

Feasibility Study: Automated Painting of
Pipe Pieces, Hangers, and Other Small Parts:
Maximizing Shop Painting Operations
Task 3.84.4

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By
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DEDICATION

This report is dedicated to the memory of Jim Castle, who served as NASSCO's Paint/Outfitting Superintendent from 1982 until August 1986.

During his years of involvement with the SP-3 Coatings Panel, Jim contributed significantly from his vast knowledge of the industry.

Jim's desire to improve painting methodology at NASSCO supplied the inspiration for this project in its final form.

ABSTRACT

Shipyards 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. This is particularly true when comparisons are made to other industries.

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:

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

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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, Outfitting 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 Darrei 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.

FOREWORD

This feasibility study represents the reincarnation of a research project initiated several years earlier by Avondale Shipyards under the purview of SNAME Panel 0-23-1 (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 paint-

ing. 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.

SECTION 1. 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. [t 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.

- 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.

SECTION 2. 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.

Ž 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.

SECTION 3. 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).

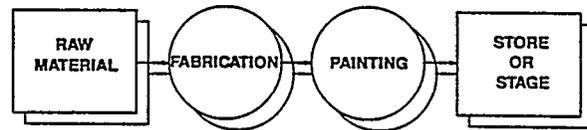
Nevertheless, painting is difficult to define as an "independent operation" or small parts when viewed as part of a continuing process flow.

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.

Parts Painting is not just some unrelated operation...

IT IS PART OF THE MANUFACTURING PROCESS.



- 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.

SECTION 4. 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? Hardly! 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. Further discussion on this subject can be found in Appendix B (Parts Tagging).

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 in Section 5.

SECTION 4.1 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 to other operations after period four.

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

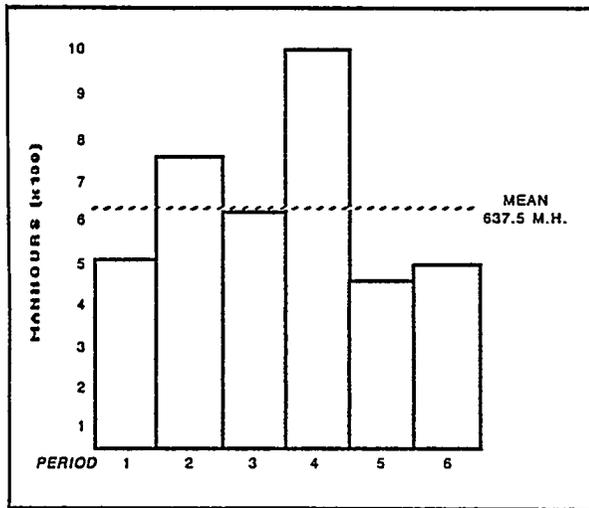


Figure 2

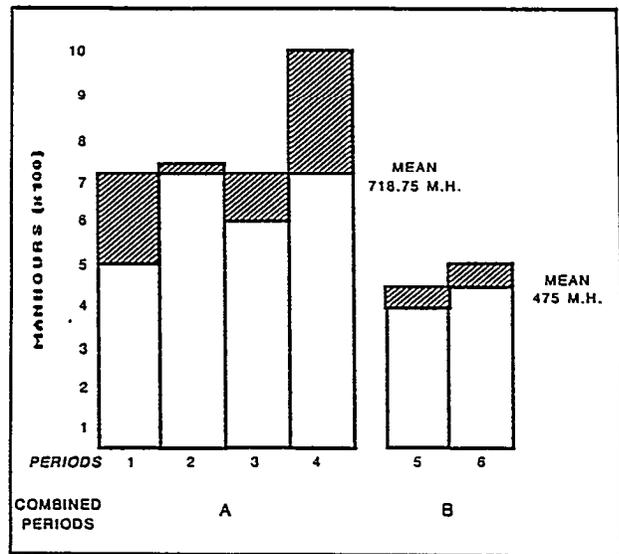


Figure 3

SECTION 5. 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 in Figure 4.

THE INDUSTRIAL ENGINEERING METHOD

INDUSTRIAL ENGINEERING is concerned with integrated systems of people, material and equipment.

- Engineering Analysis
- Design
- Evaluation

TECHNIQUES used for this study:

- Flow Process Charts
- Flow Diagram
- Comparative Evaluation
- Time Study

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			
INSPECT			.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

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).

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).

