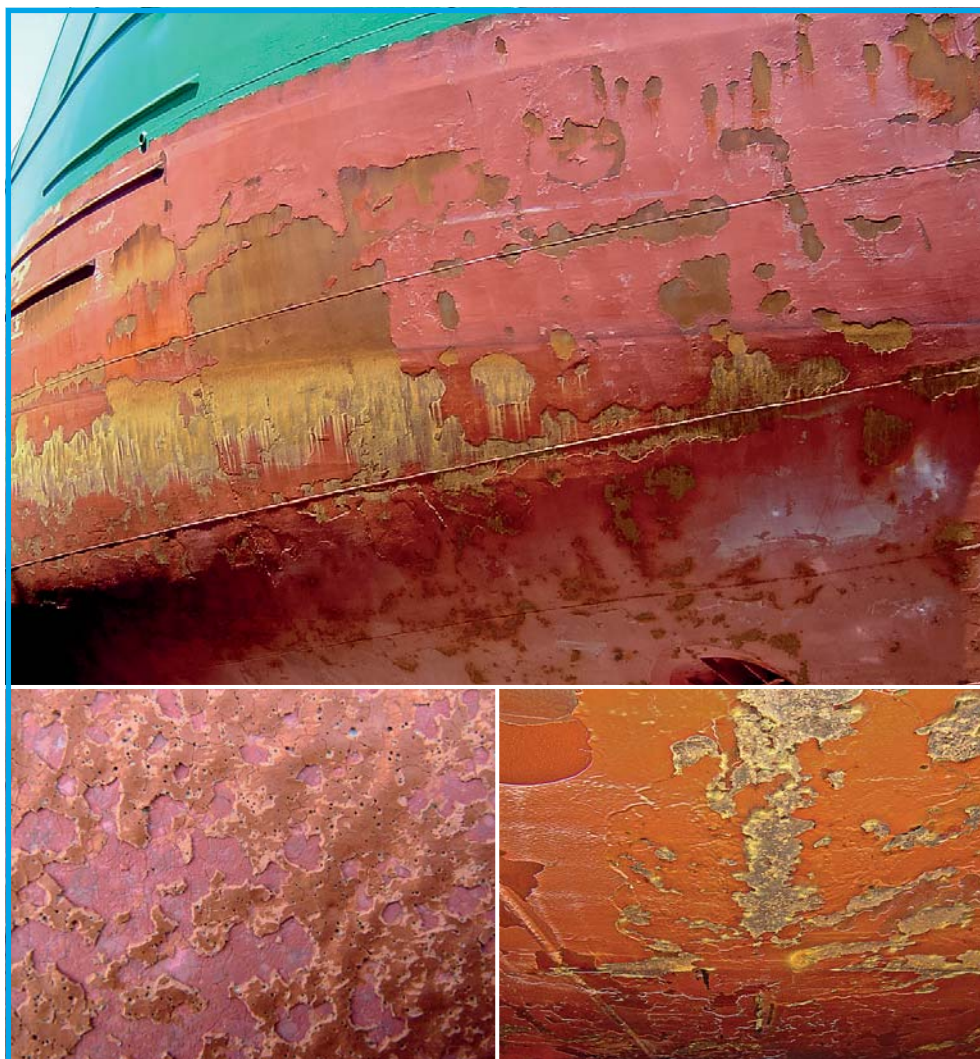


WHITE PAPER

Hull Coating Degradation - the Hidden Cost



**How to avoid large fuel penalties,
without repeated drydocking
and hull repainting**



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Part I. Introduction

“A ship scheduled for such surface preparation [blasting down to bare steel] – whatever coating system is being used – would normally be 10-15 years old. The blasting will change the hull condition from rough and possibly fouled, to smooth and clean. We know that this surface preparation can improve fuel consumption by about 25-40 per cent, depending on prior condition.”

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Bjørn Wallentin, Jotun

The statement, made by Bjørn Wallentin, Jotun Coating’s global sales director for hull performance solutions, appeared in an article in the June/July 2011 issue of *Marine Propulsion*.¹

Mr. Wallentin’s statement represents general conventional wisdom on the subject in the shipping industry. It is well known and accepted: by the time a ship with a biocidal antifouling or with a fouling release hull coating system reaches 10 years or so since the last time it was fully blasted to bare steel, it will have increased fuel consumption by 25-40% compared to initial sea trials, even when it is not heavily fouled.

There seems to be very little scientific information which quantifies the exact proportion of fuel penalty which can be attributed to hull coating degradation as opposed to biofouling, but the evidence that there is a combined fuel penalty of this magnitude is very clear and well known to informed technical superintendents and those responsible for the fuel efficiency of ships around the world. A 10-year-old ship goes to drydock, the hull is grit blasted, a full new coating system is applied properly (any type) and the fuel consumption subsequently drops

dramatically.

This increase in fuel penalty does not occur suddenly. It is a gradual process from when the ship is first launched, through the various drydockings in which the hull coating is patched, touched up, partially repaired and reapplied until, after 10 or 12 years the coating has degraded so much that it has to be entirely blasted off and reapplied completely. Throughout those 10 years, the fuel efficiency has gradually become worse and worse. A great deal of money has been spent unnecessarily to maintain power and speed despite increased hull resistance.

In days gone by, a ship’s engines were built with 40% surplus power. One reason for this was to compensate for what was thought to be “engine degradation” as the ship aged. But was it “engine degradation” or was it simply “hull coating degradation”? The evidence would indicate that the additional power was needed to maintain initial trial speeds as the hull friction increased over time.

This White Paper aims to collect available information on the effects of hull coating degradation, invite reader participation in gathering additional experiential information, and highlight a system which does not undergo degradation over time but in fact becomes hydrodynamically smoother as the ship ages, operating as it does on entirely different principles than the coating systems in general use.

The rewards of successful application of such a system include a greatly reduced fuel bill for ship operators and a consequent reduction of CO₂, NO_x, SO_x, black carbon and other environmentally unwanted emissions.

¹ Bjørn Wallentin, Jotun Coatings, “The illusion of fuel savings,” *Marine Propulsion* June/July 2011.

Part II. Time for change – \$70 billion at stake?

The time is certainly right for an overhaul of current, traditional hull coating practices.

A major incentive to change is the high and rising cost of bunker fuel coupled with tight budgets required by many shipping companies in order to operate profitably, by navies and other government owned fleets where budget constraints are requiring more efficient operation and by the shipping industry as a whole. A fuel penalty of 25-40% represents tens of billions of dollars wasted annually across the world fleet.

