Guns and Ships
Using Dry Ice Blasting in the Conservation of Cast Iron

Laurie King, Will Hoffman
The Mariners' Museum and Park
100 Museum Drive, Newport News, Virginia 23601

Contact: Lking@marinersmuseum.org

INTRODUCTION

This poster presents an assessment of dry ice blasting as a treatment method for the removal of paint and corrosion from cast iron objects, with the successful application of results on cast iron naval guns. The Batten Conservation Complex (BCC) within The Mariner's Museum and Park (TMMP), in Newport News, VA, is responsible for the conservation of a variety of archaeological and historic maritime objects. Conservation was required for two naval guns, which date to the 1781 Battle of Yorktown.

The guns were raised from the York River in 1934 through a partnership between The National Park Service, Newport News Shipbuilding, and TMMP. Since their recovery, the objects have been displayed both outdoors and indoors, subjecting them to fluctuating environments. In 2015, it was noted that the protective paint coatings previously applied to the guns had failed, and there was evidence of recent corrosion on the objects' surfaces. Removal of the paint and corrosion, in addition to desalination, was required. Dry ice blasting was investigated as a potential solution to remove the corrosion and paint layers.

Fig 1: Before treatment six-pound gun

Fig 2: Before treatment four-pound gun, taken while on display

OBJECTIVES

In 2009, a similar treatment involving the removal of paint and corrosion from a cast iron IX-inch Dahlgren shell gun was conducted. This treatment involved a combination of mechanical and chemical cleaning using solvents, scalpels, and dental tools over a 9-month period. In order to find a more time-efficient treatment procedure, research on dry ice blasting as a paint and corrosion removal process was conducted. The BCC had previously researched the application of dry ice blasting as a treatment for wrought iron with successful results, identifying safe cleaning parameters and appropriate blasting equipment. This project expanded the previous research, using the wrought iron cleaning methodology and testing procedures previously developed as a starting point.

Project Goals:

- **Determine if dry ice blasting is a suitable and minimally abrasive treatment for cast iron**
- **Determine if dry ice blasting is an efficient paint removal method**

DRY ICE BLASTING

Dry ice blasting is a process in which solid carbon dioxide is used as aggregate particles, in conjunction with compressed air, to remove dirt, corrosion, and other contaminants from a surface without abrasive damage. Dry ice pellets sublime on impact with the surface, meaning that the only waste material is the unwanted contamination being removed from the object's surface. Dry ice has a Mohs hardness scale rating of 2.5. The unit used in these tests is a ColdJet SDI Select 60, which is capable of implementing blasting with three different sized aggregate types: pellets (3 mm), shaved pellets (0.2 mm-0.1 mm), or shaved block/snow (0.15 mm). Air was supplied to the machine through an Ingersoll Rand R55i rotary screw air compressor coupled with a Ingersoll Rand NVC300 - 460V refrigerant air dryer to supply highly dried air at a range of pressures.

Fig 3: Detail of unit control panel. The ColdJet SDI Select 60 has a variable feed rate of 0-6 lb of aggregate per minute and a blast pressure range of 20-250 psi. The blast applicator has an interchangeable nozzle connector.

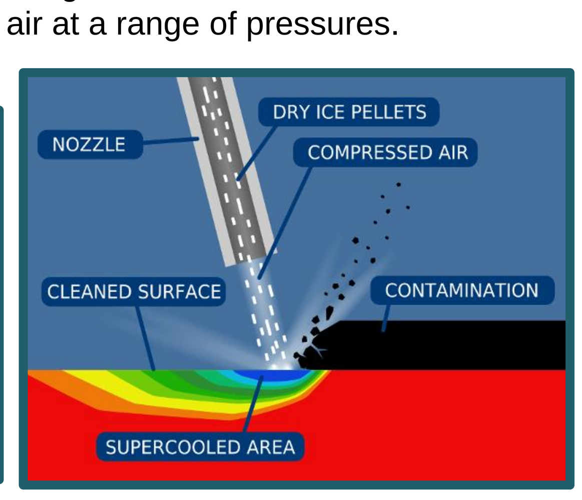

Fig 4: Detail dry ice blasting method http://www.jettyrobot.com/jetty-system/blasting-media/dry-ice-blasting/ (accessed April 21, 2017).