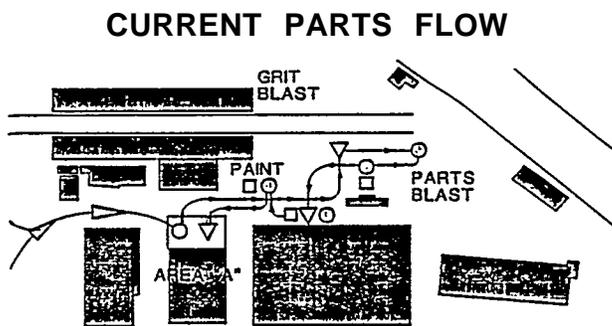


Figure 5

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.

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.

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'LS HELD FOR PROCESSING OR DELIVERY
D	DELAY	DRYING TIME CURING TIME ANY WAITING TIME
□	INSPECT	CALL INSPECTOR WAIT FOR INSPECTOR INSPECT PARTS OR MAT'LS

Figure 6

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.

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

SECTION 6. 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 location/shop of 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 E 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

AOE 6 SPECIFIED PAINT SYSTEMS

COAT NO.	LOCATION		
	EXTERIOR TOPSIDES	INTERIOR, DRY SPACE	INTERIOR, WET SPACE
1	INORGANIC ZINC SILICATE	MIL-P-24441 EPOXY (F-150)	DOD-P-23236 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

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 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.

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	11**	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 definitions in order to emphasize GT application in this study. ** Codes may be added for zone, storage location, etc.				

Figure 8

SECTION 7. 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 Section 4, '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 (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/finspection 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 instructions 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.

SECTION 7.1 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. ¹

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 (3), and have developed work distribution percentages that greatly compare to those developed by NASSCO. A comparison is made for reference and illustration. (Figure 9)

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

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

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

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

¹ See Section 5 for a representative Flow Process Chart.

WORK DISTRIBUTION

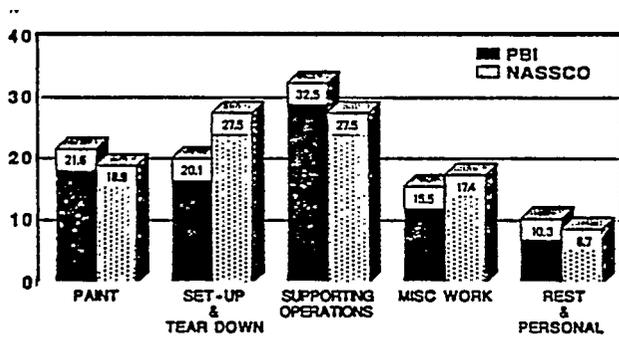


Figure 11

TIME STUDY RESULTS AND INTERESTING FINDINGS

WORK DESCRIPTION	WORK DISTRIBUTION	
	PBI %	NASSCO %
PAINT	21.6	18.9
SET-UP AND TEAR DOWN	20.1	27.5
SUPPORTING OPERATIONS	32.5	27.5
MISC. WORK	15.5	17.4
REST AND PERSONAL	10.3	8.7
	<u>100</u>	<u>100</u>

SECTION 7.2 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 14.4% 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.

SECTION 7.3 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...

- **Transportation To and From The Facility**
- **Handling Within The Facility**
- **Identification**
- **Scheduling**

THESE CAN EQUAL OR EXCEED THE PAINTING AND PREPARATION COSTS.

To dramatize this we asked painting supervisors the following

IF YOUR PAINTER HAS...

- **The Right Paint**
- **The Right Equipment**
- **Proper Support**
- **The Right Part**

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

SECTION 8. 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 predefine 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.

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.

IDEAL BLAST, PRIME & PAINT LINE

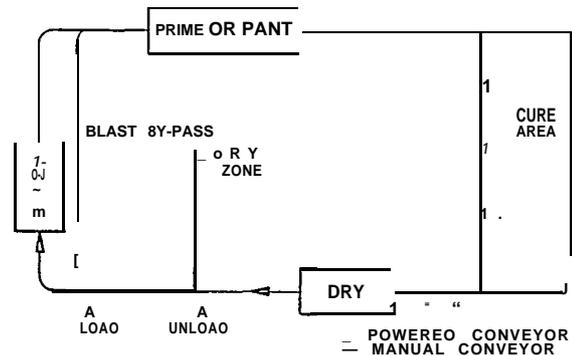


Figure 12

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 Tie" 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 a 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 conveyerized system this is done via switching and manually controlled 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 refer-

ence 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.

SECTION 8.1 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.

	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

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).

		MANHOURS PER SLU	
SYSTEM	DESCRIPTION	IDEAL SYSTEM	REAL SYSTEM
A	Manual Blast	0.250	0.344
B	Auto Blast		
C	Auto Blast		
D	Auto Blast		

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.