The IMO Second GHG Study placed the total world non-military shipping fuel consumption for 2007 at 333 million metric tons.² It also showed an increase of 80 million tons over a 5-year period. Projecting these figures forward to 2012 would provide an estimate of well over 400 million tons of fuel consumed by non-military shipping in 2012.

Bunker prices in February 2012 averaged over \$700 per ton.³ That would put the world shipping fuel bill at \$280,000,000,000 for the year. While these figures are estimates, one can easily see that a reduction of 25% fuel consumption as a result of best available hull protection and fouling control practices **could save \$70,000,000,000 worldwide in one year.** That does not include navies.

At a time when pressure to reduce air emissions from shipping is mounting, such a significant reduction in fuel consumption would make a real difference to the global air emissions from ships.

Another factor which reduces the profita-

bility of shipping companies is the frequent need to drydock in order to repair or replenish conventional biocidal antifouling coatings and to clean and repair fouling release coatings. If the drydocking interval could be increased to 7½ or 10 years, the reduction in drydocking and cost of paint reapplication would help to drastically reduce the cost of transport by sea as a whole. The main reason for a shorter drydocking interval is hull coating maintenance. Were it not for having to repaint, many vessels could stay out of drydock for much longer periods.

There are therefore many reasons, both economic and environmental, to seek a hull protection and fouling control system which does not require frequent renewal, which does not degrade as a ship ages, and which can, economically and without damage to the coating itself or to the environment, be kept clean of any fouling heavier than a light slime.

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² IMO, Second IMO GHG Study 2009.

³ Bunkerworld Daily E-mail, 10 February 2012.

Part III. The problem of hull coating deterioration

Dr. Robert Townsin's well-known paper, "The Ship Hull Fouling Penalty," published in 2002, states the problem of hull friction as follows:

Almost all vessels have an antifouling paint coating over the underwater hull. Generally, propeller blade surfaces are of polished metal *e.g.* manganese bronze, and will have no antifouling provision. As far as the hull coating is concerned, a number of problems can arise. Firstly, a new antifouled surface may be hydrodynamically rough, usually as a result of poor paint application management *e.g.* drips, runs, sagging, overspray, grit inclusion. Secondly, the coating may become rougher in service due to paint system partial failures and mechanical contact damage. Thirdly, the antifouling provision may be inadequate over time, resulting in slime development, and then weed and shell growth, variously distributed over the hull.⁴

To the list of reasons the coating may become rougher in service could be added, "repeated repairs to the damaged coating which can result in a very rough surface."

Dr. Townsin goes on to say in the same paper:

Whilst the ablation of these products [ablative coatings] and the consequent biocide leach rate was their prime *raison d'être*, it was also noted that any initial roughness due to application was

smoothed out in service. The name 'self-polishing' for these products was therefore applied by the marine coatings industry to indicate smoothing properties, although, whilst the paint itself became smoother, the hull, overall, often became rougher due to surface damage. The added resistance due to paint surface damage was a problem recognized by Holzapfel.⁵

Dr. Townsin's paper does not concern itself with solutions to the fuel penalty from hull coating degradation. It discusses ways of measuring such a penalty.

In his PhD thesis, "An Economic and Environmental Optimization Methodology for Hull-Cleaning Schedules," Michael E. Klein of Webb Institute stated:

A vessel's hull experiences an increase in frictional resistance throughout its service life. One significant source of this increased resistance is the increased hull roughness caused by the deterioration of the underwater coating system through damage or corrosion. Structural issues such as shell-plate deformation and corrosion also contribute although to a much lesser degree.⁶

Hull friction due to biofouling has been dealt with extensively in earlier White Papers in this series, particularly Hydrex White Paper No. 1 "Ship Hull Performance in the Post-TBT Era," and Hydrex White Paper No. 2 "The Slime Factor."

⁴ R. L. Townsin, "The Ship Hull Fouling Penalty," Biofouling, 2003 Vol 19 (Supplement), pp 9-15 (2002).

⁵ Ibid.

⁶ Michael E. Klein, "An Economic and Environmental Optimization Methodology for Hull-cleaning Schedules," BSc thesis, Webb Institute, June 2011, p 24.

Hull coating degradation was not addressed as a specific problem all of its own.

Neither Townsin nor Klein consider the deterioration of hull coating caused by spot repairs to AF and FR coatings due to the problems inherent in these coating types.

Klein does note

The added monthly cost from roughness increases over time until the next dry-docking, when the underwater hull will be grit-blasted and roughness will be drastically reduced.⁷

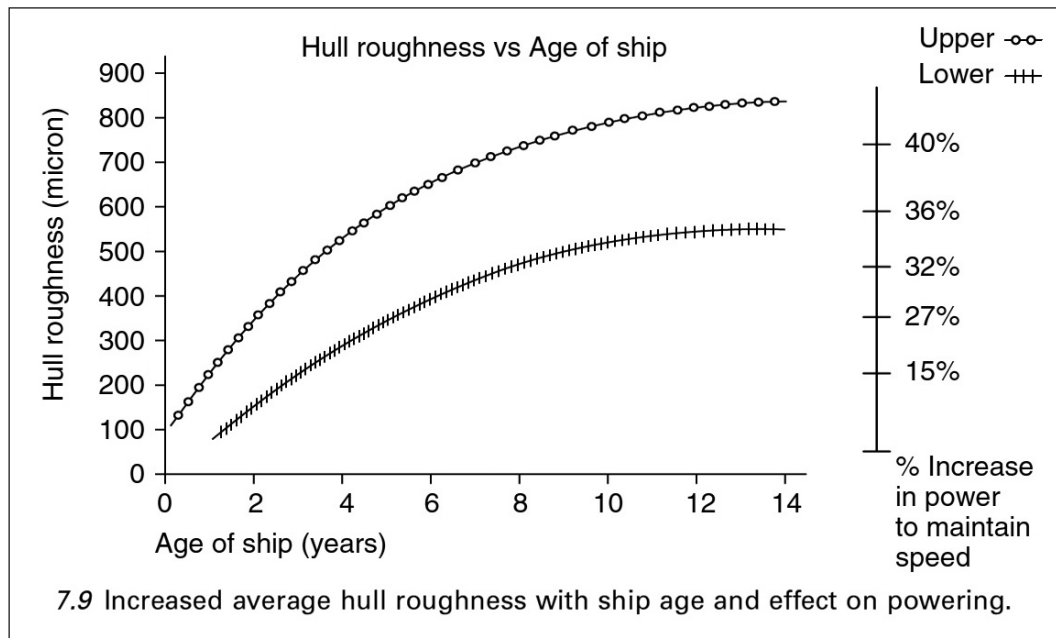
However, as will be shown below, the general practice is for ships to go for two, three or more drydocking cycles with only spot repairs to the coatings and to be fully blasted and recoated only once every ten years or more. Each partial repair causes additional hull friction.

