Testing and Certification of Industrial Abrasives Manufactured From Recycled Glass

NIST MEP

Environmental Program

TESTING AND CERTIFICATION OF INDUSTRIAL ABRASIVES MANUFACTURED FROM RECYCLED GLASS

FINAL REPORT

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TABLE OF CONTENTS

Page

TABLE OF CONTENTS ... i

EXECUTIVE SUMMARY ... iii

1. PROJECT OVERVIEW ... 1

1.1 BACKGROUND ... 1

1.1.1 Other Information Identified Regarding Recycled Glass Abrasives ... 4

1.1.2 California Air Resources Board Certification ... 5

1.1.3 TriVitro Corporation Project ... 6

1.2 PROJECT OBJECTIVES ... 7

2. CALIFORNIA AIR RESOURCES BOARD TESTING ... 7

2.1 MATERIALS TESTED ... 8

2.2 TEST RESULTS ... 8

3. COMPARATIVE ABRASIVE TESTING ... 8

3.1 DESCRIPTION OF TESTS PERFORMED ... 8

3.2 TEST RESULTS ... 12

3.2.1 Productivity Test Results ... 12

3.2.2 Sieve Analysis ... 18

4. OBSERVATIONS AND RECOMMENDATIONS ... 22

4.1 OBSERVATIONS ... 22

4.2 RECOMMENDATIONS FOR ADDITIONAL STUDY ... 26

5. ACKNOWLEDGMENTS ... 27

6. APPENDICES

A. BLAST TEST RAW DATA FORMS (AVAILABLE FROM CWC ON REQUEST)

B. SIEVE ANALYSIS DATA FORMS (AVAILABLE FROM CWC ON REQUEST)

C. CALIFORNIA AIR RESOURCES BOARD TEST RESULTS & LISTING

D. PROJECT PHOTOGRAPHS (AVAILABLE FROM CWC ON REQUEST)

E. KTA TATOR TEST RESULTS

LIST OF TABLES

Table 1 - Comparative Product Testing Schedule

Table 2 - Summarized Abrasive Test Results

Table 3 - Cost Estimates for VitroGrit #16

Table 4 - Cost Estimates for VitroGrit #30

Table 5 - Comparative Abrasive Test Results

Table 6 - Comparative Abrasive Test Results

Table 7 - Percentage of Abrasive Sample Retained On Each Size Sieve - VitroGrit #16

Table 8 - Percentage of Abrasive Sample Retained On Each Size Sieve - VitroGrit #40

Table 9 - Percentage of Abrasive Sample Retained On Each Size Sieve - VitroGrit #30

Table 10 - Percentage of Abrasive Sample Retained On Each Size Sieve - VitroGrit #30

Table 11 - Percentage of Abrasive Sample Retained On Each Size Sieve - VitroGrit #50

Table 12 - Percentage of Abrasive Sample Retained On Each Size Sieve - Green Diamond 3060 & Kleen Blast #35 & #3060

LIST OF FIGURES

Figure 1 - VitroGrit #16

Figure 2 - Abrasive Blast Test Arrangement

EXECUTIVE SUMMARY

This report summarizes laboratory and field testing of industrial abrasives manufactured from post-industrial and post-consumer recycled glass made in Washington. Tested abrasives are from *TriVitro Corporation* (*TriVitro*), a Seattle, Washington-based company, manufacturing abrasives as well as other products from recycled glass. This project attempts to address some of the remaining serious and substantial barriers to opening significant markets for crushed recycled glass.

Previous research by other testing firms and from customer experience by *TriVitro* indicated that recycled glass abrasives have a number of inherent advantages because of their physical nature. Also, because of their sources, recycled glass contains essentially no heavy metals which smelter slag-derived abrasives contain.

The testing program included certification testing by the *California Air Resources Board* (*CARB*) for dust-generation characteristics. This testing was needed to enable *TriVitro*'s products in part to qualify for the Federal Qualified Products List (QPL). This testing was successful and *TriVitro*'s abrasives have received certification.

In addition to *CARB* testing, additional abrasive blasting tests were conducted to compare side-by-side productivity with two other competing slag abrasive products and to determine optimum blast parameters. Tests did not include parameters which had been determined in an earlier study by another testing service, *KTA-Tator, Inc*. (breakdown rate, dust generation, embedment, or rust back). Tests did include blasting tests under varied pressures, varied substrates, varied coatings, and with several different nozzle sizes. Each test included sieve analysis of spent grit. Based upon the productivity rates observed, costs per square foot blasted were calculated using typical cost factors for labor, abrasive, and disposal of spent grit.

Generally, the test program met the objectives of the project. On a performance basis, recycled glass abrasives are competitive with slag products for industrial blasting applications. Many variables are involved with abrasive blasting which can confound any testing program and add an element of "art" and experience to optimizing all the parameters and conditions.

The results indicate that higher productivity and lower costs are associated with larger nozzle sizes and higher blast pressures. Observed dust generation is also higher with higher blast pressures. Labor is the most significant cost factor in estimating blasting costs per square foot, however, there is a complex tradeoff between abrasive consumption rates and cleaning rates. Lower cleaning and consumption rates are partially offset by reduced abrasive and disposal costs.

For glass, it may be true that reducing blast pressure and increasing nozzle size may result in more favorable (lower total cost per square foot) operating conditions than for competing slag products. Because glass is less dense, more particles per given weight are propelled at the surface being blasted than for slag, which may provide the better cleaning rate.

Surface profile tests after blasting indicate that the recycled glass abrasives yield an acceptable profile for anchoring new coating. The surfaces appear bright and were observed to resist rust back for an extended period of time.

The tests yielded a large volume of data which indicate that abrasives manufactured from recycled glass are competitive in the industrial marketplace on a performance basis. Recommendations are made for additional replications where tests were limited. Additional tests for mill scale removal in particular are needed. Also, additional replications of tests for VitroGrit #16 were recommended to provide additional evidence of whether increasing nozzle size and decreasing blast pressures may be the preferable method of blasting with glass abrasives.

1. PROJECT OVERVIEW

1.1 BACKGROUND

This report summarizes laboratory and field testing of industrial abrasives manufactured from post-industrial and post-consumer recycled glass made in Washington. Tested abrasives are from *TriVitro Corporation* (*TriVitro*), a Seattle, Washington-based company, manufacturing abrasives as well as other products from recycled glass. This project attempts to address some of the remaining serious and substantial barriers to opening significant markets for crushed recycled glass. Abrasive blasting with recycled glass sand has the potential to consume tens of thousands of tons per year of recycled glass in the Northwest. This report provides some key comparison productivity data for use by large volume users of blasting abrasives and others to assist them in deciding to select glass-based abrasives. Work performed on this project was conducted under a contract with *Clean Washington Center*.

Research performed by *KTA-Tator, Inc.*, Pittsburgh, PA (as reported in their report titled "Blast Cleaning Abrasive Evaluation Program, Test Results, Purchase Order No. 1256", January 8, 1996, and included as Appendix E in this report), analysis performed by *NVL Laboratories*, Seattle, WA, and *TriVitro's* own experience working with its customers suggest that *TriVitro's* recycled glass abrasives have a number of inherent advantages, including:

- Glass sand particles are angular to subangular and have the ability to cut many coatings exceptionally well when used in abrasive blasting;
- Glass sand can produce a "white metal" finish which may be superior to other abrasives;
- The finish produced by glass was observed by *KTA-Tator* to produce a low "rustback". Unlike other abrasives, glass does not contain significant chlorides or other salts which may serve to accelerate the corrosion of cleaned surfaces;
- Glass may have the potential for lower dust generation than some other abrasives during use;
- With less dust generation, glass may leave less abrasive residues on cleaned surfaces thereby reducing post-blast cleanup costs;

- *KTA-Tator* observed that recycled glass sand can produce an excellent "surface profile" (anchor pattern for paint or other coatings);
- Glass abrasives may be reused more than some other lower cost abrasives before becoming "spent";
- Glass is slightly less dense than other abrasives, producing more volume per ton, which may be favorable for productivity (i.e., more abrasive particles directed at the surface to be cleaned for a given weight);
- Possibly because it is less dense, glass may produce lower surface embedment than other abrasives;
- Unlike many other mineral based abrasives, glass has no detectable "free" or "crystalline" silica, greatly reducing the potential for worker health hazard from silicosis, a lung damaging disease which can be fatal;
- Unlike slag-based abrasives, glass contains essentially no heavy metals which can potentially increase occupational exposure during abrasive use and increase potential environmental contamination when the spent abrasive must be disposed (as reported by *NVL Laboratories*); and
- Glass is recycled from materials predominantly produced in the local area, whereas slag-based abrasives, by example, are copper and nickel smelter wastes produced outside the region.

Since its plant startup in July 1996, *TriVitro* identified two key issues which affected their ability to significantly penetrate local and regional markets for abrasives:

1. In order to receive unconditional approval by federal and state agencies for use on their construction and maintenance projects, *TriVitro's* recycled glass abrasive products must be listed on the Federal Qualified Products List (QPL).

For instance, the *Puget Sound Naval Shipyards* and other federal sites include QPL products in their specification in the Requests for Bid documents for ship work. Also, the *Washington Department of Transportation* follows the federal QPL in specifying abrasives to be used for their projects such as bridge re-painting. While it is theoretically possible to sell abrasive products on a case-by-case basis to these potential customers, the bureaucratic barriers to products not on the QPL prevent widespread sales.

The first requirement to be met for listing on the QPL is that each abrasive product must be tested and certified by the *California Air Resources Board* (*CARB*) as being a product that does not generate excessive dust during use. Specific testing requirements are discussed in Section 1.1.3 below.

2. While there is strong informal evidence of glass abrasives' effectiveness, ultimately many customers have demanded test reports to show that glass abrasives will compete on a cost basis with slag-based abrasives: i.e., the customer's cost per square foot of surface cleaned will be comparable or lower for a variety of surfaces.

Many customers require this information before even testing samples of the abrasive. To determine this, a number of field tests must be performed comparing glass abrasives with slag abrasives for different product grades and on different surfaces. Productivity includes two factors which must be determined in order to calculate cost per square foot cleaned: square foot cleaned per hour (for labor calculations) and pounds of abrasive used per square foot (for product cost and spent abrasive disposal cost calculations). Because glass has a lower specific gravity than slag and other abrasives, many customers believe that glass abrasives will not perform as well and therefore have been reluctant to switch from slag based products. While *TriVitro* has found some evidence that glass abrasives can be cost effective, there had been no side-by-side comparisons with copper slag abrasives, the main competing abrasive product in the Pacific Northwest.

The two key issues identified above formed the basis for this study. In addition, the test was designed to allow evaluation of varying nozzle size and pressures to adjust for the specific gravity differences between glass and slag. *TriVitro* experience suggested that maximum productivity for glass may require a larger nozzle size and lower blasting air pressures than for slag to compensate for the density differences, however, no prior testing of this hypothesis had been performed.

