

MINERAL SLAG ABRASIVE SURVEY AND SPECIFICATION

APRIL 1984

Prepared by
OCEAN CITY RESEARCH CORP.
IN COOPERATION WITH
AVONDALE SHIPYARDS, INC.

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FOREWARD

This report is the result of one of the many projects managed and cost shared by Avondale Shipyards, Inc. under the auspices of the National Shipbuilding Research Program. The program was a cooperative effort with the Transportation Department, Maritime Administration Office of Advanced Ship Development.

On behalf of Avondale Shipyards, Inc., Mr. John Peart was the Program Manager responsible for technical direction and publication of the final report. Program definition and guidance were provided by the members of the Society of Naval Architects and Marine Engineers Ship Production Committee panel 023-1 Surface Preparation and Coatings.

The experimental work described in the report took place at the Ocean City Research Corporation Laboratory in Ocean City, New Jersey under the direction of Mr. E.C. Flounders, Lead Engineer.

The principal objectives of the program were to catalog sources of mineral slag abrasives for U.S. shiyards and to develop a tentative material specification for mineral slag abrasives. These objectives are in concert with one of the main objectives of the National Shipbuilding Research Program which is to reduce shipbuilding costs in U.S. shipyards through improved standardization.

EXECUTIVE SUMMARY

Because of potential silicosis problems, the U.S. shipbuilding industry has largely abandoned the use of open-air sand blasting. The predominant abrasives now being used for open-air blasting are mineral slags having a low free silica content. Concerns about their continued availability as well as batch-to-batch variations in quality prompted the subject program. Avondale Shipyards authorized the Ocean City Research Corporation to: (1) catalog sources of mineral slag abrasives for U.S. shipyards and (2) develop a tentative material specification for mineral slag abrasives consistent with the requirements of U.S. shipyards.

The two tasks have been completed and are presented as appendices to this report. Appendix A lists 15 suppliers of mineral abrasives. Detailed are the type of abrasive supplied, abrasive grades, and cost. Appendix B presents a tentative material specification for mineral slag abrasives. The following report summarizes the methodology and rationale behind the development of the specification.

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SECTION 1

Introduction

INTRODUCTION

In shipyards, abrasive blasting has traditionally been the favored method for preparing a structural steel surface prior to application of a protective coating. Abrasive blasting removes mill scale, rust, paint, and other surface soils providing a clean surface to which the coating can adhere. Abrasive blasting also develops an "anchor pattern" to improve the mechanical bond between coating and steel substrate. Until several years ago, the principal abrasive used in shipyards was sand. However, with the disclosure that free silica in the air from the blasting operation creates a severe health hazard (silicosis), the use of sand as an abrasive material in shipyards has largely been discontinued. To a great extent, mineral abrasives with a low free silica content have replaced sand as the favored abrasive material.

There are several different types of mineral abrasive that can be used by shipyards for abrasive blasting. Some mineral abrasives are obtained from naturally occurring sources (e.g. staurolite sands) while others are slags produced as by-products of refining or smelting operations. The mineral slags derived from the fritted ash of coal used in electric power generation and from copper and nickel smelting processes are widely used in shipyards as abrasive materials.

Considering the varied sources from which the mineral slag abrasives are derived, the shipbuilding industry is concerned about possible variations in performance as well as availability. Some shipyards have reported long lead times in obtaining mineral slag abrasives. Cognizant technical personnel are concerned about the suitability of different slag materials as abrasives because of possible contamination with chlorides or other contaminants that might adversely affect paint adhesion. Because of these concerns, a program was initiated to catalog sources of mineral slag abrasives and develop a material specification suitable for use by shipyards. The following presents the results of the program.

SECTION 2

Technical Approach

TECHNICAL APPROACH

Catalog Of Abrasive Suppliers

The following sources of information were consulted in order to identify current suppliers of mineral abrasives:

- o Thomas Register of American Manufacturers
- o Selected shipyards and shipbuilding consultants (30 total)
- o The Maritime Administration
- o The California Air Resources Board
- o Various abrasive suppliers

Based on the information gathered, fifteen abrasive suppliers were identified. Subsequently, each supplier was personally contacted by telephone in order to locate cognizant personnel willing to complete a questionnaire concerning the supplier's abrasive products. A questionnaire was then mailed to each supplier.

The main intent of the questionnaire was to determine the types and grades of abrasive supplied, and the cost of these abrasives. Only those abrasives having a free silica content of less than 1.0% were of interest.

Of the fifteen abrasive suppliers contacted, ten responded in writing. The other five provided information over the phone. After all of the questionnaires were completed, the data were reduced into catalog form. Finally, each supplier was called once again in order to verify the data in the catalog (as of April 1983) .

Material Specification

This task was accomplished by subjecting abrasive samples to a series of standardized tests and critically evaluating the data in order to develop a rational basis for characterizing and qualifying mineral slag abrasives for use by shipyards. The abrasive samples included in the test program were chosen to be representative of those currently used by the shipyards. The abrasives included coal slags, copper slags, nickel slags, and a 50/50 mixture of a coal and copper slag. The laboratory tests included chemical and physical tests (e.g. chloride content or particle hardness) as well as blasting performance tests (e.g. cutting rate). Selection of the different tests was based on a review of MIL-S-22262 (SHIPS), the military specification for sandblasting, and other pertinent literature (1), (2), (3), (4). The methodology associated with the different tests-is described as part of the tentative material specification.

Based upon the literature review, the chemical and physical characteristics of the abrasives considered to be the most important were:

- o pH
- o Chloride Content
- o Electrical Resistivity
- o Moisture Content
- o Free Flow
- o Hardness
- o Grain Shape
- o Specific Gravity
- o Sieve Analysis

The importance of each of these characteristics is discussed below:

pH, Chloride Content, Electrical Resistivity. Each of these characteristics can be used as a basis for assessing to what extent an abrasive is contaminated with soluble salts that might adversely affect a freshly blasted steel surface. A low pH abrasive would suggest the presence of acid salts, which if left as a residual on a blasted surface, could cause premature rusting of the steel surface prior to painting and adversely affect paint adhesion. The presence of chlorides could cause similar effects. An abrasive exhibiting a low electrical resistivity (as measured in a deionized water slurry) would also suggest the presence of soluble salts which again might tend to initiate premature surface corrosion or cause subsequent blistering of the paint film.

Moisture Content, Free Flow. It is necessary to determine the moisture content of the abrasive material so that when buying abrasive by weight, corrections can be made for the weight added by water. The free flow test is designed to insure that if thoroughly wetted, the abrasive can be completely dried and will not form into clumps.

Hardness, Grain Shape, Specific Gravity. A hardness test is necessary to eliminate abrasives with appreciable amounts of soft materials. The grain shape requirement attempts to limit the use of rounded particles as a blast material because the anchor pattern formed by their use is not as desirable as that formed using sharper particles. The specific gravity of the abrasive is critical in that it effects the kinetic energy of a particle as it impacts upon the surface. The greater the specific gravity, the greater the kinetic energy of a particle for a given velocity. Thus, more energy is available for metal removal.

Sieve Analysis. The sieve analysis is an important factor because different particle size distributions are used for various blasting objectives.

The blasting characteristics considered to be the most important were as follows:

- o Cutting Rate
- o Breakdown Rating
- o Dust Production
- o Surface Profile of Blasted Surface

Cutting Rate. The cutting rate or metal removal rate is critical because it determines the amount of productive blasting that can be accomplished with a particular abrasive for the given test conditions. Thus, all other factors being equal, the abrasive with the highest cutting rate will be the most economical.

Breakdown Rating. The breakdown rating indicates the extent to which the individual abrasive particles fracture. Energy expended during particle breakdown represents lost energy that could have been used for removing metal. This is also of interest because it determines the percentage of abrasive that can be recycled as well as providing an indirect measurement of the dust produced during blasting.

Dust Production. Dust generation must be limited in order to meet safety requirements as well as meet minimum visibility requirements. Also, the more dust present in the air, the greater the likelihood of fine abrasive particles settling on and contaminating the freshly blasted surfaces.

Surface Profile Of Blasted Surface. Different abrasives yield different surface profiles. Because the surface profile has a significant effect on the adhesion of a coating, it is desirable to qualify abrasives based on the surface profile which they tend to produce.

SECTION 3

Results

RESULTS

Catalog of Abrasive Suppliers

Appendix A presents a catalog of mineral slag abrasive suppliers compiled as a result of the abrasive supplier survey. The catalog lists the supplier's address, type and grades of abrasive, and cost (as of April, 1983) . Listing of an abrasive supplier does not constitute an endorsement on the part of the Maritime Administration, Avondale Shipyards, or the Ocean City Research Corporation. The suppliers are listed only to identify possible sources of supply.

The catalog also lists the suppliers alphabetically by state and shows their location on a U.S. map. Supplier location is an important consideration because transportation costs can greatly influence the delivered price of an abrasive. The prices listed in the catalog are F.O.B. plant (depending on grade, method of packaging, and quantity) . A cost analysis using these prices should also consider transportation costs.

The overall quality of an abrasive is also a contributing factor in a cost analysis of blasting. An abrasive can have a high initial cost and yet be low dusting, high in metal removal, and produce a clean, well prepared surface. This benefit might overcome the initial price of an abrasive.

The abrasive suppliers that were contacted all indicated that they are able to supply enough abrasives to meet the general demand. Problems can arise when insufficient lead time is given on an order. In the past, rail delays have affected the availability of abrasives. Local shortages have developed for shipyards that use coal slag since they must compete with the roofing industry which uses coal slag in the production of roofing shingles.

