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Author: Matt Reiley

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THE CASE FOR COLD: USING DRY ICE BLASTING TO REMOVE LACQUER COATING FROM THE *KING JAGIELLO* MONUMENT IN CENTRAL PARK

MATT REILEY

This case study provides an overview of the use of dry ice blasting as a suitable method for Inralac coating removal on a heroic-scaled equestrian bronze sculpture as part of the development of a sustainable program of protective coatings maintenance. In 2016, the Central Park Conservancy initiated a conservation project on the *King Jagiello* monument, which included the use of dry ice blasting to remove a failing coating. Dry ice blasting was selected because it is dry, nondestructive, environmentally conscious, and for its relative speed. The project, and previous methods of Inralac lacquer removal tested at two other bronze monuments provide points of comparison. This case study shares findings from the project's use of the dry ice blasting system with considerations for use in an outdoor environment and an empirical assessment of results. The rationale for replacing Inralac coating with a protective hot wax coating on *King Jagiello* is also discussed.

KEYWORDS: Bronze, Central Park Conservancy, Collections care, Dry ice blasting, Inralac, King Jagiello, Lacquer removal, Outdoor sculpture, Protective coatings

1. INTRODUCTION

1.1 History of The *King Jagiello* Monument

King Jagiello, created by sculptor Stanislaw K. Ostrowski (1879–1947) for the Polish Pavilion of the 1939–1940 New York World's Fair, has resided in Central Park since 1945 (fig. 1). The highly detailed bronze dramatically depicts Wladyslaw II Jagiello, Grand Duke of Lithuania (1377–1401) and King of Poland (1386–1434), on horseback raising two swords overhead, memorializing the political unification of east central European groups against the Teutonic Order of the Cross and commemorating their victory at the Battle of Grunwald in 1410. Following the Nazi invasion of Poland in World War II, the monument was presented to the City of New York by the exiled government and is an important symbol of Polish-Americans' independence and national identity (Nowakowska 2013).

1.2 Treatment History

King Jagiello's past treatment reports indicate a sporadic history of care since the monument's relocation to Central Park (Valera 2016). A condition assessment performed in 1984 by Washington University Technology Associates, Inc. (WUTA) found the bronze in poor condition, having suffered from vandalism and exposure to acid rain deposition (Weil 1986). The sculpture's pitted surface was encrusted in a layer of greenish corrosion products identified as copper sulfates and chlorides (Weil 1986), features were missing, and it was partially disengaged from its anchorage to the base due to "rust jack" expansion of internal steel supports (figs. 2, 3).

Conservation treatment was undertaken in 1986 under the auspices of the Central Park Conservancy (CPC) and included the removal of the corrosion crust with glass bead peening, repatination, and an application of the acrylic lacquer Inralac to the surface as a protective coating (The Daily Plant 1986). The deteriorated condition of the sculpture's anchorage and associated damage to the bronze was noted and its replacement advised, but it was not part of the scope of WUTA's work in 1986.

1.3 Inralac Application and Performance

With the inception of the CPC's cyclical program of bronze conservation in the early 1990s, the majority of the park's bronze monuments had Inralac coatings applied. Inralac's performance life is three to five



Fig. 1. S. K. Ostrowski, *King Jagiello*, 1939, bronze, 4.14 m H at crown, plus 1.9 m to top of sword. City of New York, accession number 793

years; the complete removal of aged coatings and the reapplication of new coatings is required to adequately protect outdoor bronze sculpture (Bierwagen et al. 2001). Removing and reapplying coatings on a large collection of outdoor bronze monuments on a three- to five-year cycle would require massive resources and planning. In reality, as the monuments' coatings degraded, repeated touch-ups—and, in some cases, complete overcoatings—were applied. Until recently, these patchwork coatings have rarely been removed and refurbished. As a result, the Incralac coatings on many of the park's bronze monuments have now far surpassed their performance life and are, by turns, embrittled and flaking or cross-linked and difficult to remove. Due in part to the ongoing maintenance using sacrificial, pigmented paste wax, the bronzes retain an acceptable appearance but the lacquer coatings no longer provide adequate protection from the factors causing corrosion. Additionally, the underlying surface condition and sculptural detail may be obscured by the degraded coating, and nuances of patina and light reflectance are negatively affected (Chase and Veloz 1985).



Fig. 2. Detail of corroded surface of *King Jagiello* in 1984, Courtesy of WUTA

King Jagiello was no exception. The coating was weathered and failing to adequately protect the bronze despite a complete overcoating of Inctalac in 1991 (Rabinowitz 1991) and an ongoing program of applying paste wax. The coating's deterioration was accelerating, as evidenced by partial removal from pressure washing during annual maintenance (Reiley et al. 2004).

2. PROJECT BACKGROUND

2.1 Sustainability Assessment

From 2010 to 2012, the CPC devised an aspirational, multiyear plan to remove all of the Inctalac coatings from the park's monuments and develop a more sustainable coatings maintenance regime. The CPC has employed other coatings removal methods prior to the *King Jagiello* project, including chemical



Fig. 3. Detail of damage from rust jack expansion of internal support

gel stripping and laser ablation. Recent conservation projects in Central Park using those removal methods are briefly detailed in the following case studies. The CPC assessed each process to determine its suitability based on various factors, such as safety, removal rate, ease of use, and cost. Findings were balanced against considerations of seasonal conditions, sculpture scale and detail, condition of the monument, setting, and accessibility.

