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DEVELOPMENT OF A THERMAL RECLAMATION SYSTEM FOR SPENT BLASTING ABRASIVE

by

Bruce G. Bryan
Michael C. Mensinger
Amir G. Rehmat

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3424 South State Street Chicago Illinois 60616

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Development of a Thermal Reclamation System for Spent Blasting Abrasive

Bruce G. Bryan
Michael C. Mensinger
Amir G. Rehmat, Ph.D.
Institute of Gas Technology
Chicago, Illinois

ABSTRACT

Abrasive blasting is the most economical method for paint removal from large surface areas such as the hulls and tanks of oceangoing vessels. Tens of thousands of tons of spent abrasive are generated annually by blasting operations in private and U.S. Navy shipyards. Some of this material is classified as hazardous waste, and nearly all of it is currently being either stockpiled or disposed in landfills. The rapid decline in available landfill space and corresponding rise in landfill tipping fees pose a severe problem for shipyard operators throughout the U.S.

This paper discusses the results of a research and development program initiated by the Institute of Gas Technology and supported by the U.S. Navy to develop and test a fluidized-bed thermal reclamation system for spent abrasive waste minimization. Bench- and pilot-scale reclaimer tests and reclaimed abrasive performance tests are described along with the current status of a program to build and test a 5-ton/hour prototype reclaimer at a U.S. Navy shipyard.

INTRODUCTION

Abrasive blasting is the preferred method for paint removal in many industrial maintenance situations. Blasting is the only economical method available for structures having large surface areas, such as steel bridge spans and the hulls of oceangoing vessels.

Abrasive materials ranging from relatively soft plastic pellets to steel shot and sized metal slags can be used. A number of different blasting technologies are also available. All involve the projection of abrasive materials at high velocity against the surface being cleaned, using either centrifugal force or a stream of high velocity air or water.

The selection of blasting abrasive and method depends on several factors. These include size, shape, materials of construction, and intended use of the surface being cleaned, the thickness of the coating to be removed, and the physical and chemical properties of both the coating and the abrasive. The method yielding the highest removal rate and/or lowest abrasive media usage, and an acceptable profile on the cleaned surface, is generally the most economical.

Hard media abrasive projected with high-pressure air is currently the most economical method to remove the anticorrosive (AC) and antifoulant (AF) coatings used to protect the underwater hulls and ballast spaces of oceangoing vessels. The abrasives used for this purpose are waste slags generated in coal-fired power plants and nickle and copper ore smelting operations.

The coatings removed are formulated to survive in harsh marine environments and are among the most durable, and consequently the most expensive, paints available. AF coatings contain various biocidal compounds to deter the attachment and growth of marine organisms on the underwater hull and inside ballast tanks. The service life of modern AF coatings varies from 30 to 60 months (1), after which time the ship must be placed in dry dock for blasting and repainting.

Depending on the size of the ship, 300 to 900 tons of abrasive media are required to clean the underwater hull. The abrasive is contaminated during use with the coatings being removed. The concentration of paint contaminants is generally only 1 to 2 weight percent, but this renders the spent abrasive unsuitable for reuse in blasting operations. Large volumes of solid waste are therefore generated in shipyard blasting activities.

Spent abrasive contaminants include organic paint binders, organometallic biocides such as tributyltin (TBT), and various inorganic pigments and biocides. Heavy metals are often present. Elements that could be leached from the spent abrasives include arsenic, barium, copper, chromium, cadmium, lead, nickel, and zinc. The hazard classification of spent abrasive depends on the abrasive used, the coatings removed, and the environmental regulations in force where they are generated and disposed. In most states, the EPA's TCLP toxicity criteria determine the hazard classification. In California, however, the more stringent California Title 22 Toxic Waste Tests must be followed.

Reduction of spent abrasive waste streams through reclamation will result in large savings in shipyard operating costs. Savings will result from both the avoided cost of new abrasive ($50-$100/ton) and landfilling ($50-$300/ton). An additional benefit, less easy to quantify, is the reduction of long-term environmental liability for the shipyards. The changing and increasingly stringent nature of environmental regulations make landfilling waste an undesirable option for private and federal waste generators alike. Spent abrasive landfilled in full compliance with today's regulations may still require expensive removal and treatment actions under future regulations.

ABRASIVE RECLAMATION SYSTEM REQUIREMENTS

The requirements for a commercially viable abrasive reclaimer are 1) that it produce reclaimed abrasive meeting the procurement specifications of the user, 2) that the reclaimed abrasive gives acceptable performance in blasting operations, and 3) that the system operates in a reliable, cost-effective, and environmentally acceptable manner.

