The Future of Ballast Tank Coatings
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Introduction
There is a great need for well-performing ballast tank coatings simply because that is what the main stakeholders, the port state control, and the general public demand of the marine industry. This demand in quality is expressed also in the International Association of Classification Societies (IACS) Enhanced Survey Programme (ESP) requiring hard coatings, which must perform to a very high standard. The Oil Majors also have their own stringent quality requirements, whereby cargo and water ballast tanks in ships they use or charter are inspected and scrutinized by other inspecting and surveying organizations. The pattern of raising the quality and performance of coatings in ship’s tanks is a continuous challenge and one which the marine industry has taken seriously for many years. But there is a cost to this!

Ships operate in a truly global and very competitive business environment, and they provide an environmentally efficient service at low cost. The beneficiaries of low-cost shipping services ultimately favour the consumer, which few would deny is a good thing! However the cost of stopping an ocean-going ship and putting it into a repair shipyard for the purpose of recoating ballast tanks is phenomenal. Such repair costs have to be recovered and passed on to end users.

New construction shipyards are also working in a cutthroat, competitive business environment and strive well to build ships in a safe and environmentally responsible manner. The shipyards must follow contract specifications to the satisfaction of their customers and adjust to meeting the differing demands of customers and their varied specifications.

To deliver ships built to varying standards within the same yard using the same laborers to different customers will inevitably lead to putting stress on production. Standardization should lead to enhanced productivity, and so the quest of shipyards to standardize working methods and quality is fully understandable.

Could there be a case, therefore, for rethinking certain aspects of current coating practice and application methodology with the objective of further improving performance standards of water ballast (WB) tank coating systems?

All parties in the industry are aware of the need to rise to challenges posed by the IMO Performance Standard for Protective Coatings (PSPC) regulations, and there is common concern about how best these challenges can be met.
In this paper, the authors bring together their views based upon their respective experience in different branches of the industry. They have tried to summarise current industry practice in the coating of WB tanks. They offer some comments upon the IMO PSPC regulations, suggest some consequences for shipbuilders and marine paint manufacturers, and propose some ideas on the way forward.

This paper, therefore, attempts to take a holistic view of the problem and poses certain challenging approaches for both shipbuilders and paint manufacturers, which it is hoped will contribute towards finding new solutions for the industry at reasonable cost. The paper comprises the following four sections.

- Section 1: Current position of WBT coating systems in new construction
- Section 2: Summary of the IMO PSPC regulations
- Section 3: Some consequences of the IMO PSPC regulations
- Section 4: The Way Forward

**Section 1: Current position of WBT coating systems in new construction**

Shipbuilding output has now become practically dominated by three countries, Korea, Japan and China, to the extent of 75-80% of global tonnage. It is therefore clear that any assessment of the overall performance in service of WB tank coating systems will be heavily influenced by the standards of application, the type of products selected, and the quality control (QC) procedures adopted by shipbuilders in these countries. By the same token, the implementation of any new application methodology, coating system, or QC process is going to depend upon how or the extent to which proposed changes can be integrated into the very high volume construction process, which has become the outstanding feature and economic success of far eastern shipbuilding for some 40 years.

**Generic types**

Current practice amongst shipbuilders is to broadly offer either modified epoxy systems, or tar-free epoxy systems for ballast tank coating. The terminology of tar-free epoxy can mean any one of three main product types: solvent-borne modified epoxies, solvent-borne pure epoxies, and solvent-free epoxies.

In the general case, modified epoxies are most commonly specified by Chinese and Japanese builders, whereas yard-standard offers from Korean builders are usually pure epoxy systems. Some Korean builders are now specifying solvent-free epoxies for drinking water tanks. Only some European builders specify solvent-free epoxies for full application in WB tanks.

In summary, it appears that some 90 to 95% of WB tank spaces are now coated with either modified epoxy or pure epoxy systems, and probably less than 5% of these with solvent-free epoxy systems.

The term modified epoxy originally referred to technical modifications made to the product binder. The inclusion of some lower cost raw materials was found to improve various properties, such as surface tolerance, adhesion, and flexibility.
Coal tar epoxy became the most widely used modified epoxy in shipbuilding. When applied in WB tanks in two coats to dry film thickness between 300 and 400 microns, with good inspection, such a system could achieve good long-term performance.

However, the intensely competitive nature of the shipbuilding industry led to earlier shipyard specifications of two-coat tar epoxy systems being reduced to one-coat systems. Equally, pressure by shipyards on manufacturers to further reduce costs resulted in the manufacture of some lower cost tar epoxy products, achieved by raising the tar content and lowering the proportion of higher cost epoxy resin. The objective of these actions was essentially to find a minimum specification and cost for painting WB tanks to a standard sufficient enough to avoid claims by owners arising within the shipbuilders 12-month standard warranty.

Following concerns in the 90’s about certain raw materials being used in the manufacture of tar epoxies, and in response to the International Association of Classification Societies (IACS) recommendations to use two-coat, light colour, hard coating systems in WB tanks, the industry moved on to use replacement products such as non-tar, bleached tar, epoxy mastic, and pure epoxy systems. Different shipbuilders favoured each of the different product types, and there is evidence of good performance for each type. Recent product developments in both pure epoxy and modified epoxies have been directed towards improving performance.