2.2 Practical Application of Lacquer Removal Methods

2.2.1 Chemical Gel Stripper

A large bronze bust of the Italian statesman, Giuseppe Mazzini (1805–1872), by G. Turini (1841–1899) (fig. 4) was treated in 2011 as a pilot project for the development of the CPC's sustainable coatings removal and replacement plan. The aged Inctalac coating originally applied in 1994 was darkening unevenly and negatively affecting the sculpture's appearance. The coating was removed by repeated applications of the methylene chloride gel stripper Rock Miracle, which was agitated with nylon bristle brushes, and subsequently cleared with a pressure washer. This process does not require specialized equipment; thus, effective coating removal was attained at low cost. The rate of removal was slow but deemed acceptable due to the bronze's relatively modest size and simple form.

The use of methylene chloride chemical gel strippers has several important drawbacks, especially when used on large statuary in an outdoor environment. The gel itself is messy and difficult to control. The efficacy of a methylene chloride gel stripper is weather and temperature dependent. Conservators applying the gel must wear personal protective equipment (PPE), such as full-face respirators with organic vapor cartridges to minimize the hazard from the inhalation of vapors and chemical-resistant garments to prevent burns (OSHA 2012).¹ Technicians, the surrounding landscapes, and adjacent structures must be protected from residue and runoff, which are safety and environmental hazards.



Fig. 4. G. Turini, *Giuseppe Mazzini*, 1878, bronze, Westerly granite, $4.3 \times 1.2 \times 1.2$ m. City of New York, accession number 992

The uncontrolled residue, which may include mobilized corrosion products and pigments, can stain adjacent masonry and redeposit on the bronze surface, compromising the adhesion of new coatings if not done with great care (Lins 1992).

In the case of the *Mazzini* bust, a team of three technicians completed the Inctalac removal over three days. The bronze was subsequently repatinated and coated with a two-part system of G. J. Nikolas lacquer RFU 11565 and a top coat of Uralac 9978 acrylic urethane which has acted as a pilot for empirical evaluation of alternative coatings. The Nikolas coating system is intact after six years; with annual maintenance of washing and applying wax, the desired aesthetics of the finish remain consistent.

2.2.2 Laser Ablation

In 2013, the cleaning and conservation of the friable surface of the Central Park Obelisk, a nearly 3500 year old Egyptian monolith also known as *Cleopatra's Needle*, left little tolerance for surface loss because

of its historical significance. Laser ablation is effected by using laser parameters such as wavelength and pulse duration, which are tuned to discriminate between surface soiling and substrate. The laser energy is absorbed by the offending substance, which is excited and ejected from the surface, while harmlessly reflecting off the underlying material. The process was found to have no mechanical impact on the granite and to be environmentally responsible, whereas all other cleaning methods tested were unsuitable (Wheeler 2013). Laser ablation was also selected for lacquer removal treatment of the Obelisk's 19th century replica bronze crabs, which support each of the monolith's four corners and are in direct contact with the stone. The crabs' lacquer was flaking and the underlying surface was covered in corrosion crust. Carefully selected lasering parameters for the removal of the failing coating simultaneously altered the corroded surface to a more stable oxide, cuprite (Dajnowski, Jenkins, and Lins 2009).

The rate of coatings removal was found to be relatively slow, similar to that of gel stripping (Dajnowski, Jenkins, and Lins 2009). The cleaned crabs were patinated and a hot wax coating applied, which is regularly inspected and renewed as needed (fig. 5).

Using lasers in a public setting presents important factors to consider. Strict site controls must be established and maintained to protect technicians and the public. Special Class 4 protective eyewear must be worn to prevent accidental viewing of the harmful, 1064 nm near-infrared wavelength emitted during lasering. Hazardous vapors are created when coatings are laser ablated, requiring respirators and/or a fume extraction system (Dajnowski, Jenkins, and Lins 2009). Laser equipment is relatively fragile, weather sensitive, difficult to maintain, and expensive. Skilled technicians trained in Class 4 laser safety and use are required to achieve an effective rate and degree of removal while ensuring that operating parameters are appropriate, and to eliminate potential of damage to cultural property.²



Fig. 5. Replica crab during laser cleaning. Unknown artist, *Cleopatra's Needle*, 1871, bronze, 30.48 × 86.36 × 66.04 cm. City of New York, accession number 1129

3. DRY ICE BLASTING OVERVIEW

3.1 Dry Ice Blasting Mechanism

Dry ice or CO₂ blasting accelerates solid carbon dioxide pellets/particles (fig. 6) in a pressurized air stream to impact a surface to be cleaned or prepared. The process employs three distinct factors acting in concert. First, a mechanical pellet kinetic energy effect is at work, in which dry ice pellets are accelerated toward the surface at high speeds, weakening the superficial level of soiling or contamination. Then, a thermal shock effect follows as the surface is rapidly chilled to -109°F (-78.5°C), causing the soiling to contract and weaken its bond with the substrate. Lastly, the sublimation effect is imparted as the pellet media impacts the surface, instantaneously phase-changing from solid to gas and expanding roughly 800 times in volume. This creates “micro explosions” that contribute to the removal by lifting the soiling/film off of the substrate (Liu, Maruyama, and Matsusaka 2011; Continental Carbonic Products, Inc. 2016).