Tentative Material Specification

Appendix B presents the initial draft of a specification for mineral slag abrasives. The specification was prepared using MIL-S-22262 as a guideline. The quality assurance requirements written into the specification represent: (1) the requirements of MIL-S-22262 that appear suitable for mineral slag abrasives based on an analysis of the results of the laboratory tests conducted in the subject program and (2) additional requirements not covered by MIL-S-22262 that appear worthwhile based also on an assessment of the laboratory test results. Tables I, II, III, and IV summarize the results of the laboratory tests.

Statistical analysis was used to establish qualifying criteria when there was no precedent in MIL-S-22262 or in any related literature. The statistical approach consisted of extreme value probability analysis. Extreme value probability analysis determines the probability of a parameter exceeding an

TABLE I - Summary Of Chemical And Physical Test Results

<u>Abrasive Sample</u>	PH	<u>Chloride Content ppm</u>	<u>Solution Restivity Ohm-cm</u>	<u>Moisture Content %</u>
1. Copper Slag	7.24	42.5	5100 4800	0.0
2. Coal Slag	7.84	16.5	42000 45000	0.0
3. Copper Slag	9.14	15.5	64000 61000	0.0
4. Coal Slag	7.68	0.5	26200 26200	0.0
5. Copper Slag	8.94	0.5	14200 12800	0.0
6. Coal Slag	8.12	0.5	28000 27000	0.0
7. 50-50% Coal & Copper Slag	7.65	258	1900 1900	0.0
8. Nickel Slag	9.47	3.5	28200 27000	0.1
9. Coal Slag	6.07	9.5	9800 *	0.2

* Not duplicated

TABLE I - Continued

<u>Abrasive Sample</u>	<u>Free Flow</u>	<u>Hardness</u> <u>Mho ' S</u>	<u>Grain Shape</u>	<u>Specific Gravity</u>
1. Copper Slag	No visible clumping	≥ 6	Angular to rounded	3.6
2. Coal Slag	"	≥ 6	Angular	2.6
3. Copper Slag	"	≥ 6	Angular	2.8
4. Coal Slag	"	≥ 6	Angular	2.7
5. Copper Slag	"	≥ 6	Angular	3.6
6. Coal Slag	"	≥ 6	Angular	2.6
7. 50-50% Coal & Copper Slag	"	≥ 6	Angular	2.8
8. Nickel Slag	"	≥ 6	Angular to rounded	3.0
9. Coal Slag	"	≥ 6	Angular	2.6

TABLE II - Summary of Sieve Analysis

<u>Abrasive Sample</u>	% Retained								<u>Pan</u>
	<u>#10 Sieve</u>	<u>#20 Sieve</u>	<u>#30 Sieve</u>	<u>#40 Sieve</u>	<u>#50 Sieve</u>	<u>#60 Sieve</u>	<u>#70 Sieve</u>	<u>#100 Sieve</u>	
1. Copper Slag	16	60	13	7	2	<1	<1	<1	1
2. Coal Slag	0	73	21	5	1	0	0	0	0
3. Copper Slag	2	45	24	17	9	2	<1	<1	0
4. Coal Slag	2	74	18	5	1	0	0	0	0
5. Copper Slag	20	33	29	15	2	<1	<1	0	0
6. Coal Slag	29	60	8	2	1	0	0	0	0
7. 50-50% Coal & Copper Slag	15	73	9	2	1	0	0	0	0
8. Nickel Slag	2	97	1	1	0	0	0	0	0
9. Coal Slag	13	69	12	5	1	0	0	0	0

TABLE III - Summary of Blasting Test Results

Abrasive Sample	Total Spent Abrasive (gms)	Total Dust Generated (gms)	Weight Percent of Dust Generated	Plate Weight Loss (gms)	Cutting Rate g of metal removed kg of abrasive	Breakdown Rating
1. Copper Slag	1778.0 1424.0	162.5 101.5	9.1 7.1	5.1 3.8	2.9 2.7	0.47 0.40
2. Coal Slag	1223.5 1085.5	125.0 98.0	10.2 9.2	3.4 2.8	2.8 2.6	0.34 0.35
3. Copper Slag	1023.0 1144.5	124.5 113.5	12.2 9.9	1.9 4.1	1.9 3.6	0.39 0.39
4. Coal Slag	1409.5 1141.0	118.5 92.5	8.4 8.1	2.9 2.6	2.1 2.3	0.35 0.37
5. Copper Slag	11698.5 1161.5	152.0 132.5	9.0 8.0	4.5 4.2	3.0 2.5	0.45 0.43
6. Coal Slag	1111.0 1196.5	88.5 110.0	8.0 9.2	2.0 2.2	1.8 1.8	0.29 0.29
7. 50-50 Coal & Copper Slag	1717.5 1681.0	101.0 111.5	5.9 6.6	3.6 3.6	2.1 2.1	0.37 0.37
8. Nickel Slag	1691.5 1379.5	54.0 54.0	3.2 3.9	1.8 1.5	1.1 1.1	0.47 0.51

TABLE IV - Summary of Resulting Surface Profile On Steel
Test Plates (90° Angle of Blast)*

<u>Abrasive Sample</u>	<u>Surface Profile (mils)</u>		
	<u>Elcometer</u>	<u>Press-O-Film</u>	<u>Surfanalyzer</u>
1. Copper Slag	3.5	3.6	3.8
2. Coal Slag	3.7	3.4	3.5
3. Copper Slag	3.3	3.2	4.0
4. Coal Slag	3.6	3.2	2.0
5. Copper Slag	3.3	2.7	2.8
6. Coal Slag	3.5	3.6	4.1
7. 50-50% Coal & Copper Slag	3.7	3.7	3.8
8. Nickel Slag	3.7	3.7	3.0
9. Coal Slag	-	3.3	-

* Surface profiles were measured using three methods: (1) Elcometer gauge, (2) Press-O-Film, and (3) a Surfanalyzer.

extreme low or extreme high value. The indicated extreme values are considered to represent the extreme characteristics of the general population. While extreme value analysis has proven itself valid in many studies, its validity in this program was limited by the small data base generated. However, the tendency of the data to fit an extreme value trend rather than a normal distribution suggested an extreme value analysis was more appropriate. The collection of more data will be necessary to confirm and refine the qualifying criteria.

Where a qualification criterion was established based on statistical analysis of the test results, the limiting value was arbitrarily selected as that value equivalent to a 95% cumulative probability. In other words, only 5% of the population (as sampled) should exhibit values outside the limiting value.

In general, the criteria associated with the quality assurance provisions derived from MIL-S-22262 are not based on a statistical interpretation of the data but are based on precedent (the MIL-S-22262 specification, itself). Included are such parameters as percent moisture, free flow, grain shape, and hardness.

The specification as drafted applies only to "utility grade" mineral slag abrasives since this was the only grade of abrasive fully represented in the laboratory tests. The qualifying criteria established for the quality assurance parameters and the rationale behind the specified criteria are as follows:

PH. The pH of a mineral slag abrasive slurry mixture is not to have a pH less than 6.2. It is desirable to eliminate the possibility of steel exposure to acid moisture since the corrosivity of acid moisture is greater than alkaline moisture. Therefore, a logical limit to the pH of a slurry mixture would be 7.0. However, the qualifying test procedure requires the use of ASTM D 1193-77, Type III reagent water which has a lower pH limit of 6.20. As a result, it would not be appropriate to assign a low limit of 7.0. It was reasoned that if the abrasive lowers the reagent water below its 6.2 limit then it is acidic and possibly unsuitable for use.

Chloride Content. The chloride content is specified not to exceed 300 ppm. The chloride content of 8. of the 9 abrasives tested was significantly below this value. While the data suggests the chloride limit might be reduced without eliminating a majority of abrasives, there is no compelling evidence that a 100 ppm or 50 ppm limit would be more beneficial than a 300 ppm limit. Therefore, it was decided to retain the limit specified in MIL-S-22262.

Electrical Resistivity. The tentative specification requires the electrical resistivity of the abrasive to be higher than 2,000 ohm-cm. This value was arrived at by considering the extreme

corrosivity of 20 ohm-cm seawater on bare steel. At least a two order of magnitude difference between the resistivity of an abrasive slurry and the resistivity of seawater seems appropriate.

Moisture Content, Hardness, Free Flow, Grain Shape. For these particular characteristics, there did not appear to be any compelling reason to change the requirements of MIL-S-22262. The test results suggest that most utility grade mineral slag abrasives will meet the requirements as derived from MIL-S-22262.

Specific Gravity. The tentative specification requires the specific gravity of the abrasive not to be less than 2.20. This value was established based on an extreme value probability analysis of the test data. Figure 1 shows an extreme value plot of the data along with the 2/3 control lines. The plot suggests that there is only a 5% probability that a sample of mineral slag abrasive obtained from batches similar to those represented in the test program will exhibit a specific gravity less than 2.20. This criterion also agrees with the criterion specified by MIL-S-22262 for Class 3 abrasives.

Sieve Analysis. The criteria proposed for the initial sieve analysis reflect the range of particle sizes encountered during the laboratory sieve analysis of all of the abrasives tested. The requirements are not extremely stringent, thus individual suppliers can tailor their product as they feel will be most effective.

Cutting Rate. The tentative specification requires the cutting rate of the abrasive not to be less than 0.8 gram of metal removed per kilogram of abrasive. Figure 2 shows the extreme value probability plot which provided a basis for this value. It is important to note that the cutting rate requirement is valid only as a comparison under the specific test conditions of this program and is not necessarily representative of the cutting rate that would be observed under actual blast conditions.