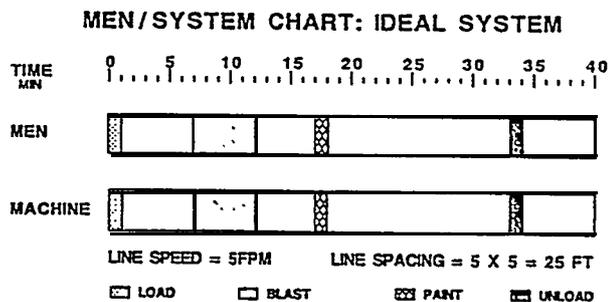


Figure 15

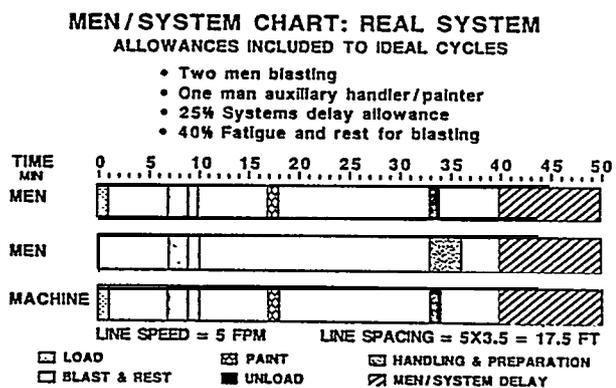


Figure 16

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 (see Section 7.2). 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. (Blasting systems are discussed in Appendix D).

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.

SECTION 9. 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:²

- 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
- 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. Sections 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.

² These systems are relative to Systems A, B and C described in Section 8. However, they are not identical and therefore should not be compared directly.

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 11, 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. are as follows:

SYSTEM 1	\$235,000.00
<i>Option: If air compressors are required, add the approximate amount of</i>	
	\$50,000.00
SYSTEM II	\$345,000.00
<i>Option: If air compressors are required, add the approximate amount of</i>	
	\$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 in Section 8, This permits the reader to see a continuum of comparative data as would be required in any specific system proposal.

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

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

SECTION 9.1 ADDENDUM TO EMPIRE WEST CORP. SURVEY

This is a list of qualified manufacturers of the basic types of equipment outlined:

Blast Cleaning Equipment

1. *R. A. Barnes Inc.*, Seattle, WA
2. *Whee/abrator*, Mishawwaka WI
3. *Pangborn,Hagerstown, M D*
4. *Blast Star Co. (R. Walka)*, St. Helena, CA
5. *CAB Systems*, Kent, WA

Conveyor Equipment:

1. *High Beam Conveyor Inc.*, La Habra, CA
2. *Jervis B. Webb*, Los Angeles, CA
3. *Blast Star Co. (R. Walka)*, St. Helena, CA

Drying Equipment:

1. *Industrial Systems, Inc.* South Gate, CA
2. *George Koch Sons, nc.*, Evansville, IN

Spray Equipment & Booths:

1. *Empire West, Inc.* Cerritos, CA
2. *Grace, Inc.*, Minneapolis, MN
3. *Binks Mfg. Co.*, Chicago, IL

SECTION 10. 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 (Section 5), 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 observation 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 discussed in Section 7. The specific data used to develop work cycle times was developed from those studies. Results are shown in Figures 17 and 18.

Figure 17 summarizes time study results for blasting and related operations for a Single bad 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.

BLASTING	MIN/SLU
Load/Unload/Handle Parts	2.3
Blast Parts	3.0
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

The details of data accumulation, analysis and evaluation must be left to a specific proposal project 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 losing, 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 = annual savings ÷ 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.

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

SECTION 11. 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 withtion 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.

The emphasis placed upon "Planning" for Manufacture" in Section 4, 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 is not only set forth in Section 5, but 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**

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APPENDIX A: 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.

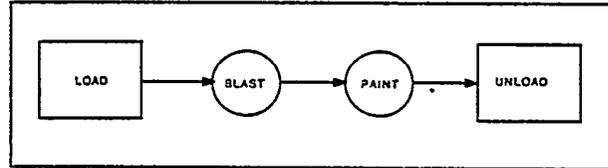


Figure 1

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!

A SIMPLE APPROACH THRU METHODIZATION

- Evaluate Current Methods and Time Values
- Look for Obvious Improvements
 - Minimize Transportation Distances
 - Maximize Flow With Good Layout
 - Reduce Multiple Handling
 - Use Various "Movers": Forklift, Hand Cart, Conveyor

THIS CAN BE ACCOMPLISHED WITH LITTLE, IF ANY, CAPITAL INVESTMENT!

