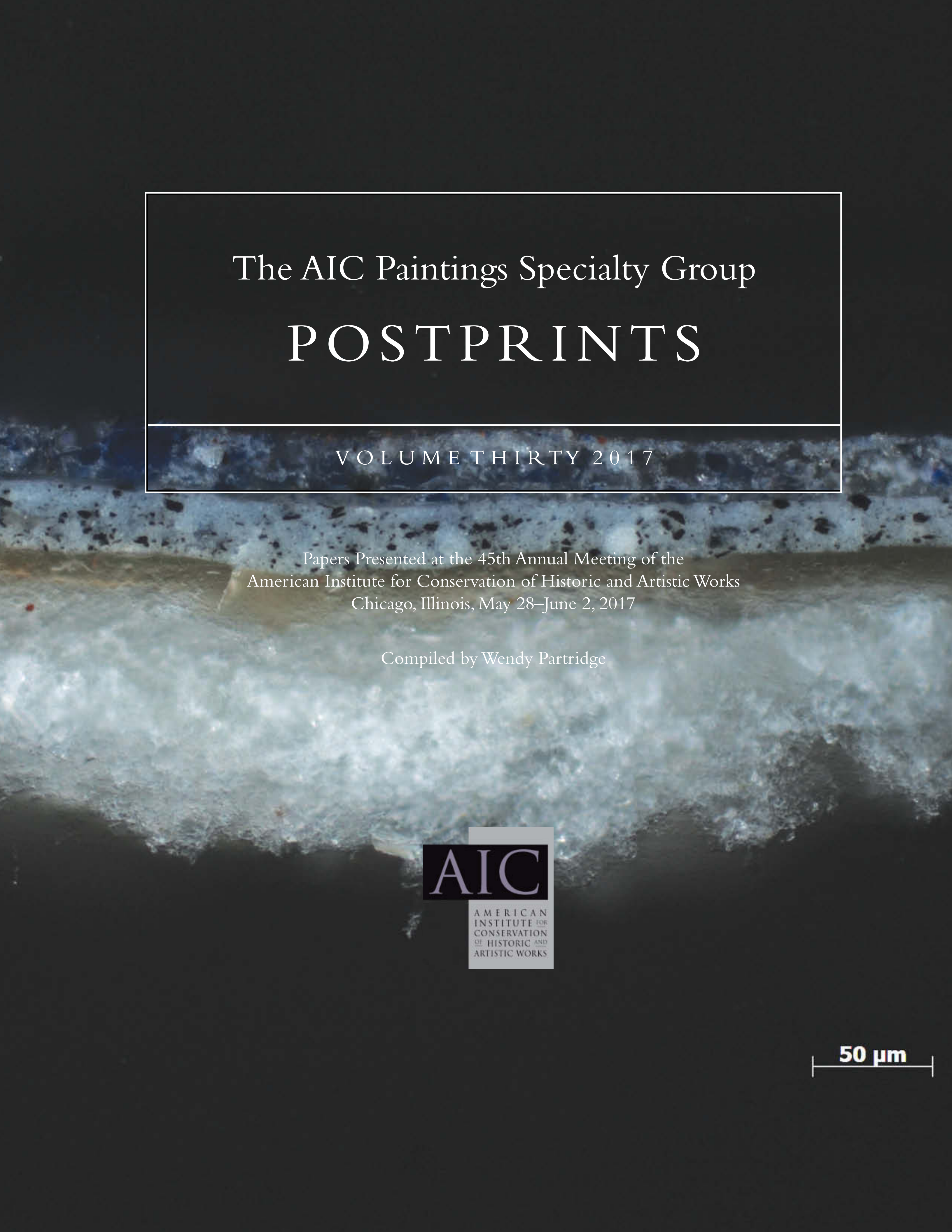

The AIC Paintings Specialty Group

POSTPRINTS

VOLUME THIRTY 2017

Papers Presented at the 45th Annual Meeting of the
American Institute for Conservation of Historic and Artistic Works
Chicago, Illinois, May 28–June 2, 2017

Compiled by Wendy Partridge

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STUDIO TIP: Innovative Applications of Mild Heat Transfer Mat and Low-Pressure Systems for the Lining and Minimal Structural and Cleaning Treatment of Paintings and Other Artworks

ABSTRACT

The tip presentation shared recent applications and directions of research into the application of mild heat transfer for diverse conservation treatments, specifically deploying small, flexible precision heating mats. The mats were first developed in 2003 and substantially refined during the European Intelligent Mobile Multipurpose Accurate Thermo-Electrical Device (IMAT) Project (2011–2014) by the innovative application of carbon nanotubes and smart textile technologies. The mats were designed with numerous treatment-driven features to deliver ultraprecise and steady heat to a variety of surface geometries, as an alternative to the imprecise and limited devices that conservators historically have in the laboratory. Notably, the mats offer the ability to transfer heat in the mild range (20°C–40°C), which has been previously inaccessible to conservators, offering new opportunities for professionals the field.

