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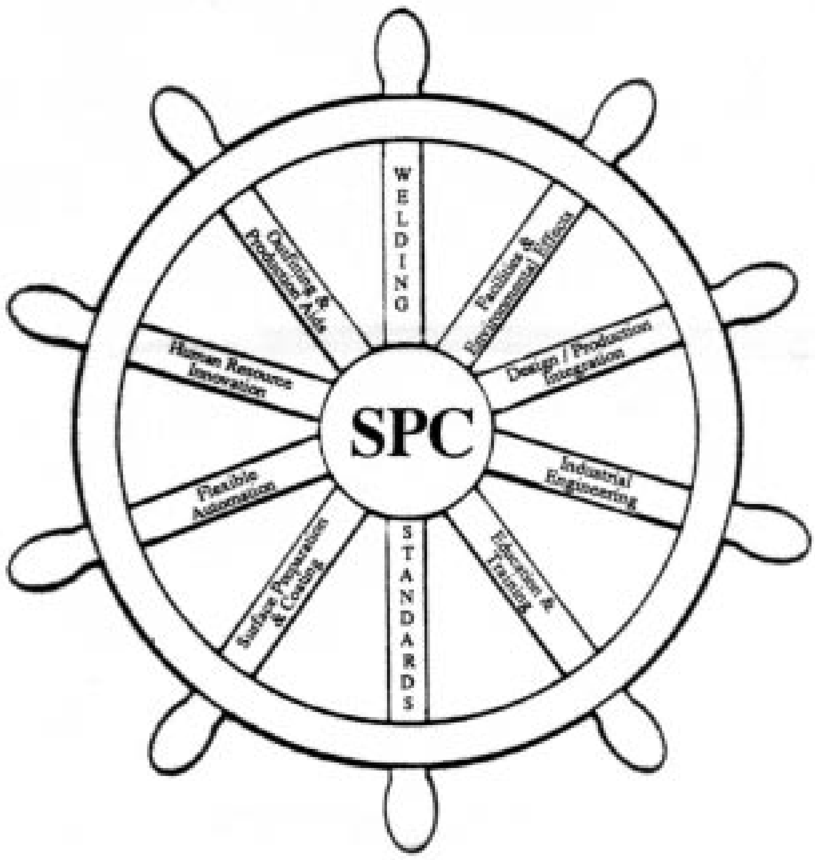

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The Development of CO_2 Blasting Technology in Naval Shipyards

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ABSTRACT

What is CO_2 blasting? CO_2 blasting is a relatively new paint removal-technology that turns liquid carbon dioxide into pellets. The most promising applications are elimination of hazardous waste, dust plumes, and contaminated water associated with the use of slag abrasives.

This paper will describe the process that Naval Sea Systems Command used to take CO_2 blasting from the "talking" stage to implementation in naval shipyards. The process started with a visit from a vendor and ended with a thirty day test of the blasting system.

TEXT

Navy ships bottoms are painted with antifouling paints that contain pesticide ingredients that are used to control attachment and growth of marine animals and plants living in association with structures that are in prolonged contact with salt or fresh water. Significant growth of these "fouling" marine organisms, such as barnacles, seaweed, and algae, can restrict the openings of piping, increase the weight of buoys or other navigational equipment, constrict moving parts such as propellers, inhibit vessel maneuverability, and cause roughness that reduces boat/ship speed and increase fuel consumption. Fouling organisms may damage surface coatings, promote corrosion, interfere with sonar equipment by increasing noise levels, increase maintenance costs, and detract from the appearance of the vessel.

These antifouling paints and other coating systems installed through out the ship require removal periodically. The industry accepted method for coating removal and surface preparation is abrasive blasting using an abrasive slag. These slags must meet the military specifications to be acceptable for use on Navy ships. A list of acceptable slags is maintained by Naval Sea Systems Command. In naval shipyards, paints and other coatings are removed from surfaces and the surfaces are prepared for recoating by abrasive blasting. This process generates large quantities of spent abrasive which is considered hazardous in some states. In addition, work schedules are limited because dust plumes generated by these abrasives are restricted by opacity requirements. National Pollutant Discharge Elimination System (NPDES) discharge permits limit the heavy metals and other constituents that can be leached from the abrasive into water discharged from the dry dock.

