Laser cleaning of the Nickerson House exterior

What damage does the smoke of Chicago do to the architectural interests of the city? It does incalculable damage, both from an artistic and financial standpoint. What chance has any light color in Chicago?... There is soot everywhere.

A City's Smoke and Soot, Chicago Daily Tribune; August 18, 1888

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The "smoke nuisance" as it was referred to by the denizens of nineteenth-century Chicago, was caused predominantly by the burning of bituminous coal. During the late-nineteenth century, bituminous coal was the preferred fuel for industrial, transportation, and domestic use in major urban centers such as Chicago. By 1890, the city of Chicago consumed almost eight billion tons of bituminous coal annually. While the coal proved to be a cheap and bountiful source of energy, it was also exceedingly dirty, as one contemporary architect bemoaned,

The smoke has an injurious effect on the stone…The smoke destroys all beauty and brightness, and in a few years buildings have the appearance of being three or four times their real age. From the looks of the buildings erected shortly after the fire we could set Chicago up as being an ancient city. And it is all on account of the smoke.

As with many new buildings in post-Fire Chicago, the "smoke nuisance" took a heavy toll on the exterior of Samuel Nickerson's stately residence. The first through third floors of the mansion are clad in an extremely porous yellow brown sandstone from Berea, Ohio. Due to its porosity the stone readily attracts pollutants. Period photographs show that within five years of construction the exterior masonry had accumulated a heavy layer of soot.

By 2003, the building was covered in a black crust comprised of more than a century's worth of pollution and grime. Conservators conducted a preliminary survey of the sandstone exterior in the fall of 2003. Petrographic analysis determined that the sandstone has a silica binder and contains iron oxides and pyrites that are visible as many small red granules within the stone matrix. The stone is gray in color when newly cut, but after exposure to weather, the surface develops a natural brown/yellow patina over a five to ten year period. The black soot encrustation was found to be a complex mixture of industrial pollutants, containing carbon and a mixture of metals including lead and zinc. In certain areas of the façade, the accumulated layers of soot were found to be as much as 20 mils thick.

The preliminary survey of the exterior revealed that, despite its age, the sandstone masonry was in a relatively good state of repair. However, the survey did confirm that the century old accumulation of black soot was causing the erosion of decorative stone elements. The most common and problematic deterioration issue was the visible chipping, spalling and erosion occurring at the underside of belt-courses and protruding stone elements. This deterioration was caused by water infiltration at the exposed top of the stone that was then trapped at the bottom by the heavy soot incrustation. The trapped water would freeze and expand in winter conditions, causing the sandstone matrix to disintegrate. The deterioration of the belt-courses and decorative stone was ongoing and accelerating. In order to prevent further damage to the sandstone it was determined that the soot encrustation would have to be removed.

In October 2003 and March 2004, a variety of cleaning systems were tested for their efficacy in removing the soot encrustation from the sandstone while causing the least amount of damage to the stone below. An area of the east elevation that was fully enclosed within a light well between the Nickerson Mansion and the Murphy Auditorium was used for testing. Mock-ups were completed using both controlled chemical cleaning methods and a laser cleaning system to remove the black encrustation from the sandstone exterior. The chemical cleaning tests ranged from mild to relatively aggressive, and employed soap and solvents and diluted acids. The chemicals were

applied both as washes with short dwell times and poultices with extended dwell times (poulticing is a cleaning technique whereby chemicals are mixed with absorbent powders to form a paste which is then applied to the stone surface. As the poultice dries, impurities are drawn out from the stone over a period of hours. When the dried poultice is removed it reveals the clean surface of the stone). The applications were then rinsed with HPLV water. Abrasive methods, such as micro-blasting, were determined inappropriate from the beginning of the testing regimen due to potential surface loss.

Some of the chemical tests proved to be so potent that the surfaces of certain test areas turned an unnatural bright white, devoid of any detail. It became evident that the belt courses and other ornamental details were more difficult to clean than the flat stone ashlar. In addition, the difficulty of cleaning the more intricate decorative areas of stone led to a disparity in the finish between the different surfaces.

Initially the laser cleaning system was brought in to address the heavy soot on the belt courses. The process of laser cleaning has been used in conservation since the 1980s, to remove built up pollution from objects and sculptures. The initial intention in terms of the Nickerson project was to use the laser to clean smaller areas of the Nickerson façade of heavy soot build up. Testing on mock-up panels showed that the laser produced dramatic results on both the belt courses and flat stone ashlar. The laser proved to be highly capable of removing soil deposits located on the underside of molding profiles. The sandstone in these areas was extremely friable. Had wet and/or abrasive methods been used, material would have been lost to erosion. Wet cleaning methods also had the potential for causing staining from corrosion.

