Jessica Ford and Courtney VonStein Murray
Winterthur/University of Delaware Program in Art Conservation

Arabian Knights: the conservation of a historic pinball back glass

ABSTRACT – The early 1950s are known as the golden age of pinball, although many cities banned the activity during the mid-20th century because it was associated with gambling and youth rebellion. *Arabian Knights* pinball game was released in a limited run of 700 machines in November of 1953 by D. Gottlieb & Company. The game's artwork was created by Charles Leroy (Roy) Parker, a highly regarded artist in the pinball world, known for his attention to detail, inclusion of blonde women, and witty storytelling style. In the vividly colored *Arabian Knights* back glass, Parker's design captures post-war America's fascination with exoticism in popular culture.

The *Arabian Knights* back glass is composed of soda-lime-silica glass screen printed with layers of alkyd paints to form the design. Over time, the paint layers have become embrittled and detached; nearly half of the image was lost when the object arrived for examination by students in the Winterthur/University of Delaware Program in Art Conservation (WUDPAC). Stabilization of the flaking paint was carried out using Aquazol® 200 in isopropanol, applied first with an ultra-sonic mister and then with a brush. To visually compensate for the lost portions of the image, a digital reconstruction was printed onto a clear plastic film that was positioned as an underlay. Although this solution seemed simple, in practice it involved creating the image from scratch using Adobe Illustrator and Photoshop and a colorimeter; seeking a professional printing company willing to collaborate on a highly specific project; and working through an imperfect revision process. In the end, this non-invasive approach interacts with the object visually to complete a vibrant representation of 1950s popular culture.

1. INTRODUCTION

When the back glass of a historic pinball machine entered the WUDPAC for conservation, its treatment was taken up as a collaborative project between a paintings conservation student (Jessica Ford) and an objects conservation student (Courtney Murray). The screen-printed painting on glass once served as part of the 1953 *Arabian Knights* pinball game, a mass-produced electromechanical arcade game released by the influential manufacturer D. Gottlieb & Company. The project presented an excellent opportunity to test the use of a digital reconstruction for loss compensation, an option that was expected to save time without sacrificing quality. The authors learned a lot through the process of implementing this plan, and

the challenges encountered provide valuable reference points for similar projects in the future. This paper first presents the object's historical context, followed by a description of the object and its treatment, including both the idealized proposal and the reality of what took place. Finally, considerations for the making of digital reconstructions based on the experiences of this project will be shared.

2. HISTORY

Pinball has been around in some form or another for hundreds of years. Its roots are in billiards, bowling, and shuffleboard (Porges, 2005). "Bagatelle" was a popular table-top game that developed in France in the mid-18th century. In this game, a player would ricochet balls off of fixed wooden pins and into holes to gain points. Thin metal pins and a spring launcher were soon added to the game. In 1869 a spring-loaded, bar-top size version of bagatelle was introduced in the U.S., and pinball was born (IPDB, 2012).

D. Gottlieb & Co. started business in 1927, around the time when technology began to play a big role in pinball's development (Squidoo, 2012). In 1931 Gottlieb released the first commercially successful, coin-operated pinball machine, called Baffle Ball (BMI Gaming, 2012). At seven balls for a penny, pinball provided cheap drugstore entertainment in the depths of the Great Depression (Shalhoub, 2008). Active parts, such as bonus holes that repel the ball back into play and electrified bumpers, were introduced soon after. Gottlieb released Humpty Dumpty in 1947, the first game with flippers (Squidoo, 2012). Skill was now a factor in how long the ball stayed in play and which targets it would hit, and thus America entered the Golden Age of Pinball (Temple, 1991).

