ERDC/CERL TR-01-37

US Army Corps of Engineers®
Engineer Research and Development Center

High-Performance Materials and Systems Research Program

Recycled Steel Abrasive Grit

Evaluation of Rounding and Its Effects on Adhesion

Alfred D. Beitelman

August 2001

Construction Engineering Research Laboratory

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ERDC/CERL TR-01-37
(TR HPMS-01-1)
August 2001

Recycled Steel Abrasive Grit

Evaluation of Rounding and Its Effects on Adhesion

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Final report

Approved for public release; distribution is unlimited.

Prepared for U.S. Army Corps of Engineers
Washington, DC 20314-1000

Under HPM&S Work Unit 33116

Foreword

This study was authorized by Headquarters, U.S. Army Corps of Engineers (HQUSACE), as part of the High-Performance Materials and Systems (HPM&S) Research Program. The work was performed under Work Unit 33116, "Demonstration of New Coating Technologies," for which the Principal Investigator was Mr. Alfred D. Beitelman, U.S. Army Research and Development Center (ERDC), Construction Engineering Research Laboratory (CERL).

Dr. Tony C. Liu was the HPM&S Coordinator at the Directorate of Research and Development, HQUSACE. Mr. Andy Wu, HQUSACE, was the HPM&S Program Monitor. Dr. Mary Ellen Hynes, ERDC Geotechnical and Structures Laboratory (GSL), was the ERDC Lead Technical Director for Infrastructure Engineering and Management. Mr. James E. McDonald, GSL, was the HPM&S Program Manager.

The work was performed for the Materials and Structures Branch (CF-M) of the Facilities Division (CF), CERL, by KTA-Tator, Inc., Pittsburgh, PA, under contract DACW42-00-P-0462. The technical editor was Linda L. Wheatley, Information Technology Laboratory — Champaign. Mr. Martin J. Savoie was Chief, CF-M, and Mr. L. Michael Golish was Chief, CF. Dr. Paul Howdyshell was the associated Technical Director and the Director of CERL was Dr. Alan W. Moore.

The Commander and Executive Director of ERDC is COL John W. Morris III, EN, and the Director of ERDC is Dr. James R. Houston.

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1 Introduction

Background

The use of recycled metallic abrasives (e.g., steel grit) is becoming more common on U.S. Army Corps of Engineers (COE) projects for preparation of steel surfaces prior to application of thermal-sprayed metallic and liquid-applied coatings. The angularity of the resulting surface profile is critical to the adhesion of the thermal-sprayed coatings, and enhances the adhesion of liquid-applied coatings.

Crushed steel grit, when new, provides for adequate angularity of the surface. However, repeated impact against the steel surfaces causes the media to become sub-angular and even rounded as the steel grit is recycled multiple times. Contractors using steel grit media should routinely add new media to maintain the proper mix of abrasive size and shape to ensure consistent surface profile depth and angularity. If this is not done routinely, however, the angularity of the surface profile may be compromised. A rounded (or peened) surface generated by a round abrasive (steel shot) has been shown in prior COE research efforts to adversely affect the adhesion of thermal-spray coatings, independent of the depth of the profile. It is not known whether steel grit, after multiple recycles, will lead to similar reductions in adhesion.

Currently, there are no established field methods that a COE inspector can use to evaluate the angularity of the abrasive or the angularity of the surface after abrasive blast cleaning has been performed. Further, other than a minimal amount of information collected under a separate COE research objective, there is little data illustrating the level of angularity actually required for adhesion of thermal spray coating materials.

Objectives

The objectives of this research effort were to determine the effect that the recycling of metallic abrasive has on the adhesion of thermal-spray (zinc/aluminum 85/15) and liquid-applied epoxy zinc-rich coatings, and to recommend an approach that can be used to generate industry standards for recycled abrasive.

The data may also be helpful in developing field inspection methods for surface and abrasive angularity that can be used to verify proper surface preparation.

Approach

The work was conducted in three phases. Phase I entailed the preparation of steel test panels using crushed steel abrasive media both as manufactured and after it had been recycled a number of times. During this phase, the shapes of the abrasive grains were continually evaluated based upon an article published by J.D. Hansink (March 1994), and included "very angular," "angular," "sub-angular," "sub-rounded," "rounded," and "well-rounded" (Appendix A). Surface profile depth, angularity, and peak density measurements were obtained from the prepared specimens.

Phase II involved the application of two coating systems [(a) 85 percent zinc/15 percent aluminum metallizing applied by electric arc spray and (b) an epoxy zinc-rich primer] to the prepared steel specimens.

Phase III included an assessment of the tensile adhesion strength of the coating systems to the prepared surfaces.

Abrasive media and prepared (uncoated) test specimens representing each abrasive grain shape were preserved for future use in the development of field inspection standards.

Scope

The abrasive shape and resulting surface profile shape appear to influence the adhesion of metallizing. Reduced adhesion is most apparent as the abrasive shape becomes sub-rounded and rounded. The difference in surface profile shape, however, is not reflected in the surface profile measurements, as the depth of the surface profile is unchanged. Visual or tactile standards need to be developed in order to assess the abrasive and/or the surface after blast cleaning. Abrasive and surface profile shapes do not appear to influence the adhesion of the liquid-applied epoxy zinc-rich primer.

Mode of Technology Transfer

It is recommended that the information contained in this report be used as a basis for developing an industry specification for recycled abrasives.

Units of Weight and Measure

U.S. standard units of measure are used throughout this report. A table of conversion factors for Standard International (SI) units is provided below.

SI conversion factors		
1 in.	=	2.54 cm
1 sq in.	=	6.452 cm^2
1 gal	=	3.78 L
1 lb	=	0.453 kg
°F	=	(°C x 1.8) + 32

2 Test Procedures

The testing procedures used to perform the research are described below. Custom forms were developed to document test conditions and quality control procedures. Appendix E shows photographs of the test apparatus, and blast cleaning and coating procedures.

Fabrication of Steel Test Panels

Hot rolled, tight mill scale bearing carbon steel test panels (ASTM A 36) measuring ¼ in. x 4 in. x 8 in. were used for the study. After fabrication, each panel face was stenciled with an identifying code. The panel number corresponds to the abrasive grain shape used to blast clean the steel and the disposition of the prepared panels (surface characterization, coated, or reserved for future use). After stenciling, the test panels were prepared in accordance with SSPC-The Society for Protective Coatings (SSPC) Surface Preparation Method No. 1 (SSPC-SP1, "Solvent Cleaning") to remove fabrication lubricants.

Abrasive Media

One thousand pounds of G50 crushed steel grit abrasive was used for the project. The steel grit was manufactured by Barnes Steel of Butler, PA. The abrasive size was chosen in order to generate a surface profile of 3 to 4 mil as required by the Corps of Engineers Guide Specification (CEGS) 09971, *Metallizing: Hydraulic Structures*. The actual depth of the surface profile was verified prior to project start-up by blast cleaning scrap steel test panels using the project-specific design parameters (nozzle size, blast pressure, and nozzle distance). Additionally, the metering valve setting was optimized at this point in the project.

The same steel grit abrasive was used for the entire process. The objective was to recycle the abrasive enough times to alter the shape in accordance with the classifications shown in Appendix A.

Testing Procedures

A procedural checklist (Appendix B) was developed to ensure that each step of the research was properly performed and documented by project personnel. Specifically, the following test procedures were used.

Impaction of the abrasive media was performed using a specially designed abrasive media breakdown chamber. A No. 7 (7/16 in.) venturi blast nozzle was positioned 18 in. from a steel impaction plate located inside the breakdown chamber. The abrasive media was exhausted from the abrasive hopper through the metering valve, into the abrasive hose/blast nozzle assembly, then impacted against a 1 in. steel plate. The steel plate was monitored for wear and frequently replaced to maintain the distance parameter. The impacted abrasive media fell to the base of the chamber for reuse, while the airborne dust was drawn off into a dust collection system. Use of the breakdown chamber permitted the control of spent abrasive media, so that it could be recycled with minimal material loss. Compressed air cleanliness was verified daily (ASTM D 4285) and blast nozzle pressure was verified weekly using a hypodermic needle pressure gage. Blast cleaning pressure was maintained with an Atlas Copco (Holyoke, MA) 375 CFM air compressor. Cleanliness of the compressed air was achieved by installing a condensate/desiccant air dryer in-line between the compressor and the abrasive hopper. Nozzle wear was also monitored weekly by using a pressure blast analyzer gage (nozzle orifice gage). After each abrasive grain shape was achieved, the entire supply of abrasive was passed through an air wash system equipped with a fine mesh stainless steel screen to remove abrasive fines and scale generated during the blast cleaning process. Step-by-step procedures were developed to control project quality. These procedures are summarized below.

Initial Procedure

Step 1: Sample 125 lb of virgin abrasive material (grain shape "very angular").

Step 2: Sample virgin material (1 gal or approximately 35 lb). Place a desiccant packet inside the gallon container and seal. Label the container "Grain Shape 0.5."

Step 3: Microphotograph sample of virgin material and record actual magnification.

Step 4: Blast clean 12 carbon steel test panels (use approximately 95 lb) using a No. 7 nozzle, 95-100 pounds per square inch (psi), 18 in. distance. Achieve SSPC-SP5/NACE 1. Document the panel numbers and corresponding grain shape.

Step 5: Individually wrap panels in rust inhibitive paper. Preserve panels in a drying oven.

In-Process Procedure

Step 1: Energize the abrasive hopper with the entire quantity of remaining steel grit (approximately 875 lb). Use No. 7 blast nozzle, 95-100 psi, 18 in. distance.

Step 2: Repeatedly impact the entire quantity of abrasive media until each grain shape is achieved (angular, sub-angular, sub-rounded, rounded, and well rounded). Routinely examine a sample to ensure each end point is not exceeded. Record the actual number of cycles required to achieve each grain shape.

Step 3: Remove 125 lb of the impacted abrasive after each grain shape is achieved.

Step 4: Sample each grain shape (1 gal or approximately 35 lb). Place a desiccant packet inside the gallon container and seal. Label container according to the grain shape.

Step 5: Microphotograph a sample of each grain shape. Record the actual magnification.

Step 6: Blast clean 12 carbon steel test panels with each grain shape (use approximately 95 lb) using a No. 7 nozzle, 95-100 psi, 18 in. distance. Achieve SSPC-SP5/NACE 1. Document the panel numbers and corresponding grain shape.

Step 7: Individually wrap panels in rust inhibitive paper. Preserve the panels in a drying oven.

Step 8: Air wash the remaining abrasive to remove fines after each grain shape is achieved.

Assessment of Surface Profile Depth, Peak Density, and Angularity

After abrasive blast cleaning operations were completed, the surfaces of triplicate test panels representing each grain shape were characterized for surface profile depth, peak density, and relative angularity. The following procedures were used.

Surface Profile Depth

Triplicate test panels prepared with each abrasive grain shape were examined for the average surface profile imparted into the steel surfaces during the abrasive blast cleaning procedures. Surface profile measurements were made in accordance with the procedure described in ASTM D 4417, "Field Measurement of Surface Profile of Blast Cleaned Steel," Method C (Testex Replica Tape). X-Coarse Plus (4 to 6.5 mils) or X-Coarse (1.5 to 4.5 mils) Replica Tape was used. Triplicate measurements were obtained on each test panel, culminating in a total of nine measurements for each representative abrasive grain shape used during the blast cleaning process. The surface profile data generated during this study are summarized in Chapter 3, **Test Results**. Appendix C gives the raw data.

Surface Profile Peak Density

Triplicate test panels prepared with each abrasive grain shape were examined for the relative density of the surface profile peaks generated during the abrasive blast cleaning procedures. Peak density measurements were made using a Mitutoyo (Aurora, IL) Surftest 301 Profilometer, using the "peak count" function. Six measurements were obtained on each test panel, culminating in a total of 18 measurements for each representative abrasive grain shape used during the blast cleaning process. The peak density data generated during this study is summarized in Chapter 3, **Test Results**. Appendix D gives the raw data.

Surface Profile Shape (Angularity)

Triplicate test panels prepared with each abrasive grain shape were examined for the relative shape or angularity of the surface profile peaks generated during the abrasive blast cleaning procedures. Photomicrographs were obtained using an R.J. Lee (Monroeville, PA) *Personal* ™ Scanning Electron Microscope (SEM). Test panels were sectioned to create a smaller sample. Samples were taken from the center area of the test panels. One photomicrograph (25x) was obtained for each test panel, culminating in a total of three images for each representative abrasive grain shape used during the blast cleaning process. The 25x magnification was selected to match the magnification used to photomicrograph the abrasive shape throughout the study, and the magnification can be duplicated in the field using standard field microscopes. The photomicrographs generated during this study are shown in Appendix E1.

Application of Coatings to Prepared Steel Test Panels

Triplicate test panels prepared using each abrasive grain shape were coated with a metal spray (zinc/aluminum wire applied using electric arc deposition) or with an organic (epoxy) zinc-rich primer. A description of each coating procedure follows.

Metallizing Application

Triplicate test panels prepared (abrasive blast cleaned) using each abrasive grain shape were metallized. The application of the metallizing and the equipment, conditions, and coating thickness data are documented on a custom form (Appendix F). Metallizing was performed using electric arc spray and 1/8-in. diameter 85 percent zinc/15 percent aluminum wire as required by CEGS-09971 specifications for System 6-Z-A. The equipment and wire were manufactured by TAFA Technologies (Concord, NH). Coating thickness was measured at three locations (spots) on the front and back of each test panel using a PosiTector® Model 6000 Type 2 coating thickness gage (DeFelsko, Ogdensburg, NY) calibrated over the prepared surface using plastic shims. Each spot measurement consisted of three individual gage readings. Nine measurements on each panel surface were averaged. The thickness data are contained on the metallizing form (Appendix F). Coating thickness ranged from 13.5 mils to 20 mils on the front (numbered) sides and 13.7 to 19.8 mils on the back (un-numbered) sides. CEGS-09971 System 6-Z-A specifications require a minimum of 14 mils and an average of 16 mils. Three or four passes were required on each panel side to achieve the specified coating thickness. Multiple passes were applied in opposing directions. After application was complete the coating thickness measurements were documented and adhesion testing was performed. Appendix E2 shows representative photographs of the metallizing procedure.

Organic (Epoxy) Zinc-Rich Application

Triplicate test panels prepared (abrasive blast cleaned) using each abrasive grain shape were coated with a commercially available three component organic (epoxy) zinc-rich primer system that complies with the requirements of SSPC Paint 20, Type II. The equipment and application conditions were documented on a custom form (Appendix F). Coating application was performed using conventional (air) spray equipment manufactured by Binks Equipment (Glendale Heights, IL). The coating was applied using a semi-automated spray arm equipped with an automatic spray gun. Coating thickness was measured at three locations (spots) on the front and back of each test panel using a PosiTector® Model 6000 Type 2 coating thickness gage calibrated using National Institute of Standards and Technology (NIST) Calibration Plates. A 1.0-mil base metal reading was subtracted from the gage readings. Therefore, the coating thickness data represents the coating thickness above the peaks of the surface profile. Each spot measurement consisted of three individual gage readings. Nine measurements on each panel surface were averaged. Thickness data are contained on the Coating Thickness Record (Appendix F) for each panel surface. Coating thickness ranged from 2.9 to 4.6 mils on the front (numbered) sides and

3.0 to 7.4 mils on the back (unnumbered) sides. The average coating thickness ranged from 3.7 to 5.1 mils above the peaks of the surface profile. After application was complete and coating thickness measurements were documented, the panels were stored at room temperature for subsequent adhesion testing of the applied coating.

