

# MATCHING THE COATINGS PROCESS TO SHIPYARD NEEDS

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## SUMMARY

*“Before I begin on this subject, I shall give a few necessary cautions which ought to be minded in fitting and preparing the parts that are designed to be painted, otherwise your paint, (Which undeniably is a very good Preservative, if rightly apply’d) will be of little Use or Service.....Sutherland: Of painting ship-work 1717”.*

The coating process has long been considered to have less importance to the shipbuilding process than steel work and outfit work. However as the other processes have become more efficient over recent years, the problems being encountered in the coating activities are increasing. The problems manifest themselves in a number of ways, but increasingly in terms of time, cost and quality.

## 1. INTRODUCTION

The major facility technology developments in shipbuilding took place in the 1960’s and early 1970’s in Japan and Sweden and subsequently Korea, papers written at that time [1, 2, 3] placed heavy emphasis on the development of steelwork activities, with only one of the papers affording some mention of coatings:

*“The method of surface pre-treatment will be shifted from the mechanical process of shot blasting to a chemical treatment of spraying acid or rust removing chemicals from now on. It is being studied whether to perform this operation after sub-assembly or after completion of hull blocks. The hand spraying method of painting, which is the current practice, may be replaced in the future by electro static spray or flow on painting conducted after sub-assembly or completion of hull blocks, or by the submersion of hull units or blocks in a tank of paint. Another treatment system under study is to pour paint into ships tanks to be coated. In any case, development of new paints themselves and the large quantity of paints to be stored still remain as a problem to be solved” – Takezawa 1972*

Since that time there was a steady increase in shipyard investment in steel production and outfit facilities, until by the early 1990’s it became clear that the coating process was becoming a bottleneck to shipyard output and production and would result in considerable problems in the integration of the coating process to the much shorter production times [4].

Since 1994, the pace at which productivity has had to be increased to enable yards to remain competitive and the increased in environmental awareness as well as end-user demands have placed considerable pressure on shipyards around the world resulting in real problems in managing the coatings process and making the coating process the bottleneck to production capacity.

## 2. PROCESS CONTROL

Coating activities raise a unique set of problems for shipbuilders, as the processes involved in coating can be subject to considerable variation making the process unpredictable (unstable).

The normal shipyard coating processes usually consists of:

Treatment or primer line (sometimes undertaken by subcontractor)

Some shop coating work (Fillet welds on the panel line)

Secondary surface preparation and coating on block (outside or in workshops)

Post erection coating works (erection butts and seams, keel blocks, finish coats and cosmetic coats etc.).

The sources of variance in the processes is primarily from 4 sources:

Unpredictable schedule (weather conditions, Temperature, humidity, dew point etc.).

Unpredictable drying times for coatings

Interference with other processes resulting in re-work.

Subjective nature of acceptance criteria at inspection

The schedule within the paint department is considerably affected by the weather. Even with enclosed workshops, weather can still create problems as if it has been raining, blocks may enter wet or even covered with snow and hence result in additional cycle time needs. If a TACT time of  $+2\sigma$  [5] were to be used to balance the production line then the yard output would be reduced to a level that would not be commercially sustainable. However, it is surprising how often the author visits yards that do not

alter the coating production schedule between summer and winter months.

Drying time is subject to considerable variation as a result of:

- Poor thickness control
- Unpredictable temperature

The application process of coatings has largely been based on the airless spray method. As worker skill has decreased (painting is very dirty and relatively lower paid than other shipyard skills, making it hard to retain workers), the paint technology has been changed to enable the paints to be more easily applied (reducing runs and sags). This has in turn resulted in over application of coating, resulting in high thickness and considerably increased drying time with a large variation.

The unpredictability of the ambient temperature further increases the variation in the drying time. Enclosed and heated workshops, in theory should reduce the variance, but the practical aspect of the cost to heat these large workshops is often a barrier to their effective use.

Depending on ship type and size, shipyards can experience re-work levels in excess of 30% of total man-hours for coating activities (with some Naval yards running nearer 60% of total man-hours for coating activities).

Considerable work has been undertaken since the late 1960's to improve accuracy and quality of the steel and outfit production work [5]. This has not been matched by an equivalent effort in coating activities/facilities.

The objective of all this work was to bring processes under control to enable predictability of performance so that production systems can be better engineered to Standardise, specialise and simplify [6].

Dr Shinto re-enforced the importance of gaining control of production and the role of management systems to achieve process control in the work he undertook in the early 1960's [7]. In this work Dr Shinto reviewed both steel and outfit work. However even at this time the challenges required to gain control of the Steel and Outfit work was so great that very little effort was applied to understanding coatings. However the groundwork was set for the first attempts to consider coatings in the form of the Hull Block Coating Method (HCBM) that was introduced at IHI at that time.