1. AN OLD PROBLEM WITH HEAT TRANSFER

When treating sensitive traditional, modern, and contemporary artwork materials, the degree of accuracy and the steadiness of heat transfer are essential to limit the invasiveness of the treatment, while achieving effective and safe consolidation of paint, treating planar deformations and cupped cracks, lining, enzymatic cleaning, and other treatments. Historically, restorers used crude heating methods in which uncontrolled heat, pressure, and moisture resulted in unpredictable and unsatisfactory outcomes. Heating tables and most of the instruments used today lamentably lack precise controls and even heat distribution across the surface, which limits the approaches and degree of success of conservators in their practice. Typical instruments, even if thermostatically controlled, have poor performance with wildly fluctuating temperature cycles that correspond only "on average" to the temperature desired. These instruments are usually regulated only at temperatures above 40°C, making mild temperature ranges inaccessible. Conservators lack portable precision instrumentation for heat transfer over large surfaces, and economically unsustainable hot tables are notorious for "hot" or "cold" spots, which impair effective treatment and threaten the safety of the artwork. These large units have high voltage and power requirements and are infeasible to use on-site and in laboratories without special power outlets. How are conservators expected to refine their treatments with such blunt instruments?

2. MOBILE PRECISION HEAT TRANSFER METHODS USING FLEXIBLE HEATERS WITH NANOMATERIALS

Although flexible heaters are broadly applied in diverse industries, they have had limited use in conservation. The flexible mat design was first proposed by H. Ruhemann in the 1960s but was not developed. The colossal *Panorama Mesdag* (1881) in The Hague was lined in the 1990s with a perforated silicone rubber mat designed and built as a rigid heating platen by J. van Och (SRAL, Maastricht). A different approach was taken by the authors who used their own flexible heating mat prototype in 2003 to treat two murals on canvas (1937) by H.S. Sewell as well as other paintings (Markevičius and Olsson 2010). The methodologic advantages realized in these early applications encouraged the pursuit of additional performance features to complement the accuracy and versatility of the new portable heat transfer system and flexible mats that can be applied over the artwork of any size or geometry and operate in full range of temperatures that may be required in diverse conservation treatments. Both transparency and permeability to airflow and water vapors were desirable because humidity is often used in conjunction with heat transfer. The latter was not possible with the existing technical status quo, and the innovative solution was found in electrically conductive nanomaterials such as carbon nanotubes (Markevičius et al. 2013a), which became the main focus of the European IMAT project (2011–2014), during which nanotube heating mats were created in ultrathin profiles with nontack surfaces, in transparent and permeable forms, using electronic textiles with woven carbon yarns. The project consisted of the design of a novel heat-sensing, control, and monitoring system that provides even heating with accuracy of 0.1°C (fig. 1) (Markevičius et al. 2013b).

3. TOWARD THE NEW TREATMENT METHODOLOGY

Flexible wound wire and etched foil heaters have been applied in a series of treatments since 2003 by the authors. Since 2011, the newly developed IMAT prototypes with conductive nanomaterials operate over the same full range of temperatures. In fact, they exceed those used in conservation practice (ambient 85°C), outperforming heating tables by precision, versatility, and tailored heat transfer over small or large areas with reduced heating and cooling times. Nanomaterials allow thermal conduction at the ultralow and safe voltage of 36 V that cannot pass the skin barrier. High conductivity of nanotubes coupled with low thermal mass results in very fast thermal response, short heating and cooling times, and steady temperature control—both in higher (40°C–85°C) and lower ranges (20°C to 40°C)—to deliver heat that gradually and uniformly permeates the entire paint, ground, and canvas structure. The thin flexible profile of the mat allows it to be inserted between the canvas verso and the wood secondary support so conservators can perform minimally invasive treatments while the work remains on the stretcher. Air permeability combined with the flexible heater offered new opportunities in treating planar distortions, conservation of earlier treatments, and more. IMAT mats have also been used experimentally to optimize enzymatic gels and hydrogels on paper and canvas support in cleaning treatments and in a