3.2 Rationale for Choosing Dry Ice Blasting

In 2013, as CPC conservation staff assessed the relative advantages and limitations of the methodologies of previous and concurrent lacquer removal projects, we began investigating dry ice blasting as another means of lacquer removal. Sustainability criteria for future coatings removal projects prioritized a process capable of being done in-house, adaptable to the variable conditions of an urban park setting, and nondestructive to works in the collection. The CPC required a method that successfully addressed the conservation needs of individual monuments and could surmount time constraints for completing the work while minimizing hazards to the public and to staff. The reduced environmental impact of the dry ice blasting process as compared with other abrasive cleaning processes and its potential as an in-house process for a cyclical coatings maintenance program aligned with the CPC’s mission. Because the CO₂ media sublimates in the ambient environment, there is no residual blasting media to control. This is a major benefit of the process for use in Central Park. Other abrasive blasting systems can produce large



Fig. 6. Photograph of 3-mm diameter dry ice pellet media

volumes of a contaminated medium that is classified as a hazardous material, which is labor intensive and costly to control and dispose of. The only by-product produced with dry ice blasting is the removed coating itself, although potential impurities in the CO₂ should be taken into consideration (Liu, Maruyama, and Matsusaka 2011).

An effort began to research and study technical publications and contact conservation professionals who were using dry ice blasting to inquire about their research, experiences, and impressions for its use on Central Park's collection, specifically large-scale outdoor monuments. The information and feedback received supported our original hypothesis: that with proper testing and precautions, dry ice blasting is a viable approach as part of a cyclical coatings maintenance program.

3.2.1 Potential Damage Assessment of Dry Ice Blasting

Similar to traditional abrasive removal methods that have been shown to remove/damage the bronze surface, the mechanical or kinetic effect is understood to be the most important factor determining the efficacy of dry ice blasting. It also poses the greatest potential risk of alteration to surfaces or damage to the microstructure of the bronze (van der Molen et al. 2010; Chase and Veloz 1985). However, dry ice (measuring approximately 1.5 on the Mohs hardness scale) is softer than other blast media types for cleaning bronze (which measure 3.0–3.5 Mohs) (van der Molen et al. 2010; Uhlmann and Krieg 2005). In 2010, a joint study by conservators and scientists from the University of Amsterdam and the Netherlands Institute for Cultural Heritage concluded that dry ice blasting at a variety of pressure settings up to 101.5 PSI/7 bar at extended dwell times of up to one minute, gradually removes corrosion and patina but does not damage the bronze substrate (van der Molen et al. 2010). Nevertheless, selecting parameters to obtain an acceptable rate and degree of removal while minimizing risk of damage, adopting an incremental, “do no harm” approach informed by scientific test data, as well as testing and analysis of use on the specific object, are all critical for the conservator applying this treatment to bronze statuary.

3.3 Preproject Testing on the Polish King Project

A Cold Jet Aero 40FP dry ice blaster designed to operate with pellets was tested on representative but inconspicuous surfaces of the bronze prior to the start of the *King Jagiello* project. Previously, CPC conservation staff worked closely with representatives and technicians from the machine's manufacturer to establish appropriate equipment and settings. The mobile, mid-size Aero 40FP was found to be the most versatile machine for the particularities of the project and for potential future treatments of other outdoor sculptures in the collection. The pellet machine was judged to be more user-friendly than machines that shave the carbon dioxide media from a block. The full pellets maximally exploit the mechanical kinetic effect and, when used with the Mern-style nozzles (built-in shaver), media can be delivered in various particle sizes depending on the setting selected. Dry ice blasting was judged to be a rapid, effective, and appropriate means of coating removal on large-scale bronze sculpture and the best removal process available to successfully handle the time constraints imposed by the *King Jagiello* conservation project.

3.4 Existing Patina Condition

A key goal of the *King Jagiello* project was to retain as much of the existing patina as possible. CPC conservators had intended to spot patinate the bronze to visually blend any unevenness of tone following coating removal and subsequently apply a protective coating. However, as the dry ice blasting removed the layers of Incralac, it appeared that it was also aggressively and completely removing the patina, leaving a strongly contrasting, lightly toned substrate (fig. 7). Initially troubling, subsequent gel stripping tests at several locations revealed that what was being stripped was a pigmented coating rather than a traditionally applied patina (Reiley 2016) (fig. 8).