1.1.1 Other Information Identified Regarding Recycled Glass Abrasives

Research on use of recycled glass abrasives was previously performed by *TriVitro*, (formerly named *IMTEK, Inc*.) over a period of three years. On a previous *Clean Washington Center* contract, *TriVitro* constructed and successfully operated a pilot scale plant for manufacturing sand products from post-consumer and post industrial recycled glass. That plant, located at the *Olivine Corporation* facility in Bellingham, tested a specific type of mill for processing the glass and found customers for the products produced. Market reception was sufficiently encouraging such that *TriVitro* proceeded with private construction of its current commercial scale plant.

TriVitro obtained marketing literature and held technical conversations with other companies processing recycled glass, including: *Vitreous Environmental Group, Universal Ground Cullet, Glass Recycling, Inc.,* and *Strategic Materials Inc*. From those conversations, it was determined that the body of data developed to date (i.e., reproducible, representative, credible) does not yet exist so that industry will readily specify glass abrasives.

TriVitro conversations with sandblast industry experts in the region from 1994 to present (*Duncan & Bush, Long Painting, Todd Shipyards*) indicated that there must be data produced which show that their specifications can be met. Their customers require the same information from them.

Steel Structural Painting Council, Journal of Protective Coatings and Linings and various other publications were reviewed. From these general industry sources, the need for generating data for glass abrasives on the criteria of production rate, consumption rate, breakdown, dust generation, and recyclability, as well as nozzle size, blast pressure, substrate and coating type was identified.

National Shipbuilding Research Council, Panel SP-3 Meeting Minutes, July 15-17, 1996, were reviewed and a conversation was held with Program Manager John Meacham. It was apparent that in this presentation to a panel of leading shipyards across the nation, glass abrasives have been introduced and some of its reported advantages were introduced. More information and verification is needed, and corroborating evidence is needed. Mr. Meacham informally provided advice on this testing program, providing a list of 23 variables to be considered. From this information, the testing form used in this project was developed.

1.1.2 California Air Resources Board Certification

CARB certifies abrasives on a manufacturer-by-manufacturer basis for products produced for the entire U.S. Although originally intended for abrasive products to be sold in the state of California, the federal government adopted the *CARB* testing process for products to be listed on the QPL. The products must be re-certified every two years. With *CARB* certification, *TriVitro* products will be also accepted for sale in California.

TriVitro obtained the September 1996 list of certified abrasives from *CARB* and observed that at least three companies manufacturing recycled glass abrasives in the eastern U.S. were successful in having their products certified, including:

- *Allwaste Recycling, Inc.* for Whiteblast 20x40
- *Glass Recycling Inc.* for GlassBlast 12/40
- *Universal Ground Cullet, Inc.* for sizes E-1010, E-1015, M-1010 & M-1015

Under Title 17 of the California Code of Regulations, *CARB* is required to certify abrasives used for permissible dry outdoor blasting as complying with specific performance standards. The test in effect measures “friability” of abrasives, or the tendency of the particles to crumble and form dust.

The testing procedure was developed by *CARB* and consists of two separate tests: 1) “Visible Emission Evaluation Test Method for Selected Abrasives Used in Permissible Dry Outdoor Blasting”, as adopted November 8, 1990; and, 2) “Method of Test for Abrasive Media Evaluation”, Test Method No. California 371-A, dated May 15, 1975. The first test requires the abrasives shall not contain more than

1% by weight material passing through a #70 U.S. standard sieve before blasting. The second test uses a specialized blasting chamber designed by *CARB*. The chamber allows for blasting of the test abrasive at 100 pounds per square inch nozzle pressure at a distance estimated to be four feet against an un-coated steel surface. Spent abrasive is collected and tested using a hydrometer to determine percentage less than 5 microns. Post-blasting, the abrasive cannot contain an amount less than 5 microns exceeding 1.8% by weight.

No other agency is capable of certifying abrasives for qualifying for the federal QPL. Therefore, no competitive process could be undertaken for this testing. *CARB* maintains its testing facility in Sacramento, California, and all products to be tested must be shipped to the facility in 5-gallon buckets. *TriVitro* shipped these samples to *CARB* as in-kind contribution to completion of this project.

1.1.3 TriVitro Corporation Project

In order to compare performance of recycled glass-based abrasives with competing products, a set of comparative tests were performed. While *CARB* testing was underway, *AERCO Inc., P.S.* and *Pacific Northwest Coatings* conducted the comparative abrasive testing portion of the project on behalf of *TriVitro*. A blast booth for testing was constructed in a portion of the existing building at the *TriVitro* plant located at 351 Elliott Avenue West, Seattle, WA. Samples of *TriVitro's* VitroGrit abrasives were provided for the testing. *United Western's* Seattle warehouse provided test samples of nickel slag abrasive and *OCL Industrial Minerals* in Vancouver, B.C. provided the first samples of copper smelter slag abrasive. Additional copper smelter slag was purchased directly from the *Kleen Blast* facility in Tacoma, WA.

Initially, the testing program was directed toward comparisons among abrasives as applied to mill scale on new steel. However, once the project was underway, *TriVitro* requested that the testing be modified to focus primarily on coated steel rather than mill scale. This change, approved by Clean Washington Center, resulted in an overall decrease in the number of total tests to be performed because re-coating of test samples was required. *Pacific Northwest Coatings* provided the additional labor and equipment to apply the coatings. *TriVitro* provided the additional coatings as in-kind contribution to the project.

1.2 PROJECT SCOPE & OBJECTIVES

The scope of this project includes the following goals: 1) obtain *CARB* testing and certification of several different recycled glass abrasive products; 2) perform comparative testing of samples of copper & nickel slag abrasives and recycled glass abrasives to determine productivity and cost per unit area for different substrate/coating combinations; and 3) prepare a summary report documenting the work and findings for public review.

Objectives consistent with the scope of this project are:

- Prepare and ship representative samples of *TriVitro* recycled glass abrasives for *CARB* testing and certification for dust generation during use;
- Complete and transmit the *CARB* Application for Certification of Abrasive for Permissible Dry Outdoor Blasting forms;
- Construct a temporary abrasive blasting booth at TriVitro's plant at 351 Elliott Avenue West, Seattle, to allow productivity testing of abrasives;
- Perform sieve analysis of all abrasives tested both before and after blasting to determine re-use potential;
- Conduct side-by-side productivity testing of different size fractions of *TriVitro's* glass compared with Kleen Blast and Green Diamond slag-based abrasives; and
- Document work performed and findings so that Washington businesses can assess the technology.

2. CALIFORNIA AIR RESOURCES BOARD TESTING

As previously discussed, *CARB* testing and certification is needed for widespread acceptance of abrasive blasting products by federal and state agencies for their projects. This section discusses the materials sent to *CARB* for testing as well as presenting the results of the *CARB* testing of *TriVitro* abrasives.

2.1 MATERIALS TESTED

Abrasive feedstock materials selected for testing included mixtures of the following recycled glass:

1. post-consumer bottle glass obtained from sources representative of those currently sending recycled glass to *TriVitro*; and
2. post-industrial plate glass obtained from window manufacturers in the Seattle area.

Although the original scope of work indicated that four samples of *TriVitro* VitroGrit products would be tested by *CARB*, *TriVitro* later decided to only pursue certification for the three most likely products to be sold to federal and state agencies. Three representative bulk samples of mixed post-industrial and post-consumer recycled crushed glass sand abrasive were prepared: VitroGrit #16, VitroGrit #30, and VitroGrit #40. Each of these samples were placed in five 5-gallon plastic buckets (a total of 15 buckets each weighing 40 lbs.), sealed, and shipped by common carrier to the *CARB* testing facility in Sacramento. Accompanying the sample buckets was a completed *CARB* Application for Certification of Abrasive for Permissible Dry Outdoor Blasting forms.

2.2 TEST RESULTS

Testing of *TriVitro*'s abrasive samples were completed in July 1997. The testing demonstrated that each grit described in Section 2.1 fully passed *CARB* certification. Copies of the *CARB* test results and subsequent listing are included in Appendix C.

3. COMPARATIVE ABRASIVE TESTING

3.1 DESCRIPTION OF TESTS PERFORMED

Through discussions with the *TriVitro* distributors, *United Western* in Seattle and Portland and *OCL Industrial Minerals* in Vancouver, B.C., as well as others, key parameters to be tested were identified. From these, the testing program was identified which would allow not only comparisons with slag, but optimization of recycled glass abrasive blast parameters. The testing program schedule is presented in Table 1.

Several parameters normally considered during blasting tests were NOT evaluated here. These include:

1. <u>Breakdown Rate</u>**:** These tests require that a special chamber be used to allow capture of spent abrasive as well as dust generated during blasting. Such a chamber was not available and was outside the scope of this effort. Breakdown tests were performed by *KTA-Tator* in their previously-referenced report.
2. <u>Dust Generation</u>**:** This test similarly requires the use of the special chamber whereby the amount of dust captured as a percentage of abrasive used can be determined. Dust generation was considered during blasting tests only in a qualitative way. *CARB* tests provide a better estimate of the potential for dust generation. Laboratory dust generation tests were performed by *KTA-Tator* in their previously-referenced report. In field applications, the amount of dust generated is determined to some extent by the blast technician in the application of air pressure, consumption rate, distance of nozzle from surface, and other factors.
3. <u>Embedment</u>**:** This test requires detailed evaluation of the blasted surface using magnification techniques. This level of testing was outside the scope of this project. Laboratory embedment tests were performed by *KTA-Tator* in their previously-referenced report.
4. <u>Rust Back</u>: This test determines whether the abrasive media promotes a rapid rust "bloom" on prepared steel surfaces. The test requires a special chamber to maintain humid conditions around specially prepared steel plates. Such a chamber was not available and therefore this test was not included in the scope of work for this project. Laboratory rust back tests were performed by *KTA-Tator* in their previously-referenced report.

Blasting Tests

In order to determine productivity, tests were performed according to Table 1 on samples nominally ten square feet in area with different substrates and coatings. A Clemco 6-cubic foot blasting pot was used along with two different diesel-powered air compressors to provide the abrasive blasting. A Chicago Pneumatic compressor was the larger unit that was used for the 1/2" and other early tests, and an Ingersoll-Rand 175 compressor was used for most of the 1/4" & 3/8" nozzle tests. A 150-foot hose with a 2-inch diameter was used because of typical field applications and to allow placement of the blast pot on the electronic scales during testing. Blasting pressures were determined by using a needle gauge to measure pressure at the blasting nozzle and were compared to the blasting pressure indicated on the compressor.

The tests measure the amount of abrasive and the time required to achieve the required finish on a specially prepared plate of the selected substrate. Steel was selected for most of the studies, with aluminum selected for testing two finer abrasive products.

Sample Plates

For the epoxy tests, sections of ship hull were purchased at a nearby shipyard which were pre-coated with a relatively uniform coating thickness (over 15 mil scale of gauge, estimated at around 20 mil). The boat owner reported that the coating had been applied during mid-summer of 1996 and so was well cured.