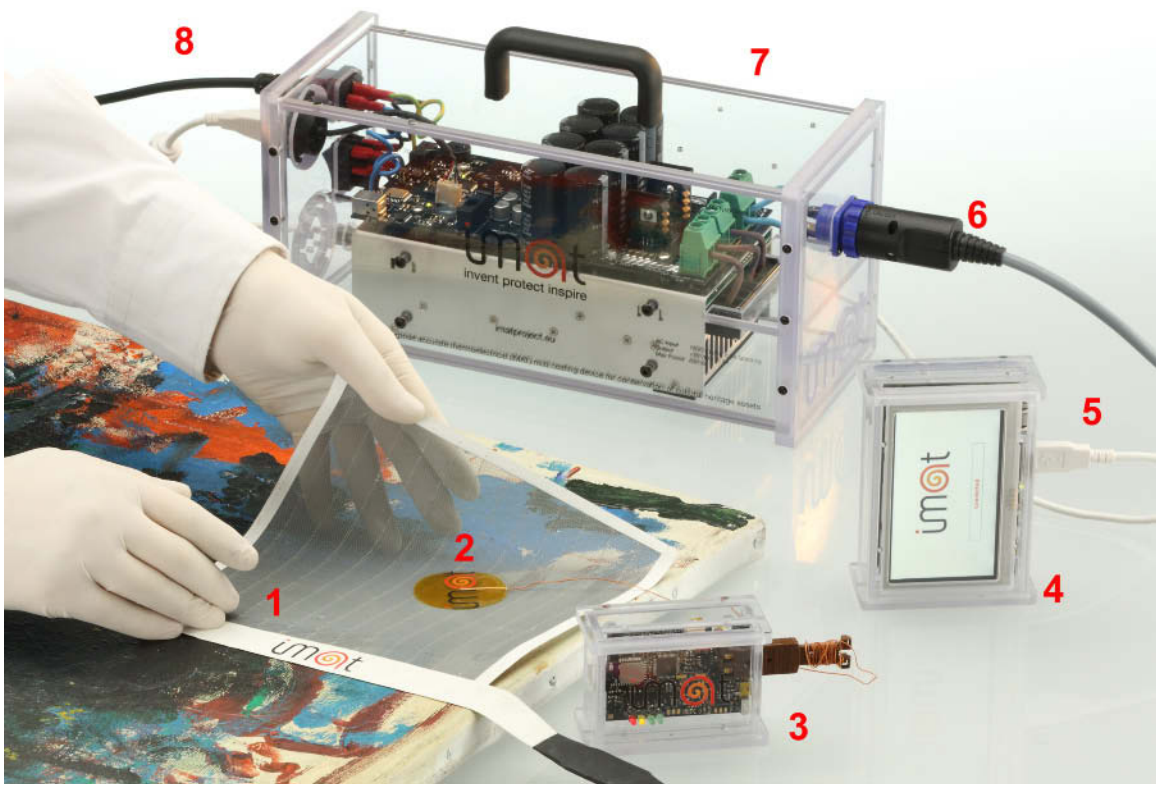


Figure 1. Components of the IMAT mild heat transfer instrument: (1) breathable heater, (2) temperature sensor (thermocouple), (3) wireless temperature sensor, (4) touch screen pad, (5) USB cable, (6) power out cable 36 V, (7) temperature controller, (8) power cable in 120/230 V.

nonsolvent removal of pressure-sensitive tape and laminated on paper support.

4. TREATMENTS

4.1 Lining, consolidation, and treating of planar deformations

Treatment of Howard S. Sewell's *The Coming of the White Man* and *Immigration* (1937, oil on cotton, 153 cm × 690 cm Oregon City High School, Oregon City, Oregon) presents an interesting case study of a mobile treatment of large format paintings on-site. In 2003, a prototype heater was custom-designed for use in the treatment of two New Deal mural paintings on canvas that required relocation. The silicone rubber heating mat with wound wire elements was custom-made (91 × 168 cm) to accommodate the height of the paintings, each composed of three separate sections originally marouflaged to the wall as a single image. The works were lined onto a single continuous needled felt backing with a Reemay interleaf loaded with BEVA 371. A vacuum envelope was created on-site with Dartek with two outflowing points connected to a GAST-0523 vacuum pump. The works were then heat bonded in sections to the backing, positioning the thermocouple between the heater and the backing surface. The heating mat allowed the work to be conducted on-site at the school using a 240-V circuit.

The flexible heater was indispensable for treatment of Kenneth Hudson's *Allegory of State of Oregon and the University of Oregon* (1928, oil on canvas, 117 × 203 cm, Straub Hall, University of Oregon, Eugene, Oregon). The mural was originally tacked directly onto the masonry wall and was exposed to condensation that caused severe planar deformations of the canvas. The lunette was tensioned onto a provisional strainer with muslin strips adhered to the edge with BEVA film, and the entire canvas verso was humidified for 1 hour. As the stiff, hardened canvas became supple, the tension of the canvas was adjusted to target and improve planarity in the most distorted areas. Mild heating was applied to the recto, beginning at 22°C and incrementally raised to 40°C over a period of 15 minutes, then maintained at 40°C for 45 minutes until dry, with periodic substitution of blotters to absorb the introduced humidity. The use of precision mild heating at low temperature, introduced gradually, and maintained over an extended period allowed for successful elimination of all surface distortions (fig. 2). The mural was housed in an architectural niche, located in the entrance foyer of a high-traffic public building lacking stable ambient conditions. In the next step, Dibond, an aluminum-clad composite panel with polyethylene core, was prepared. The painting was removed from the provisional strainer, positioned onto a panel, and nap bonded within a low-pressure envelope at the 65°C activation temperature using a flexible heater.