Tensile Adhesion Testing of Applied Coatings

Triplicate coated test panels representing each surface preparation and coating system combination were evaluated for tensile adhesion in accordance with ASTM D 4541, "Pull-off Strength of Coatings using Portable Adhesion Testers." The apparatus used to perform the testing is described in Appendix A.4 of ASTM D 4541 as a "Self-Alignment Adhesion-Tester Type IV." A Pneumatic Adhesion Tensile Testing Instrument (PATTI) Model 3 equipped with an F-4 (0-2,000 psi) piston manufactured by SEMicro Corporation (Rockville, MD) was used. A current Certificate of Calibration is on file with the tester. Triplicate pull stubs designed for use with the pneumatic tester were glued to the panel surfaces using Hysol 907, a two-component epoxy adhesive manufactured by Dexter Corporation (Seabrook, NH). A plastic cut-off ring was placed around the perimeter of each pull stub to displace the fillet of adhesive around the base of the pull stub. The cut-off rings were removed prior to adhesion testing. After a 24-hr room temperature cure, the test panels were placed in an oven maintained at 100 °F for 72 hr to ensure a complete cure of the epoxy adhesive. Adhesion testing was performed on 10 and 11 July 2000. The piston burst strength for each pull stub was converted to psi pulling force using the F-4 piston conversion chart supplied with the tester. The location of adhesion break was recorded as adhesion (a distinct break between the substrate and the coating), cohesion (a break within a single layer), or glue (piston burst pressure exceeded the strength of the epoxy adhesive used to adhere the pull stub). Results of the adhesion testing are summarized in Chapter 3, **Test Results**. Appendix G gives the raw data. Percentages for adhesion or cohesion shown on test results are determined based on the corresponding percentage of failed surface area under the pull stub.

3 Test Results

The results of the research are summarized in the following tables. The raw data are contained in Appendices C, D, and G. Photomicrographs of the abrasive media and of the surfaces generated by each are also attached to this report (Appendices E3 and E1, respectively).

Recycling Data

Table 1 lists the number of recycles required to generate the various abrasive grain shapes of G50 crushed steel grit. The corresponding photomicrograph number is also indicated. Photomicrographs of the abrasive at specific intervals (2, 6, 8, 10, 11, 13, 15, 17, 19, 21, 27, 30, 49, 55, 60, 70, 80, 90, 100, 120, 140, 160, 180, and 200 cycles) are also attached for reference in Appendix E3.

Table 1. Results of abrasive recycling testing.

Abrasive Shape[1]	No. of Recycles Required	Photomicrograph No.
Very Angular	None (initial condition)	1
Angular	6	4
Sub-Angular	11	6
Sub-Rounded	30	13
Rounded	200*	25
Well Rounded	Never achieved	N/A

[1] Based on Figure 1 from "Maintenance Tips," *Journal of Protective Coatings and Linings*, Vol 11, No. 3, March 1994, p 66, attached as Appendix A.

* Grain shape approached "rounded." Two-hundredth cycle completed before abrasive shape changed from sub-rounded to rounded.

Surface Profile Depth Data

The surface profile generated by each of the five abrasive grain shapes is summarized in Table 2. Appendix C contains the raw data.

Table 2. Surface profile data.[1]

Panel Numbers	Abrasive Shape	Surface Profile Range	Surface Profile Average
1, 2, 3	Very Angular	4.1 – 4.5 mils	4.3 mils
13, 14, 15	Angular	4.1 – 4.3 mils	4.2 mils
25, 26, 27	Sub-Angular	3.9 – 4.5 mils	4.2 mils
37, 38, 39	Sub-Rounded	4.2 – 4.7 mils	4.4 mils
49, 50, 51	Rounded	3.5 – 4.5 mils	4.1 mils

[1] Data generated using ASTM D 4417, Method C Testex Replica Tape.

Surface Profile Peak Density

The surface profile peak density generated by each of the five abrasive grain shapes is summarized in Table 3. The values in Table 3 represent the number of peaks per linear inch. Appendix D contains the raw data.

Table 3. Surface profile peak density data.[1]

Panel Numbers	Abrasive Shape	Peak Density Range	Peak Density Average
1, 2, 3	Very Angular	76 - 109	91
13, 14, 15	Angular	84 - 114	96
25, 26, 27	Sub-Angular	84 - 114	97
37, 38, 39	Sub-Rounded	76 - 97	89
49, 50, 51	Rounded	89 - 127	101

[1] Data generated using a Mitutoyo Model 310 Surftest "Peak Count" Mode.

Surface Profile Shape (Angularity)

Fifteen photomicrographs (25x magnification) illustrating the relative angularity of the surface profile for each of the five abrasive grain shapes produced by this study are attached as Appendix E2.

Tensile Adhesion Data – Metallized Surfaces

The results of the tensile adhesion testing for the metallized surfaces are summarized in Table 4. Adhesion values and corresponding abrasive grain shape are also plotted on Graph 1. Appendix G contains the raw data and Graph 1.

Table 4. Tensile adhesion data – metallized surfaces.[1]

Panel No.	Abrasive Shape	Adhesion Value (psi)		Primary Location of Adhesion Break
		Range	Average	
7	Very Angular	1,427 - 1,631	1,508	87% cohesion; 13% adhesion
8		1,345 – 1,467	1,426	60% cohesion; 40% adhesion
9		1,304 – 1,427	1,359	98% cohesion; 2% adhesion
19	Angular	1,325 - 1,386	1,366	100% cohesion
20		1,304 - 1,345	1,325	66% cohesion; 34% adhesion
21		1,345 - 1,427	1,386	83% cohesion; 17% adhesion
31	Sub-Angular	1,304 – 1,386	1,331	90% cohesion; 10% adhesion
32		1,467 – 1,508	1,481	70% cohesion; 30% adhesion
33		1,386 – 1,467	1,413	98% cohesion; 2% adhesion
43	Sub-Rounded	1,100 – 1,182	1,127	40% cohesion; 60% adhesion
44		1,182 – 1,345	1,263	47% cohesion; 53% adhesion
45		N/A	1,427	47% cohesion; 53% adhesion
55	Rounded	1,223 – 1,263	1,250	43% cohesion; 57% adhesion
56		1,182 – 1,223	1,209	43% cohesion; 57% adhesion
57		1,100 – 1,182	1,141	47% cohesion; 53% adhesion

[1] Data generated using a Pneumatic Adhesion Tensile Testing Instrument (PATTI) 3 tester equipped with an F4 piston.

Adhesion failures covered 50 percent or more of the pull stub surface for sub-rounded and rounded, suggesting that the surface profile shape at these levels does influence adhesion. For very angular, angular, and sub-angular, the primary break occurred cohesively within the metallizing.

Tensile Adhesion Data – Organic (Epoxy) Zinc-Rich Coated Surfaces

The results of the tensile adhesion testing for the organic (epoxy) zinc-rich coated surfaces are summarized in Table 5. Adhesion values and corresponding abrasive grain shape are also plotted on Graph 2. Appendix G contains the raw data and Graph 2.

Table 5. Tensile adhesion data – organic (epoxy) zinc-rich coated surfaces.[1]

Panel No.	Abrasive Shape	Adhesion Value (psi)		Primary Location of Adhesion Break
		Range	Average	
10	Very Angular	1,876 – 1,957	1,916	100% cohesion
11		1,876 – 1,957	1,916	100% cohesion
12		1916 – 1,957	1,943	100% cohesion
22	Angular	1,835 – 1,957	1,903	100% cohesion
23		1,876 – 1,957	1,916	100% cohesion
24		1,876 – 1,957	1,916	100% cohesion
34	Sub-Angular	1,876 – 1,957	1,930	100% cohesion
35		1,876 – 1,957	1,903	100% cohesion
36		1,774 – 1,876	1,828	100% cohesion
46	Sub-Rounded	1,916 – 1,957	1,943	100% cohesion
47		1,876 – 1,957	1,903	100% cohesion
48		1,916 – 1,957	1,937	100% cohesion
58	Rounded	1,896 – 1,998	1,937	100% cohesion
59		1,916 – 1,957	1,937	100% cohesion
60		1,835 – 1,978	1,910	100% cohesion

[1] Data generated using a PATTI 3 pneumatic adhesion tester equipped with an F4 piston.

4 Conclusions

Based upon the results of the testing described in this report, the following conclusions are drawn.

The number of recycles required to change the abrasive grain shape from very angular (new condition) to sub-angular (minor-to-moderate rounding) is relatively low (11). The required number of recycles nearly triples to 30 to generate sub-rounded particles. To remove all particle angularity (generate a "rounded" abrasive), more than 200 recycles are required.

Based on the data generated, it does not appear that surface profile depth decreases with abrasive recycling (up to 200 cycles). Surface profile depth measurements cannot be used in the field as an indicator that the shape of the abrasive or the shape of the surface profile is changing. Also, based on the peak count data generated by the Mitutoyo Surftest 301, the peak density (number of peaks per linear area) cannot be used as an indication of a change in the topography of the surface or a reduction in the surface area created by blast cleaning.

It is apparent that the adhesion of the metal spray coating is affected by the shape of the abrasive and the shape of the surface profile (even at similar profile depths). A reduction in the adhesion bond between the prepared surface and the metallized coating was apparent when the abrasive shape changed to sub-rounded and rounded. This same trend cannot be said for the organic (epoxy) zinc-rich primer, as the adhesion of the coating to the prepared surfaces was never compromised, independent of the abrasive shape and resulting surface topography.

5 Recommendations To Develop Industry Standards

Based upon the research conducted for this study, it is apparent that the existing methods for assessing surface profile depth cannot be used to indicate a change in surface topography. Further, there are no known visual standards for surface topography or abrasive shape that can be used by field personnel to monitor the quality of surface preparation prior to metallizing operations. Accordingly, there is a need to develop a set of visual or tactile standards that can be used by field personnel to monitor these attributes. Possible approaches to such standards include:

- The images generated by the SEM (25x magnification) could be mass-produced as a guide (similar to the SSPC Visual Standards) for use by field personnel when assessing the surface preparation prior to metallizing. The inspector would have to be equipped with a 25x field microscope (commercially available), so that a true comparison of the visual guide and the prepared surface could be made.
- Similarly, the photomicrographs of the abrasive media at the various stages (contained in this report) could also be published as a visual guide. (Similar to the SEM images, a field microscope would be required to magnify the abrasive.) Additionally, or alternatively, samples of abrasive media could be "potted" in a clear epoxy and used as a reference for abrasive shape.
- Another possibility involves the development of blast cleaned coupons (similar to the Keane-Tator Surface Profile Comparator), which, when compared to the surface under magnification, would show differences in surface profile shape.

Independent of the approach to be taken, the number of abrasive grain shapes and resulting surface topography should be limited to four references (i.e., very angular, sub-angular, sub-rounded, and rounded).

Although the Corps of Engineers could proceed to independently develop a standard based on one of the approaches above, it would be more desirable for an industry consensus group such as SSPC or NACE to develop the needed standard. An industry-developed standard would have greater acceptance by contractors within the painting industry.

References

ASTM A 36, *Specification for Carbon Structural Steel* (American Society for Testing and Materials [ASTM], Philadelphia, PA).

ASTM D 4285, *Test Method for Indicating Oil or Water in Compressed Air* (ASTM 1993).

ASTM D 4417, *Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel* (ASTM 1993).

ASTM D 4541, Appendix A4, *Self-Alignment Adhesion-Tester Type IV* (ASTM 1995).

ASTM D 4541, *Test Method for Pull-off Strength of Coatings Using Portable Adhesion-Testers* (ASTM 1995).

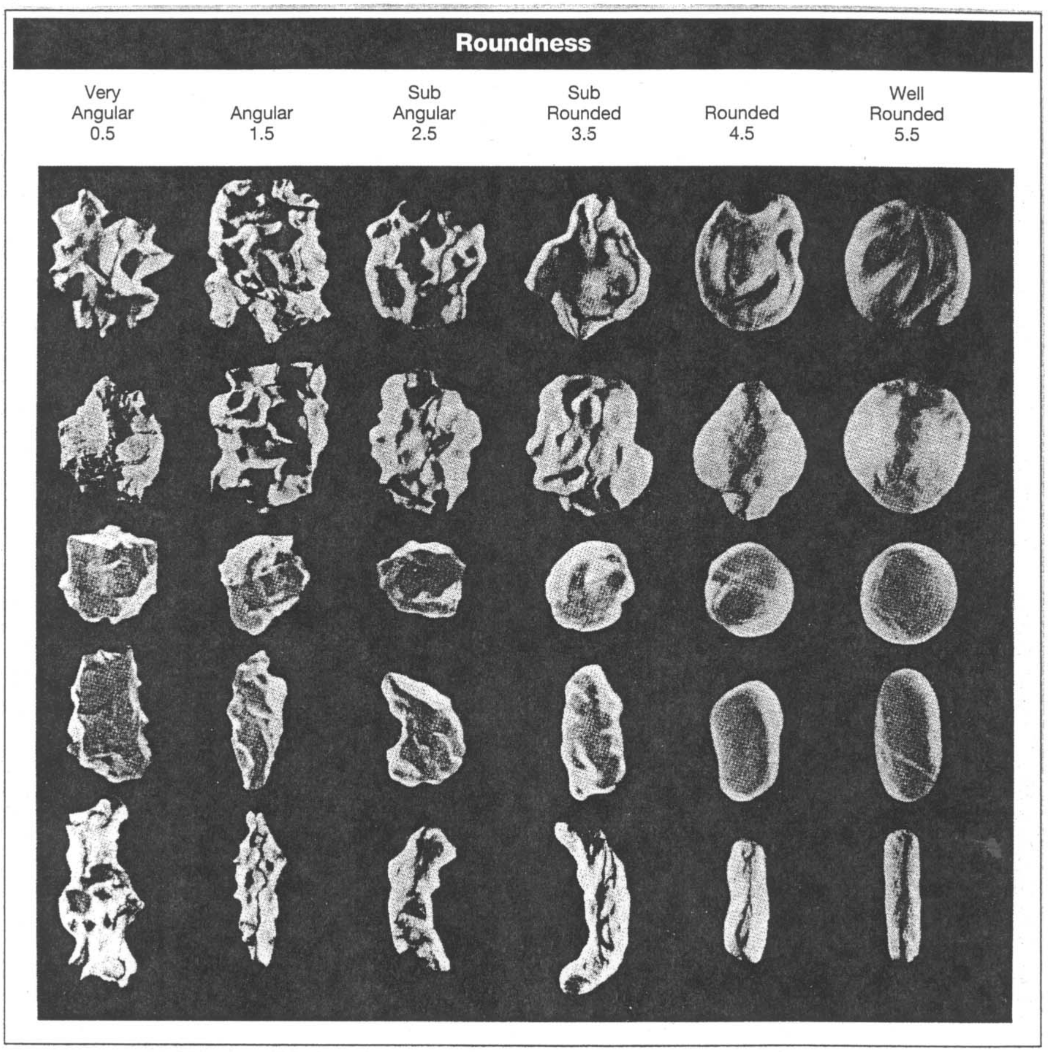
Corps of Engineers Guide Specification (CEGS) 09971, *Metallizing: Hydraulic Structures*, specification for system 6-Z-A (U.S. Army 1992).

Hansink, J.D., "Maintenance Tips," *Journal of Protective Coatings and Linings*, Vol 11, No. 3, March 1994.

SSPC-SP1, Solvent Cleaning (Society for Protective Coatings [SSPC] Surface Preparation Method No. 1 [SP1]).

SSPC-SP5/NACE 1 (National Association of Corrosion Engineers).

Appendix A: Abrasive Grit Shapes



Source: J.D. Hansink, Maintenance Tips, *Journal of Protective Coatings and Linings*, Vol 11, No. 3, March 1994, p 66, Figure 1.

