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THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

Cost-Effective Clean Up of Spent Grit

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

in cooperation with
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DISCLAIMER

COST-EFFECTIVE CLEAN UP OF SPENT GRIT

FINAL REPORT
FOR THE SP-1 PANEL
NATIONAL SHIPBUILDING RESEARCH PROGRAM

MICHAEL AYRES
NATIONAL STEEL AND SHIPBUILDING COMPANY

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1.0 INTRODUCTION

The National Shipbuilding Research Program and, in particular, the SP-1 and SP-3 panels have long recognized the economic and environmental significance of surface preparation and coating in the building of a ship. While the SP-1 panel has routinely sought to make environment the priority, the SP-3 panel has regularly sought various ways to reduce overall costs, while increasing productivity. In December 1999, the SP-3 Technology Panel reported in its *State of the Art Report* that "the surface preparation and painting of ships is still one of the most labor-intensive parts of shipbuilding and ship repair" (6). In its search for the major cost drivers for paint shops, the panel found that "a significant amount of labor hours is being spent for simple activities like brush painting and clean up of spent abrasive." One report author suggested that "on average, approximately 15% of the paint shop's budget is being spent on job site clean up, with one shipyard estimating their cost was 48% of their labor budget."

The author went on to say that the general feeling among the yards surveyed for the panel's 1999 report was that "while job site clean up is a nuisance cost, it's not as big an issue at this time as surface preparation and paint application—the areas where most paint shops would like to invest more money in order to reduce their overall cost."

With the publication of *The Shipyard State of the Art Report (May 2000)*, however, those simple activities were now contributing to bigger issues and provoking new thinking about how paint shops do business: "Surface preparation and coating activities in US shipyards continue to be challenged by a variety of issues. Perhaps the greatest impact has been through constraints imposed by federal and state environmental regulations" (53). As evidenced in the 1999 report, surface preparation technology was driven by economic considerations. Now the technology is driven equally by environmental expectations.

In truth, the point of view is not new. It was commonly offered in NSRP literature through the 1990's, as reports regularly emphasized the impact that surface preparation and coating activities had on the environment. In NSRP 0387, a 1993 study intended to demonstrate the feasibility of blasting tanks with recoverable steel grit, it was reported that "(n)ewly enacted and proposed clean-air, waste reduction/disposal and worker safety and health regulations will result in a severe reduction in the use of open air abrasive blasting for preparing surfaces. This will necessitate the increased use of recyclable abrasives, dust containment, and vacuum shrouded power tools. Regulatory pressures have already resulted in increased application of these alternatives in bridge, municipal structures, and industrial facilities painting operations."

OPEN AIR BLASTING IN THE SHIPYARD

A 1999 NSRP 0509 Report, entitled "Methods to Control Hazardous Airborne Dust," shared the theme, though it first took up the matter of productivity, reporting that conventional abrasive blasting "is by far the most productive and effective technique for preparing steel substrates for painting." The report went on to suggest additional advantages, including its widespread use, availability of equipment, and familiarity with the use of the method. "However," the report continued, "abrasive blasting produces large volumes of dust and large quantities of waste materials." This brings disadvantages, such as increased health risk to exposed workers; increased amounts of potentially heavy metals; increased cost for disposal when spent grit combines with waste classified as hazardous; and, emissions into the surrounding community.

More recently, in the May 2000 issue of *JPCL*, Eduardo Perez Riu Indasa writes, ”The environmental effects of high levels of dust emissions and disposal of large amounts of used abrasive are two main problems associated with open blasting…Conservation of the environment is a priority…” (“A Vision of the Future of Coating Work in Shipyards,” 46).

When it comes to dust emissions, job site clean up, and disposal of large amounts of used abrasive, the SP-1 panel has long emphasized the impact that surface preparation activities have on the environment and the need to control those activities. In fact, environmental expectations are changing every US shipyard’s routine. This note is sounded in several NSRP reports, including a 1994 report entitled, “Hazardous Waste Minimization Guide for Shipyards.” In that report, the writer states that “(I)n the past, abrasive blasting was often done without much concern for how much waste was made. The expansion in regulations regarding hazardous waste disposal has changed this routine (54).” Today, shipyards are called upon to work within more stringent laws, less flexible regulations, and stricter definitions.

Alongside SP-1 and SP-3 reports discussing the challenges of environmental expectations, some offered solutions for meeting increasingly demanding federal, state, and local regulations. More popular solutions included enclosures to contain the blast cleaning operations; localized containment of the blasting activities; and, alternate surface preparation methods that reduce or eliminate dust and debris. Containment strategies have long been a favorite solution. Most recently, Doug Ward at Alaska Ship and Drydock in Ketchikan, Alaska, was looking for “innovative industrial enclosures for use on the ASD floating dry dock.” Originally, he felt that an important finding would be that “with containment, abrasive clean-up can be speeded up significantly.” Even though his final report is less about the high cost of clean up and more about “a range of enclosure strategies,” one of the important themes of Ward’s study--and of this one-- is showing off the relationship between containment strategies and methods of clean up, while achieving and ensuring environmental compliance. (See Doug Ward’s project report, N3-95-5.) In a larger context, his study—again, like this one--supports the need to look for productivity and environmental solutions in the combined SP-1 and SP-3 panel reports about abrasive media selection, alternative approaches to surface preparation, containment, environmental consequences and considerations, and handling and clean up of spent abrasive.