We have been attempting to eliminate any discharges from our dry docks thus we have actively pursued any improved method to cut down or eliminate contaminates. Alternative methods of surface preparation tend to complicate the problem. High pressure water blasting and Water-ring abrasive blastina generate additional water treatment problems from leached metals and corrosion inhibitors. Organic abrasives (corn cobs, walnut shells, etc.) eliminate the heavy metals but are dusty and, when confined, present explosive hazards. Performance of the plastic media blast was equal to organic abrasives but the spent abrasive mixed with the removed coating created additional disposal problems.

In July 1987 a vendor provided the Naval Sea Systems Command (SEA 07) with a brochure and a video tape describing the CO_2 blasting process that demonstrated the potential to resolve some of the problem. Blasting with CO_2 does not have any adverse impact on the environment since CO_2 is a naturally occurring gas. Furthermore, this process does not add contaminates to the coating being removed. Only the paint or coating must be disposed of when the evolution is complete. We scheduled showings of the tape for our technical codes and various management personnel. Each group was pleased with the tape and suggested further evaluations.

We obtained information packets for each of our naval shipyard commanders and for both the Atlantic and Pacific Fleet Maintenance Officers during the month of March 1988. Each packet contained (2) "Blast Cleaning With CO2 ?", (2) "CO_2 Cleanblast" brochures and (1) videotape. These packets provided a brief description of this technology and suggested various uses of the process. Each shipyard commander had their shipyard review the material and provide feedback to headquarters. SEA 07 requested each shipyard not to conduct evaluation tests since we were planning a preliminary evaluation of co2 blasting.

We enlisted David Taylor Research Center to design a preliminary test to determine the effectiveness of this technology. The test consisted of twenty-one panels, with standard navy coatings applied. The panels are listed in Table 1 with a description of the coating applied. Various naval shipyards were included in the test by providing the test panels.

Table 1

Panel No.	Description
1	Light Baked Enamel Coating
2	Heavy Baked Enamel Coating
3	Water Base Fire Retardant Coating w/o primer
4	Water Base Fire Retardant Coating w/Devoe 201 primer
5	Chlorinated Alkyd w/o primer
6	Chlorinated Alkyd w/zinc chromate primer
7	Tank Coating (Devoe 215W)
8	Formula 84/111 Enamel
9	Nil-D-3135 Underlayment w/o primer
10	Mil-D-3135 Underlayment w/Devoe 201 primer
11	150 Series Epoxy Primer
12	150 Series Epoxy Primer w/F121 antifouling paint
13	150 Series Epoxy Primer w/RFE-490
14	Powdered Epoxy Coating
15	Aluminum thermal spray coating with Type I sealer (two coats, top coat only)
16	Aluminum thermal spray coating with Type II sealer (epoxy only, top coat)
17	Experimental epoxy anti-corrosion with sand non-skid
18	Non-skid-Comp, G, Class II Roller
19	Non-skid-Comp, G, Class II Troweled
20	Non-skid-Comp, L, Roller
21	Non-skid-Comp, L, Troweled

The equipment used for this preliminary evaluation was a patented CC2 pellet blasting system. The pelletizer uses 500 lbs/hr of liquid co_2 to produce 250 lbs/hr of pellets by compressing the CO2 flakes with an extruder through an orifice. We used l/S-inch diameter pellets for our test. 1/4- inch diameter pellets are available with a different extruder. The pellets were propelled through a l-inch nozzle at 700-800 ft/sec using 750 CFM of air at 250 psi. Air pressure at the nozzle was 210 psi. The liquid CO2 costs approximately $0.03 to $0.04 per pound. The manufacturer provided the equipment and labor to conduct the test. The test consisted essentially of placing each panel in a vice and blasting a strip across the top of each panel. The time used and the area blasted were recorded. The results are contained in Table 2. These figures are not be used to extrapolate removal rates for larger surface areas, other factors must be included such as fatigue, condition of surface area and shape of the surface. This test determined the feasibility of this process for paints and coating removal.