Appendix B: Procedure Checklist

PROCEDURE FOR USACERL ABRASIVE STUDY
KTA PROJECT NO. 200298

Starting Abrasive Quantity – 1,000 pounds G50 Steel Grit abrasive

Procedure A

Step 1: Obtain 125 pounds of virgin abrasive material (grain shape 0.5)

Step 2: Sample virgin material (one US Gallon or approximately 35 pounds). Place desiccant packet inside gallon container and seal. Label container "Grain Shape 0.5"

Step 3: Microphotograph sample of virgin material. Record magnification

Step 4: Blast clean panels 1-12 with balance of abrasive (approximately 95 pounds) using No. 7 nozzle, 95-100 psi, 18" distance.

Step 5: Individually VPI wrap and plastic seal panels 1-12 and preserve in oven.

Procedure B

Step 1: Energize the Schmidt pot with 875 pounds of virgin steel grit. Use No. 7 blast nozzle, 95-100 psi, 18" distance (Note: pre-establish metering valve setting).

Step 2: Impact 875 pounds until grain shape 1.5 is achieved. Examine sample after 2, 4, 6, 8 and 10 cycles, then increments of 5 cycles thereafter. Record the number of cycles required to achieve grain shape 1.5.

Step 3: Remove 125 pounds from impacted material representing grain shape 1.5.

Step 4: Sample grain shape 1.5 material (one US Gallon or approximately 35 pounds). Place desiccant packet inside gallon container and seal. Label container "Grain Shape 1.5"

Step 5: Microphotograph sample of 1.5 material. Record magnification

Step 6: Blast clean panels 13-24 with balance of abrasive (approximately 95 pounds) using No. 7 nozzle, 95-100 psi, 18" distance. ***Alternatively, the 95 pounds can be containerized, labeled and used to blast clean panels 13-24 at a later date.***

Step 7: Individually VPI wrap and plastic seal panels 13-24 and preserve in oven.

Step 8: Air wash remaining 750 pounds

Procedure C

Step 1: Energize the Schmidt pot with 750 pounds of Grain Shape 1.5 steel grit. Use No. 7 blast nozzle, 95-100 psi, 18" distance.

Step 2: Impact 750 pounds until grain shape 2.5 is achieved. Examine sample after 2, 4, 6, 8 and 10 cycles, then increments of 5 cycles thereafter. Record the number of cycles required to achieve grain shape 2.5.

Step 3: Remove 125 pounds from impacted material representing grain shape 2.5.

Step 4: Sample grain shape 2.5 material (one US Gallon or approximately 35 pounds). Place desiccant packet inside gallon container and seal. Label container "Grain Shape 2.5"

Step 5: Microphotograph sample of 2.5 material. Record magnification

Step 6: Blast clean panels 25-36 with balance of abrasive (approximately 95 pounds) using No. 7 nozzle, 95-100 psi, 18" distance. ***Alternatively, the 95 pounds can be containerized, labeled and used to blast clean panels 25-36 at a later date.***

Step 7: Individually VPI wrap and plastic seal panels 25-36 and preserve in oven.

Step 8: Air wash remaining 625 pounds

Procedure D

Step 1: Energize the Schmidt pot with 625 pounds of Grain Shape 2.5 steel grit. Use No. 7 blast nozzle, 95-100 psi, 18" distance.

Step 2: Impact 625 pounds until grain shape 3.5 is achieved. Examine sample after 2, 4, 6, 8 and 10 cycles, then increments of 5 cycles thereafter. Record the number of cycles required to achieve grain shape 3.5.

Step 3: Remove 125 pounds from impacted material representing grain shape 3.5.

Step 4: Sample grain shape 3.5 material (one US Gallon or approximately 35 pounds). Place desiccant packet inside gallon container and seal. Label container "Grain Shape 3.5"

Step 5: Microphotograph sample of 3.5 material. Record magnification

Step 6: Blast clean panels 37-48 with balance of abrasive (approximately 95 pounds) using No. 7 nozzle, 95-100 psi, 18" distance. ***Alternatively, the 95 pounds can be containerized, labeled and used to blast clean panels 37-48 at a later date.***

Step 7: Individually VPI wrap and plastic seal panels 37-48 and preserve in oven.

Step 8: Air wash remaining 500 pounds

Procedure E

Step 1: Energize the Schmidt pot with 500 pounds of Grain Shape 3.5 steel grit. Use No. 7 blast nozzle, 95-100 psi, 18" distance.

Step 2: Impact 500 pounds until grain shape 4.5 is achieved. Examine sample after 2, 4, 6, 8 and 10 cycles, then increments of 5 cycles thereafter. Record the number of cycles required to achieve grain shape 4.5.

Step 3: Remove 125 pounds from impacted material representing grain shape 4.5.

Step 4: Sample grain shape 4.5 material (one US Gallon or approximately 35 pounds). Place desiccant packet inside gallon container and seal. Label container "Grain Shape 4.5"

Step 5: Microphotograph sample of 4.5 material. Record magnification

Step 6: Blast clean panels 49-60 with balance of abrasive (approximately 95 pounds) using No. 7 nozzle, 95-100 psi, 18" distance. ***Alternatively, the 95 pounds can be containerized, labeled and used to blast clean panels 49-60 at a later date.***

Step 7: Individually VPI wrap and plastic seal panels 49-60 and preserve in oven.

Step 8: Air wash remaining 375 pounds

Procedure F

Step 1: Energize the Schmidt pot with 375 pounds of Grain Shape 4.5 steel grit. Use No. 7 blast nozzle, 95-100 psi, 18" distance.

Step 2: Impact 375 pounds until grain shape 5.5 is achieved. Examine sample after 2, 4, 6, 8 and 10 cycles, then increments of 5 cycles thereafter. Record the number of cycles required to achieve grain shape 5.5.

Step 3: Remove 125 pounds from impacted material representing grain shape 5.5.

Step 4: Sample grain shape 5.5 material (one US Gallon or approximately 35 pounds). Place desiccant packet inside gallon container and seal. Label container "Grain Shape 5.5"

Step 5: Microphotograph sample of 5.5 material. Record magnification

Step 6: Blast clean panels 61-72 with balance of abrasive (approximately 95 pounds) using No. 7 nozzle, 95-100 psi, 18" distance. ***Alternatively, the 95 pounds can be containerized, labeled and used to blast clean panels 61-72 at a later date.***

Step 7: Individually VPI wrap and plastic seal panels 61-72 and preserve in oven.

Assuming NO losses, approximately 250 pounds should remain. This allows for a loss of 50 pounds during each Procedure (A-F, above).

Grain Shape Reference:

0.5: Very Angular (virgin material)
1.5: Angular
2.5: Sub Angular
3.5: Sub Rounded
4.5: Rounded
5.5: Well Rounded

PROCEDURAL CHECKLIST
USACERL ABRASIVE STUDY; KTA PROJECT 200298

Step Description	Step Complete (√)	Initials
Procedure A		
Initial weight ___________ pounds		
Number of cycles to create grain shape (0.5) N/A		
Grain shape achieved	N/A	
Bulk sample collected and preserved		
Microphotograph obtained		
Twelve panels prepared		
Twelve panels preserved		

Step Description	Step Complete (√)	Initials
Procedure B		
Initial weight ___________ pounds		
Number of cycles to create grain shape (1.5) ____		
Grain shape achieved		
Bulk sample collected and preserved		
Microphotograph obtained		
Twelve panels prepared		
Twelve panels preserved		
Air wash complete		

Step Description	Step Complete (√)	Initials
Procedure C		
Initial weight ___________ pounds		
Number of cycles to create grain shape (2.5) ____		
Grain shape achieved		
Bulk sample collected and preserved		
Microphotograph obtained		
Twelve panels prepared		
Twelve panels preserved		
Air wash complete		

Step Description	Step Complete (√)	Initials
Procedure D		
Initial weight ___________ pounds		
Number of cycles to create grain shape (3.5) ____		
Grain shape achieved		
Bulk sample collected and preserved		
Microphotograph obtained		
Twelve panels prepared		
Twelve panels preserved		
Air wash complete		

Step Description	Step Complete (√)	Initials
Procedure E		
Initial weight ___________ pounds		
Number of cycles to create grain shape (4.5) ____		
Grain shape achieved		
Bulk sample collected and preserved		
Microphotograph obtained		
Twelve panels prepared		
Twelve panels preserved		
Air wash complete		

Step Description	Step Complete (√)	Initials
Procedure F		
Initial weight ___________ pounds		
Number of cycles to create grain shape (5.5) ____		
Grain shape achieved		
Bulk sample collected and preserved		
Microphotograph obtained		
Twelve panels prepared		
Twelve panels preserved		

Air Cleanliness (daily check)

Date	Initials	Date	Initials	Date	Initials	Date	Initials	Date	Initials

Nozzle Pressure (95-100 psi) weekly check

Date	Initials	Date	Initials	Date	Initials	Date	Initials	Date	Initials

Nozzle Orifice (7/16”) weekly check

Date	Initials	Date	Initials	Date	Initials	Date	Initials	Date	Initials

Appendix C: Surface Profile Depth, Raw Data

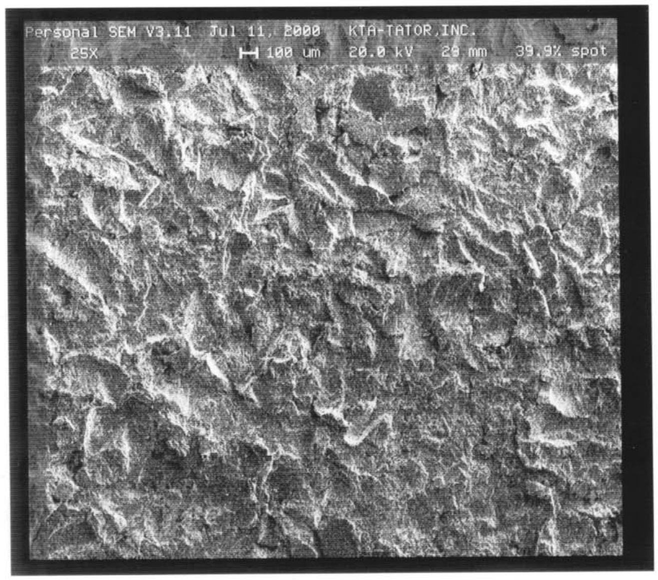
Panel No.	Abrasive Grain Shape	Surface Profile (mils)		
1	Very Angular	4.3	4.1	4.5
2		4.5	4.2	4.2
3		4.2	4.2	4.5
13	Angular	4.1	4.2	4.3
14		4.3	4.2	4.2
15		4.2	4.1	4.3
25	Sub-Angular	4.3	3.9	4.5
26		4.3	3.9	4.3
27		3.9	4.1	4.5
37	Sub-Rounded	4.3	4.3	4.7
38		4.3	4.3	4.4
39		4.3	4.2	4.4
49	Rounded	4.2	3.9	4.3
50		3.5	3.9	4.5
51		4.0	4.0	4.4

Appendix D: Surface Profile Peak Density, Raw Data

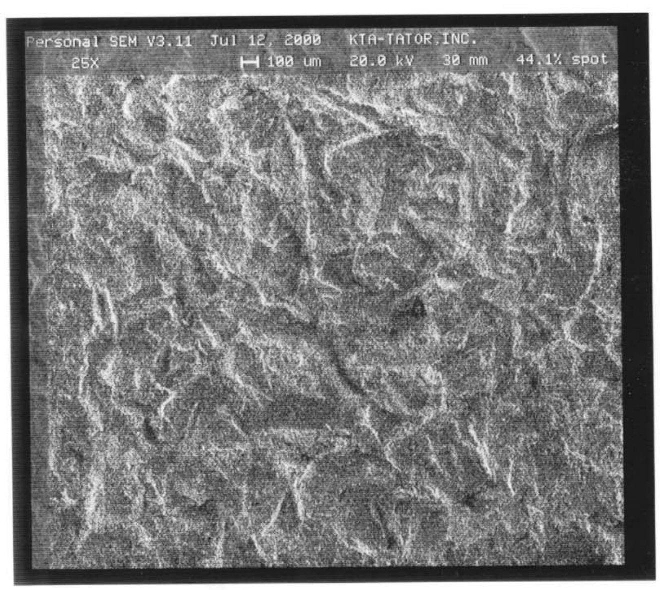
Panel No.	Abrasive Grain Shape	Peak Count (No. of peaks per linear inch)					
1	Very Angular	84	89	84	89	84	97
2		76	102	97	84	89	84
3		84	109	89	97	97	102
13	Angular	89	102	89	102	102	89
14		97	89	97	89	114	114
15		89	89	97	84	109	89
25	Sub-Angular	114	84	97	109	109	84
26		97	84	109	84	102	109
27		97	89	97	97	102	84
37	Sub-Rounded	97	97	97	97	97	89
38		89	89	76	76	97	97
39		84	76	84	97	84	84
49	Rounded	89	97	102	109	102	89
50		97	102	122	97	127	89
51		102	89	97	109	114	89

Appendix E: Photographs

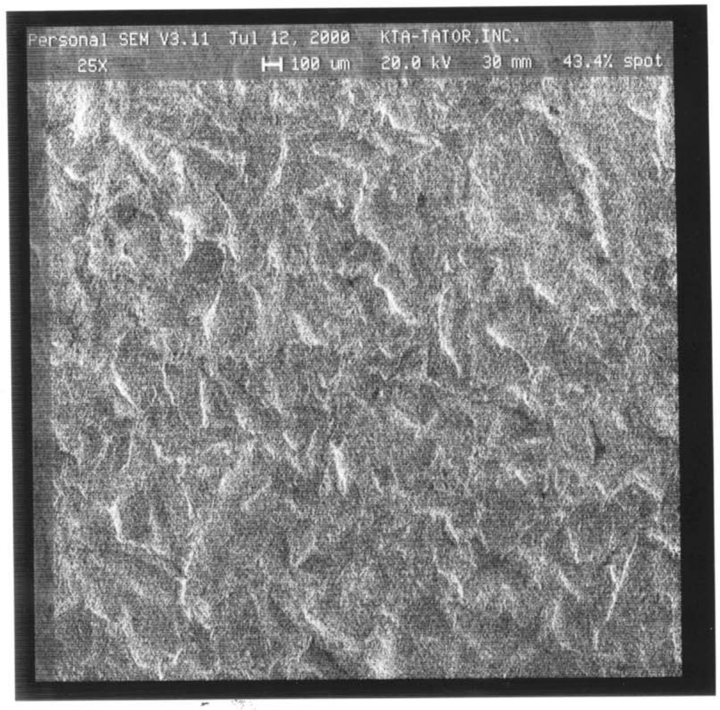
E1: Abrasive Blast Cleaned Surface Topography



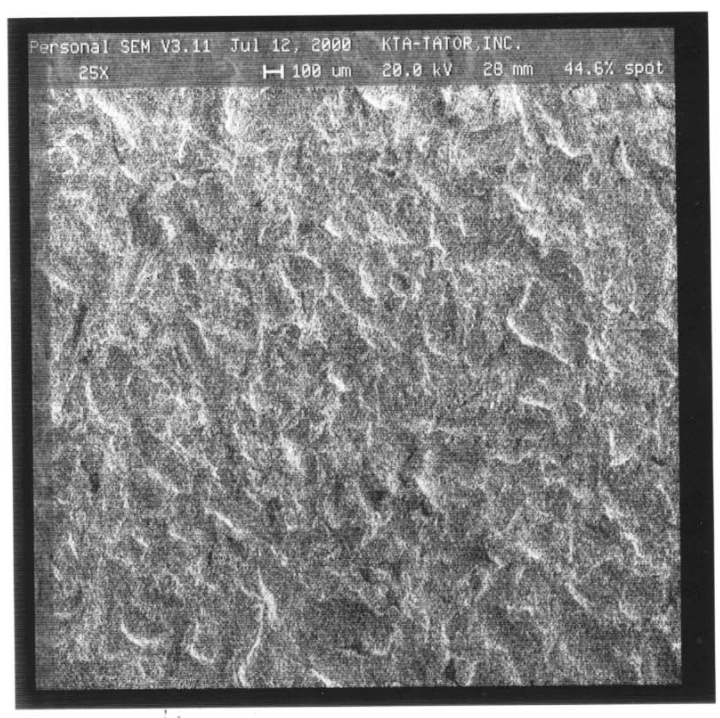
Photomicrograph 26 (25x)
Specimen No. 1
"Very Angular" Abrasive