SPENT ABRASIVE FINDS IT WAY TO THE GROUND

2.0 THE PROJECT

N1-95-4 (See Appendix) was intended to provide "an efficient and cost effective method to clean the spent grit while meeting all permit discharge limits." This meant reviewing the existing methodologies for handling abrasive waste with emphasis on methods that totally contain and prevent escape of abrasive and dust into the air and water. While the dry dock was the location of interest, the study proposed looking at all shipyard areas.

Also, the project proposed to identify systems available "to determine benefits, cost, capacity, effectiveness, and applicability in a shipyard environment." The intended outcome was to test the most appropriate (i.e., efficient and cost effective) system in various locations throughout a shipyard. The expectations as detailed in the project proposal were high: "The shipbuilding industry will be able to review the project task reports, test data, and recommendations and then choose a spent abrasive handling system that best fits the needs of each yard. With the emphasis on eliminating air and water pollution, this project will provide shipyards a solution to a major pollution source and thus keep shipyards in compliance with current environmental regulations."

Because of limited resources, the scope of the project was streamlined in 1999 to include the identification of methods of cleaning up spent grit in key areas of a shipyard, the clean-up rate at these key locations, and the overall effectiveness of the method employed. Finally, based on the data collected, a general table is provided describing the suitability of the clean up methods based on the criteria and comment in Table 1.

TABLE 1. SUITABILITY OF THE CLEAN UP METHOD

CRITERIA	COMMENT
COST	What is the cost to install, operate, and maintain an abrasive clean-up system?
MANPOWER	What is the number of people required to operate and maintain the system?
CAPACITY	How much material can the system handle and at what rate?
ENVIRONMENTAL IMPACT	When operating, does the system meet shipyard environmental requirements by eliminating air and water emissions and does the system provide a clean, environmentally acceptable handling system, including fines and dust containment?
HAZARDOUS WASTE	Is the handling of hazardous material covered by the system?
SHIPYARD ACCEPTABILITY	Is the handling of hazardous material covered by the system?

3.0 SHIPYARD VISITS

Between September 1999 and June 2000, six shipyards in the United States and one shipyard in Canada were visited. In the US, the following yards were visited and grit operations discussed:

- Bath Iron Works (Maine)
- Electric Boat (Connecticut)
- Newport News Shipbuilding (Virginia)
- Puget Sound Naval Shipyard (Washington)
- South West Marine (California)
- Todd (Washington)

The unsegregated paint and grit clean up operations in Vancouver Shipyards provided an interesting starting point for the project since in some ways it seemed to characterize the early days of paint shops in the US, where large amounts of dust were generated during a clean up operation and the requirement to clean up did not preclude painting in the near vicinity of the dust. Today, much attention is given to that fugitive dust not only for its potential to contaminate clean surfaces, but also to contaminate the air, land, and water.

UNSEGREGATED PAINT AND GRIT CLEAN UP OPERATIONS

Most of the spent grit at Vancouver Shipyards does eventually make its way to a grit pile—a common destination of used grit in many shipyards, foreign and domestic.

THE SPENT GRIT PILE: A COMMON SHIPYARD PRACTICE

4.0 SHIPYARD SURVEY

While shipyard visits provided first-hand observation and the opportunity to question knowledgeable people and test some of the early conclusions, the true heart of the project was a twelve-question survey (Appendix) that intended to extract from the respondents a number of things--chief among them four key elements:

- Where do you blast? (LOCATION)
- How do you clean up the abrasive grit? (METHOD)
- How fast do you clean it up? (RATE)
- How effective is your clean-up method? (EFFECTIVENESS)

The survey was also able to provide important information about the media types; reusability and recyclability; blasting methods; types of structures being blasted; types of containment employed; and, the perceived and real impact of environmental rules and regulations on blasting at various locations in a shipyard. By the end, thirteen shipyards were provided the survey electronically and eleven responded.

The original thirteen yards included:

- Alabama Shipyard
- Alaska Ship and Dry Dock
- Atlantic Marine
- Avondale
- Bath Iron Works
- Cascade General
- Electric Boat
- Halter
- NASSCO
- Newport News
- Puget Sound Naval Shipyard
- Todd
- South West Marine

5.0 LOCATION

Where do you blast? While shipyard location terminology can vary from yard to yard, there was general consensus about the following seven locations in a shipyard where abrasive blast activity takes place. These included a blast house, a building dock, a floating dry dock, a building or sliding ways, on ground, on board, and at berth. (See Table 2.)