This preliminary evaluation demonstrated that the CO2 blasting system was not effective in removing epoxy paints, non-skids, or underlayment. The system was effective in removing the softer coatings, such as vinyl antifouling paints, baked **enamels,** chlorinated alkyds, Formula 84/111 enamel, water base fire retardant paints, and tank coatings such as Devoe 215W. See Table 2 for the specific results. Further, the evaluation indicated that the Co2 blasting system should be tested and evaluated in an industrial environment in order to establish removal rates, fatigue factors and safety precautions.

To avoid each naval shipyard testing and evaluating CO2 blasting system, Norfolk Naval Shipyard was requested to conduct an evaluation of CO2 blasting system and report on the various shipyard applications. The evaluation test was designed by Norfolk and consisted of open air blasting and blasting in an enclosed area (a connex box) to simulate an enclosed space aboard ship. From 9 September through 20 October 1989 eighty-three different items were provided by the various shops and blasted. The Shipyard's Safety and Health Office monitored the open air blasting. The Naval Environmental Health Center monitored and sampled the air to assure that the level of oxygen and carbon dioxide did not exceed the acceptable limits. If at any time monitoring results indicated

Table 2

Panel No.	Cleaning Time In minutes	Area cleaned Square inches	Rate Square inches per minute
1	1:04	21	19.7
2	1:03	21	19.7
3	:09	6	40.0
4	:58	6	6.2
5	:15	6	24.0
6	:16	6	22.5
7	:20	6	18.0
8	:20	6	18.0
9	:35	3.8	6.4
10	1:18	7.5	5.8
11	2:05	9	4.3
12	:08	9	67.5
13	1:53	9	4.8
14	2:45	8	3.0
15	:15	9	36.0
16	1:16	9	7.1
17	1:03	6	5.7
18	2:20	9	3.9
19	1:30	6	4.0
20	3:00	8.3	2.8
21	2:06	6	2.9

TABLE 3

LIQUID CO2 CLEANLINESS REQUIREMENTS

The following listed contamination values are to be considered the MAXIMUM permitted unless specifically noted to be otherwise.

COMPONENT	VALUE	TEST METHOD
CO2 purity (min)	*+ 99.9%	Caustic absorption
Oxygen	* 30 ppmv	Trace 02 analyzer
Water (H_2O)	* 32 ppmw	Electrolytic hygrometer
Nitric Oxide (NO) (v)	2.5 ppmv	Color Detector tube/GC
Nitrogen Dioxide (NO_2)	2.5 ppmv	Color Detector tube/GC
Sulfur Dioxide (SO_2)	* 5.0 ppmv	Total sulfur analyzer/QC
Other Sulfur compounds including Hydrogen Sulfide	* 0.5 ppmv	Total sulfur analyzer/QC
Carbon Monoxide (CO) (V)	10.0 ppmv	Infrared analyzer
Volatile H'carbons (v)	*40.0 ppmv	Flame ionization type total h-carbon analyzer
Acetalhyde	* 0.2 ppmv	Gas chromotragph
Heavy hydrocarbons	* 10.0 ppmv	Flame ionization type total h-carbon analyzer
Other toxic materials	none	Gas Chromatograph
Inserts	* 1000 ppmv	Gas Chromatograph
Order	* Free of foreign odor	Sensory

* = Test perfored on vaporized liquid
v = Test performed on vapor in equilibrium with liquid
GC = Gas Chromotgraph with appropriate detector
\+ = Minimum permitted for this value

TABLE 4

REMOVE GREASE FROM CHOCKS FOR A LATHE

OLD METHOD

REMOVE BY HAND USING TRICHLCRIETHANE	
$49.39/LB X .5 LH TO REMOVE GREASE =	**$24.70**
Trichlorethane used 1 ga1/$5.00 per gal =	**5.00**
Disposal of used Trichloroethane	
(1 gal) x ($2.50 per gal) =	**2.50**
Old Method Total =	**$32.20**