Contaminants in spent abrasive exist mainly as fines smaller than 70 mesh (210 microns) resulting from impact-fracture of abrasive particles, together with small paint chips. Paint chips may constitute only 1 to 2 weight percent in a typical spent abrasive, while the overall fines concentration may vary from 5 to 50 weight percent.

The minimum action necessary to meet requirement 1 above is that the paint chips be removed or destroyed and that the -70 mesh size fraction be reduced to less than 1 weight percent. This degree of reclamation is sufficient for most private shipyards in all states except California. Reclamation systems have been developed that achieve this level of reclamation relying solely on physical separation techniques such as screening and air classification. An example of this type of reclaimer is the Apache Reclaiming System, developed and tested under the National Shipbuilding Research Program, funded in part by the Maritime Administration (MARAD) and Avondale Shipyards (2). At least one commercial reclaimer is in operation using this system, serving private shipyards in the Pacific Northwest.

The stimulus for further reclaimer development comes from the fact that heavy metals tend to concentrate in abrasive reclaimed by physical separation alone. This acts to limit the number of times that the abrasive can be reclaimed and used. In California, where Title 22 sets the metal concentration limits, spent abrasives generally fail after the first use and cannot be successfully reclaimed by physical separation.

This is also the case in all U.S. Navy shipyards. While only two of the eight Navy shipyards are located in California, the Navy requires that reclaimed abrasives meet the military specification for new abrasive, which in turn requires that they meet California Title 22 limits for total and soluble metals. With some 50,000 to 100,000 tons of spent abrasive generated in the Navy shipyards each year, a strong incentive for additional reclaimer development exists.

FLUIDIZED-BED THERMAL RECLAIMER DEVELOPMENT

The Institute of Gas Technology (IGT) has been involved in the development of fluidized-bed technologies for over 30 years.

Most of the resulting technologies produce fuel gas or synthesis gas through gasification of various fossil and biomass fuels. One such technology is the U-GAS process, which has recently been licensed to Tampella, Ltd., of Finland, where it is being further developed for Integrated Gasification Combined Cycle (IGCC) power plant applications. The U-GAS process employs a unique, sloping gas-distribution grid and a solids discharge device, which eliminate many of the process gas distribution and solids discharge control problems often associated with the operation of high-temperature fluidized beds.

In 1981, IGT began a preliminary research effort aimed at finding new applications for the fluidized-bed sloped-grid (FBSG) technology. The first new application tested was for the reclamation of spent, clay-bonded foundry sand. Bench-scale feasibility testing led to Process Development Unit (PDU) and Pilot-scale testing, in which over 40 tons of foundry sand were successfully reclaimed for the American Foundrymen's Society and a major U.S. automaker.

THE FBSG RECLAIMER

The thermal reclamation system that resulted from the above development work is shown in Figure 1. The reclaimer system design provides drying, thermal treatment, and size classification of contaminated solids in a single-stage fluidized bed. Air for fluidization and combustion enters through the sloped air-distribution grid at the bottom of the fluidized bed. An additional air stream enters at the bottom of the central