By the 1940s, the game was actually illegal in most cities, because it was associated with gambling (Shalhoub, 2008). Before the invention of flippers, results were based on chance, and players placed bets. After the incorporation of flippers, high scores resulted in the accumulation of free games, which could be exchanged for money at some venues (BMI Gaming, 2012). Mayor La Guardia of New York City helped pass a ban in 1940 to protect the city's school children from throwing away their hard-earned money and falling into delinquency (Porges, 2005). He also staged Elliot Ness-style raids on pinball halls, smashing the offending machines with a sledgehammer and dumping the pieces into the river. Most bans were overturned

beginning in the mid-1970s because games of chance were already subject to other laws, and games of skill usually do not have the same restrictions. In Delaware in the twenty-first century, pinball still falls under the same regulations as gambling, and zoning laws only allow so many games under one roof (Morrissette, 2013). In Ocean City, New Jersey, pinball is still banned on Sundays (Porges, 2005).

Mid-century pinball was also distinctive for its artwork, which did not usually present wholesome images. The goal was to create a "five-cent fantasy" for working class males between the ages of 10 and 25 (Shalhoub, 2008). Each back glass was a dazzling, readily accessible glimpse of impossible dreams, which involved many scantily clad women. Adventure was also a major theme. Travel, exotic destinations, sporting events, games of chance, Broadway shows, and nightclub environments completed the escape from the everyday grind (Heimann and Schooling, 2007).

Roy Parker was the sole artist responsible for artwork on Gottlieb pinball machines from 1930 to1966 (Temple, 1991). His artwork is widely recognized as the best, partly because of his excellent design and draftsmanship and his attention to detail (Tuukka, 2011). However, the most successful aspect of his artwork was how he catered perfectly to the target market. His characters resemble the comic and pinup artwork of the era: intentionally unrealistic and therefore unintimidating. His humor diffused any potential self-consciousness that the racy images might otherwise cause in public; they were easy to look at and hard to forget (Sharpe, 1977, 144). *Arabian Knights* was released in a production run of 700 machines in the midst of this defining era, and in 2010 the product was retroactively recognized as 1953's Game of the Year by the Professional and Amateur Pinball Association (IPDB, 2012).

In the 1970s, circuit boards and digitization brought competition from newer, smaller, technologically snazzier, and easier-to-service video games that essentially crowded out the beloved but clumsy pinball machines. With business declining in 1977, the Gottlieb brand changed ownership several times in short succession, and in 1996 Gottlieb's assets were sold to the benefit of its creditors (Squidoo, 2012). Currently in the US, there are two pinball manufacturers, Stern in Chicago, a comfortable relic of the Golden Age, and Jersey Jack, a newcomer that is working to establish itself. Most of the market is made up of private collectors, and arcade-themed bars have largely replaced independent arcades (BMI Gaming, 2012). Pinball is a rare find within one of these establishments, however, due to the expensive and frequent

upkeep required. For example, at Wilmington's 1984 barcade, owner Matt Morrissette earned $40/week from a pinball machine, fittingly called the Black Hole, and spent up to $300/week to keep it running (Morrissette, 2013).

For entrepreneurs like Matt, pinball cannot be replaced by other arcade games. Each play is spontaneous and unique. The dramatic shape and decoration of the play boxes provide his bar with "elegance" as he puts it, and the physical mechanics contrast appealingly with modern video games. Add to this pinball's enduring Golden Age reputation of forbidden glamour, and you have an icon of American subculture that appeals far beyond the original "reckless youth" target market.

3. OBEJCT DESCRIPTION

The back glass measures 22 by 20 inches, and it is a quarter of an inch thick. It consists of alkyd paints screen-printed onto a clear glass substrate, a sort of reverse painting on glass since the display surface is the glass side (fig. 1). The design centers on a core group of 5 figures: four scantily clad women and one "Arabian" man dressed in a vibrant costume. Persian architectural elements adorn the area just behind the man's head, and the title "Gottlieb's *Arabian Knights*," is written in an arc above the central group of figures. Blocks of numbers used for scoring surround the group. A checkerboard floor provides the foreground of the scene with two additional women added in this area. At least 10 colors are present in the composition; some of these have faded or shifted due to the presence of organic colorants. Evidence of the screen-printing process is visible in misalignment of the color layers and in the hatched indentations from the screens on the back of the paint.

Fig. 1 Before treatment image of recto.

