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# REFURBISHMENT OF SRB ALUMINUM COMPONENTS BY WALNUT HULL BLAST REMOVAL OF PROTECTIVE COATINGS

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16. ABSTRACT

A test program was conducted to develop, optimize, and scale-up an abrasive blasting procedure for refurbishment of specific SRB components: Aft Skirt, Forward Skirt, Frustrum, and painted piece parts.

Test specimens utilizing 2219 T87 aluminum substrate of varying thicknesses were prepared and blasted at progressively increasing pressures ($2.76 \times 10^5$ - $5.52 \times 10^5$ N/m$^2$) with selected abrasives. Specimens were then analyzed for material response. The optimum blasting parameters were determined on panel specimens and verified on a large cylindrical Integrated Test Bed (ITB). This report presents findings and conclusions of that study.

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TECHNICAL MEMORANDUM

# REFURBISHMENT OF SRB ALUMINUM COMPONENTS BY WALNUT HULL BLAST REMOVAL OF PROTECTIVE COATINGS

## INTRODUCTION

The Solid Rocket Boosters (SRB) were designed and developed to be used with Space Shuttle Main Engines to provide the initial thrust to lift the Shuttle from the launch pad to an altitude of 44 km. At that altitude, the SRBs will separate and start their return to Earth. A parachute recovery subsystem provides for controlled descent. The SRBs are recovered from the ocean and transferred to Kennedy Space Center (KSC) for disassembly and refurbishment.

Refurbishment consists of cleaning, analysis, and repair of the SRB Structures Subsystem Components and return to the inventory for the next flight. The Structures Subsystem, Thermal Protection System (TPS), will be completely removed after each flight with an assessment of paint degradation and repair, as required, prior to replacement of the TPS. After 3 to 5 flights the paint will be totally removed and new new paint applied. This study was initiated to develop an abrasive blasting process to strip paint from the aluminum components in the most economical and expeditious manner with minimal damage to the aluminum substrate.

## SURFACE PREPARATION/BACKGROUND

Bare aluminum, exposed to the elements, particularly ocean water and spray will corrode rapidly, therefore the surface must be provided with a barrier to the destructive forces in the form of a well bonded protective (paint) coating. Before application of the protective coating, the substrate surface must be prepared with consideration to processing economics, harmful effects to the substrate and the ease of operations. Available surface preparation methods for surfaces already coated with oxidized or damaged paint include chemical stripping which is slow and presents effluent disposal problems, and mechanical methods such as wire brushing and hand sanding, which are slow and labor intensive.

Experience acquired at this Center and descriptions in the literature show the most efficient and practical method for paint removal from SRB structures to be abrasive blast cleaning. This is a process in which contaminants, old paint coatings, etc., are removed from metal surfaces by forceful impingement of an abrasive material to provide a clean surface suitable for the application of protective coatings (the abrasive blast cleaning process is not final in itself but is the initial stage of a subsequent three coat finish process, in the case of aluminum, consisting of a chromate conversion coating, primer coat, and paint topcoat). The type and availability of equipment to propel the abrasive particles was a consideration. There are basically two ways of providing the energy source to the abrasive media in the blasting process. One utilizes compressed air as the vehicle to propel the abrasive to the surface of the work article, and the other is airless blasting whereby power of a hardened blast wheel provides centrifugal force to propel the abrasive. The latter method was not considered for this work, since correctly sized equipment was not available.

The compressed air blasting techniques use compressed air to propel a stream of abrasive particles at high velocity onto a substrate surface. The expended energy of these particles on impact has the effect of breaking up surface contaminants and coatings and effecting their removal with creation of a patterned or cratered surface profile on the substrate surface. This surface pattern is often referred to as anchor pattern.

In order to achieve optimum conditions for maximum efficiency in the operation, the abrasive cleaning equipment must have integrated design features. The equipment components, such as, hoses, nozzles, metering valve, pressure controls, couplings, etc., must be properly sizes and configured with the appropriate relationship to the selected abrasive and the total energy of the system. The kinetic energy the abrasive transmits is computed according to the formula:

$$E = 1/2\ mV^2$$

or energy transmitted is proportional to the mass (or weight) of abrasive and to the square of its velocity.