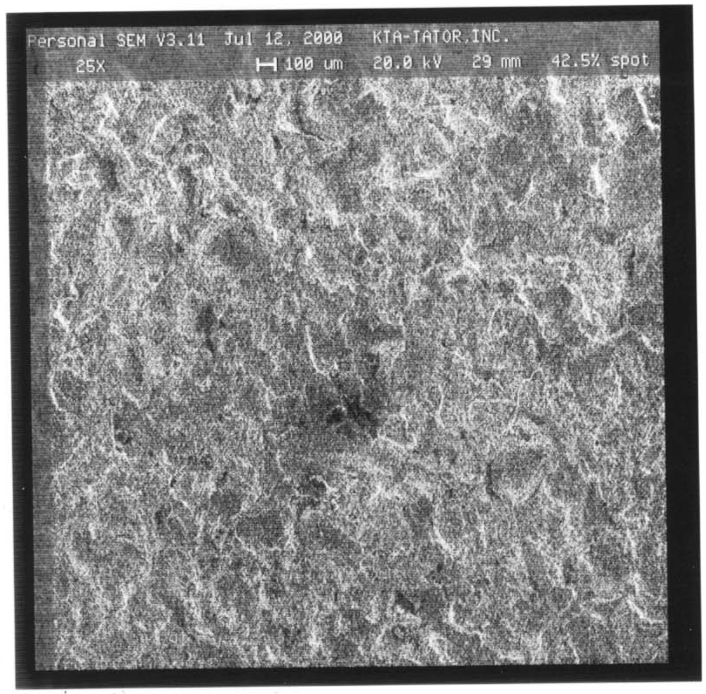
Photomicrograph 27 (25x)
Specimen No. 2
"Very Angular" Abrasive



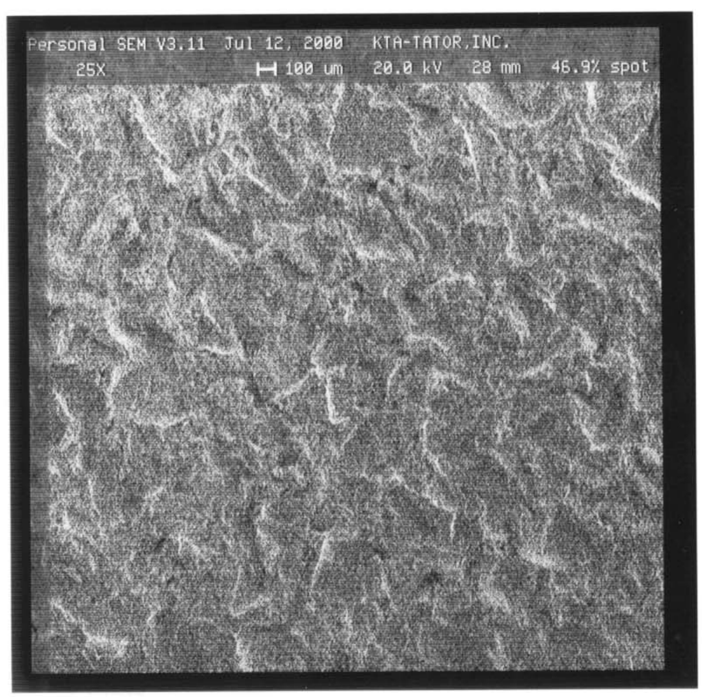
Photomicrograph 28 (25x)
Specimen No. 3
"Very Angular" Abrasive



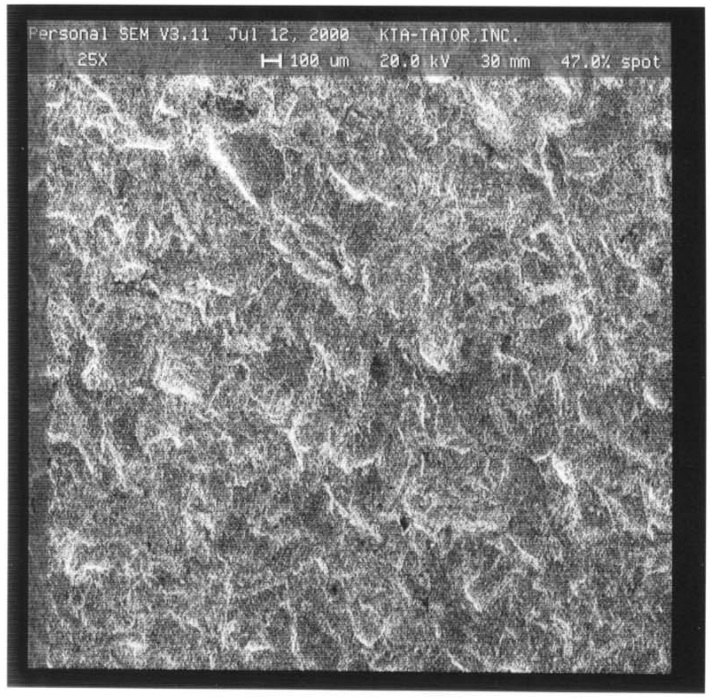
Photomicrograph 29 (25x)
Specimen No. 13
"Angular" Abrasive



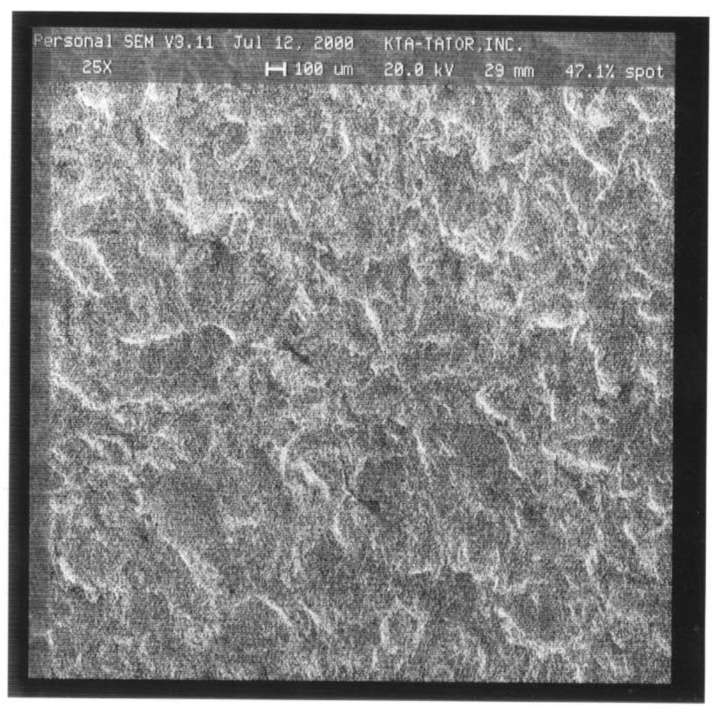
Photomicrograph 30 (25x)
Specimen No. 14
"Angular" Abrasive



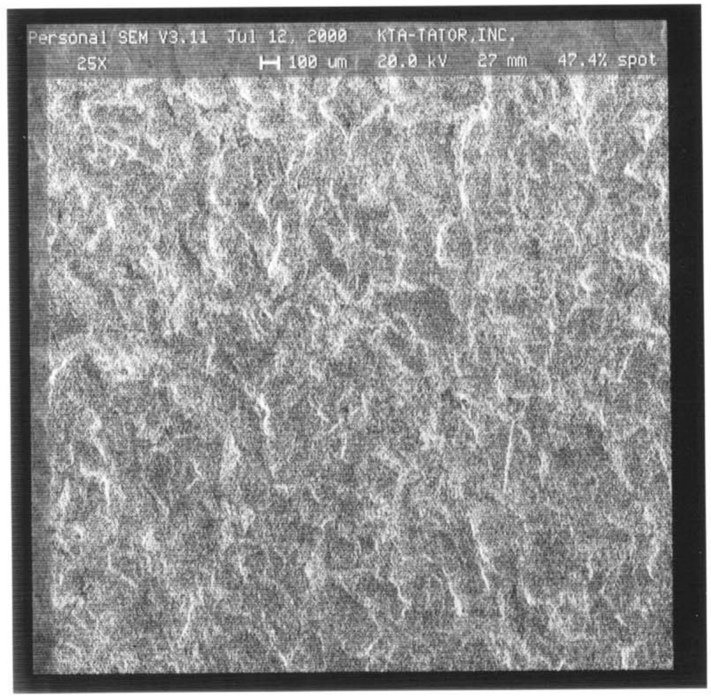
Photomicrograph 31 (25x)
Specimen No. 15
"Angular" Abrasive



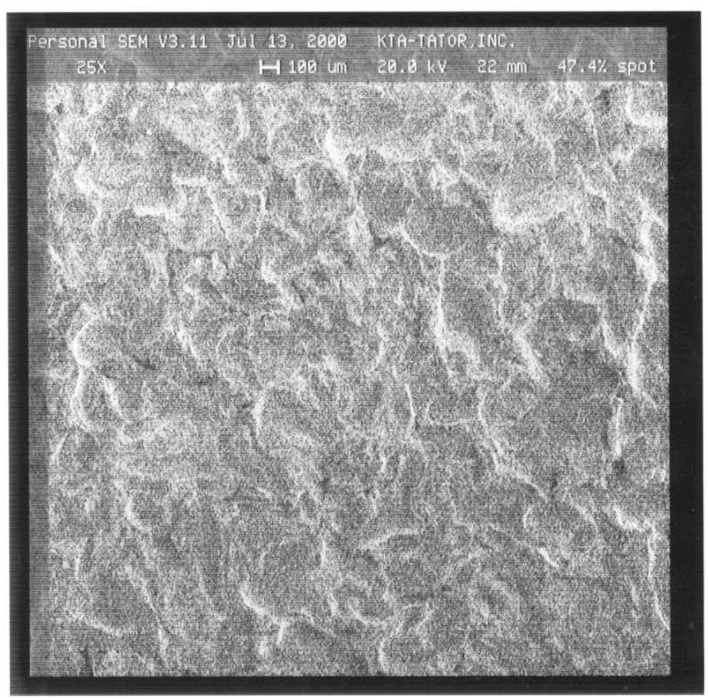
Photomicrograph 32 (25x)
Specimen No. 25
"Sub-Angular" Abrasive



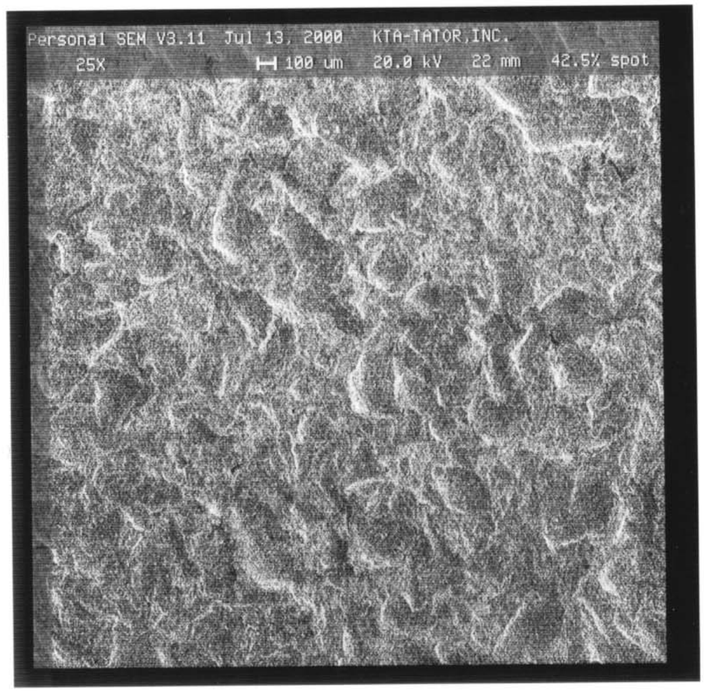
Photomicrograph 33 (25x)
Specimen No. 26
"Sub-Angular" Abrasive



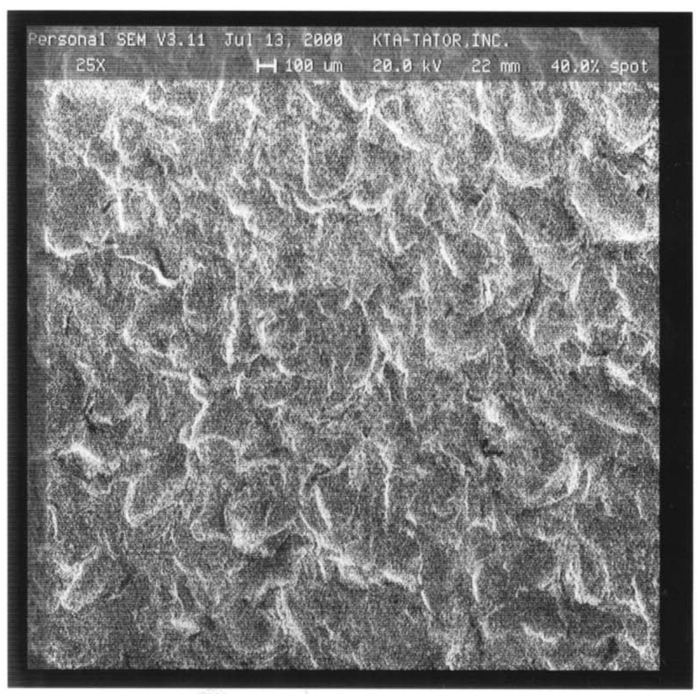
Photomicrograph 34 (25x)
Specimen No. 27
"Sub-Angular" Abrasive



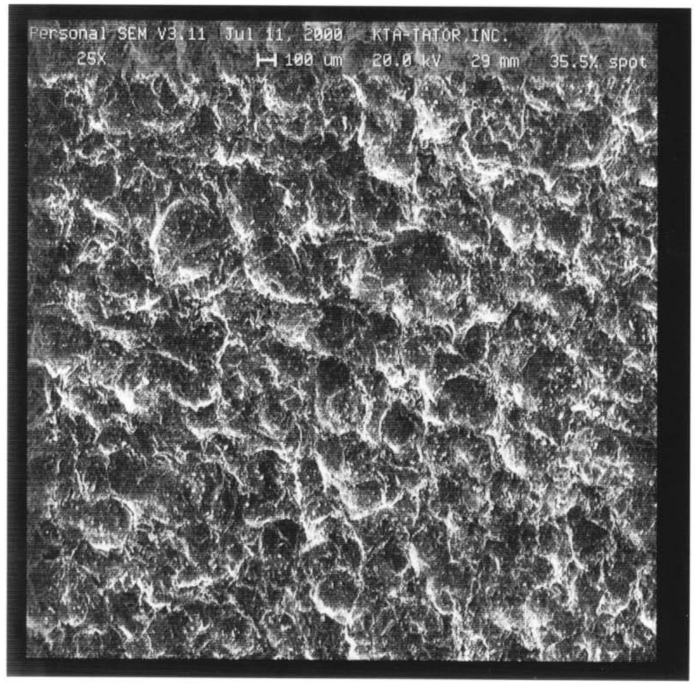
Photomicrograph 35 (25x)
Specimen No. 37
"Sub-Rounded" Abrasive