3.1 MATERIALS AND MANUFACTURE

Analysis with x-ray fluorescence (XRF), coupled with observed fluorescence characteristics, suggests that the glass is a soda-lime-silica glass, the most common glass type in the 20th century (Koob, 2006). It is made from an amorphous network of silica and oxygen, with sodium and calcium used to modify and stabilize it. XRF analysis also suggests that a small amount of arsenic was added as a fining agent to help remove bubbles. Alkyd paint, made from oil-modified polyester resin which cross-links to dry, was popularized in the United States in the 1940s (fig. 2). A significant refinement of oil-modified alkyds was introduced after WWII, which led to alkyd paints becoming the preferred choice in decorative paints due to their low

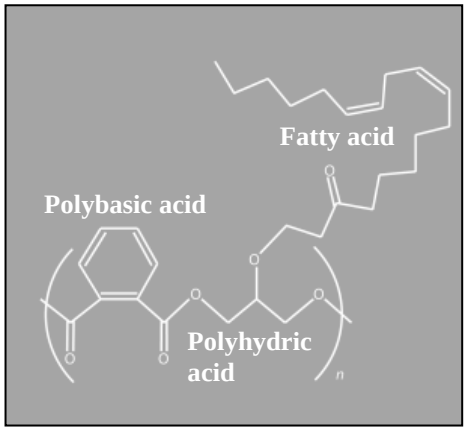

Fig. 2 Idealized structure of alkyd resin.

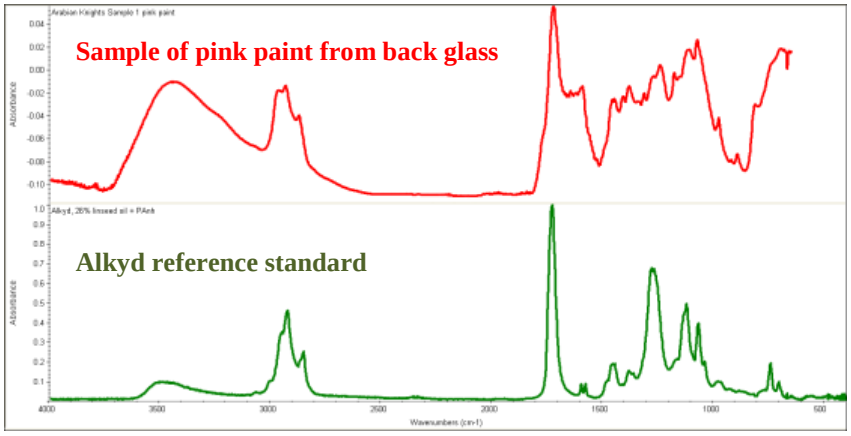

Fig. 3 Comparison of FTIR spectra from pink paint sample (red) and alkyd reference (green).

cost, superior film leveling and durability, and quick dry times (Learner, 2008). Alkyd paints were commonly recommended for smooth substrates such as glass (Kosloff, 1975). To identify the material, Fourier transform infrared spectroscopy (FTIR) was performed, and the spectrum from a sample taken from *Arabian Knights* compared favorably with an alkyd reference standard (fig. 3; Derrick, et al., 1999). Also, the cross section had a positive reaction for oils with Rhodamine B fluorochrome staining. The colorants in *Arabian Knights* were analyzed using polarized light microscopy and x-ray fluorescence. Both traditional pigments and synthetic colorants were used to make the 12 flat colors.

To create the image, black outlines were printed first, directly against the glass, followed by screens of each color. A white diffusion layer was printed next, overall, and finally there was a selective, light-absorbent black layer that allowed only certain areas of the image and score to

be illuminated (fig. 4). The back glasses were screen printed in factory-like settings, with workers quickly producing back glasses in assembly lines to keep up with the high demand. This inevitably led to inconsistencies in color and alignment (Temple, 1991). To keep the layers extremely thin yet vibrantly colored, the paint was likely thinly bound.