However, during recent years, it appears that owner preference is moving in favour of pure epoxy products and away from modified epoxies. The preference for solvent free epoxies by some European shipbuilders is partly driven by their having to comply with the EU Solvent Emissions Directive (SED) and their contribution towards improving health and safety during application in shipyards which, in itself, is a positive development.

Solvent-free epoxies tend to score well technically with characteristics, such as good retention at edge due to slower flow and lower internal stress in some formulations. While both these properties are desirable for long life performance in the WB tank environment, the reduced flow also means less opportunity for surface wetting. Some progress has been made with improving their rather slow curing at low temperatures, but the improvements achieved have, so far, not proved sufficiently attractive for adoption by any of the major far eastern yards. A good coating product, therefore, must meet the needs of both the shipbuilder and the shipowner before it can become a solution.

**Secondary surface preparation**
A widely recognised and much talked about issue is that of how to treat sharp edges found in tank internal steelwork. Early coating failure has long been
observed to begin on sharp edges where paint thickness has been much below the specification thickness on flat surfaces. The purpose of grinding sharp edges and stripe coating, therefore, was to promote the build-up of greater coating thickness over sharp edges, rough welds, and other surface defects.

It has been industry practice for many years to pre-treat steelwork in fully coated cargo tanks in this manner. Sharp edges arise from plates (which have been gas or plasma cut), rough welds, weld undercuts, construction lugs, and the sharp edges of stiffening bars. Steelwork pre-treatment work is usually carried out at the panel assembly stage and does require additional manhours at some yards.

Whilst WB tank coating systems can fail prematurely if such steel pre-treatment work is not carried out, industry practice and indeed performance in WB tanks has varied widely.

The extent to which sharp edge treatment in WB tanks is actually undertaken varies greatly through the industry. Current practice seems to be far removed from any common standard, and whether edge treatment is carried out or not may be dependent upon how the paint specification has been written or acceptance or not of some additional cost by the shipowner in the building contract.

It should therefore come as no real surprise to the industry to find that the IMO PSPC regulation seeks to impose some common standards across the global shipbuilding industry by adopting standards of good coating practice, which have proven beneficial when coating other locations in ships.

**Application practice**

The major shipbuilders have all constructed large block coating halls during the last 15 years or so. At the present time, the block coating facilities in Korea lead the field in the Far East. In Europe, particularly in Germany, Denmark, and The Netherlands, there are also some excellent block coating facilities. In general, the size and type of ships built in Europe are of smaller deadweight tonnage than in the Far East, and the WB tank spaces tend to be smaller in surface area and harder to access.

Block coating, in both large and small shipyards, is often a bottleneck in the fabrication process and consequently becomes a critical time constraint on overall production. Shipbuilders, therefore, with their primary focus on production, will always seek a coating process that will minimise the cycle time of blocks in the coating cells. Whilst the time to apply and check a typical WB tank 2-coat system will be controlled by the time each coat takes to be dry enough to walk on, the overall application time for a 4- or 5-coat exterior hull system will be limited by minimum overcoating intervals. If application, stripe coating, and QC checking of the WB tank system should take longer than the overall time to apply
the exterior hull coating, then the WB tank system becomes more critical, and methods of reducing this critical time will be of interest to shipyards.

Each yard has been free to develop their own system of work that will fit best with their facility and the type of vessels they build. Coating facilities vary greatly in size and capacity. There is no common standard that might describe the extent of application that will be carried out within the block coating facility and how much may be carried out in the open after removal of the block to some intermediate or post-erection storage area.

Application practice of recent years appears to have approached the common standard of a 2 coat epoxy system with a nominal dry film thickness (ndft) of 250 to 300 microns. Common standards for stripe coating practice remain less than clear.

Current shipyard practice is to apply either one or two stripe coats. Despite many advances in industry practice in recent years, there are still some yards that are going to have to seriously upgrade their WB tank coating practice when IMO PSPC comes into full force mid-2008. It is already in force for tankers and bulk ships of specific sizes, under IACS Common Structure Rules (CSR).

**Inspection procedures**

In a typical application of a 2-coat epoxy system, including 2 stripe coats to WB tank areas at block stage, the following sequence of work is a common practice approach.

New building Shipyards:
- Steel Preparation
- Inspect
- Secondary Surface Preparation
- Clean
- Inspect
- Coat
- Inspect
- Stripe
- Coat
- Stripe
- Inspect

There are four separate stages in the sequence where QC inspections are required. In accordance with the new IMO.215(82) PSPC, these inspections must be jointly agreed upon and made by properly approved Inspector/s. This does not mean that other inspectors cannot also be involved.
**Current problems in service**

The principal failure characteristic of the high-solid type epoxies, currently so widely specified and applied in WB tanks, is one of cracking. Coating cracks are caused by internal stress released by shrinkage. The most common locations to exhibit this problem in WB tank spaces are block joint areas and on butt, seam, and fillet welds.

In the authors’ general experience, 70 to 80% of cracking failures will occur within the shipbuilders normal 12-month warranty and so will give rise to a claim against the builder by the ship owner. The shipbuilder will then pass the problem forward to the paint supplier to examine and resolve. Sometimes, such failures take longer to develop and can then become an unanticipated cost problem to be resolved within the owners’ maintenance budget.

There can be several causes to the internal strain (stress) causing such cracking to occur, including excessive film thickness, poor surface preparation, poor product formulation, incorrect over-coating intervals, internal stresses, movement of lower scantling high tensile plating, retarded solvent evaporation (poor ventilation or too cold steel), and thermal cycling of structure adjacent to heated cargoes. There may be a combination of these factors.