Breakdown Rating, Dust Production. The minimum acceptable breakdown rating according to the tentative specification is 0.25. The weight percent dust generated is not to exceed 13.5%. Figures 3 and 4 show the extreme value probability plots which suggest these values.

Surface Profile. The tentative specification requires a resulting surface profile of 2-4 roils, peak-to-valley. These values are consistent with the requirements of most hull paints. Press-O-Film* is specified as the means of measuring the surface profile because of its ease of use and its wide acceptability within the industry. The laboratory test results (Table III)

* Available from Testex Inc., P.O. Box 867, Newark, Delaware, 19711.

Figure 1. Extreme Value Probability Plot Of Specific Gravity Data

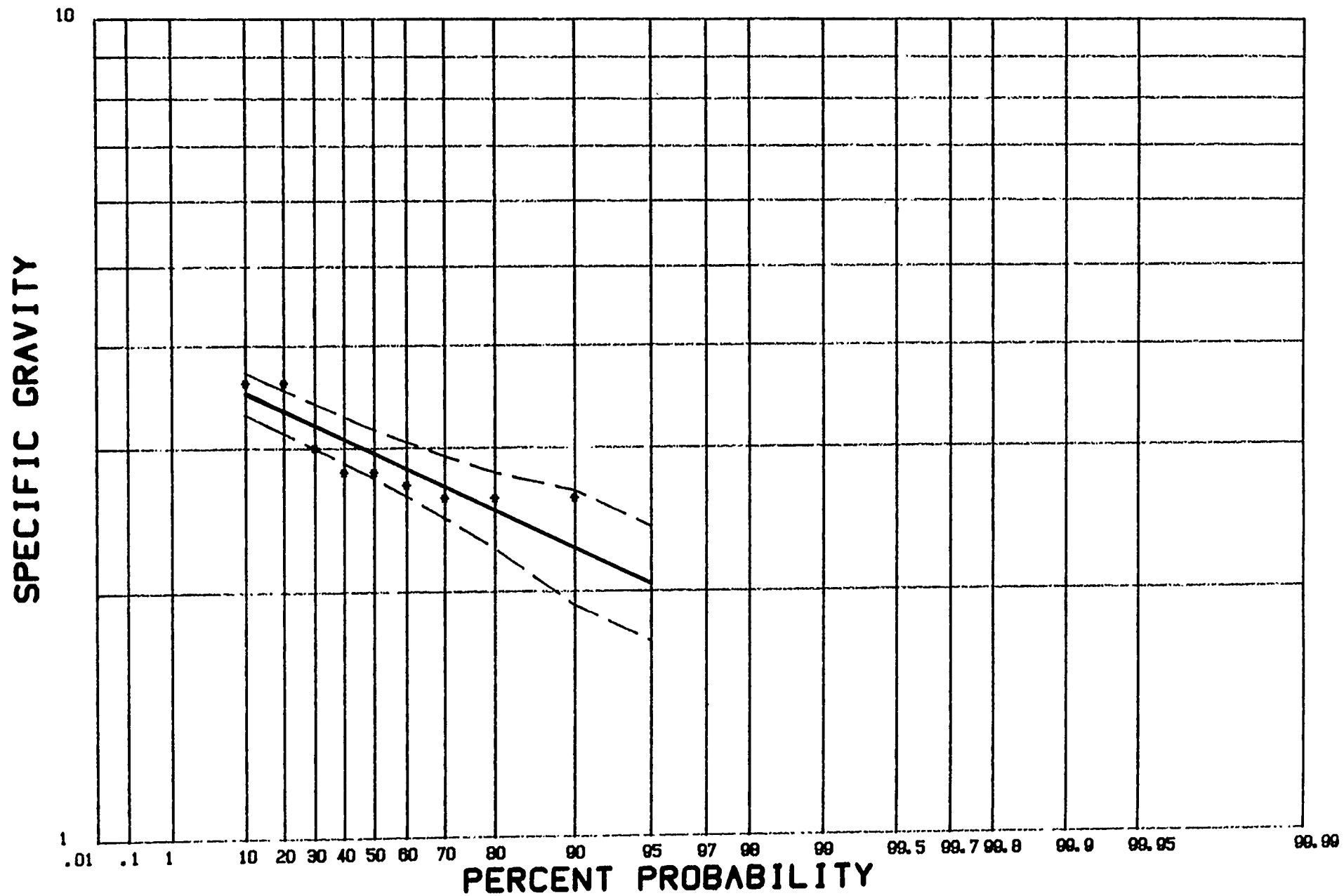


Figure 2. Extreme Value Probability Plot Of Cutting Rate Data

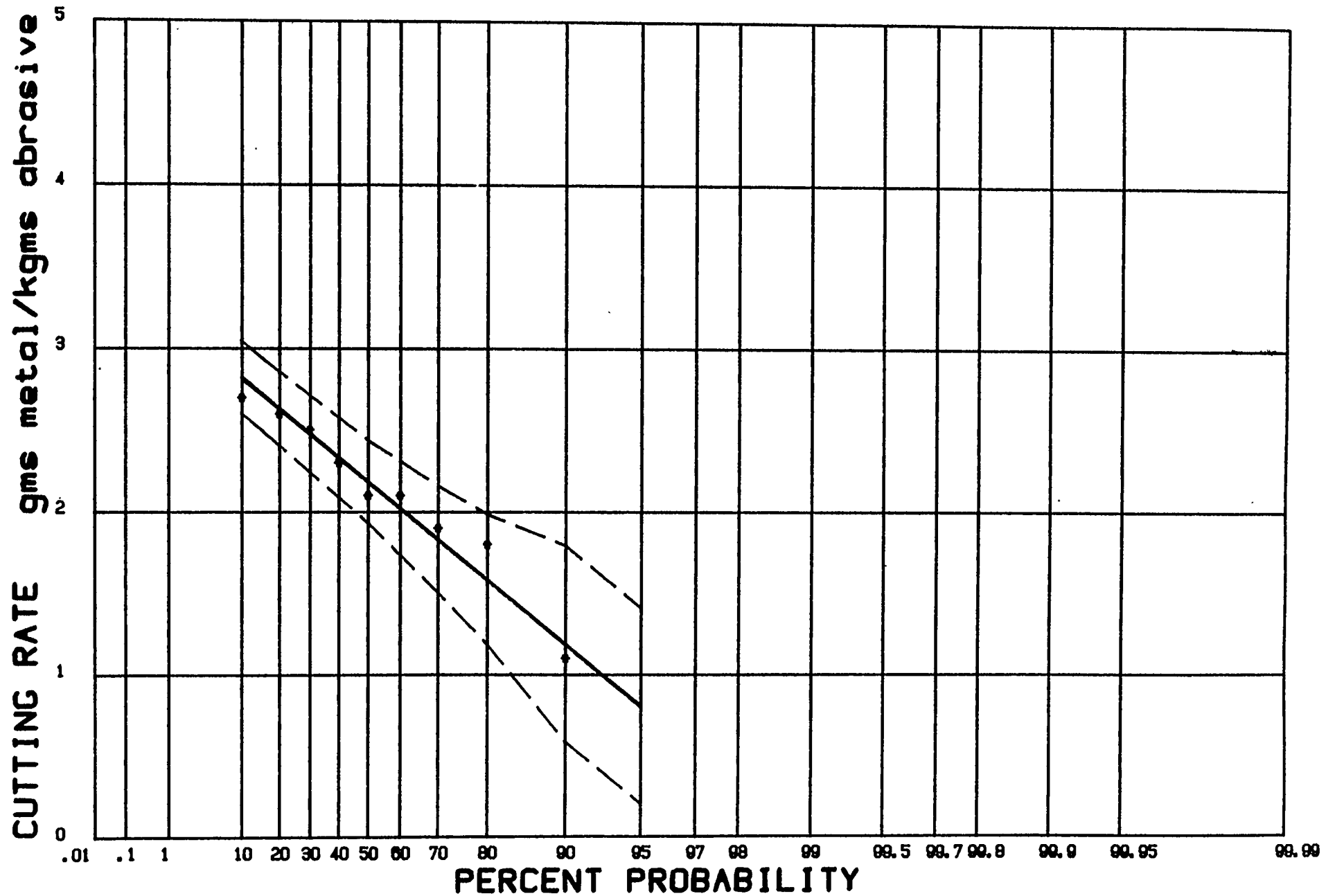


Figure 3. Extreme Value Probability Plot of Breakdown Rating Data

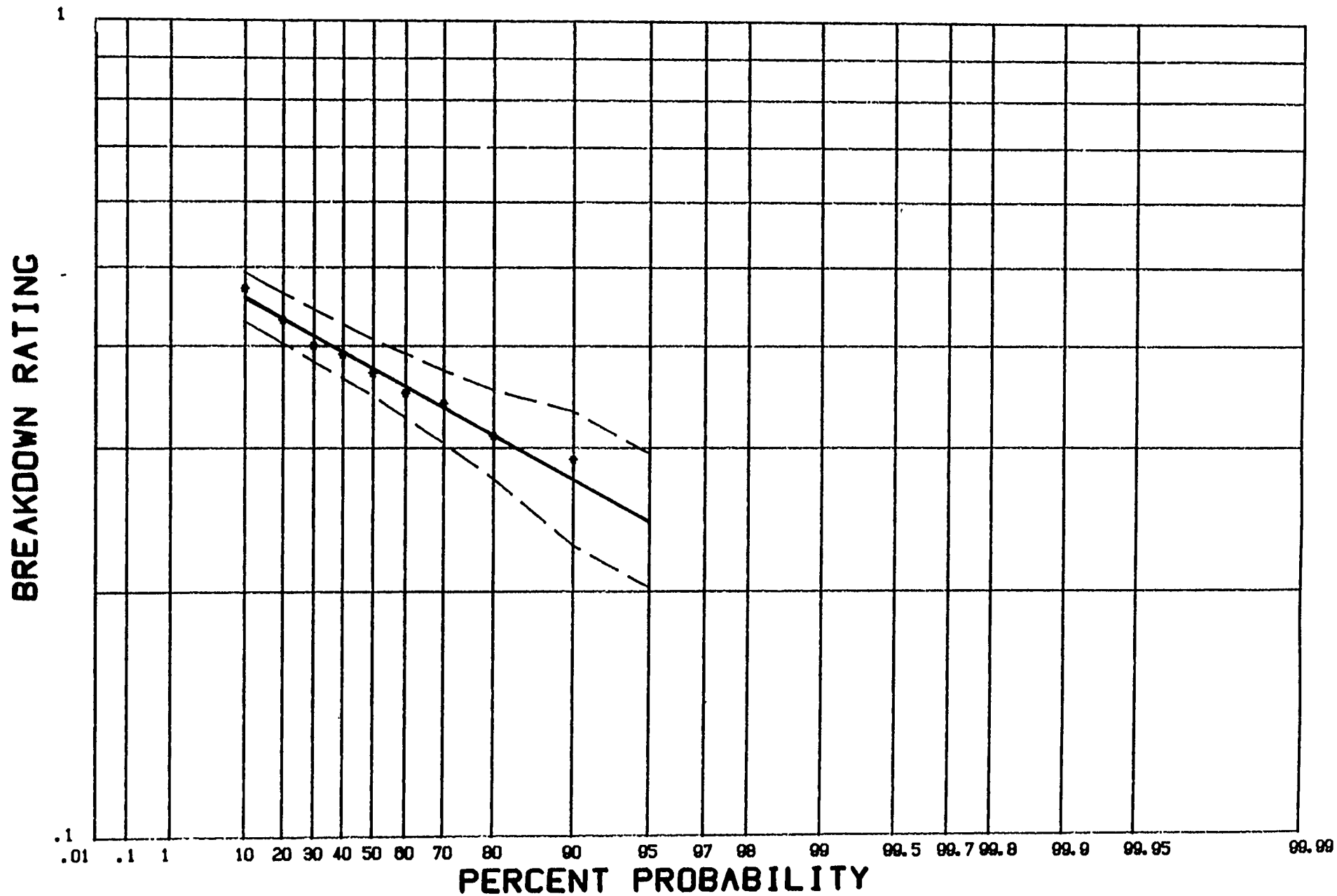
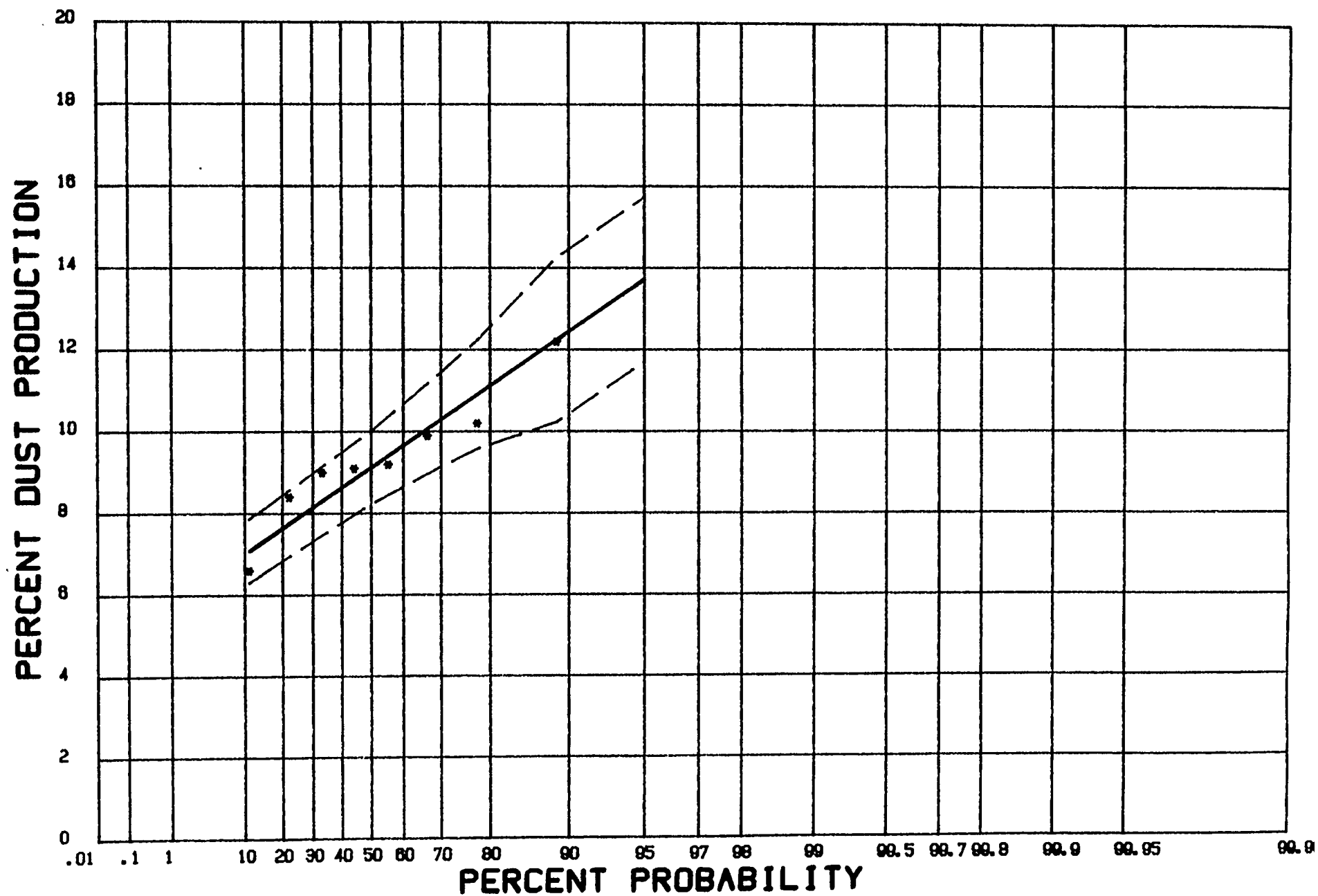


Figure 4. Extreme Value Probability Plot Of Dust Production Data



suggest that the Press-O-Film technique produces results similar to those obtained using other surface profile measuring techniques.

Additional Test Data

In addition to the laboratory test data obtained on various mineral slag type abrasives, it was also of interest to obtain data on a natural stauralite abrasive. Appendix C summarizes the results.

SECTION 4

Summary and Recommendations For Future Work

SUMMARY AND RECOMMENDATIONS FOR FUTURE WORK

The subject program produced a catalog of mineral abrasive suppliers and a tentative material specification. The catalog provides a convenient list of suppliers for the shipyards. The material specification represents the initial step toward standardization of mineral slag abrasives, currently in use by the shipyards.

Based on the results of this program, the following work is highly encouraged:

1. The catalog of abrasive suppliers should be periodically revised and updated.
2. Because little work has been conducted concerning the critical concentration levels of chloride present in abrasives that may be detrimental to surface preparation, preprinting corrosion, and paint performance, it would appear worthwhile to conduct some sort of standardized test with abrasives of different chloride levels. For example, an abrasive could be either treated with chlorides or leached of excess chlorides and then used to blast steel plates. Some of the plates could be painted and some left freshly blasted. These plates could then be subjected to exposure in a seacoast environment comparable to a shipyard along with appropriate controls. This type of testing could yield valuable data from which truly meaningful requirements could be established. This type of parametric testing could be carried out not only for chlorides but also for pH, electrical resistivity, and specific gravity.

SECTION 5

References

REFERENCES

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2. C.L. Shaw, "Abrasive Blasting Study", Long Beach Naval Shipyard Report, 1963.
3. B.D. Murray, "Development of Specifications for Blast Cleaning Abrasives", California Department of Transportation, Report No. CA-DOT-TL-3145-1-75-32, October, 1975.
4. Hughes Aircraft Company, "Development of Test Procedures for Evaluation of Abrasives at Long Beach Naval Shipyard", September, 1978.

APPENDIX A

Catalog of Abrasive Suppliers

PREFACE

The following catalog presents a comprehensive listing of mineral abrasive manufacturers and prime suppliers. It does not include local distributors who purchase from prime suppliers. The information is current as of April, 1983.

The information was compiled under the auspices of Avondale Shipyards for the Maritime Administration. The catalog was prepared as an aid for shipyards. In the past, the availability of different mineral abrasives has been known to vary.