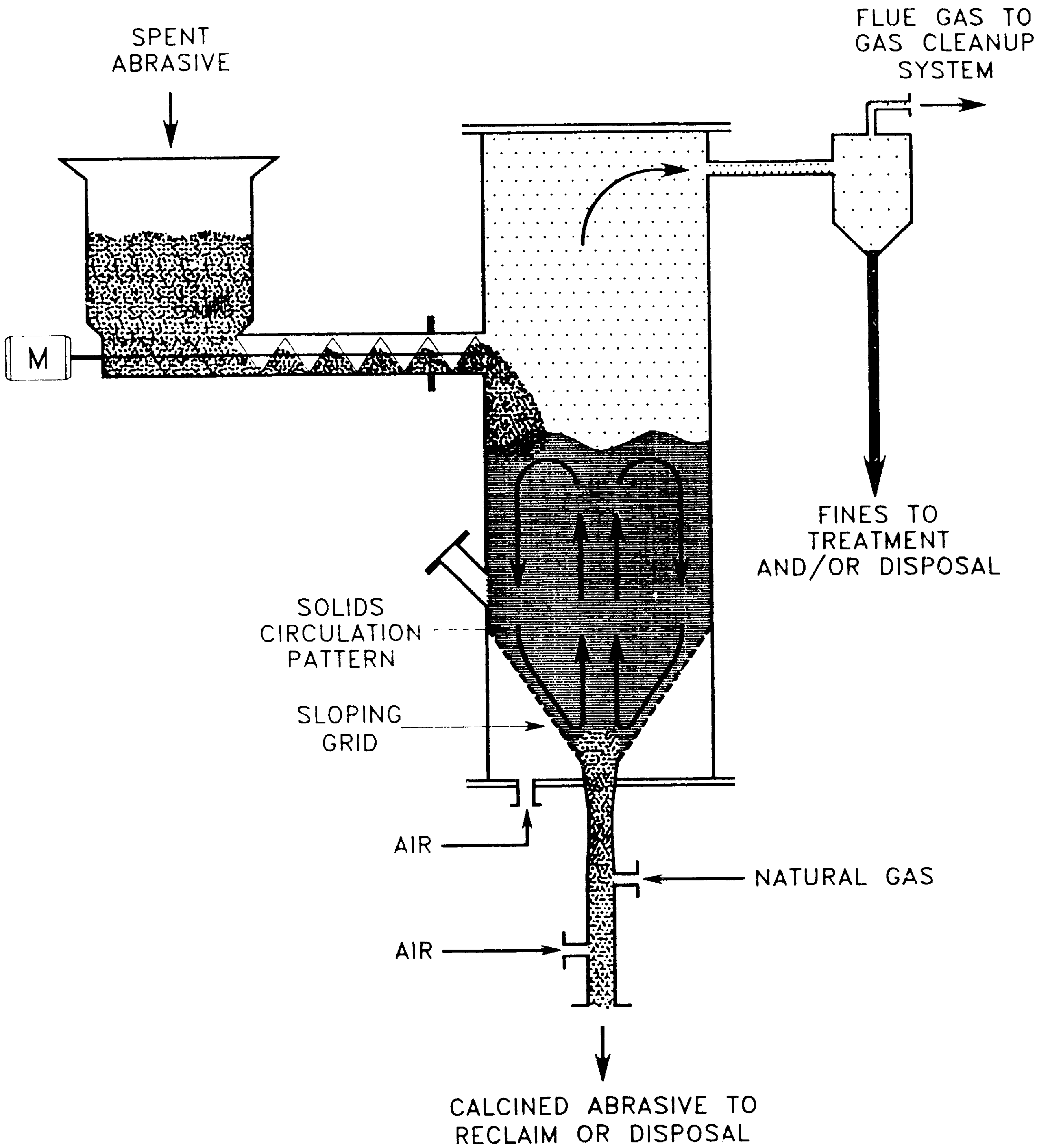

Figure 1. FLUIDIZED-BED SLOPED-GRID RECLAIMER

discharge pipe. A central fuel gas pipe supplies high heating value fuel gas along the centerline of the bed.

The sloped grid enhances the naturally occurring solids circulation pattern (downward at the wall and upward in the center) within the fluidized bed. The additional air and fuel gas introduced at the bed centerline also reinforce this circulation pattern. This promotes the intense gas-solids mixing and even temperature distribution required to achieve high destruction and removal efficiency (DRE). The sloped grid automatically directs any oversize tramp material to the central discharge port at the base of the conical grid. The same mechanism will remove any agglomerated ash particles that may form from low melting-point ash compounds in the waste feed. Problems resulting from long- or short-term accumulation of oversize material on the gas distributor are therefore avoided.

The discharge port provides precise discharge rate control by a terminal-velocity mechanism. The device has no moving parts and has been successfully demonstrated in over 10,000 hours of coal gasification service with agglomerating and nonagglomerating coal ashes. In addition to rate control, the discharge port separates fines from the discharging solids by air classification and carries them back into the fluidized bed. Thermal efficiency is increased by the partial recovery of heat from the discharging solids.

The central fuel jet permits efficient mixing of combustion air and fuel gas within the fluidized bed. A zone of intense combustion directly above the fuel jet insures complete destruction of organic contaminants from the fluidized solids as they enter the discharge port.

As fine particles accumulate in the fluidized bed, the rate at which they elutriate from the bed increases until it matches the rate at which fines enter with the solids feed. Attrition and elutriation studies have shown that few fines are actually formed within the fluidized bed itself (4). Fines carried out of the reclaimer with the combustion gases are collected by a cyclone for further treatment and/or disposal.