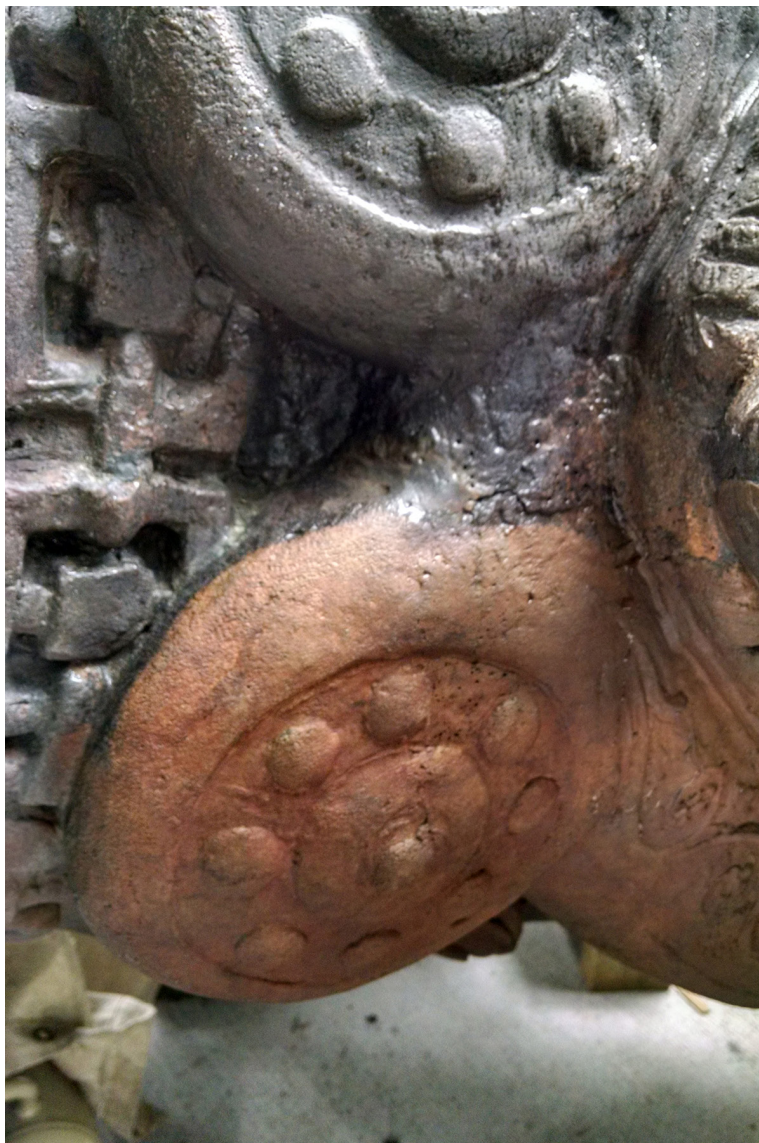


Fig. 7. Dry ice blast cleaning revealed a lightly toned substrate that contrasted with the darkly toned coating

This coating, believed to be a mixture of mineral pigments and Incralac, had been applied over the entire surface of *King Jagiello*. Incidentally, this contrast offered a helpful visual guide to gauge the rate and degree of coating removal. The bronze's surface condition was continually assessed as blasting proceeded. It was found that, although pitted and exhibiting many casting defects, the glass bead-peened bronze appeared remarkably uniform and free of corrosion 30 years after treatment (Reiley 2016).

4. KING JAGIELLO PROJECT BLASTING PARAMETERS

Dry ice blasting operating parameters for *King Jagiello* were optimized by determining the minimal settings needed to quickly remove the aged coating. Operating parameters were established by incrementally increasing the pressure to levels deemed safe yet still capable of achieving an acceptable removal rate and degree. Eventually, settings were optimized at or below 65 PSI (4.48 bar) and in a range of 1.0 to 2.5 lbs./0.45 to 1.1 kg per min. mass flow. Although blast pressure remained relatively constant



Fig. 8. Gel stripping test confirming that brown coloration was a pigmented coating

throughout the project, certain variables of blasting changed according to conditions, such as equipment performance, site conditions, and surface detail that required an adaptive approach to the selection of equipment, mass flow settings, nozzle types, stand-off distance, blast angle, and dwell time. In practice, the selected pressure settings and dwell time on the *King Jagiello* project were always set significantly lower than the maximal safe settings in a 2010 study executed by van der Molen, Joosten, Beentjes, and Megens (2010).

4.1 Blasting Approach

Two separate phases of blasting were undertaken to maximize the progress of work. The first phase began after the sculpture was removed from the base and laid down on its side to perform additional conservation treatment. This included forming and welding repairs, and the removal of the corroded steel internal supports which were replaced with an engineered stainless steel structure. The second phase saw the coating removal completed once the reinforced bronze sculpture was reinstalled on the base and scaffolding erected around it, providing access to previously untreated surfaces (figs. 9, 10).

4.1.1 Phase 1 Blasting

During the first phase of blasting, done while the sculpture was laid down and much of its surface readily accessible, the variable fragmenting MERN nozzles were primarily used (#323v1 and #323v2; 58.4 cm/23" length with 2.5 cm and 4.6 cm blast swath respectively) (fig. 11).