METHOD: INITIAL TESTING

Before detailed research began, spot testing was applied to the base of one of the guns (using similar settings to those successful for wrought iron) to determine if dry ice blasting would be an efficient mechanical cleaning and/or paint removal method. Initially, it was found that dry ice blasting alone was not effective at removing the paint from the surface (Fig 5). However, it was decided to test combining the mechanical cleaning effect of the dry ice blasting with solubilizing effect of solvent treatment (Savogran Strypeeze® varnish & paint remover), in a similar method to the Dahlgren gun conservation. Figure 5 shows the difference in these two procedures, showing that the combination of solvent application followed by dry ice blasting was extremely effective for paint removal.

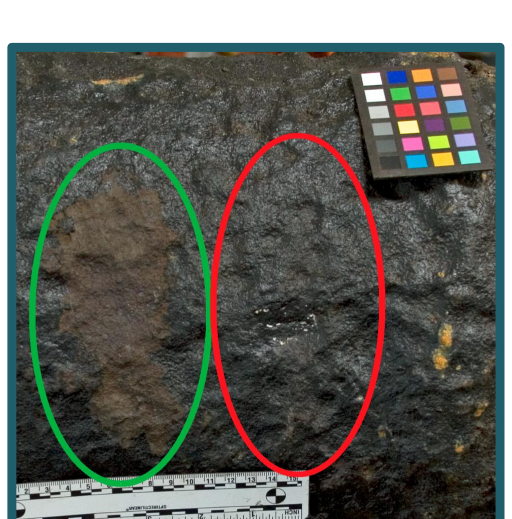

Fig 5: Test comparing dry ice blasting alone (red circle) to dry ice blasting with solvent (green circle).

METHOD: SAMPLE PREPARATION

- Test samples were created to analyze the damage level of dry ice blasting on cast iron, with variables altered to determine safe and successful cleaning parameters.
- Samples were made from modern gray cast iron, which was cut into small pieces and mounted in Buehler EpoKwick 2-part epoxy resin. Samples were polished using a Buehler Phoenix 4000 Sample Preparation System, followed by ultrasonic cleaning in ethanol.
- Samples were kept in air-tight containers with desiccant to prevent flash corrosion.
- Samples were examined and photographed at 350x magnification using a HIROX digital microscope KH7700. Samples were examined before and after testing to determine damage threshold.
- Samples were made, analyzed, and tested based on the methodology developed by Will Hoffman as presented in "Testing Dry-Ice Cleaning on Archaeological Wrought Iron from the USS *Monitor*" at AIC's 43rd Annual Meeting.

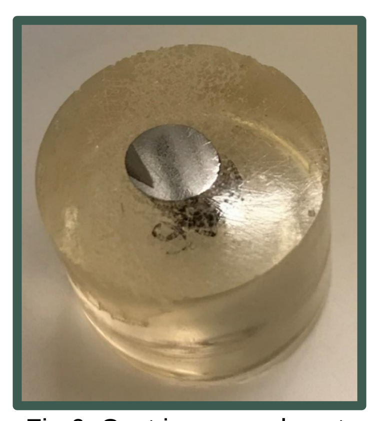

Fig 6: Cast iron sample set in resin

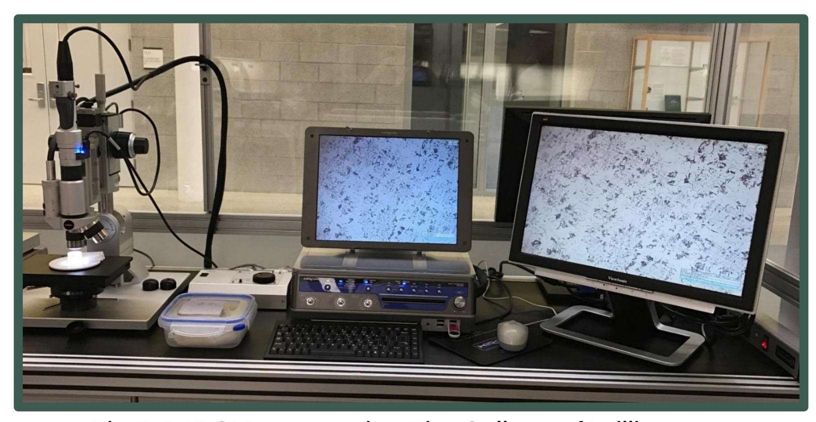

Fig 7: HIROX accessed at The College of William and Mary Applied Research Center

TESTING METHODOLOGY

The application of dry ice blasting involves multiple variables that can alter the abrasive effect on the substrate, including the size and shape of the nozzle, aggregate size, pounds-per-square-inch (psi) of compressed air, pounds of dry ice aggregate per minute, and the distance between the nozzle and the substrate, all of which must be taken into consideration.