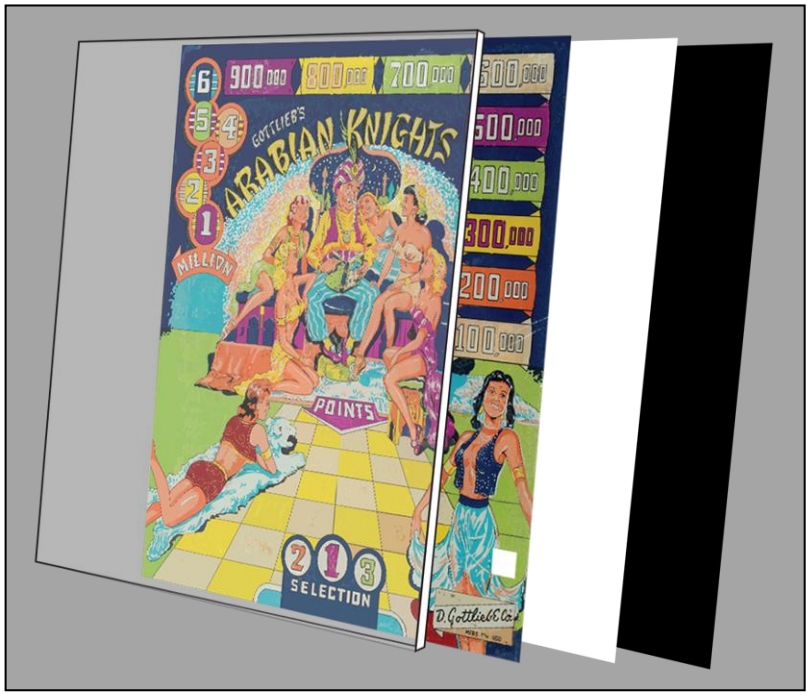

Fig. 4 Illustration of layering system.

4. TREATMENT

The object was actively flaking when it arrived at Winterthur Museum, and about 45% of the image was already lost. The printed imagery was likely degraded first by years of heat from incandescent lamps that lit the back glass from behind, and then by handling after being separated from the machine. Consolidation was clearly needed as the first treatment step. Then, for loss compensation, a high resolution photograph and Adobe Photoshop could be used to create a digital reconstruction of the lost areas, which could be printed on a clear substrate and mounted behind the original back glass as an underlay. This method of visually restoring the image to a high level of detail is both noninvasive and reversible, and it also appeared that this method would be simple and fast. These compelling reasons, as well as curiosity about the digital reconstruction process, made this solution seem preferable to more traditional options, such as inpainting on the object or hand-painting an underlay. The treatment proposal estimated 20 hours for stabilization and 18 hours for loss compensation.

4.1 STABILIZATION

In 2012, WUDPAC paintings major Laura Hartman carried out an independent study on consolidants for reverse paintings on glass, and her findings served as a basis for the back glass

treatment. Aquazol® 200 was selected as consolidant for several reasons. Aquazol® is composed of poly-2-ethyloxazonline, a synthetic polymer that is soluble in low alcohols and miscible in water (fig. 5; Von der Goltz, et al., 2012). Most importantly, Aquazol® has strong adhesion to glass, and its refractive index (RI) is a good match for the substrate. The RI of soda-lime-silica glass ranges from 1.51-1.53, and the RI of Aquazol® is 1.52 (Koob, 2006). It is also available in a range of molecular weights, so a middle ground could be chosen that would resist the environmental fluctuations that the object might encounter in private ownership, but it would still be able to flow into microscopic gaps and fissures.

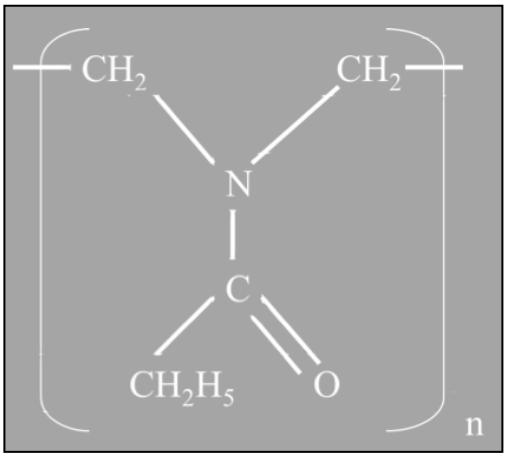

Fig. 5 Poly-2-ethyloxazoline.