Selection of abrasives for evaluation was therefore governed by the following characteristics of the abrasives and of the substrate/process.

| Abrasive Characteristics | Substrate/Process Characteristics |
|---|---|
| 1. Abrasive size | 1. Condition of surface to be cleaned |
| 2. Abrasive shape | 2. Surface finish required |
| 3. Abrasive hardness | 3. Type of component |
| | 4. Component hardness |
| | 5. Economics |

Given the intent (guidelines) to completely remove the SRB paint every 3 to 5 flights with no more than 9 mils total metal removal over the duration of 20 flights, the rationale was to find a fast, successful, and realistically priced method that would inflict minimal component substrate damage in terms of:

1) Metal removed

2) Induced stress

3) Warpage

4) Surface roughness.

This document is the result of that effort.

## ABRASIVES

Natural abrasives used for surface finishing include the diamond, emery, carborundum, sand, crushed garnet and quartz, tripoli, and pumice. Artificial abrasives are mostly silicone carbide, aluminum oxide, boron carbide, or boron nitride marketed under trade names [1]. Apricot pit, pecan, black walnut, english walnut, and rice shells (hulls) as well as corn cobs also serve as natural organic abrasive materials when properly crushed and graded with sieves [3].

Successful processing depends on the uniformity of size of the abrasive employed. Coarse or oversize particles cause deep scratches which are difficult to remove, and an excess of finer particles will slow production. Abrasive grains are graded on a series of screening and grading devices and should not be allowed to become mixed or to come in contact with oil or oily dust [2]. Recirculation of abrasives eventually renders them ineffective, since continued inpact causes grain cracking, rounding of edges, and loss as dust.

TABLE 1. PHYSICAL PROPERTIES OF ABRASIVES [4]

| Abrasive | Chemical Formula | Specific Gravity | Hardness (Moh's) |
|---|---|---|---|
| Aluminum Oxide | $Al_2O_3$ | 3.5 - 3.9 | 9 |
| Silicon Carbide | SiC | 3.217 | 13 |
| Silicon Dioxide | $SiO_2$ (quartz) | 2.653 - 2.66 | 7 |
| Garnet (common) | $3CaO.Fe_2O_3.3SiO_2$ | 3.64 - 3.9 | 6.5 - 7.0 |
| Walnut Hulls | – | 1.25 | – |
| Carbonite | $Al_2O_3$ (corundum) | 3.97 - 4.10 | 9 |

## PRELIMINARY TESTING

At the beginning of the study several test samples were prepared and blasted. This served as a mechanism through which operators were trained in proper use and maintenance requirements of test instruments. This initial analysis was also used to standardize the angle and distance of gun from substrate that would produce optimum results. It was concluded that a 90 deg angle and 0.127 m (5 in.) from the substrate gave best results. Samples for preliminary testing were prepared in the same way as the study test specimens.

## HARDWARE TESTED

### Substrate

Since the aft skirt, forward skirt, and frustum, the major SRB components to be refurbished by NASA are built of Aluminum 2219-T87, it was chosen as the substrate to be used in the development of an abrasive blasting process for the removal of the protective coating. The test specimens were prepared as rectangular panels with an exposed area of $9.29 \times 10^{-2}$ $m^2$ (144 in.$^2$) from three different thicknesses: $1.57 \times 10^{-3}$ m (0.062 in.), $3.18 \times 10^{-3}$ m (0.125 in.), $6.35 \times 10^{-3}$ m (0.250 in.). The test specimens were prepared using the procedure specified in Marshall Specification 10A00528:

1) Clean

2) Iridite

3) Prime with Bostik 463-6-3

4) Paint with Bostik white epoxy top coat

5) Cure.

Because of the physical characteristics of this substrate and past experience with abrasive blasting processes, different abrasives and sizes were deliberately selected to inflict minimal substrate damage.

