

SHIP PRODUCTION COMMITTEE
FACILITIES AND ENVIRONMENTAL EFFECTS
SURFACE PREPARATION AND COATINGS
DESIGN/PRODUCTION INTEGRATION
HUMAN RESOURCE INNOVATION
MARINE INDUSTRY STANDARDS
WELDING
INDUSTRIAL ENGINEERING
EDUCATION AND TRAINING

September 1989
NSRP 0310

THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

1989 Ship Production Symposium

Paper No. 19: A Systems Approach to Small Parts Painting

U.S. DEPARTMENT OF THE NAVY
CARDEROCK DIVISION,
NAVAL SURFACE WARFARE CENTER

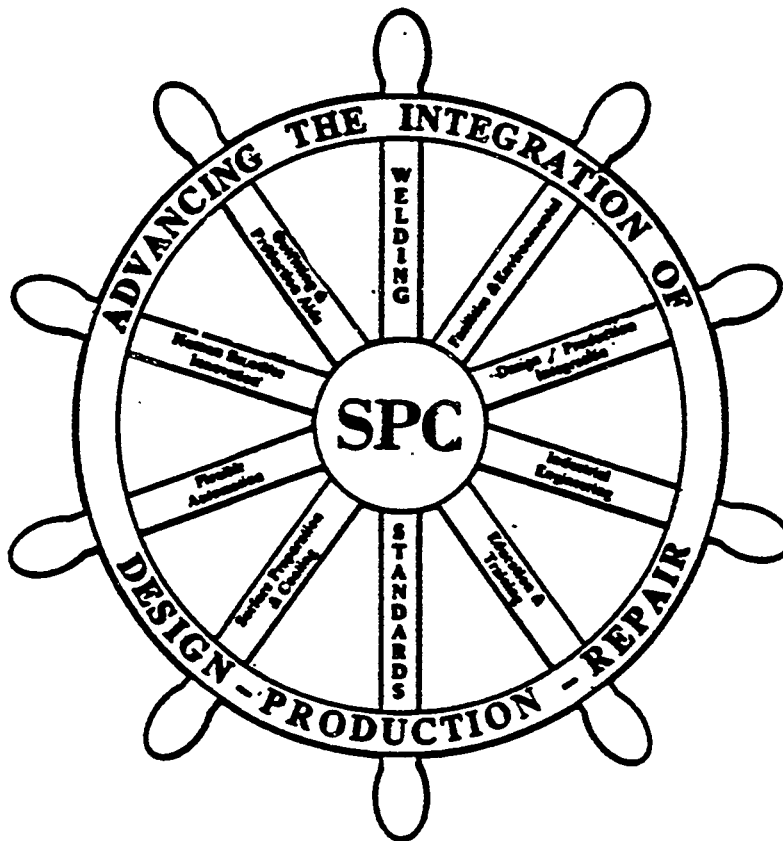
Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE SEP 1989		2. REPORT TYPE N/A		3. DATES COVERED -	
4. TITLE AND SUBTITLE The National Shipbuilding Research Program 1989 Ship Production Symposium Paper No. 19: A Systems Approach to Small Parts Painting				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Surface Warfare Center CD Code 2230 - Design Integration Tools Bldg 192 Room 128 9500 MacArthur Blvd Bethesda, MD 20817-5700				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT SAR	18. NUMBER OF PAGES 25	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

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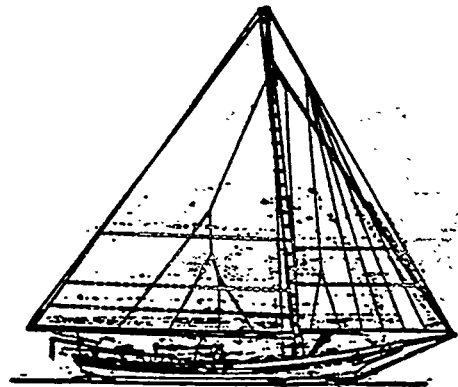
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THE NATIONAL SHIPBUILDING RESEARCH PROGRAM 1989 SHIP PRODUCTION SYMPOSIUM

NSRP
0310



SEPTEMBER 13-15, 1989
SHERATON NATIONAL
Arlington, Virginia



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A Systems Approach to Small Parts Painting

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ABSTRACT

Shipyard painting is most often viewed as pure ship construction operations, where the painting of the hull, deck, superstructure, and cargo spaces makes up the total effort and cost. This view may be justified when analyzing various trade production costs as parts of the total ship cost. However, parts preparation and painting costs are significant when looked at in summary as a new construction or repair contract sub-cost item.

Once addressed, the historical means and methods for small parts painting in shipyards appears to leave much room for improvement. What happens, then when a systems approach is applied to shipyard small parts painting? Can study techniques, analysis and design be adapted to facilitate painting systems which are cost effective for this industry? This paper attempts to answer these questions by presenting discussion of:

- 1 Manufacturing Concepts of Parts Painting
- 1 Use of Industrial Engineering Analysis
- 1 Systems Configurations
- 1 Systems Cost and Justification

FOREWORD

This feasibility study represents the reincarnation of a research project initiated several years earlier by Avondale Shipyards under the pervue of SNAME Panel O-23-1 (now SP-3), Surface preparation and Coatings. Avondale discontinued work on this project shortly after contract award. The objective of the earlier study was to establish the feasibility of automated painting of small parts, with emphasis on state-of-the-art automated material handling, blasting and coating equipment and systems.

The focus of the present study has been shifted to include the broader scope of all collateral parts painting operations, as well as coating process methodology. Automation is viewed not necessarily as an end, but rather one choice in a series of possibilities to maximize shop efficiency. The revised objective has therefore become the establishment of a true "Systems Approach" to small parts painting. The desired result is reduced shop painting costs through improved productivity and ultimately overall shipbuilding cost savings.

The economic significance of productivity improvements in shop painting should not be overlooked. Combined costs of painting small parts at NASSCO, averaged for the previous several contracts, are estimated to comprise nearly 20% of the entire ship painting budget.

The authors have intended this report to be highly user oriented. The target audience, then, is the Production Departments and specifically Paint Supervision. In addition, Shop Managers, Planners and other Staff Support personnel may glean useful information from the discussions herein. Hopefully, the ideas and recommendations put forth in this report, in whole or in part, will benefit the entire shipbuilding industry.

INTRODUCTION

Automation. . . . A high sounding term, a stock seller on Wall Street, a bright beacon to an undergraduate engineer, "tomorrowland" to the man on the street, and reality for manufacturing of the 1980s and 90s. It is here, it works and more often than not, it is expensive-very expensive. Therein lies the reason for addressing automated painting of small parts in a feasibility study.

- 1 What level of automation fits?

- What are the costs?
- Are the costs justifiable?
- IS there something else?

These are the questions; this study is intended to provide the answers. However, this project is not intended to address automation for painting small parts in a narrow context, but to develop a larger overview of maximizing shop painting operations. This study, therefore, also deals with planning, scheduling, handling and handling equipment, and rework reduction—in short, a Systems Approach to painting small parts. Some specific problems will be addressed and solutions will be proposed along with costs versus potential savings.

The study will utilize the latest painting technology from various sources and accepted Industrial Engineering practices to develop improved methods or systems and determine the feasibility of implementing these improvements in terms of capital investment, time, and ongoing costs.

To address automated painting of small parts in a shipbuilding/repair setting without a full comprehension of that setting would be a useless exercise. Since highly developed, sophisticated systems require equally balanced systems and methods for planning, scheduling, identifying and controlling materials and material movements, this must be a study in overview which ultimately works down to detailed possibilities.

This study will:

- IDENTIFY and CLASSIFY Groups and Families of Small Parts. [Group Technology]
- DETERMINE CURRENT SYSTEMS and METHODS In Use for Controlling and Processing Small Parts.
- DEVELOP PROPOSED IMPROVED SYSTEMS for Doing the Same: Planning, Scheduling, Handling, Mechanizing and Automating.
- ANALYZE the FEASIBILITY for Such Improvements.

STUDY PREPARATION

A feasibility study conducted with a view toward shipyard industry-wide benefits suggests several things concerning potential results:

- Certain results or data presented by the study may be applicable to one yard and not to another.
- Even where two yards may have exactly applicable situations, the view on economic justification may vary widely resulting in acceptance by the one and rejection by the other.
- Only partial data extracted from context could be applicable.

Therefore, at the outset, this study required scope and objectives which could permit generalization of results and, at the same time, maintain clear and specific details for ease of application and use. Moreover, a base of reference was needed. . . . actual small parts painting operations. Since the project did not permit a scope whereby multi-yards could be used as a basis, NASSCO'S more recent work contracts as well as the current contract for the Navy AOE-6 were selected.

If automation and the many other factors leading up to and/or supporting automation were not already present in the operations (and they were not), other bases were needed. Leading paint suppliers for coatings, equipment and shop systems would be approached along with production organizations outside the shipyard industry. This, then, formed the three position bases for study references.