As the steel and outfit work was better understood and brought under control, the importance of the management systems required to assure predictability was also highlighted and led to the next big challenges in control of the shipbuilding process.

The inspection of many aspects of the coatings activity (surface cleanliness, finish of coating) are often subjective, rather than objective). This means that often the variation in expectations can add considerable unscheduled work for the yard (this situation is likely to be aggravated by the new IMO MSC.215 (82) performance standard for ballast tank coatings. There is a real need to better standardise the assessment in a readily measurable way and to ensure that the data to be recorded for the Coating Technical File required by the regulations also does not overburden the yard.

### 3. PROCESS IMPROVEMENT

Shipbuilding process improvement has often shown that it is not the technology that is a barrier to improvement but the managerial processes and worker skills that are required to effect change, that are the most important elements.

Managerial tools are needed to bring processes under control, to improve stability and most importantly in coating activities to increase predictability by reducing variation.

Imbalance in the development of shipbuilding technology and management systems between, design, pre-production activities, steel, outfit and coating work lead to "islands of automation" [8] this results in inherently unstable and non-predictable processes, that are difficult to balance and hence difficult to control and schedule effectively and give poor quality output and hence increased costs.

The importance of putting in place good management control systems to enable productivity improvements to be made with modest technology investments was comprehensively reviewed By Ohno and Sekiya [9] in 1990.

However what has become clear over the last 20 years is that despite all the work undertaken to bring both management and production processes under control to improve productivity is that somehow the coating process and often the coating department has been left behind and the recent challenges raised by the environmental regulations and the end-user focus on coatings has highlighted these failings in many yards around the world.

### 4. RECENT DEVELOPMENTS

In the last 17 years there have been no less than 20 pieces of regulation that have impacted in one form or another on how shipyards prepare steel and apply coatings. These have included:

- TBT ban
- VOC management
- Ballast tank coatings

Ballast water treatment technology  
Worker exposure limits  
Etc.

There have also been IACS guidelines as well as concerns raised by accelerated corrosion and the uses of higher tensile steels on vessels of all types but in particular Bulk Carriers.

This rate of change has tended to further de-stabilize the coating process at a time when the production tempo (TACT time) has been steadily improving to maintain competitiveness.

It has also meant that yards have had to continually adapt their processes at both pre-production and production to meet the needs of the changing regulatory environment.

Despite all these problems that have burdened the coating process in shipyards, over the last 10 years, There have been at least 4 major shipyard developments (in China, Korea, Europe and the USA) where inadequate consideration was given to the need to integrate the coating process into the facilities and build strategy and indeed in two of the yards major investments in steel throughput was not matched with any investment in coating facilities to deal with the increased output, resulting in severe bottlenecks and poor return on investment in terms of improved throughput.

Some shipyards have attempted to buy their way out of trouble by investment in new facilities, most notably paint cells or climate control. However this is an expensive route for yards to adopt as coating facilities are not cheap.

Often the management systems have also simply failed to get the best out of the facilities or indeed, the facilities were poorly served as a result of lack of investment in infrastructure (such as transport/materials handling to support the facilities).

## 5. TECHNOLOGY DEVELOPMENT

It is a fact that the description of the technology used in coatings given by Takezawa in 1972 is still a fairly accurate description of the coating processes today. So why is this the case? When in many other aspects of ship production technology from design to welding and from cable trays to the chemistry of the paints, technology has moved on considerably and has often left the processes of 40 years ago unrecognisable.

It should therefore be no mystery to understand why the coating process is causing difficulties today.

The penalties of the lack of control and stability in the coating process manifest themselves in quality, time and cost penalties [10].

In their paper [10] the authors reported a study of the leading US shipyards under the auspices of the National Shipbuilding Research Programme SP-3 Panel (Paint and Blast) and developed a benchmarking tool to enable them to compare best practice from Europe, Korea and America in both pre-production and production activities.

The work highlighted the need for new technologies and better management tools to manage the coating process and bring it under control. However most importantly it identified the lack of integration or consideration of coating activities when other processes are being planned for both facility development and the physical production process.

The work also highlighted the poor levels of understanding of other departments within the yard of the role of coatings and the increasingly high proportion of man-hours the coating process now absorbs out of the total shipbuilding man-hour budget.

The time penalties in many yards are significant as time lost at the bottleneck is time lost at the whole facility. This has been recently demonstrated during the discussions revolving around the introduction this year of the IMO Resolution MSC.215 (82), or the Performance standard for protective coatings for ballast tanks and double sided skin spaces.