Block joint areas are the most susceptible to such failure. Cracking around butt, seam and fillet welds, as in photo 1, are other locations for early coating failure. This usually arises from excessive power tool cleaning, which may have polished the metal and left no surface profile.

In a written response\(^3\) to IMO.215(82) on the draft regulations, the following comments summarise the problem: “the cost and difficulty of abrasive blasting at post-erection has meant that power tooling methods have become accepted practice in many major new-building locations,” and experience led this party to conclude “that general coating performance is inferior on ‘join-up’ areas compared to that found on the main body of the tank coated at block stage.” The IMO 215.(82) PSPC\(^2\) does allow power tool cleaning of erection join areas since this is the common practice today in most yards around the world. The text does state Sa 2 ½ where practical, indicating that it is aware of the inferiority of power tool cleaning as compared to abrasive blasting in terms of predictable performance.
An important point to note is that most of the cracks run laterally across the weld. This shows that the coating first detached, or became delaminated, from the steel, which is an adhesion failure. In this case, the cracking or cohesive failure of the coating has been a secondary action and occurred after the adhesion failure.

It can be seen how the cracks mostly extend across the typical width of the stripe coat. In this case, high paint thickness may have been a principal contributing factor for the adhesion failure.

There has also been a lot of discussion and research into the way structural movement may act as a contributor to the cracking of internal coatings, but, so far, the results of laboratory simulations have not been able to show that structural movement is a primary contributing factor. Photo 3 is notable because it also shows some cracking in the coating near the angular corner of the vertical stiffening, and yet at this point in the structure there will be virtually no movement.
Cracking is also often found in corners and other local areas where the sprayer has had physical difficulty in laying down an even coat and has overcompensated from some awkward position. These situations can easily result in raising dry film thickness to levels that raise the risk of solvent entrapment and consequential stress cracking at some later period.

Further, the lower the temperature the slower the solvent evaporation, and this will give rise to increased solvent retention in the coating when cured.

**Current performance**

Over the years, there have been quite a few case histories where certain ship-owners, who, recognising the importance of good WB tank protection, wrote and contracted for their own high standard specifications at new building. They accepted some additional cost, budgeted for regular coating maintenance in WB tanks, and have achieved 15 years and more performance in service.

However, the fact is that current performance of WB tank coatings in general is still falling short of the forthcoming IMO 15-year target life for these areas.

Learning from the manner of current coating performance in WB tanks, there appear to be four main issues.

1. Raising the general standard of WB tank coating practice in some shipyards, and in particular the standards of secondary surface preparation and application
2. Researching new coating products to improve performance, achieve better resistance to cracking, and that will remain manageable by the applicator.
3. Changing the general approach of some ship-owners to accepting the need for some planned and regular WB tank coating maintenance and to cost this into their repair budgets
4. Providing easier, more objective methods of inspection

The best of past practice in the industry certainly suggests that IMO’s 15 year performance target objective is entirely realistic, but to raise the general level of coating performance still requires good specification, good work, and good maintenance to achieve the “GOOD” standard required by the IMO 215(82)² PSPC.

**Section 2: Summary of the IMO PSPC regulations**

The IMO document is long and detailed. It is in the public domain and can be referenced easily. This paper will now summarise some of the main requirements for coating systems.
**Primary aims**
The primary aims of the PSPC are the following.

- To achieve a 15-year target life performance for ballast tank coating systems, after which time the overall condition of the coating system can be surveyed and described as being ‘Good,’ where ‘Good’ condition is defined in resolution A.744(18) and is “minor rust spotting affecting < 3% of flat plate surfaces, and < 20% of welds and edges”

- To influence the wider adoption of better coating systems with reduced maintenance

- To improve safety at sea through better structural protection of WB tank steelwork and reduction in steel wastage

- To highlight the need for good coating system maintenance supported by an appropriate costing system to achieve the 15-year target performance condition

- To make the ballast tank application more transparent

In a nutshell, the aim is to achieve a better level of protection performance than the coating system in photo 4.
Principal requirements\textsuperscript{1} of WB tank coating systems

Principal requirements of WB tank coating systems shall be the following.

- Selection of the coating system shall take into account the in-service conditions and planned maintenance.

- All coatings shall be epoxy based or equivalent and consist of multi-coat layers of contrasting colour.

- The top coat shall be a light colour

- All coatings shall have a Statement of Compliance or Type Approval Certificate issued by a third-party independent of the coating manufacturer.

Principal requirements\textsuperscript{1} for coating system approval

- Epoxy coatings or equivalent shall be allowed

- Testing must have been carried out to the defined standard in Annex 1 of the PSPC or equivalent (e.g. Marintek B1).

- Epoxy-based systems in existence before the entry into force of these new standards and new alternative systems shall require documented field exposure for 5 years, with a final coating condition of not less than “Good,” or laboratory testing.

- All independent test laboratories must meet requirements set out in International Association of Classification Societies (IACS) Uniform Recommendation (UR) Z17\textsuperscript{4}.

Most coatings used today have already passed Marintek tests with a B1 rating.

For block stage application

Secondary surface preparation shall be the following.