After blasting with some of the earlier tests, some ship hull sections were re-coated for additional testing. For the enamel tests, paint and primer were purchased from Rodda Paints in Seattle, WA. The primer was "Barrier III Type 981" and paint over the primer was Quick Drying Alkyd Acrylic Enamel. The paint was applied with sprayers and allowed to cure at an even temperature for at least 5 days before being tested. For the alkyd tests, alkyd paint was again purchased from Rodda Paints. The alkyd was also applied with a sprayer over previously blasted steel plate, but with no primer. Testing was performed after four days of curing. Coal Tar Epoxy was applied by a sprayer with no primer over previously blasted steel plate and allowed to cure for a minimum of four days before testing. All newly coated surfaces were touched up with abrasive blasting prior to applying the coatings.

Sieve Analyses

Samples of each product were collected at time of testing to perform sieve analyses. A total of seven different abrasives were tested providing a total of twelve pre-blast sieve analyses. After use in the blasting tests, samples of spent abrasive were collected from the previously cleaned blast booth floor adjacent to each sample plate to allow additional sieve analysis. A total of 27 samples of spent abrasive were collected for sieve analyses. Sieve analysis was performed using *TriVitro*'s sieve lab.

Weight of Media Used During Test

For all test runs, the blast pot was placed on a Cardinal "Floor Hugger" model 5,000-lb. electronic platform scales certified for commerce by the City of Seattle in April 1997. The weights as indicated by the scales were recorded before and after each run to determine amount of abrasive used for that test run. Correction for weight of material contained in the blast hose before and after each test were made as needed.

Measurements

Before each run, a portable mil gauge ("Pro Gauge II" paint thickness gauge manufactured by *Gardco*, 1 - 14 mils scale) was used to determine approximate coating thickness. Coating thickness varied across each sample plate, and an average was reported. At least four points were measured randomly across the sample plate. For tests using the section of boat hull, the epoxy coating thickness exceeded the gauge's upper scale, and so an estimate was made.

After each test run, the surface area of plate cleaned was determined using a steel tape measure. The target area to be cleaned during the early tests performed covered approximately 10 square feet area. As experience was gained through the testing period, later tests reduced the target area to about 6 square feet.

Surface profile was determined using a standard tape profile tester ("Press-O-Film" tape, X Coarse: 1.5 to 4.5 mil, and dial thickness gauge, 0.0001" to 0.050", manufactured by *Testex*, Newark, NJ). Generally only one profile measurement was taken from a randomly selected point on the test plate, although for comparison purposes, multiple readings were taken for a number of the tests.

All test data along with the time required to clean each test plate was recorded on a standard test form.

3.2 TEST RESULTS

3.2.1 Productivity Test Results

Table 2 presents a tabulated summary of the data gathered during the blasting tests along with calculated productivity results for each test.

Productivity Costs

Table 3 extracts a subset of Table 2 data and adds a derived cost per square foot for VitroGrit #16 for various nozzle sizes and operating pressures. This derived calculation is intended to reflect more accurate costs for abrasive blasting. For this calculation, the cost elements of labor, abrasive purchased, and spent abrasive disposal costs were considered. Values of $20.00/hour was assumed for loaded labor costs, assumed $85.00/ton cost for new abrasive, and a disposal cost of $26.00/ton assumed for spent abrasive. These assumptions are based upon recent *TriVitro* experience in the Puget Sound region.

The formula used to calculate the Cost in $/sq. ft. is as follows:

Labor Cost = ($20.00/hour) divided by (sq. ft./hour) Cleaning Rate from Table 2;

plus

Abrasive Cost = ($85.00/ton) divided by (2000 lb./ton) times (lb./sq. ft.) Consumption, Table 2

plus

Disposal Cost = ($26.00/ton) divided by (2000 lb./ton) times (lb./sq. ft.) Consumption, Table 2

Other costs factor into the total job cost for a particular blasting job, however, these costs would normally be incurred independent of abrasive type. The costs considered in the calculation above are the primary variable costs that need to be considered. From the costs included in the far right column Table 3, it can be seen that the lowest costs are generally associated with larger nozzles and higher blast pressures. A graphic plot of this relationship is shown in Figure 1 below. A graphic of the test arrangement is also shown in Figure 2. As the nozzle size increases, the total blast cost per square foot generally declines disproportionately. As the blast pressure increases, the cost advantage of larger nozzles also increases disproportionately.

Tables 4, 5 and 6 also extract subsets of Table 2 data, adds the derived total cost per square foot as described above in a column on the far right side of each table, and presents the data to show the relationships among blast pressures, coating types, cleaning rates, and abrasive consumption rates. Table 5 in particular shows the comparative parameters for VitroGrit #40, Kleen Blast #35 and #30/60, and Green Diamond #3060. VitroGrit #40 most nearly matches the other abrasives regarding particle size distribution.

TABLE 1

COMPARATIVE PRODUCT TESTING SCHEDULE

Nozzle	Nominal Blast Pressure	Substrate	Coating	VitroGrit				KleenBlast		Green Diamond
				#16	#30	#40	#50	#35	#30/60	#30 - 60
1/4" Nozzle	80 psi	Steel	Epoxy	1						
	100 psi	Steel	Epoxy	1						
3/8" Nozzle	80 psi	Aluminum	None				1			1
	80 psi	Steel	Mill Scale		1		1			
	100 psi	Steel	Mill Scale		1	1				
	40 psi	Steel	Epoxy	1	1			1		
	60 psi	Steel	Epoxy	1	1			1		
	80 psi	Steel	Epoxy	2	3					
	100 psi	Steel	Epoxy	3	2	1		1	1	2
	80 psi	Steel	Coal Tar Epoxy		1					
	100 psi	Steel	Coal Tar Epoxy		1	1		1		
	80 psi	Steel	Enamel		1		1			
	100 psi	Steel	Enamel		1		1			
	80 psi	Steel	Alkyd		1		1			
	100 psi	Steel	Alkyd	1	1		1			1
1/2" Nozzle	80 psi	Steel	Epoxy	1						
	100 psi	Steel	Epoxy	1						
			Total Tests:	12	15	3	6	4	1	4

Total of All Tests:	45

Table 2 - Summarized Abrasive Test Results

Test No.	Abrasive	Grit Size	Nozzle Blast Pressure (psi)	Nozzle Size (inches)	Substrate	Area Blasted (sq. ft)	Coating Type	Coating Thickness(mils)	Cleaning Rate Sq. Ft./Minute	Cleaning Rate Sq. Ft./Hour	Consumption Rate lbs/hr	Consumption Rate lbs/sq ft.	Surface Profile (mils)	Level of Cleaning
1	VitroGrit	#16	100	3/8	Steel	10.00	Epoxy	>15	1.64	98.63	1370	13.9	3.3, 4.6	SP-10
2*	VitroGrit	#16	85	3/8	Steel	10.00	Epoxy	>15	-	-	-	-	-	-
3	VitroGrit	#16	95	1/4	Steel	9.75	Epoxy	>15	0.552	33.11	428	12.9	4.0	SP-10
4*	VitroGrit	#16	80	1/4	Steel	8.09	Epoxy	>15	0.63	37.82	1005	26.58	2.9	>SP-10
5	VitroGrit	#16	75	3/8	Steel	7.75	Epoxy	>15	0.705	42.27	518	12.26	3.7	>SP-10
6	VitroGrit	#16	103	1/2	Steel	10.53	Epoxy	>15	2.257	135.4	797	5.89	3.8	SP-10
7	VitroGrit	#16	85	1/2	Steel	10.28	Epoxy	>15	1.927	116	911	7.87	3.6	BSP-6
8*	VitroGrit	#30	81	3/8	Steel	9.80	Epoxy	>15	1.26	75.8	1133	14.95	3.1	SP-5
9	VitroGrit	#30	81	3/8	Steel	9.80	Epoxy	>15	0.713	42.8	288	6.73	2.8	SP-10
10	VitroGrit	#16	100	3/8	Steel	10.16	Epoxy	>15	1.00	60.0	684	11.42	4.3	SP-10
11	VitroGrit	#16	100	3/8	Steel	10.59	Epoxy	>15	1.44	86.7	1489	17.19	4.0	SP-10
12	VitroGrit	#16	85	3/8	Steel	10.79	Epoxy	>15	1.23	74.0	651	8.80	4.1	SP-10
13	VitroGrit	#30	85	3/8	Steel	10.00	Epoxy	>15	1.29	77.42	766	9.90	3.9	SP-10
14	VitroGrit	#30	105	3/8	Steel	10.50	Epoxy	>15	0.977	58.6	541	9.24	4.0	SP-10
15	VitroGrit	#30	100	3/8	Steel	12.03	Epoxy	>15	1.34	80.2	893	11.74	3.4	SP-10
16	VitroGrit	#30	85	3/8	Steel	14.50	Millscale	~1-2 est.	1.45	87	666	7.66	3.7	SP-5
17	VitroGrit	#50	85	3/8	Steel	9.94	Millscale	~1-2 est.	1.47	88.4	418	4.73	2.0	SP-5
18	VitroGrit	#30	95	3/8	Steel	10.47	Millscale	~1-2 est.	1.57	94.2	639	6.78	2.6	SP-10
19*	VitroGrit	#30	95	3/8	Steel	11.11	Enamel	6 - 10	5.80	348	250	0.72	3.8	SP-10
20	VitroGrit	#30	75	3/8	Steel	35.38	Enamel	6 - 10	5.66	340	403	1.19	3.0	SP-10
21	VitroGrit	#50	75	3/8	Steel	22.75	Enamel	6 - 10	5.69	341	1275	3.74	3.3, 3.5	SP-5
22	VitroGrit	#50	95	3/8	Steel	21.69	Enamel	6 - 11	6.68	401	1329	3.32	3.5	SP-5
23*	VitroGrit	#50	100	3/8	Steel	6.33	Alkyd	6 - 11	0.704	42.2	760	18.0	3.0	SP-5
24*	Kleen Blast	#35&#16/30	100	3/8	Steel	16.32	Epoxy	>15	1.15	68.7	1103	16.1	4.4	SP-10
25*	Kleen Blast	#35&#16/30	100	3/8	Steel	10.13	Epoxy	>15	0.96	57.86	1103	19.1	4.0	SP-10
26	Green Diamond	#3060	100	3/8	Steel	8.27	Epoxy	>15	1.44	86.3	1314	15.23	4.0	<SP-10
27	Green Diamond	#3060	100	3/8	Steel	8.88	Epoxy	>15	1.18	71.0	928	13.1	3.8	SP-10
28	Green Diamond	#3060	100	3/8	Aluminum	14.00	None	N/A	3.91	235	1056	4.5	3.6	SP-5
29	Green Diamond	#3060	100	3/8	Steel	5.08	Alkyd	5 - 10	0.677	40.7	768	18.9	3.0	SP-5
30	VitroGrit	#30	100	3/8	Steel	12.58	Coal Tar Epoxy	4 - 11	2.19	131	856	6.52	3.8	SP-10
31	VitroGrit	#30	100	3/8	Steel	13.88	Alkyd	4 - 11	1.35	81.22	907.3	11.17	3.7	SP-5
32	VitroGrit	#30	75	3/8	Steel	6.86	Coal Tar Epoxy	4 - 11	2.33	140	880	6.29	3.7	SP-5
33	VitroGrit	#30	75	3/8	Steel	6.86	Alkyd	4 - 11	1.37	82.3	828	10.1	-	SP-10
34	Kleen Blast	#35	100	3/8	Steel	6.35	Epoxy	>15	1.81	109	977	8.98	3.6	SP-10
35	Kleen Blast	#35	100	3/8	Steel	4.95	Coal Tar Epoxy	6 - 8	1.48	89	900	10.1	3.6	SP-10
36	Kleen Blast	#30/60	100	3/8	Steel	4.516	Epoxy	>15	1.69	102	1598	15.72	4.0, 3.7	SP-10
37	VitroGrit	#40	100	3/8	Steel	7.64	Epoxy	>15	2.09	125	1048	8.38	4.1, 3.6	>SP-10
38	VitroGrit	#40	100	3/8	Steel	4.833	Coal Tar Epoxy	6 - 8	1.76	106	1091	10.35	3.1	>SP-10
39	VitroGrit	#40	100	3/8	Steel	4.587	Millscale	~1-2 est.	2.39	144	970	6.76	2.5	SP-10
40	VitroGrit	#16	100	3/8	Steel	6.745	Alkyd	8 - 10	1.84	110	900	8.15	4.3, 4.1	>SP-10
41	VitroGrit	#50	75	3/8	Steel	6.674	Alkyd	8 - 10	1.05	63.2	910	14.4	2.8	SP-5
42	VitroGrit	#50	75	3/8	Aluminum	13.67	None	N/A	3.56	214	924	4.32	2.8	SP-5