The following statement occurs in a paper published by International Paint Ltd. (Akzo Nobel) in 2004 entitled “Hull Roughness Penalty Calculator”:

During the period 1976 – 1986, two substantial hull roughness studies were carried out. These studies showed that over time, ships generally get rougher due to mechanical damage from anchor chains, tugs, grounding, berthing, etc. and from mechanical damage, cracking, blistering, detachment, corrosion etc. of applied surface coatings. The increase in roughness was found to differ markedly depending on which antifouling type was used. With traditional antifoulings the increase in Average Hull Roughness (AHR) over time was found to be 40 microns per year, with part of this increase resulting from the reasons mentioned earlier and part resulting from maintenance painting at each drydocking (assuming no reblasting). Fouling was removed prior to measurement of roughness.⁸

“...over time, ships generally get rougher due to mechanical damage from anchor chains, tugs, grounding, berthing, etc. and from mechanical damage, cracking, blistering, detachment, corrosion etc. of applied surface coatings.”
International Paint

Torben Munk and Daniel Kane of Propulsion Dynamics, Inc., USA and D. M. Yebra of Pinturas Hempel S.A., Spain, in chapter 7 of



⁷ Ibid, p 31.

⁸ International Marine Coatings, “Hull Roughness Penalty Calculator: The economic importance of hull condition,” Akzo Nobel, 2004.

Advances in marine antifouling coatings and technology, entitled “The effects of corrosion and fouling on the performance of ocean-going vessels: a naval architectural perspective,” include useful information and a graph concerning hull roughness compared to age of ship.⁹

Among the conclusions listed at the end of the chapter, the authors state the following:

“The basic hull treatment in drydock has a pronounced influence on added resistance after drydocking. In the best cases, the baseline added resistance will only be 0% - 4%. A partial hull blasting treatment with new coating system has been seen to result in an added resistance of 5%-20%, while in the worst cases there is no benefit at all from dry-docking.”

*T Munk, D Kane,
D M Yebra*

3. The basic hull treatment in drydock has a pronounced influence on added resistance after drydocking. In the best cases, the baseline added resistance will only be 0% - 4%. A partial hull blasting treatment with new coating system has been seen to result in an added resistance of 5% - 20%, while in the worst cases there is no benefit at all from drydocking.¹⁰

This conclusion and indeed the whole chapter does not, however, quantify the effects of coating degradation as an independent source of hull friction separate from biofouling. In fact, surprisingly, no studies have been found by the authors of this White Paper which do measure the added friction of a hull as the vessel ages, despite the common knowledge among the shipping industry that the simple fact of blasting a hull back to bare steel after a vessel has been in service for around 10 years makes a massive difference to the ship’s subsequent fuel efficiency, regardless of type of coating, degree of fouling or any other condition.

A simple comparison of the fuel efficiency gain (or lack of it) after a third drydocking involving hull cleaning, spot blasting and partial hull coating repair, versus

the fuel efficiency gain after a full blasting to bare steel and complete recoating would give a clue as to the degree of added hull friction caused by hull coating degradation alone, regardless of the state of fouling of the hull. In each case the fouling would be completely removed so the difference of fuel efficiency after each drydocking would show the degree of hull friction increase (and therefore fuel penalty) resulting from coating degradation alone. This would be a worthwhile study. Probably the data exists in some records somewhere, but it does not appear to have been made public.

Considering the drive for greater fuel efficiency in the world fleet and for profitable operation by fleet and ship operators, quantification of and a solution to the problem of hull friction due solely to coating degradation would be extremely valuable. This current White Paper examines hull coating degradation as a separate problem from hull fouling – one that can be addressed and solved relatively simply.

Why and how do hull coatings degrade as a vessel ages?

The problems of hull deterioration associated with biocidal antifouling coating systems (AF) and also with silicone or fluoropolymer based fouling release coating systems (FR) are built into these coating systems from inception by the very nature of the coating systems themselves and the methods used for interim repair and reapplication. These systems are composed of multiple layers (4-7 or more) of non-homogeneous coatings. In both cases the topcoats, whether leaching biocides or having non-stick qualities, are rather thin (4-600 microns total) easily damaged, and in the case of biocides, are designed to deplete and wear away. Over

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⁹ 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,

¹⁰ T. Munk, D. Kane, D.M. Yebra, “The effects of corrosion and fouling on the performance of ocean-going vessels: a naval architectural perspective,” Chapter 7 *Advances in marine antifouling coatings and technologies*, edited by Claire Hellio and Diego Yebra, Woodhead Publishing Ltd. p 161.

time, with damage, spot repairs, reapplications of some of the layers and not others, these coatings tend to build up internal stress, blister, crack and delaminate. They are subject to undercreep and corrosion of the underlying steel. They are not well able to withstand cavitation. Partial repairs to these coatings in the form of spot blasting, touch-ups and replenishment of the antifouling biocides and replacement of the foul release coatings add to the problem so that over time the ship's hull becomes cratered, chipped, cracked and generally very rough. Hull friction is thus greatly increased through coating degradation alone regardless of the state or degree of fouling.

The cycle is summarized here, as described by an independent, SSPC/NACE certified paint inspector and protective coatings consultant who specializes in steel surfaces including ship hull coatings.¹¹ This information was not found well-expressed elsewhere and Mr. Gunnar Ackx is gratefully acknowledged for sharing his succinct description of the hull coating deterioration process as a vessel ages, based as it is on long term direct observation and experience.

The hull coating deterioration process

Many older ships have been coated with traditional antifouling coating systems which usually consist of an adhesive corrosion-resistant primer, typically two epoxy midcoats and two antifouling topcoats. The antifouling topcoats typically contain toxic substances so that the marine growth which tries to attach itself to the antifouling coating ingests these toxins, dies and detaches from the hull. Most of those coatings are based on the principle of toxins being leached out of

the antifouling layers, killing off not only much of the marine life trying to attach itself to the hull of the ship, but also unfortunately a great deal of non-targeted marine life.