### Equipment

The equipment selected was a Pauli & Griffin Type I Dry Honer model DH48 (Fig. 1). This is a self-contained abrasive blast unit. The abrasives are suspended and propelled by a high velocity air stream. After striking the work surface, abrasives fall to the cabinet hopper and are conveyed to the cyclone separator. The dust and light weight abrasives that do not settle down are directed to a dust collector for disposal. The heavier abrasives that pass through the screen are returned to the storage hopper and then back to the blasting system: Model DH48 has a 4.54 kg (10 lb) cleaning powder capacity and the blasting gun is a suction type with a $4.76 \times 10^{-3}$ m (3/16 in.) air jet and $9.53 \times 10^{-3}$ m (3/8 in.) nozzle. Figure 2 shows a front view of the gun, nozzle, and hose. The nozzle is considered the most important component of the system. The amount of energy dissipated and cleaning speed are functions of the nozzle distance to the work surface. The nozzle diameter is selected in accordance to the air power supply available and system design. Another factor in the selection of the nozzle is its length. A long nozzle will provide a high velocity with increased concentration of abrasive on impact, while a relatively short nozzle provides a wider area of impact with the abrasive being spread and decreased velocity [4].

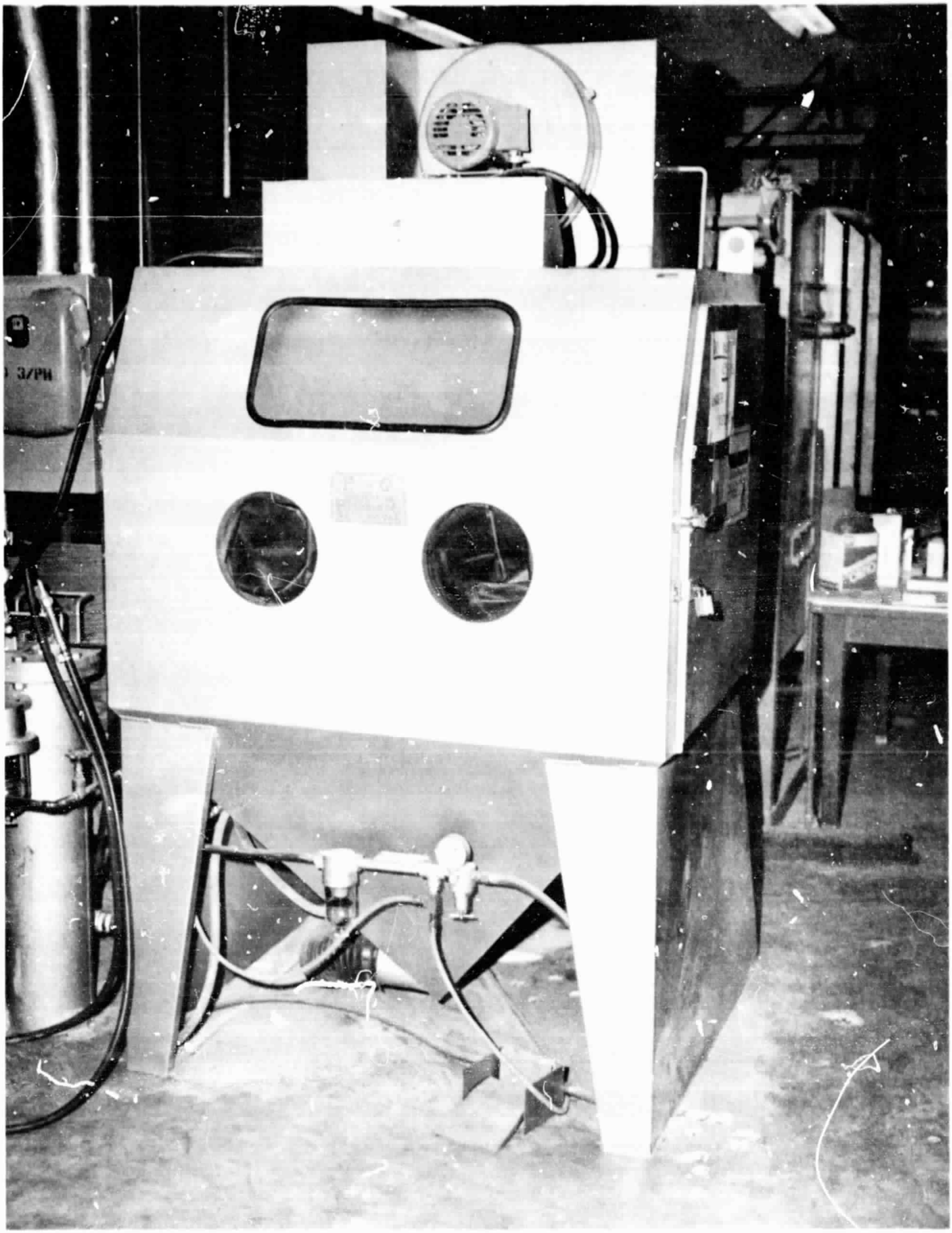


Figure 1. Pauli & Griffin Type 1 dry honer model DH48.

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Figure 2. Gun, nozzle, and hose.

### Instrumentation

Non-destructive techniques were utilized to measure residual stress and surface roughness. The X-ray method was used to measure the induced stress in the aluminum specimen; it was possible to use this method because of the elasticity of the aluminum [5]. A Brush Instruments Surf Indicator was used to measure the average surface roughness. Test specimen's warpage and thickness were measured with a Vernier Caliper and a straight edge. All readings used are an average of data collected.

A Dermitron thickness measuring instrument was used to determine the paint thickness. Test specimens were weighed before and after blasting and the metal loss was found to be negligible.

