SUCCESSFUL USE OF SOFT ABRASIVES (WALNUT SHELLS) FOR CLEANING OUTDOOR BRONZE SCULPTURE BY AIR JETS

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Introduction

In 1870, in his patent application for the "sand-blast", Benjamin C. Tilghman stated, "Articles of cast or wrought metal may have their surfaces thus smoothed and cleaned from slag, scale or other incrustation." [U.S. Patent No. 108408]. (Tilghman, 1870) Somewhat in keeping with this proposal, outdoor bronze sculpture has been "cleaned" by a process known as glass bead peening since the mid 1970's. This process utilizes "glass microspheres", approximately 100 microns in diameter, as an air driven abrasive at 60-80 psig. Because it was felt that this treatment was too harsh for many applications, and since it was not considered to be reversible, an alternative was sought.

The use of air driven abrasives held potential because, as stated by Tilghman, the ". . . action takes place upon irregular surfaces, concavities, corners and recesses hardly accessible to ordinary methods." (Tilghman, 1870) Tests were carried out on a variety of softer abrasives and preliminary tests indicated that ground walnut shells appeared to remove virtually all of the dirt, grime, and loose or friable corrosion products--without causing any discernible alteration of the metal's surface. Walnut shells were then successfully used in 1979 to clean the Felix de Weldon sculpture of Admiral Richard Evelyn Byrd in Arlington, Virginia. This statue was blasted with commercially available walnut shell blasting media (60/200 mesh) at a pressure of 40 psig. Since then, a number of other bronze statues have been similarly blasted as a portion of their conservation/preservation treatment.

A marked difference in appearance was noted between sculptures blasted with glass beads and those blasted with walnut shells. A search of conservation literature yielded no information on the specific actions or effects of these abrasives on metallic surfaces. Therefore, the literature search was expanded to trade and industrial journals and technical publications related to erosion and wear. Tests were also designed to try to understand the specific actions and effects of the two media on the surfaces of outdoor sculpture. It was also hoped these tests would help evaluate popularly held beliefs that: that glass bead peening does not "remove any metal"; and the use of glass bead peening decreases the corrosion rate of sculpture.

Samples and blasting techniques/equipment

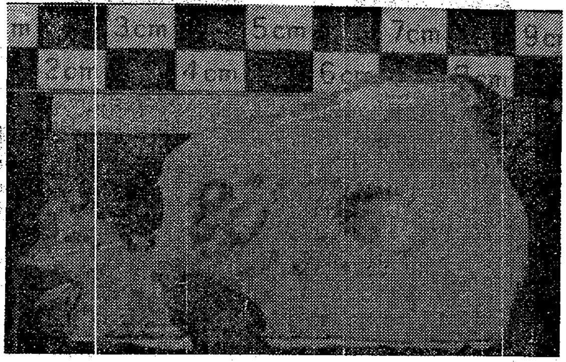
Tests were carried out on samples of wrought copper; a "weathered" bronze plaque; two small, commercially sand-cast test plaques of 85-5-5-5 bronze; and smaller coupons of 90-10 bronze, 87-10-3 bronze, and 71-26-3 bronze. Coupons were cast in the laboratory and metallographically polished before blasting. Both media (walnut shells and glass beads) were used in a commercial sand-blaster following standard "statue cleaning" practices. In this sand-blaster, the blasting media, under pressure, is "injected" into a moving air stream via a controlling valve. The media then mixes with the air stream, is accelerated through the "sand hose", and is ejected through the nozzle where the stream is directed at the surface of the object being blasted. Equipment controlled variables were the same for both media. Operator controlled variables such as air/abrasive ratio, dwell time and working distance were maintained as equitably as possible, for both media. In all tests a 5/32" nozzle was used with a 12 ft. sand hose. A working pressure of 40 psig was maintained by a regulator mounted at the sand-blaster.