APPENDIX B: THE NASSCO PROJECT

During research and development of this project, NASSCO was concurrently planning production of the AOE-6 Navy Supply Ship. Since the ship specification required a significant amount of flame spray (wire sprayed aluminum) application, a management decision was made to setup an in-house flame spray facility. The facility planning and procurement was a joint effort of the Paint, Corrosion Control, and Facilities Departments.

Management directed that a total concept for integrating small parts painting and flame spray be developed in order to:

- Combine the operations for space and flow utilization
- Develop Production Control and Scheduling
- Produce the efficiencies offered by Mechanization of the operations.

Therefore, the NASSCO project focused on conveyorization of small parts painting and flame spray including staging, blast, flame spray, painting, and material movement.

The flame spray facility has been installed—supported by a plan to add conveyorization at some future date. Presented here is the background to the planning, which is derived totally from the project and text.

First, the Paint Department staff developed Process Flow Charts showing the concepts to support the relationships found in flame spray and simple painting of parts (Figures 2 and 3). Secondly, the conveyorized flow concept was developed (Figure 4) to depict the objectives and relationships of stations, alternative routes, and system terminal.

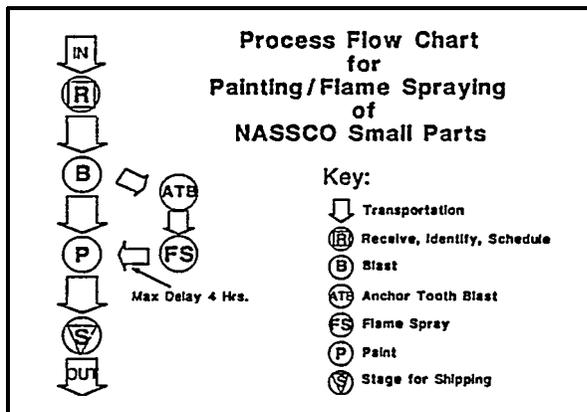


Figure 2

The Facilities Engineers are, at this writing, developing the plans and specifications for the system.

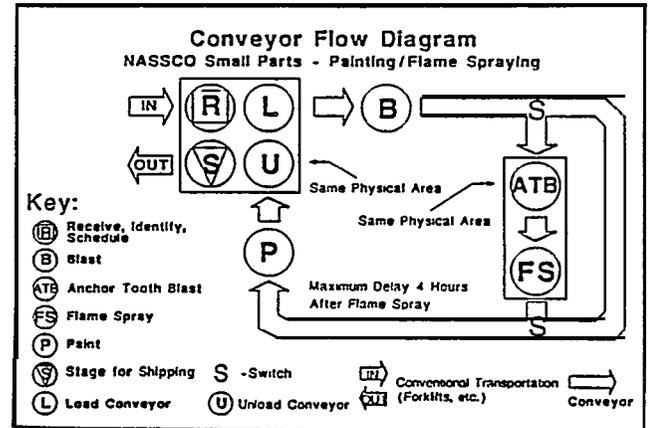


Figure 3

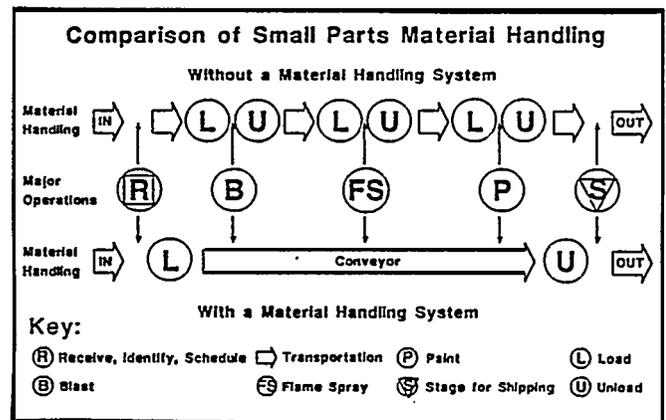


Figure 4

Assumption:

Effort for each handling task is roughly the same

Conclusion:

Number of handling tasks with handling system: 2

Number of handling tasks without handling system: 10

Advantage to handling system by over 5 times or a direct labor factor of 20%

Parts Tagging

One of the immediate benefits to NASSCO resulting from this study was the development of improved identification procedures for parts requiring blast and paint.

Temporary identification is required on all fabricated parts to ensure they end up in the right installation location. Since any information written directly on parts would be lost during blast and paint, tags are commonly used. When tags are fastened with wire, the risk of being torn loose and lost is high. Also, part configuration does not always allow a tag to be attached by tying. Therefore, NASSCO has traditionally used welded metal tags (aluminum or steel) for parts identification.