## TESTING

### Stress

In abrasive blasting, particles are propelled toward the material being blasted with velocity which causes surface indentations. These indentations result in local plastic yielding. As the expansion of an affected area occurs, adjacent material, not plastically affected, restrains this imposed expansion. The plastically deformed layer, being dimensionally deformed and yet restrained from compensating expansion into adjacent space, is compressively stressed during the operation and retains a certain amount of residual stress. Residual stresses may be defined as stresses that would remain in an elastic solid body if all external loads were removed. One important consideration was to find an abrasive that would induce minimum compressive stress in the surface being cleaned.

Eight different abrasives were selected based on past experience and desired results on the substrate:

1) Silica sand 40/70

2) Silica sand 80/90

3) Garnet 25

4) Garnet 80

5) Silicon carbide 30/60

6) Aluminum oxide 36

7) Aluminum oxide 80

8) Walnut hulls 12/20.

Test specimens were analyzed with a Faststress Analyzer (automated X-ray diffraction) This is a non-destructive technique used to determine induced surface stress on the substrate; strains are measured only at the surface where the stress is relieved in the normal direction. Table 2 shows the average stress values recorded from the analyzer. No surface stress was detected in panels blasted with walnut hulls when analyzed with Fastress Analyzer.

TABLE 2. AVERAGE COMPRESSIVE STRESS (40-80 psi PRESSURE RANGE)

| Abrasive | Average Compressive Stress (ksi) |
|---|---|
| Garnet 25 | – |
| Silicon Carbide 30/60 | 23.6 |
| Aluminum Oxide 36 | 25.81 |
| Silica Sand 40/70 | 30.51 |
| Garnet 80 | 28.43 |
| Aluminum Oxide 80 | 33.85 |
| Silica Sand 80/90 | 33.10 |
| Walnut Hulls 12/20 | no stress detected by analyzer |

## Warpage

When a specimen is blasted, residual compressive stress induces convex curvature (warpage) on the peened side. Warpage is dependent upon the amount of abrasive striking the surface (the amount is proportional to blasting time) and to abrasive particle size, speed, direction, hardness, and rheological properties.