These longer nozzles feature a relatively large swath or cleaning spot for quicker cleaning and are designed to maximize the velocity of media and augment the mechanical, pellet kinetic energy effect. In general, the Incralac was very quickly removed to a near-total degree with two to three sweeping passes with 70° to 90° range of inclination to the surface at a stand-off distance ranging from 4 to 18 in. based on the conditions. Those parameters, while basically intuitive to the operator, have been demonstrated to encompass the most effective and uniform blast performance (Spur, Uhlmann, and Elbing 1999). A total



Fig. 9. Dry ice blasting while sculpture was deposited from base

dwel time at the cleaning spot was estimated at less than five seconds. Blasting was shared by up to three technicians a day to minimize fatigue and to randomize cleaning styles, thus limiting any latent tendencies in individual operators' technique.

The application of the dry ice blasting system (fig. 12) was particularly successful and rapid in this case because of the aged and embrittled condition of the Inrcalac (Cutulle and Kim 2015). This was coupled with another factor known to benefit the efficacy of the cleaning process—the heating of objects to exploit the thermal shock effect. Studies show evidence for improved cleaning/coatings removal depending on the increased temperature differential between the media and substrate (Spur, Uhlmann, and Elbing 1999; Cutulle and Kim 2015). A significant temperature differential existed between the dry ice media (-109°F [-78°C]) and the surface subjected to the torrid summer heat on several days during the project. Amplified by the thermal mass of *King Jagiello*, surface temperatures reached 115°F (46.1°C), a 224°F (106.6°C) temperature differential (Reiley 2016).



Fig. 10. Dry ice blasting while sculpture was deposed from base

4.1.2 Phase 2 Blasting

The MERN-type nozzles tended to be used less frequently in instances when the nozzle's large size complicated access to the surface. This was especially the case during the second phase of blasting, after the sculpture was reinstalled on the base. The shorter conical nozzle (#310S.5. 25.4 cm, 10-in. length, 1.1 cm blast swath) was favored because it offered an increased ability to adapt to site conditions, such as reduced lighting and workspaces that were restricted because of the scaffolding (fig. 13). This nozzle's smaller, more focused cleaning spot also enabled a more direct accessibility and close monitoring of removal by the operator on areas with complex surfaces.

The wider cleaning swath of MERN type nozzles is harder to monitor and it is possible that they do not always provide uniform removal. Minute amounts of coating remaining on recessed edges of surface pits was noted.



Fig. 11. Assortment of dry ice blasting nozzles with MERN-type #323v1 and #323v2 at the outer edges and the shorter conical nozzle #310S.5 at center right

In the future, an improved degree of removal may be achieved on intricate or pitted surfaces prone to more stubborn purchase of Incolac (fig. 14) by increasing pressure settings, increasing dwell time, and/or providing additional blast passes with divergent inclination to the surface (Cutulle and Kim 2015). These intuitive techniques, while likely beneficial, were not pursued comprehensively owing to project time constraints and the already adequate degree of removal. Remnants of Incolac were removed completely during subsequent patina application with a combination of torch heating and careful preparation of the sculpture surface with bronze bristle brushes. Overall, the sculpture's coating removal was very rapid, comprising a total of approximately 18 blasting hours completed in six days. Dry ice blasting conferred significant time savings on the project when compared with projected time estimates of the other coating removal methods used previously. The total bulk of dry ice pellets used for the project is estimated at 1,500 lbs.



Fig. 12. Dry ice blasting system with aftercooler in foreground

5. FINDINGS

5.1 Support Equipment

A well-used air compressor, 1987 Ingersoll-Rand generator model P 175 A-W-D, was adopted to supply air for the Aero 40 FP dry ice blast unit. The compressor was incapable of providing a full range of operating PSI (20–250 PSI) because it did not meet the specifications for air consumption. However, it did provide a range of blast pressure (maximum of 80 PSI/5.5 bar) sufficient for the rapid, near total removal of the coating in this case. The blasting system's inherently reduced capacity was initially welcomed as a built-in limiting factor, allowing for a cautious approach to the dry ice blasting process. However, future projects may require an increased range of pressure, highlighting the need to obtain an air compressor specified to support dry ice blasting.

There are clear indications that using an in-line aftercooler (Cold Jet 400P: 2M0023-G1), that removes moisture from the air supply is important when conducting blasting operations with a diesel-fueled compressor, especially in humid conditions (see fig. 12). When moisture enters the system, it can form “water ice” inside the machine and clog nozzles (Cold Jet LLC 2004). In addition, water ice is harder (Mohs 2.5) than the CO₂ media and can be propelled at the object being cleaned, increasing the potential for damage.

5.2 Logistics and Limitations

The dry ice blasting process has some drawbacks that should be considered before using it on any project. Chief among these are the noise generated and considerable logistical site challenges presented by using dry ice blasting equipment. To achieve a full range of blasting pressure, the Aero 40 FP system requires a



Fig. 13. Blasting with short conical nozzle in the more restricted workspace of the scaffolded monument

gas engine compressor capable of delivering 185 cfm of air, which produces noxious fumes and noise. Sufficient space should be dedicated to the compressor's placement on the project site to minimize exposure to workers and the public (Ribis 2016). This and the relatively large and cumbersome components of the system preclude it from being a viable option for use indoors, although various manufacturers do offer indoor-appropriate models.