SHIPYARD BLAST AND PAINT HOUSE DOORS

Over 40% of blast activity in a shipyard, according to respondents, takes place in the blast house. Nearly 30% of blast activity takes place in floating dry dock/dry dock. While aimed chiefly at location, the responses also say something about what is being blasted at the location. The blast house accounts for most of the new construction blasting, including new steel with preconstruction primer, small parts, subassemblies, and blocks. The floating dry dock/dry dock accounts for most of the repair blast activity. Again, according to the responses, as much as 90% of the blasting done in a floating dry dock/dry dock is reported as repair blasting.

TABLE 2. BLAST LOCATION

BLAST LOCATION	PERCENTAGE OF BLAST ACTIVITY
BLAST HOUSE	42%
BUILDING DOCK	2%
FLOATING DRY DOCK/DRY DOCK	28%
SLIDING (BUILDING) WAYS	3%
ON GROUND	12%
ON BOARD	8%
AT BERTH	5%

6.0 METHOD

What method of clean up do you employ at those locations? Again, several methods were identified, including:

- Automated (closed loop)
- Direct Load
- Mechanical/Manual
- Manual

7.0 RATE

What is the rate of the method employed at these locations? Each yard expressed rates in tons per hour. The survey uncovered some of the elusiveness of finding established rates. One respondent seemed to speak for other yards when he remarked, “The cleaning rates...vary greatly...making it impossible to give a relevant cleaning rate. The rate will vary from 50% of the blast time to 400% of the blast time--the average being 100% in all areas.” This statement reinforces a comment in NSRP Report 037: “Cleaning up spent abrasive contributes a significant cost to the abrasive blasting operation. In many cases, the labor cost involved in cleaning up spent abrasive exceeds the labor cost of applying the abrasive” (29).

CLEANING UP SPENT ABRASIVE CAN COST MORE THAN GENERATING IT

8.0 EFFECTIVENESS

How effective is the process at that location? The final question was intended to have respondents take both environmental and productivity points of view. To get both viewpoints, each of the yards expressed this in one of three ways: (1) The process is cost effective and meets environmental requirements; (2) the process meets environmental requirements but is not cost effective; and, (3) it is increasingly difficult to meet environmental requirements with the current process. As the survey will show later, as blast operations moved away from the blast house, environmental concerns rose.

9.0 DETAILS OF THE SURVEY – METHOD AND LOCATION

AUTOMATED – BLAST HOUSE

BLAST LOCATION	PERCENTAGE OF BLAST ACTIVITY
BLAST HOUSE	42%

THE SHIPYARD BLAST HOUSE

The survey revealed that the blast house accounts for 42% of the abrasive blast activity that takes place in the shipyard. While a variety of surface preparation activities can take place in the blast house—from sweep blasting to white metal blasting—the most common surface preparation is SP-10, which according to respondents is accomplished by air blasting. Typically, the yard employs the air blasting method because it is, as Charles Munger points out *in Corrosion Prevention by Protective Coatings*, “the most versatile type of surface preparation method, involves the lowest cost, and the most effective method of surface preparation, especially for coatings that are to be used in highly corrosive areas” (221). Good production, good profile, good clean, dry surface.

At the blast house, steel is the abrasive of choice, which past NSRP projects have pointed out provides important productivity and environmental advantages. Economically, "steel shot and steel grit require a high initial outlay of capital, but they can be reused to the point that they are more cost effective" ("Power Tool Cleaning" 54). The researchers go on to calculate the savings and report that "the use of recyclable steel grit is the most cost effective method of surface preparation at $.34 per square foot. The substitution of a copper slag disposable abrasive increases the cost substantially at $1.13 per square foot" (16). Environmentally, **"**the volume of waste generated can be reduced by using blast media that is relatively easy to recycle." ("Hazardous Waste Minimization," 54). The feasibility study (i.e., NSRP 0387) found that "the use of recyclable steel abrasive offers significant opportunity to reduce spiraling waste disposal costs," suggesting as much as "a 99% reduction in waste using steel abrasive" (13-14).

The blast house also enjoys another advantage in the shipyard: the blast operation is totally contained and is typically characterized by an abrasive reclamation system. As the authors of *The Shipyard State of the Art Report* point out, "Primary surface preparation is performed indoors, which permits the use of efficient controls for airborne emissions of fugitive blasting dust…" (57). The steel grit recovery system is a complete, closed-loop system in which the spent abrasive is typically collected and fed into an auger style conveyance system, cleaned, reclassified, and stored for reuse. One shipyard describes his system: " At the shothouse, there is a built in recovery system in the floor on both sides of the booth. The center is solid and shot builds up there, but we use a bobcat to push/feed the auto recovery device. There are areas where we use vacuum retrieval as well, and they are also part of the booth set up." In any blast house, there is some percentage of manual intervention, but for the most part the clean up is automated.

Eight of the eleven shipyards, which had blast houses, felt that this clean-up method was cost effective**.** One yard said it wasn't effective "because for a high percentage of our blasting we use copper slag," a single use media. The goal in this yard was "to introduce recyclable steel grit in the near future." The driver there is cost. "It costs (our shipyard) three times as much to use copper slag than steel shot." Another yard felt it wasn't cost effective because they did have a blast house, but the method of clean up was manual since there was no auger-style abrasive reclamation system. Still, no matter what media was used or what method of clean up was employed, none of the respondents expressed any environmental concerns. Not surprisingly, the rate of clean up at the blast house location was 4.89 tons/per hr.