Under the old system, necessary information—part, drawing or other reference numbers—was stamped on tags by hand, one character at a time. Tags were then spot-welded to the part after fabrication and eventually removed on-block or on-board after part installation. This method proved costly and created specific problems for the Paint Department. Removal of the welded tags required laborious chipping and grinding that damaged surrounding coatings. Also, since the area behind the tag has been shielded from earlier shop blasting and painting, extensive surface preparation and touch up was necessary after tag removal. This touch

up operation was usually performed on-board, late in the outfitting cycle, thus increasing labor costs and disrupting adjacent work.

During the “Proposed Improved Methods” phase of the study, a small ad-hoc committee of Paint and Production Planners was formed to investigate the tagging problem and offer solutions. The group’s recommendations focused on all aspects of the problem. First, use an automatic Address-O-Graph machine to imprint the metal tags, saving the labor of hand-stamping. Then, attach tags to parts with a weld stud pin. Studs are “shot” from an electric gun, using a minimum of effort and cost. The tags—with holes at each end—are then placed over the pins and the pins are partially bent down. This arrangement secures the tag while allowing it to rotate for blast and paint accessibility behind. Removal of studs is accomplished easily with a hammer and chisel. Minimal, if any, paint touch up is required after stud removal.

At the time of this writing, the new tagging proposal has been accepted by NASSCO Management and is being put into effect for the AOE-6 contract. A justification cost analysis for the new tagging system indicated labor and material savings of over two dollars per tag. At this rate, the full capital investment required for the new system will be recovered before completion of the first ship.

APPENDIX C: AUTOMATED PAINTING

Automated parts painting for shipbuilding presents a unique situation when compared with other manufacturing industries, such as automotive or aircraft. Ship construction is not generally considered an “assembly line” process due to the length of the building cycle and individuality of design. Few if any, shipyard jobs are identical in the usual manufacturing sense. It follows, then, that the parts making up assemblies are diverse in size and configuration, as evidenced by this study’s “Typical” Parts List (Appendix E).

Thus, if automation in any form is to be applicable, it must be highly flexible in nature. Flexible automation is defined as any automated or semi-automated process which is able to adapt or to be rearranged to some degree to accommodate changing job configurations, sizes, times or other important conditions (4). Clearly, any successful attempt to automate parts painting would need to fit this description.

A reference summary on automation is very desirable. The possibilities are great and all major producers of painting equipment offer some ready to use automation. However, most applications will need customization to match equipment, system and specifications to the requirements.

Let us therefore briefly discuss the various types of automated systems to establish a reference base.

- Linear Reciprocating Systems—typical of the blast and prime lines for mill plates. NASSCO uses this type of system for pre-construction priming of all plates and shapes.

The speed of the material passing the point(s) paint application is coordinated with the speed of guns moving back and forth along a fixed linear path. Control systems can be pneumatic, low-voltage, computerized or other.

- Multi-linear Reciprocating Systems—same as linear except the set-ups can be varied (within limits) to permit change in the linear path. For very sophisticated systems, the path change can be initiated from computerized controls or manually called in from part to part.

These systems are used in high-production conveyorized parts systems where “families” of parts are coated and pattern changes are required “on the fly.” By using multiple gun arrangements, different paints can be sprayed in the same set-up.

- Robotic Systems—generally the most advanced state of the automation. Fully programmable, robots can duplicate the movements of a man.

The use of robots for parts painting maybe indicated where several thousand (or more) identical items are to be coated. Costs for these systems are extremely high at present, and the justification requires comparable extremes.

The researchers for this project believe that the multi-linear system may be the practical maximum for shipyard applications. Many parts are similar, but rarely are large quantities of parts identical.

The NASSCO studies show that manual painting within a well developed mechanized conveyor system yields the greatest flexibility combined with efficiency.

Blasting, then, may be the place to look for automation

APPENDIX D: BLASTING SYSTEMS

This may be far and away the key to mechanization, semi-automation or automation where small parts painting is concerned. Many experts consider direct blasting to require four times the labor cost of direct painting.

Manual Blast = 4 X Manual Painting
This is a significant direct cost condition.

“A very comprehensive discussion of automated blasting was presented to the project group by Mr. R. A. Walka, President of the Blast Star Company. Excerpts from his presentation are included here.

The use of automated blast equipment is intended to eliminate manual airblast by introducing several types of centrifugal or wheel blast machines. Air as a energy transfer system is always less desirable than more effective methods like hydraulic and mechanical. Thus, costly air compressors should be avoided whenever possible. Figure 5 shows a comparison of costs for three methods of blasting: air blast with sand, air blast with steel grit, and wheel blast with steel shot. (Support data used in this analysis is included at end of section.)