FEASIBILITY TESTING WITH SPENT ABRASIVES

Bench-scale testing to determine the suitability of the FBSG Reclaimer for thermal processing of spent blasting abrasives was conducted as an in-house R&D project at IGT in 1986 (3). Four tests were conducted using spent copper and nickel abrasives supplied by Long Beach Naval Shipyard. A schematic diagram of the bench-scale fluidized-bed reactor used for this testing is shown in Figure 2. The reactor is constructed of 2-inch-diameter stainless steel pipe surrounded by an electric radiant-coil furnace. The temperature within the reactor can be closely controlled over a range of 1000 to 2000°F. Air is introduced through a flat distribution grid at the bottom of the reactor by blending nitrogen and oxygen from high-pressure supply cylinders. There is no provision for the combustion of natural gas in the reactor. The desired temperature is obtained through radiant heating by the electric furnace. Given the low organic content

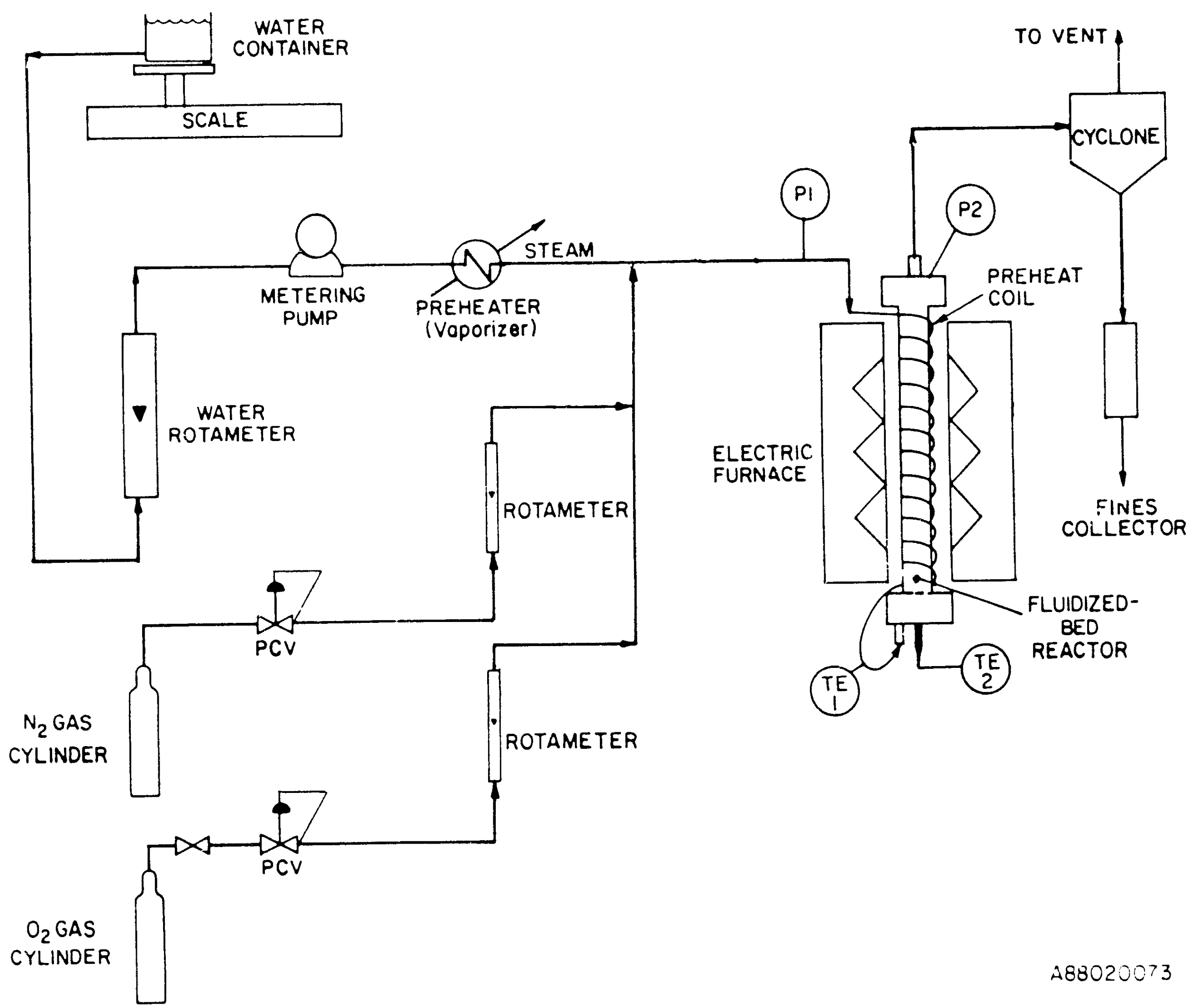

Figure 2. BENCH-SCALE FLUIDIZED-BED REACTOR

(1 weight percent) of the spent abrasives tested, very little heat was contributed by the combustion of organic contaminants.