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MINERAL ABRASIVE SUPPLIERS

1. Anchor Abrasives Corporation
324 Hamburg Turnpike
Wayne, NJ 07470

201-835-6502

Abrasive Type: Copper Slag
Brand Name: Mono-Kleen Mineral Grit
Plant Location: Carteret, NJ
Abrasive Grades: 10-40 Medium

cost : \$30/ton bulk and \$38/ton bag F.O.B. Plant

2. Apache Abrasives, Inc.
10690 Shadow Wood Drive
Suite 112
Houston, TX 77043

713-468-5647

Abrasive Type: Copper Slag
Brand Name: Apache-Blast
Plant Location: El Paso, TX
Copperhill, TN
Abrasive Grades: 6-20
8-20
10-50
16-50

cost: \$24/ton F.O.B. Plant

3. R. A. Barnes, Inc.
4510 Loma Vista Ave.
Vernon, CA 90058

215-583-8066

Abrasive Type: Copper Slag
Brand Name: Tuf Cut
Plant Location: Vernon, CA
Abrasive Grades: Tuf Cut 16
Tuf Cut 36

cost : \$85/ton bag and
\$70/ton bulk F.O.B. Plant

4. Copper Mountain Abrasive Co.
P. O. BOX 2509
Monterey, CA 93942

800-824-3996 or
800-824-4995

Abrasive Type: Copper Slag
Brand Name: Copper Blast
Plant Location: Salt Lake City, UT
Abrasive Grades: 6X12 Navy Coarse Blend
10x16 Coarse
16X25 Medium
25X60 Fine

cost: Information not available

5. Diamond Grit, Inc.
631 S. Central Ave.
Melrose, MN 56352

612-256-3331

Abrasive Type: Coal Slag
Brand Name: Diamond Grit
Plant Location: Melrose, MN - bulk & bag
Woodbury, MN - bulk only
Abrasive Grades: 12-50 Coarse
20-40 Medium-Fine

cost: \$45-64/ton F.O.B. Melrose, MN
\$26-44/ton F.O.B. Woodbury, MN
depending on grade, packaging and quantity

6. E. I. DuPont de Nemours & Co., Inc.
Chemicals & Pigments Dept.
Wilmington, DL 19898

302-774-9524 or
800-441-9442

Abrasive Type: Natural Stauralite Mineral
Brand Name: Starblast
Plant Location: Starke, FL
Abrasive Grades: 50-140

cost: \$42/ton bulk and \$54/ton bag F.O.B. Plant

7. Gibbco, Inc.
P. O. Box 255
West High St.
Lawrenceburg, IN 47025

812-537-2405

Abrasive Type: Coal Slag
Brand Name: Gibbco #11 Slag
Plant Location: Lawrenceburg, IN
Abrasive Grades: 10-30 Medium

cost: \$30/ton bulk & \$45/ton bag F.O.B. Plant

8. Industrial Mineral Products, Inc.
P.O. Box 95
Ravensdale, WA 98051

206-432-1286

Abrasive Type: Copper Slag
Brand Name: Abrasive Blasting Grit
Plant Location: Tacoma, WA
Abrasive Grades: 6x40 Utility
8x40 Medium
12x50 Fine
20x50 Extra Fine

cost: \$45-65/ton depending on grade, packaging and quantity F.O.B. Plant.

9. International Mineral & Chemical Corporation
Imcore Division
421 E. Hawley Street
Mundelein, IL 60060

312-566-2600

Abrasive Type: Natural Olivine Mineral
Brand Name: Green Lightning
Plant Location: Burnsville, NC
Abrasive Grades: GL40 Medium-Coarse
GL50 Medium
GL70 Fine
GL90

cost: \$50-50/ton bulk depending on grade and quantity F.O.B. Plant.

10. Kleen Blast Division
of Leisure Investment Co.
30100 Mission Blvd.
Hayward, CA 94544

415-471-2100

Abrasive Type: Copper Slag
Brand Name: Kleen Blast
Plant Location: Spokane, WA
Abrasive Grades: 8-12
16
16-30
35

cost: \$29/ton F.O.B. Plant

11. Lone Star Minerals, Inc.
8149 Kennedy Avenue
Highland, IN 46322

219-923-4200

SUBSIDIARIES

H.B. Reed & Co., Inc.

Abrasive Type: Coal Slag
Brand Name: Black Beauty
Plant Locations: Concord, NH
Gary, IN
Memphis, TN
Moundsville, Wv
Kearny, NJ
Rockdale, TX
La Cygne, KS
Abrasive Grades: 1040--Utility
1240 Medium
2040 Fine
3060 Extra Fine

Mineral Aggregates Co., Inc.

Abrasive Type: Coal Slag
Brand Name: Saf-T-Blast
Plant Locations: East Tampa, FL
Greenville, KY
Satsuma, AL
Abrasive Grades: 1040 Utility
1240 Medium
2040 Fine
3060 Extra Fine

Mineral Aggregates Co., Inc.

Abrasive Type: Nickel Slag
Brand Name: Green Diamond
Plant Locations: Riddle, OR
Abrasive Grades: 1040 Utility
1240 Medium
2040 Fine
3060 Extra Fine

cost : \$22-31/ton bulk F.O.B. Plant depending on location.

12. MDC Industries, Inc.
Collins & Willard Streets
Philadelphia, PA 19134

215-426-5925

Abrasive Type: Blended Mix (50-50%) of coal and copper slag.
Brand Name: Poly-Grit
Plant Locations: Philadelphia, PA
Abrasive Grades: #40 Medium
#80 Fine
#100 Very Fine

cost: \$40/ton F.O.B. Plant

13. Stan-Blast Abrasives Co.
P.O. Box 968
3300 River Road
Harvey, LA 70059

504-341-0451

Abrasive Type: Coal Slag
Brand Name: Stan-Blast
Plant Locations: Harvey, LA
San Leon, TX
Longueuil, Quebec
Canada
Abrasive Grades: 1040 Heavy Blast
1250 Medium Blast
3060 Fine Blast

cost : \$27-30/ton F.O.B. Harvey, LA
\$42/ton F.O.B. San Leon, TX - Medium Blast only.

14. Valley Abrasive Shot
15533 E. Arrow Highway
Irwindale, CA 91706

213-337-6590

Abrasive Type: Copper Slag
Brand Name: Easy Blast
Plant Locations: Irwindale, CA
Abrasive Grades: 8 Easy Blast #1
30 Easy Blast #2
50 Easy Blast #50

cost : \$58/ton bulk F.O.B. Plant

15. Virginia Materials Corporation
3306 Peterson Street
Norfolk, VA 23509

804-855-0155

Abrasive Type: Coal Slag
Brand Name: Black Blast
Plant Locations: Norfolk, VA
Abrasive Grades: 8-40 Commercial Grade

cost: Information not available

INDEX OF SUPPLIERS BY STATE

Alabama

1. Lone Star Minerals, Inc. (Mineral Aggregates Co., Inc.) , Satsuma

California

1. R. A. Barnes, Vernon
2. Valley Abrasive Shot, Irwindale

Florida

1. E. I. DuPont de Nemours & Co., Inc., Starke
2. Lone Star Minerals, Inc. (Mineral Aggregates Co., Inc.), East Tampa

Indiana

1. Gibbco, Inc., Lawrenceburg
2. Lone Star Minerals, Inc. (H.B. Reed & Co., Inc.), Gary

Kansas

1. Lone Star Minerals, Inc. (H.B. Reed & Co., Inc.), La Cygne

Kentucky

1. Lone Star Minerals, Inc. (Mineral Aggregates Co., Inc.), Greenville

Louisiana

1. Stan-Blast Abrasive Co., Harvey

Minnesota

1. Diamond Grit, Inc., Melrose
2. Diamond Grit, Inc. , Woodbury

New Hampshire

1. Lone Star Minerals, Inc. (H.B. Reed & Co., Inc.), Concord

New Jersey

1. Anchor Abrasives Corp., Cateret
2. Lone Star Minerals, Inc. (H.B. Reed & CO., Inc.) , Kearny

North Carolina

1. International Mineral & Chemical Corporation, Burnville

Oregon

1. Lone Star Minerals, Inc. (Mineral Aggregates Co., Inc.),
Riddle

Pennsylvania

1. MDC Industries, Inc. , Philadelphia

Tennessee

1. Apache Abrasives, Inc., Copperhill
2. Lone Star Minerals, Inc. (H.B. Reed & Co., Inc.),
Memphis

Texas

1. Apache Abrasives, Inc., El Paso
2. Lone Star Minerals, Inc. (H.B. Reed & Co., Inc.),
Rockdale
3. Stan - Blast Abrasive Co., San Leon