The yards were very quick to realise the implications of the increased demand placed on them by this regulation, while owners were rightly concerned about the through life performance of their assets.

The cost penalties are not insignificant, apart from the investment in facilities the cost of re-work has at times come very close to bankrupting some yards. In recent years a number of yards (from around the world) have suffered huge cost over-runs resulting from poor control of the coating processes and the problems are being evidenced by increasing number of claims being settled both within the public eye and in private.

## 6. SOURCES OF INADEQUACY

The current status of the coating process within shipyards is unsatisfactory. The coating processes need to be made more predictable and brought under better control.

They also need to be properly integrated into the production strategy and the levels of re-work in the form of touch-up, burn damage etc. reduced to levels that are more in line with those achieved in steel and outfit work.

To suggest improvements, the nature of the failures/inadequacies must first be understood. The author has been fortunate to be involved with many shipyard projects related to the evaluation of the performance of coating activities. As a result of this work over the last 17 years the author has been able to

categories the inadequacies under the following headings:

- Design
  - Ship design
  - Facility design
- Coating selection
- Coating production technology
  - Surface preparation
  - Application
- Management systems
  - Quality
  - Training and education
  - Inspection
  - Environmental
  - Health and safety
  - Planning/Scheduling
  - Etc.
- Human issues

The focus of any improvement activity must be based on Quality (to minimise re-work and improve ease of production), Cost (man-hours) and Delivery (time).

In terms of quality this has to be reflected in both design and production, man-hours can only be controlled through good management systems and stable processes. While delivery in terms of coating activities is about productivity improvement, planning and scheduling and this is normally dictated by factors such as:

- Drying time
- Access time
- Over-coating intervals
- Transport time
- Re-work time

These three elements Q (quality), C (cost) and D (delivery) must be applied to all aspects of the inadequacies that arise so as to improve the performance of the coating activities in total and leave them in balance (no island of automation) with each other and with steel and outfit work.

It is also therefore important to standardise the processes, simplify the work and enable productivity increase through specialisation.

The challenge therefore is to:

- Identify the sources of the inadequacies
- Prioritise the benefits that can be gained by their management and subsequent elimination.
- Put in place the tools/culture to enable the inadequacies to be reduced over time.

The achieving of cultural change is the greatest barrier to productivity improvement and as how this can best be achieved is different from one company to the other, the remainder of this paper will focus on the technical

elements/tools and emerging technologies that a shipyard can use to help meet the challenges posed by the coating activities.

This however should not in any way indicate that a shipyard could achieve benefits of change without cultural change. As Ohno and Sekiya [11] declared:

*It is first necessary to create a sense of trust among all members of an organisation, from top to bottom. By this there will emerge "open communication" between the management and workers. Thus both will often have "common sharing of the objective" and "general knowing of the results". It is also necessary that the managers and workers have informal meetings on some occasions...*

Thus it is very important to create the right cultural environment to enable the challenges posed by the coating process to be tackled successfully.

## 7. IMPROVEMENTS

The experience of the author indicates that the critical factor to the longevity of the applied coating through life is its application during new build. The better the quality of the initial application, the longer the life of the coating in service. There are still occasionally problems with the paints themselves but often premature failure is caused by inadequacies in the coating process itself.

Taking each of the sources of inadequacy in turn, some possible solutions/techniques are proposed and some suggestions made as to how yards should modify their current practices to meet the future challenges.

### Material selection

Of course in shipbuilding the first challenge posed for coatings is that of material selection. The use of mild steels in one form or another for the hull structure and many other aspects of the vessel, and the placing of the vessel in an electrolyte (seawater) will lead to corrosion unless a barrier can be created between the Air, Metal, Cathode, Electrolyte (ACME).

The current chosen form of this barrier is a coating applied in a liquid form and allowed to cure.

### 7.1 DESIGN

Design has to be broken into two elements, the design of the ship itself and the design of the shipyard facilities for coating work

#### 7.1.1 Ship Design

Designers have long been accustomed to designing ships to meet the operational criteria and also to allow ease of production and outfit installation. However, little or no attention has been paid to design for corrosion prevention. In fact the tendency is to design in corrosion problems by:

Creating complex geometries that are difficult to prepare and coat and result in many edges that can corrode.

Creating tight spaces that are difficult to access and to ventilate/de-humidify

Creating tight spaces that cannot be easily coated using an airless spray gun but require build up coats to be applied by brush and roller.