A more recent and still ongoing comprehensive treatment of the Orazio Gentileschi painting *Judith and Her Maid Servant with the Head of Holofernes* (1611, oil on canvas, 136.5 × 159.5 × 2.5 from the Nasjonalmuseet, Oslo, Norway) included the replacement of a failed 19th century glue-paste lining. The innovative lining was carried out using a prestretched lining canvas in a low-pressure envelope and a modular heat transfer using a transparent 36-V IMAT mat with carbon nanotube heating element to activate the BEVA 371 film. The lining canvas was loomed on a modular metal frame fully enclosed in a sealed Dartek envelope with four outflowing points connected to a GAST-0523 vacuum pump. Heat activation of the BEVA film was accomplished in sections using the IMAT mat (60 × 90 cm), which was placed under the envelope (fig. 3). To ensure an optimal heat conductivity and uniform heat transfer, the IMAT was placed on a corrugated paper board, which allowed the weight of the loom to improve contact between the envelope and the heating mat. The temperature was controlled with two separate sensor: one under the envelope (to run the heater) and one on the surface of the painting to monitor the temperature of the painted surface. Each section was heated up to 65.5°C for 15 minutes (fig. 4). The method allows for a minimally invasive lining on paintings of any size to be carried out using easily portable equipment.

Robert Motherwell's *Open No.16 in Ultramarine with Charcoal Line* (1968, acrylic on canvas, 252.7 × 473.7 cm, ex.-collection Dedalus Foundation, New York, New York), was damaged during transport, leaving a 13-cm concave and dimpled dent in the center of the composition and two areas of surface distortions in the lower corners. The work had been previously cold-lined with BEVA-Gel onto cotton canvas. Owing to the large format and transport status of the work, the treatment was conducted at a storage facility, with the painting mounted vertically to provide access to both faces. A thin-profile (22 × 28 cm) heating mat was introduced between the wood stretcher and the canvas and heated to 40°C for 10 minutes to soften the lining adhesive and relax the canvas and paint layers. Once softened and smoothed, the deformation sites were cooled between two heat sink plates held in place for 30 seconds from either side. The same procedure was used to smooth the concave dent in the center. Various features of the heating mat system were ideal in resolving the challenges involved in this specific case: the portability of the system allowed work to be conducted on site; the size of the heating mat allowed the heating of an area slightly larger than the dent sites; the thin profile of the heat transfer mat allowed for heat transfer to the verso otherwise inaccessible because of the stretcher; and the