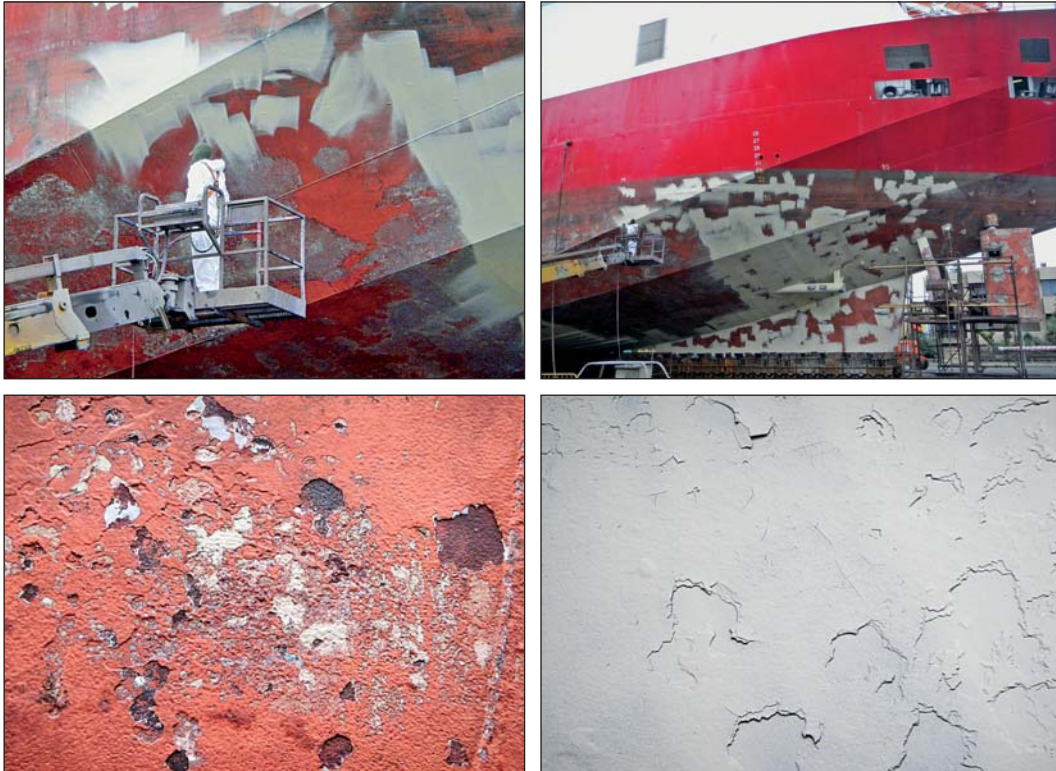
These coatings generally last for a period of 3 - 5 years of antifouling operation on the ship. After a while the toxins have leached out, the coatings have worn away and the ship needs to go to drydock to get the coating repaired and replaced.

Most of those ships, even the new ones, after 3 - 5 years will have extensive mechanical damage, rust spots and damaged coating flaking off in spots. It becomes necessary to spot-blast rust spots, remove any flaking coating, blast those areas, touch them up again typically with one primer coat and two midcoats, before reapplying the two full antifouling coatings to the whole hull.

The antifouling coating has to be reapplied after 3 - 5 years as the biocides have all leached out, but because the midcoats are just standard epoxy coatings, and because a standard AF system is limited in thickness to between 400 and 600 microns in total, they are easily damaged. A scratch will go right through to the bare steel.

Some photos will illustrate the problem, the repair and the results:

¹¹ Interviews and personal correspondence with Gunnar Ackx, Managing Director and Partner of SCICON, Bruges, Belgium based independent Specialist Coating Inspection and Consulting company.



(Above) Hull coating repair as currently practiced. (Below left) The results of coating degradation and repair. (Below right) Completed coating repair showing a very rough hull.

False economy?

Because the shipping industry has operated for a long time on cheap fabrication and installation costs, many owners have chosen cheaper coating systems, based on low cost surface preparation methods. This basically undermines the whole integrity of a good ship hull coating in the long run because if the surface preparation is not what it ideally should be there will be less adhesion and therefore more damage when the ship hits something.

Here is an example of a typical low budget application. During newbuild most ships are fabricated in blocks or sections constructed from plates. Before they assemble the sections they will preblast the plates and apply what they call a shop primer to them. They use various materials for the shop primer,

such as an epoxy shop primer that will typically have a thickness of 30 - 40 microns maximum or a somewhat better quality zinc-silicate shop primer. The mill scale will be blasted off and the shop primer applied just to stop the steel from rusting again during the construction phase. The plates are usually blasted with round abrasive, called shot abrasive, which creates a completely different profile than when using angular abrasive typically used to create a proper profile for long-lasting surface treated coatings (STCs) for example.

So the process begins with a different (much shallower) anchor profile. The shop primer is applied for the construction phase, and once the sections are assembled or one section is finished, application of the hull coating system

begins. Very often that initial shot blasting is all the profile the steel will receive. Typically the primer and one or two midcoats will then be applied to the blocks and the antifouling is usually applied once the ship is completely assembled and is in the fabrication hall. Then the seams will be welded, the preliminary coatings will be built up on the weld seams and then the full antifouling coating applied on the entire hull.

In that all too typical process the initial surface preparation is far from ideal: the shot profile provides less adhesion surface for the coating. The result is four or five layers of paint to a total thickness of 4 - 600 microns on a relatively shallow surface profile which is bound to lead to less adhesion and more under-creep corrosion in the case of any damage.

It is cheaper to manufacture a ship in that way than to manually blast all the plates of the whole ship. For the nearly 20 years that Gunnar Ackx has been working as a paint inspector he has seen ships typically being constructed in that way. They then come into drydock every 3 - 5 years so that the hull coating can be repaired and reapplied.

Foul-release coating systems

Over the last 10 years or so there has been somewhat of a change in the industry. The major drive for change was the attempt to remove the toxins from the antifouling. The TBT or copper in the antifouling was found to be killing off not only the marine growth trying to attach itself to the ship's hull, but also a lot of non-targeted sea life. There are so many ships in the sea leaching so many toxins

that there are harbors where there isn't any sea life any more. In an attempt to reverse that process local or international bans were placed on TBT and copper antifoulings which led the manufacturers to come up with alternative hull coatings that are not as toxic.

This led to the development of foul-release coatings which are designed to work not on the principle of releasing toxins to kill off the sea life growth but of providing a surface that is smooth, and has non-stick characteristics which make it harder for the barnacles and algae to attach themselves to the hull. They work best if the ship is under way, preferably at higher speeds. If the ship is at anchor or moored in the harbor, or if it doesn't sail at high speeds, foul release coatings do not work very well because they are dependent on the speed of the ship in the water to naturally wash down anything which tries to attach itself to the ship's hull.