- NASSCO AOE-6 Contract Planning: Actual Shipyard Requirements
- Most Current Equipment and Systems: New Sources Data
- Other Industry Users: Actual Operational Data

The generalized objectives of the study could be lost if the process started from a current condition (NASSCO operation) and worked through a single revised (improved system) condition, thus being rather heavily subjective. As a matter of fact, the capability to do exactly that was a most desired result of the study; however, it had to be applicable to essentially any shipbuilding or repair yard, wholly or in part. Therefore, the study had to work from several perspectives. simultaneously; gathering data from the three study bases and analyzing the applications to both specific NASSCO operations on one hand and a valuable industry-wide potential on the other. Thus, the study was initiated on several fronts.

A further question arose in completing the preparations. How could data best be compiled concerning current small parts painting operating practices? Ultimately, some quantitative analyses would be made in order to deal with economic justification, and the industrial engineering method filled this requirement. The application of this technology is discussed in a later section.

These were guidelines for the work of this study:

- A Scope Permitting Generalized Results Supported By Sufficient Details.
- A Three-Point Base of Reference.
- The Industrial Engineering Method.

SMALL PARTS PAINTING: A Manufacturing Operation

Let us place small parts painting into the context of building a ship. When a part has been fabricated, it requires painting; and when a weldment (sub-assembly/assembly) has been completed, it requires painting. Some purchased parts require painting other than supplied by the vendor. Therefore, small parts painting is technically an operation within a continuum for the completion of a part prior to the next order of assembly.

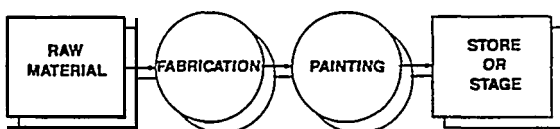
This relationship can be seen in the Classic Manufacturing Shop, where work flows through fabrication operations to paint to inventory or shipping. Thus, a yard may ask if paint operations shouldn't be contiguous to other fabrication source operations, What does this do to transportation costs, control costs, damage or other factors?

Should painting operations be self-contained and for what reasons? Is this justified? It may be that a highly cost-effective automated or semi-automated Paint Shop should be self-contained and centralized due to decentralized fabrication and receiving sources (in the case of purchased items).

Nevertheless, painting is difficult to define as an "independent operation" for small parts when viewed as part of a continuing process flow.

Parts Painting is not just some unrelated operation...

IT IS PART OF THE MANUFACTURING PROCESS.



Once painted, the part can be stored, even in bad weather, for the next weld or assembly operation.

Painting may be an independent operation for many reasons from yard to yard. These reasons should be analyzed.

- Painting is a *SEPARATE TRADE*, a *SEPARATE DEPARTMENT*.
- Mixing painting with other fabrication is not desired.
- Air pollution controls, requirements, etc. present complications.

These may be some concerns and there are others.

To be contiguous, the parts painting operation does not have to be housed with the afore occurring fabrication operations, however, the flow relationship should be evaluated. Is the cost to move to and through the paint operation reasonable or are there cost effective alternatives? This study offers" some methods for evaluating the problem.

PLANNING FOR MANUFACTURE

If a yard wishes to advance the cause of small parts painting through automation or semi-automation, should it go for the expenditure, train some people and turn the paint group loose? Hard-Iy! Well, it might just work for the yard that has perfect flow, perfect planning and scheduling, and perfect methodization for small parts painting, but is any yard at this point?

The assumption is that most yards need to get through an evaluation of the current state of their "Planning for Manufacture" as relates to small parts. Problems exist whether the painting operations are centralized or decentralized.

PLANNING FOR MANUFACTURE

- Part Operation Planning
- Part Operation Scheduling
- In-Process Control
- Finish Part Storage
- Proper Identification

These activities need to be perfected as a foundation for a good manual paint operation as well as the most automated one. Therefore, let us examine each in some detail.

Planning: Either the part fabrication planner must know paint planning as well as fabrication planning, or a fabrication planner and paint planner must work side by side. A shop routing card saying "paint" or "paint green" just is not enough.

What surface preparation is required? What paint system and which coats are required? Are there special instructions? What is the post-paint routing? These questions, properly answered, are the foundation of any good planning practice.

Scheduling This goes hand in hand with planning. Whether your yard works to "Just in Time" or "Inventory" or, as is common in most cases, a combined approach, you should be clear as to a finish date and, therefore, the start date. The latter is where each yard tends to develop its own best method. When to start a part, based upon a given finish date, has to do with: How long the fabrication cycle takes; how much level loading of labor, machines and processes are required; and what particular bottle necks or limiting operations exist.

This study cannot deal with these issues in detail, but it is most important to give recognition to the essential nature of good scheduling.

Parts painting schedules are derivatives of parts fabrication scheduling. It's fair to say, "Who gets to schedule parts painting? The parts come, always late, and you blast and paint them as best and fast as you can!" This study tends to find agreement that parts painting by nature is a vassal to the fabrication operation, however, all the more reason for the dual, simultaneous planning for fabrication and paint. There is reason to look at communication across the related activities (yard trades) to test the strength of these foundations.

in-Process Control: This is an individual function with each yard and each shop within a yard. There are many ways to achieve this control. The important point in this study is simply that it be done, be re-evaluated, and upgraded as necessary.

The key to any flow lane, any shop, any process is "through-flow". Handling and re-handling does not improve or change the value of a part... never did and likely never will. The physical layout and facilities relationships of a good small parts painting operation are covered later. However, the best

through-flow layouts tend to yield the easiest In Process Control Systems and procedures (and least in process delays).

Storage, Staging and Routing What good does it do a yard to perform all that precedes this point to perfection and not do well here? The ultimate operation for the properly fabricated and painted part is the proper and safe location for that item to be used at the next level of assembly.

Evaluate this function as a key to analyzing your state of planning for manufacture.

Identification: It is all too easy for a yard to expend costly labor hunting, correcting, repainting or remaking misidentified parts. Most yards are not having problems with original identification, this is covered on the prints. The real problem is the physical identification of the part(s), which has to do with how (The Method) and what data need be included. Will Part Number do or is next assembly identification required as well? The answer will generally depend on the coding system employed by design engineering. Both questions are important.

There are many supporting techniques for good manufacturing planning. Quantification of process time and man-hours is of the utmost importance. Operation overview through flow process and operation analysis along with some other industrial Engineering Methods deserve some review and are discussed later.

A Thru-Put Technique

If a yard can schedule parts painting as the last fabrication operation as suggested previously, a delivery date can be determined and a specific priority schedule can be followed through the painting cycle. If a "first-in/first-out" policy is the norm, some kind of priority-setting is required. Here is a simple thru-put technique which requires order and discipline to set up and maintain but will offer a good plan for man-loading action.

Desired things to know:

- (1) Delivery Date or need date. Where this is not predetermined, set this date from receipt plus three days or five days...whatever fits.
- (2) Available Date or date received. Make certain to manifest all parts received daily. Tag the parts with a brightly colored tag.

- 3) Process Time Available is the difference between (1) and (2). If Parts are late or will be late when complete even if expedited, these are the number one priority.
- (4) Establish a Measurable Unit (M.U.). This may be a large or medium part like a foundation or large valve. It is also a quantity of small parts, maybe 25 hangers.
- (5) Determine a Rate Per M.U. in man-hours. How many man hours to blast? To paint? (Include all handling and set-up time).

Now, on a daily basis record the date received, the delivery date required and the number of M.U.s for every work item (along with proper identification, work item numbers, etc.) Then, by day or week all M.U.s can be summed and the product of (M.U.) x (RATE) can be determined. If a small computer is available, a D-base or Lotus 1-2-3 spread sheet can be used. The computer is not, however, necessary.

A sample analysis for a six period thru-put (Figure 1) shows how simple this can be.

The leveling analysis, which deals with the over demand or under demand for a given work period, is most important (Figure 2). Since the mean (man-hours) for six periods will vary with the production requirement, management must decide whether to vary the manpower provided from period to period or to move the work forward and backward in order to keep a fixed crew size over the six periods.

The key questions are:

1. Can manpower be easily and efficiently moved from small parts painting to other operations?
2. Is the work available for forward moves in schedule?
3. Can some work be moved backward in schedule? Which work?

in the combining of periods for further level load analysis (Figure 3), it can be seen that two levels exist with a mean difference of almost 250 man-hours (243.75). This strongly directs management to look for work "to fill" or manpower to move tooth-er operations after period four.

THE INDUSTRIAL ENGINEERING METHOD

The Industrial Engineering Method, like all technology of the twentieth century, has simple beginnings, a rapid history of development, and a high-tech presence. Simple and more basic tools were needed for this study and, fortunately, these are easy to learn and apply no matter the size or complexity of yard operations under study.