Preliminary tests carried out on the weathered plaque and the wrought copper samples showed a definite change in the metal surface following glass bead peening. It was similar to Tilghman's description of a sandblasted metal surface, ". . .a frosted, dull, matt, or dead appearance." (Tilghman, 1870). Ground walnut shells and other soft abrasives, however, had no visible effect on the surface finish of the metal. They did appear to remove virtually all accumulations of dirt, grime, and loose or friable corrosion products. On the copper, following walnut shell blasting, there appeared to be a uniform coating of copper oxide with small patches of very tightly adhering corrosion products. Microscopic examination revealed no alteration of the metallic surface from shell blasting. However, microscopic examination of the glass bead peened surface revealed a surface uniformly covered with craters, having small "flaps" at the edges of some (described by Ruff and Wiederhorn, p. 103). Similar results were observed on all samples of different alloys and on both cast and polished surfaces.

Hard, sharp, angular particles gouge and cut a malleable material when they strike. Rounded or spherical particles compress the surface corresponding to the size, shape, velocity, and density of the particle (Evans, Balcar and Woelfel, Ruff and Weiderhorn). If the metal is not deformed beyond its elastic limit it rebounds and the particle bounces off the surface. When it is deformed beyond its elastic limit, its plasticity causes it to retain the new shape, including the formation of craters. When the next particle hits in an adjacent area the metal is again deformed plastically until it work-hardens and becomes brittle. As the surface becomes more deformed, and work-hardened, the craters become embrittled, and fragments are broken off by subsequent impacts, producing microscopic flakes, similar in appearance to flaked breakfast cereal. If, however, the abrasive particle is more elastic than the surface it is striking, much of the force of impact is absorbed by particle deformation rather than surface deformation.

Weight (surface) loss and surface deformation

Although claims have been made that glass bead peening does not remove metal, experiments carried out on the newly cast plaques (85-5-5-5 bronze), the small coupon (90-7-3 bronze), the large plaque, and a scrap of 87-10-3 bronze indicated otherwise.



Illus. 1 Hole formed by one minute blast of glass beads (100 micron) at 80 psig.

Both the large plaque and the scrap were subjected to a directed blast of glass beads, in one location, for one minute at both 40 and 80 psig. (Illus. 1) In both instances a large conically shaped hole with "rippled" sides developed. A similar directed blast with walnut shells, at the same parameters, showed no alteration of the surface.

In another experiment, a small coupon of 90-7-3 bronze was blasted with glass beads and the two small plaques were blasted with walnut shells and glass beads. In all instances blasting was lightly done with 40 psig. pressure. The two plaques were weighed prior to blasting. There was a loss of 0.6 grams from the plaque blasted with glass beads, but no discernible weight change noted in the shell blasted plaque. A comparable weight loss was also noted in the small coupon of 90-7-3 bronze when it was blasted with glass beads.

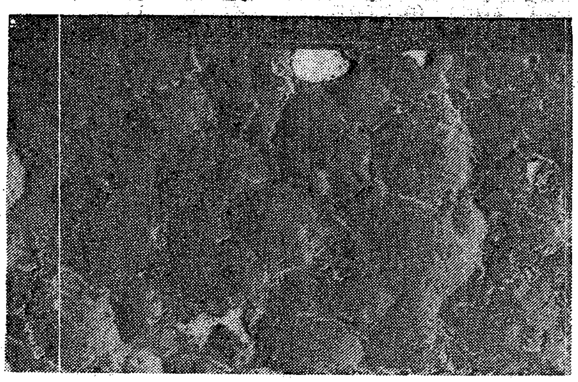
Table I. Weight loss from glass bead peening
(40 psig pressure, 5/32" nozzle, @ 700 grams abrasive used in 15 seconds)

Sample	Before	After	Loss	Loss/Unit area
Small plaque	1506.2g	1505.6 g	0.6g	$2.0 mg/cm^2$
Coupon	78.8428g	78.8093g	0.0335g	$1.4 mg/cm^2$

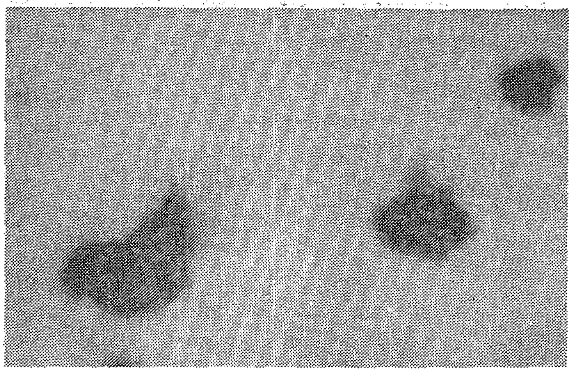
Based on these figures, it can be calculated that approximately $2.16 cc/m^2$ (or approximately 2 microns from the surface) is lost with minimal to moderate blasting with glass beads. Loss would be increased significantly with higher pressures, more aggressive blasting, or from an object having small details, sharp angles, corners, or other surface roughness.