Efficient dry ice blasting operations with the Aero 40 FP machine are best achieved as a coordinated effort among two or more technicians. Swapping duties and closely monitoring site conditions, blast parameters, media supply, and support equipment are essential for minimizing worker fatigue and maximizing blast time. Periodic replenishment of dry ice media is required throughout the process. The unit's hopper holds 40 lbs./18.14 kg of pellet media, which supplies approximately 15 to 20 minutes of blast time at 2.5 lb. (1.1 kg)/min. mass flow between refills.

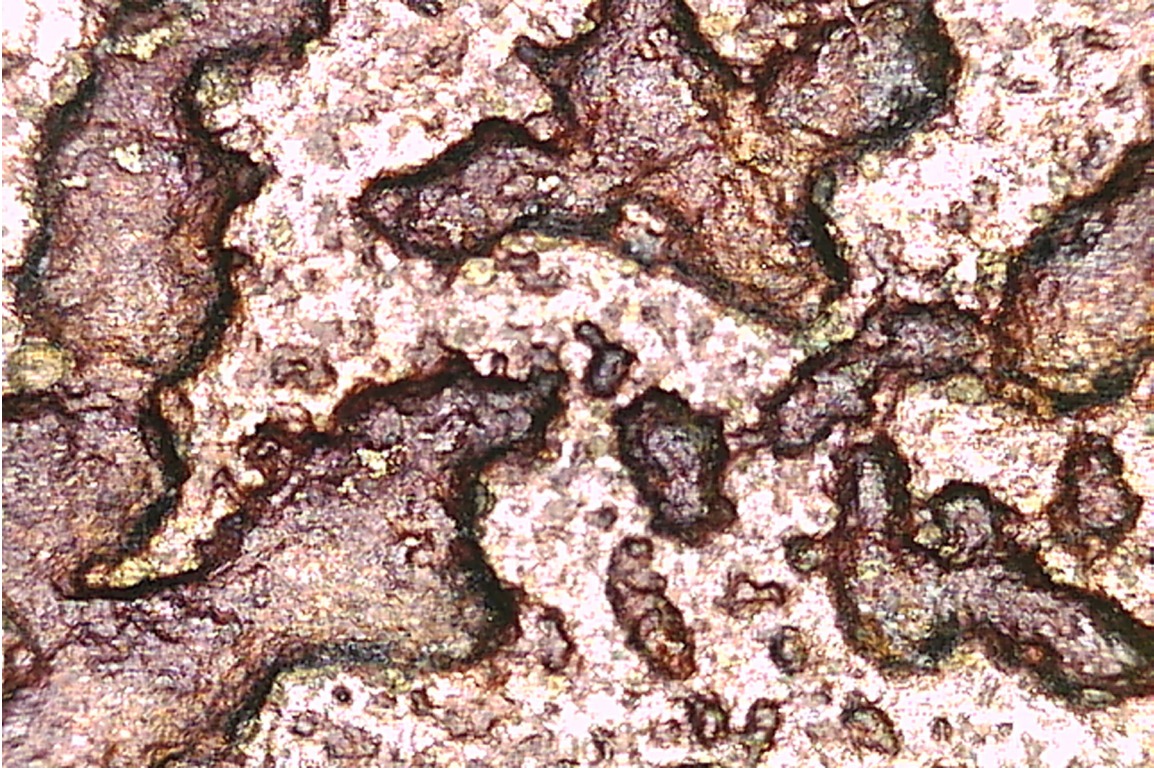


Fig. 14. Bronze surface at 150 \times . The undercut edges of pits provided a more stubborn adherence of Incralac

Carbon dioxide pellets are available from regional suppliers with a one- to two-day lead time and are delivered to the work site in approximately 500 lbs. of bulk. The CO₂ pellet media must be used as soon as possible to limit waste due to sublimation. Typical sublimation is approximately 2% to 10% per day depending on the climate and the container (Cold Jet LLC 2004). To arrest media sublimation during the project, technicians created an additional seal with plastic stretch wrap around the lid of imperfectly sealed containers at the end of each of work day.

Inconsistencies in the quality of the pellet media and the insulated containers have been encountered over the course of multiple deliveries. It is important to work closely with a responsive dry ice provider to communicate the medium's specific use to ensure its quality, as it seems that much end use of the product does not require optimal quality.

6. SAFETY

Dry ice blasting presents safety hazards to consider and mitigate. Personal protective equipment for ear and eye protection are required at all times when operating the machine on site. Solid CO₂ is a cryogenic material that can cause frostbite if handled without thermal gloves. The process generates considerable noise and, although it does not produce secondary waste, it does disperse dust from the ejected material into the air. To measure conservation staff's exposure levels during the *King Jagiello* project, the CPC's Environmental Health and Safety department conducted personal air sampling and sound-level measurements, providing recommendations based on Occupational Safety and Health Administration (OSHA) and American Conference of Governmental Industrial Hygienists (ACGIH)/National Institute

for Occupational Safety and Health (NIOSH) standards (Ribis 2016). The resulting measured air dust concentrations were below the Permissible Exposure Limit (PEL) and as such did not require a respirator, although they were used voluntarily anyway. Sound levels were measured at 112 decibels recorded at the operator's ear; noise levels are expected to increase in correspondence with increased operating pressures and blasting in hollows. To minimize exposure, both earplugs and defender muffs were required and a maximum of three blasting hours (actual time the applicator trigger is engaged) per operator per day was instituted. Recommendations were made for wearing protective garments to shield from dust and segregate the day's work clothes for storing and washing (Ribis 2016).