The Flow Process Chart can be the foundation for analyzing a small parts painting operation (or any yard operation for that matter). A sample from our study is shown here in Figure 4.

This form is classic and the symbols have been standardized through years of practice. The chart can be used for actual studies where a person can observe what is being done and record the work, the time it takes, the distances involved, and notations, therefore establishing basic data (1), (2).

PERIOD	1	2	3	4	5	6
M.U.* Count	1000	1500	1250	2000	900	1000
RATE/M.U.**	.5	.5	.5	.5	.5	.5
Manhours	500	750	625	1000	450	500
Mean***	637.5	637.5	637.5	637.5	637.5	637.5
Leveling	+137.5	-112.5	+12.5	-362.5	-187.5	+137.5
COMBINED PERIODS	A			B		
	1	2	3	4	5	6
Mean M—Hrs (A)	718.75	718.75	718.75	718.75		
Leveling (A)	+218.75	-31.25	+93.75	-281.25		
Mean M—Hrs (B)					475.0	475.0
Leveling (B)					-25.0	+25.0
* M.U. is Measured Unit ** Manhours/M.U. *** Average for 6 Periods						

Figure 1

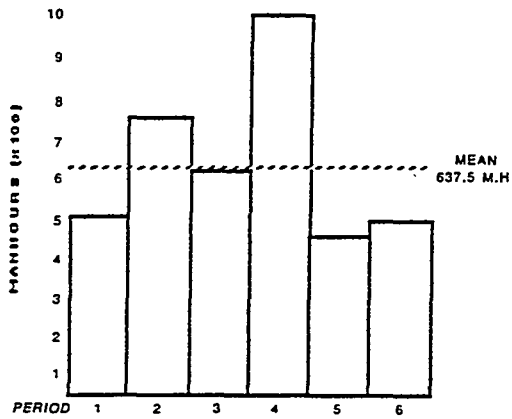


Figure 2

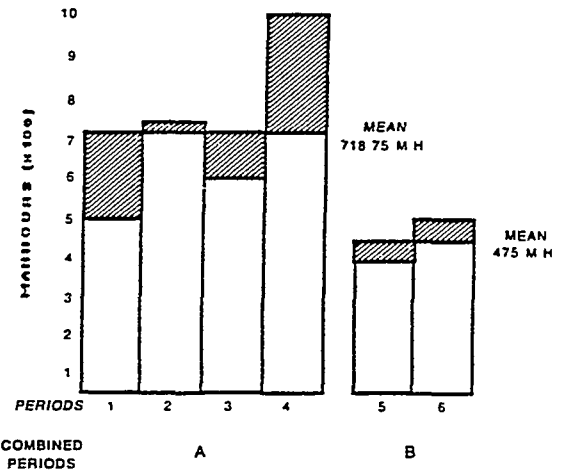
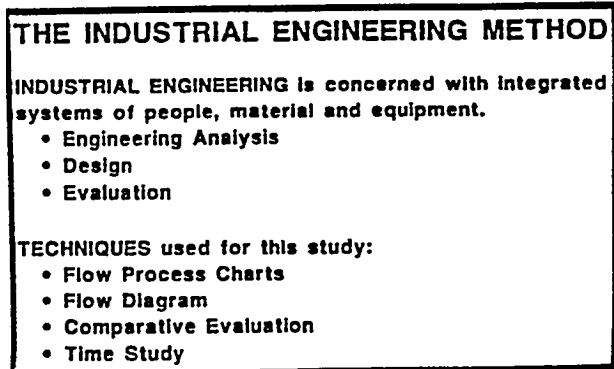


Figure 3

FLOW PROCESS CHART

SUBJECT: VENT DUCT/STEEL - BLAST & PAINT 4' LG X 8" DIA. (LOT SIZE) - ONE PIECE PER PALLET CHART BEGINS: SHEETMETAL STORAGE CHART ENDS: POST-PAINT STORAGE (AREA 'A')						
DESCRIPTION	SYMBOLS	DISTANCE MOVED IN FEET	UNIT OPER TIME IN HOURS	UNIT TRANS TIME IN HOURS	DELAY TIME IN HOURS	STORAGE TIME IN HOURS
PER SHOPCARD, MOVE PALLET FROM S/M STG TO AREA 'A'	○ → □ ▽	1500		.31		
MAT'L REC'D BY MAT'L HANDLER AND PAINT DEPT.	● → □ ▽		.08			
MOVE FROM AREA 'A' TO BLAST	○ → □ ▽	800		.20		
BLAST STORAGE	○ → □ ▽					
MOVE TO PARTS AREA OF BLAST	○ → □ ▽	40		.10		1 SHIFT - 3 DAYS
BLAST (MANUAL)	● → □ ▽		.78			
MOVE TO STAGING AREA	○ → □ ▽	50		.10		
BLOW-OFF MATERIAL	● → □ ▽		.02			
INSPEC"	○ → □ ▽		.03	.10		
MOVE TO PAINT AREA STORAGE	○ → □ ▽	100				
PAINT STORAGE	○ → □ ▽					MINS - 2 SHIFTS
I.D. AND MARK COATING	● → □ ▽		.08			
INSPECTION (NAVY)	○ → □ ▽		.03		(4)	
MOVE TO PAINT WORK STATION	○ → □ ▽	40		.10		
PAINT (PRIME ONLY)	● → □ ▽		.79		(DRY) 4.0	
INSPECT	○ → □ ▽		.03			
REMOVE AND PLACE ON PALLET	● → □ ▽		.02			
MOVE TO AREA 'A'	○ → □ ▽	40		.10		
STORAGE PRIOR TO SHIPPING	○ → □ ▽					1 SHIFT - DAYS

Figure 4



The chart can also be used in analyzing a proposed operation using the basic data established by previous study observations. Final procedures or instructions for a new operating plan can be presented on the chart, which is easy to read and understand.

The Flow Diagram is the product of the flow process study(s).

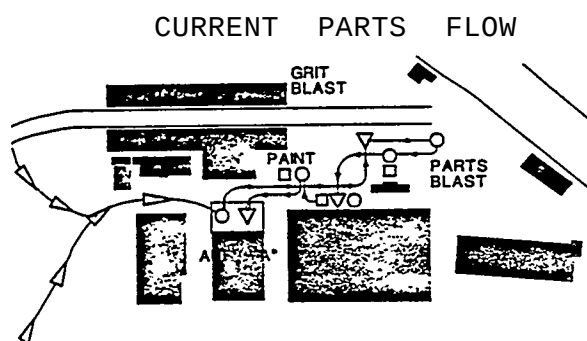


Figure 5

The use of a scale plan view of the physical area is recommended for analysis as well as presentation to management. The "before" and "after" effect can be dramatic since movements and distances are vivid. Often it is necessary to use large scale sizes (and therefore print sizes) for this work when there is great detail within an area or great distances to show.

Flow Symbols and a recommended use are important. Make certain that a common understanding exists as to what each symbol is to represent. Define this before any studies are started and then maintain these definitions throughout the project.

Not all activities are necessarily identified above. However, each and every significant activity should be assigned a standard symbol for consistency of data accumulation and evaluation.

These accepted uses of the symbols are recommended.

SYMBOL	GENERAL REPRESENTATION	FOR THIS FEASIBILITY STUDY
○	OPERATION	PAINTING OPERATIONS BLASTING OPERATIONS SET-UP OPERATIONS MANUAL HANDLING
◻	TRANSPORTATION	INTRA-AREA MOVEMENT INTER-AREA MOVEMENT
▽	STORE	PARTS OR MAT'L'S HELD FOR PROCESSING OR DELIVERY
D	DELAY	DRYING TIME CURING TIME ANY WAITING TIME
□	INSPECT	CALL INSPECTOR WAIT FOR INSPECTOR INSPECT PARTS OR MAT'L'S

Figure 6

Time Values are important to the ultimate study accomplishments. Time to perform work is the direct labor cost of the painting or related activity and idle time is a probable non-productive cost. The use of a wrist watch with a sweep second hand is recommended in these kinds of Flow Process Chart studies. A minute is an acceptable level of accuracy although .25 minute intervals may be desired and can be easily read and recorded. Where something more critical is desired the time study watch or decimal stop watch will be needed.

When a number of studies are made (this will generally be the case) the data must be correlated. This is most easily done by a spread sheet recap. Accumulate all like elemental work time values, delays, distances, etc. and arrive at unit time values, such as: time per piece, square foot, 100 feet moved.

Comparative Evaluation, most popularly called the Before and After, has to be the ultimate objective of the Industrial Engineering Method. This forms the bases for action, direction, and justification.

Where two or more existing or proposed small parts painting operations or systems can be flow analyzed and timed, total times and total distances and all other appropriate data can be compared and a total cost for one possibility versus another (or others) established. This then determines the levels of expected improvement, payoff, return on investment, or whatever basis a yard may use to justify expense and/or capital funding.