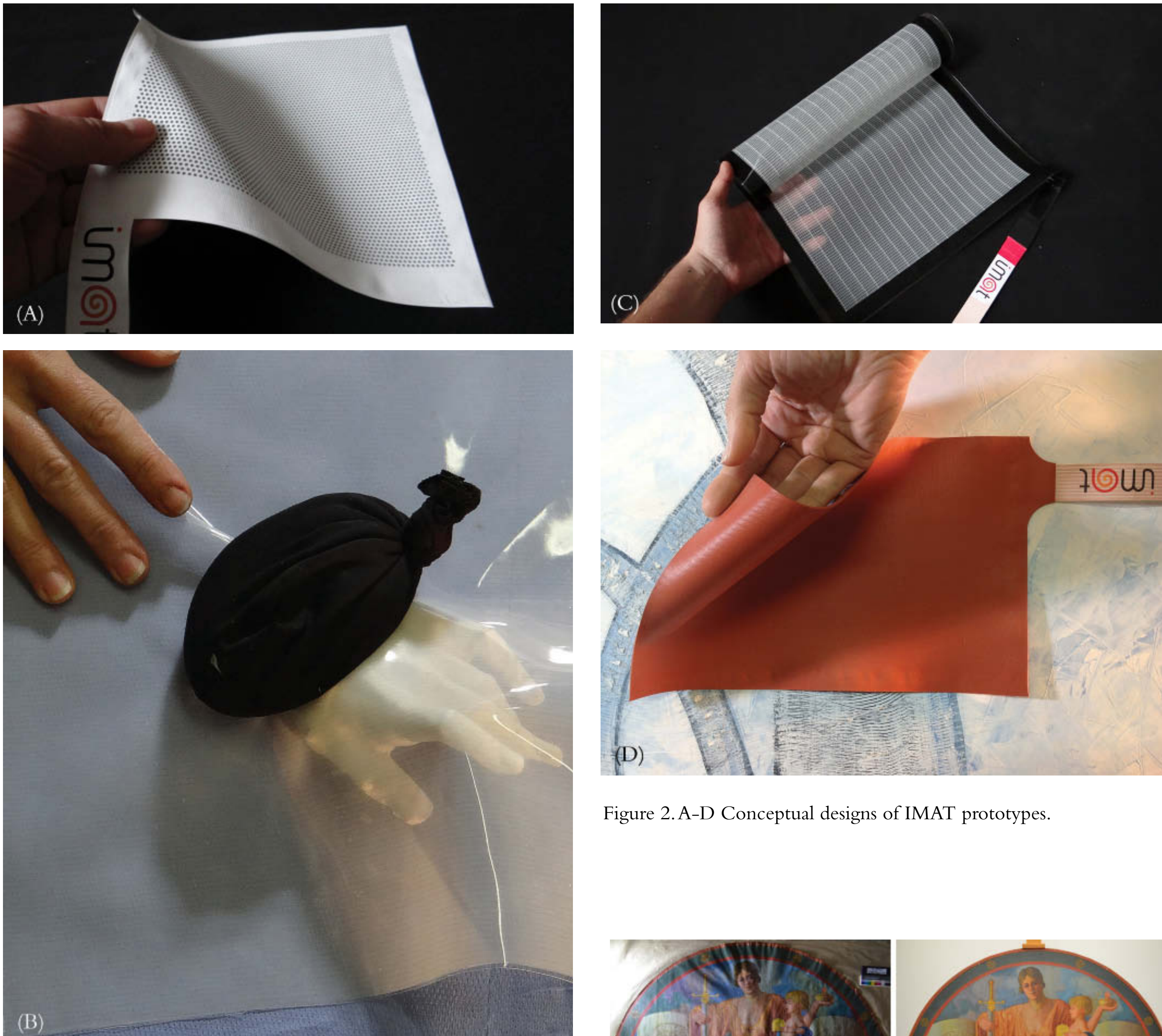


Figure 2. A-D Conceptual designs of IMAT prototypes.

Figure 3. Kenneth Hudson's *Allegory of State of Oregon and the University of Oregon* (1928): planar deformations (top left), provisional tension with strips (bottom left), treatment of the planar deformation with mild heat (bottom right), AT after lining (top right).

accurate low temperature was ideal in treating the acrylic paint film in the safest range (fig. 5).

4.2 Temperature-optimized removal of a pressure-sensitive tape

Removal of an aged pressure-sensitive tape can be challenging when the paper substrate is sensitive to solvents. In this case, pressure sensitive tape was removed from the surface of a collectible 1970s *Star Wars* paper box. A spot test indicated that the printing ink was sensitive to solvents, and "dry" removal using a heat spatula was ineffective since the adhesive cooled (and hardened) too quickly, leaving no time for the removal under the microscope. Extended, steady heat transfer was required during the tape removal process. The solution was found by placing the IMAT under the paper substrate. Various temperatures were tested. At 38°C the adhesive softened enough to allow a safe, gradual tape removal under the microscope. Steady, low-temperature heat transfer was the critical factor that allowed for safe and effective dry tape removal without the use of solvents and within minimally invasive limits (fig. 6). This successful experiment encourages further development of effective, green, and safe temperature-optimized, nonsolvent methods for tape removal and treating paper documents laminated with the acetate films.

4.3 Cleaning with temperature-optimized gels

A pilot study on the application of temperature-optimized gels with and without enzymes was carried out at the Munch Museum, Oslo, Norway, in 2016–2017. In the pilot study the IMAT nanotube mat was experimented with to regulate temperature conditions to optimize cleaning treatments using viscous gels, hydrogels, and hydrolytic enzymes. The testing showed that temperature modulation allows control of diffusivity, capillary action, reaction rate, and enzyme dynamics. Enzymes are temperature specific and their activity could be raised substantially by increasing the temperature, as can be seen in the test sample removing a pigmented glue layer with the protease enzyme Alcalase 2.4L at the same concentration but at different temperatures (fig. 7) (Markevičius and Olsson et al. 2017).

A temperature-based and capillary action approach was used for the surface cleaning of Edvard Munch's *Vampire* (1916–18, oil on canvas, 82 × 110 cm, Munch Museum, Oslo, Norway, catalogue raisonné M1172). A 5% agar gel, containing a hypertonic water solution, was used to clean the unvarnished surface. Having established the optimal application temperature, the liquid hydrogel was applied by brush at 39°C. As it cooled to room temperature, the soiling became entrapped in the agar though the capillary action of agar pores. The solidified hydrogel was lifted after 1 minute, revealing the intact and cleaned surface. The cleaning action was