Utah

1. Copper Mountain Abrasive Co., Salt Lake City

Virginia

1. Virginia Materials Corporation, Norfolk

Washington

1. Industrial Mineral Products, Inc., Tacoma
2. Kleen Blast Division of Leisure Investment Co., Spokane

West Virginia

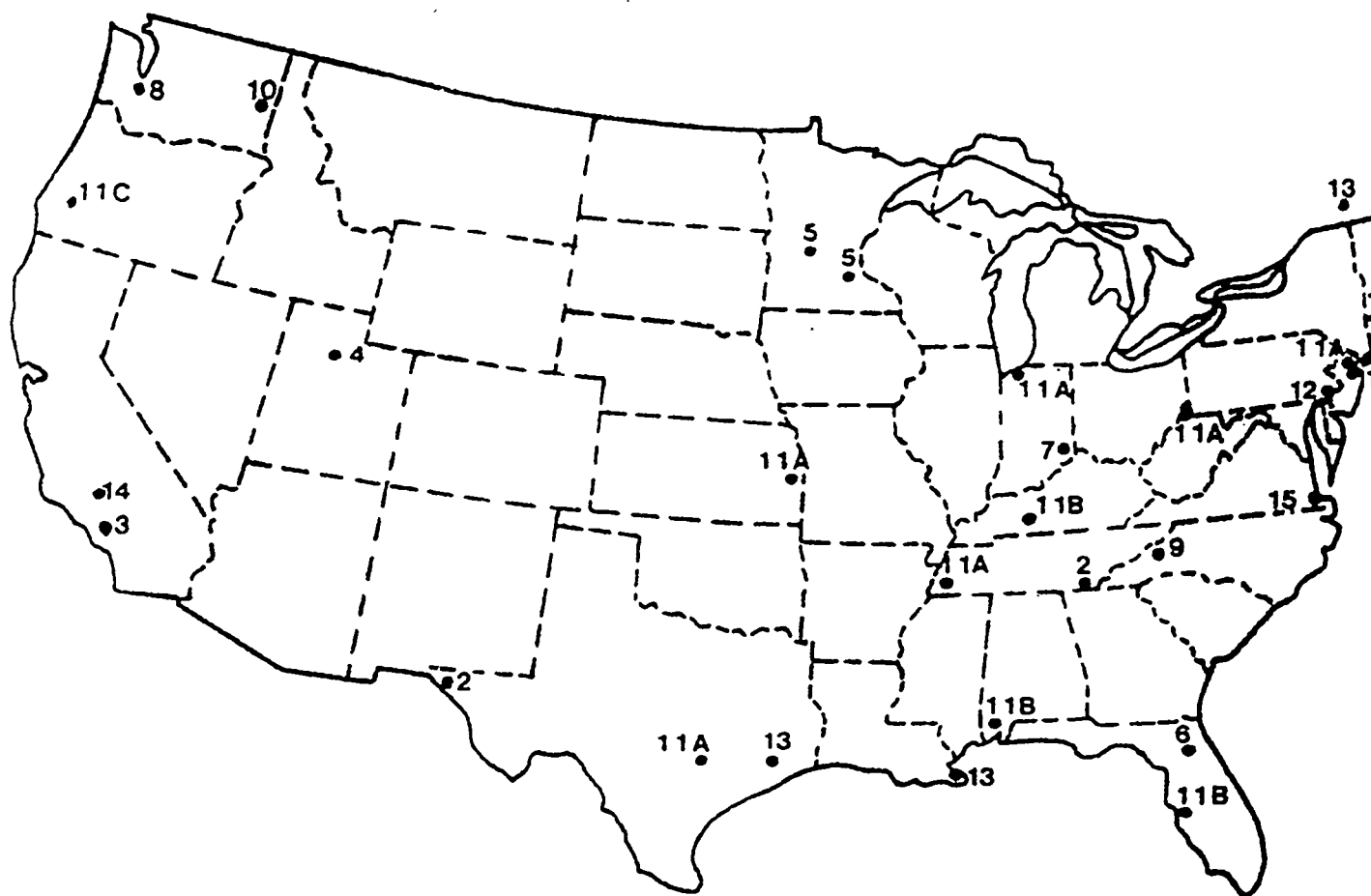
1. Lone Star Minerals, Inc. (H.B. Reed & Co., Inc.),
Moundsville

Canada

Quebec

1. Star-Blast Abrasive Co., Longueil

LOCATION OF MINERAL ABRASIVE PROCESSING PLANTS



- | | | |
|--|---|--|
| 1. Anchor Abrasives Corp.
Cateret, NJ | 8. Industrial Mineral
Products, Inc.
Tacoma, WA | B. Mineral Aggregates Co
Inc.
East Tampa, FL
Greenville, KY
Satsuma, AL |
| 2. Apache Abrasives, Inc.
El Paso, TX
Copperhill, TN | 9. International Mineral &
Chemical Corporation
Burnville, NC | C. Mineral Aggregates Co
Inc.
Riddle, OR |
| 3. R. A. Barnes
Vernon, CA | 10. Kleen Blast Division of
Leisure Investment Co.
Spokane, WA | 12. MDC Industries, Inc.
Philadelphia, PA |
| 4. Copper Mountain Abrasive
Company
Salt Lake City, UT | 11. Lone Star Minerals, Inc. | 13. Stan-Blast Abrasive Co.
Harvey, LA
San Leon, TX
Longueuil, Quebec, Canada |
| 5. Diamond Grit, Inc.
Melrose, MN
Woodbridge, MN | A. H.B. Reed & Co., Inc.
Concord, NJ
Gary, IN
Memphis, TN
Moundsville, WV
Kearny, NJ
La Cygne, KS
Rockdale, TX | 14. Valley Abrasive Shot
Irwindale, CA |
| 6. E. I. DuPont de Nemours &
Company, Inc.
Starke, FL | | 15. Virginia Materials Corp.
Norfolk, VA |
| 7. Gibbco, Inc.
Lawrenceburg, IN | | |

APPENDIX B
Tentative Specification;
Mineral Slag Abrasives

TENTATIVE SPECIFICATION: MINERAL SLAG ABRASIVES

1. SCOPE

1.1 scope This specification covers mineral abrasives such as coal slag, copper slag, nickel slag or any slag mixtures which are suitable for removing rust, scale, old paint, and marine growths from ship hulls and tanks by blast cleaning.

1.2 Classification - This specification covers only those abrasives commonly known as utility grades.

2. APPLICABLE DOCUMENTS

2.1 The following specifications and standards, of the issue in effect on date of invitation for bids, form a part of this specification to the extent specified herein:

SPECIFICATIONS

ASTM C 702-80
ASTM D 451-80
ASTM D 1125-82
ASTM D 1193-77

3. REQUIREMENTS

3.1 Material - The abrasive may be any material meeting the requirements of this specification. It shall be composed of clean sound hard particles essentially free from foreign or deleterious substances such as dirt, toxic substances and organic matter.

3.2 Material Certification - The abrasive supplier shall certify that any product to be delivered conforms to all requirements stated herein.

3.3 pH - A slurry mixture prepared in accordance with 4.4.1 shall not have a pH less than 6.20.

3.4 Chloride Content - The chloride content of the abrasive shall not exceed 300 ppm when tested as specified in 4.4.2.

3.5 Electrical Resistivity - The electrical resistivity of the abrasive shall be higher than 2,000 ohm-cm when tested in accordance with 4.4.3.

3.6 Moisture Content - The moisture content will not exceed the limits specified below when tested in accordance with 4.4.4.

3.6.1 Delivery in Sacks - The moisture content for material delivered in bags or sacks shall not exceed 0.5 percent.

3.6.2 Delivery in Bulk - When "dry" material is specified the moisture content shall not exceed 0.5 percent, otherwise there is no moisture limitation. If purchase is by weight, the moisture in wet material shall be determined and the net weight of the material determined by correcting the gross weight for moisture content, according to the formula in 5.4. No weight correction is required for "dry" material.

3.7 Free Flow - At least 99% of the abrasive material shall flow freely from the test cylinder when inverted to 75 degrees below the horizontal after having the abrasive wetted and dried. The test shall be carried out in accordance with 4.4.5.

3.8 Hardness - The abrasive material shall have a minimum hardness of 6 on Moh's scale when tested as specified in 4.4.6.

3.9 Grain Shape - The individual abrasive grains shall be from angular to rounded in shape.

3.10 Specific Gravity - The specific gravity of the abrasive material shall not be less than 2.2 when tested in accordance with 4.4.7.

3.11 Sieve Analysis - The material shall comply with Table I when tested in accordance with 4.4.8.

Table I - Sieve Analysis, Utility Grade Abrasive

Standard US Sieve No.	% Abrasive Retained, by weight	
	Minimum	Maximum
6	0	
10	0	35
20	45	100
30	0	25
40	0	20
50	0	10
60	0	1
70	0	1
100	0	1
Pan	0	1

3.12 Cutting Rate - The abrasive material shall demonstrate a cutting rate greater than 0.8 gram metal removed per kilogram of abrasive when tested in accordance with 4.4.9.

3.13 Breakdown Rating - The breakdown rating of the abrasive material shall be greater than 0.25 when tested in accordance with 4.4.9.

3.14 Dust Production - The weight percent dust generated shall not exceed 13.5% or local health regulations, whichever is lower, when tested in accordance with 4.4.9.

3.15 Surface Profile - The abrasive material shall produce a surface profile (peak-to-valley) of 2-4 roils when tested in accordance with 4.4.9.

4. QUALITY ASSURANCE PROVISIONS

4.1 The supplier is responsible for the performance of all certification requirements prior to product delivery. The supplier may utilize his own facilities or any independent laboratory. Records of the examinations and tests shall be kept complete and available to the purchaser as specified in the contract or order.

4.2 Sampling for Quality Assurance Tests

4.2.1 Filled Sacks - When the abrasive material is delivered in filled sacks, not less than two nor more than five sacks shall be chosen at random for testing. Each sack shall be thoroughly mixed and then a composite sample shall be formed by thoroughly mixing one quarter from each sack. The resulting sample is to be reduced following ASTM C702-80 Method B into a single sample of approximately 50 lbs. This sample shall be placed in a clean, dry, airtight metal container which shall be tightly sealed and properly marked.

4.2.2 Bulk Shipments - If possible, samples shall be obtained while the abrasive material is being unloaded. The sampler should realize that particle size segregation may occur. Samples shall be taken at three or more locations during the unloading of each vehicle and shall be taken from the entire cross section of material flow. Samples from a loaded vehicle such as a gondola-type railroad car shall be taken from approximately three trenches dug across the car at points which appear to be representative of the material. The bottom of the trench should be at least one foot wide at the bottom and should be level. Equal portions shall be taken at approximately 9 equally spaced points along the bottom of the trench by pushing the shovel downward into the material. Two of the points shall be directly against the sides of the car. Sampling tubes capable of withdrawing vertical samples from top to bottom of product may also be used. A sufficient number of insertions shall be made to provide the requisite sample. Samples from stockpiles shall be taken at or near the top, at or near the base and at an intermediate point. A board shoved into the pile just above the point of sampling will aid in preventing further segregation during sampling. The total weight of the samples taken shall not be less than 200 lbs. This sample is to be reduced following ASTM C702-80 Method B into a single sample of approximately 50 lbs. This sample shall be placed in a clean, dry, airtight metal container which shall be tightly sealed and properly marked.