COMPARATIVE ANALYSIS

- BEFORE AND AFTER
- THIS VERSES THAT
- SYSTEMATIC ANALYSIS OF EXISTING AND/OR SUGGESTED CONDITIONS
- RELATIVE EVALUATION OF ELEMENTS AS WELL AS TOTAL EFFECTS

Subsequent sections will include some actual applications of the Industrial Engineering Method just discussed.

SMALL PARTS IDENTIFICATION AND CLASSIFICATION

The first order of business for the project was identification and classification of small parts to be included in the study. This step would, in effect, define "small parts" and provide a scope for all further studies and analyses to be conducted. Theoretically, any item painted prior to block (module) or unit assembly, or prior to on-board installation, could be considered a painted "part". There are thousands of such items on a typical large hull.

A reasonable starting point for small parts definition would be to include all, or nearly all, items traditionally painted in NASSCO's Main Paint Area (an open air "shop") or any "satellite" paint area adjacent to the fabrication shops. Points of origin (NASSCO shops, outside vendors, etc.) for these items are significant for sections of the study related to planning, scheduling, routing and handling.

Next, a grouping by size and weight would be required to further narrow the parts scope to a meaningful range for the project. The maximum part size chosen was 60" X 60" X 24" to permit inclusion of a majority of the steel angle foundations commonly encountered. This upper limit size corresponds to a weight of several hundred pounds or more and would require a fork lift and/or small crane for handling. The smallest part could be a 2" x 3" staple weighing a fraction of a pound.

In addition to parts, raw stock shapes (angles, flat, bar, pipe, etc.) to be used in parts fabrication or on-board outfitting, were also included in the study since much of this material is primed in the Main Paint Area. Raw stock varies in cross sectional dimensions and weight and is generally handled in twenty foot lengths.

A parts classification list was developed using NASSCO's AOE-6 contract as a point of reference. Parts were grouped by type, indicating origin, and an approximate quantity was noted. From this list, thirteen items were selected as best representatives to form the "Typical Parts List" used as a basis for further study. (See Appendix 2 for List).

A further approach to classification would be to examine parts in the context of their respective coating requirements. Parts can be grouped by the type of coating and extent of the system to be applied at the shop painting stage. For example, some parts may receive primer only, others one or more intermediate coats, and still others a full system including topcoats. Parts receiving identical coatings can then be grouped together for purposes of surface preparation and painting. Typical coating systems used as a basis for this study are those specified by the NAVY for AOE-6. (Figure 7)

At this point, a question may arise concerning how to determine the extent of the coating system to be applied at the shop painting stage. Is it best to apply primer only, a full system, or somewhere in between? This clearly is a production planning issue and should be given considerable attention early in the planning process with strong input from the Paint Department.

Several factors will need to be considered and analyzed, however the bottom line is the overall cost of shop painting vs. painting at other construction stages. On the surface, it would appear shop painting is clearly most cost-efficient, since an industry rule-of-thumb says on-board labor costs are generally two to three times higher than shop labor costs for identical work. However, when inserting onboard and on-block paint rework costs into the equation, the picture may change significantly.

Consider the amount of potential coating damage encountered after a part leaves the Paint Shop: Transportation and handling damage; environmental damage from the elements; dirt, grease and oil contamination; and probably most significant is the damage caused during installation, either by welding or installation tools. In addition, ECNs, PCNs or missed schedules frequently create hotwork damage long after part installation.

When these paint rework costs can be accurately determined and analyzed, they may make a strong case for applying only prime or intermediate coats in the shop and all finish coats as late as on-board schedules will allow. Certainly, this analysis should

COAT No.	LOCATION		
	EXTERIOR TOPSIDES	INTERIOR, DRY SPACE	INTERIOR, WET SPACE
1	INORGANIC ZINC SILICATE	MIL-P-24441 EPOXY (F-150)	DOO.P23236 EPOXY
2	MIL-P-24441 EPOXY (F-151)	DOD-C-24596 W.B. FINISH	DOD-P-23236 EPOXY
3	TTE-490: SILICONE ALKYD	DOD.C-24596 W.B. FINISH	—
4	TTE-490: SILICONE ALKYD	—	—

WATER BASED

Figure 7

be made on a case basis for individual outfitting items or families of parts. Where coating damage is expected to be minimal or non-existent (such as on machinery), a full-system shop application would likely be justified. Finally, all attempts should be made to reduce on-board paint rework to a bare minimum.

In passing, we mention a technique that we consider the best methodology for properly setting up a classification system of parts where numbers, variables, and computer codification are involved. This methodology is broadly known as Group Technology and is covered in a forthcoming SP-1 Project Report. An example is shown in Figure 8.

CURRENT METHODS

Small parts painting procedures and methods have remained virtually unchanged over NASSCO's long history of building ships. This aspect of operations has been, for one reason or another, basically overlooked whenever facility improvements were considered. Possibly, parts painting is the victim of the adage: "If it works, don't fix it", or "Out of sight, out of mind" since the parts area is set off in a remote corner of the shipyard. Whatever the reason, we think it will be obvious from this discussion of NASSCO's current parts painting methods that there is plenty of room for improvement. More than likely, this will be the situation at many other shipyards.

San Diego is "blessed" with a very mild and dry climate. So NASSCO, unlike most yards, is in the unique position of being able to perform much of the blast and paint operation in the open air, without the need for enclosures or even covered areas. The few rainy days that do occur in the winter may present a minor problem in the form of schedule delays. This seemingly ideal situation may, however, be a mixed blessing. Having a large, undelineated area available for parts blasting and painting can foster inefficient use of that space, while the physical limits inherent in a building or enclosure usually encourage a close look at flow and efficiency.

A few comments regarding parts scheduling are appropriate at this point. This subject was discussed in a previous section, "Planning for Manufacture". Scheduling of material into the paint/blast shop is virtually nonexistent. That is to say the fabrication shops that supply parts to be painted cannot adequately predict, in advance, when those parts will be completed and ready to ship. Therefore, blast and paint supervision is forced into a reactive mode for manpower and material planning on a daily basis. Level-loading of shop work and personnel becomes nearly impossible, impacting overall departmental scheduling and budgeting performance.

NASSCO's small parts blast and paint areas are separate and adjacent, with the paint area located upwind from blasting to avoid dust contamination

GROUP TECHNOLOGY:* A technique which identifies and categorizes parts based upon the "sameness" or similarities of physical specifications or processes in order to improve the manufacturing economics of those parts.				
Referring to earlier comments of this section, a GT matrix of classification (and possible codifications) would be as follows:				
PHYSICAL SIZE	PRIME	INTERMEDIATE	FULL SYSTEM	SPECIAL
Small	1	12	13	14
Medium	21	22	23	24
Large	31	32	33	34
* This is not a direct quotation but rather a combination of many definition in order to emphasize GT application in this study. Codes may be added for zone storage location, etc.				

Figure 8

(see Figure 5). The two areas are operated independently by shop General Foremen under the overall jurisdiction of a Blast/Paint Manager. Daily work planning is the activity common to both, since coordination is required to ensure that blasted parts are painted quickly.

Each area requires a staging zone for incoming and outgoing material. All parts arrive and leave by forklift on pallets or in baskets. Forklifts are also used for transporting and handling (positioning, turning, etc.) material between work stations, so a high level of forklift activity is usually the norm. A "mule train" transportation system consisting of several rolling carts pulled by a single forklift was created several years ago to alleviate the problem. This system has proven to be a good solution for improving the efficiency of NASSCO's forklift-dependent transportation operations.

Parts arriving in the blast receiving area are logged in and stored to await blast (several hours to several days). No formal prioritization system presently exists, so the informal "first in, last out", or "whoever screams the loudest gets their's first" systems are usually in effect. As previously mentioned, most blasting is performed manually, outside, and on pallets at ground level with at least one turning operation required per piece. Steel grit is used where possible and reclaimed/recycled via brooms, shovels, sweepers, 'bobcats' and a collector/classifier. An automatic airless table blast machine and wheelabrator are also available for specialized blasting operations.

When blasting is completed, parts are moved (via forklift) to a blow-down/inspection station to remove residual dust in preparation for painting.

The first step in the paint operation is a check of the part identification and determination of the coating requirements. If precise instruction do not accompany the work piece, labor-consuming research of engineering drawings and the ship's paint schedule is necessary prior to coating. Painting is accomplished on pallets at ground level, or parts are arranged on worktables or racks and usually require turning for complete coverage. Portable air spray or airless equipment is used as appropriate. Parts are dried in place between applications or coats, creating an obvious bottleneck in the system, especially with long dry time epoxy coatings.

Following the coating and drying processes, parts are inspected and then moved, again by forklift, to a shipping/holding area to await transportation to a storage or installation location.

The procedures described above apply to NASSCO's central paint area or shop. Painting is also performed in satellite facilities adjacent to fabrication shops—most notably the sheetmetal and machine shops. These are small, open air areas for painting (no blasting), operating similar to the main shop. The use of these satellites reduces transportation to and congestion in the main shop.