- Sa2½ standard of preparation on welds and damaged shop primer

- Sa2 standard, removing at least 70\% of intact shop primer if the shop primer has not passed a pre-qualification test as part of the applied scheme

- Water-soluble salt levels on the steel after surface preparation, but before painting, are specified to be less than or equal to 50 mg/m\textsuperscript{2} sodium chloride. Conductivity is measured in accordance with ISO 8502-9.
Steel profile shall be 30 to 75 microns or that recommended by the coating manufacturer and is according to ISO 8503-1/3 as per the shop primer specification.

Paint thickness and number of coats are specified as follows.
- Nominal system dft to be 320 microns in total with inspection following the 90/10 rule.
- Paint thickness should be achieved in a minimum of 2 coats and 2 stripe coats.
- Typical specifications will be 2 x 160 microns, but coats of differing thicknesses are allowed.
- It is understood by most observers that the stripe coats shall be carried out by brush to edges and welds, and roller to be used in scallops, etc., only. The text is, however, ambiguous, and IMO will be required to clarify this at an upcoming conference.
- The second stripe coat may be omitted on welds if the ndft can be met by the coats applied.

Photo 5  Typical example of good stripe coating.  Note the care employed not to over build.
**For block joint areas and damage repairs**
Steel profile is not specific, and the regulations essentially avoid the issue.

Secondary surface preparation shall include the following.
- Butts (‘join ups’) should be prepared prior to coating to “St3 or better or Sa2½ where practical,” as per ISO 8501-1. The text says “or better,” which indicates that IMO were not only concerned but expects improvements. IMO concluded that it was not ready to mandate a higher standard at this point.
- Small damages, up to 2% of the total area, are to be prepared to St3 standard prior to coating.
- Contiguous damage over 25 m² or over 2% of the total area of the tank should be prepared to Sa2½. Care is to be taken not to damage surrounding areas.
- All coating repairs are to be feathered in the overlap

Paint thickness and number of coats shall be the same as for the block stage application.

This is essentially the common practice in most shipyards today!

**The Coating Technical File** (CTF)
This composite record of all data relating to the WB tank coating system and its application during new construction, must be compiled by the shipbuilder. A fully complete and audited version must be handed to owners on delivery of the vessel. This is an entirely new requirement for WB tanks, and the responsibility for it has now been properly placed with the shipbuilder.

The Coating Technical File will contain the following documents.
- Statement of compliance or Type approval of coating
- Documented performance records of the coating and criteria for selection
- Specification
- Technical data sheet supplying all data needed
- Shipyard work (and owner) records: location, times, surface preparation, environmental conditions, etc.
- Inspection procedures and repair of coating during construction (and also in-service maintenance)
- Coating log issued by the coating inspector
- Shipyards inspection report

All of the above information must be brought together, and it will help all parties if the format can be such that the information therein can be easy to access, easy to understand, and user-friendly for the ship owner to maintain what should
increasingly become a really useful onboard database for each ship to guide future maintenance to keep the tanks in “good” condition.

It is the authors hope, therefore, that detailed attention will be given to these points, because the alternative might be that CTFs could become just an unused document, containing a massive amount of useful data which the ship just carries on board for its entire life.

Section 3: Some consequences of the IMO PSPC regulations

For Shipbuilders

Many yards will have increased QC work to do during both block stage and in situ applications of WB tank coatings. Whether this work is done by the painting subcontractor or by the yard’s own team manpower, there will be an increase in inspection man hours. Increased inspection time may lead to some addition to the coating cell cycle time for each block. Some relatively minor increases in QC costs seem a likely consequence.

Lead QC personnel are required to have qualifications to Frosio level 3, NACE level 2, or equivalent. A surge in demand for the training of such personnel can therefore be expected in all shipbuilding countries. There will be both an initial and an ongoing additional cost of training personnel to these standards. In fact, the Inspector charged with validating the IMO 215(82)\(^2\) compliance has to be certified. Other inspectors do not.

Yards are responsible for compiling the CTF. The systematic collection and assembly of the necessary information will therefore be a yard cost.

Some yards may have to consider the investment cost in new or additional coating facilities, something that progressive shipyards have been doing for years, simply because of the gains in productivity and financial returns which may follow.

For Marine Paint Manufacturers

There will be additional costs arising from the following factors.

The need to outsource independent testing of new coating products and systems to obtain mandatory approvals

The need for these independent test laboratories to meet requirements set out in IACS UR Z17\(^4\) will create its own additional cost of testing fees these labs will charge paint manufacturers

The coating manufacturer having to meet the requirements of
IACS UR Z17\textsuperscript{d} at all of their overseas factory locations manufacturing ballast tank coatings

- Identical Products manufactured at different locations must be shown by infra red and specific gravity measurements that they are identical to that tested, or individual approval tests will be required from each location.

- Preparation of new data sheets

- Training of some Field Technical inspection personnel to the same Frosio, NACE, or equivalent levels as for shipbuilders. It shall be noted that it is the agreed person in charge with the validation of the standard who must be Certified. Other persons can perform inspections as well.

- The need to supply personnel with higher levels of qualification than hitherto. Higher levels of qualification usually carry an expectation of higher salaries. In addition, more personnel might be required.

- Less failures and claims can be expected as a result.

A general consequence of raising the cost of the whole inspection process to all parties will create a new business environment in which the cost of inspection services becomes a more visible cost for all parties.

Some other consequences of this huge testing regime seem likely to make coating manufacturers carry out more exhaustive in-house testing of WB tank coating systems before committing to expensive third-party testing.

However, whilst the cost of system testing is viewed by manufacturers as expensive, it is useful to give this matter some perspective by considering the following.