Note: Tests marked with "*" are anomalous: see test form

Table 3 - Cost Estimates for VitroGrit #16

Test No.	Nozzle Blast Pressure (psi)	Nozzle Size (inches)	Coating Type	Cleaning Rate Sq. Ft./Hour	Consumption Rate lbs/hr	Consumption Rate lbs/sq ft.	Cost $/sq. ft.
4	80	0.250	Epoxy	37.82	1005	26.58	$2.00
3	95	0.250	Epoxy	33.11	428	12.9	$1.32
5	75	0.375	Epoxy	42.27	518	12.26	$1.15
12	85	0.375	Epoxy	74.0	651	8.80	$0.76
1	100	0.375	Epoxy	98.63	1370	13.9	$0.97
10	100	0.375	Epoxy	60.0	684	11.42	$0.97
40	100	0.375	Alkyd	110	900	8.15	$0.63
7	85	0.500	Epoxy	116	911	7.87	$0.61
6	103	0.500	Epoxy	135.4	797	5.89	$0.47
Note: Anomalous tests removed							

Table 4 - Cost Estimates for VitroGrit #30

Test No.	Nozzle Blast Pressure (psi)	Coating Type	Coating Thickness(mils)	Cleaning Rate Sq. Ft./Hour	Consumption Rate lbs/hr	Consumption Rate lbs/sq ft.	Surface Profile (mils)	Cost $/sq. ft.
33	75	Alkyd	4 - 11	82.3	828	10.1	-	$0.80
31	100	Alkyd	4 - 11	81.22	907.3	11.17	3.7	$0.87
32	75	Coal Tar Epoxy	4 - 11	140	880	6.29	3.7	$0.49
30	100	Coal Tar Epoxy	4 - 11	131	856	6.52	3.8	$0.51
20	75	Enamel	6 - 10	340	403	1.19	3.0	$0.12
19*	95	Enamel	6 - 10	348	250	0.72	3.8	$0.10
8*	81	Epoxy	>15	75.8	1133	14.95	3.1	$1.09
9	81	Epoxy	>15	42.8	288	6.73	2.8	$0.84
13	85	Epoxy	>15	77.42	766	9.90	3.9	$0.81
15	100	Epoxy	>15	80.2	893	11.74	3.4	$0.90
14	105	Epoxy	>15	58.6	541	9.24	4.0	$0.85
16	85	Millscale	~1-2 est.	87	666	7.66	3.7	$0.66
18	95	Millscale	~1-2 est.	94.2	639	6.78	2.6	$0.59
Nozzle Size for all Tests = 0.375"			Substrate for all Tests = Steel					
Note: Tests marked with "*" are anomalous; see test form								

Table 5 - Comparative Abrasive Test Results

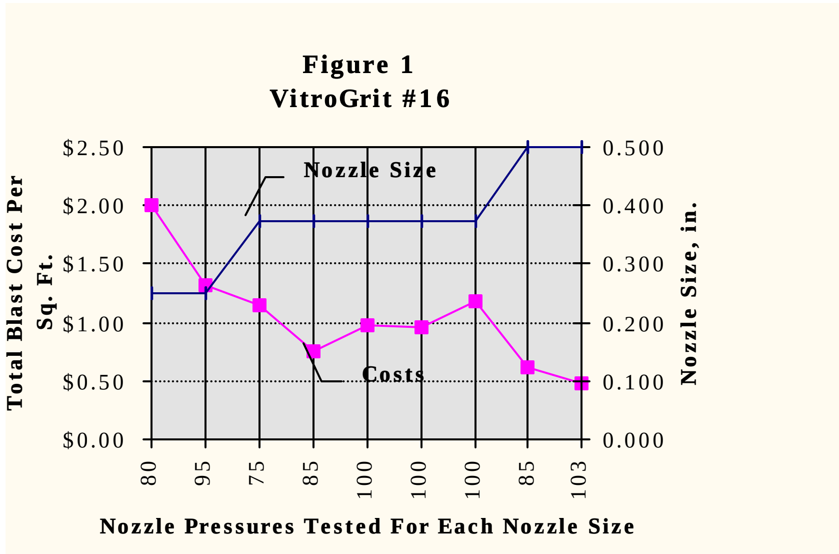
Test No.	Abrasive	Grit Size	Nozzle Blast Pressure (psi)	Coating Type	Coating Thickness(mils)	Cleaning Rate Sq. Ft./Hour	Consumption Rate lbs/hr	Consumption Rate lbs/sq ft.	Surface Profile (mils)	Cost $/sq. ft.
37	VitroGrit	#40	100	Epoxy	>15	125	1048	8.38	4.1, 3.6	$0.63
38	VitroGrit	#40	100	Coal Tar Epoxy	6 - 8	106	1091	10.35	3.1	$0.76
39	VitroGrit	#40	100	Millscale	~1-2 est.	144	970	6.76	2.5	$0.51
36	Kleen Blast	#30/60	100	Epoxy	>15	102	1598	15.72	4.0, 3.7	$1.07
34	Kleen Blast	#35	100	Epoxy	>15	109	977	8.98	3.6	$0.68
35	Kleen Blast	#35	100	Coal Tar Epoxy	6 - 8	89	900	10.1	3.6	$0.79
24*	Kleen Blast	#35&#16/30	100	Epoxy	>15	68.7	1103	16.1	4.4	$1.18
25*	Kleen Blast	#35&#16/30	100	Epoxy	>15	57.9	1103	19.1	4.0	$1.41
26	Green Diamond	#3060	100	Epoxy	>15	86.3	1314	15.23	4.0	$1.08
27	Green Diamond	#3060	100	Epoxy	>15	71.0	928	13.1	3.8	$1.01
29	Green Diamond	#3060	100	Alkyd	5 - 10	40.7	768	18.9	3.0	$1.54

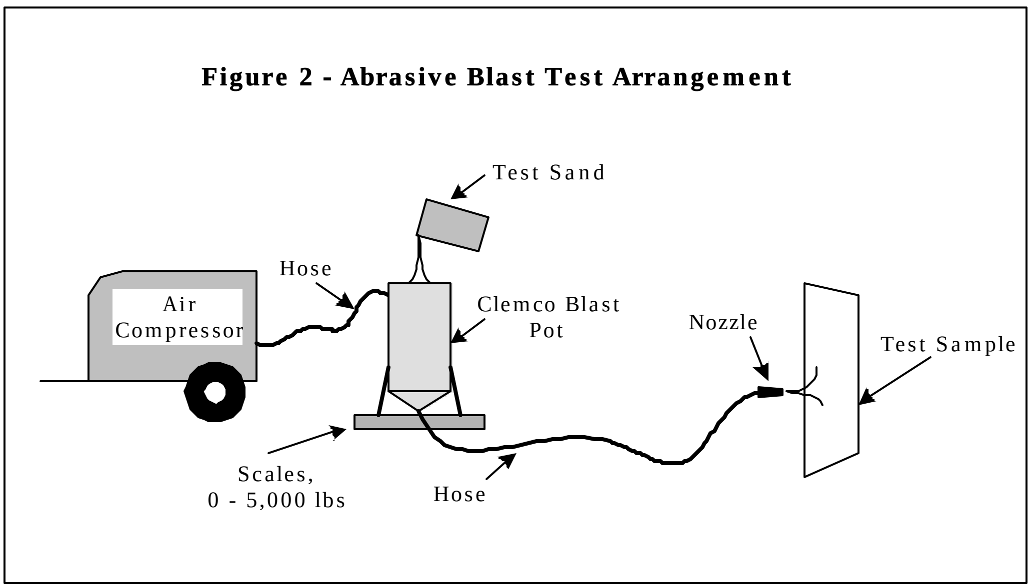
Substrate for All Tests = Steel
Note: Tests marked with "*" are anomalous; see test form

Table 6 - Comparative Abrasive Test Results

Test No.	Abrasive	Grit Size	Nozzle Blast Pressure (psi)	Substrate	Coating Type	Coating Thickness(mils)	Cleaning Rate Sq. Ft./Hour	Abrasive Usage lbs/hr	Abrasive Usage lbs/sq ft.	Surface Profile (mils)	Cost $/sq. ft.
28	Green Diamond	#3060	100	Aluminum	None	N/A	235	1056	4.5	3.6	$0.33
42	VitroGrit	#50	75	Aluminum	None	N/A	214	924	4.32	2.8	$0.33
21	VitroGrit	#50	75	Steel	Enamel	6 - 10	341	1275	3.74	3.3, 3.5	$0.27
41	VitroGrit	#50	75	Steel	Alkyd	8 - 10	63.2	910	14.4	2.8	$1.12
17	VitroGrit	#50	85	Steel	Millscale	~1-2 est.	88.4	418	4.73	2.0	$0.49
22	VitroGrit	#50	95	Steel	Enamel	6 - 11	401	1329	3.32	3.5	$0.23
23*	VitroGrit	#50	100	Steel	Alkyd	6 - 11	42.2	760	18.0	3.0	$1.47

Nozzle Size for all Tests = 0.375"
Note: Tests marked with "*" are anomalous; see test form





3.2.2 Sieve Analysis

Tables 7 through 12 present summaries of the sieve analyses performed on abrasive samples collected during testing. Samples were collected and analyzed for both pre-blasting and after impact. Samples of new abrasive were collected at the time of charging the blast pot for testing. Spent abrasive samples were collected off the blast booth floor immediately after each test. Care was taken to clean the floor before the next test to prevent cross-contamination between tests. Notably, the Green Diamond slag products were observed to generate high levels of dust. This dust is likely to have migrated further from the test area such that the samples of spent abrasive collected may be biased toward the coarser fraction.