Creating spaces that are subsequently difficult to repair and maintain

Having flat surfaces with no camber, tumble-home or rise of floor to assist with drainage

Making use of dissimilar metals

Poorly designing outfit items for installation, resulting in corrosion traps.

To overcome some of these problems the author suggests some possible solutions that may be considered at the design stage:

Conduct a shadow analysis of the compartment. This can be undertaken by a Computer Aided Design system (CAD). It would provide a measure of the difficulty to coat a compartment. If the CAD system can be used to provide the basic view a worker would see before he starts work on a surface then a flat surface (external hull) would have a shadow area of 0%, as the worker can see the complete surface. As the surface becomes more complex then the percentage of shadow areas (those the worker cannot see from his work position) increases, making the work harder. The aim of the designer therefore is to try and design spaces to reduce shadow areas. This will tend to result in alternative structural configurations such as corrugated sandwich panels [12] using laser welding. These structures have shown how complex internal spaces could be built using structural configurations that could offer 0% shadow.

Conduct an edge analysis as for shadow analysis by CAD. Stripe coating of edges is a very time consuming, labour intensive and hence costly exercise. Despite the availability of edge retentive coatings there is inadequate confidence to eliminate these from critical areas [13]. This is a key area for designers to consider and again could be helped by alternative structural configurations.

A material analysis should be conducted to see which elements of the design can be replaced by materials that offer greater resistance to corrosion, whether that is in the form of alternative steels or alternative materials for non-structural elements. For

example increasing use of composite pipes and other fittings.

Access analysis could also be made to ensure that the area to be coated can be worked on with minimum access requirements and provide good ventilation routes as well as ingress and egress for workers and equipment.

Total area coating analysis earlier in the design phase would allow better planning and scheduling activities. Some CAD systems have this capability but often there is a degree of inaccuracy or it provides only limited information.

Structural detail of individual components should be reviewed to make them easier to prepare and coat and hence aid longevity of coating through life.

### 7.1.2 Facility Design

Facility design for coatings often has less engineering thought and effort put into it than that which is applied to other steel and outfit facilities. Faced with the current levels of variability in the production process there is a need for flexibility in how the facilities can be used to allow for the variation. Yet all too often the layout or design of the facilities create bottleneck themselves for example by only having one route in and out or by providing zero capacity to deal with the known variation in the process.

As build times have steadily reduced, then the degree of surface preparation has been reduced in some yards, as the shop primer has been able to afford adequate weathering capability.

As vessel size/block size has steadily increased, many paint workshops have become too small to be efficient in their use.

Using single workshops for both preparation and coating also creates problems in terms of efficiency, cleaning and maintenance as well as good schedule control.

There is therefore a need for a more engineering based approach to the design and layout of coating facilities based around the present and future production technology.

## 7.2 COATING SELECTION

Paint selection methods have not changed for many years. Yards create a makers list and develop a standard generic specification to try and fix on a standard approach. However, there is a considerable reliance on the paint supplier to create the contract specific specification (often with some consultation with the ship owner).

This approach creates considerable problems for the shipyard. In general terms the shipyard scheme may state that for the ballast tanks the coating must be in line with the new IMO regulations and would be a multi-coat scheme of 320 $\mu$  nominal Dry Film Thickness (DFT), plus two stripe coats.

This is then issued to the paint suppliers to bid against. The paint supplier has now been provided with a target answer that must be met, and hence can now only compete on price.

Instead the shipyard should consider the important functional aspects of paint selection for each area or each task it will perform. For example in ballast tanks, drying time to gain access for the second coat is very important, so one of the functional requirements should be drying time at the appropriate DFT. Each vessel area should be reviewed in a similar manner and the key functional attributes required of the coating identified. In addition the criticality of the area to enable the yard to meet schedule can be further assessed so that the importance of each attribute can be determined.

Undertaking a paint specification assessment in this manner often provides very different results to the generic scheme approach and also offers real opportunities to integrate the coating scheme into the requirements of the build programme.

In the experience of the author, this fundamental change in approach can save yards in the region of 10-15% of total coating costs during new build.

It also allows consideration of the ideal time for scheme breaks and an assessment of coating progression on a compartment-by-compartment basis to maximise integration, improve quality and delivery time and hence reduce costs.

For many years the selection of shop primer has been the choice of the shipyard. This has allowed the yard to standardise its processes. There is evidence of the potential for think about standardising on other products. The emergence of the “universal primer” offers the potential for yards to select the best-fit anti-corrosive and use that exclusively on all contracts and hence move the selection for this away from the owner. A yard has much to gain from the selection of the right functional specification for a universal primer to enable integration with the production process.