Study Conditions, Method and Results

Flow process studies were conducted of NASSCO's small parts operations to obtain time and cost values for the current situation. The data was accumulated in work elements, averaged for SLUs (Single Load Units) of 3' x 3' to 5' x 5' mean, and summarized for comparisons to alternative proposals.

The time values were recapped, summed and evaluated with respect to various types of work performed: handling, blasting, painting, etc. Idle time which could not be specifically related to personal needs, work or other factors was ignored.

When work elements were developed per average SLU, only specific work values were included. Fatigue, rest and personal time were added to the work cycle as a standard allowance. Total study time was grouped (in this case all time for both Blast and Paint was treated as the data universe) and a distribution set by percentage was taken.

Peterson Builders, Inc. of Sturgeon Bay, Wisconsin conducted in SP-3 Project, the Economics of Shipyard Painting (2), and have developed work distribution percentages that greatly compare to those developed by NASSCO. A comparison is made for reference and illustration. (Figure 9)

When the data is grouped further into five major sub-divisions the following results:

This grouping graphically points out the importance of performing methods and equipment analysis for all work factors, and not subjective work factors (blast and paint) alone. It follows that blast and paint productivity will rise if blast and paint operation time, as a function of total time, is increased. Doubling the latter would double productivity (or reduce by one half the crew size). Can setup and teardown time be reduced? The same for other groups?

As the summary and bar chart shows (Figure 11), the data is quite comparative and suggests that small parts blasting and painting operations may be relative throughout shipyards.

PERCENT OF TOTAL TIME			
OPERATION	PBI BLASTING	PBI PAINTING	NASSCO COMBINED
1. Blast or Paint	20.6	21.6	18.9
2. Setup and Teardown Equipment	27.4	18.6	24.3
3. Cleanup	4.9	5.2	6.1
4. Instructions	2.7	5.2	5.5
5. Prepare Surface (Other than Blasting)	1.3	3.6	4.5
6. Setup and Teardown (Operation)	5.4	1.5	3.2
7. Taping/Untaping	7.6	12.4	10.1
8. Remove Spent Abrasive	16.6	—	*
9. Load/Unload Parts	—	13.4	14.4
10. Mix Paint	—	4.1	3.0
11. Rotate Parts	—	2.6	*
12. Get Tools	—	1.5	1.3
13. Rest and Personal	13.5	10.3	8.7
	100.0	100.0	100.0

* Not categorized in NASSCO study

Figure 9

PERCENT OF TOTAL TIME			
OPERATION	PBI BLASTING	PBI PAINTING	NASSCO COMBINED
Blast or Paint	20.6	21.6	18.9
Setup and Teardown	32.8	20.1	27.5
Supporting Operations	16.6	32.5	27.5
Miscellaneous Work	16.5	15.5	17.4
Rest and Personal	13.5	10.3	8.7
	100.0	100.0	100.0

Figure 10

WORK DISTRIBUTION

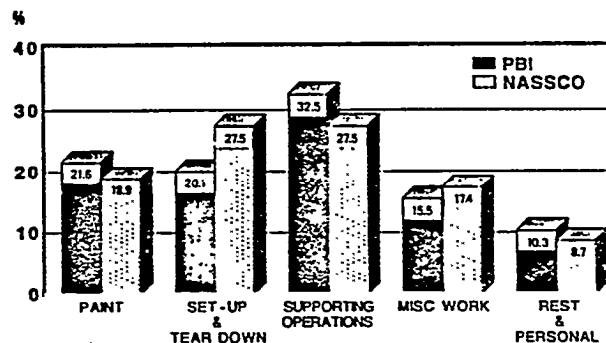


Figure 11

Field Studies:

Small Parts Painting in other Industries

Field surveys and interviews were conducted to determine what other industries are doing. The sources were:

- Air Frame Manufacturer
- Mobile Equipment Manufacturer
- Oil Tool and Equipment Manufacturer
- Medium Size Shipyard
- Steam Turbine Manufacturer
- Large Sheet Metal Job Shop.

While each source had widely varying conditions of material and surface preparation requirements as well as paint coating and curing, one inevitable factor ran throughout. ..they all used conveyors. Overhead conveyors were prevalent, but floor type were used where more desirable. Floor types have a disadvantage of "fouling" due to foreign items getting in the drive. The more sophisticated systems used switchable conveyor trackage and several used power and push (manual) sections. These features depend upon the needs and variations of the system.

What Do Conveyors Do?

Handling (direct cost) is sharply reduced for a rather reasonable cost. This is not meant to say that automated paint booths are inexpensive, but ordinary conveyors are far less expensive. It should be noted that only one source used automated paint application and that was, surprisingly, the job shop. Economics is addressed later in the report.

Handling was found to be 144% of the blast and paint work cycles from the NASSCO studies. This does not include the forklift handling caused by a lack of thru-flow that a well planned mechanized system can eliminate. Equipment setup and teardown was 24.3%. since the work was not "moved thru" but rather the equipment "moved to" the work.

It appeared that the genius of the conveyor would be the center piece of any system intended to decrease parts handling and equipment setup. The sum of handling and setup in the NASSCO studies was 38.7% and it was estimated, based upon the experience of others, that this could be reduced to 10% to 15%. These are reasons for targeting mechanization prior to automation.

In most systems where cold rolled or galvanized steel is being painted the preparation is chemical washing, however, shipbuilding generally uses blasting. Paint booths were single (one man painting both sides of a part) or double (two booths facing opposite each other and two men paint opposite part sides). Larger, flat parts work best with the latter.

From Current Methods To Revised Methods

The study developed a focal point and ironically it was the non-painting work, rather than specific painting of small parts that took the spotlight.

SOME NON-PAINTING AND PREPARATION COSTS ARE...

1 Transportation To and From The Facility
1 Handling Within The Facility
1 Identification
1 Scheduling

THESE CAN EQUAL OR EXCEED THE PAINTING AND PREPARATION COSTS.

To dramatize this we asked painting supervisors the following:

IF YOUR PAINTER HAS...

1 The Right paint
2 The Right Equipment
1 Proper Support
2 The Right Part

HOW LONG DOES IT TAKE TO PAINT A 5'X5' PANEL?
HOW MUCH TIME DID ALL THE REST OF THE WORK
AND SUPPORT TAKE TO PAINT THE 5'X5' PANEL?

The answers varied between two minutes and five minutes to perform the actual painting and an hour to two hours to perform all the supporting work. The exact numbers will vary greatly from yard to yard. However, it is safe to say that 75% to 90% of all the work is non-painting.

This new perspective therefore weighed heavily on the direction that the project should take and resulted in the decision to look at a *Systems Approach* to small parts painting. Analyses of the three levels of automation, semi-automation and mechanization were developed. A fourth and somewhat separate level, that of semi-mechanization, is included so that a more complete economic range of systems are represented. The latter will be treated as an appendage to the main three levels which have "mover" systems in common. (See Appendix 1)

THE IDEAL SYSTEM (MODEL)

Let us start at the beginning with the Ideal System. Many managers and engineers might argue that since nothing in ship production is ideal, such an approach is a waste of time and effort. There are always restrictions: physical, economic, time, facility or equipment life span, and others. This is most true. However, if a system attempted for production and cost improvement reasons is started with all restrictions as a forefront criteria, two important possibilities are sacrificed. First, the ideal system allows for the 100% potential level, never attainable, but measurable (The ultimate system can be measured against the ideal). Second, the forefront objectives should be stated and constantly pursued throughout the proposal development and evaluated with respect to each restriction as each comes into play. This permits separate, justified decisions relative to each restriction rather than a predefined or implied acceptance of the restrictions at the outset.

For example, if an ideal system is developed and given a rating of 100% based upon all attainable objectives and carries an implementation cost estimate of \$1,000,000, another more economic proposal could be related to it. It is possible that 50% of all attainable objectives might cost \$250,000, a considerable difference in cost. The ideal permits comparison in a dramatic way and thus a relative merit can be easily seen between proposals.

The ideal small parts paint system for a representative yard would contain the following:

- A mover system: an overhead conveyor.
- A blasting system.

- A prime and paint booth.
- A drying system: air or force.
- A curing zone.

The basic configuration to this system is shown in Figure 12.

IDEAL BLAST, PRIME & PAINT LINE

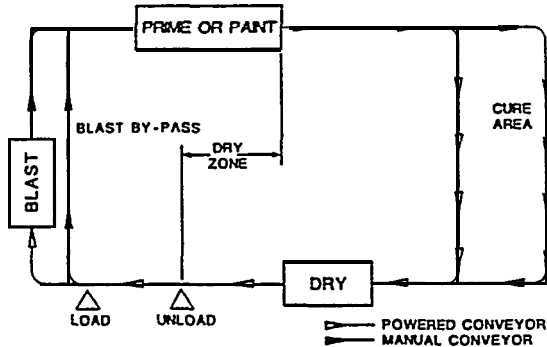


Figure 12

The ultimate possibilities for the system are virtually unlimited and this study recognizes that condition, however, certain narrow assumptions were required in order to focus upon specific issues. Moreover, each yard will be required to do methodization, and costs should be included for this work when preparing a proposal.