The cost of a full ship supply of all WB tank coatings for a VLCC newbuilding is in the region of $1.5 million. The cost of testing one WB tank coating system over one shop primer is about $6000 or 0.4% of the WB tank coating supply value for one ship. However, the coating system may have to be tested over 10 to 20 leading shop primers, and so the total testing cost might be as high as 4% - 8% of the supply value. If the shipyard application cost were to be added, then the total cost of the WB tank coating installation may be in excess of $5,000,000. Wwhilst the relative cost of the testing falls, it could still be in the range 0.1% - 2.4% of the value of the installation cost.
If the WB tank coating should fail and the WB tanks were to be recoated, the total cost for supply of coating material and application would be in the region of $20,000,000. The cost of testing would then be in a range of 0.03% - 0.6% of the total recoating work.

For smaller ships, such comparison of the cost of testing will appear proportionately higher. However, in practice the paint manufacturers will need to defray these costs across their total new construction supplies.

**For Shipowners**

Shipowners and operators of large tankers and bulkers, especially for ships in which the WB tank areas are large, can expect the following.
- New building prices will increase.
- Ship owners will have to maintain the ballast tank coating
- Coating Technical File (CTF) will be on board each new ship. The format of this document should allow subsequent records of coating maintenance carried out to be entered and maintained.
- Ship owners will see considerable financial benefit from the reduced costs of recoating, which should feed into lower through life costs. (If not a considerable improvement why do it.)

**Section 4: The Way Forward**

**The IMO PSPC regulations**

Initially, these new regulations seem certain to result in some additional costs for both shipbuilders and paint manufacturers, which builders and paint manufacturers can be expected to try and recover through price increases.

The regulations mandate a new requirement for higher standards of steelwork preparation than some yards are used to, more product testing and laboratory approvals, training of personnel to higher levels of inspection competence, and additional documentation and record keeping.

The cracking problems being experienced with both modified and pure epoxy-type products when sprayed cold or over-thick, and with regard to adhesion in the block joint areas, are occurring because of technical characteristics of such products. These problems are not likely to be eliminated by these regulations, but since the suppliers are in fact required to supply product systems for 15-year performance, it might help. This is particularly interesting in the block joint areas, where the regulations leave the surface profile specification out of step with that specified for the main block areas.
The problems of secondary surface preparation on the block joint areas are essentially of a practical nature. There is no easy way to achieve an even surface profile in the range of 35 to 75 microns in these interior spaces, due to an industry reluctance to develop a more productive, portable vacuum blasting or Sponge-Jet type technology, which can deal with the structural profiles used in shipbuilding construction. The power tool option is therefore used, and the tendency is to polish and eliminate the original surface profile to give a bright ST3 finish, which is clean and looks good visually, but in fact a rougher surface is needed to promote paint adhesion. It is common practice to use higher texture grinding discs to enhance the situation, albeit not generating an equivalent surface profile to that achieved by grit blasting.

*For Shipbuilders*

This is a time for a lot of new thinking on how to manage the new requirements arising from the IMO PSPC regulations. However, shipbuilders should not feel locked into a box of current products and standards, because it is stated several times within the IMO PSPC regulations that alternative products and innovation are encouraged.

If current estimates of consequent loss in productivity and additional costs are even remotely found to be correct, the major shipbuilders are likely to react and disallow such productivity loss to become permanent. This will stimulate more intensive research by shipbuilders into alternative and faster methods of application of WB tank coating systems. The objectives of such research will be about how to gain productivity and reduce costs as a consequence of the new IMO regulations. The directions of shipyard research might therefore focus upon the following points.

**Block coating**

Find products and methodology which could speed up the processes of paint curing and QC procedures. This might allow blocks to be moved more quickly from coating cells and might be a counter action against loss of productivity.

Find new coating materials with tolerance to higher relative humidity than the current norm of 85% and lower temperature curing than the +5 deg C limit of many epoxies. Such wider application limits might enable shipyards to make some cost savings in their operation of environmental controls used in block coating cells during application.

**After erection**

Consider the possibility of using alternative coating materials in these areas. Waiting for new technologies to become more acceptable, the shipyards have only limited practical options for carrying out secondary surface preparation in these locations, and they seem likely to continue with the general use of power tools. In that case, varying standards of
surface finish will continue to be the norm in practice. Therefore, a different type of coating might be better suited to the conditions of application in these areas. The coating overlap adhesion and likely in-service performance would clearly have to be tested.

With productivity being shipyards’ primary issue and if shipyards should conclude that some innovative coating process and material, could reduce coating cycle times, improve productivity, and yet deliver a better performing, long life WB tank coating system, then they could decide to treat the application process as a shipyard engineering issue. If the potential benefits from such a change should be found important enough, shipbuilders may conclude that it would be in their best interests to exercise more control over the process, even to the extent whereby yards will specify the WB system(s) they will provide. The authors have learned that at least one major Korean shipbuilder has taken the first steps in this direction. This would also mean that the yards would assume more responsibility for the performance of the coatings.

Shop primer has long been a shipyard supply item because of its impact on construction processes. Similarly, in the auto industry, the customer can choose the colour and kind of finish, but they have no say in the primer process and product selection. Such decisions are part of the engineering process, fundamental for guaranteeing better performance, and selected by the manufacturer. Likewise, coating performance expectations in the auto industry are much longer than the 1-year warranty typically given by shipbuilders.