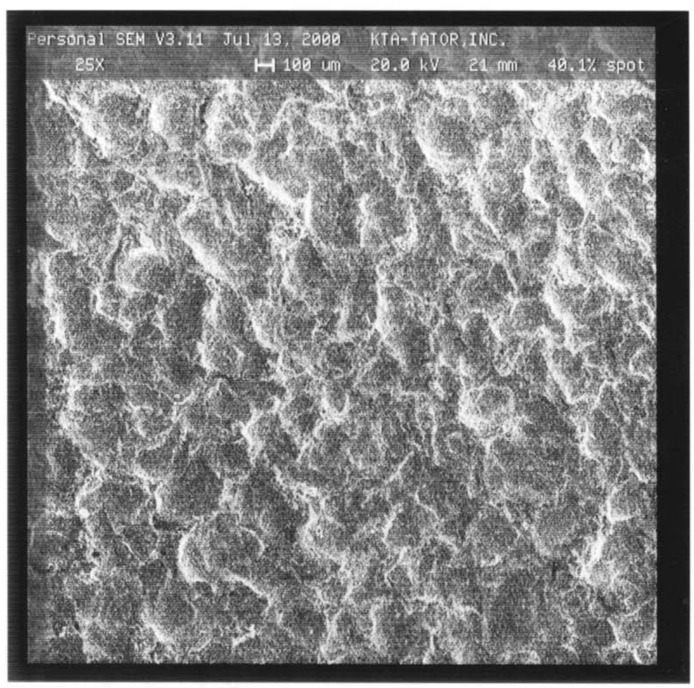
Photomicrograph 36 (25x)
Specimen No. 38
“Sub-Rounded” Abrasive



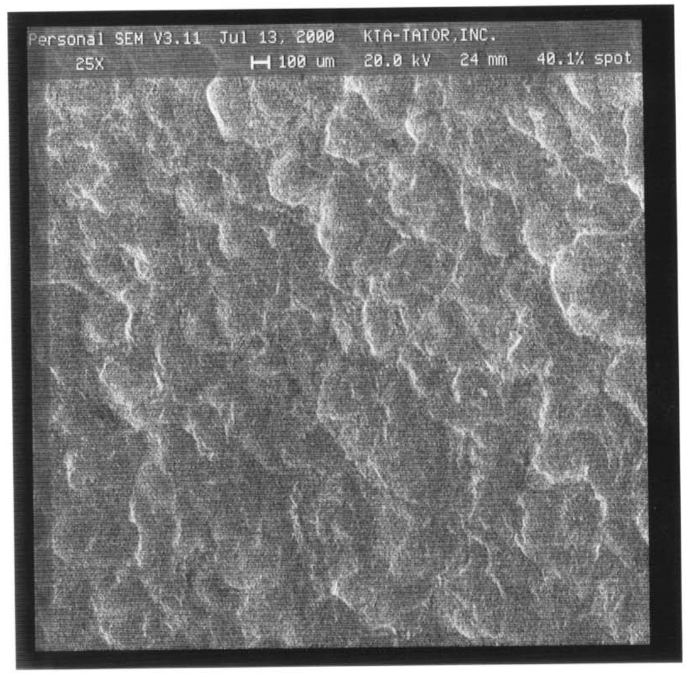
Photomicrograph 37 (25x)
Specimen No. 39
“Sub-Rounded” Abrasive



Photomicrograph 38 (25x)
Specimen No. 49
"Rounded" Abrasive



Photomicrograph 39 (25x)
Specimen No. 50
"Rounded" Abrasive

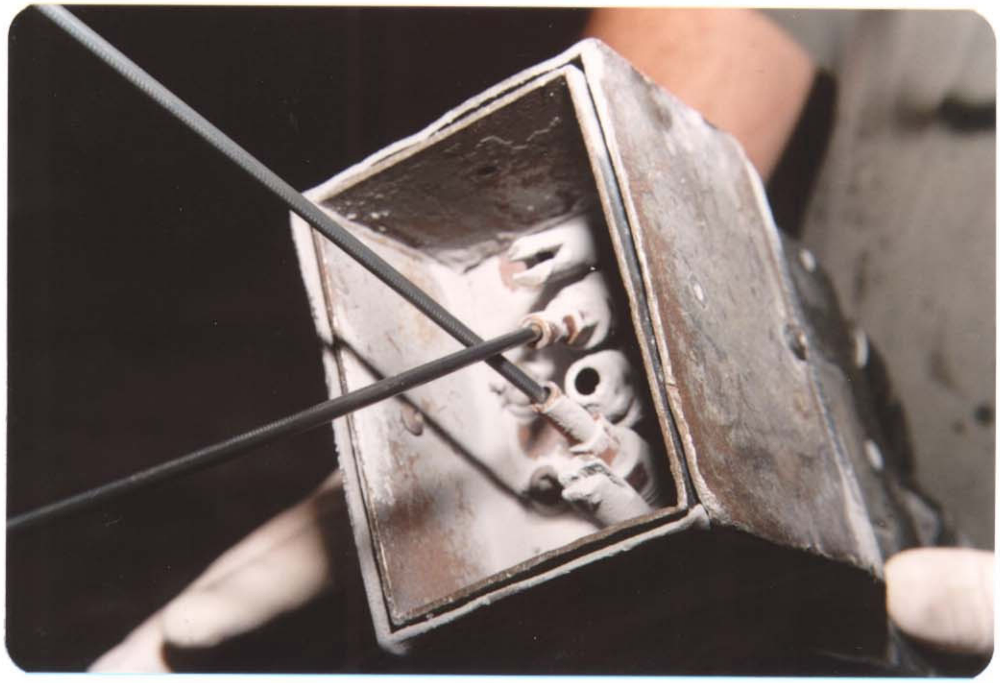


Photomicrograph 40 (25x)
Specimen No. 51
"Rounded" Abrasive

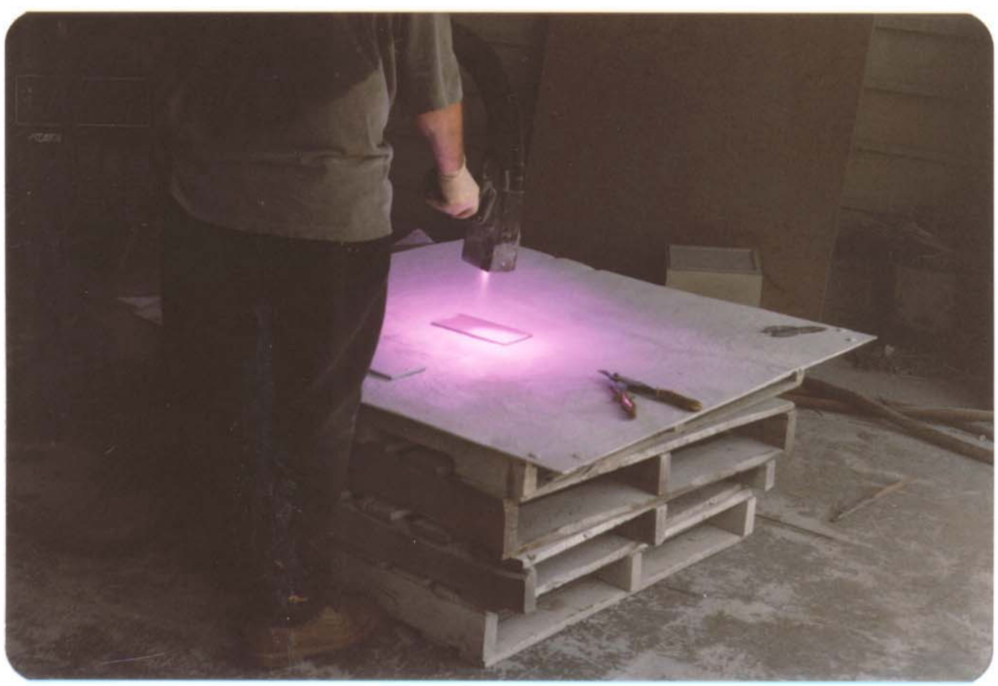
E2: Metallizing Application

Photograph 1
Removal of Protective Coverings Prior to Metallizing

Photograph 2
Representative Condition of Test Panels Prior to Metallizing

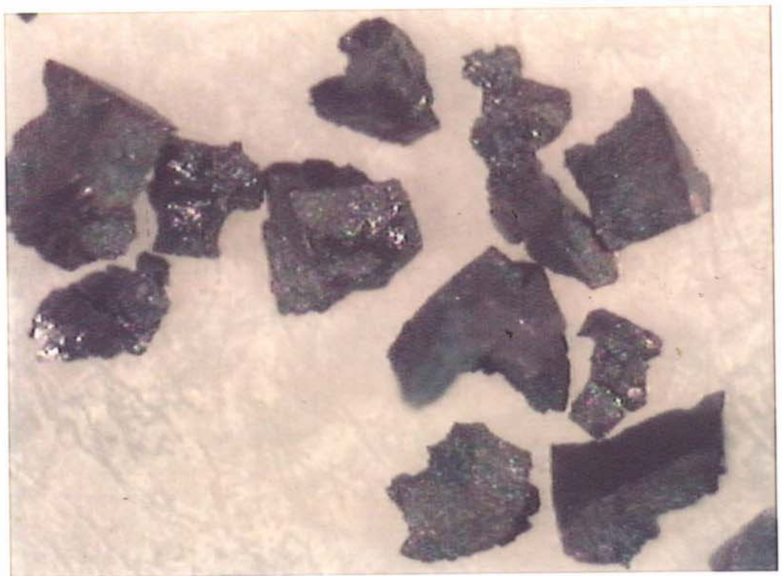


Photograph 3
Zinc/Aluminum Wire Exit Ports on Electric Arc Metallizing Gun



Photograph 4
Application of Metallizing to Representative Test Panel

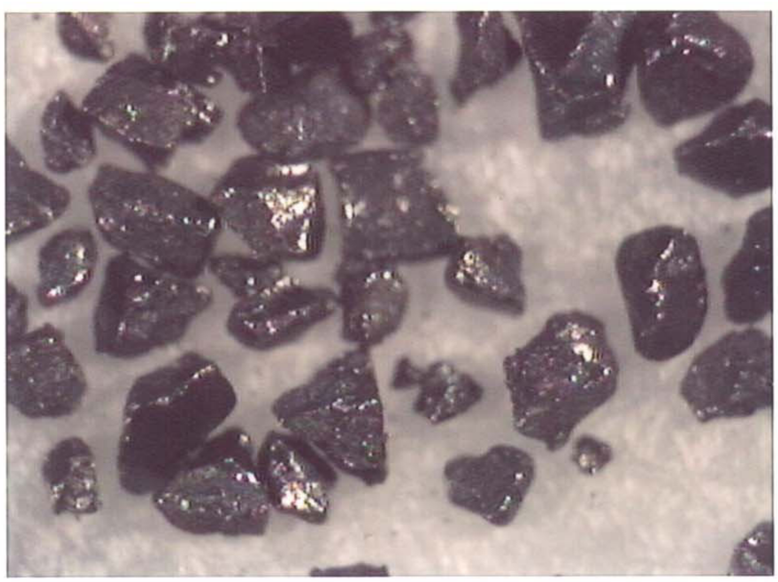
E3: Abrasive Grain Shapes



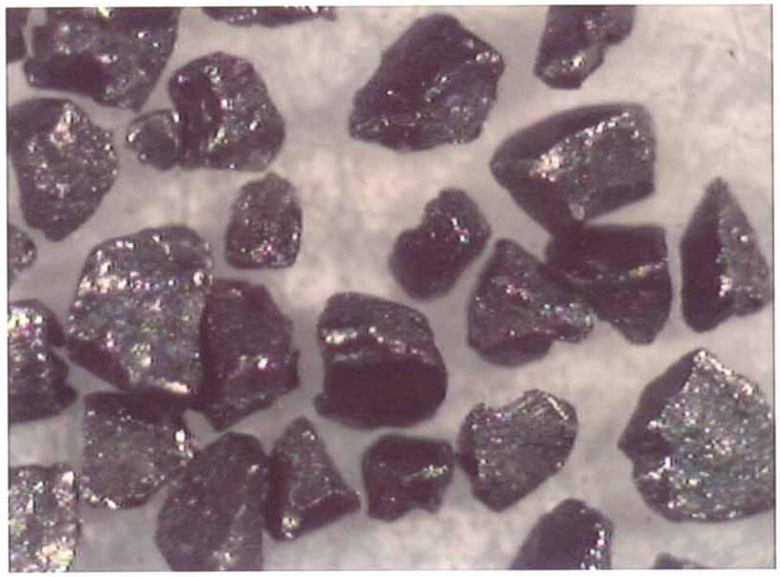
Photomicrograph 1 (25X)
No. of Recycles: None (initial condition)
Abrasive Grain Shape: Very Angular

Photomicrograph 2 (25X)
No. of Recycles: 1

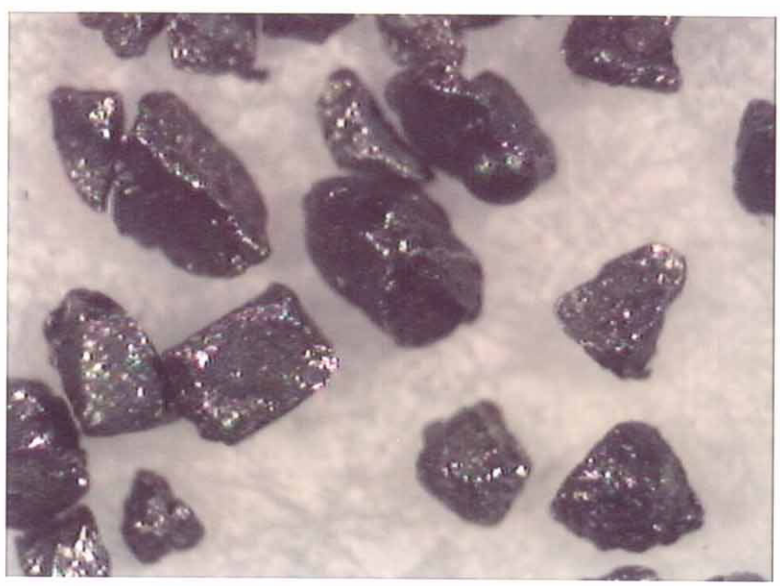
Photomicrograph 3 (25X)
No. of Recycles: 2



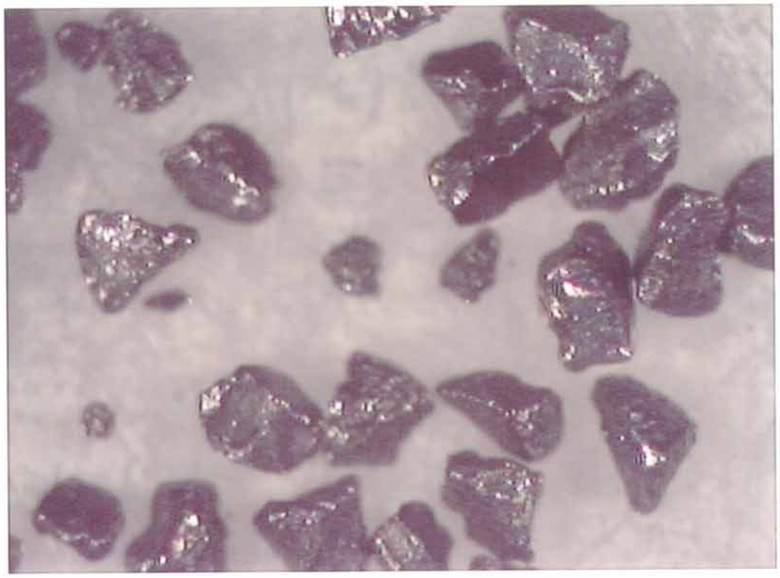
Photomicrograph 4 (25X)
No. of Recycles: 6
Abrasive Grain Shape: Angular