4.3 Certification Requirements - The samples selected in accordance with 4.2 shall be subjected to the tests specified in 4.4. If the sample fails one or more of these tests as judged by

the requirements stated in sections 3.1 through 3.15, the entire lot shall be rejected. Rejected lots may be resubmitted for acceptance tests provided the contractor has removed or reworked all nonconforming material.

4.4 Test Procedures

4.4.1 pH Test - A 100 gram representative abrasive sample is to be crushed using a mortar and pestle. Approximately 50 grams of the crushed sample is to be added to 200 ml of ASTM D1193-77, Type III Reagent Water. The pH of this slurry is then determined through the use of an electronic pH meter with an accuracy of ± 0.01 pH unit or better. The pH meter should be calibrated with NBS traceable pH buffers which encompass the pH of the slurry.

4.4.2 Chloride Content - The test for chloride content shall be as follows:

4.4.2.1 Reagents

4.4.2.1.1 Standard Silver Nitrate Solution - The standard silver nitrate solution shall be 0.0100 molar.

4.4.2.1.2 Potassium Chromate Indicator Solution - The standard potassium chromate indicator solution shall be made by dissolving 20 grams of analytical quality potassium chromate in one liter of distilled water.

4.4.2.1.3 Phenolphthalein Indicator - Dissolve 5 grams of phenolphthalein in 1 liter of a 50 percent solution of ethyl alcohol in distilled water.

4.4.2.1.4 Sulfuric Acid - To 975 ml of distilled water slowly add, while stirring, 15 ml of concentrated sulfuric acid.

4.4.2.1.5 Sodium Hydroxide - Dissolve 20.0 grams of sodium hydroxide in 500 ml of distilled water and dilute to 1 liter.

4.4.2.2 Procedure

4.4.2.2.1 A 100 gram representative abrasive sample is to be crushed using a mortar and pestle. Exactly 50.0 grams of the crushed sample is to be added to exactly 250.0 ml of ASTM D1193-77 Type III Reagent Water. Heat the resulting slurry to 50°C and hold approximately at this temperature for ten minutes. If a large temperature excursion occurs causing the solution to boil, the test procedure should be restarted. At the end of the 10 minute period allow the solution to cool and then pour the solution into 50 ml centrifuge tubes and centrifuge until clear. Centrifuge at least 100 ml of solution. Pipet 25.0 ml of clear sample into a 125 ml Erlenmeyer flask. Place a magnetic stirring rod in the beaker and place on a stirrer at low speed. Add four drops of phenolphthalein indicator to the sample. If the solu-

tion is already alkaline (i.e. the solution is pink) neutralize the solution to the acid side of the indicator by dropwise addition of the sulfuric acid. If the solution is already on the acidic side of the indicator, add dropwise, sodium hydroxide solution until the pink color appears and then just eliminate the pink color with the sulfuric acid solution. Add 2 ml of the potassium chromate indicator which will turn the solution yellow. Titrate the solution with the silver nitrate standard from a Class A 10 ml burette until the solution just turns apricot. If the solution turns brick red the end point has been exceeded, and the titration should be performed again. Record the burette reading to the nearest 0.01 ml. Three separate titrations should be completed, and the average of the three runs should be used for the chloride content determination. If any of the three recorded volumes of titrant varies by more than 0.05 from the others, the entire procedure should be repeated.

4.4.2.2.2 Blank - Run a blank determination using 25.0 ml of the distilled water used to make the slurry.

4.4.2.2.3 Calculations

Chloride content, ppm = $(A-B) \times (71)$

A = average ml of three silver nitrate titrations

B = ml of silver nitrate used in blank titrations

4.4.3 Electrical Resistivity

4.4.3.1 Method - The electrical resistivity shall be determined in accordance with ASTM D1125-82 Method B for solutions having conductivities greater than 10 $\mu\text{mhos/cm}$ (resistivities less than 100 Kohm-cm). The test shall be carried out with a dip-type cell meeting the requirements of ASTM D1125-82. The procedure for making the test solution is described below.

4.4.3.2 Test Solution - Rinse all apparatus to be used with ASTM D1193-77, Type III water until the rinse water has a resistance of 1 Megohm-cm or higher. Measure equal volumes of abrasive and of Type III water and mix together. Stir this slurry for five minutes. Centrifuge the solution in order to remove suspended abrasive. Into a 250 ml graduated cylinder, pour enough clear solution to reach the 200 ml mark. This cylinder will hold the solution for testing under the procedures of ASTM D1125-82 Method B.

4.4.4 Moisture Content - Approximately 200 grams (gm) of the sample shall be weighed to the nearest 0.1 gm in a tared weighing dish and dried at 105 to 110°C for 3 hours or more until successive weighings after additional 1-hour heating periods show a weight change of not more than 0.1 percent. The percentage of moisture shall be calculated as follows:

$$\text{Percent moisture} = \frac{\text{Original weight} - \text{final weight}}{\text{Original weight of sample}} \times 100$$

4.4.5 Free Flow - A representative sample of the material shall be placed in a suitable bronze cylinder having an inside diameter of 1.25 inches and a length of 6 inches. One end of the cylinder shall be capped and the other shall be closed with a cap having holes made with a number 40 drill (approx.). The abrasive material shall be placed in this cylinder with the solid cap at the bottom and the cylinder shall be filled with water. After standing 1 hour, the cap with the holes shall be placed on the cylinder, which shall then be inverted. The solid cap shall be removed, and the water allowed to drain through the holes of the bottom cap. The cylinder shall then be placed in an oven at 115 to 120°C until all the water is evaporated. The cylinder shall then be removed from the oven, cooled in air, and inclined to an angle of 75 degrees below horizontal so that the abrasive can flow freely by gravity. Any solidification of the abrasive in the cylinder will be cause for rejection of the sample.

4.4.6 Hardness - Hardness shall be determined as follows: Examine the abrasive material under a low-power microscope (10X), and if grains of different color or character are present, select a few grains of each. Place in succession, the grains thus differentiated between two glass microscope slides. While applying pressure, slowly move one slide over the other with a reciprocating motion for 10 seconds. Examine the glass surface and, if scratched, the material shall be considered as having a minimum hardness of 6 on Moh's scale. If any grains that fail to scratch glass are present in any appreciable quantity, the lot is subject to rejection.

4.4.7 Specific gravity - Specific gravity shall be determined as follows: A 300 gram sample of material previously dried is placed in a 500 ml graduated cylinder previously filled with 250 ml of distilled water. The reading of the graduated cylinder, minus 250, will give the volume of the granules. The specific gravity is computed as follows:

$$\text{Specific gravity} = \frac{\text{Weight of sample (grams)}}{\text{Water level after addition of sample}-250(\text{ml})}$$

4.4.8 Sieve Analysis - The representative 50 lb abrasive sample is to be split into four samples in accordance with ASTM C702-80 Method B. Three of these four samples are to be further reduced to 200-250 gram samples in accordance with ASTM C702-80 Method A. Each of these samples is to be sieved in accordance with ASTM D451-80. The selected sieve screens shall be Nos. 10, 20, 30, 40, 50, 60, 70, 100 and a catch pan. Record the percent abrasive retained on each screen and in the pan. If the percent abrasive retained on any one sieve screen for a particular 200-250 gram sample varies by more than 5% from another sample, combine all four large samples and begin again. Record the

percent retained on each screen for the average of the three samples.

4.4.9 Blasting Tests for Cutting Rate, Breakdown Rating, Dust Production, and Surface Profile

4.4.9.1 Test Requirements - All testing shall be done using a test chamber similar to that shown in Figure B-1. A source of clean, dry, oil-free air should provide 90 psig at a 1/4" nozzle. The pressure at the nozzle tip should be measured with a hypodermic needle gauge. The nozzle tip shall be 7 1/4" from the steel test plate. The steel test plate shall be 3" x 5" X 1/4" (SAE 1018, hot rolled) and mounted at a 90° angle to the blast nozzle.

4.4.9.2 Test Procedure - Load the abrasive feed pot with approximately 3000 grams of abrasive. Start the compressor and regulate the pressure until 90 psig is obtained at the nozzle. Open the abrasive feed valve until the abrasive flow is just visible. Re-check the nozzle pressure. If it is still at 90 psig, shut off the air upstream of the air regulating valve. Insert and secure the nozzle into the nozzle mount. Insert a practice plate in the plate holder. While viewing from above, open the air valve and check that abrasive impingement occurs at the center of the plate. Reposition the nozzle if necessary. When the nozzle is aligned properly, shut off the air flow. Open the test chamber and thoroughly rid the chamber of all dust.

Inset a preweighed (to the nearest 0.1 gram) test plate into the specimen holder. Preweigh the filter bag and the abrasive catch bucket to the nearest 0.1 gram. Fill the abrasive feed pot with approximately 3,000 grams of sample. Turn on the air flow and blast the plate until at least 1,000 grams of abrasive have been consumed. When the blasting is complete, remove and weigh the filter bag. Record this value. Open the chamber top to brush the dust from the baffles and walls into the abrasive catch bucket. Remove the bucket and weigh it. Record this value. Record the post-blast weight of the test plate.