- **Inspection and data management**
  Develop better and faster systems for inspection and collection and collation of data to generate the required CTF documentation and speed up the inspection process.

For instance, if one dft reading is taken every 5m², across 250,000 m² of WBT area in a VLCC, this means 50,000 readings will need to be recorded. A system for processing this data to meaningful conclusion, formatting for entry to the CTF and retrieval for audit purposes and to feed into the future planned maintenance through life, is clearly going to be required. With the objective of minimising total time and effort, a number of such systems are now being developed to help shipyards compile the initial CTF and then help owners continue with the appropriate entry of coating maintenance data during the vessel’s service life.
**For Marine Paint Manufacturers**
Following on from the previous section, where some perceived needs of shipbuilders have been suggested, this could now become a time of great opportunity for marine paint manufacturers.

It will be very surprising if, in 15 to 20 years’ time, major shipbuilders are still applying two-coat epoxy systems in WB tanks according to coating methodology generally in use today.

WB tank areas are just too big in terms of square metres for shipyard painting and too important in terms of the structural integrity of the hull for the industry to accept the status quo to continue with regard to both product and methodology. Essentially, the industry is still geared to coating technologies pioneered in the 1940’s and significantly re-engineered in the 1960’s. However, cost and productivity issues, which are being triggered by the new IMO PSPC regulations, are of a magnitude sufficient to initiate a major drive for change in shipyard coating methodology.

Marine paint manufacturers are well aware of their need to follow and satisfy the demands of their shipyard customers, and there can be little doubt that important research projects will already be in the pipeline. Coating manufacturers must now also focus more on performance, with a 15-year life demand – a positive change.

**Short to near term view: 1 – 5 years**

• **Solvent-borne epoxy systems**
Efforts will likely be concentrated upon the improvement of existing epoxy products already accepted by the market. Primary effort to reduce internal stress and thus improve flexibility in existing WB tank products seems probable. Internal stress in coatings has been one characteristic attributed to some cracking failures in recent years, and so improving on that, and thus lowering the propensity to crack, should contribute to better longer-term performance. Any modification should not negatively alter other vital characteristics such as water resistance (vapour transmission rates, etc.).

It is worth restating that not only is the cohesive strength important, but also the adhesive strength, and these strengths must be matched. To have a fully cohesively intact coating not adhering because it has been pulled off by shrinkage does not help much.

There are also some new products in the market that claim to have improved resistance to cracking. Information on one of these, described as fibre reinforced, was presented at PCE Marine® 2006. It is still too early to review in-service feedback reports.
In recent years, other manufacturers have made improvements to the edge retention characteristics of some epoxy products, and research in this area will no doubt continue. This must, however, not come at the expense of other vital characteristics, such as flow and wetting. Raising the volume solids content has been another general and ongoing development.

**Solvent-free epoxies**

Solvent-free epoxies, in general, do have far better flexibility. They offer the best environmental response in terms of future pressures on shipyard painting practice, and further product development of this type can be expected. However, at present, some solvent-free epoxies have other characteristics that are not so user friendly for yards with high rates of block throughput. For example, drying times are sometimes slower, which impedes walk-on QC inspection; low temperature curing versions are still in general slower than with normal epoxies; and there is concern about their surface wetting ability because such products do not flow much after surface contact. They have in general, however, better edge retention as a result. There are also very fast curing solvent-free epoxies on the market, and new curing agents have made faster and lower temperature cure possible and much safer than with solvent-borne epoxies. The solvent-free systems generally require application by plural-component pumps for proper control of the mixing and spraying process. This type of pump is more expensive than the standard airless spray type widely favoured by shipyards for many years.

Some yards are specifying this kind of product for application in relatively small tanks which are spray applied *in situ*. Drinking water tanks are an obvious choice. Some Japanese yards have been using this kind of product for this purpose for many years, and more recently some Korean builders have begun to favour these products for the same purpose.

**Rapid cure systems**

Interestingly, in the United States the NSRP Technical Panel\(^6\) SP-3 reported in 2005 that Navsea was researching technologies for single-coat, multi-pass, rapid cure systems in tanks with the purpose of improving application productivity by eliminating two stripe coats and all the associated QC inspection work. If such an innovative approach can confirm good performance, then the applications engineering aspect of such technology must be of serious interest to commercial shipyards. The authors understand that this research has recently reached the stage where some poly-novo, solvent-free system will undergo shipyard application trials shortly.

If such tests should prove satisfactory for the block coating process, and if a practical application solution for block joint areas can be found, there will still be the issue of establishing customer confidence in such technology in what has long been a traditional and cautious market.
If this US technology, mentioned above, does prove manageable by shipyards and can be shown to reduce the block coating cycle time for WB tank areas, then a challenging scenario might develop. A successful outcome of this work might lead logically towards the development of a whole new range of products based on this rapid cure technology. Such products might be technically suitable for use on other locations, such as on decks, in cargo holds, or on the exterior hull above the waterline.

• **The Dual Bonding Mechanism (DBM) approach**
  The marine paint majors have long been aware of the differences in standards of secondary surface preparation, physical access, and degree of environmental control with which they have to contend between blocks coated in a purpose built painting cell and block joint areas coated inside the ship structure. Since this part of the modern ship construction process is a fact of shipbuilding life and unlikely to change, why not recognise this major difference in application conditions between block and block joint areas?