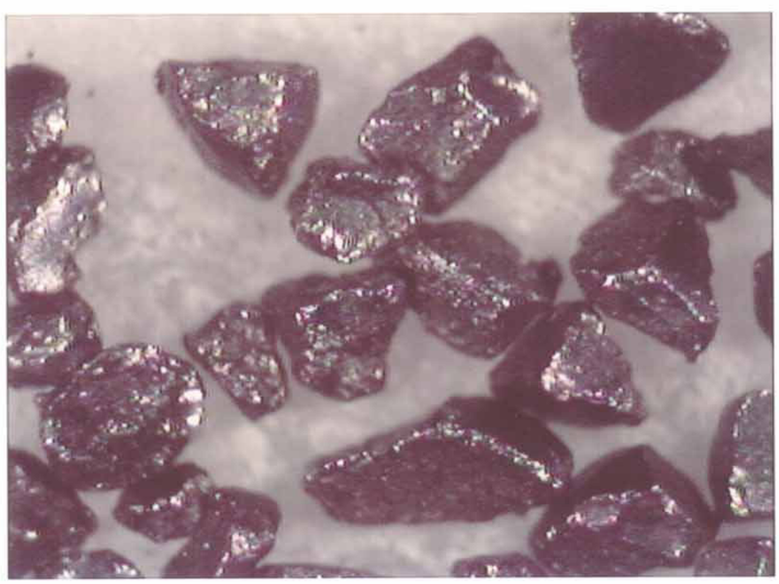
Photomicrograph 5 (25X)
No. of Recycles: 8



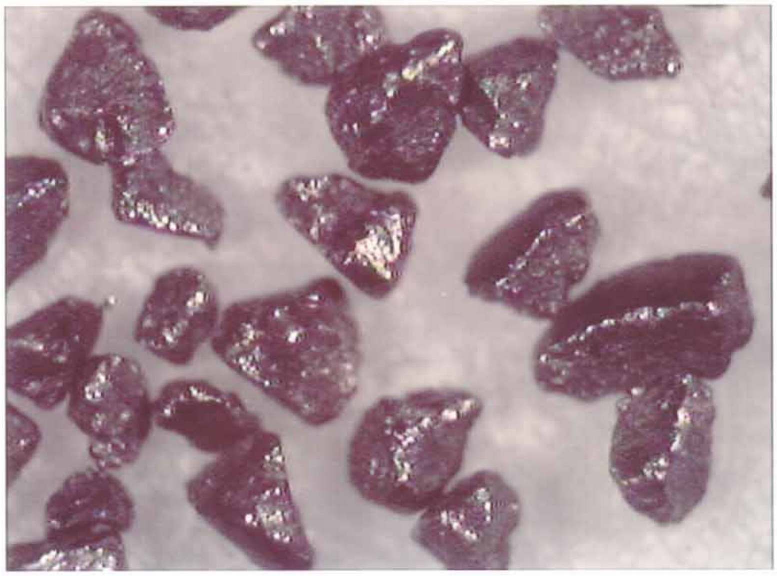
Photomicrograph 6 (25X)
No. of Recycles: 11
Abrasive Grain Shape: Sub-Angular



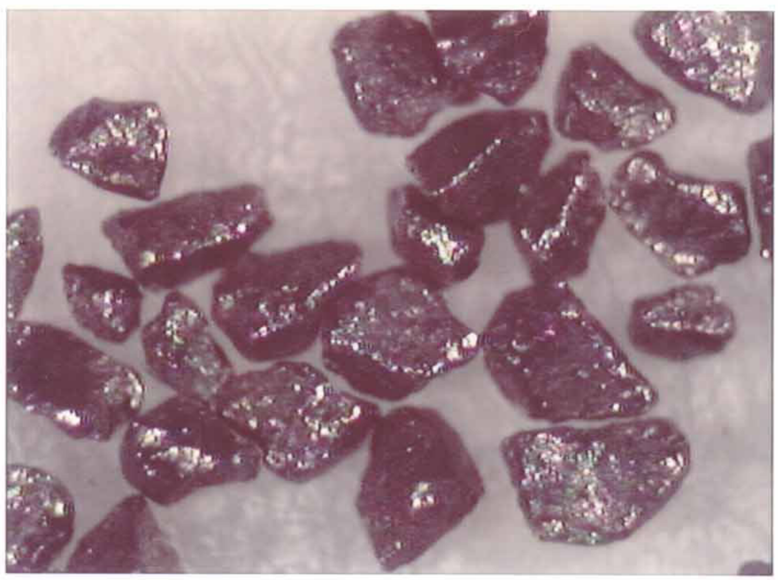
Photomicrograph 7 (25X)
No. of Recycles: 13



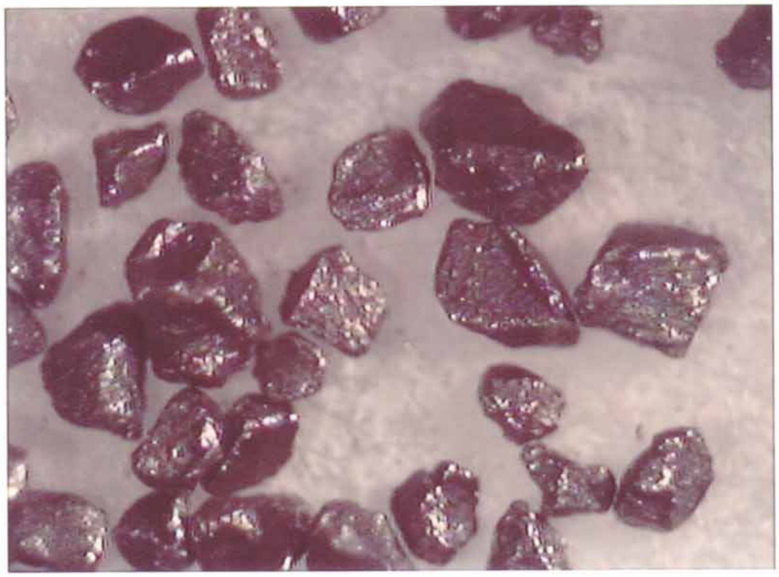
Photomicrograph 8 (25X)
No. of Recycles: 15



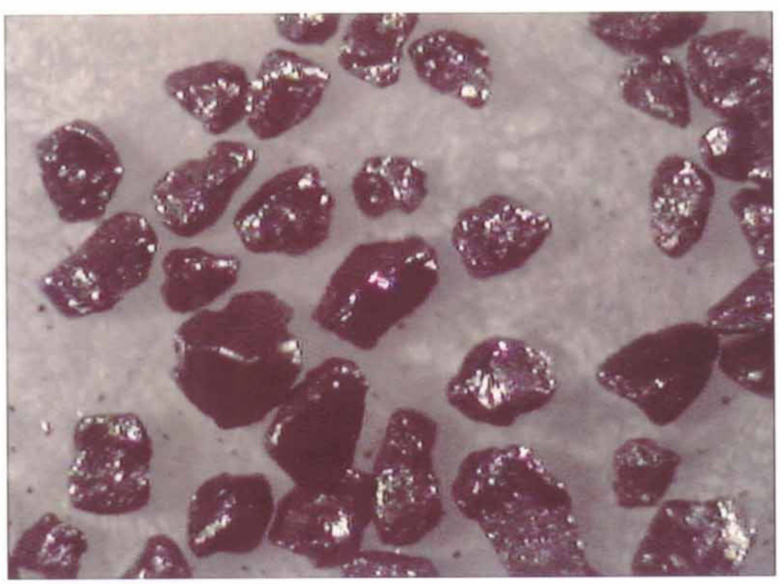
Photomicrograph 9 (25X)
No. of Recycles: 17



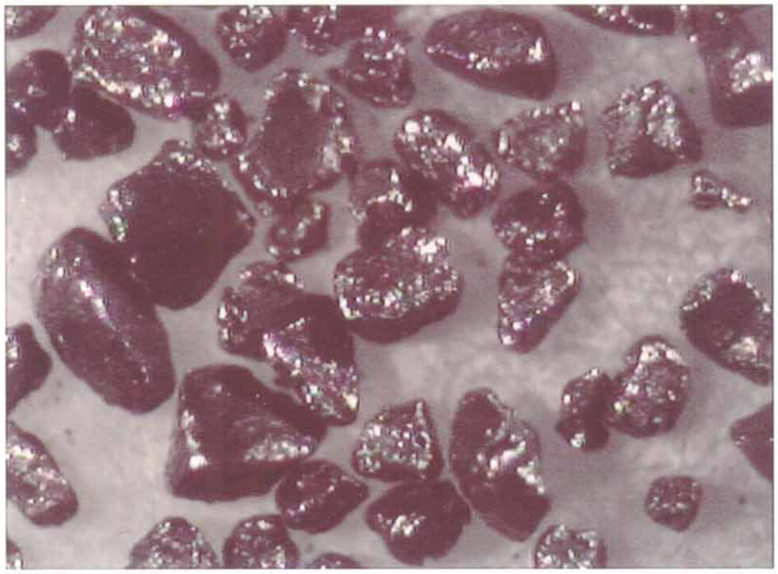
Photomicrograph 10 (25X)
No. of Recycles: 19



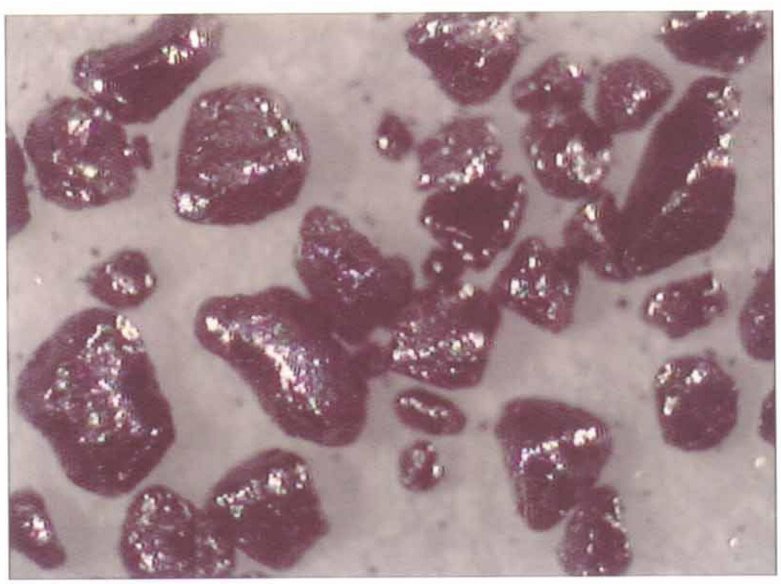
Photomicrograph 11 (25X)
No. of Recycles: 21



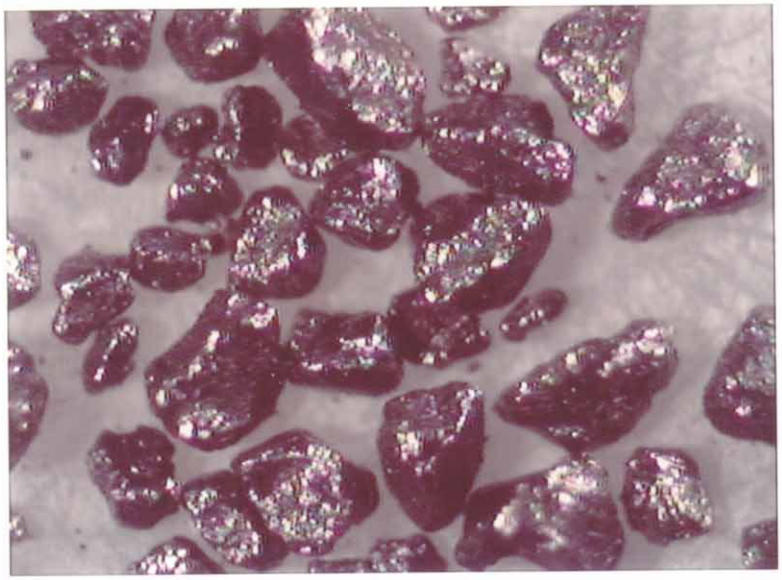
Photomicrograph 12 (25X)
No. of Recycles: 27



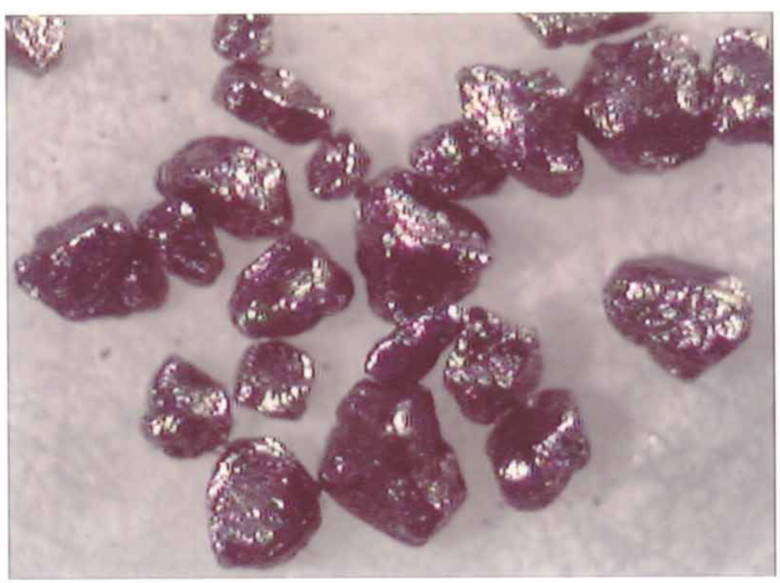
Photomicrograph 13 (25X)
No. of Recycles: 30
Abrasive Grain Shape: Sub-Rounded



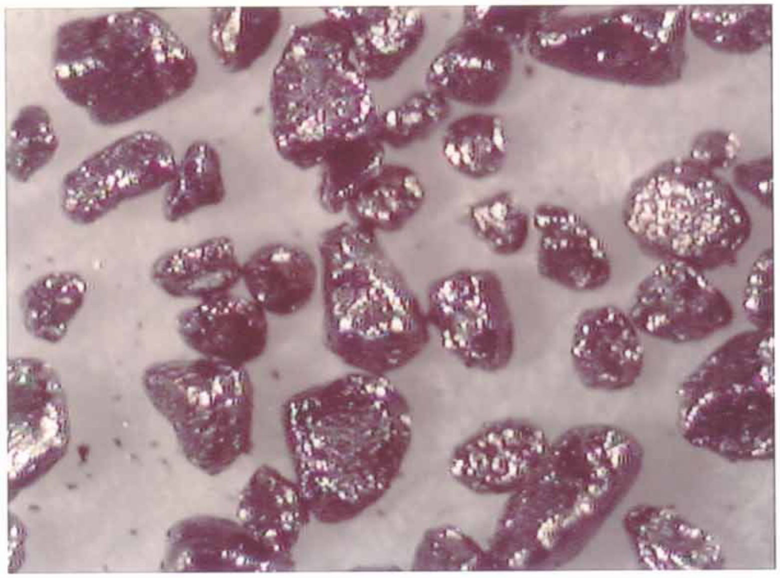
Photomicrograph 14 (25X)
No. of Recycles: 49