The laser works through a process called ablation. A pulsed, highly focused beam of light is directed at the surface creating thermal pressure. The surface contaminant (in this case the soot encrustation) is both turned to a plasma and a micro-crack structure forms that breaks the mechanical bond between the stone and soil layer. The process is dependent upon having a relatively reflective substrate. While there are certain risks associated with laser cleaning, the process is essentially self-limiting. Once the laser reaches the reflective substrate, after all of the soil is removed, the cleaning process stops. It is important to note that although laser ablation can be considered a self-limiting process, it is not an intelligent self-controlling solution to conservation problems. The skill and care of the operator makes all the difference. The operators were required to move the optics very quickly in random patterns to prevent the laser from dwelling on the surface for too long, which had the potential to cause burns, and to prevent visible patterns from forming.

The first laser system tested was a Q-switched YAG Laser by the French manufacturer Quantel. The system provided a single narrow beam of pulsing light that was focused through a flexible fiber optic cable to a hand held gun. Despite the successful results, the 5mm wide beam and limited power of the laser proved to be a very time consuming method of cleaning. A second laser system, distributed by Adapt Laser Systems, was brought in and adapted for cleaning stone masonry. The Adapt System used two different types of hand pieces. One was shaped like a gun and worked well on the flat surfaces. The second optic was a more compact stylus that produced a more intense beam. The stylus performed well on areas with architectural detail.

In 2004, Conservation of Sculpture & Objects Studio, Inc, of Forest Park, IL, received the commission to clean the entire building using the Adapt Laser System equipment. The project was budgeted in two ways; the first option was to clean the flat stone ashlar with chemicals and the belt courses with the laser, the second was to clean the entire building with laser. The cost savings achieved by using the chemicals was negligible, and the decision was made to avoid the risks of the chemical cleaning altogether.

The final laser cleaning standard was set during trials on March 2–4, 2004. Based on this standard, the crust was successfully removed from the exterior sandstone, restoring the original porosity to the stone. The level of cleaning was determined to be accurate to the age of the building and the original patina and veining of the stone were preserved. The soil was inconsistent throughout the four elevations of the building, differing in thickness and tenacity. The cleaning rate that was determined during the March trials was in practice rarely attainable and never sustained. On average the laser cleaned at a rate of approximately 2.5 square feet per hour.

Of the three major elevations cleaned, the soil on the east elevation was moderate, thinner, and more easily cleaned. Throughout most of the east elevation the cleaning rate was consistent with the standard determined during the trials. The one exception to this was the oriel window projecting from Mrs. Nickerson's Sitting Room on the 2nd floor. The bow window was coated with a thick crust that sat in all the recesses and cavities of the foliate carved stone ornament. The slow cleaning rate of this area was compounded by technical problems that the operators experienced with the laser.

The south elevation, facing Erie Street, was far more difficult to clean. Due to the thickness of the crust and the more elaborate ornamentation of the south elevation, the average cleaning rate across the entire elevation dropped to approximately 2 square feet per hour. The cornice was heavily contaminated and the soot encrustation was thick and very hard. It took almost two months to completely clean. The window surrounds at the southeast corner of the mansion were both heavily soiled and badly stained. Despite all efforts to remove it the staining remained after laser cleaning the masonry three times.

The encrustation on the west elevation was thin to moderate on the lower two thirds of the elevation. It was removed much more easily than anticipated. Projections for the cornice on the west elevation were based on the cleaning rate achieved on the south elevation. The masonry in proximity to the second floor windows was very dirty. Here, work slowed significantly, to approximately two square feet per hour. Numerous stones were cleaned twice to remove residual soil and stubborn marks. The west elevation of Mr. Nickerson's Art Gallery, at the north end of the building was heavily soiled and took five weeks to clean. Much of this time was spent cleaning the balustrade and cornice. Despite the painstaking cleaning effort, the cornice retains dark stains and the stone appears to be insufficiently clean. The west elevation has numerous stones previously stained by the corrosion of the iron oxides beneath the black crust. These stains have been cleaned as well as possible and cannot be cleaned any further with laser treatment.

The north elevation at the rear of the property was mildly to moderately soiled. The soil was removed easily and relatively quickly. The interior side of the gallery balustrade was very badly soiled and, in a similar fashion to the soil on the south elevation, the contaminant was densely compacted.

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The surface area of stone cleaned totaled approximately 20,000 square feet and the work took eighteen months to complete. The small beam width of the laser in comparison to the large surface area, the inconsistent thickness and tenacity of the soil, and the technical problems experienced with the equipment made for a treatment that was painstaking and time consuming. Throughout the stone exterior, black and brown stains or halos exist approximately one inch from the mortar joints, which indicates that water in the stone migrated toward the joint and could escape through neither the crust nor the mortar joint.

Despite the difficulties encountered the results are very satisfying from a conservation standpoint. The original patina, veining, coloration of the stone, and friable elements were preserved. The cleaned exterior masonry will now be permitted to breath. Any water that infiltrates the stone will easily evaporate, where previously it had become trapped by the soot encrustation. The cleaning has assisted in creating an age appropriate aesthetic appearance characterized by muted tones. The stone does not appear overly clean. The removal of the soot encrustation allows the stone to oxidize naturally and since the completion of the laser cleaning the stone has proven to darken somewhat over time.