The Ideal System shown in Figure 12 operates as follows:

1. The parts are loaded to the overhead conveyor at the load station. Some fixturing in a "Christmas Tree" fashion is required for smaller parts, but medium and larger parts are hung individually.
2. Parts proceed via the conveyor line through the blast station. All surfaces are blasted to the required condition. Since blast may require three to five times the paint cycle time, some variation in the line is necessary. A five minute blast cycle per SLU is assumed for the Ideal System. Expanded blast capacity can be developed to permit the volume of blast work to be balanced with the painting work.
3. The parts are primed or painted as required. The assumed paint cycle time for this system is one minute. This

represents the average time needed to apply a single coat to an SLU.

4. The parts are dried. Where there is sufficient conveyor length and speed, this can be accomplished simply by air drying on the conveyor from the point of painting to unloading.

For example: Ten feet per minute is a common speed for many lines. If the distance from the paint station to the unload station is 150 feet the dry time is fifteen minutes.

5. A cure area will be needed for various paint coatings. In a conveyORIZED system this is done via switching and manually control led track "spurs". Parts can be held in these areas for extended periods while the main system continues operation.
6. A by-pass for blast will be required where already blasted/primed or painted parts require additional coats. Another option would be to shut down the blast booth and run the parts through.

Balancing the Ideal is a necessary early step in developing the system concept. Here the intent is to be able to load, blast, paint, dry and unload without a "bottleneck" or out-of-balance operation. The flow process chart is the place to begin.

The Ideal System in Figure 12 shows a basic priming operation. The assumed Single Load Unit (SLU) is a large or medium part or a "Christmas Tree" of small parts. At a conveyor line speed of five FPM and the developed line length of two hundred feet it will take thirty-four minutes without line stoppages for a single load to make a total cycle (the forty minutes for the line cycle less the six minutes (30 ft.) of "dead space" between the assumed load and unload points). However, the productive rate of the system will be the same as the "limiting cycle", in this case five minutes to blast the SLU. That is, as in any manual blasting operation, where one man takes five minutes to completely blast the single load unit. In other words, when this system operates without stoppages, a SLU is produced every five minutes, twelve items per hour.

Three systems were developed, using various configurations of equipment. These establish a reference for this discussion as well as further applications covered in the next section.

System A: Manual Blast and Manual Paint

System B: Auto Blast and Manual Paint

System C: Auto Blast and Auto Paint

All three systems use the conveyor routing as shown in Figure 12.

Referring to System A, a Single Load Unit is produced with fifteen man-minutes or .25 man-hours operating the line with three men (5 min. x 3 men).

System B changes the limiting cycle to one minute since the blasting time is now shortened, via automation, to match the paint time. This is potentially five times faster than System (A) with sixty SLU's per hour. Manning the line with three men, the production rate is three man-minutes per unit or .05 man-hours.

System C has the same limiting cycle of one minute but potentially can be operated by two men at a production rate of two man-minutes per unit or .033 man hours.

Recognizably, great arguments can be made concerning this data and the related assumptions. However, while these assumptions are based on real, observed conditions, they are submitted within this study as a point of reference and not an absolute. The greatest value in this exercise is the applicability of the concept to any small parts system proposal, whether a continuous line or a separate forklift fed work station basis is used.

Making The ideal Model Real

The ideal model and flow analysis was exactly that . . . a pure ideal, but capturing a very workable concept(s). What then is REAL? How do we make it workable?

First, the flow analysis can be re-evaluated in terms of reasonably expected line stoppages or delays. These are:

- Mechanical or electrical maintenance.
- Wait for materials.
- Supervision.
- Miscellaneous.

Some history for these types of systems suggests an expectation of 10% to 25% (of course in an actual application this should be established as early as possible once the learning curve settles down). For study purposes, the most conservative delay value was utilized (25%). Applying the delay factor increases the total system cycle time from thirty-four to fifty minutes.

Second, and most importantly, the manual activities require evaluation. Basic questions need to be asked:

- Can a man maintain the one minute work cycle in loading and unloading?
 - Not without some fatigue, rest and personal time allowances.
- More seriously, can a man maintain the painting cycle of one minute?
 - This type work probably requires the highest allowances for fatigue, rest and personal time.
- When the Single Load Units are small parts hung on "Christmas Trees" won't an auxiliary handler(s) be required?
 - Yes, and at least for planning analysis purposes the general practice is to add an auxiliary man (or more) to the line crew and include that time in the expected operating labor cost.
- If manual blasting is to be used, won't two blasters be required since that is the limiting cycle?
 - Not necessarily. This would appear to be the best answer if the system is planned to run "full out" for extended periods. When one blaster works the other rests. This must be evaluated on a per piece basis since it might be better to have both blast and rest in unison.

The manpower utilization is much better when working in unison, as shown in Figure 13.

Applying some of these intuitive factors will bring the ideal system further into the area of the real system. Each system is adjusted to show man-hour effect for system and human delays. (Figure 14)

	WORK CYCLE (Minutes)	DELAY TIME (Minutes)	DELAY % OF WORK CYCLE
1 Man Blast	5		
1 Man Rest		5	
TOTAL	5	5	100%
2 Men Blast	2.5		
2 Men Rest		1	
TOTAL	5	2	40%

Figure 13

		MANHOURS PER SLU	
SYSTEM	DESCRIPTION	IDEAL SYSTEM	REAL SYSTEM
A	Manual Blast	0.250	0.344
B	Auto Blast	0.050	0.138
C	Auto Blast & Paint	0.033	0.093

Figure 14

Men/machine charts are shown below for System A in Figures 15 and 16. The initial (Ideal) and expected (Real) are compared. This is an effective method for depicting time, work operations, and system relationships. It will work well for facilities utilization analysis in general.

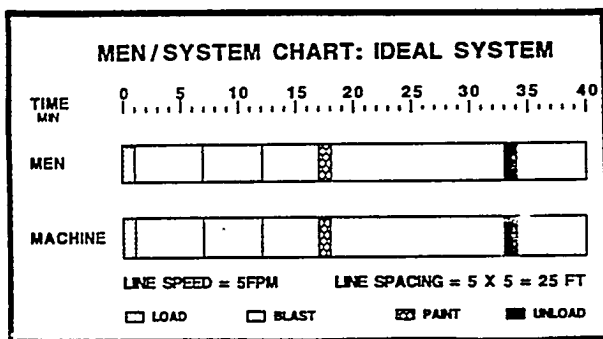


Figure 15

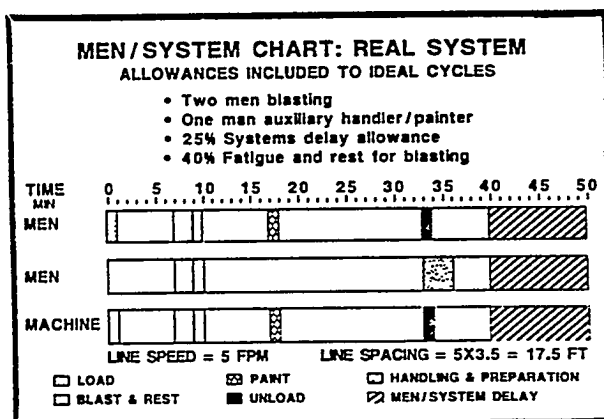


Figure 16

A final set of comments concerning this exercise:

The conveyor type system can be analyzed at whatever speed and length of line is reasonable. Most systems viewed as part of the study moved at 10 to 12 feet per minute. The ultimate length will be governed by the air dry cycle required, economics, or space.

The manning of the system is totally variable based upon the degree of automation and system reliability. One system had over a thousand feet of continuously moving conveyor and a two man crew—one a handler and the second a line operator/maintenance man. The total system was automated except for loading and unloading the conveyor. It should be added that this line used a washer system rather than blasting to prep parts.

For shipyard conditions and practices, blasting holds equal importance with painting. Automated blast cabinets require much research prior to acquisition and much operational methodization after acquisition and installation.

Also, the "Christmas Tree" method for handling small parts has great impact. Remember, if ten small parts are contained in one SLU the expected man hours per part is factored 10 times.

Finally, once the initial analysis has been reduced to reasonable expectations, the Ideal nature of the system will still exist, but in a Real form. Answer questions like: Do you have the physical space? What configuration will fit? Are utilities adequate? Access to and from? Parts staging? Then begin the process for developing the proposal.

SMALL PARTS PAINTING SYSTEMS

What will these kinds of systems cost? Can automation be affordable and justifiable or should mechanization at a lower level be the goal?