Table 7 - Percentage of Abrasive Sample Retained On Each Size Sieve

VitroGrit #16 (All Surfaces Blasted Were >15 mil Epoxy Over Steel)

U.S. Standard Sieve	Before Blasting	After Impact		Before Blasting	After Impact		
	Test Nos. 6 & 7	*Test No. 6* Blasted @ 103 psi	*Test No. 7* Blasted @ 85 psi	*Test Nos. 10,11 & 12*	*Test No. 10* Blasted @ 100 psi	*Test No. 11* Blasted @ 100 psi	*Test No. 12* Blasted @ 85 psi
	Percentage Retained (%)	Percentage Retained (%)	Percentage Retained (%)	Percentage Retained (%)	Percentage Retained (%)	Percentage Retained (%)	Percentage Retained (%)
#12	7.2%			7.0%			
#14	21.5%			17.7%			
#16	16.9%	1.0%	2.5%	15.1%	4.1%	2.8%	2.5%
#20	27.2%	2.1%	5.4%	28.2%	7.4%	5.6%	5.8%
#30	19.9%	3.1%	10.0%	23.9%	10.6%	10.9%	10.7%
#40		4.2%	16.4%		15.1%	19.6%	17.7%
#50		14.9%	17.1%		15.1%	18.5%	16.8%
#70		26.6%	16.2%		14.5%	14.0%	14.6%
#100		18.1%	12.2%		11.3%	9.4%	11.0%
Fines (Pan)	7.3%	30.0%	20.2%	8.1%	21.8%	19.1%	20.9%

Table 8 - Percentage of Abrasive Sample Retained On Each Size Sieve

VitroGrit #40

U.S. Standard Sieve	Before Blasting		After Impact	
			Test No. 38 Coal Tar Epoxy Blasted @ 100 psi	*Test No. 39* Millscale Blasted @ 100 psi
	Percentage Retained (%)	Percentage Retained (%)	Percentage Retained (%)	Percentage Retained (%)
#25	7.2%			
#30	17.7%	3.0%	2.5%	3.4%
#40	42.0%	16.1%	10.0%	13.9%
#45	16.8%	14.0%	8.2%	9.9%
#50	12.4%	17.4%	10.8%	11.3%
#60	3.5%	15.0%	10.7%	10.2%
#70	0.3%	12.8%	11.4%	9.9%
#100		13.7%	18.4%	15.1%
Fines (Pan)	0.0%	8.1%	27.9%	26.4%

Table 9 - Percentage of Abrasive Sample Retained On Each Size Sieve

VitroGrit #30

U.S. Standard Sieve	Before Blasting	After Impact					
		Test No. 18	*Test No. 19*	*Test No. 20*	*Test No. 30*	*Test No. 31*	*Test No. 32*
		Millscale Blasted @ 95 psi	Enamel Blasted @ 95 psi	Enamel Blasted @ 75 psi	Coal Tar Epoxy Blasted @ 100 psi	Alkyd Blasted @ 100 psi	Coal Tar Epoxy Blasted @ 75 psi
	Percentage Retained (%)	Percentage Retained (%)	Percentage Retained (%)	Percentage Retained (%)	Percentage Retained (%)	Percentage Retained (%)	Percentage Retained (%)
#20	5.5%						
#25	18.7%	0.9%	3.3%	1.0%	7.6%	9.3%	6.9%
#30	24.9%	1.6%	4.7%	2.2%	3.4%	6.3%	5.5%
#40	40.0%	6.7%	13.2%	10.6%	12.6%	16.7%	16.5%
#45	9.0%	5.3%	8.0%	8.3%	12.2%	9.4%	10.4%
#50	1.3%	7.0%	8.7%	9.5%	14.9%	10.0%	11.6%
#70	0.2%	17.1%	16.2%	19.3%	21.6%	16.0%	19.1%
#100		18.9%	13.7%	16.7%	11.9%	11.1%	12.6%
Fines (Pan)	0.2%	42.7%	32.2%	32.5%	15.8%	21.1%	17.3%

Table 10 - Percentage of Abrasive Sample Retained On Each Size Sieve

VitroGrit #30

U.S. Standard Sieve	Before Blasting	After Impact			
		Test No. 13	*Test No. 14*	*Test No. 15*	*Test No. 16*
		>15 mil Epoxy Blasted @ 85 psi	>15 mil Epoxy Blasted @ 100 psi	>15 mil Epoxy Blasted @ 100 psi	Millscale Blasted @ 85 psi
	Percentage Retained (%)	Percentage Retained (%)	Percentage Retained (%)	Percentage Retained (%)	Percentage Retained (%)
#20	22.5%				
#25	15.0%	6.5%	2.7%	4.8%	1.1%
#30	14.1%	5.1%	2.8%	4.0%	1.4%
#40	23.0%	13.3%	10.1%	12.4%	5.2%
#45	11.8%	8.6%	8.7%	9.1%	4.3%
#50	9.1%	9.0%	11.1%	10.4%	5.9%
#70	3.9%	14.8%	19.6%	17.6%	14.8%
#100		12.5%	14.4%	13.3%	16.8%
Fines (Pan)	0.5%	30.3%	30.6%	28.3%	50.5%

Table 11 - Percentage of Abrasive Sample Retained On Each Size Sieve

VitroGrit #50

U.S. Standard Sieve	Before Blasting	After Impact	Before Blasting	After Impact			Before Blasting	Afte
	Test No. 17	*Test No. 17*	*Test Nos.21,22,23*	*Test No. 21*	*Test No. 22*	*Test No. 23*	*Test Nos.41,42*	*Test No. 41*
		Millscale Blasted @ 85 psi		Enamel Blasted @ 75 psi	Enamel Blasted @ 95 psi	Alkyd Blasted @ 100 psi		Alkyd Blasted @ 75 psi
	Percentage Retained (%)	Percentage Retained (%)	Percentage Retained (%)	Percentage Retained (%)	Percentage Retained (%)	Percentage Retained (%)	Percentage Retained (%)	Percentage Retained (%)
#30	3.2%	2.7%		0.2%	0.3%	0.2%	0.2%	0.4%
#40	4.2%	5.0%	4.0%	1.2%	1.6%	1.0%	3.2%	1.1%
#45	15.0%	4.0%	15.4%	4.7%	7.7%	5.3%	15.0%	4.4%
#50	27.0%	5.4%	28.0%	10.7%	16.0%	12.1%	26.9%	9.5%
#60	24.9%	6.1%	26.6%	14.7%	19.7%	15.4%	27.0%	13.5%
#70	18.8%	8.3%	19.8%	17.8%	19.3%	17.2%	20.6%	16.9%
#100	6.0%	17.5%	5.9%	22.6%	17.7%	21.0%	6.6%	22.9%
Fines (Pan)	0.9%	51.0%	0.3%	28.2%	17.7%	27.8%	0.5%	31.2%

Table 12 - Percentage of Abrasive Sample Retained On Each Size Sieve

Green Diamond 3060 & Kleen Blast #35 & #3060

U.S. Standard Sieve	Before Blasting	After Impact
	Test No. 26	*Test No. 13*
	Green Diamond #3060	>15 mil Epoxy Blasted @ 100 psi
	Percentage Retained (%)	Percentage Retained (%)
#25	0.3%	
#30	0.4%	0.4%
#40	26.9%	11.6%
#45	27.5%	15.2%
#50	25.6%	20.1%
#60	11.3%	14.6%
#70	5.4%	12.7%
#100		14.6%
Fines (Pan)	2.6%	10.8%

U.S. Standard Sieve	Before Blasting	After Impact		Before Blasting
	Test Nos. 34,35	*Test No. 34*	*Test No. 35*	*Test No. 36*
	Kleen Blast #35	>15 mil Epoxy Blasted @ 100 psi	Coal Tar Epoxy Blasted @ 100 psi	*Kleen Blast #3060*
	Percentage Retained (%)	Percentage Retained (%)	Percentage Retained (%)	Percentage Retained (%)
#20	19.5%			
#25	22.9%	7.2%	11.9%	17.4%
#30	24.8%	7.8%	11.9%	18.0%
#40	24.2%	20.2%	25.2%	35.8%
#45	4.5%	10.4%	10.1%	10.2%
#50	2.4%	10.6%	9.4%	7.2%
#60				4.2%
#70	0.9%	17.5%	13.8%	3.1%
#100		12.1%	8.5%	
Fines (Pan)	0.8%	14.1%	9.1%	4.0%

4. OBSERVATIONS AND RECOMMENDATIONS

4.1 OBSERVATIONS

Comments and interpretation of the data collected in this project are presented in this section. General comments are as follows:

1. From the results obtained, *TriVitro* testing met the objectives of the project, as subsequently modified. Only three samples were sent to *CARB* for certification testing rather than four at *TriVitro's* request;
2. **On a performance basis, recycled crushed glass abrasive is competitive with slag products for industrial blasting uses;**
3. Abrasive blasting is more nearly an art than a science. There are a large number of independent variables to contend with for a given blasting job make optimizing all the parameters and conditions more a matter of the blast technician's experience and observation than by design;
4. The data indicate that the abrasive metering valve plays a key role in productivity and costs. The metering valve used for this project was a standard model used by many blasters. For field projects, the valve can be adjusted as needed to meet abrasive flow requirements for the job. For testing, finding the optimum metering valve setting was not possible because of the short duration of each test and the wide variety of abrasives, pressures, and coatings being tested. The results obtained are necessarily relative and representative of what can be achieved with each abrasive. The results are not necessarily the optimum that can be achieved;
5. Dust generation can be somewhat controlled by the blast technician by varying the blast pressures, abrasive feed rate, nozzle placement, among other factors. From a qualitative standpoint, the copper slag based material appeared to generate slightly less dust in the blast booth than did the other products. The glass abrasives were only slightly more dusty. However, the nickel slag abrasive generated far more dust than either of the other two abrasives. These observations were confirmed after each test through querying the blast technician performing the tests.

6. The main blast technician performing the work for this test program had over 5 years of experience with abrasive blasting. The technician was instructed to quickly find the optimum blasting angle and distance for each test based on the given equipment settings and to move steadily and uniformly as possible during each test. The importance of minimizing the variability of the operator's motions was evident throughout the tests.

Comparative Cleaning Rates

As shown in Table 2 above, the Cleaning Rates observed in this project varied from:

- a high value of 401 square feet per hour for VitroGrit #50 applied at 95 psi through a 3/8" nozzle to enamel on steel (Test #22);
- a low value of 33.11 square feet per hour for VitroGrit #16 applied at 95 psi through a ¼" nozzle to boat hull epoxy on steel (Test #3).

The high value demonstrates the ease of which recycled glass abrasives can remove enamel on steel. Understandably, these tests also indicated some of the lowest total costs of $0.23 - $0.27 per square foot as shown on Table 6.

The lowest values also demonstrate the effect of increasing nozzle size, with the cleaning rate increasing three fold (to 116 - 135 sq. feet per hour in Tests 6 and 7) when the nozzle size is increased to ½" as shown in Table 3.