All four feasibility tests were conducted in the batch mode. The results indicated that at fluidization velocities above 3 ft./sec. and temperatures in the range of 1200 to 1500°F, both organic contaminants and fines are removed from spent abrasives in a single-stage fluidized bed. Of equal importance, heavy metal contaminant levels were also reduced, as the metal oxides were at least partially volatilized and carried out of the reactor with the flue gas and entrained fines. On cooling, the metals condensed and showed a strong tendency to be absorbed onto the fines, due to their large available surface area.

PILOT-SCALE RECLAMATION TESTS

Based on these results, a program to reclaim spent abrasives in IGT's 3-foot-diameter, pilot-scale FBSG reclaimer was developed by IGT and representatives of the U.S. Navy under the Navy's Hazardous Waste Minimization Program. The testing was coordinated by the Navy's David Taylor Research Center and funded by the Naval Facilities Engineering Command (NAVFAC) at the request of the Naval Sea Systems Command's shipyard branch (NAVSEA Code 07). The objectives of the test were to evaluate the performance of the reclaimer for organics destruction and fines removal, determine the distribution of trace metals in the reclaimed product and effluent streams, and obtain design data for a prototype reclaimer system for field demonstration (4).

Three spent mineral abrasives were processed separately in two test burns conducted in November and December 1988 in IGT's pilot plant facility in Chicago, Illinois (3). Approximately 30 tons of spent abrasives were processed at feed rates up to 1500 pounds per hour. The three different spent abrasive/paint combinations tested included both coal slag and copper smelter slag abrasives contaminated with copper- and tributyltin-based paints. Organic content, the quantity of -80 mesh fines, and priority pollutant metal concentrations were determined for the abrasives before and after reclamation. New coal and copper slag abrasives were also analyzed for comparison.

The operation of the reclaimer was stable and easily controlled throughout the tests. The control strategy used was to fix the spent abrasive feed rate to the reclaimer while controlling the solids discharge rate to maintain the desired solids inventory (and therefore residence time) in the fluidized bed. Natural gas flow was regulated to control the fluidized-bed temperature while combustion air was controlled to maintain the desired fluidization velocity and excess oxygen concentration in the flue gas.

The test burns confirmed the bench-scale feasibility test results by reducing the level of organics in all three spent abrasives to levels near or below those found in new abrasive. Organics levels as low as 0.02 weight percent (200 ppm) were achieved.

In the TBT test burn, organotin compounds were destroyed in the reclaimed abrasive to below the detection limit of 50 parts per trillion (ppt). Modified Method 5 stack sampling revealed that organotin levels in the fines and flue gas leaving the reclaimer were also below the analytical detection limit, which was sufficient to confirm that the target value for organotin DRE of 99.99% had been achieved.

Evaluation of the effectiveness of the FBSG reclaimer in destroying tributyltin was complicated by the fact that no established procedures existed for either stack-gas sampling or analysis of organometallic compounds. Methods for organotin sampling from stack gases and for organotin analysis of solid and liquid samples were developed by IGT's Analytical Services group under a separate contract with Argonne National Laboratory (ANL). Details of these procedures have been reported previously (5).

RECLAIMED ABRASIVE EVALUATION

Composite samples of the three reclaimed abrasives were submitted to the Navy for complete analysis per the requirements of military specification MIL-A-22262A, "Abrasive Blast Media Ship Hull Blast Cleaning," including the California Title 22 Hazardous Waste Tests and Sieve Analysis. A sufficient quantity of each of the three abrasives was reclaimed to permit evaluation of their performance in blasting operations by the Navy. The performance testing and analysis were performed by Mare Island Naval Shipyard in California.