Approximately 650 g. of beads used in blasting the small plaque were caught. A 1 g sample was placed in a beaker with 10 ml of concentrated ammonia. Another sample of beads which had been through the sand-blaster and caught for a flow rate test were placed in another beaker with concentrated ammonia, as a control. After about 20 minutes the sample containing the beads used for blasting the plaque turned blue, indicating the presence of copper. There was no corresponding color change in the control sample.

Another sample (approximately 10 g) of "used" beads from the plaque were sprinkled into a small beaker of di-ido methane (methylene iodide). The beads floated on the surface and were removed. The remaining material was filtered and numerous small flakes of bronze, like those shown by Ruff and Wiederhorn (p. 103), remained on the filter paper.



Illus. 2 Scanning electron micrograph of wrought copper sample after glass bead peening. Note craters and "flaps". [photo, Walt Brown, WSNMNH, SI]



Illus. 3 Small flakes of bronze from sample plaque after blasting with glass beads. (100X) [photo, WTC, FGA]

A small polished disk of 90-10 bronze was divided, masked, and blasted with walnut shells, glass beads, and sodium bicarbonate at 40 psig pressure. A polished, unblasted segment, and the walnut shell and glass bead peened segments were examined microscopically and with a scanning profilometer. The tracing of the glass bead peened segment illustrates significant surface deformation.

Effects of glass bead peening on corrosion rate

Glass bead/shot peening is utilized industrially to reduce stress corrosion through increasing residual compressive stresses in the surface region (ASM, Shot Peening, Shot Peening of Metal Parts MIL-S-13165B). Tests indicated that there is no reduction in atmospheric corrosion. and in fact corrosion may be increased.

Dr. Jerome Kruger and Steve Gollege (Corrosion Studies Center, Department of Metallurgy and Materials Science, Johns Hopkins University) ran potentiometric curves using Sodium sulfate (0.1 N) as an electrolyte. On a series of 87-10-3 bronze samples, no difference was seen between polished, walnut shell blasted surfaces, and glass bead peened surfaces. These results do not support the popularly held belief that glass bead peening reduces the atmospheric corrosion rate of outdoor sculpture.

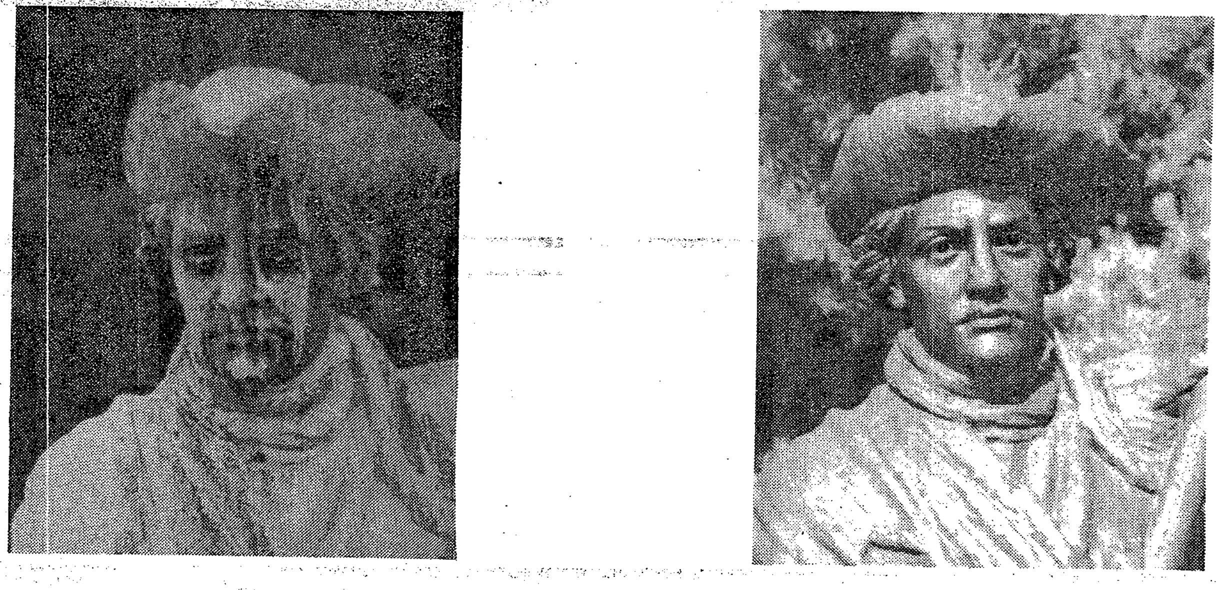
W.H.J. Vernon found in preparation of samples for tests on corrosion/humidity relationships that "sand blasting" increased the corrosion rate of copper when it was exposed to an atmosphere containing SO_2 and H_2S (Vernon, 1931). Following blasting with walnut shells and glass beads, the two small plaques were place in a bell jar containing a beaker containing dilute sulfuric acid. Bands of plastic were used to keep the samples upright and after about 2 months a definite change in coloration of the glass bead peened plaque was evident between the area exposed to the corrosive atmosphere and the area protected by the bands. The sectionally blasted disk has shown more change in coloration in the area blasted with glass beads than in the areas blasted with walnut shells and left polished. Small samples of wrought copper blasted with walnut shells and glass beads were placed in bottles containing 2-3 drops of corrosive water containing 100 ppm sulfate, chloride, and bicarbonate (as described in ASTM D1384-80). Within 3 months obvious visual changes occurred on the glass bead peened surfaces, with the development of numerous dark brown spots. There was no noticeable change in the samples blasted with walnut shells, or in the back (unblasted) of the samples, when compared with other control samples placed in a dry jar at the same time.