Table 3 shows clearly the positive effects on cleaning rate for VitroGrit #16 when increasing not only the nozzle size, but the blast pressure to 100 psi. Understandably, Table 3 shows that generally higher cleaning rates reduce the total cost per square foot as well. However, the Table **also reveals that there is a complex tradeoff between consumption rates and cleaning rates when calculating the total costs**. Although cleaning rates may decrease somewhat (and labor costs increase proportionally) when consumption rates are reduced, the effect on total costs is offset to some degree by reduced abrasive and disposal costs. The effects vary and do not appear linear, however, the margin of error and repeatability in the experimental methods used in this study do not allow a more detailed analysis.

Two sets of tests shown on Table 3 are useful in confirming the hypothesis that reducing the blast pressure and increasing nozzle size may result in more favorable (i.e., lower total costs per sq. ft.) operating conditions. Because glass is less dense than slag products, there are more particles for a unit weight of abrasive. If a larger nozzle size is used, a comparable consumption rate can be achieved however it is believed that higher cleaning rates will also be achieved. The first indicator that this may be true is shown in comparing Tests 3 and 5. Test 3 used a ¼" nozzle at 95 psi and the cleaning rate was 33.11 sq. ft/hour at a consumption rate of 12.9 lb./sq. ft. resulting in a total cost of $1.32/sq. ft. When Test 5 was performed, it used a 3/8" nozzle at 75 psi and the cleaning rate was 42.27 sq. ft./hour at a consumption rate of 12.26 lb./sq. ft. resulting in a total cost of $1.15/sq. ft. This is a savings in abrasive as well as an increase in cleaning rate.

The second set of tests in Table 3 involves Tests 1 and 10 versus Test 7. Again, going from a 3/8" nozzle at 100 psi to a ½" nozzle at 85 psi indicates that the cleaning rates go from 60 to 99 sq. ft./hour up to 116 sq. ft./hour and total costs are reduced from $0.97 to $0.61 per sq. ft. Although the data are limited in this test, the hypothesis that moving to lower pressures and larger nozzle sizes with glass is more productive and cost effective.

Comparative Consumption Rates

As shown in Table 2 above, the Consumption Rates for abrasives observed in this project varied from:

- a high value of 1489 pounds per hour for VitroGrit #16 applied at 100 psi through a 3/8" nozzle to boat hull epoxy on steel (Test #11);
- a low value of 250 pounds per hour for VitroGrit #30 applied at 95 psi through a 3/8" nozzle to enamel on steel (Test #19, although this test was anomalous because the blast pot experienced abrasive flow problems).

As discussed in the general comments, the flow metering valve setting is a key parameter that is difficult to hold constant because of differing flow rates for different abrasives at different blast pressures with the same meter valve setting. In actual practice with large areas to be blasted (not small sample plates) the experience of the blast technician is used to set the meter valve to optimize blast rates.

An interesting observation in Table 3 is shown in the data for Tests 1 and 10. With all else being held constant, the consumption rate varied between 684 and 1370 lb./sq. ft. However, the cost of blasting was calculated to be the same at $0.97 per sq. ft. The higher consumption rate of Test 1 was offset by the correspondingly higher cleaning rate. In actual practice, lower consumption rates may actually mean lower total costs per sq. ft. because there is physically less spent abrasive to manage before disposal.

Comparative Surface Profiles

VitroGrit abrasives result in comparable profile under similar blasting conditions than the slag products tested. As shown in Table 5, VitroGrit #40 is compared against Kleen Blast #35 and #3060 (Tests 24 and 25 are not considered because two grit sizes were mixed inadvertently) and Green Diamond #3060 which are comparable sieve ranges. Blasting VitroGrit #40 at 100 psi against boat hull epoxy yielded a surface profile which varied between 3.6 and 4.1 mils. Kleen Blast #35 blasted under the same conditions at the same boat hull epoxy surface yielded a 3.6 mil profile. Kleen Blast #30/60 blasted under the same conditions at the same epoxy surface also yielded profiles which varied between 3.7 and 4.0 mils.

VitroGrit #50 is a lighter product than Green Diamond #3060, however, the two were compared in two blast tests against an un-coated aluminum plate. VitroGrit #50 yielded a 2.8 profile when blasted at 75 psi through a 3/8” nozzle. Green Diamond #3060 was more aggressive, and when blasted at 100 psi through a 3/8” nozzle it yielded a 3.6 mil profile. Reportedly, a profile on aluminum of between 2.0 and 3.0 mils is the most desirable for surface preparation purposes. VitroGrit #50 is capable of achieving this profile.

As expected, VitroGrit #30 is the most aggressive abrasive for millscale. Tests 16 and 18 showed surface profiles of 2.6 to 3.7 mils. VitroGrit #40 is slightly less aggressive, yielding a surface profile of 2.5 mils. As discussed above, VitroGrit #50 is the least aggressive of the abrasives tested.

Coating Effects

Glass abrasives are well suited for hard coatings such as epoxy and enamels. The enamel tests were by far the most productive tests and resulted in the lowest removal costs of any of the coatings tested ($0.10 to $0.27 per sq. ft.). The alkyd coatings, which were applied apparently, did not fully harden before testing and were slightly gummy. This was noticeable in the decreased production rates for those tests.

4.2 RECOMMENDATIONS FOR ADDITIONAL STUDY

These tests were necessarily limited in replications. Replications of several of these tests are recommended. In particular, testing VitroGrit #50 on additional mill scale samples is desirable because it appears that this product is well suited for mill scale removal with a moderate profile. For the one test that was performed, the surface profile was found to be 2.0 mils. This type of profile may be very desirable in a variety of coating applications where coating savings can result from the lower profiles.

In addition, more replications of larger and smaller nozzle sizes for smaller grits than VitroGrit #16 would provide additional evidence of whether increasing nozzle size and decreasing blast pressures may be the preferable method of blasting with glass abrasives.

5. ACKNOWLEDGMENTS

CWC is a nonprofit organization providing recycling market development services to both businesses and governments, including tools and technologies to help manufacturers use recycled materials. CWC is the managing partner of the Recycling Technology Assistance Partnership (ReTAP), an affiliate of the national Manufacturing Extension Partnership (MEP) – a program of the US Commerce Department's National Institute of Standards and Technology. The MEP is a growing nationwide network of extension services to help smaller US manufacturers improve their performance and become more competitive. ReTap is also sponsored by the US Environmental Protection Agency.

The following contributed their time, effort, support and understanding during the conduct of this project:

1. *OCL Industrial Minerals*, Vancouver, B.C.
2. *United Western*, Seattle, WA.
3. Mr. Robert Van Buskirk, *Universal Ground Cullet,Inc.*, OH
4. Mr. John Meacham, *National Shipbuilding Research Council*
5. *California Air Resources Board*, Sacramento, CA
6. *TriVitro Corporation*, Washington.
7. *Pacific Northwest Coatings*, Seattle, Washington
8. *Clean Washington Center*, Seattle, Washington.
9. *AERCO, Inc., P.S.*, Lynnwood, Washington.

In addition, the following organizations provided work which is referenced in this report:

1. KTA-Tator, Inc., Pittsburgh, PA.
2. NVL Laboratories, Seattle, WA.

6. APPENDICES

C. CALIFORNIA AIR RESOURCES BOARD TEST RESULTS & LISTING

***Cal*/EPA**

California Environmental Protection Agency

Air Resources Board

P.O. Box 2815
2020 L Street
Sacramento, CA
95812-2815

August 14, 1997

Mr. Mark Anderson

TriVitro Corporation
351 Elliott Avenue West
Seattle, Washington 98119

Dear Mr. Anderson:

Abrasive Blasting Certification

We are pleased to inform you that your company's products, Vitrogrit VG #16,30, and 40, will be certified under our Abrasive Blasting Program from August 31, 1997 until August 31, 1999. I have enclosed with this letter a copy of the results of our testing.

Should you have any questions or need further assistance, please contact Ms. Kathryn Gugeler at (916) 327-1521. All correspondence should be addressed to me at the post office box above.

Sincerely,

James J. Morgester, Chief
Compliance Division

Enclosures

Abrasive Certification
Summary Data Sheet 1996

TriVitro Corporation
Mark Anderson — (206) 301-0181
351 Elliott Avenue West — (206) 301-0183
Seattle, WA 98119

Vitrogrit **VG #16**

Plant Location: 351 Elliott Ave. W., Seattle, WA

TEST DATA

Sieve Analysis

Size	Wt.gm
16	197.3
20	158.4
25	68.6
30	45.6
40	37.7
50	3.4
70	0.3
Pan	0.1
Initial Wt.	512.4

Percent Passing #70 Sieve: 0`
cpff: 0 or 70 whichever is larger

Blasting & Hydrometer Tests

Blast Sample	A	B	C
5 Micron %:	0.8	0.8	0.3

Average Percent 5 Micron or Less: 0.7

Specific Gravity: 2.52

Tested in accordance with Test Method No. California 371-A

Abrasive Certification
Summary Data Sheet 1996

TriVitro Corporation
Mark Anderson — (206) 301-0181
351 Elliott Avenue West — (206) 301-0183
Seattle, WA 98119

Vitrogrit **VG #30**

Plant Location: 351 Elliott Ave. W., Seattle, WA

TEST DATA

Sieve Analysis

Size	Wt.gm
16	0.2
20	4.2
25	62
30	116.9
40	224.3
50	78
70	10.1
Pan	0.2
Initial Wt.	498.9

Percent Passing #70 Sieve: 0`

cpff: 0 or 70 whichever is larger

Blasting & Hydrometer Tests

Blast Sample	A	B	C
5 Micron %:	0.8	0.9	1.9

Average Percent 5 Micron or Less: 1.2

Specific Gravity: 2.52

Tested in accordance with Test Method No. California 371-A

Abrasive Certification
Summary Data Sheet 1996

TriVitro Corporation
Mark Anderson (206) 301-0181
351 Elliott Avenue West (206) 301-0183
Seattle, WA 98119

Vitrogrit **VG #40**

Plant Location: 351 Elliott Ave. W., Seattle, WA

TEST DATA

Sieve Analysis

Size	Wt.gm
16	0.4
20	0
25	0.4
30	1.7
40	99.2
50	334.9
70	65
Pan	2
Initial Wt.	504.3

Percent Passing #70 Sieve: 0.4`
cpff: 0 or 70 whichever is larger

Blasting & Hydrometer Tests

Blast Sample	A	B	C
5 Micron %:	1.9	1.3	1.9

Average Percent 5 Micron or Less: 1.7

Specific Gravity: 2.53

Tested in accordance with Test Method No. California 371-A

E. KTA-TATOR TEST RESULTS

EXECUTIVE SUMMARY

KTA-Tator, Inc. was contracted by IMTEK to determine the properties of four (4) crushed glass abrasives: Two (2) samples representing post-consumer recycled container glass (20 x 30 and 30 x *50* mesh); and Two (2) samples representing post-industrial recycled plate glass (20 x 30 and 30 x 50 mesh). The four abrasives were evaluated for breakdown rate; dust generation rate; cleaning rate; surface profile; embedment; hardness; water soluble contaminant content; and rust back characteristics of surfaces cleaned with each abrasive.