STEEL GRIT RECLAMATION SYSTEM FOR BLAST HOUSE

Interestingly, one yard was able to take the closed-loop system into a graving dock. The system included a blasting containment dust enclosure, blast pot, pneumatic floor tube, contaminated media recovery, vacuum and reclaim system, contaminated air return, and dust collector. What makes the system unique, of course, is its portability. This shipyard understands the advantages of the closed-loop blasting system, including reduced emissions of fugitive dust and paint debris, ability of other trades to work in adjacent areas, reduced risk for paint debris to enter a dock sump and then local waterways. The other respondents indicated that such a solution—while attractive—was "too costly."

Indeed, inserting a blast house in a shipyard is a costly endeavor; as much as several million dollars. Before embarking on that endeavor, competing points of view must be considered. To the Paint Manager, if a coating fails, the cost of repair can be several times that of the original coating cost. And, good surface preparation (e.g., air abrasive blasting) is very good insurance against coating failure, especially in critical areas. To the Environmental Manager, however, spent abrasive dropped on the floor of the dry dock creates the potential for a costly environmental consequence. One yard Environmental

Manager said, “One of the most difficult issues facing us is the inadequacy of current containment to keep the grit from getting into the storm drains or receiving bodies of water….”

No decision can be made today without calculating both productivity and environmental gains and losses.

GRIT DEBRIS FOLLOWING OPEN AIR BLASTING

MECHANICAL/MANUAL – FLOATING DRY DOCK

BLAST LOCATION	PERCENTAGE OF BLAST ACTIVITY
FLOATING DRY DOCK/DRY DOCK	28%

FLOATING DRY DOCK

The floating dry dock accounts for nearly one third of all blast activities in a shipyard, according to survey respondents. Like the blast house location, a variety of surface preparation activities can take place in a dry dock. Over half of the respondents reported that SP-5, SP-10, SP-6, and SP-7 are achieved at this location, but the common method employed by all the reporting shipyards is an SP-10. Beyond the amount of activity and surface preparation requirements, the comparison between a yard's blast house and the dry dock ends. The control method employed in the blast house—walk in a blasting room with controlled ventilation and an abrasive reclamation system—is not generally achievable in a dry dock, though as Doug Ward with ASD has commented, there are a number of enclosure strategies (i.e., controls) that are possible in the dry dock setting. (See NSRP Project 3-95-5.)

In the dry dock, most yards use copper or coal slag, which is a single pass media. The slags are commonly used in Repair because they perform well. However, as a single use media, slag gets low scores because of its potential to generate a large amount of waste, to produce uncontained dust and debris, and to require increasingly significant clean up and disposal costs. (For more detail, see NSRP Report 0387.)

Unlike the blast house, which totally contains the blast activity, dry dock containment reported by the responding yards was varied. This seems to support recent findings. Because there is no universal containment strategy, Doug Ward at ASD says that choice of containment is usually determined on "a case by case analysis of a specific shipyard's unique conditions." (See Doug Ward's project report, N3-95-5.)

TYPICAL LOCALIZED CONTAINMENT (SHRINK WRAP)
IN DRY DOCK

The case-by-case point of view is reflected in containment strategies described by the eleven shipyards responding to the survey. The mix of strategies includes shrink wrap, curtains, fixed assets, and the ship's structure. In two instances, it was reported, "there was no containment at all." More than half of the respondents reported that the method of clean up used in the dry dock was not cost effective and one-third felt that it was becoming increasingly difficult to meet current and emerging environmental requirements. Each of the yards discussed the importance of housekeeping, which included cleaning up spent abrasive as soon as possible. In the dry dock, a variety of clean up methods are employed and most are characterized as Mechanical/Manual, including snow plows, bobcats with front loaders, bobcats with front-end sweepers, wet/dry vacuums, vacuum pump trucks, air blow down nozzles, brooms, and shovels. Because of the increasing manual involvement, the clean up rate in the floating dry dock is 3.44 tons per hour. Because of varying amounts of manual involvement and “too many variables,” the rate can be elusive, ranging between 4 tons per hour to slightly more than 1 ton per hour.

For instance, in one eight-hour period, a three-man blast crew calculated that they were able to move approximately 30 tons of spent grit from the tanks that had been blasted in dry dock to transportation bins. According to the crew, the spent slag was brushed, blown, swept, and shoveled to an access opening in the tank; dumped onto the floor below; vacuumed up into a spent grit bottle; emptied into a transportation bin; and then taken by forklift to a site in the yard for later pickup and disposal. For this on-board application, the estimated clean up rate was 3.75 tons per hour.