4.4.9.3 Post-Blast Data Reduction

4.4.9.3.1 Cutting Rate - The cutting rate is defined as the grams of metal lost from the test plate per kilogram of spent abrasive. It is computed as follows:

$$\text{cutting rate} = \frac{\text{plate weight loss (gms)}}{\text{spent abrasive (gms)}} \times 1000$$

where,

$$\text{plate weight loss, gms} = (\text{pre-blast plate weight}) - (\text{post-blast plate weight})$$

$$\text{spent abrasive, gms} = (\text{post-blast weight of filter bag} + \text{abrasive catch bucket weight}) - (\text{pre-blast weight of filter bag} + \text{abrasive catch bucket weight})$$

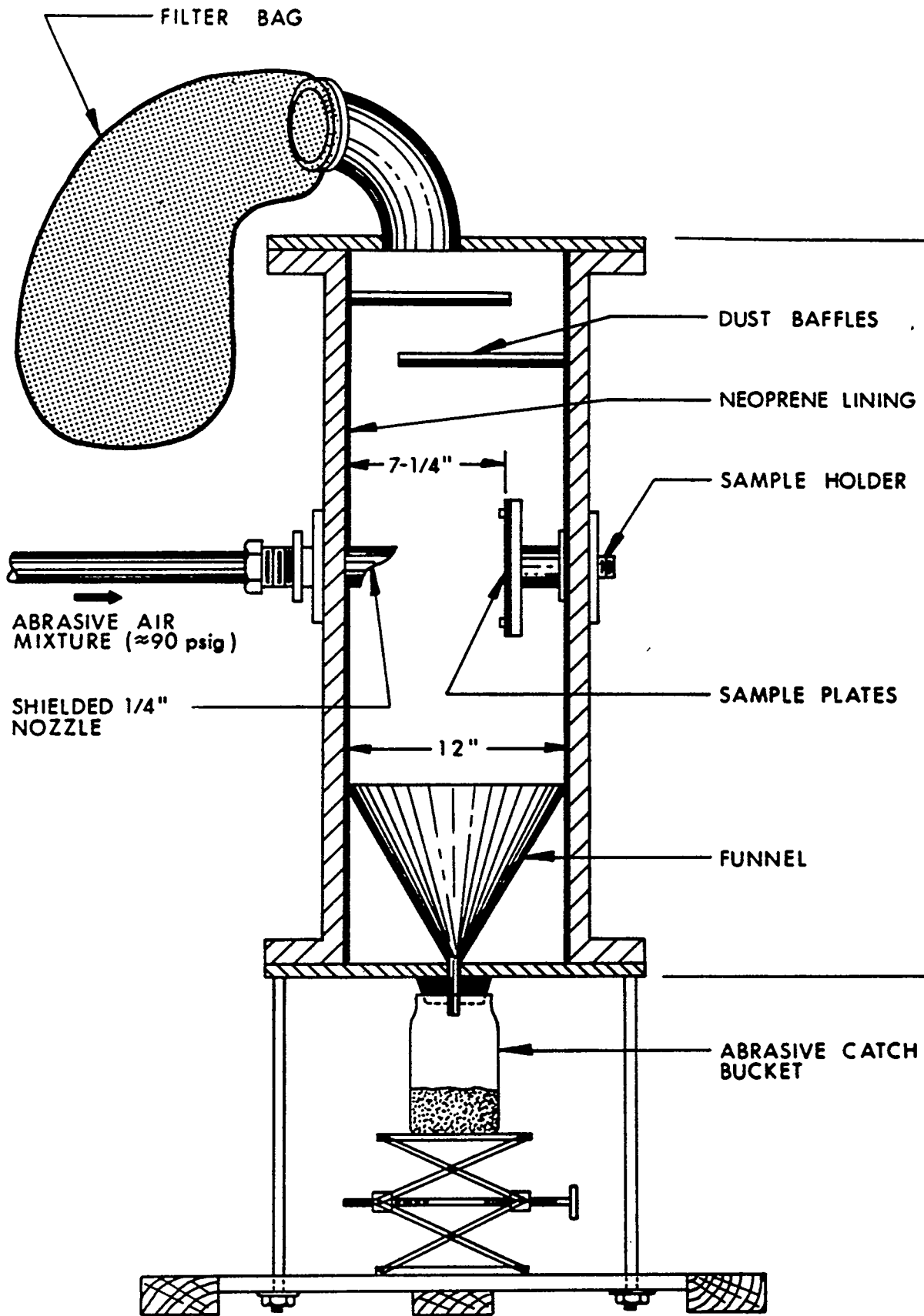


FIGURE B-1. Abrasive Blasting Test Chamber

4.4.9.3.2 Breakdown Rating - The spent abrasive in the catch bucket shall be split into a 200-250 gram representative sample in accordance with ASTM C702-80 Method A. The sample shall then be sieved in accordance with ASTM D451-80. As in 4.6.8 the pans shall be Nos. 10, 20, 30, 40, 50, 60, 70, 100 and a catch pan. Record the percent abrasive retained on each screen. Only one sample shall be sieved after testing. The breakdown rating shall be calculated as illustrated in the example below. (It is necessary to use the pre-blast sieve analysis performed in 4.6.8)

Example

<u>Sieve No.</u>	<u>Average Opening</u>	<u>Pre-Blast Sieve Analysis</u>		<u>Post-Blast Sieve Analysis</u>	
		<u>%</u>	<u>Factor</u>	<u>%</u>	<u>Factor</u>
10	0.08583	15.37	1.3192		
20	0.05610	60.52	3.3952	21.79	1.2224
30	0.02854	14.29	0.4078	17.51	0.4997
40	0.02018	5.54	0.1118	16.46	0.3322
50	0.01427	1.81	0.0258	15.16	0.2163
60	0.01083	0.11	0.0012	5.80	0.0628
70	0.00909	0.45	0.0041	5.33	0.0484
100	0.00713	0.11	0.0008	6.90	0.0492
Pan	0.00295	0.23	<u>0.0007</u>	11.61	<u>0.0342</u>
		Sum =5.2666		sum = 2.4653	

where,

% = Weight percent abrasive retained on each screen
Factor = % x Average opening

$$\text{Average opening*} = \frac{(\text{Sieve Opening} + \text{Previous Size Opening})}{2 \times 25.4}$$

(in inches)

thus ,

$$\text{Breakdown Rating} = 2.4653/5.2666 = 0.47$$

* As examples,

$$\text{For No. 10} = (\text{No. 10} + \text{No. 8})/2 = (2.00 \text{ mm} + 2.36 \text{ mm})/2 \times 25.4 = 0.08583$$

$$\text{For No. 20} = (\text{No. 10} + \text{No. 20})/2 = (2.00 \text{ mm} + 0.850 \text{ mm})/2 \times 25.4 = 0.05610$$

4.4.9.3.3 Dust Production - The percent dust production is defined by the following formula:

$$\% \text{ Dust Production} = \frac{(\text{post-blast wt. of filter bag} - \text{pre-blast wt.})}{\text{spent abrasive}}$$

where, spent abrasive is as defined in 4.6.9.3.1.

4.4.9.3.4 Surface Profile - The surface profile shall be measured at the center of the test plate using Press-O-Film*. The coarse grade shall be used for profiles of 0-2 roils and the x-coarse grade for profiles of 1.5-4.0 roils. The manufacturer's directions shall be followed in using the film.

5. NOTES

5.1 Intended Use - The abrasives covered by this specification are intended primarily for use in the blast cleaning of the underwater surfaces of ship hulls and of tank surfaces prior to painting.

5.2 Ordering Data - Procurement documents should specify the following:

- (a) Title, number, and date of specification.
- (b) Whether for sack or bulk shipment.
- (c) Total size of shipment.
- (d) If shipment is in bulk, whether "dry" material is required; whether the unit of measure is net weight or volume; whether delivery is to be by rail or truck, and if by rail the type of car to be used.

5.3 Tests Prior to Award of Contract - The award of a contract shall be made only on abrasives which have been certified to have passed all of the tests of this specification.

5.4 Correction of Gross Weight of Bulk Shipments for Moisture Content - When other than "dry" abrasives are procured by net weight in bulk, it is necessary that the moisture content of the material be accurately determined at the time of weighing and the net weight calculated by subtracting the amount of moisture present from the gross weight as indicated in the following formula:

$$\text{Net weight} = \text{Gross weight} - \frac{\text{Gross weight} \times \text{Percent moisture}}{100}$$

APPENDIX C
Test Date on
Natural Stauralite Abrasive

TABLE C-I - Summary of Chemical and Physical Test Results
On Natural Stauralite Abrasive

<u>pH</u>	<u>Chloride Content ppm</u>	<u>Solution Resistivity Ohm-cm</u>	<u>Moisture Content %</u>
9.04	42.5	41000 38000	0.0
<u>Free Flow</u>	<u>Hardness Mho's</u>	<u>Grain Shape</u>	<u>Specific Gravity</u>
No visible clumping	≥6	Angular to Rounded	3.6

TABLES C-II - Summary of Sieve Analysis On
Natural Stauralite Abrasive

% Retained								
<u>#10 Sieve</u>	<u>#20 Sieve</u>	<u>#30 Sieve</u>	<u>#40 Sieve</u>	<u>#50 Sieve</u>	<u>#60 Sieve</u>	<u>#70 Sieve</u>	<u>#100 Sieve</u>	<u>Pan</u>
0	0	1	6	26	16	19	26	6

TABLE C-III -Summary of Blasting Test Results
On Natural Stauralite Abrasive

<u>Total Spent Abrasive (gms)</u>	<u>Total Dust Generated (gms)</u>	<u>Weight Percent of Dust Generated</u>	<u>Plate Weight Loss (gms)</u>	<u>Cutting Rate g of metal removed kg of abrasive</u>	<u>Breakdown Rating</u>
677.0	46.0	6.8	1.2	1.8	0.84
1644.0	83.0	5.1	2.5	1.5	0.81

TABLE C-IV - Summary of Resulting Surface Profile On Steel Test Plates
(90° Angle of Blast) - Natural Stauralite Abrasive

<u>Surface Profile (mils)</u>		
<u>Elcometer</u>	<u>Press-O-Film</u>	<u>Surfanalyzer</u>
1.4	1.5	1.8