20 x 30 Mesh Post Consumer and Post Industrial Recycled Glass Sand

Post consumer and post industrial recycled glass sand (20 x 30 mesh) abrasives were evaluated for breakdown rate and dust creation, cleaning rate, surface profile generation, product embedment, hardness, and water soluble contaminant content. Also, rust back characteristics of steel prepared (blast cleaned) using the two abrasives were evaluated. In summary, the abrasive materials exhibited particle breakdown rates ranging from 59.1% to *65.4%,* and dust generation ranging from 11.1% to 14.8 %. The post industrial product exhibited a higher breakdown rate (and correspondingly higher dust generation) than that of the post consumer product. Cleaning rates (removal of tight mill scale to achieve SSPC-SP 5, "White Metal BlasC') ranged from 1.137 to 1.340 square feet per minute; consumption rates ranged from 7.375 to 10.667 pounds per square foot. The production rate was higher for the post consumer product, yet the same product required less quantity of material to blast clean the surfaces to an SSPC-SP 5 condition. The surface profile ranges from 2.8 to 3.2 mils. The profile generated is considered identical for both the post consumer and post industrial products. Embedment ranged from 0.40% to 1.27%. The quantity of embedment was higher for the post industrial product. The Knoop hardness of the abrasives ranged from 540 to 542, and is considered comparable for both products. Water soluble contaminants (conductivity) of the two materials ranged from 114 to 630 micro-ohms/cm. The post consumer product exhibited a higher conductivity; however, both products were below the SSPC threshold of 1000 micro-ohms/cm. Finally, steel surfaces prepared with both abrasives exhibited rust back ranging from nil (0.0%) to 0.03% (ASTM D 610 Rust Grade 9 to 10).

30 x 50 Mesh Post Consumer and Post Industrial Recycled Glass Sand

Post consumer and post industrial recycled glass sand (30 x 50 mesh) abrasives were evaluated for identical properties listed above. In summary, the abrasive material exhibited breakdown rates ranging from 55.5% to 57.4%, and dust generation ranging from 13.8% to 20.6%. As with the 20 x 30 mesh products, the post industrial product exhibited a higher breakdown rate and corresponding dust generation rate, compared to the consumer product. Cleaning rates ranged from 1.128 to 1.408 square feet per minute; consumption rates ranged from 8.0 to 9.917 pounds per square foot. Similar to the production characteristics of the 20 x 30 mesh products, the cleaning rate was higher for the post consumer product, yet the product exhibited a lower consumption rate. The surface profile ranged from 1.9 to 2.1 mils, which is considered comparable. Embedment ranged from 0.0% to 0.07%, which is also considered comparable. Conductivity ranged from 200 to 230 micro-ohms/cm, which considered comparable. Finally, rust back characteristics of prepared steel surfaces were the same for both products (0.03%; Rust Grade 9). Hardness was not evaluated on the 30 x *50* products.

Summary Table (Averages)

Test	20 x 30 Post Cons.	20 x 30 Post md.	30 x 50 Post Cons.	30 x 50 Post md.
Breakdown Rate[1]	59.1%	65.4%	55.5%	57.4%
Dust Generation	11.1%	14.8%	13.8%	20.6%
Cleanin Rate	1.340 ft2/min	1.137 ft2/min	1.408 ft2/min	1.128 ft2/min
Consumption Rate	7.375 IbsIft2	10.666 lbsIft2	8.000 lbsIft2	9.917 lbsIft2
Surface Profile[2]	3.2 mils	2.8 mils	2.1 mils	1.9 mils
Embedment	0.40%	1.27%	0.00%	0.07%
Micro Hardness[3]	542 HK	540 HK	not tested	not tested
Conductivity[4]	630 micro mholcm	114 micro mholcm	230 micro mholcm	200 micro mholcm
Rust Bac~	0.01% (10)	0.03% (9)	0.03% (9)	0.03% (9)

'ASTMCl36
2 ASTM D4417, Method C
3 ASTM E384
4 ASTM D4940
5 ASTM D610

ABRASIVE TEST SAMPLES

The following abrasive materials comprised the evaluation program.

Material Identiflcation Manufacturer/Source	Type/Size	Quantity Received
IMTEK Barrel # 1	30 x *50* Mesh	1 Drum, 588 lbs.
	Post Consumer Recycled Container Glass Sand	
IMTEK Barrel #2	20 x 30 Mesh	1 Drum, 625 lbs.
	Post Consumer Recycled Container Glass Sand	
IMTEK Barrel # 3	30 x *50* Mesh	1 Drum, 599 lbs.
	Post Industrial Recycled Plate Glass Sand	
IMTEK Barrel #4	20 x 30 Mesh	1 Drum, 599 lbs.
	Post Industrial Recycled Plate Glass Sand	

TEST DESCRIPTIONS RESULTS AND DATA INTERPRETATION

A description of the test protocol for each of the evaluations conducted follows, along with a summarization and interpretation of test results. Specific test results are contained in the tables and graphs appended.

Pre-blast Particle Size Distribution

Test Description

Sieve analysis was performed for the test abrasive to establish pre-blast particle size distribution. The information was subsequently used to calculate breakdown characteristics of the abrasive materials. Testing was performed in general accordance with ASTM C136 "S tahdard Test Method for Sieve Analysis of Fine and Coarse Aggregates". Briefly, the entire amount of each abrasive was "riffled" twice to obtain a uniform mixture of particle sizes. Subsequently, a one-hundred (100) gram sample of each abrasive type was tamped through a series of twelve sieves for seven (7) minutes. The USA Standard sieve sizes used for the testing included No.'s 12, 16, 20, 30, 40, 50, 60, 70, 100, 140, 200, 270, and a solid pan at the base of the sieves. The abrasive retained on each sieve was weighed on a balance capable of measuring to 0.1 gram. The percent abrasive retained on each sieve was recorded. Data are found in Appendix A.

Test Results

The results of the four pre-blast sieve analyses and the post-blast analyses (for calculating breakdown characteristics) are found in Appendix A.

Breakdown Rate/Dust Generation

Test Description

Breakdown rate/dust generation testing was performed to determine post-blast cleaning particle size distribution and the quantity of dust generated by the test abrasives. A specially-designed blast chamber equipped with an impact plate and a dust reclamation bag was used for the testing. Using a 1/2" diameter feed orifice (located at the base of the blast pot) and a ¼” nozzle, a 25 lb. quantity of each abrasive was propelled into the chamber at 100 psi against a 3/16" steel plate at a distance of 18" from the nozzle to the steel plate. The dust accumulated in the reclamation bag was weighed to determine the amount of dust generated (percentage of total sample weight). The dust was then combined with the spent abrasive, and the resulting mixture riffled two (2) times to obtain a uniform mixture of particle sizes.

A sieve analysis was performed on the riffled spent abrasive to determine the post blast cleaning particle size distribution and resulting breakdown (see method described in the "pre-blast particle size distribution").

Abrasive breakdown was calculated based on the comparison of the pre-blast versus the post blast particle size distribution of the abrasive mixture. Breakdown rate was determined by summing the differences in material retained in each sieve size (see tables appended). Abrasive breakdown data is useful in assessing the recyclability of an abrasive. It refers to the percentage of the original particle size distribution that "shifted out" (decreased) as a result of surface impingement during blast cleaning.

Test Results

The breakdown rate evaluation was initially conducted at 100 psi nozzle pressure. Breakdown rates at this pressure ranged from 55.5% to *65.4%*. This breakdown rate would categorize the abrasives as "non-recyclable", as insufficient quantities of large abrasive particles would likely reduce productivity and surface profile generation, and increase dust generation. Accordingly, at the request of INITEK, Inc., KTA conducted the identical test procedure at 80 psi nozzle pressure (20 x 30 mesh products) and 60 psi nozzle pressure (20 x 30 post industrial only), to determine of revised nozzle pressures would reduce breakdown. Reduced nozzle pressure did not result in decreased breakdown rates. However, dust generation decreased by 3% to 5%. Breakdown rate data is further illustrated in Appendix B as significant "post blast curve shifting" to the right side of the graph (closer to the sieve pan) is indicative of breakdown. Sieve Analysis results are located in Appendix A. Appendix B, Table B-i provides test results.

Data Interpretation

The test results yielded the following conclusions:

- The abrasives tested possessed a high particle breakdown rate; consequently, they are not deemed a good candidate for recycling.
- The abrasives tested exhibited a relatively high level of dusting which are a result of high particle breakdown rates.
- The 20 x 30 mesh size abrasives exhibited less dust generation then did the 30 x 50 mesh abrasives.
- The post consumer abrasives exhibited lest dust Generation then did the plate glass abrasives.

Cleaning/Consumption Rate

Test Description

Cleaning/consumption rate analysis was performed to determine the production rate and abrasive consumption associated with blast cleaning tight mill scale bearing steel to a "White Metal" condition (SSPC-5P5). Three (3) - 2' x 2' x 3/16" commercial grade hot rolled carbon steel test panels (tight mill scale bearing) were used for testing. A 1/2" feed orifice (located at the base of the blast pot), a 1/4" nozzle, and 90-100 psi nozzle pressure was used.

Each panel side was blast cleaned to "White Metal" (SSPC-5P5) by one operator using a 50 pound quantity of abrasive, and the blast cleaning time was recorded. Following each blast cleaning period, the unused abrasive was emptied from the pot and weighed to determine (by difference) the amount that was consumed during blast cleaning operations.

Test Results

The productivity (cleaning rates) of the post-consumer products (20 x 30 and 30 x 50) ranged from 1.340 to 1 .40S square feet per minute. The post industrial products ranged from 1.128 to 1.137 square feet per minute. For reference, the published cleaning rate for 16 x 35' silica sand is *1.525* square feet per minute.

Consumption rates of the post consumer products ranged from 7.375 to 8.000 pounds per square foot. The post industrial products ranged from 9.917 to 10.667 pounds per square foot. The consumption of silica sand (16 x 35) is comparable to the post industrial products, and higher than the post consumer products, based on the data available.

Specific test results are attached in Appendix C, Table C-2

Data Interpretation

Blast cleaning of tight mill scale bearing steel at 100 psi yielded the following conclusions regarding cleaning and consumption rates;

- The cleaning rate of the Post-Consumer and Post-Industrial products is higher than that of the reference 16 x 35 silica sand cleaning rate.

- The consumption rate of the Cost-Consumer products is lower than that of the reference 16 x 35 silica sand abrasive' consumption rate. The Post-Industrial product consumption is comparable to the referenced silica sand.

Surface Profile

Test Description

Surface profile generation measurement was performed on the 2' x 2' blast cleaned panels prepared during the cleaning rate study. Surface profiles were measured in accordance with NACE RP 01.78-89 "Standard Recommended Practice Field Measurement of Surface Profile of Abrasive Blast Cleaned Steel Surfaces Using Replica Tape". X-Coarse Testex Press-O-Film Replica Tape *(1.5* - 4.5 mils) was used for evaluating surface profile. Six (6) measurements were taken (two per panel) to obtain an average surface profile.