BOTTLES AND BINS: PART OF THE CLEAN UP PROCESS
WHILE IN FLOATING DRY DOCK

On the other side, in a vacuum recovery test conducted as part of NSRP 0387, researchers found that a blast crew was able to clean up 4 tons of spent slag in 3 hours, a clean up rate of 1.3 tons/hour. The researchers were quick to point out, “Conclusions cannot be drawn for actual on-board applications based on this test data, as conditions and costs may be different…(31).   Still, the range and variability of rates needs to be remarked on, especially in the Mechanical/Manual category.

Only one yard among the eleven responding considered the clean-up method cost and environmentally effective. “We use bobcats with power sweeper attachments. Grit is swept up and dumped directly in 20-yard transportation bins on the dock floor. (It) takes about 8 hours to pick up 300 to 350 tons of grit.”

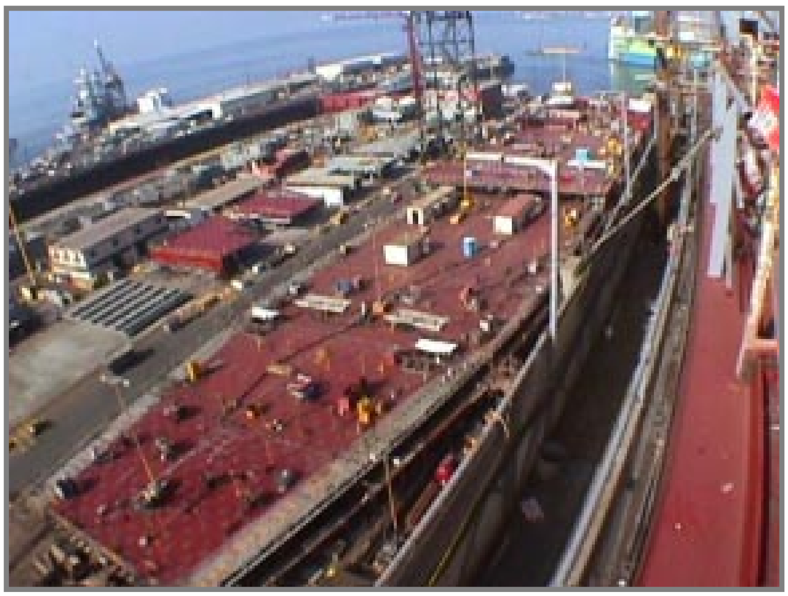
**BOBCAT WITH POWER SWEEPER ATTACHMENT
COMPLETING SPENT GRIT CLEAN UP**

In two of the responses, there was discussion of bringing recyclable blasting to the dry dock. This point of view has been well documented. Indasa remarked recently that “no major changes are predicted in the use of dry abrasive blasting for ship repairs. The one exception could be in the use of recyclable abrasives to minimize the cost of disposal. The cost of disposing of used abrasive has increased tremendously, and so using recyclable abrasive has to be considered. The higher price of recyclable abrasives and the added costs of recycling are offset by the fact that they can be used several times” (43). This seems to some of the yards to be an attractive alternative to slag blasting. Why? In part because of the reduction in clean up time. In NSRP 0387, the author comments, “The spent abrasive clean up time for copper slag was 3.1 hours as compared to 2.2 hours for steel grit. The difference in clean up time indicates a savings of about 30% when using steel grit.” Further, “Steel grit does have a distinct advantage over other abrasives in the clean up process. Slag and mineral abrasives produce large amounts of dust during blasting. This dust normally adheres to all exposed tank surfaces, such as bulkheads, stiffeners, and overheads. Dust must be removed prior to painting to prevent coating failure. Removal of dust by brushing, sweeping, blowing down with air is labor intensive, especially in complex tanks. Since steel produces significantly less dust than other abrasives, dust clean up time is reduced and cost savings are realized" (31).

Despite the need for changes in areas like a dry dock, the survey responses seemed to indicate that shipyard processes are most often performed as they always have been. Where mineral abrasives are used, following the blast operation, spent abrasive is collected and transported and is eventually sent out of the shipyard for disposal or reprocessing. In that routine, there are opportunities for fugitive emissions. As the feasibility study cautions: "Care must be taken during collection, transportation and temporary storage process to ensure that waste products are not accidentally released into or near any water source" (11). Unfortunately, as blasting moves farther away from the blast house, environmental consequences press in.

DIRECT LOAD - FLOATING DRY DOCK/DRY DOCK AND SLIDING WAYS

BLAST LOCATION	PERCENTAGE OF BLAST ACTIVITY
FLOATING DRY DOCK/DRY DOCK	28%
SLIDING (BUILDING) WAYS	3%



DIRECT LOAD IN SLIDING WAYS

Direct load is a method employed at two shipyards and is used in a sliding ways and dry dock. At those locations, the typical surface preparation is SP-10, the air abrasive blast method is used, and copper slag is the media. The direct load method is reasonably straightforward: following blast, material is vacuumed up to grit bottles on the main deck. When the bottles are full, they are craned into position above supplier trucks. The material is transferred to the trucks and the spent grit is taken offsite. While the method is only slightly more cost effective than the mechanical/manual method, it better satisfies environmental requirements, especially as it eliminates some of the transfer and handling weak points inherent in the more conventional clean up methods. The rate is 4.10 tons per hour.