Any increase the atmospheric corrosion rate is not completely understood, but it may possibly be explained by a number of factors, either individually or in aggregate. Following the use of glass bead peening there is an increase in surface area (about 1% on the upper surface, calculated from profilometer tracings on the segmented disk) however, the formation of flaps undoubtedly increases it more. The craters and flaps may form minuscule pockets holding particulate material and water droplets.

Conclusions

Based on observations of statuary which has been treated using the glass bead peening method and walnut shell blasting, there is significantly less visual disturbance of the surface texture and aesthetic qualities with shell blasting. Current research indications there is no decrease in atmospheric corrosion rates with the use of glass bead peening, and in fact there appears to be an increase following the use of such hard air driven abrasives.

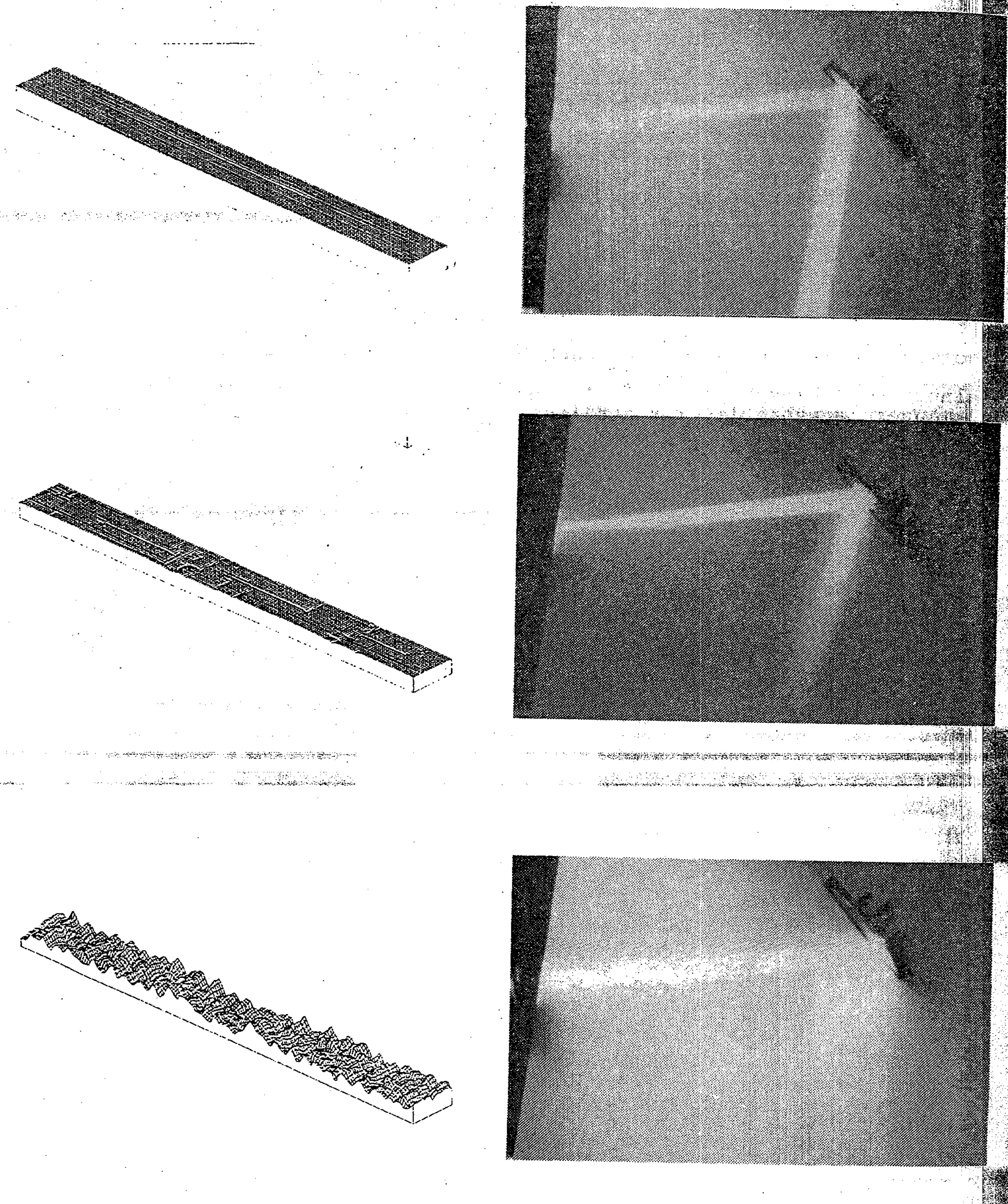
Walnut shell blasting appears to remove dirt, grime, and corrosion products in a manner acceptable for application to the conservation of outdoor metal sculpture.



Illus. 4 New Jersey Monument, Valley Forge, PA. Appearance before and after treatment which included blasting with 60/200 mesh walnut shells at 20 psig. pressure to remove dirt and corrosion products. (photos, NFV, NPS)

A number of variables both operator and system controlled can significantly influence the success or failure of the procedure. Through a variety of tests, it has been found that smaller particles are more "effective" in cleaning corroded and dirty surfaces than are larger particles. Since initial testing of all available sizes of abrasive particles, 60/200 mesh media has been regularly used. The total mass of air/abrasive is a very significant