These costs become more conservative when related to actual experience for small parts. The figures are based on structural shapes and plate, which provide a good basis for continuous airblasting without constant stopping and overspray as with small parts. For specific parts, such as the pipe

hangers used extensively by shipyards, the savings could be a hundred-to-one over airblasting, even with a durable abrasive such as steel grit, Examples of how to use the information in Figure 5 will be provided later.

BLAST CLEANING COST ANALYSIS			
Costs Per Square Foot to “Near White” Blast			
COST COMPONENT	SAND \$/HR	GRIT \$/HR	WHEEL \$/HR
Labor	\$37.50	\$30.00	\$ 8.00
Electric	3.35	4.47	4.80
Abrasive	50.00	8.25*	26.40*
Maintenance			
A. Blast Equipment	.75	1.30	12.00
B. Compressor	1.60	1.60	.04
Abrasive Disposal	**	—	—
Total Cost/Hr.	\$93.20	\$45.62	\$51.24
divided by Sq. Ft. per Hour	300	300	4800
= Cost per Sq. Ft.	\$.31	\$.152	\$.011

* Assume 100 recycles (conservative)

** Disposal costs not included; may vary from 0 to \$90 per ton

Figure 5

A look at the different types of wheelblast machines and the material handling process itself can point out the attractiveness of the wheel blast alternative.

Airblast typically involves using a ASME pressure vessel to store abrasive and introduce it into an air-stream of equal pressure for propelling the material through a hose. The abrasive is accelerated to approximately 400 MPH or more through a nozzle of much smaller orifice than the hose diameter. In the case of steel grit, a large nozzle of 1/2" diameter will propel as much as two tons an hour. This would require one man to handle the blasting. Air blasting with sand or slag is so cost prohibitive that it is out of the question except for very small amounts of blasting.

Wheel or centrifugal blasting is the introduction of abrasive, usually steel or iron shot, to a revolving series of spokes or blades from the center. The shot then is literally flung by the speed of the rotation of the "wheel" on which the flat blades are mounted. The ultimate abrasive velocity is determined by the length of the blade and the speed of the rotation. Two hundred MPH is typical abrasive speed from a wheel—less than the rate achieved by airblast.

It is through the anchor pattern achieved and amount of abrasive expended that the wheel shows its substantial increase in efficiency. An extremely large horsepower wheel (75 HP) can throw more than a ton of shot per minute. The 1/2 airblast nozzle would need at least a half hour to do this with an air compressor requiring 75 HP or more.

The airblast nozzle can create an effective pattern of about 6" diameter. The large wheel can blast a pattern of 48" high and 6" wide. This wheel pattern is a constant flow of abrasive which requires little or no dwell time to blast the exposed surfaces clean.

Using a S-230 size shot, the number of abrasive impacts achieved per minute would be 840 million. In many wheel machines, multiple wheels are used simultaneously in both perpendicular and angular attitudes to the work to create a literal "metal laundry!" Use of round shot rather than angular grit results in tremendous rebounding and ricocheting of the abrasive and, therefore, more effective cleaning.

There are a number of configurations of wheel blast machines all suited for certain types and sizes of work. Some special purpose models are not general enough to be usable for broad applications. These include skew roll pipe machines, multi-table small parts down blasters, and large part car tables.

The primary machines to be described differ in how the part is handled and whether the part dwells for a period of time under the blast pattern. In-place or cycle machines like the tumbleblast, table, and spinner-hanger hold the part(s) in front of the blast for several minutes. Pass-through machines for plate and structural shapes move the part continuously without delay. The number of wheels in a machine determines both the production rate and size of part that can be blasted. However, most pass-through machines have at least two wheels on each side.

Automated and semi-automated blasting of small parts may utilize any number of machine configurations. General purpose machines include:

1. **TUMBLEBELT.** The cycle machine is designed primarily for large numbers of very small parts. A quantity of parts is dumped onto a metal link or rubber belt directly under the blast pattern of the wheel. The slipping, sliding and flipping action of the belt insures complete coverage of even the most complex part. Typically found in highly repetitive applications, like foundries and automotive part rebuilder, it is by far the most popular of wheel machines. While shipyards may not have the high production of small parts that is typical for belt machines, they may represent the only reasonable way to automatically prepare some small parts.