Test Results

The 20 x 30 mesh products generated a surface profile ranging from 2.8 to 3.2 mils, which is essentially equivalent to the published reference surface profile of 16 x 35 silica sand (3.3 mils). The 30 x 50 mesh products generated a surface profile ranging from 1.9 to 2.1 mils, which is lower than the reference silica sand. This result is anticipated, as particle size influences surface profile depth.

Specific test results are attached in Appendix C, Table C- 1.

Data Interpretation

Blast cleaning of tight mill scale bearing steel at 100 psi yielded the following conclusions:

- Differences in the surface profile generation between Post-Consumer and Post-Industrial products is negligible.

- The 20 x 30 mesh products generate a surface roughness essentially equivalent to 16 x 35 silica sand and approximately 1.0 mil deeper than the 30 x 50 mesh products.

Embedment

Test Description

Embedment evaluation was performed on the tight mill scale bearing panels blast cleaned during the cleaning rate study at 100 psi nozzle pressure. Fifteen (15) areas (five per panel side) were visually evaluated to determine the average percent embedment of each abrasive. A 1/2" x 1/2" square grid divided into 100 smaller squares was used to determine the percent of embedment. The grid was placed on the panel surface and viewed through a lOX magnifier.

Any trace of abrasive embedment observed in a square was counted as 1 unit (1%) of embedment. The number of squares exhibiting embedment were summed and recorded.

Test Results

Use of the post consumer products resulted in embedment ranging from 0.00% (30 x 50) to 0.40% (20 x 30). The post industrial product revealed embedment ranging from 0.07% (30 x 50) to 1.27% (20 x 30). More significant though is the comparison of the embedment characteristics of the 16 x 35 silica sand, which is 24%.

Specific test results are attached in Appendix C, Table C-i.

Data Interpretation

Blast cleaning of tight mill scale bearing steel at 100 psi yielded the following conclusion regarding embedment;

- Independent of mesh size and consumer versus industrial product, the percent embedment is low, and significantly lower than the reference 16 x 35 silica sand abrasive.

Microhardness

Test Description

Knoop Microhardness was conducted on the 20 x 30 mesh products by Industrial Laboratory Services Corporation, Pittsburgh, PA in accordance with ASTM E384. An explanation of the testing procedure is provided in the test report (Appendix C, Table C-4).

Test Results

The Knoop Microhardness of the 20 x 30 mesh products ranged from 540 - 542 (specific test results are attached in Appendix C).

Data Interpretation

None required.

Rust Back

Test Description

Rust back testing was performed to determine whether the abrasive media causes rapid rust "bloom" on prepared steel surfaces. Triplicate test panels (3/16" x 4" x 6") were cleaned with each of the abrasives, then immediately placed in an enclosed plastic chamber containing a few inches of water (the panels were not immersed in water). Eighty to ninety percent (80-90 %) relative humidity was maintained for four (4) days (relative humidity was previously determined by the use of an electronic hygrothermograph that was placed inside the chamber). Upon completion of the test, the panels were examined visually for the presence of rust bloom and evaluated in accordance with ASTM D610, "Standard Test Method for Evaluating Degree of Rusting on Painted Steel Surfaces".

Test Results

Specific test results are attached in Appendix C. A summary table is provided below;

Rust Back Evaluation

Sample	Rust Grade
30 x 50 Post-Consumer	Grade 9
20 x 30 Post-Consumer	Grade 10
30 x 50 Post-industrial	Grade 9 to 10
20 x 30 Post-industrial	Grade .9 to 10

Independent of the product and mesh size, rust bloom ranged from nil~$_{10\sim}$ (0.0%) to less than .03%(9).

Data Interpretation

None required.

Water Soluble Contaminants

Conductivity analysis on the test abrasives was conducted in accordance with ASTM D4940, "Standard Test Method of Conductimetric Analysis of Soluble Ionic Contamination of Blasting Abrasives", attached. Briefly, this analysis involves measuring approximately 300 milliliters of the abrasive and agitating it for approximately one minute in 300 milliliters of deionized water. The sample remains undisturbed for eight minutes and then is agitated for approximately one minute. The sample is then filtered and the liquid portion tested using a conductivity bridge.

Test Results

Post-Consumer products ranged from 230 to 630 micro-mhos per centimeter. PostIndustrial products exhibited a lower conductivity, ranging from 114 to 200 micro-mhos per centimeter.

Specific test results are attached in Appendix C.

Data Interpretation

The current industry accepted threshold established by the Steel Structures Painting Council (SSPC) for conductivity of Mineral and Slag Abrasive Blast Cleaning Media is 1000 micro-rnhos. A significant level of contamination beneath the coating film and an adequate concentration of water will create an osmotic force, drawing liquid through the coating film and causing blistering. The conductivity levels of the test abrasive are below the SSPC established threshold.

Table B-1

IMTECK, Inc.

Breakdown Rate and Dust Generation Data Summary

for 25 lbs of Abrasive at listed nozzle pressures

Mixer Valve Setting 1/2" hole
Nozzle 1/4"

Drum # 1 30 x 30 Post-Consumer		Percentage of Breakdown	Dust Generation
Nozzle Pressure (psi)	100 80 60	55.5%	13.8%
Drum # 2 20 x 30 Post-Consumer			
Nozzle Pressure (psi)	100 80 60	59.1% 59.9%	11.1% 7.8%
Drum # 3 30 x 50 Post-Industrial			
Nozzle Pressure (psi)	100 80 60	57.4%	20.6%
Drum # 4 30 x 50 Post-Industrial			
Nozzle Pressure (psi)	100 80 60	65.4% 60.2% 57.7%	14.8% 9.8% 8.2%

Table C-1
Profile and Embedment Test Results
IMTEK, Inc.

Nozzle Pressure 100 psi
Mixer Valve Setting 1/2" hole
Nozzle *1/4* inch Boride

	Sample	Profile 1	Profile 2	Profile Avg.	Imbedded Particles 1	2	3	4	5
Drum #1 30 X 50 Post-Consumer	1A	1.6	1.8	1.7	0%	0%	0%	0%	0%
	1B	2.2	2.8	2.5	0%	0%	0%	0%	0%
	1C	1.7	2.5	2.1	0%	0%	0%	0%	0%
	Average Range	2.1 0.9			0.0% 0.0%				
Drum #2 20 X 30 Post-Consumer	2A	2.9	3.1	3.0	0%	0%	0%	0%	0%
	2B	2.9	2.8	2.9	0%	0%	0%	0%	0%
	2C	3.1	3.2	3.2	0%	0%	0%	0%	1%
	Average Range	0.4		3.0	0.07% 1.0%				
Drum #3 30 X 50 Post-Industrial	3A	1.7	1.7	1.7	0%	0%	0%	0%	0%
	3B	2.0	2.1	2.1	0%	0%	0%	0%	0%
	3C	2.1	1.7	1.9	0%	0%	1%	0%	1%
	Average Range			1.9 0.4	0.07% 1.0%				
Drum #4 20 X 30 Post-Industrial	4A	2.9	3.1	3.0	0%	0%	1%	4%	4%
	4B	2.8	2.8	2.8	0%	0%	0%	5%	2%
	4C	2.7	2.7	2.7	3%	0%	1%	0%	1%

	Average			2.8					
	Range			0.4	1.27%				
					5.0%				
Retest Drum #2 20 X 30 PostConsumer	5A	3.2	3.3	3.3	1%	0%	2%	1%	0%
	5B	3.0	3.2	3.1	0%	0%	0%	5%	0%
	5C	3.3	3.2	3.3	1%	0%	0%	0%	1%
	Average			3.2					
	Range			0.3	0.40%				
					2.0%				

Drum #2 was retested as the abrasive was wet during initial test

Profiles measured in accordance with:

NACE RP 01.78-89 Standard recommended Practice
Field Measurement of
Surface Profile of Abrasive Blast Cleaned Steel Surfaces
Using Replica Tape

INDUSTIAL TESTING LABORATORY SERVICES CORP.

IIJ

635 ALPHA DRIVE - R.I.D.c. PARK
PITTSBURGH, PA 15238
PHONE 412-963-1900
• : FAX 412-963-1926
''.li:

PURCHASEORDER NO. 95P0677 **TEST REPORT** **DATE:** December 27, 1995

TO: K.T.A. **ITLS REPORT NO.** 65424
115 Technology Drive
ADDRESS Pittsburgh, PA 15275
ATTENTION Mike Melampy

Material received:

IDENTIFICATION

Two (2) samples of recycled glass identified as "#5 - Plate" and "#6 - Post Cons."

RESULTS

We prepared a compartmented metallographic specimen of high-strength epoxy containing several hundred randomly selected particles from each sample.

We determined the Knoop microhardness in accordance with ASTM E384 using a 100 gram load (as recommended by ASTM C730) and obtained the following readings on particles that did not crack during the test.

	hardness	
sample #	HK	HRC*
5	537	50
5	552	51
5	537	50
6	537	50
6	537	- 50
6	548	50

*Converted from HK to HRC using the ASTM E140 paragraph X1.1.4 equation.

The "Handbook of Chemistry and Physics" 39 Ed. pg. 2016 gives the following Knoop/Mohs comparisons.

HK	Nohs
32	2
135	3
163	4
430	5
560	6
820	7
1340	8

Thus, the glass samples that you submitted would have a Mohs hardness of about 5.7.

INDUSTIAL TESTING LABORATORY SERVICES

ALLEN B. CEDILOTE, P.E.
Chief Metallurgist

LABORATORY INVESTIGATION

The conductivity of four abrasive materials was determined in accordance with ASTM D-4940. The results of this testing were as follows:

Sample	**Conductivity**
30 x 50 Post Cons. #1	230 µ rnho/cm
20 x 30 Post Cons. #2	630 µ rnholcrn
30x 5O Plate #3	200 µ rnho/cm
2Ox3O Plate #4	114 µ mholcm

Table C-3
Rust Back Test
IMTEK, Inc.

	Environmental Conditions During Blast Cleaning Operations													
	Blast Time	Dry Bulb	Wet Bulb	Relative Humidity	Dew Point	Sample Temp.	Sam. No.	Sam. No.	Sam. No.	ASTM D 610 Rating			% Surface Rusted
										Ind.	Avg.	Range	
Drum #1 30 x 50 Post - Consumer	11:00 AM	66°	54°	44%	44°	68°	1A	1B	1C	9,9,9	9	0	<.03%
					°								
Drum #2 20 x 30 Post-Consumer	11:12 AM	66°	54°	44%	44°	68°	2A	2B	2C	10,10.10	10	0	<.01%
Drum #3 30 x 50 Post-Industrial	11:20 AM	66°	54°	44%	44°	68°	3A	3B	3C	10,9,10	9.66	1	<.03%
Drum #4 20 x 30 Post-Industrial	11:26 AM	66°	54°	44%	44°	68°	4A	4B	4C	10,9,10	9.66	1	<.03%

ASTM D 610, Standard Test Method for Evaluating Degree of Rusting on Painted Steel Surfaces

Rust Grades

10 - no rusting or less than 0.01% of surface rusted

9 - minute rusting, less than 0.03% of surface rusted

8 - few isolated rust spots, less than 0.1% of surface rusted