The same problem exists with this type of coating. As described above, the surface preparation is often less than ideal. This is usually followed by the application of a primer, two epoxy coats and then the silicone based topcoats. One is still looking at a 4 -5 layer coating system which requires 4 - 5 application procedures, and the result is still coatings that have a typical thickness of 4 - 500 microns and are quite easily damaged.

Repair

Examining the hull of such a ship in drydock after the fouling has been removed, one can see scratches, gouges, damage, and the same undercreep corrosion because of the poor anchor profile –

the less than ideal surface preparation. So this also has to be repaired. And silicone-based antifoulings are not easy to repair because they are non-stick; repairing an area requires some overlap of that repair patch with the existing coating. It's tricky to repair because epoxy will not stick well on the silicone.

The same problem occurs when trying to repair conventional (biocidal) antifoulings. Ships that have come into drydock several times will be spot blasted, spot repaired and then the antifouling will be renewed. After two or three times, again because of the less than ideal surface preparation, the coating around the previously blasted and patched area will have delaminated to some degree and this then becomes the new weak link in the system. The patch repair will overlap the edges, but already there is an edge which does not have good adhesion, so when the ship comes in for the next drydocking it will often be seen that the spot repair is still intact but right around it there is new rust, new coating flaking off, so this now becomes a new area to repair.

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Gunnar Ackx

Full blasting and recoating

With every drydocking this increases until it becomes simply too much to spot blast, at which point the entire hull will have to be blasted to bare steel with an SA 2.5 profile (or an SP 10 in US standards) and the full multiple coat system will need to be applied.

How often that complete reblasting and replacement of the entire coating occurs depends to some degree on the type of antifouling, on the type of ship, on where it sails. If it sails in the Arctic, how much it gets damaged, if it's just a

container vessel or if it's a pilot vessel in a harbor for example, that will get a lot more mechanical abuse than the average cargo ship. On average a complete reblast and recoat will be needed every 3 to 5 drydocking cycles, somewhere between 9 and 15 years.

These practices and estimated numbers of drydockings and drydocking intervals apply to both biocidal AF coating systems and FR systems. In the case of the FR systems, because they tend to be even more easily damaged, even more spot repairs are needed every drydock cycle until eventually so much repair is needed that it becomes more efficient to blast the hull down to bare steel and reapply the entire coating system.

Stress and coating degradation

Every time the ship is drydocked and the hull coating repaired and reapplied, new layers are being built up on top of old layers, adding further stress in the coating system to the total stress which is already in there. Every coating system shrinks when it cures so by definition that means that stress is building up inside that coating system during the curing phase. Every new layer applied on top of existing layers adds stress to the point where something has to break somewhere. And that again comes down to that less than ideal surface preparation, where the weak link will be the interface between the steel and the primer. That's where it will start coming off and there will be corrosion again and again.

So the more layers that are built up with every drydocking cycle, the quicker the damage occurs because more stress is

added to the coating. In the case of one particular cruise ship in drydock recently, the top side of the stern was being blasted and there were 2-2.5 mm flakes coming off with 15-16 paint layers that had been applied one on top of another.

This then is the cycle of hull coating degradation.

The information above is confirmed in an April 2010 paper by Daniel Kane presented at NACE STG (Specific Technology Group) 44 entitled “Hull Roughness Issues”:

Full blast and full recoating is recommended for most ships after 10 years of service, if it is not done before that date. The reason being that experience has shown that the average hull roughness after two times partial repair tends to be high....

Daniel Kane

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In-water cleaning

For a number of reasons, neither AF nor FR coatings are suitable for in-water cleaning except for the removal of light slime from FR coatings. In confirmation of this, one major paint company’s contract recently stipulated that the warranty for the AF coating would be voided if the ship was cleaned underwater. For environmental reasons, biocidal AF coatings should never be cleaned in the water. In many places the practice is forbidden. There are no cleaning systems which collect all the debris and biocides which are discharged suddenly when biocidal coatings are subjected to in-water cleaning. Additionally, the in-water cleaning damages the coating. Similarly, FR coatings are not suitable for in-water cleaning of anything beyond a light slime because the coating itself can easily be damaged by the cleaning

process. Once the FR coating has been damaged, it loses the very properties on which it is based and can rapidly become fouled. And there are questions about the environmental hazard posed by FR coatings.

Most shipowners simply apply the AF or FR coating system, and hope that the biocides or the speed of the vessel through the water will keep the hull majorly free of fouling until the next drydocking, three to five years later. However, slime and some macrofouling usually builds up over the period in between drydocking, contributing to the overall increased fuel penalty.

Despite the unsuitability, there are attempts to clean both AF and FR coatings in the water and, as explained above, this tends to accelerate the coating degradation and increase the fuel penalty which such cleaning is attempting to mitigate.

Summary

Much work has been carried out to demonstrate the relationship between hull friction and fuel efficiency. Extensive research exists on the subject of the combined effects of deteriorated hull paint condition and biofouling on ship hull resistance. No work has been found which addresses the effects of increased hull friction due solely to deteriorating hull paint condition as a result of aging, mechanical damage and of spot and partial repairs in drydock, separate from added friction due to hull fouling.

Observation and anecdotal information indicates that a full blasting of a 10-year old ship’s hull and recoating with any system will result in a remarkable, dramatic, incredible change in the ship’s fuel efficiency (these are the adjectives used by ship superintendents to describe the increase in

¹² Daniel Kane, “Hull Roughness Issues,” NACE STG 44, 15 April 2010.

fuel efficiency from such treatment). Yet drydocking an older ship, removing all fouling and carrying out spot, partial repairs to the coating and reapplying antifouling (or foul release coatings produces nothing like the effect of a full blast down to bare steel and recoating). Figures of 25 - 40% are acknowledged. These figures are much higher than any achieved by in-water cleaning of a somewhat fouled AF or FR coating or drydocking and partial repair of such coatings.

As mentioned above, it would be valuable

research to establish the actual fuel penalty attributable to coating deterioration alone. Especially since such deterioration is not inevitable as there are coatings which do not deteriorate as the ship ages and in fact improve in hydrodynamic smoothness and overall hull friction with routine and repeated in-water hull cleaning.

The current well-known problems of hull coating degradation are attributable to the types of coating in general use and the current practices for maintaining these coatings.

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Part IV. General principles of a practical solution

It should be clear that a solution to the paint degradation and consequent added fuel penalty described above would consist of

1. A coating which does not increase hull friction as it ages;
2. A hull maintenance routine which does not result in a damaged, deteriorated, rough hull coating with consequent increased drag for the ship.