7. COATINGS REPLACEMENT RATIONALE

The CPC's ongoing plan of Inctalac removal is based on identifying a more sustainable model for the preservation of the park's bronze monuments. Experience has shown that Inctalac is difficult to apply and remove and that its useful lifetime ranges from three to five years. Thus, every three to five years, efforts must be made to remove the old coating system and reapply a new coating. Minimizing the recurrence of removing and then reapplying a new coating can be achieved by finding a better coating system to replace the Inctalac and wax system. A new coating with a longer performance life would require less time, money, and energy spent on removal and reapplication, ultimately minimizing potential harm to the bronze during conservation treatments (Bierwagen et al. 2001; Weil 1980).

While assessing *King Jagiello* to select a new protective coating, lacquer was dismissed as a replacement. The bronze was found to be an assembly of very thin casts produced from both sand mold and plaster investment lost wax techniques, which exhibited many small voids and cracks in the surface (Reiley 2016) (fig. 15).



Fig. 15. Detail of voids in *King Jagiello* cast

During the welding repair phase of the project, only a selection of the worst voids—those facing skywards on horizontal surfaces where water infiltration was a constant—were welded closed. The remaining holes and cracks in the cast were seen as problematic for the longevity and performance of a replacement lacquer coating. The inability to “close the envelope” of the sculpture’s exterior made the use of a lacquer film inappropriate, as the many points of attack from the inevitable discontinuities would lead to premature failure (Reiley 2016). An object lesson learned from the former cyclical maintenance of this bronze monument was that it had effectively devolved into the conservation of the deteriorating Incralac coating.

A protective hot wax coating, on the other hand, can be readily applied and maintained on a one- to three-year cycle (Montagna 1989). Unlike the previous annual treatment, consisting of an overall application of paste wax over the failing lacquer, a hot wax coating does not require an overall application each year. Rather, it can be selectively applied in areas of wear, significantly reducing the manpower needed for coating application (Chase 2002).

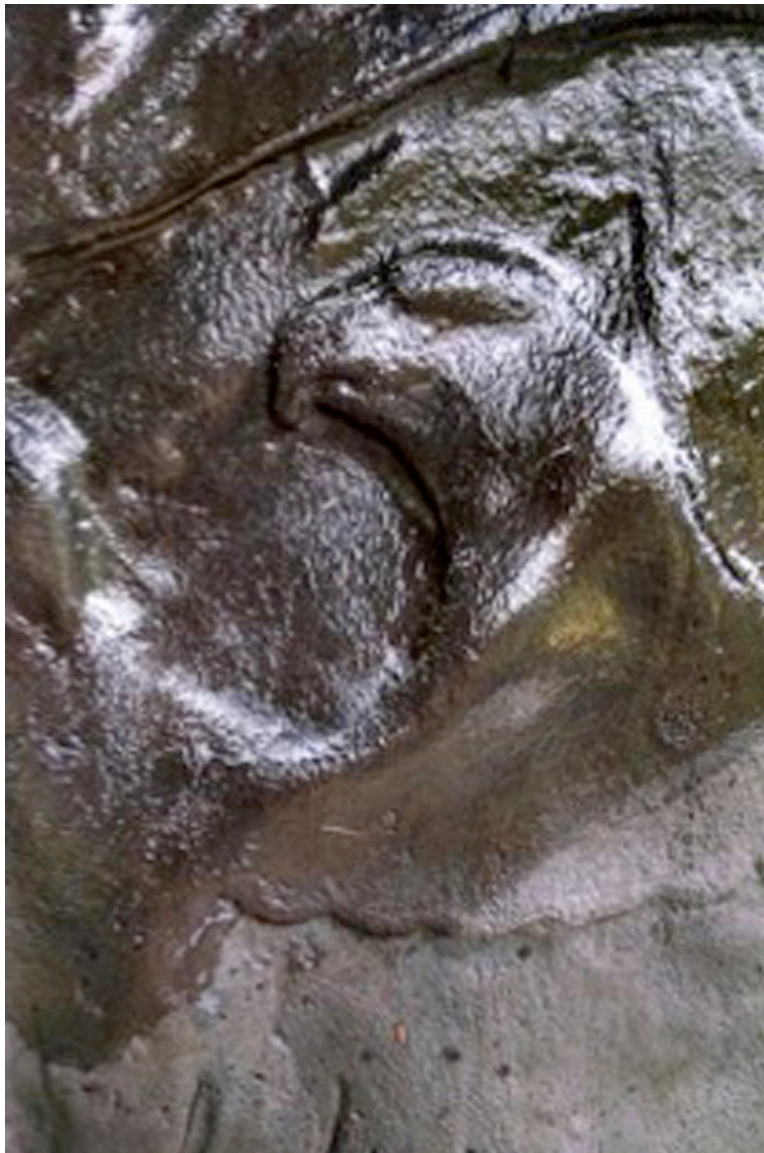


Fig. 16. Detail of hot wax application that protects, darkens, and adds gloss to the bronze surface

Successive coats of a formulated blend of wax based on the National Park Service recipe (71% Victory brown microcrystalline wax, 13% Polywax 2000, 13% petronauba, and 3% Cosmolloid H-80) were applied to the heated surface of *King Jagiello* and carefully dispersed with brushes to ensure penetration, selectively infill pitted areas, and establish complete coverage of a thin film.