Instead of having to use the same product for the total internal WB tank area, why not consider developing a block stage product with the primary need of aiding shipyard productivity and an associated objective of countering the potential loss in productivity that some shipbuilders are currently predicting? Of course, this will result in additional testing requirements.

• **Main coating applied in block coating facility**
  The constant demand on block coating cell space points to the need for a product that will greatly speed up the drying process so that walkover QC checks can be made very soon after application. Yet, the product should retain a maximum overcoating capability, so that a second full coat application can be made within hours. This idea envisages that two full coats, and stripe coats, can all be applied, QC checked. and the block complete its full WB tank coating cycle in 24 to 48 hours. This should go a long way towards helping shipbuilders gain productivity above the present situation. How shipbuilders then decide to balance or integrate the block coating of the external hull will become another issue. It is, however, quite possible that solvent-free systems of similar characteristics can be used on other areas, reducing the number of coats and application time.

• **Coating of block joint areas in the ship**
  As explained earlier, surface preparation standards in the block joint areas are generally lower than for the main block. Therefore, why not consider a separate technical approach towards better product performance when application must be done under these different conditions?

The primary requirements suggested are good adhesion, low internal stress, and good flexibility. However, the most important difference between the *in situ* application and the coating cell application is that the secondary surface preparation of the block joint area, carried out in the ship, can often remove the
surface profile. This therefore raises the question about whether it might be better to consider a coating for block joint areas that can develop its adhesion to 'smooth' steel by a chemical process rather than by mechanical adhesion, which the surface profile provides, and that is what the coating cell enables?

The chemical process would mean stimulating some reaction between the wet paint and the steel surface. There may be several technical routes through which such a chemical bond might be achieved.

This approach would use two different products, each of which gain adhesion by different principles. These actions might therefore be described as ‘dual bonding mechanisms’ or the DBM approach.

The concept of using two different products to form one system with the first coat of the system acting as a ‘glue’ coat is not that new. Remember the old T-wash to make vinyl coatings stick. Of course if a ‘glue’ coat should be developed and prove successful in the WB tank environment, then this might open the door for a much wider application of the concept.

A solvent-free product that maintains a safer working environment within WB tanks would be a bonus but is not essential. Colour matching would be, but some shade difference might actually be an advantage in a WB tank, if two different suppliers were being used.

Good adhesion across the overlap with the block coating would be fundamental, and the question inevitably arises, “over what?,” if one manufacturer was unable to supply approved products for both the block coating and the block joint area. There would therefore be issues about testing for the parties to resolve. Clearly, it will also be very important to gain owners confidence. Whilst this hybrid approach might be unusual, it could be technically possible.

WB tank areas of large, double hull tankers can typically be 280,000 to 300,000 m2 per ship. Therefore, if block joint areas and damages totalled 5%, this would mean 14,000 - 15,000 m2 per ship. This is no small area, and would actually be a large supply contract for a small manufacturer holding some special technologies in maintenance, assuming the manufacturer could obtain PSPC approval for their product. If such a product were to be used in the block joint areas, then it would become first choice for any ongoing maintenance and coating repair for the ship’s WB tanks once in service.

Shipyards’ normal procurement policies are to limit suppliers to one or two manufacturers per ship. However, if any products should be found by the shipbuilder to be particularly suitable for use in block joint areas, and the manufacturer was not the same as that favoured for the main block coating supply, then this hybrid approach, using best technologies from two different manufacturers, might be workable. The shipbuilder will always be in a position to
pull such concepts together within the terms of their Shipbuilders Warranty, but it will be the performance of the products and systems themselves that will have to generate sufficient confidence with shipbuilders to convince them to take such steps.

**Mid term view: 3 - 8 years**

• **Innovative primer system**
There were big problems in the auto industry some 15 to 20 years ago when bodywork paint systems were found to be generally deteriorating after even 2 or 3 years, a situation that customers found unacceptable.

One manufacturer researched the situation and came up with a completely innovative methodology and product type for priming the steel bodywork. This resulted in far superior performance and has subsequently been wholly adopted by the auto industry. The consequence of adopting this technology enabled auto manufacturers to work out a new deal for customers, where success of the process has led to bodywork perforation warranties these days of 5 to 7 years. Against a shipbuilder’s standard 12-month guarantee for a WB tank coating system, the marine industry offer is miserable by comparison.

Is there therefore something the marine industry can learn from the auto industry’s approach? It will be healthy development if the IMO PSPC regulation can stimulate rethinking about the WB tank requirement in conjunction with the ship construction process, and the primary interest of the shipyard in fabrication and block production.

• **The ‘glue coat’ primer proposition**
Two questions are now posed.
1. Why should the first coat and second coat have to be of the same material?
2. Can some technical combination of different coating products produce a system suitable for 15 or even 25 years performance in the WB tank environment?

We will look further at both questions.

The history of WB tank coatings is remarkably simple and uncomplicated. Hand-applied grease coatings first became available around 1910. These were low-tech products, inexpensive, highly effective, and they often lasted the life of the ship. They were mainly applied as an owners’ extra in UK shipyards when the UK was a major world shipbuilder. Their disadvantage was that WB tank special survey inspections were a hazardous nightmare.

Then one-coat applications of cement wash or bitumastic were adopted by shipyards during the 30’s and 40’s, these being cheaper and cleaner systems for both application by shipyards and subsequent tank inspections. Both coating
types were of a brittle nature and their useful lifetime was far inferior to the performance of grease paints. Both systems were still being offered in yard-standard specifications during the 50’s and 60’s.