factor; and in practical application "efficiency" seems to be improved by using a larger nozzle with decreased pressure [a 5/16" nozzle at 20 psig in contrast to a 5/32" nozzle at 40 psig] (Veloz, 1983). The most effective angle of impact is within approximately 20 degrees of perpendicular to the surface.

It is recognized that individual steps cannot dictate the complete success or failure of any preservation or conservation treatment. Each step should be approached as a segment of an entire process. However, both the means and the end should follow the conservation principles of reversibility, minimum intervention and (to borrow a phrase from medicine) doing no harm (*primum non nocere*).



Illus. 5 I Scanning profilometer tracings of segmented disk. a) polished surface, b) walnut shell blasted surface, c) glass bead peened surface. Vertical axis expanded 10X. (tracings, AWR, NBS). II Reflection of light beam from surfaces, corresponding to the adjacent profilometer tracings.. (photos, WTC and A.R. Marshall, FGA).

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SUCCESSFUL USE OF LOW PRESSURE, SOFT ABRASIVES (WALNUT SHELLS) FOR CLEANING OUTDOOR BRONZE SCULPTURE BY AIR JETS

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In 1870 Benjamin C. Tilghman stated, "Articles of cast or wrought metal may have their surfaces thus smoothed and cleaned from slag, scale, or other incrustation. The surfaces of wrought stone in buildings or elsewhere can thus be cleaned and refreshed." in his patent application for the "sand-blast" (U.S. Patent No. 108408). Since that time, sand and other abrasives have been used for cleaning a variety of materials. Outdoor bronze sculpture has been cleaned with glass bead peening since the early 1970's and it has been cleaned using walnut shell blasting since the late 1970's.