The paint layers of *Arabian Knights* were in varying degrees of instability: areas where the black layer was present were cracked and flaking, and areas of just the diffusion layer over color were so poorly bound that the mechanical contact of a brush caused disruptions (fig. 6). The first layer of consolidant, was therefore applied with an ultrasonic mister (fig. 7). After that it was safe to apply a second round by brush, promoting contact of the spray-applied layer and reinforcing adhesion of the thicker paint. In areas of cupped paint, heat and gentle pressure were applied with a tacking iron. Minor cleanup was done using isopropanol.

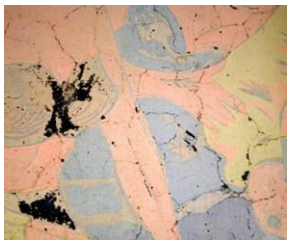

Fig. 6 (above) Detail of friable paint.

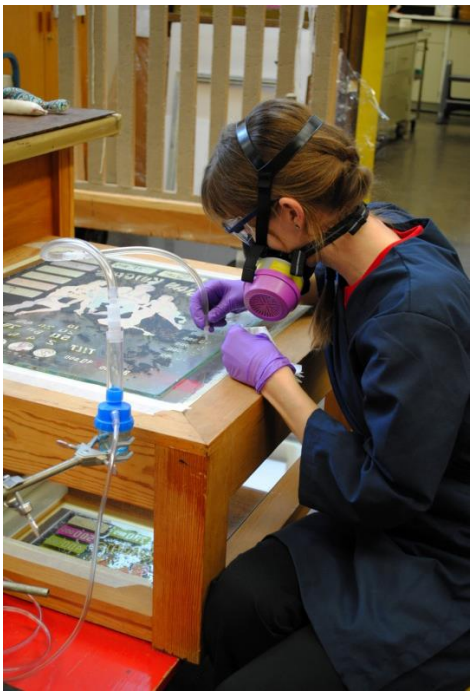

Fig. 7 (right) Jessica Ford consolidates friable paint using an ultrasonic mister.

After consultation with conservator Steve Koob of the Corning Museum of Glass, HXTAL epoxy (RI 1.52) was applied to fill two chip losses at the edge of the glass that posed a risk to the handler more than to the object (fig. 8-9; Koob, 2003). A ventilated storage housing was also

constructed from acid-free materials to protect the back glass until the owner can build a display box.

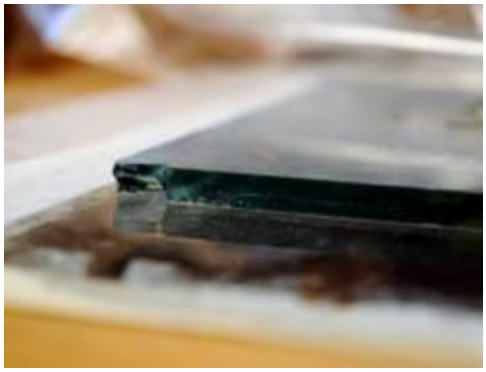

Fig. 8 Detail of chipped glass.

Fig. 9 Courtney Murray applies HXTAL epoxy fill.

4.2 LOSS COMPENSATION

A low resolution image of a reconstructed *Arabian Knights* back glass and a contemporary advertisement for the game served as the primary comparisons for how the object originally appeared. Since a high resolution image was not available, this had to be entirely re-created so that the final print would be a high quality image. The black outline was drawn first in Adobe Illustrator. The average L*a*b* values of each color on the back glass, based on three measurements of each color using a colorimeter, were used to fill in the Illustrator drawing. Since the dyes on the original had not faded

Fig. 10 Outline created in Illustrator.