Herein lies the heart of this feasibility study. To answer these questions, a separate survey was made by the Empire West Corp. of Cerritos, California. The survey used as a model the same ideal system as in Figure 12 in order to permit direct comparisons of data.

Three types of parts painting systems are being considered:¹

1 These systems are relative to Systems A, B and C described earlier. However, they are not identical and therefore should not be-compared directly.

- SYSTEM 1 (Mechanized/Manual)
- SYSTEM 2 (Semi-Automatic)
- SYSTEM 3 (Automatic).

This survey is based on the following general assumptions:

Surface Preparation:

The blasting requirement for items to be coated with inorganic zinc primer is near white blast cleaning (SSPC-SP-10). All other items require either commercial blast cleaning (SSPC-SP-6), or brush-off blast cleaning (SSPC-SP-7).

For occasional items which do not require blast cleaning, other manual cleaning methods can be considered. A limited quantity of parts will require masking of some areas prior to blast cleaning and/or coating application.

Coating:

The coating requirements for the parts include five basic paint material systems:

- Inorganic zinc primer
 - Epoxy tank coatings
 - High build polyamide epoxy primer
 - Alkyd primer
- 1 Topcoatings for each specified coating system.

All parts will require a minimum of one coat of primer.

Forced Drying:

Most of the coating materials will air dry in ambient conditions. The curing times for most materials can be reduced significantly by processing through a drying oven after a specified flash-off time period. An oven is included in each of the three preliminary systems to increase production.

Material Handling:

The vast majority of parts can be handled by an overhead powered conveyor system with start/top stations for loading and unloading. A combination power and free system could be considered for Systems 1 and 2, but is not included in the survey. Sec-

tions of horizontal conveyors in some process areas may be considered, along with four wheel carts for handling of unusual parts.

Small Parts Data:

Size: Minimum, 3" x 2" x 1"

Maximum, 60" wide, 42" high x 20' long

Weight: Maximum 100 pounds/piece

Configurations: Small assemblies (foundations), pipe hangers, U Bolts, wire-way hangers, light brackets, ladders, etc., as typical.

Substrate: Mild steel.

System 1

This plan will have the lowest purchase cost, but the highest operating cost of the three systems, as it is the most labor intensive. The plan will utilize more floor space because of the staging areas required as work flows through the processes.

Surface Preparation: All blast cleaning will be done manually in a blast booth with dust collector.

Coating: Coating application will be done manually, in a water-wash spray booth.

Drying: One two-pass conveyorized drying oven is included.

Material Handling: For this system, material handling will be accomplished primarily by overhead conveyor. Four wheel carts for special items are included.

System 2

Surface Preparation: This plan reduces manual blasting and adds a Turnblast semi-automatic machine or a table-blast machine.

Coating: An additional spray booth is included. Semi-automatic (non-computerized) coating application machines are added to reduce personnel and increase quality control.

Forced Drying: The drying oven is increased in size with two chambers to force dry the primers and top coats continuously in separate temperature zones.

Material Handling: System 2 will allow the parts to be carried, via conveyor, through the blast cycle, the primer application, flash-off period, drying oven, cooling, top coat application, flash-off period, drying oven, cooling, to unload station—all without manual handling.

System 3

Surface Preparation: This plan utilizes a four wheel airless (centrifugal) automatic blast cleaning machine in place of the manual blast booth. With proper fixtures, this machine should process all of the parts included in the survey..

Coating: The coating equipment will be fully automatic, with electronic control and sensing systems to coordinate with the conveyor drive. Four spray booths are included for continuous line flow.

Forced Drying: Drying will be through a double oven as described in System 2, to allow predictable coating application sequence.

Material Handling: The overhead conveyor will carry most parts through the automatic blast cleaning machine and all other processes.

If all included assumptions are reasonably accurate, this will be the optimum one cycle system. After loading the parts on fixtures on the conveyors, blast cleaning, coating, and drying will be automatic until the parts are unloaded, ready for inspection.

Preliminary cost estimates of each system (at the time of survey), for budgetary purposes only, areas follows:

SYSTEM 1	\$235,000.00
Option: If air compressors are required, add the approximate amount of	\$50,000.00
SYSTEM II	\$345,000.00
Option: If air compressors are required, add the approximate amount of	\$30,000.00
SYSTEM 3	\$440,000.00

The equipment costs contained in the Empire West survey were further analyzed with respect to the three systems as originally discussed. This permits the reader to see a continuum of comparative data as would be required in any specific system proposal.

These are guide line costs and can be used to develop strong indications of what system is feasible for a given yard.

SYSTEM A (with variations)	
A Manual Blast System with 200 feet of conveyor a single blast booth a single paint booth, and	
single oven	\$140,500.00
The same system without the oven	\$105,000.00
A Manual Blast System the same as above with two blast booths and two paint booths	
	\$177,000.00
SYSTEM B	
An Automatic Blast System with conveyor, auto blast cabinet. two paint booths. and single oven	\$272,000.00
SYSTEM C	
An Automatic Blast and Paint System with auto blast cabinet, auto paint booth set of two ovens and 200 feet of automated conveyor line	\$399,000.00

JUSTIFICATION

Justification for a proposal is necessary and vital for management review and decision. The proposed system must be compared to existing operations. The savings to be realized must provide return on investment and fully satisfy management criteria.

The most direct method for determining current operation methods and productivity is observation. As set forth previously under the Industrial Engineering Method, the flow process study is recommended. Complete eight hour studies, or, at a minimum, four hour studies will yield the best quality information. The time a man is working is important, how he works and at what task must be observed closely and properly recorded as well. However, of equal importance is idle time, and the reason for the idle condition requires close observance and recording. Personal time, rest, and fatigue are simply states of human-kind and have well-engineered standard values for that reason. Waiting for something is idle time, which can be changed to productive time, but must be first properly identified.

Determining how work is being done can lead directly to methods changes, which in turn increase productivity. Unneeded movements of materials, excessive handling, identification problems, instructional problems, and poor workmanship by others can be changed or eliminated. Often these changes cost little.

Observation studies were conducted at NASSCO as part of this project and were previously discussed. The specific data used to develop work cycle times was developed from those studies. Results are shown in Figures 17 and 18.

BLASTING	MIN/SLU
Load/Unload/Handle Parts	2.3
Blast Parts	3.6
Setup/Teardown Equipment	3.8
Taping	1.6
Cleanup	1.0
Instructions	0.9
Total Work Cycle	12.6
Fatigue, Rest & Personal*	2.5
Total Expected Time Per SLU	15.1 minutes

* Fatigue 10% All time of this type was deleted from
Rest 5% the study and standard allowances
Personal 5% were added to work values.
Total 20%

Figure 17

PAINTING	MIN/SLU
Load/Unload/Handle Parts	2.1
Paint Parts (Multiple Coats)	2.7
Setup/Teardown Equipment	3.5
Taping	1.4
Mix Paint	0.4
Cleanup	0.9
Instructions	0.8
Surface Preparation	0.6
Total Work Cycle	12.4
Fatigue, Rest & Personal*	2.5
Total Expected Time Per SLU	14.9 minutes

* Fatigue 10% All time of this type was deleted from
Rest 5% the study and standard allowances
Personal 5% were added to work values
Total 20%

Figure 18

Figure 17 summarizes time study results for blasting and related operations for a Single Load Unit (one or more individual parts), while figure 18 shows results for painting. Note that in both cases equipment setup or teardown times exceed the actual blast/paint operation times. Therefore it is important to maximize work package or lot size to absorb the equipment handling time (cost). Also note that the total work cycle times are nearly equal for blasting and painting. This results from comparing blasting to painting multiple (2-3) coats. Applying a single coat to a part is usually three to four times faster than manually blasting that same part.

The details of data accumulation, analysis and evaluation must be left to a specific proposal pro-

ject manager or engineer. However, for this report, in order to carry through the concept originated with the Ideal System, that particular example was taken all the way through a proposal cycle.

At this point, it is recommended that all new costs for the proposed operation be evaluated and that the particular financial form related to the yard doing the proposal be followed. Since policies, and therefore calculations vary, this example will end here.

In closing, some additional comments about the example may be appropriate. First, the potential savings versus capital investment for System A may suggest a reduction in the expenditure by deleting the oven and proposing a capital expenditure of \$105,500. This would offer a very safe economic trade-off. Moreover, proposed System C (see Figure 19) yields the greatest potential percentage of time saved (81.4%), however this same system shows the lowest annual ROI (122%) due to high investment cost ($ROI = \text{annual savings} \div \text{investment}$). System B would yield the greatest ROI (160%) and have the shortest payback period—about 7.5 months. Also note that the calculations assume a production rate of 60,000 SLUs per year. If the actual quantity of small parts processed for a particular operation was less, say 30,000, the analysis for System B would be adjusted to show a ROI of 80% and a payback period of fifteen months.