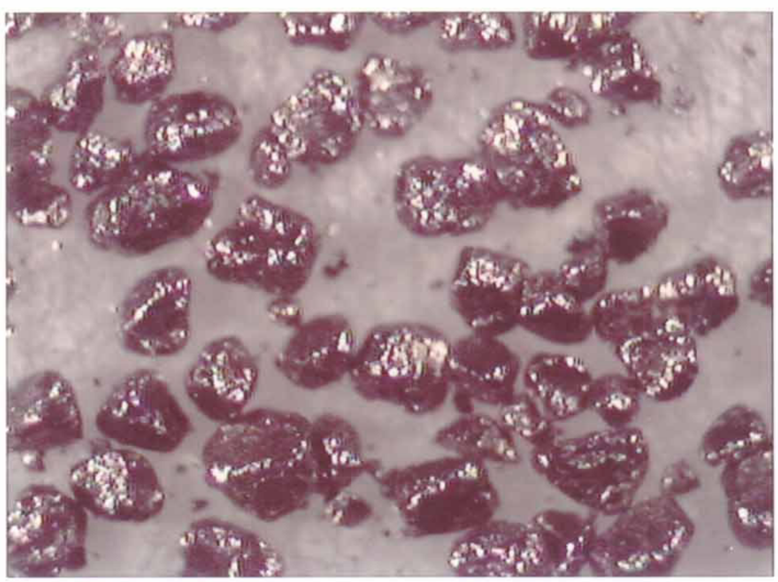
Photomicrograph 15 (25X)
No. of Recycles: 55



Photomicrograph 16 (25X)
No. of Recycles: 60



Photomicrograph 17 (25X)
No. of Recycles: 70



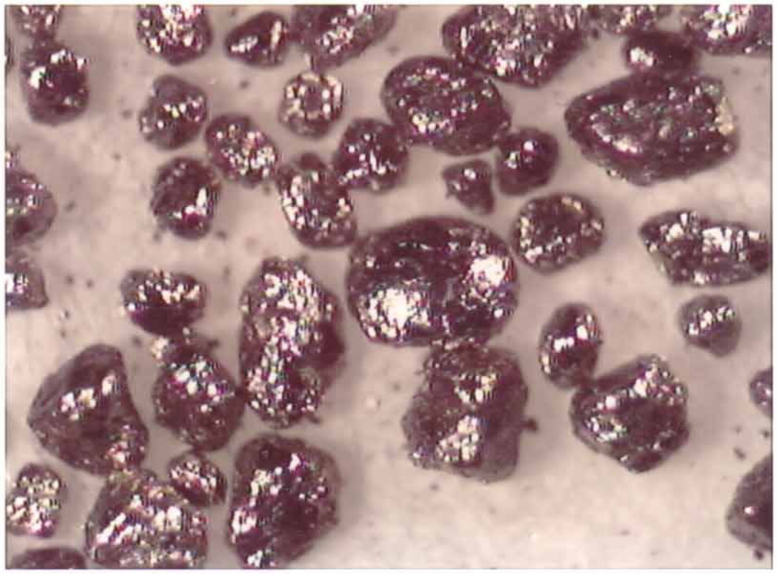
Photomicrograph 18 (25X)
No. of Recycles: 80

Photomicrograph 19 (25X)
No. of Recycles: 90

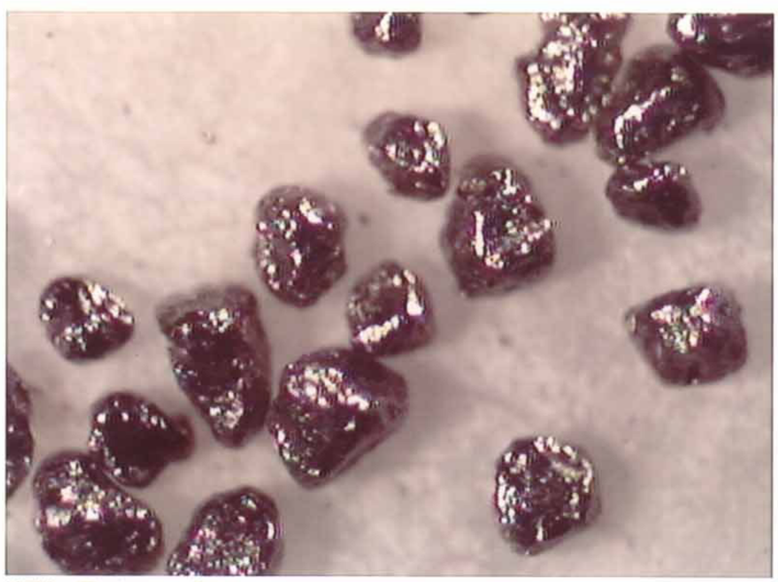
Photomicrograph 20 (25X)
No. of Recycles: 100

Photomicrograph 21 (25X)
No. of Recycles: 120

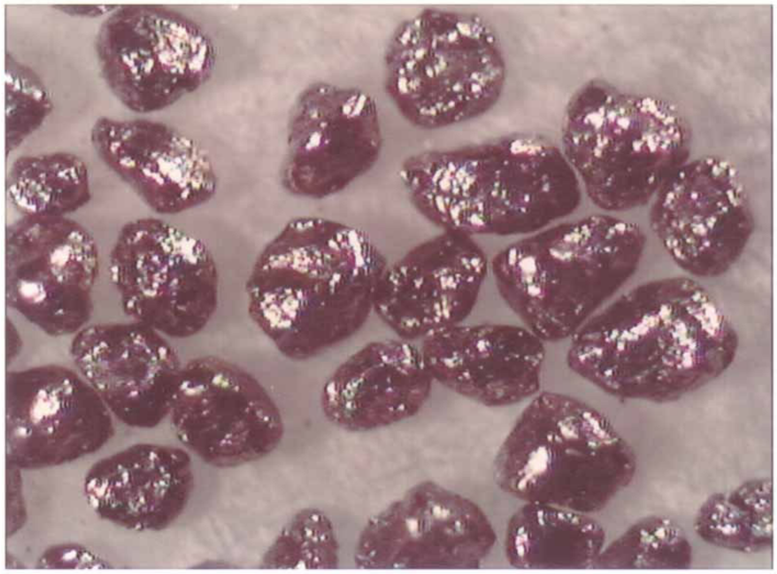
Photomicrograph 22 (25X)
No. of Recycles: 140



Photomicrograph 23 (25X)
No. of Recycles: 160



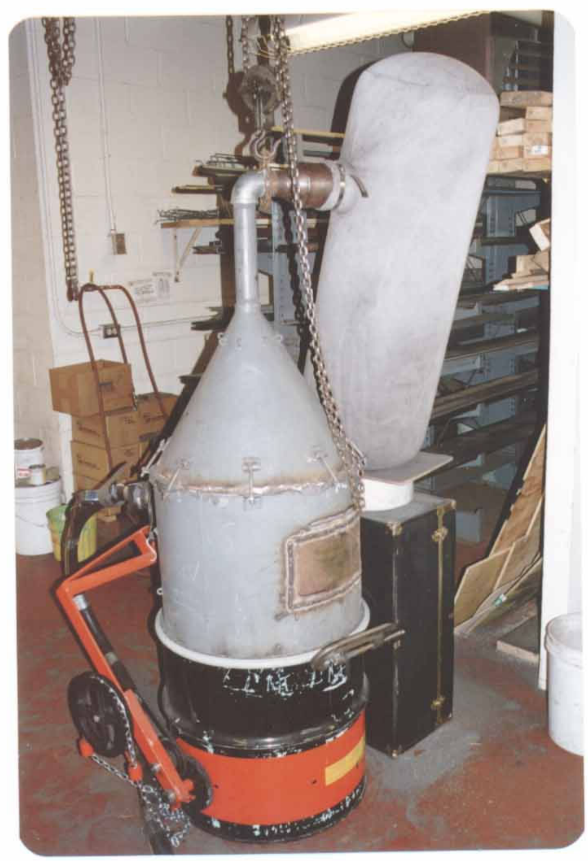
Photomicrograph 24 (25X)
No. of Recycles: 180



Photomicrograph 25 (25X)
No. of Recycles: 200
Abrasive Grain Shape: "Approaching" Rounded

E4: Abrasive Impaction and Recycling Equipment

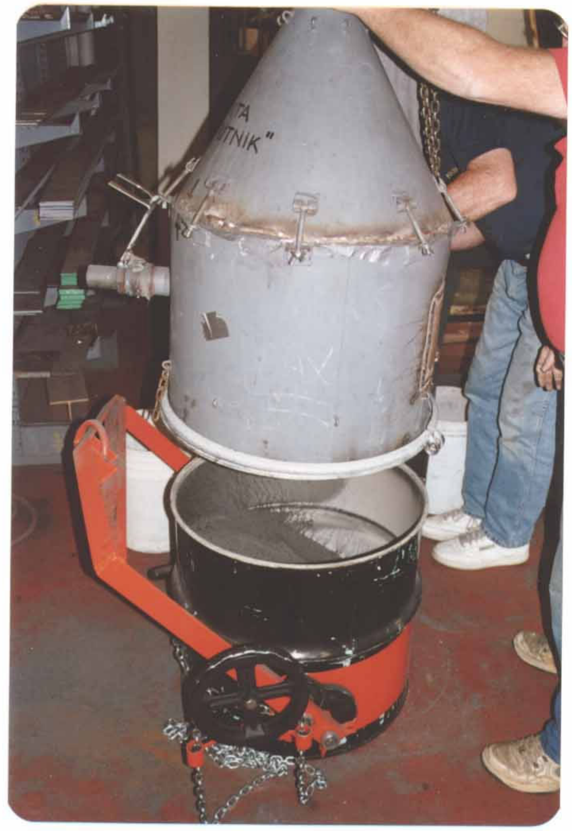
Photograph 1
Atlas Copco 375 CFM Air Compressor
used to Maintain 95 psi Blast Nozzle Pressure



Photograph 2
Abrasive Breakdown (impaction)
Chamber with collection drum &
Dust Collection Bag

Photograph 3
Schmidt Abrasive Hopper equipped with an Adjustable Metering Valve

Photograph 4
Interior of Abrasive Breakdown (impaction) Chamber with Impaction Plate Mounted



Photograph 5
Raising of Breakdown Chamber to
Access Abrasive Collection Drum

Photograph 6
Emptying of Dust Collection Bag

Photograph 7
Emptying of Abrasive Collection
Drum Into Abrasive Blast Pot

Photograph 8
Emptying of Abrasive Collection
Drum Into Abrasive Blast Pot

Photograph 9
Technician Monitoring Equipment
During Abrasive Impaction Cycle

Appendix F: Customized Forms

Metallizing Application Data

Documented Item	Enter Information in this Column
Applicator Name and Company	*Eric Numrich, Omega Coatings, Inc.*
Application Date	*July 3, 2000*
Time Application Began	*1245*
Time Application Completed	*1430*
Wire Manufacturer	*TAFA Technologies*
Wire Type	*85%/15% Zinc/Aluminum (TAFA 02A)*
Wire Diameter	*1/8 inch*
Wire Batch No.	*E46419*
Verify Wire Cleanliness	*Satisfactory (wire sample obtained)*
Electric Arc Equipment Manufacturer	*TAFA Technologies*
Electric Arc Equipment Model No.	*8860*
Amperage Setting	*275 – 300*
Distance: Gun-to-Panel	*Approximately 8 inches*
Compressed Air Cleanliness Check	*Satisfactory*
Ambient Conditions (1235)	DB: 91°F WB: 76°F RH: 49% DP: 70°F ST: 91°F
Number of Passes to Achieve 14-16 mils DFT (use multiple passes) ***(Note: change direction of spray pattern when applying multiple passes, e.g., at right angles)***	*Most panels required 3 passes. Some required 4 passes (19, 20 and 21)*
Comments	
Air pressure approximately 110 psi.	

Coating Thickness Data (numbered side)

Panel No.	Location A			Location B			Location C			Panel
Gage Reading ►	**A1**	**A2**	**A3**	**B1**	**B2**	**B3**	**C1**	**C2**	**C3**	**Average**
7	13.9	15.2	14.3	13.9	14.9	16.4	12.3	15.1	12.8	14.3
8	22.0	20.9	15.9	17.2	12.5	12.0	13.0	18.7	16.1	16.5
9	25.5	17.3	15.4	12.9	16.3	11.9	12.5	16.9	12.2	15.8
19	15.1	15.3	17.0	13.8	16.5	15.7	13.5	15.9	13.9	15.3
20	20.5	18.2	18.9	14.4	14.6	18.0	10.4	9.9	12.9	15.3
21	16.1	17.3	17.6	10.8	12.7	14.8	9.6	10.2	13.1	13.5
31	10.6	9.4	12.6	22.0	18.3	16.1	19.8	21.0	20.8	16.7
32	14.3	11.7	14.0	16.9	18.5	18.7	15.9	17.3	18.3	16.2
33	9.8	9.4	12.1	13.8	14.2	17.8	17.2	22.8	20.0	15.2
43	23.1	29.2	28.9	22.0	16.0	19.9	12.7	12.9	15.8	20.0
44	11.1	12.3	11.2	13.1	14.5	13.6	14.8	17.3	14.7	13.6
45	12.0	13.9	12.7	14.8	17.8	16.8	-	19.5	17.6	15.3
55	25.5	23.6	22.1	14.9	18.2	14.5	16.1	21.9	22.7	19.9
56	16.9	15.8	15.7	15.3	16.8	14.1	8.5	10.4	12.7	14.0
57	19.3	19.1	16.3	15.7	18.1	20.3	10.3	11.2	13.1	15.9

Coating Thickness Data (non-numbered side)

Panel No.	Location A			Location B			Location C			Panel
Gage Reading ►	A1	A2	A3	B1	B2	B3	C1	C2	C3	Average
7	18.9	19.5	22.4	17.1	21.1	18.4	18.4	21.4	21.3	19.8
8	18.0	21.7	19.8	17.4	17.2	15.7	11.4	11.5	12.8	16.2
9	14.3	11.3	13.9	15.9	14.8	17.3	12.4	12.3	14.5	14.1
19	13.4	16.1	16.7	16.4	17.1	21.2	15.2	16.2	15.4	16.4
20	16.9	14.0	15.4	12.9	19.0	18.0	11.7	11.9	14.0	14.9
21	14.7	13.6	14.8	14.0	15.2	16.3	12.3	15.6	16.6	14.8
31	23.7	24.4	23.4	20.2	19.8	17.3	11.7	13.4	14.9	18.8
32	14.9	11.2	9.0	15.4	16.3	14.5	13.6	18.2	16.0	14.3
33	16.9	15.5	13.4	16.4	17.3	15.9	19.6	21.7	21.1	17.5
43	18.4	18.5	18.6	19.5	20.8	18.7	14.8	17.0	21.6	18.7
44	16.0	11.8	12.4	17.6	20.5	19.8	14.8	15.6	17.6	15.8
45	9.7	12.3	13.2	19.1	18.7	17.4	12.0	12.1	11.3	14.0
55	15.0	12.6	15.4	17.6	19.7	18.1	16.4	16.8	18.5	16.7
56	11.4	13.7	15.1	17.8	17.1	16.9	9.5	9.4	12.2	13.7
57	14.8	18.6	16.7	17.1	15.8	18.7	13.0	12.0	17.3	16.0

Panel Numbers	
10,11,12	
22,23,24	
34,35,36	
46,47,48	
58,59,60	
Surface Preparation	
Surface Cleanliness (verify)	SSPC-SP5/NACE 1
Surface Profile Depth (mils)	See surface profile data
Type/Size Abrasive	G50
Magnetic Base Reading	1.0 mil
Mixing/Thinning	
Coating Manufacturer	Commercially available coating
Product No.	Organic (epoxy) zinc
Batch No.	(A) 03E67111E
Batch No.	(B) 11D66557E
Batch No.	(C) 02E MP1-020200 (zinc dust)
Potlife and Mat'l. Temperature	24 hours 72oF
Thinner/Amount	None added
Time of Mix	1025
Mix Ratio	Complete kit
Induction Time	30 minutes
Application	
Ambient Conditions	DB 72F WB 63F RH 61% DP 58F ST 72F Time 1045
Applicator's Name	Stanford Galloway
Time Application Began	1115
Recoat Time (actual)	N/A
Intercoat Cleanliness (visual)	N/A
Pot Agitation	Yes
Application Equipment/Conditions	
Conventional Spray Gun	Binks Model 61 and Binks Model 2001
Tip/Needle	66/E
Air Cap	67PB
Pot Pressure	15 psi
Atomization Pressure	50 psi
White Blotter Air Test	Passed
Traverse Speed (GPM)	280
Wet Film Thickness	8 - 10 mils
Dry Film Thickness	See Attached DFT Record
Time Application Complete	1130
Comments:	Signature On file
	Date June 20, 2000
	Report No. 1