Table 3 represents average warpage induced by each abrasive for pressures in the range $2.76 \times 10^5$ to $5.52 \times 10^5$ $N/m^2$ (40 to 80 psi). As shown, blasting with walnut hulls gives the least amount of convex curvature. The abrasive producing the next smallest warpage was Aluminum Oxide 80.

TABLE 3. AVERAGE WARPAGE (40-80 psi PRESSURE RANGE)

| Abrasive | Warpage (m) |
|---|---|
| Garnet 25 | $1.14 \times 10^{-2}$ m (0.4506 in.) |
| Silicon Carbide 30/60 | $1.18 \times 10^{-2}$ m (0.4636 in.) |
| Aluminum Oxide 36 | $9.41 \times 10^{-3}$ m (0.3706 in.) |
| Silica Sand 40/70 | $1.3 \times 10^{-2}$ m (0.5120 in.) |
| Garnet 80 | $8.08 \times 10^{-3}$ m (0.3183 in.) |
| Aluminum Oxide 80 | $6.15 \times 10^{-3}$ m (0.2421 in.) |
| Silica Sand 80/90 | $7.98 \times 10^{-3}$ m (0.3142 in.) |
| Walnut Hulls 12/20 | $4.90 \times 10^{-4}$ m (0.0193 in.) |

## Roughness

Surface finish of the test specimens blasted was modified by the peening action of the abrasive grains. Different factors such as abrasive size, hardness, speed, shape, and impact angle provide a wide range of irregularities. This surface irregularity is generally called anchor pattern or surface roughness. A Surf Indicator was used to measure surface finish of blasted panels. This instrument measures height irregularities created by abrasive impacts. An arithmetic average of the irregularities yields an average roughness value for a particular area being measured. Table 4 shows average roughness results for each abrasive. These values clearly indicate that panels blasted with walnut hulls exhibited the least amount of surface roughness.

TABLE 4. AVERAGE ROUGHNESS (40-80 psi PRESSURE RANGE)

| Abrasive | Average Roughness (μm) |
|---|---|
| Garnet 25 | 5.05 (199 μin.) |
| Silicon Carbide 30/60 | 4.19 (165 μin.) |
| Aluminum Oxide 36 | 4.17 (164.33 μin.) |
| Silica Sand 40/70 | 3.55 (140 μin.) |
| Garnet 80 | 3.11 (122.30 μin.) |
| Aluminum Oxide 80 | 2.06 (81.33 μin.) |
| Silica Sand 80/90 | 2.03 (79.99 μin.) |
| Walnut Hulls 12/20 | 1.06 (41.70 μin.) |

## Corrosion

Several test panels were randomly selected to simulate hardware refurbishment after being exposed to a salt water environment for seven days (it has been estimated that it would take no more than one week to recover SRB hardware in the worst possible conditions). The aluminum panels (2219 and 6061 alloys) were blasted with walnut hulls to remove the Bostik topcoat and primer, acetone wiped, and repainted with the Bostik system. The test specimens were then prepared for and placed in a 5 percent salt spray chamber for 4032 hr. Tape adhesion tests were then performed on each panel.

Test results indicated that the refurbished Bostik coating system performance was, indeed, very similar to the Bostik coating system as originally applied to the substrate. Based on the test results, it is recommended that the chromate conversion coating be thoroughly examined after walnut hull blasting, and if bare aluminum is exposed, a re-application of the chromate conversion coating is required prior to re-application of the Bostik coating system.

## BLASTING OF INTEGRATED TEST BED (ITB) HARDWARE

A relatively large cylindrical ITB segment was blasted with the selected abrasive, walnut hulls 12/20. The results of this blasting were used as the basis for scale-up estimations and recommendations.

Equipment used for blasting the ITB segment included:

1) Compressor: Schramm model JD18A, serial No. UDP26662 512

2) Hopper: Clemco model SCFW 2452, serial No. 10067

3) Nozzle: $1.27 \times 10^{-2}$ m (0.5 in.) I.D.

4) Hose: $5.08 \times 10^{-2}$ m (2.0 in.) O.D.