At the same time such a solution should be

1. Economically viable, cheaper than conventional approaches and productive of fuel savings;
2. Environmentally benign: non-toxic, suitable for keeping hull and niche areas free of aquatic invasive species, and low or no VOCs on application.

Additional factors which must be part of such a solution would be

1. The durability of the coating;
2. The ease, economy and environmental safety with which it can be maintained in the water;
3. The lack of need for frequent drydocking for maintenance or repair.

Ideally such a coating would consist of a single, homogeneous layer (rather than many different layers of non-homogeneous substances) which provides protection against corrosion and cavitation damage and is highly resistant to abrasion and any mechanical stress. Any minor repairs needed would blend smoothly in to the existing

coating without creating the rough, cratered surface associated with spot blasted and partially repaired AF or FR coating systems as they age.

As has been shown, conventional AF and FR coatings in general use do not meet these criteria.

One coating system currently available which meets all the above criteria is the glassflake vinylester resin surface treated coating (STC) combined with routine in-water cleaning. This is a completely nontoxic type of coating which does not work on the basis of leaching chemicals into the water, nor is it a fouling release type of coating. It will foul. But it is extremely easy to clean in the water with no adverse effect on the environment or the coating. It is a system which combines a hard, inert coating with routine in-water cleaning to keep the hull free of anything more than a light slime and to keep the nooks and crannies which are most susceptible to sheltering aquatic invasive species free from any macrofouling. Because it adheres so strongly to a properly-prepared hull, even when mechanical damage does occur, the coating is not subject to undercreep or delamination. Because the STC consists of a single, homogenous layer, such repairs consist of spot application of the same single coating which blends in well with the existing hull.

This type of coating is applied once at newbuild or in drydock and then lasts the lifetime of the vessel without any need for a full repaint. The cycle of application, damage or depletion, drydocking for spot blasting and

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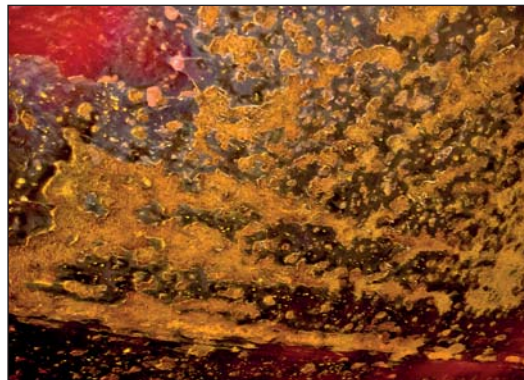
partial repairs with the resulting increased hull roughness and heightened fuel penalty as the ship ages is entirely avoided by such a system. Where mechanical damage does occur, invariably less than 1% of the coated hull is affected and can be easily and rapidly touched up during routine, class-required drydocking.

Case studies

Some photos will show the difference between hulls coated with STC compared to hulls coated with AF or FR coatings after a similar time in service under similar conditions. The photos were taken in drydock after the fouling was removed but before any repairs had been done.

The first example below is of the MV

Baltic Swan, owned and managed by Peter Doehle of Hamburg. The *Baltic Swan* is a 149 meter, 13,713 tons DWT container ship built in 2004. The first set of photos show the state of the hull coating in March 2008 after trading in ice. At that point the conventional coating was four years old. The photos were taken after cleaning but before blasting. The hull was then grit blasted and a glassflake vinylester surface treated coating (STC) was applied. Two years later after sailing between Rotterdam, Hamburg and Saint Petersburg in harsh conditions including first-year ice, and with routine in-water hull cleaning, the ship was returned to drydock in 2010 and the hull inspected. The second set of photos shows the results of that inspection.



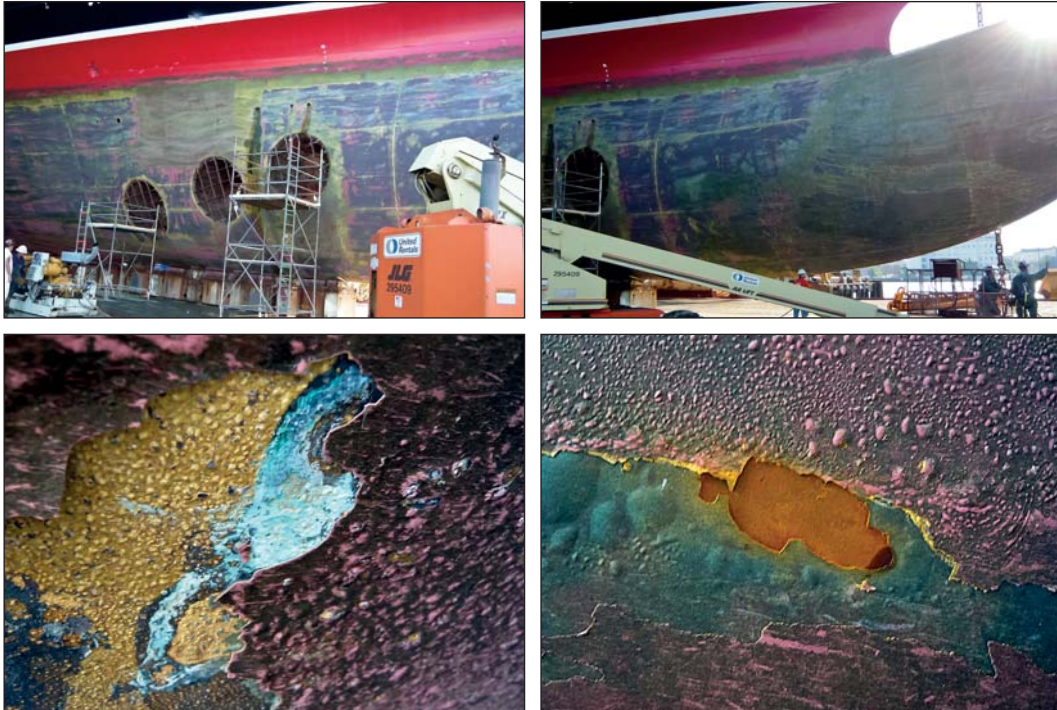
MV Baltic Swan after 4 years service with conventional hull coating (above).