Fig. 11 Complete reconstruction.

Fig. 12 Reconstruction of lost areas only.

uniformly, some relative adjustments were made. In Adobe Photoshop, the remaining original image was subtracted from the digital recreation. The owner planned to display the object as a light box, so overlap of the original and the reconstruction had to be avoided to prevent darkening of boundaries due to duplicated image density. The resulting reconstruction is a fragmented image that is analogous to inpainting in that it is only present within the areas of loss (fig. 10-12).

Finding a printer to realize the reconstructed design turned out to be a difficult endeavor. The large size, the clear substrate, the need for full-color, or a combination of these factors eliminated dozens of potential collaborators. Lifespan and image quality were also major factors, and cost also had to be considered, which eliminated making a new screen print. Table 1 contains a comparison of the most viable solutions.

Table 1. Printing Options

Process	**Producer**	**Substrate**	**Image**	**Estimated lifespan**	**Cost**	**Additional notes**
Screen print (seven colors)	Triple Stamp Press	Melinex	Acrylic or alkyd	decades	$800	Authentic; accurate layering; expensive
Window decal, double strike for density	RichArt Graphics	Vinyl	UV curable ink	5+ years	$475	Moves for readjustment with water and dish soap; eco-friendly inkjet option; vibrant color
UV inkjet, double strike for density	Barry and Homer Large Format Digital Printing	Acrylic	UV curable ink	3-5 years	$170	Easily replaceable; eco-friendly inkjet option; vibrant color
Digital photograph, Lambda printer	Barry and Homer Large Format Digital Printing	Duratrans (polyester)	Laser	5+ years	$125	Excellent image quality; eco-friendly inkjet option; vibrant color
Inkjet, HP printer	RichArt Graphics	Vinyl	Solvent ink	3-5 years	$75	Easily replaceable; poor color and density

After settling on a Philadelphia-based, large-format commercial print shop (Barry and Homer), the first printing choice was for the Duratrans photographic process. This method uses RGB lasers to transfer a digital file to a polyester substrate coated in photosensitive material, and the print is then run through a traditional series of processing baths to develop the image. The next challenge was that large-format printers do not provide hard-copy proofs, especially for a project that is relatively small in scale and quantity compared to their typical orders; it would be economically impractical for them to do so. Thus, FedEx Office was used to test the image alignment by using a series of inexpensive paper proofs. Distortions from the digital

photographic process were corrected, and the alignment of fragmented edges was refined. After 40 hours of work, the digital image was accurate and ready to order as a final print.

Duratrans did not work for a number of reasons: the color was inaccurate, the dimensions were slightly skewed, and the substrate was translucent rather than clear. In general, color is difficult to control for a light box print, because the printer settings must assume a certain light intensity and color temperature that may not be matched in reality. This did not entirely explain the Duratrans's issues though, so a compromise was negotiated with the printer to re-do the print using a different process. First, a tour of the printing facility helped provide a better understanding of the options and limitations. After this, a UV-cured inkjet print on clear acrylic was chosen as the best option, although even with a double strike the image density would be low. UV inks are water-borne, pigment-based inks that give vibrant color and resist fading, and they are easier to control and match.

Unfortunately, the revised print had incorrect dimensions again, being stretched by 1/16" on the left side, so that when the underlay was aligned with the back glass the top left exhibited small gaps in the image (fig. 13-14). The printer could not make additional revisions without