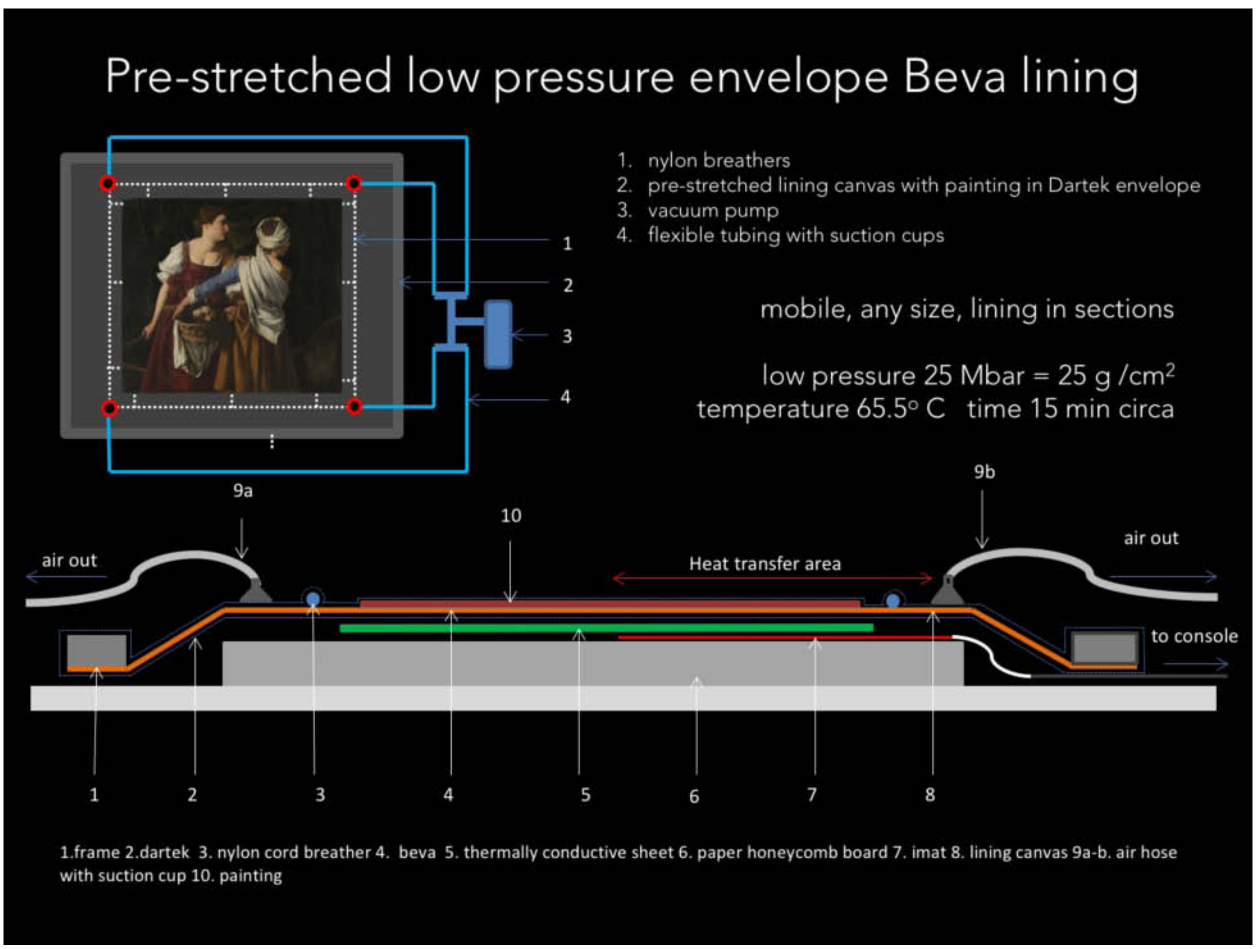
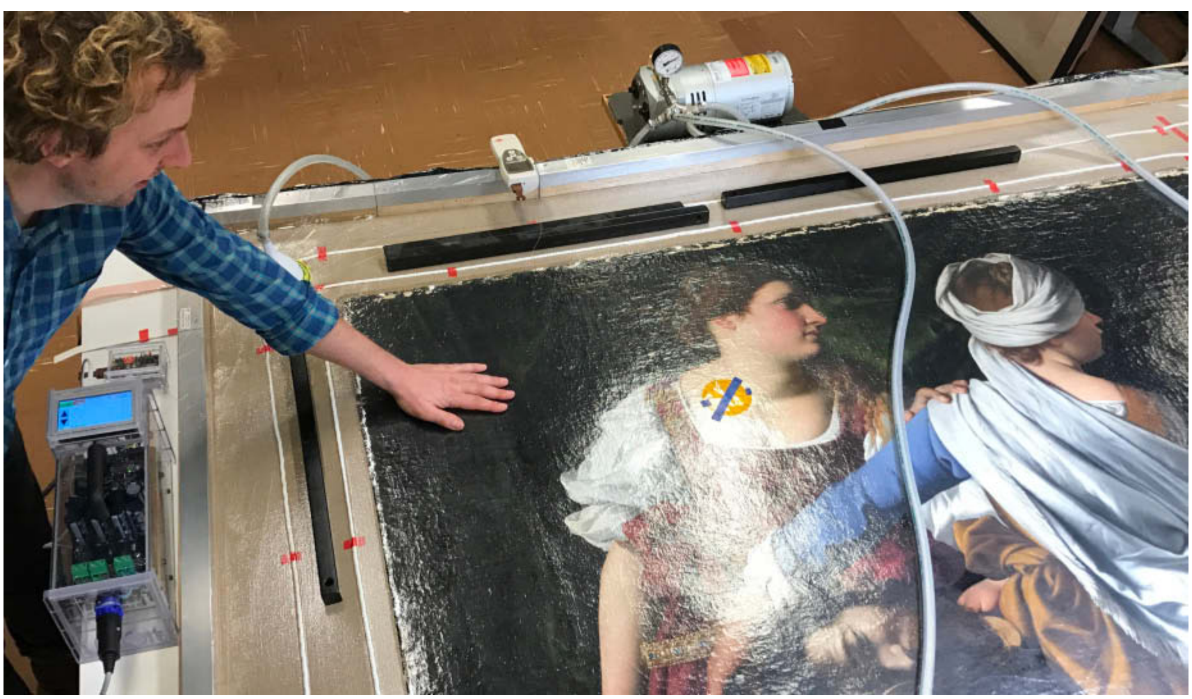


Figure 4. Diagram showing the Gentileschi lining.