Above 4 photos show the hull after 2 years of service with STC in harsh conditions with no repair needed

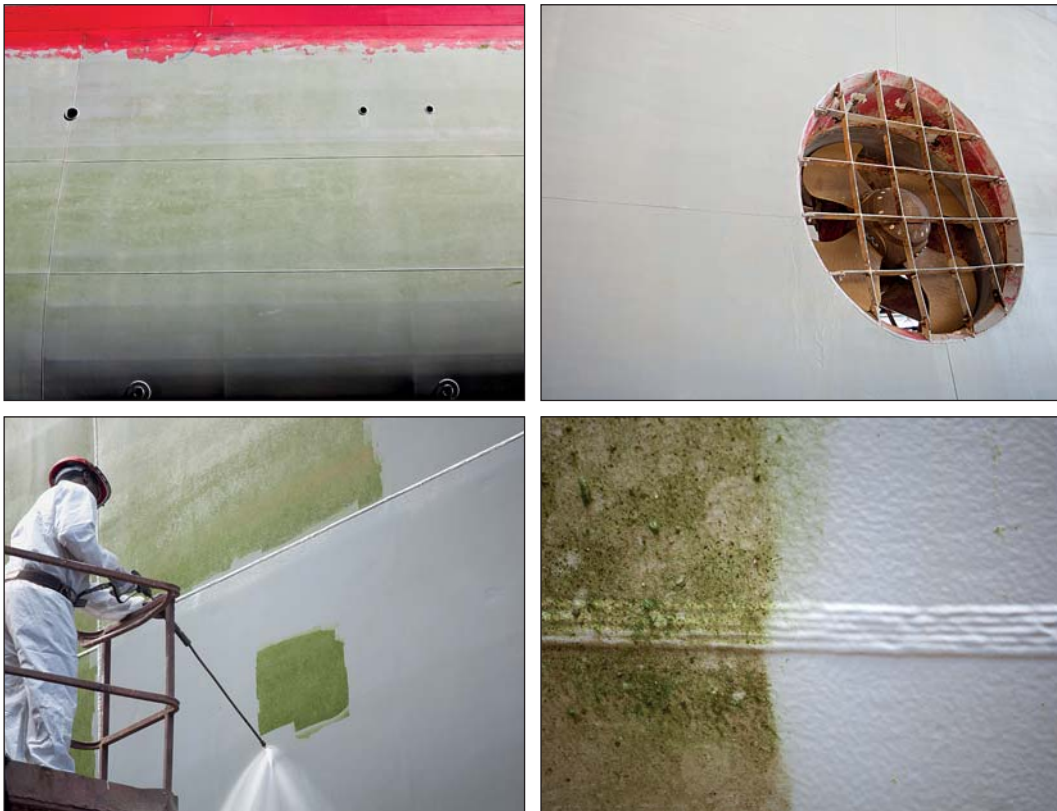
The second example is of an 80,000 ton cruise ship finished in 1998. The ship used conventional antifouling for the first 10 years of its life with the usual drydocking and repairs. In 2008 it was blasted back to bare steel and recoated with an STC. The first set of photos show the state of the hull before the

old coatings were blasted off. The second set of photos shows the state of the coating when the ship was drydocked two years later. It had been cleaned routinely in the water. The hull had a slime layer when drydocked and this was pressure washed.



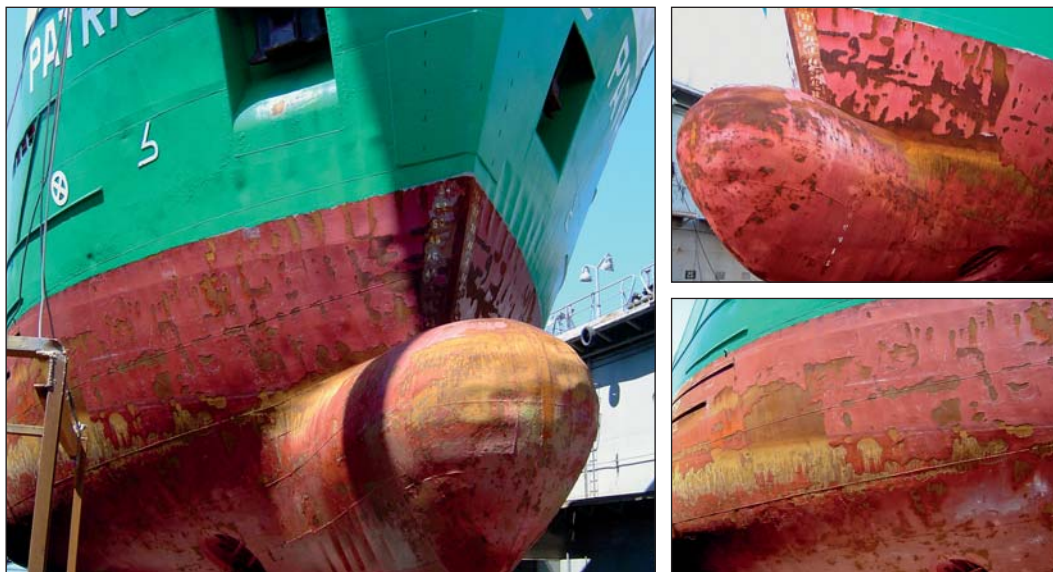
(Above) Condition of cruise ship hull 10 years after initial launch, with usual spot repairs and partial repainting during that time.

(Below) The same hull, two years after application of glassflake vinylester resin STC and routine in-water cleaning, showing almost no damage to the coating and no coating deterioration.



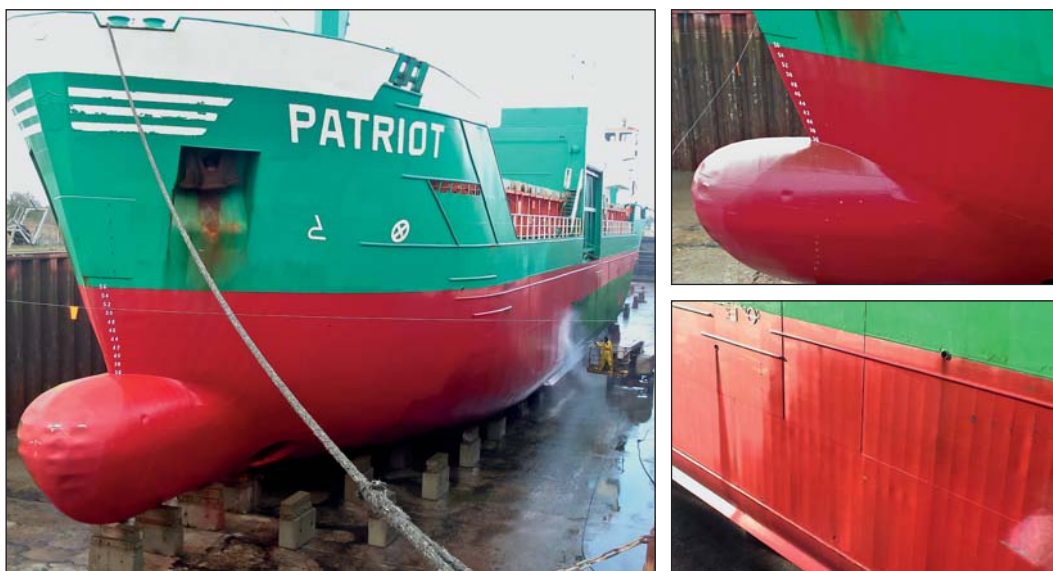
The third example here is of MV *Patriot*, owned by Interscan of Hamburg, Germany. Built in 1994, the *Patriot* is a 3,000 ton 82-meter cargo ship. Its trading takes it into first-year ice. The first three photos show the hull's condition in June 2005, two to three years after the last drydocking and conventional hull paint was applied. The photos were taken after the hull was cleaned