The big ships, which began emerging in the 60’s, had greatly increased WB tank areas to protect, and hand-applied coatings became utterly impractical. The response of manufacturers was to either ‘hot’ spray in situ a new type of grease paint or cold spray the new tar epoxy hard coatings. Grease paint applications were wholly impracticable for block application. As yard preference for block coating grew, tar epoxy systems, in either one or two coats, became the global WB tank coating standard until the IACS recommendations of the 90’s.

Some owners, mostly American, had a preference for one-coat zinc silicate systems instead of tar epoxies. Zinc silicates gave good mid-term protection but brought other problems in initial application and maintenance. Their use did not become widespread.

The authors view on question 1 is that because there is virtually no historical precedent for the use of any mix of coating products in WB tanks, the issue has not really been fully addressed.

The authors are, however, aware of a small number of exceptions to this norm. During the 80’s, a few progressive owners chose to meet the additional cost of applying a zinc silicate primer, and then overcoating this with two coats of tar epoxy. There are examples of very satisfactory performance of this type of mixed coating system still afloat today after more than 20 years in service, which therefore goes some way towards answering question 2 above.

This leads directly to the question of whether such a system could be successfully formulated to meet the needs of today’s high steel throughput shipbuilding. What if, therefore, the first coat was designed primarily to maximize adhesion to the zinc silicate shop primers generally favoured in ship construction today? The function of such a first coat would then essentially be that of a ‘glue coat.’ The second coat would then be formulated to form the anticorrosive “barrier.” It is envisioned that the following application cycle for such a system might then be possible.
Example; block of about 1000 m²

1. **Blast and clean** *(No change)*
   - Will need to be hard dry for QC inspections, not touch dry

2. **Apply Glue Primer**
   - Will need to be hard dry for QC inspections, not touch dry

3. **Stripe coat***
   - Will need to be hard dry for QC inspections, not touch dry

4. **Apply Main Coating**
   - Will need to have fast cure characteristic

5. **Wet Film Thickness control and spray correction by QC team**
   - Floors will be coated after other work completed in main areas

7. **Block Confirmation Next day Inspection**

*The striping could be done with normal high quality, solvent based paint. The same can also be used for erection seams and damages

The challenge would be how to achieve a target time of 24 hours for the completion of the above procedures on a WB tank block.

**Application equipment**

Spray pump manufacturers are usually consulted early on in the development of new technology systems because workability and application properties of the product are essential practical issues to confirm. The range of spray pumps continues to grow and requires specialist engineering in certain product areas such as the application of passive fire protection systems.

Rapid cure materials require plural-component pumps with impingement mixing for materials of short pot life. If the loss of productivity due to IMO PSPC is as real as shipyards are maintaining, and if new product technology can help speed up the application of WB tank coating systems, then the shipyards will change their methodology and gain in the process. This could, lead to a considerable programme of spray pump re-equipment by shipyards, who might choose to go forward this way.
Summary
Ships need to have good ballast tank coating during the entire ship’s service life. This will contribute towards lowering operational cost, be beneficial for the environment, be beneficial to the ship’s customers, and will be overall good economy. To change steel is expensive and time consuming.

Ships also need predictable coating performance to enable proper planning and budgeting of coating maintenance.

Marine paint manufacturers have developed the specialist coating technology to protect water ballast tanks for long-term periods and have the capability to supply various products that can meet the new performance standards, as set out by IMO to satisfy the rightful demands of the primary stake holders and their various representatives; Class, Port State Control, IACS, CDI.

The challenges for the future will be about how to employ new technologies and develop new products that can assist shipyards achieve both a higher quality of initial application and longer term performance in service. Coating technologies have entered a new dynamic phase and the IMO PSPC regulations seem certain to stimulate a substantial re-thinking of the whole methodology of painting WB tanks. In most commercial ship types, the WB tank spaces are, and will remain, the largest single location in any new ship, which the shipbuilder is required to paint. It follows that R&D effort in this area should be treated with similar importance to that traditionally given to anti-fouling. The authors anticipate that the result of such research effort should lead to something more than a one-product, one-technology solution.

Shipyards, for their part, will always seek to perform at maximum efficiency and lowest cost to enhance their competitiveness and profitability. Predictable production will therefore assist shipyards in their planning, scheduling, and costing of new ships. In this way, shipyards strive to be evermore efficient and keep their prices internationally competitive. The IMO PSPC is a challenge to shipbuilders. The authors anticipate that shipyards will now be ready to explore new options in WB tank painting more than ever before. The possibility of their adopting some major changes in methodology should not be discounted.

It is the global consumer who is the ultimate end user and beneficiary of improved efficiency and lower costs in both ship production and operation. Shipping and transport remain a small but important element in the cost of all manufactured and processed goods, and it is therefore in the interests of all countries to support any new initiative that may contribute towards the maintenance of a low-cost shipping industry. There is, in fact, no other lower cost way of transporting large volumes of food, commodities, fuels, chemicals, raw materials, and manufactured goods other than by ocean shipping services. We should never, therefore, take such services for granted.
Improving long term coating performance in WB tanks has become a major issue for the industry to resolve. The marine coatings industry may be entering an exciting time for both new product and application technologies, some consequences of which may initiate substantial change in established practices and bring some positive surprises in their train for all involved parties.

References

2. IMO.215.(82) PSPC standard.
4. International Association of Classification Societies (IACS) UR Z17.