This process saturates and slightly darkens the surface and, once it was modulated with selective buffing, achieved a nuance of tone and gloss complementary to the artist's intent and to the spirit of the material (fig. 16). With proper maintenance, the sculpture will be protected from further deterioration (Tatti 1985). *King Jagiello* will continue to be inspected yearly as part of the CPC's cyclical conservation maintenance program and will receive treatment as required. Degraded wax coatings can be reversed with a steam pressure washer or dry ice blasting and renewed as needed (Wolfe 2015). This approach to coating maintenance has restored an intimacy with the bronze surface, which, in the case of the *King Jagiello* conservation project, helped to dispel some of our assumptions about the work's technical processes of production and its treatment history.



Fig. 17. *King Jagiello* after treatment



Fig. 18. The author testing the dry ice blaster

8. CONCLUSIONS

The use of dry ice blasting was a suitable, cost-effective, rapid, and successful method to remove an aged Incralac coating on the *King Jagiello* monument (see fig. 17). The use of the process has proved to be a versatile, nondestructive, environmentally conscious, and relatively easy-to-use component of the CPC's in-house program of cyclical coatings maintenance. As stewards of the park, we believe that dry ice blasting has shown promise to fulfill our organizational commitment and professional aspiration to employ best practices and improve sustainability. Despite some limitations—the system is restricted to use as a surface treatment—dry ice blasting is a valuable addition to outdoor sculpture conservators' tool kits. Using the process solely or in combination with additional treatment methodologies has great potential for use on a range of conservation needs across a diverse collection of cultural resources in Central Park. However, further testing that produces quantitative data to determine appropriate operating parameters and establish thresholds on a variety of materials is needed.

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NOTES

1. Alternative, nonmethylene chloride gel strippers, such as Dumond Chemicals SmartStrip and Peel Away 7, have been found to be effective in removing lacquer and are the favored aqueous method for stripping lacquer on Central Park bronzes owing to improved safety and ease of use.
2. Technological advancements, such as optimization of scan pattern, are increasing the cleaning rate of lasers, at least doubling it on flat surfaces. The purposeful design of lasers for use in cultural heritage conservation have improved its safety and ease of use (Dajnowski, B. Phone Interview with author. Personal Interview. Manhattan, August 21, 2017; and from the author's direct observation on the Obelisk conservation project, June 25, 2015).

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SOURCES OF MATERIALS

1987 Ingersoll-Rand Generator Model P175 A-W-D

Ingersoll Rand
170/175 Lakeview Dr.
Dublin, Ireland
<https://company.ingersollrand.com/>

Cold Jet Aero 40 FP

Cold Jet
455 Wards Corner
Loveland, OH 45140
<http://www.coldjet.com/en/index.php>

CleanLASER 100W

Dornkaulstr. 6-8
52134 Herzogenrath
Germany
info@cleanlaser.de

CO₂ Pellets

Continental Carbonics
<https://www.continentalcarbonic.com/>

Replacement Coating System

G J Nikolas & Co., Inc.
 2800 Washington Blvd.
 Bellwood, IL 60104
http://www.finish1.com/page_home.htm

Strippers

Rock Miracle
 Samax Enterprises
 29-75 Riverside Ave., Bldg #2
 Newark, NJ 07104

Dumond Chemicals, Inc.

1475 Phoenixville Pike, Suite 18
 West Chester, PA 19380
info@dumondglobal.com

Victory Brown Microcrystalline Wax (Hot Wax Formula)

Freeman Manufacturing and Supply Company
 1101 Moore Rd.
 Avon, OH 44011

Polywax 2000 and Petronauba Waxes

Baker Hughes
 12645 West Airport Rd.
 PO Box 5050
 Sugar Land, TX 77487-5050

Cosmoloid H-80 Wax

Picreator Enterprises Ltd.
 44 Park View Gardens
 Hendon, London NW4 2PN

MATTHEW C. REILEY is associate director of Conservation for the Central Park Conservancy, where he is part of a team responsible for the stewardship and care of Central Park's historic built environment—including a collection of more than 50 bronze and stone monuments, as well as artifacts, fountains, mosaics, and architectural structures. Mr. Reiley is an adjunct faculty member of the Graduate School of Architecture Planning Preservation (GSAPP) at Columbia University and a professional associate of the American Institute for Conservation of Historic and Artistic Works (AIC). He is an inveterate foundryman and visual artist. Address: 414 E. 120th St. Apt. 6B, New York, NY 10035. E-mail: mreiley@centralparknyc.org or mreiley@excelsiorartservices.com