MANUAL – ALL LOCATIONS

BLAST LOCATION	PERCENTAGE OF BLAST ACTIVITY
ON GROUND	12%

MANUAL CLEAN UP IS OFTEN PERFORMED ON GROUND

The manual method is employed at all locations in a shipyard. Indeed, many survey respondents reported that “in all instances some percent of manual is used.” At all locations where the manual clean up method is employed, material is normally air abrasive blasted to near white metal (SP-10) with a single pass media (copper or coal slag). Some yards reported that while they used the manual method to clean up spent grit, they were using recyclable material. In these cases, the material is swept and shoveled for bobcat pickup and then dumped into the recovery system.

Containment—like any containment away from a blast house—is a mixture of shrink wrap, curtains, fixed assets, and the ship’s structure. However, where the manual method was used, it was used in areas where increasingly the report was “no containment.” Alongside that, there were increasing concerns about the cost and environmental effectiveness of the clean up method. Also, away from the blast house, manual recovery normally means no automatic recovery system. The manual rate is 1.16 tons per hour.

10.0 RATES

One of the most compelling concerns with spent grit is with the high cost of cleaning it up. Many respondents admitted that giving a meaningful rate is difficult. One shipyard felt it was impossible to give a meaningful rate since “there were too many variables involved.” While the clean up rates that follow in Table 3 generally represent the responding yards, the dissenting shipyard’s response does suggest that to be meaningful, clean up rates need to be understood within the context of the whole job. What is the whole job? What are the variables? And, once they are known, does clean up represent 5% of the cost of the whole job? 10%? 50%? 100%? 400%?

TABLE 3. RATES AT DIFFERENT LOCATIONS

METHOD AND LOCATION	RATE
AUTOMATED -Blast House	4.89 TONS PER HOUR
DIRECT LOAD -Building Dock -Floating Dry Dock/Dry Dock -Sliding Ways	4.10 TONS PER HOUR
MECHANICAL/MANUAL -Floating Dry Dock/Dry Dock -On-Board	3.44 TONS PER HOUR
MANUAL -All Locations	1.16 TONS PER HOUR

Even if an analysis were limited to the *handling* required of large amounts of abrasive during all aspects of the blast operation, that alone includes receipt, storage, transport to the blast location, set up, blasting, *clean up*, collection after blasting, and disposal. While not all of that can be addressed here, it is important nonetheless to establish at least a part of that context, and then apply the clean up rates surveyed here to typical amounts of spent grit generated during a blast operation. At least, then, some of the elusiveness of applying a meaningful clean up rate to a blast operation can be eliminated. Based generally on past NSRP report data and industry information, the following values are assumed:

TABLE 4. SPENT GRIT AND CLEANING RATE DATA

	STEEL GRIT /COPPER SLAG (LBS FT^2)		CLEANING RATE (FT^2/HR)	
	NEW	**HARD COATS**	**NEW**	**HARD COATS**
STEEL	7	15	365	125
COPPER SLAG	8	17.5	175	65

Note: In NSRP 0387, a Connex Box was blast cleaned to white metal and repainted with a 3-5 mil coating of Navy Formula 150 epoxy and its values are used here ("NEW") for comparative purposes. Of course, there is wide variation in rates. SSPC has reported abrasive usage rates of 5.5 lbs/ft^2 (steel grit) and 3.1 lbs/ft^2 (slag) on newly fabricated steel. And, for hard coated surfaces, JPCL has reported that as much as 20 lbs/ft^2 are required to remove coatings and as little as 25 ft^2 are cleaned in one hour. Values for surfaces with hard coats are at best approximate.

Four additional assumptions are included with the values described in Table 4: 10,000 square feet of steel surface to be cleaned; surface is new (see Note above) or hard coated; surface to be blasted to an SP-10; and, $30 per hour for labor. The reason for applying a labor rate is to provide an overall dollar value to spent grit clean up. Clearly, the labor rate would vary from yard to yard.

TABLE 5. APPLICATION OF RATES BY LOCATION, CLEAN UP RATE, AND GRIT TYPE

METHOD	CLEAN UP RATE (TONS PER HOUR)	GRIT TYPE	SPENT GRIT/SLAG (TONS)	LOCATION	TYPE OF STEEL	CLEAN UP (HRS)	LABOR COST ($30 PER HOUR)	CLEAN UP COST PER SQUARE FOOT
AUTOMATED	4.89	STEEL	35	BLAST HOUSE	NEW	7.2	$216	$0.02
DIRECT LOAD	4.1	SLAG	40	SLIDING WAYS	NEW	9.8	$294	$0.03
MECHANICAL/ MANUAL	3.44	STEEL	35	DRY DOCK	NEW	10.2	$305	$0.03
		SLAG	40		NEW	11.6	$350	$0.04
		STEEL	75		REPAIR	21.8	$655	$0.07
		SLAG	88		REPAIR	25.4	$762	$0.08
MANUAL	1.16	STEEL	35	ALL LOCATIONS	NEW	30.2	$905	$0.09
		SLAG	40		NEW	34.5	$1,035	$0.10
		STEEL	75		REPAIR	64.7	$1,940	$0.19
		SLAG	88		REPAIR	75.9	$2,276	$0.23

Note: While steel abrasive is not typically used in a dry dock, one yard reported doing so; therefore it has been included in Table 5 for comparative purposes.