NEW METHOD

Remove with CO2	
$49.39/LH X 64 set to remove grease X 1hr/3600 set =	**.87**
CO2 used	
(500 lb/hr) X (64 set) X (1hr 3600 set) = 9 lbs	
(9 lbs) X ($.04/lb C02) =	**.36**
Operating cost	
($20.00/hr.) X (64 set) X (1hr/3600 set) =	.36
New Method Total	$1.59

Old Method - **$32.20**
CO2 Method - 1.59

Total Savings $30.61

1. LH- Labor Hour
2. Non dollar values are rounded to nearest unit
3. Dollar values are rounded to the nearest $.01

oxygen concentrations below 19.5%, all co_2 blasting/ co2 release would cease until such time that ventilation could restore oxygen concentrations to at least 20%. After the first week of operation the Safety Office concluded that the amount of CO2 being released to the environment was not sufficient to warrant constant monitoring.

During the evaluation in the shipyard the blasters were provided personal protective equipment such as: clear plastic face shield, leather gloves, industrial leather footwear, clothing that covered the arms and legs, proper ear protection, safety glasses and for the enclosed area test oxygen monitoring devices that issued an alarm at concentration of oxygen of not less than 19.5%. The test site access was restricted to authorized personnel who were equipped with personal protective equipment and briefed of the potential hazards. Appropriate warning signs were posted for the duration of testing. Additional personal protection was available at the blast site for visitors.

Particular attention to the following parameters were recorded: the square footage of the various items; the time required to clean the item; the quality of work; blast air pressure monitored and adjusted for optimum results; carbon dioxide use; the old or present method of cleaning; and the removal rate of the old method.

Norfolk provided their final report in April 90. A problem with CO2 blasting encountered was contamination of the liquid CO_2. The CO2 needs to be food quality and sampled each time a new shipment arrives. The vendor (providing the CO_2) should certify that the liquid CO_2 is food grade and provide proof with each shipment. Contaminated CO2 caused the equipment to malfunction and delayed the test for a couple days. Table 3 provides the maximum contamination values permitted unless otherwise specifically noted.

The labor hour rate for each shop in a naval shipyard is determined by the Comptroller section and is different for each shop. The rate for individual shops is revised two or three times per year to reflect the actual cost of doing business ie. lights, steam, water etc.

Table 4 provides an example of the cost analysis used in the evaluation. The labor rate used in this example is $49.39 per hour.

CO_2 blasting will remove rust, grease and other coatings from machined parts and not destroy the machined finish. A near white metal blast (SSPC 10) is nearly impossible to obtain. The CO_2 blasting process will provide adequate surface preparation for paint application. (Provided the material had been previously blasted).

The best removal rates were obtained when the abrasive stream was perpendicular to the surface being cleaned. Additional nozzles are being developed for special uses, i.e., short, wide, and narrow nozzles.

Additional tests in conjunction with the Army, Air Force, Marine Corps, Naval Air systems Command and other activities are being conducted. The Air Force conducted a test using higher pressure and a different vendor to remove paint from their "thin skinned" airplanes. Paint on airplanes is considerably harder than paint on a ship. Norfolk Naval Shipyard is the lead activity for evaluating CO_2 blasting. This technology has proven successful on "thick skinned" applications.

The blasting in confined spaces such as bilges, tanks and voids has not been adequately investigated to date. Our evaluations have shown potential for savings in both labor and disposal costs. The only disposal cost is for the substance removed from the surface. The CO_2 returns to the atmosphere with little or no effect on the environment.

CO_2 blasting technology provides a good tool for our shipyards to use. This tool is only one of many that will provide adequate coating removal. CO_2 blasting has the potential to eliminate waste and improve working conditions. We Plan to implement this technology in all eight naval shipyards.

As you can see any new or different technology requires a dedicated effort and adequate testing to ensure a quality product. The process works.

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