### 7.3 COATING PRODUCTION TECHNOLOGY

The development of tools for surface preparation and application processes has lagged behind the rate of development of many other production technologies used in shipyards. The process of coating is still recognisable to any one who worked in a shipyard 20 - 30 years ago. This results from a lack of really large companies

involved in the marine coating tool development business sector, as it is a relatively small sector when compared to the needs of other industries. Thus developments in surface preparation methods and techniques as well as application methods have lagged as a result of inadequate investment. The use of this older technology in the increasing regulatory environment leads to waste, emissions, H&S issues that compound the fairly static productivity rates that have been achieved over that period of time, against a background of increasing areas to be coated (double hulls).

There is a real need to improve the technology associated with surface preparation and application to reduce labour costs, improve quality and reduce the time of work.

In addition there is a need to also improve inspection technology by using colour attributes in coatings [14,15]. These technologies are slowly emerging but do offer savings and better access for inspection.

### 7.4 MANAGEMENT SYSTEMS

Many studies carried out over the years have reinforced the basic finding of Deming [16] that management systems can account for up to 85% of all quality related problems. The coating process is no different.

There are a number of key processes that need to be properly managed ensure proper integration of the coating process into the production process, these are:

- Quality
- Training and education
- Inspection
- Environmental
- Planning/Scheduling

This is not an exhaustive list, but in the opinion of the author the items that are currently critical to the effective improvement of the coating process.

Quality in the form of minimising the man-hours used on re-work in the form of touch up and repair is critical. Many yards still find considerable interference between the coating process and the remainder of the production processes that often results in damage to the coatings. The cost of repair has been assessed and can be up to 14 times more costly than the initial application [17]. Thus it is very important for a yard to have a clear coating strategy that is properly integrated into the build strategy for the vessel.

Training and education is critically important, not just to improve the capability of the paint department but to raise awareness in other departments and trades of the limitations and capabilities of the coating process.

Inspection problems have been reviewed earlier, however there is clearly emerging a need for not only more objective systems of inspection, but also better data management of the records obtained for future reference by the vessel through its service life. The target life of 15 years being set for ballast tank coatings will tend to increase the inspection burden on the yard and this will result in further schedule and quality disruptions. It is important therefore that inspection systems are reviewed. It is likely that there will be an increased pressure on inspection and audit that will add an extra burden on the coating department. The obvious route to improving this process is to consider the use of computer-based tools for the collection of data records [18].

The physical process of inspection could be greatly assisted by improved designs with fewer shadow areas and reduced complex geometry as well as access.

Regulatory environment is constantly changing and yard personnel must be up to date with the regulations and assess the likely implications to the coating strategy, rather than try to make the existing procedures fit the regulations, they should be optimised/reviewed to take into account the new regulations and seek opportunities for competitive advantage.

Environmental challenges are on the increase in terms of emissions, overspray, and waste management. All these factors have added a burden to the paint process and have tended to be reviewed in a piecemeal manner rather than carefully considered within the coating strategy of the yard.

Planning and scheduling have been reviewed and the need for more predictability identified. For the present the need to consider the build strategy and the needs of the coating process are paramount to attain integration. However over time the key element will be to reduce variation and achieve higher degrees of predictability by a combination of improved, technology, systems and understanding.

#### 7.5 Human issues

Human issues are critical, coating work is perhaps the most dirty, the most dangerous and relatively poorly paid, thus ensuring workers are well motivated is important to the success of the required changes and developments. Without the people the problems will persist. There is no real evidence of automation being applied extensively in painting as there has been in welding and so the challenge of managing these personnel has to be considered carefully.

## 8. CONCLUSIONS

It has been shown that the coating process has not developed in step with other activities in a shipyard. As a result it has become the bottleneck and created an imbalance in the production process. This problem is aggravated by the fact the process experiences considerable variation.

To date a proper engineering approach to resolving these problems has always taken second place to steel and outfit technology and developments. However, this situation can no longer be sustained. The MSC.215 (82) marks a potential shift in the relative importance of the coating process at new building and what has been applied to ballast tanks, is likely to be applied to other critical areas.

Shipyards must rise to the challenge and do so in a structured and methodical way, this means looking at all aspects of the process, from design, production, product selection, management and cultural issues. If these challenges are not met head on, then the increased burden on the bottleneck, will limit the throughput of the yard reducing competitiveness.

Solutions have been proposed, some may readily be adopted while others may require some effort to put into place and gain acceptance. What is clear however is that there is much unused technology available to improve the performance of the coating process, the application must follow.

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## 10. AUTHORS' BIOGRAPHY

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