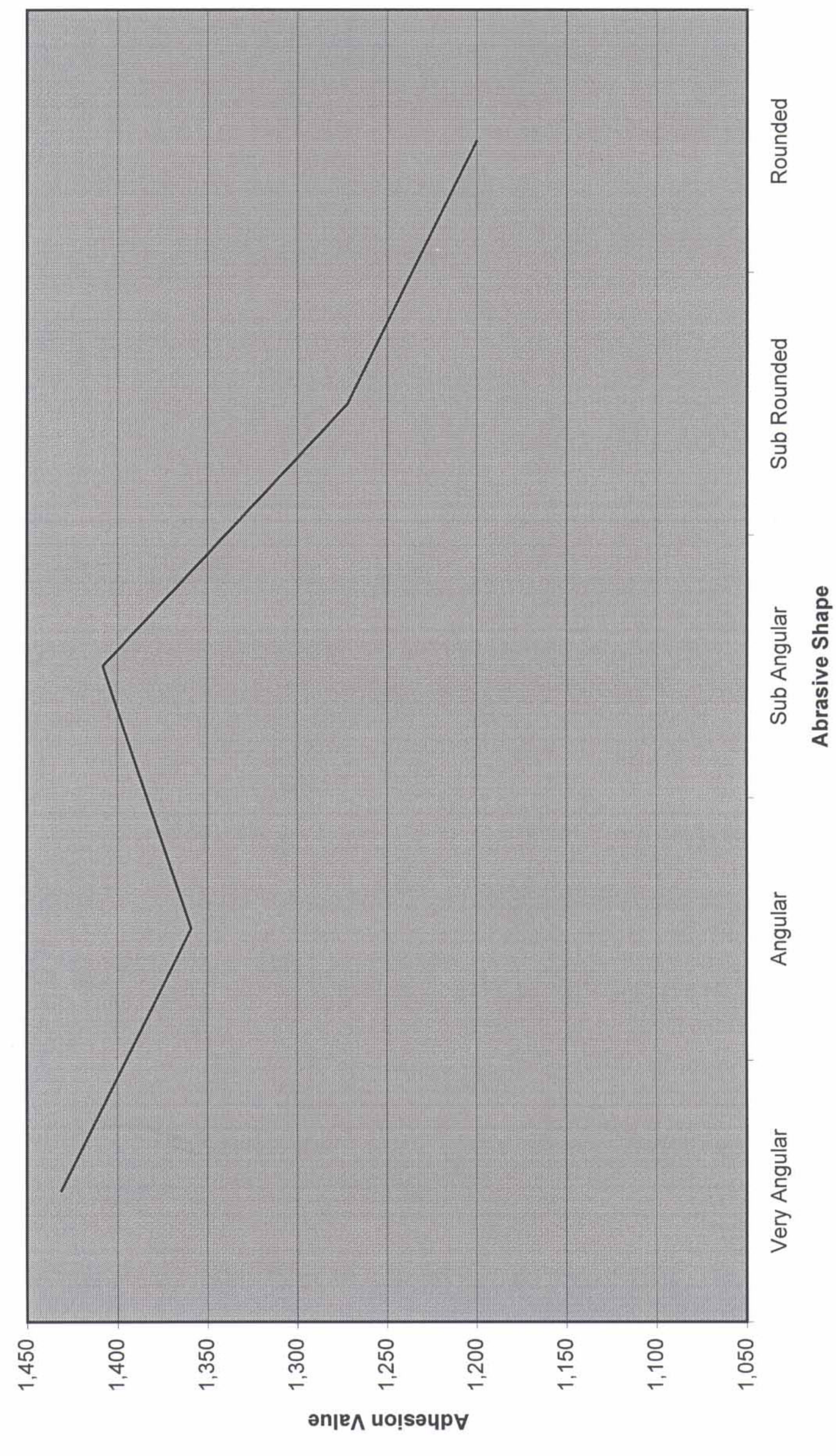
Coating Thickness Data (mils)							
Specimen No.	**Front (1)**	**Front (2)**	**Front (3)**	**Back (1)**	**Back (2)**	**Back (3)**	**Ave.**
10	4.5	4.3	4.4	5.0	5.8	5.3	**4.9**
11	4.4	4.3	3.7	5.3	7.2	5.8	**5.1**
12	4.6	3.8	3.5	5.5	7.4	5.0	**5.0**
22	4.1	3.8	3.1	4.2	4.0	3.2	**3.7**
23	4.2	3.8	3.1	4.1	4.4	3.0	**3.8**
24	3.9	4.2	3.0	4.2	4.4	3.4	**3.9**
34	4.5	3.8	2.9	4.6	4.3	3	**3.9**
35	3.8	4.3	3.2	4.1	4.0	3.3	**3.8**
36	3.6	3.6	3.6	4.2	4.3	3.1	**3.7**
46	4.0	4.6	4.0	3.8	4.2	3.8	**4.1**
47	4.3	4.3	3.9	3.6	3.7	3.8	**3.9**
48	4.3	4.4	4.2	4.2	4.1	3.3	**4.1**
58	3.8	4.0	3.7	4.0	4.2	4.0	**4.0**
59	3.8	4.2	3.5	4.1	4.2	3.6	**3.9**
60	4.0	4.2	3.8	4.2	4.1	3.8	**4.0**

Appendix G: Tensile Adhesion Testing

Metallized Panels, Raw Data

Panel No.	Abrasive Grain Shape	Pull Stub	Adhesion Value	Break Location
7	Very Angular	A	1,467	80% cohesion; 20% adhesion
		B	1,427	100% cohesion
		C	1,631	80% cohesion; 20% adhesion
8		A	1,467	50% cohesion; 50% adhesion
		B	1,467	50% cohesion; 50% adhesion
		C	1,345	80% cohesion; 20% adhesion
9		A	1,345	100% cohesion
		B	1,304	95% cohesion; 5% adhesion
		C	1,427	100% cohesion
19	Angular	A	1,386	100% cohesion
		B	1,325	100% cohesion
		C	1,386	100% cohesion
20		A	1.304	20% cohesion; 80% adhesion
		B	1,325	90% cohesion; 10% adhesion
		C	1,345	90% cohesion; 10% adhesion
21		A	1,427	100% cohesion
		B	1,386	100% cohesion
		C	1,345	50% cohesion; 50% adhesion
31	Sub-Angular	A	1,304	100% cohesion
		B	1,304	90% cohesion; 10% adhesion
		C	1,386	80% cohesion; 20% adhesion
32		A	1,467	50% cohesion; 50% adhesion
		B	1,508	80% cohesion; 20% adhesion
		C	1,467	80% cohesion; 20% adhesion
33		A	1,386	100% cohesion
		B	1,386	100% cohesion
		C	1,467	95% cohesion; 5% adhesion
43	Sub-Rounded	A	1,100	40% cohesion; 60% adhesion
		B	1,100	40% cohesion; 60% adhesion
		C	1,182	40% cohesion; 60% adhesion
44		A	1,182	50% cohesion; 50% adhesion
		B	1,263	40% cohesion; 60% adhesion
		C	1,345	50% cohesion; 50% adhesion
45		A	1,427	40% cohesion; 60% adhesion
		B	1,427	40% cohesion; 60% adhesion
		C	1,427	60% cohesion; 20% adhesion
55	Rounded	A	1,263	50% cohesion; 50% adhesion
		B	1,223	20% cohesion; 80% adhesion
		C	1,263	60% cohesion; 40% adhesion
56		A	1,223	40% cohesion; 60% adhesion
		B	1,182	40% cohesion; 60% adhesion
		C	1,223	50% cohesion; 50% adhesion
57		A	1,141	50% cohesion; 50% adhesion
		B	1,182	50% cohesion; 50% adhesion
		C	1,100	40% cohesion; 60% adhesion

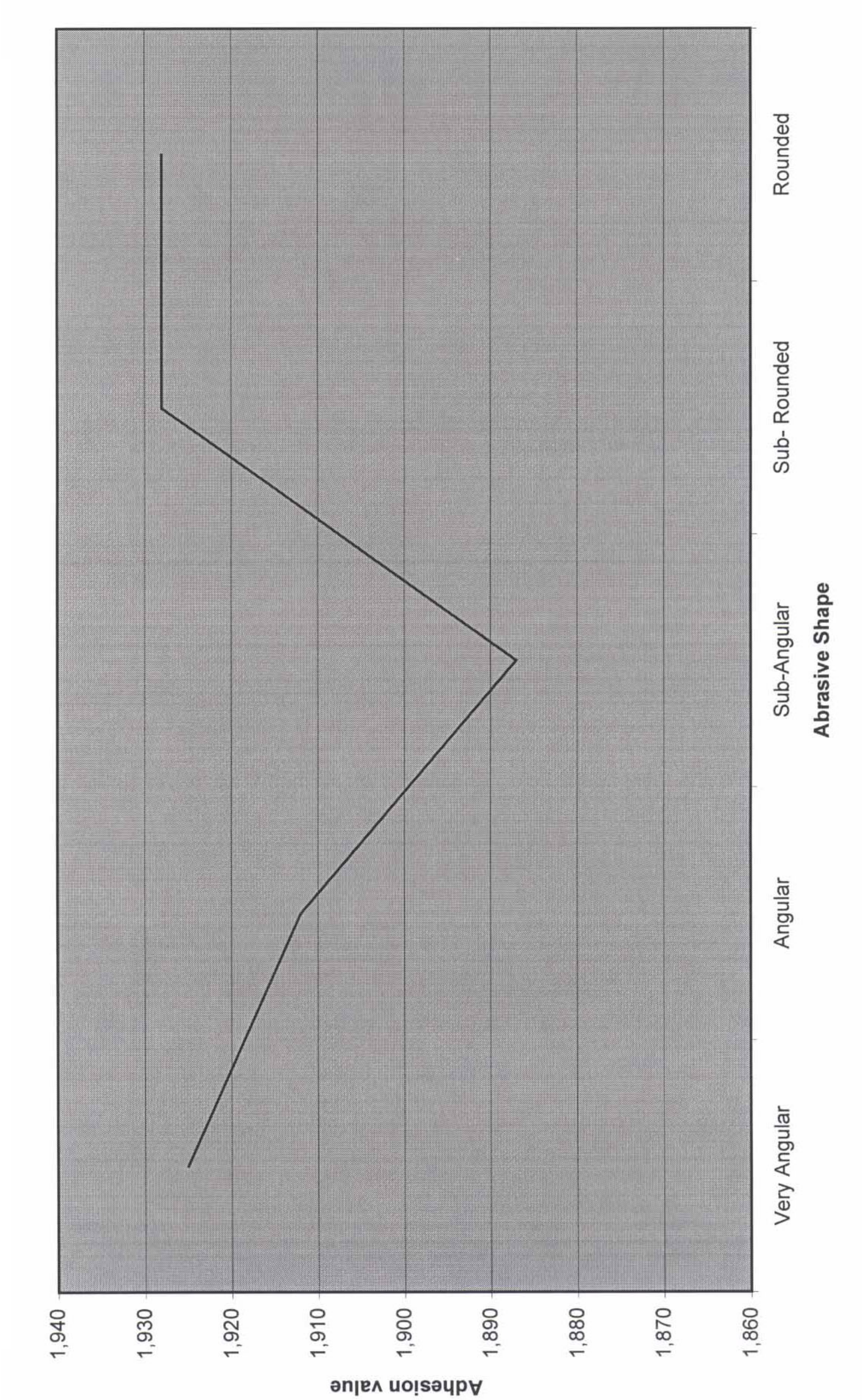
Graph 1 – Abrasive Shape Versus Tensile Adhesion of 85% Zinc / 15% Aluminum Metallizing



Organic (Epoxy) Zinc-Coated Panels, Raw Data

Panel No.	Abrasive Grain Shape	Pull Stub	Adhesion Value	Break Location
10	Very Angular	A	1,957	100% cohesion
		B	1,916	100% cohesion
		C	1,876	100% cohesion
11		A	1,957	100% cohesion
		B	1,916 1,916	100% cohesion
		C	1,876	100% cohesion
12		A	1,916	100% cohesion
		B	1,957+	100% cohesion
		C	1,957	100% cohesion
22	Angular	A	1,916	100% cohesion
		B	1,917	100% cohesion
		C	1,835	90% cohesion; 10% glue
23		A	1,916+	100% cohesion
		B	1,957	90% cohesion; 10% glue
		C	1,876	100% cohesion
24		A	1,916	100% cohesion
		B	1,876	100% cohesion
		C	1,957	100% cohesion
34	Sub-Angular	A	1,876	100% cohesion
		B	1,957+	100% cohesion
		C	1,957	100% cohesion
35		A	1,957	100% cohesion
		B	1,876	100% cohesion
		C	1,876	100% cohesion
36		A	1,774	100% cohesion
		B	1,876	100% cohesion
		C	1,835	100% cohesion
46	Sub-Rounded	A	1,957	100% cohesion
		B	1,916	100% cohesion
		C	1,957	100% cohesion
47		A	1,957	100% cohesion
		B	1,876	100% cohesion
		C	1,876	100% cohesion
48		A	1,937	100% cohesion
		B	1,916	100% cohesion
		C	1,957	100% cohesion
58	Rounded	A	1,998+	100% cohesion
		B	1,896	100% cohesion
		C	1,916	100% cohesion
59		A	1,957+	100% cohesion
		B	1,937	100% cohesion
		C	1,916	100% cohesion
60		A	1,978+	100% cohesion
		B	1,835	100% cohesion
		C	1,916	100% cohesion

Graph 2 – Abrasive Shape Versus Tensile Adhesion of Epoxy Zinc-Rich Primer (Note: Results represent cohesion breaks within the coating)



REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (From - To)
08-2001	Final	

4. TITLE AND SUBTITLE
Recycled Steel Abrasive Grit:
Evaluation of Rounding and Its Effects on Adhesion

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Mr. Alfred D. Beitelman

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER
33116

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Research and Development Center (ERDC)
Construction Engineering Research Laboratory (CERL)
P.O. Box 9005
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER
ERDC/CERL TR-01-37

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Headquarters, U.S. Army Corps of Engineers
441 G Street, NW
Washington, DC 20314-1000

10. SPONSOR/MONITOR'S ACRONYM(S)
CECW-EE

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
TR HPMS-01-1

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

14. ABSTRACT

The use of recycled metallic abrasives (e.g., steel grit) is becoming more common on U.S. Army Corps of Engineers (COE) projects for preparation of steel surfaces prior to application of thermal-sprayed metallic and liquid-applied coatings. The angularity of the resulting surface roughness is critical to the adhesion of the thermal-sprayed coatings, and enhances the adhesion of liquid-applied coatings.

There are no established field methods that a COE inspector can use to evaluate the angularity of the abrasive or the angularity of the surface after abrasive blast cleaning has been performed. The objectives of this research were to determine the effect that the recycling of metallic abrasive has on the adhesion thermal-spray (zinc/aluminum 85/15) and liquid-applied epoxy zinc-rich coatings, and to recommend an approach that can be used to generate industry standards for recycled abrasive. The data may also be helpful in developing field inspection methods for surface and abrasive angularity that can be used to verify proper surface preparation.

15. SUBJECT TERMS
coatings, metallic abrasives, adhesion, surface preparation, steel structures

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
Unclassified	Unclassified	Unclassified	SAR	68	Alfred D. Beitelman
					19b. TELEPHONE NUMBER (include area code) (217) 352-6511 x7237

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. 239.18