- For aggregate size, only **shaved pellets and shaved block** were used in testing, as the wrought iron results showed that 3 mm pellets were too severe for our purposes.
- Initial testing showed success on cast iron using a **fan nozzle** (12" Long, 1½" Wide, and ½" Deep, seen in Fig 8) at **a 3" distance** from the substrate, and at a 90° angle to the surface. All testing was conducted using these settings.
- **Two variables were altered for testing:**
  psi: tested at 150-120-100-80
  pounds of aggregate per minute: tested at 2-4-6
- Samples were tested using a custom-designed apparatus (shown in Fig 9) to hold the samples in place during testing. The tool shown in Fig 8 was used to regulate the 3" distance between the nozzle and sample surface.
- Testing was done by applying 3 passes back and forth across the sample surface, for approximately 10 secs, to mimic practical application.

Fig 8: Unit blast nozzle with attachment to regulate distance during sample testing

Fig 9: Sample held in place during testing

RESULTS

Successful results were found at **80 psi using 2-4 lb/min of shaved pellet and/or shaved block aggregate**. 150,120, and100 psi produced significant surface damage at all aggregate levels. The table below displays settings tested; highlighted areas show the successful settings.

Aggregate/psi	150 psi			120 psi			100 psi			80 psi		
Shaved Pellet	2	4	6	2	4	6	2	4	6	2	4	6
Shaved block							2	4	6	2	4	6

Figures 10 and 11 below are before and after photographs of cast iron sample tested at 80psi, 4 lb/min shaved pellet aggregate at 3" distance from surface. There is minimal visible difference at 350x magnification except the removal of a few areas of slag inclusion.

BEFORE

Fig 10: Cast iron sample before testing x350 magnification

AFTER

Fig 11: After testing at 80 psi, 4lb shaved pellet/minute x350 magnification

COMPARISON TO AIR ABRASION

For a brief comparison with another abrasive technique, cast iron samples were tested using an SS White Airbrasive® 6500 System 2 using aluminum oxide powder. Testing was performed at 70psi, powder flow at approximately 14 g/min (average user settings). The nozzle was placed at a 1", ½" and ¼" distance from the sample surface; again, this was taken from average effective user settings, rather than a direct comparison to the dry ice blasting settings. The air abrasive treatment damaged the cast iron sample surface more severely than the dry ice blasting parameters tested. Other air abrasive settings may not have damaged the surface. However, these results combined with the difficulty of containing aluminum oxide debris on a large scale, compared to dry ice blasting, solidified the decision to continue with dry ice blasting research for large-scale objects.