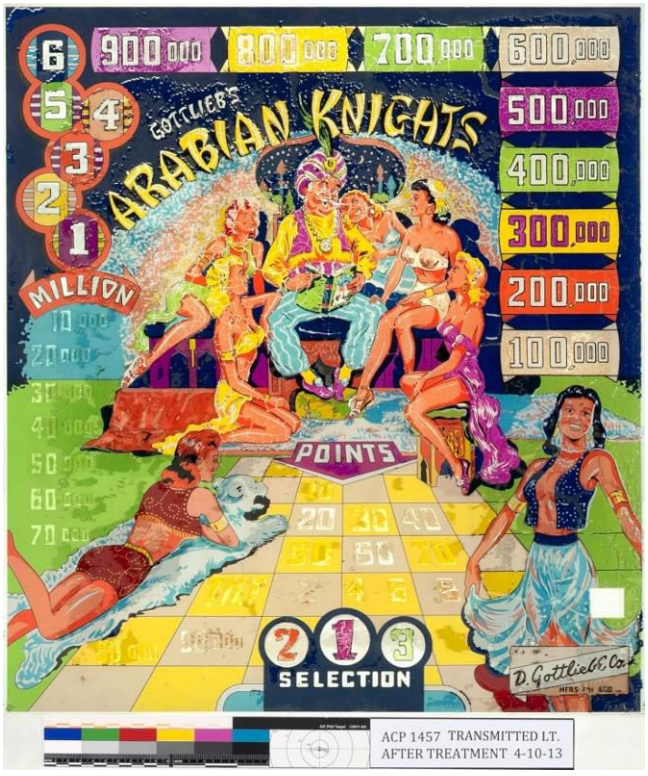

Fig. 13 After treatment image of back glass and underlay with transmitted light.

Fig. 14 After treatment image of back glass and underlay in normal light.

additional expense, and the project had already far surpassed the allotted time budget, so there was another compromise: the second print was purchased as a discounted price. The loss compensation portion of the treatment had taken 78 hours.

5. FUTURE RECOMMENDATIONS

Review of this case study provides a sense of its successes and failures and yields valuable guidance for the future. On the positive side, the original artwork from a classic pinball game is now stable, thanks to consolidation, fills, and appropriate housing. The appearance of the object is acceptable, if not ideal: the alignment and image density of the underlay could be better, and the reconstruction process was not the speedy technological miracle that had been expected. Even so, the authors feel that the digitally reconstructed underlay is still preferable to traditional inpainting for this project. Even with reversible materials, replacing this much loss on such a fragile original would be invasive, and directly inpainting the losses would likely have taken about the same amount of time. Alternatively, a non-digital underlay, meaning a clear substrate hand-painted with the missing imagery might have been better-suited to this project. Although it would not be as easily replaceable, it probably could have been completed in the same amount of time as the creation of the digital image (approximately 40 hours), and it would have avoided the lengthy printing stage of treatment.

The phase of this project with the most room for improvement was probably the collaboration with the printer. Several considerations could easily improve this process, resulting in a more satisfactory product with much less frustration. First, size is an important factor when it comes to the printing. For smaller or more isolated losses, an underlay could be printed in-house, or at a smaller printing operation with more flexibility. Secondly, displaying the artwork without a light box would make alignment and color matching much easier. There could also be other substrate options which would not require light transmittance. Standard opaque substrates like paper would be more commonly available at commercial printers, and colors are easier to predict. The location of the printing facility must also be considered. In the same way that a tour of the printer's operating floor eventually informed material and process decisions, it would have been beneficial to give the sales representative a tour of the Winterthur Museum's painting conservation studio so he could gain a better sense of the expectations and value of the project.

Because the printing facility was located fairly far away from Winterthur, this reciprocal visit was not feasible. Finally, ample time should be factored in to a treatment plan involving an outside printer to account for waiting on the file processing, revisions, and processing that the printers perform according to their schedule (those hours were not tracked during this project).

6. CONCLUSION

Even though the execution of this treatment was imperfect, it still has several benefits. It is completely reversible and does not interfere with the original material. It is easily replaceable by recreating an image from the digital file, and the owner can even order a replacement herself. It also successfully unifies the image. The potential of using digital reconstructions printed on an underlay for similar reverse-painted glass projects is promising. The information shared here is intended to help conservators weigh the pros and cons and approach such a project with a bit more savvy.