The results of the laboratory analysis are summarized in Table 1. The reclaimed abrasives were found to meet the required specifications with two exceptions. The reclaimed copper slag/

Table 1. RESULTS OF LABORATORY ANALYSES OF RECLAIMED ABRASIVES

Test	Requirement	Results: Coal Slag/ Copper Paint	Coal Slag/ TBT Paint	Copper Slag/ Copper Paint
Moisture, wt %	0.5 max	<0.05	<0.05	<0.05
Weight Change on Ignition, %	-1.0 to +5.0	<0.1	<0.1	<0.1
Chloride, %	0.03 max	<0.001	<0.001	<0.001
Free Silica, %	1.0 max	<1.0	<1.0	<1.0
Free Flow, %	99.0 min	>99.0	>99.0	>99.0
Specific Gravity	2.5 min	2.86	2.85	3.43
Carbonates and Gypsum	None	CONFORMS	CONFORMS	FAILS*
Conductivity, μmhos/cm.	100 max	24.5	10.0	120*
Oil Content, %	0.030 max	<0.001	<0.001	<0.001
Metal Content	CA Title 22 (STLC & TTLC)	CONFORMS	CONFORMS	CONFORMS
Hardness, Mhos Scale	6 min	>6	>6	>6
Radioactivity, Gross Gamma, ρCi/gr.	20 max	16	15	165*
Cobalt, ρCi/gr.	0.05 max	<0.02	<0.02	<0.02
Sieve Analysis, %	<1.0 passing 70 mesh (CA)	16.9	4.3	3.6
PASS/*FAIL	MIL-A-22262A	PASS	PASS	FAIL

copper paint abrasive did not pass the conductivity, gross gamma radioactivity and gypsum requirements. The abrasive may have contained these contaminants in its original state. All three reclaimed abrasives failed the California Air Resources Board (CARB) requirements for sieve analysis. CARB requires that not more than 1% of the abrasive pass through a 70-mesh screen. The reclaimer, however, was operated according to standard industry practice which retains all material above 80 mesh. The reclaimed material therefore contained too many fines. To meet the CARB requirements, a slight increase in air flow below the discharge port is all that is required.

The performance testing included abrasive blasting of steel panels coated with Navy standard epoxy anticorrosion paint and Navy F-121 copper AF paint. The tests determined paint removal rates, abrasive consumption, and surface profile. Blasting with new slag abrasives was conducted for comparison. Blasting with mixtures of new and reclaimed abrasives was also conducted since this is how the reclaimed abrasives are most likely to be used. The results of the blasting evaluations are summarized in Table 2.

The recycled abrasive, with an average removal rate of 245 sq. ft./hr., was slightly slower than the new abrasive. The removal rate was, however, well within the acceptable range for underwater hull paint-removal efficiency. Consumption of recycled abrasive per unit area cleaned was also comparable to new abrasive. The surface profile produced by the reclaimed abrasive was 2 to 4 mils. Surface profile measurements taken

Table 2. RESULTS OF ABRASIVE BLASTING PERFORMANCE TESTING WITH NEW AND RECLAIMED ABRASIVES

Abrasive	Removal Rate (sq. ft./hr.)	Surface Profile (mils)
New Coal Slag	288	2-3
New Copper Slag	294	4-4.5
Reclaimed Coal Slag/Copper Paint	225	3-4
Reclaimed Coal Slag/TBT Paint	242	3-4
Reclaimed Copper Slag/Copper Paint	268	2-3
50/50 Mix New and Reclaimed Coal Slag	232	3.5-4
50/50 Mix New and Reclaimed Copper Slag	266	2-3

after new abrasive blasting ranged from 2.5 to 4.5 mils. NSTM Chapter 631 requires 2 to 3 mils for proper surface preparation.

The pilot-scale test results show that the FBSG reclaimer is clearly capable of producing reclaimed abrasives that meet the required specifications. The blasting performance tests prove that the reclaimed abrasives provide coatings removal efficiencies and surface preparation comparable to new abrasives.

Based on the data generated by the pilot plant test burns, a preliminary design and cost estimate for a 5-ton/hour (23,400 ton /year) reclamation facility was prepared by IGT. It was assumed that the facility would be located at or near one of the two Navy shipyards in California. An economic analysis based on the design indicates that the system would be cost effective in processing both hazardous and nonhazardous spent abrasives.

Independent engineering and economic reviews of the design were conducted by the David Taylor Research Center. Maintenance, reliability, and environmental permitting requirements for the proposed facility were also investigated. Based on the results of these studies, funding has been requested by NAVSEA 07 for design and construction of a 5-ton/hour reclaiming facility at Mare Island Naval Shipyard in California. Contracting for the project will begin in FY 91, with design and construction expected to begin in FY 92.

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