While the gains in cost per square foot seem modest when comparing the Automated method (i.e., $.02) with Direct Load and Mechanical/Manual methods (i.e., $.03), what isn't shown is that the Automated method is performed within an enclosed area, eliminating the environmental risks and economic consequences. On the environmental side, potential risks increase as blast operations move farther away from the confines of the blast house. A common concern expressed by Environmental Managers is that new construction and repair facilities operating away from the blast house are open to the environment and therefore difficult to control. One manager reported, “The problem we face in this area is storm water run-off which has to be controlled. We typically install filters at drainage areas and contain and clean up abrasive as soon as possible before it has a chance to enter the drainage system.” Again, the Environmental Manager is concerned with controlling or containing emissions away from enclosed facilities.

On the other side, the Paint Shop Manager is faced with the costliness and sometimes the impracticality of enclosing all of the surface preparation and painting operations to meet environmental demands. The cost of containment has been estimated at between \$1.50 - \$3.00 ft^2. And, as da Maria points out, “erecting and removing containment systems can be time consuming, and the time available for work in dry dock generally does not make such allowances.” (35). There are other productivity concerns as well, especially with manual grit recovery.

Perhaps the most telling statistic in Table 5 is the high labor cost of manual clean up. In both the mechanical/manual and manual categories, the percent of the cost of clean up jumps dramatically, especially as the manual method is applied to Repair activity—as much as \$.23 per square foot. Also significant is the increase in the amount of labor clean up cost relative to the labor blasting cost. In the Automated environment, the cost of clean up is relatively low, while in a manual environment, the cost of clean up, as often reported, can easily match and even exceed the cost of abrasive blasting. While some amount of manual clean up is required at any location, wherever the manual method can be minimized, the cost of clean up—and inevitably the whole job cost--can be reduced.

An example of the importance of evaluating different clean up strategies, of comparing the costs of those different strategies, and of employing one strategy over another comes from one of the shipyard respondents. Recently, on a multi-ship contract, the yard was employing the mechanical/manual method for the clean up of tanks following blast operations. While the mechanical/manual rate in this study shows an approximate rate of 3.44 tons per hour among the shipyards surveyed, the shipyard was well off the average. In fact, on the early ships of the class, the yard found that it was achieving a not very productive clean up rate of 1.62 tons per hour. This was due in large part to the emphasis on manual involvement in the clean up. Still, this was an important finding since the blast operations involved over 600,000 tank square feet, leaving a significant amount of spent abrasive to clean up. After investigating several alternatives, the decision was made to employ Direct Load. Some modest benefits were seen over the follow-on ships. At its best, the yard was eventually able to achieve a clean up rate of 4.1 tons per hour. While data collection and analysis are ongoing, the yard hopes to maintain that rate and continue to reduce clean up costs. What is important to that shipyard is that a change in clean up method has yielded some marked improvement in the clean up cost per square foot and reduced the opportunities for fugitive dust emissions during spent grit clean up and transfer.

These days, the method of clean up, as well as containment, employed by a shipyard must necessarily represent both economic and environmental positions. Without a sound containment and clean up strategy, a shipyard can exert little control over the environmental impact of the grit-laden storm water runoff or the high cost of containing activities away from the confines of the blast house.

11.0 SUITABILITY OF THE SYSTEM

The final piece of this report, described in Table 6 below, was to define the suitability of the four methods, based on cost, manpower, capacity, environment, hazardous waste, and shipyard acceptability. The table highlights the increasing concern with environmental consequences and the high cost of mitigating them.

TABLE 6. SUITABILITY OF THE SYSTEM

	AUTO	DIRECT LOAD	MECH/ MANUAL	MANUAL
COST OF OPERATION	$	$$	$$$	$$$$
MANPOWER REQUIRED	1	1.25	1.5	4.25
CAPACITY	4.89	4.10	3.44	1.16
ENVIRONMENTAL IMPACT	LOW RISK	LOW TO MODERATE RISK	MODERATE RISK	HIGH RISK
HAZARDOUS WASTE	LOW	LOW	MODERATE	HIGH
SYSTEM INTEGRATION	$$$$	$$	$$	$

If the goal of a yard is to reduce the environmental impact (i.e., attain "Low Risk" status), including a "Low" hazardous waste value, the cost of integrating such a system (e.g., closed loop) into a shipyard is significant, but perhaps necessary. Likewise, if the goal is to accomplish clean up principally by manual means, the cost of integrating that operation into a shipyard is very low. However, the cost of operation (i.e., the amount of labor hours needed to clean up one ton of spent grit) is high, the environmental impact is high, and the hazardous waste value is high.