2. **SPINNER HANGER.** A more versatile cycle machine, which has parts hung from a hook or multiples from a "Christmas Tree", is used for parts that would be damaged from tumbling or are too large to tumble. In addition, a standardized part can be conveyed to and from the machine on an overhead conveyor. Standard spinner hangers have hooks or part trees on two loading doors. One or two wheels propel the abrasive while the parts revolve in front of the blast pattern. An interesting new option being offered is to have the wheel oscillate on its vertical axis to insure maximum coverage of the parts. The limitation of this machine is that the parts must be able to suspend on a hook or fixture.

3. **MONORAIL.** Basically a spinner hanger variation, the monorail provides "pass-through" parts handling while also offering cycling for better coverage. The parts are suspended on a hook or tree and move in a line on a conveyor. Most monorails have wheels

mounted on both sides, so revolving the part is not necessary. Four or more wheels provide the coverage, so parts can continuously move through the blast area. A high volume machine, the monorail provides the ability to do longer parts as they pass through on the conveyor. Monorails often are equipped with a series of “finger” seals instead of doors as on a spinner hanger. This would necessitate having smaller numbers of parts enter at a given time.

4. STRUCTURAL. This is a pass-through machine similar in design to a monorail. The structural machine is designed for all types of long narrow shapes, usually four feet or longer. I-beams, channels, angles and bars are ideally handled in this machine. The machine, in addition to size of opening, varies in whether it is designed for “pre” or “post” fabrication. The post-fabrication machine has the wheels angled to expose additional work surfaces that would not be reached at the 90 degree angle used in prefabrication machines. In this way, the post machine can clean weldments like stiffeners and build-up members. The structural machines will also clean pipe and bar stock in either configuration; not as efficiently as a skew roll machine, but effectively.

A fairly recent innovation in structural machines is vertical orientation. The work piece is positioned ‘on end’ in its lengthwise pass through the machine. This insures better coverage in a narrower but taller pattern. The abrasive falls off readily and therefore there is no abrasive “masking” at the ends of parts, and little or no additional cleaning of parts is necessary.

5. COMBINATION STRUCTURAL AND MONORAIL. The angled wheel pattern of the post-fabrication structural machine is similar to the design of the four or more wheel monorail, which has wheels on both sides to eliminate the need for rotating the part. Several combination machines are available with both methods of conveying—overhead rail and roller conveyor. Due to the ease of handling, most structural types have roller conveyors. These machines can blast smaller parts suspended overhead as in a monorail with continuous movement to insure cleanliness, or parts can be moved back and forth in the blast pattern.

6. PLATE. Plate machines are among the largest and most expensive blast machines due to the 8’ to 12’ pattern required to clean both the top and bottom of a standard steel plate. These are quite common in new construction shipyards, often combined with an automatic priming line. The design standard for these machines is now the vertical orientation mentioned in the structural section. Previously, most plate machines moved the plate flat through blast, thus requiring costly brush off devices.

Plate machines have been used for structural applications, but the very wide pattern of each wheel does not effectively intensify the pattern for cleaning complex shapes. These machines also required much higher maintenance than the vertically oriented systems.

7. TABLE. The table machine is a box-shaped enclosure with a round table that is revolved in front of the blast wheel(s). The table is usually attached to the door and swings out for ease of loading. These cycling machines often are large and can take the place of extensive airblast operations for finished weldments. The material handling however, is not automatic since the table has to be loaded and unloaded by hand or overhead crane.

While somewhat more cumbersome in loading, the machine can handle a wide variety of parts from small pieces on a rack to just about anything that can fit inside. Two cycles are often necessary, with parts being rearranged to achieve optimal cleaning. While it may not suit the automation of a high production arrangement, this machine is probably the most versatile for small parts blasting.

8. MESH BLAST. The mesh blast machine consists of two or four wheels firing on a mesh belt which conveys the parts. The belt is constructed of manganese alloy wire 3/16” in diameter and conveys the parts through the blast cabinet in a manner similar to an airport metal detector.

A unique feature of this machine is that long narrow parts like pipe and structural shapes can be handled in addition to small parts that would otherwise be cleaned in a tumbleblast machine. Completed parts can either be fed into a basket carrier or onto roller conveyors.

This completes a general description of the options available for selecting wheel blast systems. The capabilities of each machine must now be measured against the specific parts that are to be cleaned on a regular basis. Using NASSCO'S AOE Typical Parts List (Appendix E) as a guideline, it is possible to be more specific in evaluating the various configurations.