ACKNOWLEDGMENTS

This paper was only possible with the help of the authors' WUDPAC supervisors, especially Dr. Joyce Hill Stoner, Mary McGinn, Debbie Hess Norris, Dr. Jennifer Mass, Catherine Matsen, Richard Wolbers, Joelle Wickens, and Bruno Pouliot. Thanks are also extended to Steve Koob, Melanie Gifford, Laura Hartman, William Donnelly, and Barry and Homer Printing for the expertise they lent to this project. Thanks to WUDPAC for providing the project, the Winterthur Museum Scientific and Research Analysis Laboratory for providing analytical capabilities, UCLA/the Getty for hosting ANAGPIC 2013 and this paper, and the members of WUDPAC Class of 2014 for their support.

REFERENCES

Arabian Knights. 2012. IPDB (Internet Pinball Machine Database). www.ipdb.org/ (accessed 04/02/12).

BMI Gaming. 2012. The history of pinball machines and pintables. BMI Worldwide. www.bmigaming.com/pinballhistory.htm (accessed 04/02/12).

Derrick, M., Stulik, D, and Landry, J. 1999. Linseed stand oil. In *Infrared Spectroscopy in Conservation Science*. Los Angeles: The Getty Conservation Institute. 185.

Hartman, L. 2011. Consolidation of reverse paintings on glass. Winterthur/University of Delaware Program in Art Conservation, Wilmington, DE.

Heimann, J. and L. Schooling. 2007. *Introduction to 50s Fashion: vintage fashion and beauty ads*. Cologne, Germany: Taschen

Koob, S. 2006. *Conservation and care of glass objects*. London: Archetype Publications.

Koob, S. 2003. Tips and tricks with epoxy and other casting & molding materials. American Institute for Conservation Objects Specialty Group. Washington, D.C.: AIC. 10: 158-172.

Kosloff, A. 1975. *Screen printing techniques*. Cincinnati, OH: Signs of the Times Publishing Co.

Learner, T. 2008. Modern Paints. *Proceedings from Modern Paints Uncovered*. London.

Morrisette, M. 2013. Personal communication. 1984, Wilmington, DE.

Porges, S. 2005. End game. *Chicago Reader* 34 (39): 1, 20-24.

Shalhoub, M. 2008. *The pinball compendium: the electromechanical era*. Atglen, PA: Schiffer Publishing Ltd.

Sharpe, R. 1977. *Pinball*. New York: E.P.Dutton.

Squidoo. 2012. D. Gottlieb & Co. pinball. www.squidoo.com/gottlieb-pinball (accessed 04/30/12).

Temple, K. 1991. *Pinball art*. United Kingdom: H.C Blossom.

Von der Goltz, M., I. Birkenbeul, I. Horovitz, M. Blewett, and I. Dolgikh. 2012. Consolidation of flaking paint and ground. In *Conservation of easel paintings*, ed. J. H. Stoner and R. Rushfield. London, UK: Routledge. 369-383.

AUTHOR BIOGRAPHIES

Jessica Ford is a third-year fellow in the Winterthur/University of Delaware Program in Art Conservation. She is majoring in paintings conservation and is particularly interested in modern materials and murals. Jessica studied studio art at Ball State University, graduating *magna cum laude*. She then worked as an exhibiting artist and graphic designer before transitioning to art conservation. Jessica has completed internships at the Dallas Museum of Art, Shangri La - the Doris Duke Foundation for Islamic Art, Rosendarte Restoration, the Eiteljorg Museum of American Indians and Western Art, and the Indianapolis Museum of Art. She is currently fulfilling her third-year internship at the Lunder Conservation Center.

Courtney Murray is a third-year fellow in the Winterthur/University of Delaware Program in Art Conservation. She is majoring in objects conservation with an additional concentration in preventive conservation. Courtney graduated *magna cum laude* from Emory University in 2011 with a BA in chemistry. She has completed internships at the Royal British Columbia Museum, Toledo Museum of Art, the Michael C. Carlos Museum, the National Museum of the American Indian, and the Indianapolis Museum of Art. Courtney is particularly interested in the conservation of organic materials. She is fulfilling her third-year internship at the Denver Art Museum.