The selected blasting sequence cleaned an area of 6.233 $m^2$ (67.09 $ft^2$) and took 2040 sec (34 min) thus producing a removal rate of $3.055 \times 10^{-3}$ $m^2$/sec (1.97 $ft^2$/min) Complete paint removal was accomplished without harm to the underlying chromate conversion coating and without detectable substrate damage. Presuming the removal rate is constant, we can estimate the cleaning time for flight hardware:

1) Aft Skirt:

Area = 34.36 $m^2$ (369.85 $ft^2$)

$$\text{Time} = 34.36\ \text{m}^2 \left(\frac{\text{sec}}{3.055 \times 10^{-3}\ \text{m}^2}\right)\left(\frac{1\ \text{hr}}{3600\ \text{sec}}\right) = 3.13\ \text{hr}$$

2) Forward Skirt:

Time = 3.48 hr

3) Frustrum:

Time = 2.5 hr

The optimum blasting parameters determined for aluminum SRB structures are listed in Table 5.

TABLE 5. OPTIMUM BLASTING PARAMETERS FOR ALUMINUM SRB STRUCTURES

| | |
|---|---|
| Pressure | $5.52 \times 10^5$ N/$m^2$ (80 psi) |
| Distance to substrate | 0.3048 to 0.6096 m (12 to 24 in.) |
| Angle to substrate | 45 to 90 deg |

## ITB REFURBISHMENT

In-house refurbishment of the ITB segment proved no major reconversion coating of the aluminum substrate was required. The ITB segment was sectionally divided and blasted with walnut hulls. Two blasted sections were reprimed and repainted. Two unblasted sections were hand sanded and repainted, and one section was only repainted.

All five sections were tested using Adhesion (wet) Tape Test as per ASTM 6301.1 [8]. No paint was removed in either section.

## CONCLUSIONS

It was determined from data collected and test results that Walnut Hulls 12/20 is the best abrasive among those tested to clean aluminum SRB components while inducing minimum damage to the substrate.

Walnut Hulls were assessed as the appropriate abrasive for SRB refurbishment since:

1) No major reconversion coating of aluminum is required with Walnut Hulls (complete reconversion coating is required with other abrasives tested in this study).

2) Walnut Hulls produced the least amount of surface roughness.

3) No compressive stress is induced by Walnut Hulls.

4) Negligible warpage is created by Walnut Hulls.

5) Walnut Hulls are 100 percent biodegradable; therefore, no pollution is associated with their use.

6) When purchased in large quantities Walnut Hulls are the least expensive abrasive tested (Table 6).

TABLE 6. ABRASIVE COST AND AVAILABILITY

| Abrasive | Cost,[b] $/kg (453.59 kg) | Availability |
|---|---|---|
| Silicon Carbide 30/60 | 0.63 | Yes |
| Aluminum Oxide 30 | 0.50 | Yes |
| Silica Sand 30/90 | 0.48 | Yes[a] |
| Aluminum Oxide 36 | 0.43 | Yes |
| Silica Sand 40/70 | 0.23 | Yes |
| Garnet 80 | 0.21 | Yes |
| Garnet 25 | 0.19 | Yes |
| Walnut Hulls 12/20 | 0.14 | Yes |

a. Special Order
b. Prices subject to change.

## RECOMMENDATIONS

Based on findings and conclusions of this study, the following are recommendations for scale-up of an abrasive blasting system:

Abrasive: Walnut Hulls 12/20

Pressure: $5.52 \times 10^5$ N/$m^2$ (80 psi)

Angle to substrate: 45 to 90 deg

Distance to substrate: 0.3048 to 0.6096 m (12 to 24 in.)

Equipment: Abrasive blast unit equivalent to that employed in ITB blasting with added recirculation capability:

Compressor: Schramm model JD18A, serial No. UDP 26662 512

Hopper: Clemco model SCFW 2452, serial No. 10067

Nozzle: $1.27 \times 10^{-2}$ m (0.5 in.) I.D.

Hose: $5.08 \times 10^{-2}$ m (2.0 in.) O.D.

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