Each machine will be evaluated on a scale of A, B C or D as follows:

- A. Ideally suited; the type of part for which the machine was designed. Rating 100%
- B. Will clean effectively on a single pass or cycle, however, part may have to be mounted on special fixturing. In addition, the energy efficiency will be lower and maintenance higher. Rating 75%
- C. Marginal on single pass or cycle, however, part can be cleaned by flipping on table, repositioning on fixturing in spinner hanger, or repeated pass through on structural or monorail. Rating: 50%
- D. Totally unsuitable, part cannot be cleaned in this machine with any practicality. Rating 0%

The percentage ratings are related to a potential financial savings evaluation that could be developed along with estimates of the manual blast cost. For example, if plate, an obvious "A" for a plate machine, were evaluated, 100% of the cost savings in using a wheel blast system would be realized. If presently being done with sand, and the cost comparison figures in Figure 5 are used, the savings for a 10' by 40' plate would be:

Cost per Square foot, Sand \$.310
Cost per Square Foot, Shot .011
 Per Square Foot Savings \$.299

800 square feet (two sides) X Savings X 1.00 = \$239.20 per plate (100% of this can be used in the justification).

If the same plate were run through a combination machine, it would be graded a "C" and the savings realized would be only 50%. Now the savings per plate is:

800 square feet X Savings X .50 = \$119.60 (50% only can be used in the justification).

Using these assumptions for the list provided, each machine's value could be determined. However, for the smaller parts, time to blast each one, rather than square footage, is more applicable for a cost analysis. This time can be converted to cost through the square foot per hour assumptions used for Figure 5.

The evaluations are as shown in Figure 6.

PART EVALUATIONS - AOE								
PART	MACHINE TYPE							
	TB	SH	MR	ST	CO	PL	TA	MB
ANGLE	D	D	C	A	A	C	D	B
BAR	D	D	C	A	A	B	D	B
BRACKET	B	C	C	D	C	D	B	A
COLLAR	A	B	C	D	C	D	C	B
CABLE SUPPORT	A	B	C	D	C	D	C	B
DAMPER	D	D	A	D	A	D	C	B
DECK SOCKET	B	B	B	D	B	D	C	A
FLANGE	D	B	B	D	B	D	C	B
FOUNDATIONS	D	C	C	D	C	D	A	?
HANDGRAB	A	B	C	D	C	D	B	B
HANGER DUCT	A	B	C	D	C	D	C	A
HANGER, PIPE CLAMP	A	B	C	D	C	D	C	B
LADDER	D	D	A	C	A	C	D	B
MANHOLE	C	B	B	D	C	D	B	A
PADEYE	B	B	C	D	C	D	C	A
PADS	A	C	C	D	C	D	C	A
PENETRATIONS	A	A	C	D	C	D	C	C
PIPE HANGER, U BOLT	A	B	C	D	C	D	C	A
RAIL, HAND	D	D	A	C	A	D	D	B
RUNG	B	B	C	D	C	D	C	B
STAPLE	B	C	C	D	C	D	C	B

TB = Tumblebelt CO = Combination
 SH = Spinner Hanger PL = Plate
 MR = Monorail TA = Table
 ST = Structural MB = Mesh Blaster

Figure 6

SUPPORT DATA AND ASSUMPTIONS FOR COST ANALYSIS (Figure 5)

1. Labor Cost: \$30 per hour, in addition:
 - A. Sand or slag requires 25% cleanup.
 - B. Wheel requires minimal labor to operate.
2. Electricity Cost: \$.06 per kilowatt hour.

3. Horsepower Requirements:
 - A. Sand: 333 cfm = 75 hp compressor
 - B. Grit: 75 hp plus other equipment = 100 hp
 - c. Wheel:

Four 20 hp wheels	80
elevator	7.5
dust collector	15
<u>conveyors</u>	<u>5</u>
total	107.5

4. Horsepower to Electric. Converted at 745 watt per hp.

5. Abrasive Cost Per Ton
 - A. Sand: \$50
 - B. Steel grit and shot: \$550

6. Abrasive Usage Per Hour
 - A. Sand: One ton
 - B. Grit: 30* tbs.
 - c. Shot: 24 lbs. per wheel*

7. Cleaning Rates, Square Foot Per Minute
 - A. Sand: 5
 - B. Grit: 5
 - c. Wheel: 1 per horsepower

8. Blast Equipment Maintenance Per Hour.
 - A. Sand: \$.75
 - B. Grit: \$1.30
 - c. Wheel: \$3.00 per wheel

9. Compressor Maintenance

\$.08 per 1000 cfm

10. CFM Requirements
 - A. Sand: 333 cfm
 - B. Wheel: 8 cfm (for cleaning dust collector filters)

* Assume 100 recycles

APPENDIX E: 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 STIFF'R	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 - 1000
PENETRATION, PIPE, FLANGED, WT.	1" D×12 - 25"D×24	2,000 - 5000
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