A



B

Figure 5. A and B Gentileschi during lining.

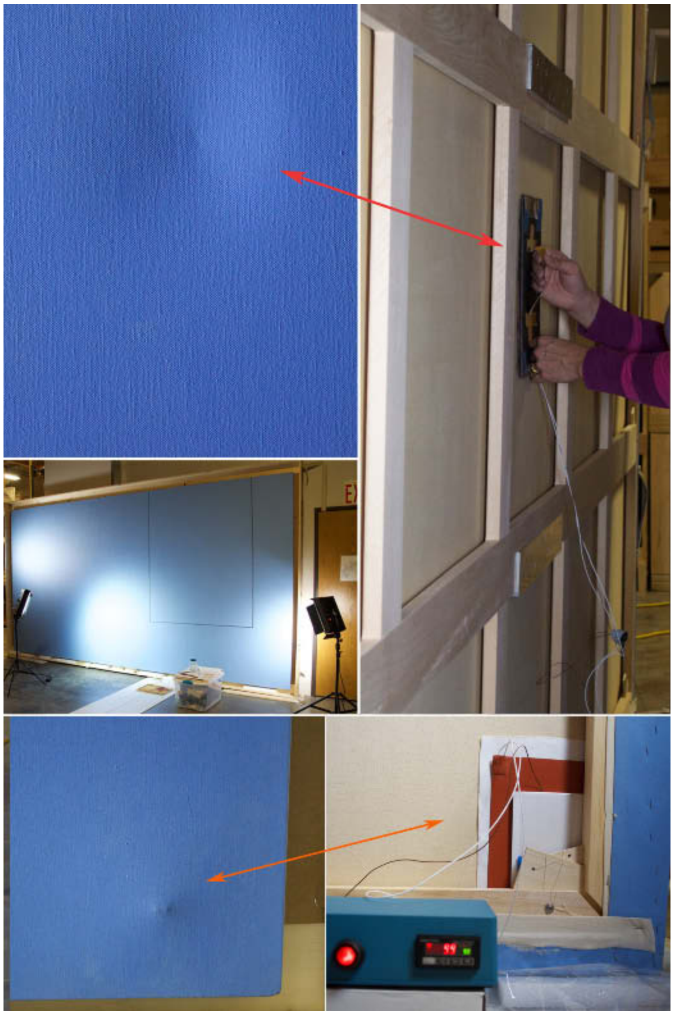


Figure 6. Robert Motherwell's *Open No.16 in Ultramarine with Charcoal Line* (1968): mild heat is applied with a mat from the verso to treat planar deformations.

temperature specific and increased at lower application temperatures. Accurate control of the gel temperature was very effective in controlling the diffusion of the active content and capillary action of the hydrogel. To maintain the agarose at 39°C (±0.1°C) during the treatment, the IMAT was wrapped around the beaker (fig. 8).

Temperature-optimized enzymatic cleaning has become a new standard for treating works on paper at the Lithuanian Art Museum (a partner in IMAT research project) in Vilnius, Lithuania. Since 2013, the IMAT has been used for diverse enzymatic treatments (removal of animal glue, starch, and oil) of more than 80 works on paper. As an example, aged glue residues were removed from a print by Gillian van der Gouwen (1640–1720, 18.8 × 11.2 cm, accession No. G-11040). Alcalase 2.5L DX at 0.1% (v/v) was used in 5% Tylose MH300. The gel was applied to both sides of the print, covered with polypropylene film, with IMAT mats positioned on both sides. While at room temperature (19°C) the enzymes did not have much effect on aged protein stains, but treatment at 45°C removed the stains completely (fig. 9).

5. CONCLUSIONS

In the context of the evolving use of precision mild heat transfer in art conservation, the tip shared a series of case histories of minimal lining and structural treatments of diverse paintings conducted over a 14-year span (2003–2017). Innovative mobile low-pressure methods and high-performance precision flexible mats with carbon nanotubes allow for highly accurate and steady mild heat transfer. Since 2003, multiple advances to their design as well as new nanomaterials have radically expanded their technical

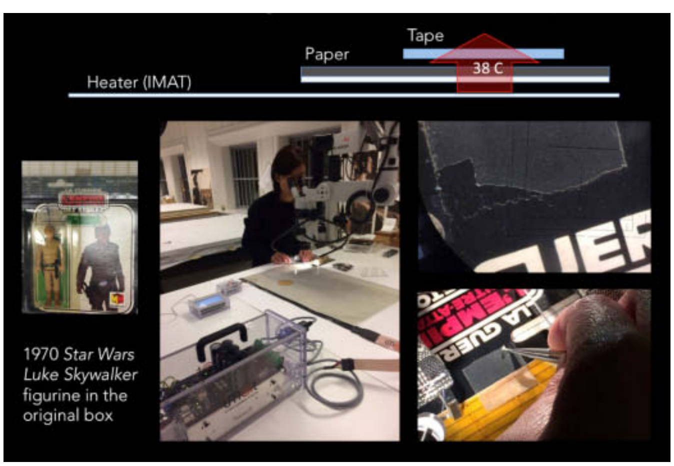


Figure 7. Removal of pressure sensitive tape from printed *Star Wars* box.