Clearly, specific SLU counts, current operation values, proposed system configurations and expected operation values, and specific equipment and installation costs will yield wide variations between individual cases.

SUMMARY AND CONCLUSION

Is automation, semi-automation, or mechanization feasible for a given yard? This study suggests that there are definitely possibilities that deserve review and analysis. The study further shows that there are cost improvement potentials with very little capital cost and that the techniques utilized here can be applied to most, if not all, shipyard operations.

The project represents a wide view. As intended, it deals with automation and mechanization of small parts painting. However, along the road to these high ends many simple and easy to perform planning, scheduling and industrial engineering techniques have marked our way. Possibly, and without original intention, the exposure to these management tools will be of the most universal value.

SYSTEMS COMPARISON					
		MAN-MINUTES/SLU	MANHOURS/SLU	REDUCED HOURS/SLU	TIME SAVED%
CURRENT	Blast	15	.25		
	Paint	15	.25		
	Combined Total	30	.50		
PROPOSED	System A		.344	.156	31.2%
	System B		.138	.362	72.4%
	System C		.093	.407	81.4%

POTENTIAL RETURN ON DIRECT CAPITAL INVESTMENTS						
	SLU'S PER YEAR	SAVING PER SLU (HOURS)	ONE YEAR DOLLAR SAVINGS*	CAPITAL INVESTMENT	RETURN ON INVESTMENT (ROI)	EXPECTED INCREASE IN OPERATING COSTS
System A	60,000	.156	\$187,200	\$140,500	133%	Power to operate conveyor and automated systems
System B	60,000	.362	434,400	272,000	160%	Ditto
System C	60,000	.407	488,400	399,000	122%	Ditto

* Assumes \$20/Hr. Labor Cost

Figure 19

The emphasis placed upon "Planning for Manufacture", as well as the side trip into "A Thru-put Technique" in the same section, may serve any yard well for very little cost. The Industrial Engineering Method, by design permeates the complete project. Identifying and analyzing the "Existing" and "Proposed" is at the heart of good, well-managed economical evaluation and justification.

The specific review of various levels of system mechanization and the ultimate of automation, along with potential costs for each, may be just what the large yards need next.

Yes, it is agreed that this project looks like "something for everyone"-and that can't be all bad. From here on, it's a "do-it-yourself" project: look at your family of painted small parts and see what can be changed and improved. Conduct the studies and use whatever techniques help.

SUMMARY

- Look at the **WHOLE PARTS PAINTING PICTURE**
- Be Aware of **NON-PAINTING and PREPARATION COSTS**
- Look at **PLANNING FOR MANUFACTURE**
- Analyze **FLOW**
- Take a **SYSTEMS APPROACH**
- Develop the **RIGHT PROPOSAL** for your yard
- Establish the **ECONOMIC JUSTIFICATION**

ACKNOWLEDGEMENTS

This research project was produced for the National Shipbuilding Research Program as a cooperative cost-shared effort between the Maritime Administration, the U.S. Navy, and National Steel and Shipbuilding Company (NASSCO). The Surface Preparation and Coatings Panel (SP-3) of SNAME's Ship Production Committee sponsored the project under the technical direction of James Ruecker of NASSCO, SP-3 Chairman and Program Manager.

The study was conducted and the report prepared by NASSCO, with Les Hansen serving as Project Manager and Principal investigator. William Appleton acted as Industrial Engineering Consultant and contributed significantly to the research, as well as co-authoring the report.

The special support and assistance offered by the following persons at NASSCO is gratefully acknowledged:

Ron Madison, Paint General Foreman; James Ruecker, SP-3 Panel Chairman; and Don White, Out-fitting Asst. Superintendent.

We thank the following shipyards and their representatives for graciously conducting tours of their facilities and providing invaluable information:

Mike Sfirri of Bath Iron Works; Jim and Kay Freeman of Ingalls Shipbuilding; Gary Higgins, Darrel Bernschien and Darrel George of Petersen Builders, Inc.; Jim Herbstritt and Dave Fenton of Puget Sound

Naval Shipyard; and Oren Funkhauser of Todd Shipyards, San Pedro.

In addition, SP-3 Panel members have freely contributed comments and other useful input at panel meetings during the course of the study.

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APPENDIX 1: THE SIMPLE SYSTEM

A simple approach to small parts painting, the previously identified Semi-Mechanization, is not to be overlooked.

Economics, a need for a small decentralized Paint Shop, or the relative volume of work may not support the kinds of systems previously discussed. This study suggests that all the principles developed thus far can be further applied to a simpler approach. (As a matter of fact, simple time study and methodization will yield immediate cost reductions).

The order of working up a proposal is exactly the same:

- Define and classify the parts
- Evaluate current methods and time values for the operations
- Develop an Ideal Plan
- Evolve to a Real Plan
- Determine Equipment and Facilities Requirements and Proposal costs
- Economically justify the proposal.

When evaluating current operations and making the transfer to the Ideal/Real System Proposal, work on Flow Concepts.

- Is a manufacturing operation continuum possible? Will transportation from the last fabrication operation to the first blast and paint operation be at a minimum?
- Will the blast and paint operations be a flow-through layout with a minimum of handling and rehandling?
- Will the layout afford good thru-put planning and in-process control?
- Can the proposal improve the cost of painting small parts?

The flow diagram in Figure 1 shows a simple flow-through arrangement that can use multiple "mover" methods: fork lift, hand cart, track, or conveyor (with or without a return loop). This system is envisioned as having manual blast and paint, air dry or oven dry facilities. However, blast could be semi-automated. If a track or conveyor is used, parts can be worked individually or "Christmas Tree" fashion as an SLU, and with a limited production demand the operation could be handled by a single worker.

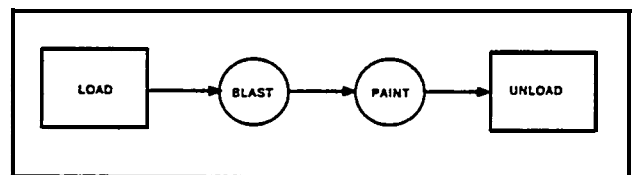


Figure 1

Spacing of the facilities will be most important in order to queue parts for each sequential operation. The key is to keep the materials moving through without double handling. This strongly suggests that the handling method or "mover" is the most important function of the system and may prove to be the most cost effective investment in the proposal.

Develop a flow process chart complete with work times and process values. Use an SLU as the basic production measure and calculate the potential savings for the proposal. Remember...keep it simple!

APPENDIX 2: TYPICAL PARTS LIST

DESCRIPTION	APPROXIMATE SIZE/RANGE	APPROXIMATE USAGE
ANGLE, REGULAR, CARBON STL., RAW MAT'L	1×1 - 9×4×20'L	100,000 FT
BAR, FLAT, CARBON STL., RAW MAT'L	1×1/8 - 6×3/8×20'L	50,000 - 100,000 FT
BAR, ROUND, CARBON STL., RAW MAT'L	1/4 - 2 DIA×20'L	25,000 - 50,000 FT
BRACKET, STANDARD	6×6 - 45×45	5,000 - 10,000
COLLAR, TIGHT, FOR TEE STIFFR	4×12 - 6×26	2,000 - 5,000
CABLE SUPPORT (MULTI-CABLE)	4×20 - 20×20	5,000 - 10,000
DAMPER, FIRE, H.V.A.C., MAN, RECT.	4×4 - 50×50	500 - 1,000
DECK SOCKET, VECH. LASHING	3×10-3×12	500 - 1,000
FLANGE, H.V.A.C., RECT., NON-TIGHT	7×7 - 54×54	> 10,000
FOUNDATIONS, STEEL, MISC., BOLTABLE	12×12 - 72×72	500 - 1,000
HANDGRAB	3×7	500 - 1,000
HANGER, DUCT, H.V.A.C.	2×28	> 10,000
HANGER, PIPE, CLAMP TYPE	1/4×4 - 12×30	> 10,000
LADDER, VERT.	16×3' - 20'L	100 - 500
MANHOLE, RAISED, OILTIGHT AND WATERTIGHT	18×23	100 - 500
PADEYE, LIFTING, PERM.	2×4 - 12×36	100 - 500
PADS	3×3 - 18×18	500 - 1,000
PENETRATION, PIPE, FLANGED, WT.	1" D×12 - 25"D×24	2,000 - 5,000
PIPE HANGER SUPPORT, U-BOLT, UNBRACED	2"×2"×2' - 3'	500 - 1,000
RAIL, HAND, 3 COURSE PIPE	42×5' - 20'L	500 - 1,000
RAIL, STORM, EXTERIOR	21'L	100 - 500
RUNG, LADDER, STIRRUP	10×16	1,000 - 2,000
STAPLE	1/2×1 - 6×8	1,000 - 2,000
VENDOR ITEMS:		
ELEC. BREAKER BOXES	18×24×6	500 - 1,000
MOTORS, SMALL	18×18	50 - 200
PUMPS		50 - 200

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