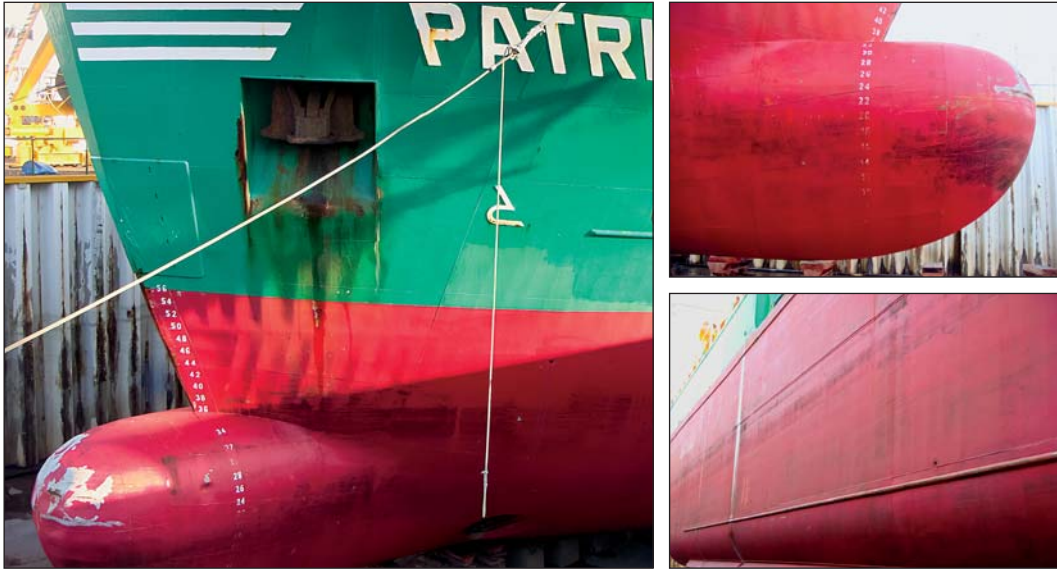
and before it was blasted and an STC was applied. The second set of photos show the hull after a year and a half of trading in harsh conditions with an STC on the hull. The third set of photos show the hull after four years of service. Some very small spots of mechanical damage needed to be repaired but the hull is still as smooth as when the STC was first applied.



(Above) The hull 6 years after launch, using conventional antifouling coating which had been repaired in drydock 2 - 3 years before.

(Below) The hull 1 1/2 years after STC was applied, ship trading in very harsh conditions (ice).





(Above) The hull 4 years after STC was first applied, with no significant repair to the coating.

The next example shows a hull coated with an STC which had to be repaired due to internal welding on the hull. The coating obviously did not survive the heat from the welding and the external hull strips where the paint was damaged by the welding had to be recoated. Due to the nature of the STC, no primer was needed. The strips were blasted

and then recoated with two coats of the STC which blended in well to the rest of the hull. This coating had been on the ship for two years and despite regular cleaning, including removal of very heavy calcareous fouling after the ship was laid up for nine months, was in pristine condition (and still is).



(Above) Damage to coating from welding on the inside of the hull being repaired by spraying on two coats of STC to match the coating thickness of 1000 microns.



(Above) The finished repair leaves the hull as smooth as when the coating was applied several years earlier.

The ship below, the tug *Valcke*, was coated with an STC in 2005. The first photo shows the hull (with a silicone FR) prior to preparation and coating with the STC. The second photo shows the same hull after 5 years with

the STC in service and with no repairs in the interim. The hull is still smooth and in excellent condition and shows no sign of coating degradation.





The following photos show the state of an STC after five years in service with no repainting compared to the previous state of

the hull after a few years in service. These photos show the fiberglass hulls of two naval mine hunters.



Conclusion

As can be seen from these examples, the STC does not undergo paint degradation over time. This coating has only been in use since 2003-4 so experience as to its longevity and performance is still being gathered. But, judging by results to date, if the hull is well prepared with an SA 2.5 profile and the

coating is standardly applied according to the requirements, then the coating will indeed last the lifetime of the vessel with only very minor (less than 1%) touch-ups at routine drydocking intervals and, most importantly, the hull will become smoother over time rather than much rougher as with conventional multi-layer coating systems.

Part V. Survey

In the interests of gathering information which will lead to better ship hull coating systems including fouling control, we would appreciate a response to the survey below from anyone who has information on the subject of hull coating degradation and its effect on performance and fuel efficiency. The more specific the information in the answers the better.

Please send us an email with your answers to the following questions (email to editors@shiphullperformance.org):

1. What hull coating system(s) do you normally use on your ship or fleet?
2. How often do your ships go to drydock for partial repainting or repair of existing coatings?
3. What is your experience as far as performance improvement or lack of improvement with such drydockings?
4. How often do you reblast to bare steel and completely reapply the hull coating?

5. What is your experience with performance improvement or lack of improvement after full reblast and reapplication of the hull coating?

6. Is there any other light you can shed on the subject of ship hull coating degradation?

If you are reading this White Paper in electronic form, please simply copy and paste the questions into an email and type your answers after each question.

If you are reading the printed version of the White Paper, then in the interests of furthering knowledge on this subject we would greatly appreciate your taking the time to type out an email with the questions and your answers.

If we collect valuable information in response to this survey we will publish the results in a separate White Paper, a revised version of this White Paper or in the Journal of Ship Hull Performance so that others can gain from your experience.

Would you like to receive future Hydrex
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editors@shiphullperformance.org

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