BEFORE

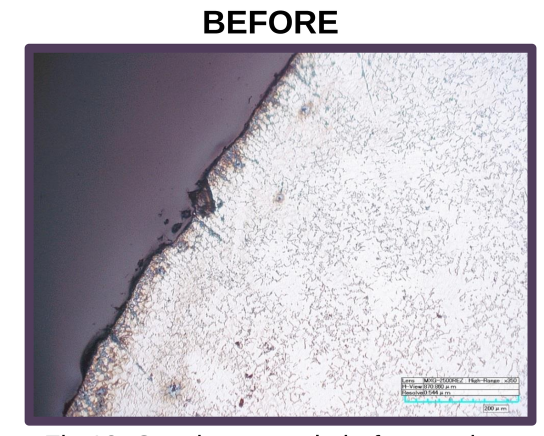

Fig 12: Cast iron sample before testing, x350 magnification

AFTER

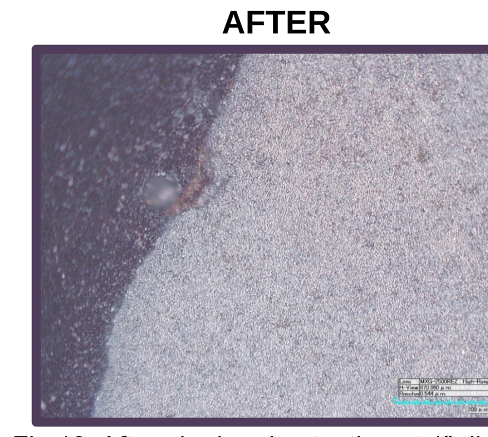

Fig 13: After air abrasion testing at 1" distance X350 magnification

APPLICATION OF RESULTS

The final application method was to apply Savogran Strypeeze® varnish & paint remover to the surface of the object with a cloth, allowing the solvent to sit for 3-5 minutes. The excess solvent was then wiped from the surface with a cloth. Then the surface was dry ice blasted until paint in the area was visibly removed. After the entire surface of the object was treated, the surface was degreased with ethanol to remove any traces of the solvent.

The entire dry ice blasting treatment and removal of paint took a total of 6 hours of treatment time. This is a significant time improvement, compared to 9-months of mechanical treatment time using solvent, dental tools and scalpel, as used on the previously mentioned Dahlgren gun. The paint and corrosion removal was extremely effective in this method. A few small pin points of paint remained adhered to the objects' surface after treatment. However, these were removed after electrolytic reduction treatment, followed by a second dry ice blasting treatment at the same settings as previously used.

Fig 14: Object before treatment

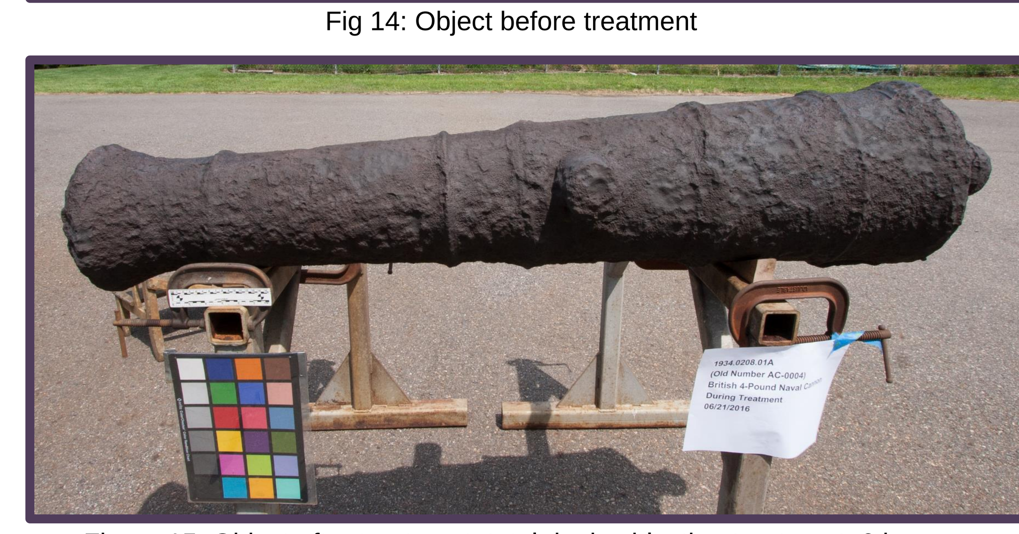

Figure 15: Object after treatment; total dry ice blasting treatment: 6 hours

CONCLUSIONS

- As seen in the images above, paint and corrosion were successfully removed from the surface of the guns using dry ice blasting in conjunction with solvent treatment. This method provided both a time efficient-treatment and minimal surface damage to the object.
- Successful parameters for dry ice blasting cast iron were found to remove corrosion using a ColdJet SDI Select 60 at 80 psi, 4 lb of shaved pellet aggregate per minute, at a 3" distance, using a 12" fan nozzle. This method could be applied to other large cast iron objects when abrasive cleaning is required for reduced treatment time. However, if a different blasting unit or nozzle is used, severity of abrasive damage to the object's surface may differ.
- Dry ice blasting process can significantly shorten mechanical treatment time, and can lessen the risk of surface damage to objects.
- Research is currently being conducted on the use of dry ice blasting to develop cleaning parameters for copper alloys.

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Images in Fig 1-3, 5-15 courtesy of The Mariners' Museum and Park

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