Sculptures treated with these two methods showed a marked difference in appearance. A search of conservation literature gave virtually no information regarding the action of the two abrasives; therefore, comparative tests were designed to compare their action and effect. A significant number of relevant publications were also found in the trade literature and particularly in the field of wear and erosion.

Abrasive blasting experiments were performed on both cast and polished surfaces. Glass beads and other hard abrasives severely deformed the surface on a microscopic scale. Tilghman described this as, "a frosted, dull, matt, or dead appearance." Ground walnut shells and other soft abrasives, however, seemed to have no significant effect on the surface finish of the bronze while they removed virtually all accumulations of dirt, grime, and loose or friable corrosion products. A weight loss of approximately 2 mg/cm^2 was found following a moderate use of glass bead peening while there was no discernible change or weight loss following a similar use of shell blasting.

Although claims have been made that glass bead peening reduces the corrosion rate of outdoor bronze sculpture, it seems that any reduction in corrosion rates are applicable to "stress corrosion", as described in the technical and industrial literature. Our tests and observations of samples blasted with walnut shells and glass beads indicated that the rate of atmospheric corrosion is actually increased by glass bead peening.

It is recognized that individual steps cannot dictate the complete success or failure of a preservation or conservation treatment. Each step should be approached as a portion of an entire process. However, both the means and the end should follow the conservation principles of reversibility, minimum intervention and (to borrow a phrase from medicine) doing no harm (primum non nocere).

En 1870 Benjamin C. Tilghman declarait "La surface des pièces de fonderie ou forgées peut ainsi être polie et debarassée de scories, oxides ou autres impuretés. La surface des pièces d'ornement dans la construction ou autrepart peut ainsi êntre nettoyée et remise à neuve". Dans l'application de son brevet pour le sablage (U.S. Patent No. 108408). Depuis, le sable et autres abrasifs ont été utilisés pour le nettoyage d'une variété de materiaux. Les sculpture en bronze d'exterieur ont été nettoyées par sablage au verre depuis le début des anneés 70 et par sablage aux coquilles de noix depuis la fin des années 70.

Les sculptures traitées par ces deux méthodes ont montré une nette différence concerrant leur apparence. Une recherche de la litterature de conservation n'a donné aucune information concernant l'action des deux abrasifs. Des tests comparatifs ont été ainsi concus afin de comparer leur action et leur effect. Un nombre significatif de publications concernant ce sujet a été trouvé dans le littérature specialisée et particulierement dans le domaine de la tribologie et de l'érosion.

Des experiences de jet d'abrasifs ont été faites sur de surfaces brute de fonderie et polies. Les particules de verre et autres abrasifs durs ont deformés microscopiquement la surface. Tilghman decrivit cela comme ayant "une apparence gelée, teure, mate, ou morte". Les coquilles de noix broyées et autres abrasifs tendres n'ont eu cependant aucun effet significatif sur la finition de la surace du bronze aloirs qu ils ont essentiellement decollés toutes les accumulations de déchets et, produits de corrosion pue adhérents ou friables. Une perte gravimetrique de 2 cm^3/m^2 a été mesurée aprés l'utilisation d'un sablage au verre modéré alors qu' aucun changement ou perte gravimétrique n'a put être mesurée aprés un sablage similaire par coquilles.

Bien qu' il ait été dit que le sablage au verre reduit la taux de corrosion des sculptures en bronze d'extieur, il semble que toute réduction du taux de corrosion peut s'aplliquer a la corrosion sous contrainte comme cela a été décrit dans la litterature technique et industrielle. Nos test et les observations d'échantillons sablés aux coquilles de noix et au verre ont indiqué que le taux de corrosion atmospherique est en fait augmenté par le sablage au verre.

On concoit que les étapes individuelles ne peuvant condurie au succés complet ou a l'echec d'un traitment de préservation ou de conservation. Chaque etape doit être considerée comme une partie su processus. Cependant, les moyens et le but devraient suivre les principes de conservation de reversibilité, d'intervention minimum et (pour emprunter une phrase employée en medecine) ne pas nuire (primum non nocre).