12.0 CONCLUSIONS

The obvious and immediate conclusion is that blasting new steel (with a hold coat) in a blast house is going to yield the best clean up rate and cost per square foot. In the blast house, grit is automatically recovered, waste is minimized, the blast operation is totally contained, and productivity is high. Also, as one yard was able to demonstrate, it is feasible to take the blast house, or closed-loop system, into other shipyard locations, though at a substantial cost. More often, however, as yards take their blast operations away from the blast house, recovery is considerably more manual, waste amounts are increased, environmental anxiety increases, and productivity numbers drop. Other, additional conclusions:

- Clean up rates are best when automated methods are employed.
- Clean up rates are best when blast activities are totally contained (e.g., blast house) and the process is controlled.
- When the activity is automated, contained, and controlled, environmental issues are minimized (i.e., escape of abrasive and dust into the air and water).
- As clean up activities move away from a contained facility, more manual clean up is employed, the clean up rate drops, less control is exerted over the process, and the potential for environmental impact goes up.
- Away from the blast house, containment methods seem less adequate, increasing opportunities for the escape of abrasive and dust into the air and water.

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APPENDIX

NSRP PROJECT N1-95-04
COST EFFECTIVE CLEAN-UP OF SPENT GRIT

LOCATION	BLAST HOUSE	BUILDING DOCK	FLOATING DRY DOCK	SLIDING WAYS	ON GROUND	ON BOARD	AT BERTH	OTHER (EXPLAIN)
1. What type of abrasive is used at this location?								
Copper slag								
Coal slag								
Steel grit/shot								
Sand								
Specialty abrasives (e.g., aluminum oxide, garnet, glass, etc.)								
Other								
2. What percent of the total abrasive blast media in your shipyard is used at this location?								
3. What percent of the total abrasive blast media used at this location is recyclable?								
4. What percent of the total abrasive blast media used at this location is one use only?								

LOCATION	BLAST HOUSE	BUILDING DOCK	FLOATING DRY DOCK	SLIDING WAYS	ON GROUND	ON BOARD	AT BERTH	OTHER (EXPLAIN)
5. What method of abrasive blasting is used at this location?								
Air abrasive blasting								
Wet abrasive blasting								
Rotary or Wheel blasting								
Vacuum blasting								
6. What structures are blast cleaned at this location?								
New steel								
Small parts								
Partial blocks/Modules								
Blocks								
Ships – Interior								
Ships – Exterior								
Other								

LOCATION	**BLAST HOUSE**	**BUILDING DOCK**	**FLOATING DRY DOCK**	**SLIDING WAYS**	**ON GROUND**	**ON BOARD**	**AT BERTH**	**OTHER (EXPLAIN)**
7. What level of surface cleanliness can be achieved at this location?								
SP 5								
SP 6								
SP 7								
SP 10								
8. What method of grit clean up is used at this location?								
High automated or mechanical clean up/Little or no manual clean up[1]								
High manual clean up/little or no automated or mechanical clean up[2]								
Roughly equal amounts of automated or mechanical clean up and manual clean up[3]								
No grit is collected at this location								

LOCATION	BLAST HOUSE	BUILDING DOCK	FLOATING DRY DOCK	SLIDING WAYS	ON GROUND	ON BOARD	AT BERTH	OTHER (EXPLAIN)

9. At what rate (expressed in pounds or tons per hour) is the grit cleaned up at this location, using the methods described below?								
High automated or mechanical clean up/Little or no manual clean up[1]								
High manual clean up/little or no automated or mechanical clean up[2]								
Roughly equal amounts of automated or mechanical clean up and manual clean up[3]								

[1] For example, closed circuit blast cleaning (abrasive and air contained in special housing) or closed loop system
[2] For example, broom and shovel cleaned
[3] For example, plowed (snow-, Bobcat) into floor trenches to conveyance system and then final broom sweep

LOCATION	BLAST HOUSE	BUILDING DOCK	FLOATING DRY DOCK	SLIDING WAYS	ON GROUND	ON BOARD	AT BERTH	OTHER (EXPLAIN)

10. What containment type is used at this location?								
Building								
Membrane system (e.g., shrink wrap)								
Curtains								
Fixed assets (e.g., Building dock walls)								
Ship's structure								
Other								
No containment								
11. How effective is the grit clean up method used at this location?								
Would not change process. It is cost effective/efficient and meets environmental requirements.								
The process meets environmental requirements, but is not cost effective/efficient.								
It is increasingly difficult to meet environmental requirements with current process.								

LOCATION	BLAST HOUSE	BUILDING DOCK	FLOATING DRY DOCK	SLIDING WAYS	ON GROUND	ON BOARD	AT BERTH	OTHER (EXPLAIN)
12. What rules/regulations govern grit clean up in your yard?								
Federal								
State/Regional								
Local								
Company BMPs								
Yard Housekeeping Policy								

If you selected “Other” in the following questions, briefly describe what “Other” is.

1. What other types of abrasive is used at this location?

6. What other structures are blast cleaned at this location?

10. What other containment type is used at this location?

Survey completed by (include your title):

Date:

Shipyard:

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