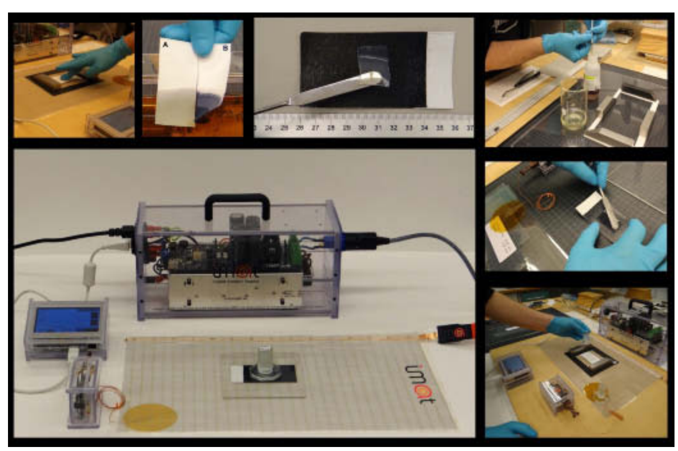


Figure 8. Pilot study on the application of temperature-optimized gels and hydrogels with and without enzymes at the Munch Museum.

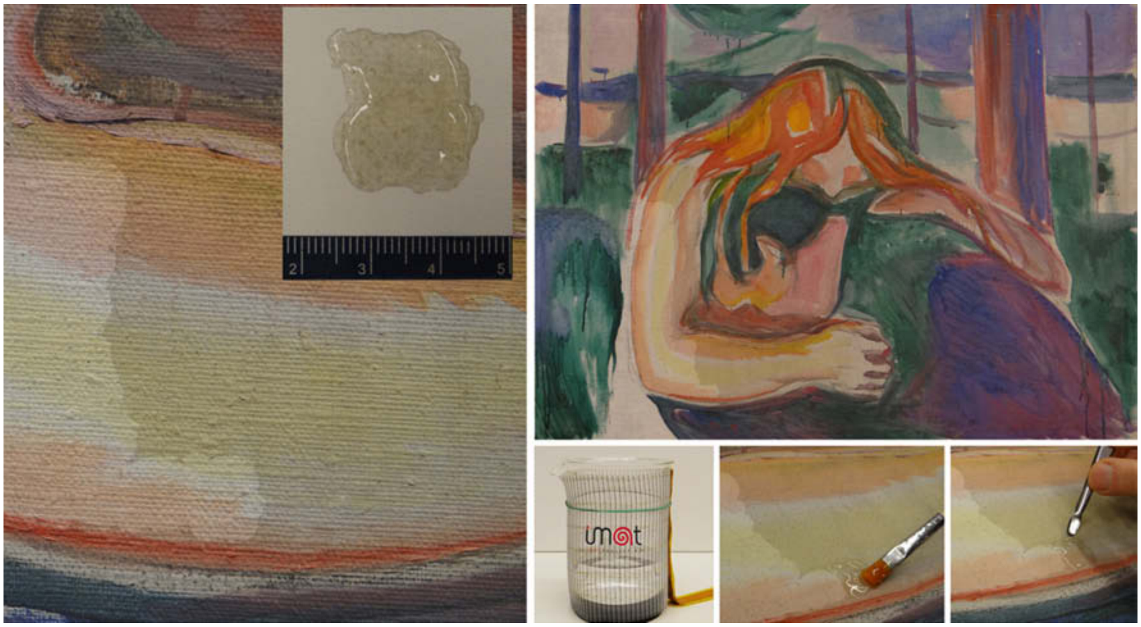


Figure 9. Surface cleaning Edvard Munch's *Vampire in the Forest* using warm agarose.

Figure 10. IMAT used to optimize enzymes to treat paper at the Lithuanian Art Museum in Vilnius.

capabilities, resulting in safer and more nuanced treatments. With the broader availability of a new nanotechnology, new treatment methods have followed, such as temperature-optimized gels and removal of pressure-sensitive tape. The operational parameters and practical advantages offered by a new warming nanotechnology and nuanced approaches taken in each particular treatment show the broad versatility of the new method and how easily it can be tailored to the needs of each particular case. This opens new opportunities for art conservators to tailor their treatments within the margins of minimal intervention and risk. As a final practical note, the authors are currently engaged in the upscaling and industrialization of the IMAT prototype so that it may be manufactured and made available to conservators worldwide. The new MAT (mobile accurate temperature) precision heat transfer system will be further improved by integrating multiple temperature sensors inside the mat and integrating temperature monitoring, safety, and alarm systems among other new features.

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Dartek, 75 mil cast nylon film, Talas, NYC, www.talasonline.com

GAST-0523 vacuum pump, Grainger Industrial Supply, www. grainger.com

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Alcalase 2.4L proteinase from *Bacillus licheniformis*, Novozymes, www.novozymes.com

5% Tylose MH300, Deffner & Johann, www.deffner-johann.de

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