Using Double-Walled PVC Foil Molds to Separately Cast Large Epoxy Resin Fills for Glass Objects

ABSTRACT

This paper presents the experimental use of a double-walled transparent polyvinyl chloride (PVC) foil mold to cast a large epoxy resin fill for a 16th*-century Austrian* façon de Venise *vessel in The Metropolitan Museum of Art's collection. To protect the cold-painted decorations, the fill was cast and finished separately from the object and then secured in place. Preparing the two-sided vacuum-formed PVC foil mold required a multi-step process of mold-making, casting and refining plaster positives, and creating auxiliary supports. This paper discusses the treatment goals and limitations, details the treatment process and practical challenges encountered, and considers potential applications for this technique.*

AUTHORS

Rebecca Gridley*
Assistant Conservator
The Metropolitan Museum of Art
rebecca.ec.gridley@gmail.com

Karen Stamm
Conservator
The Metropolitan Museum of Art
karen.stamm@metmuseum.org

**Corresponding Author*

KEYWORDS

Glass · Fills · Epoxy · PVC · Vacuum-forming · Cold paint · *Façon de Venise*

INTRODUCTION

Transparent polyvinyl chloride (PVC) foil has been utilized by conservators as a mold material for casting transparent epoxy resin fills in glass objects for two decades. PVC's thermoplasticity, transparency, and smooth surface enables the conservator to cast epoxy fills that contain no internal flaws and require minimal finishing. In 2013, conservators from The Metropolitan Museum of Art and National Museum of Slovenia introduced a new vacuum-forming method to create PVC foil molds—evolved from an earlier hand-forming technique—and detailed its advantages and limitations, practical considerations, and the equipment required. Conservators at The Met have since regularly employed and taught this method to colleagues and students, developing it further and encouraging experimental adaptations for other types of objects (e.g. porcelain, enamels). (Lemajič 2006; Mertik and Lemajič 2007; Stamm, Lemajič, and Pilosi 2013)

Published explanations of this technique have focused on its use for casting fills in situ with either one, multiple, or pieced PVC mold walls, or a combination of PVC and silicone rubber molds. This paper presents an adaptation of this method to cast fills separately from the object, involving a multi-step process of fabricating molds in silicone rubber and PVC, plaster positives, and auxiliary supports.

This paper details the treatment of a 16th-century Austrian *façon de Venise* vessel in The Met's collection (Figure 1). It has sustained significant losses but retains its lavish surface decorations, executed in diamond-point engraving and cold paints. The primary treatment objective was to replace poorly-aged modern restorations in order to bring the object to exhibitable condition. The vessel was restored to a complete form with tinted epoxy resin fills, leaving absent any imitations of the surface decorations. The cold paints posed several limitations on treatment, necessitating casting and finishing the fills separately from the object.

Figure 1. *Before treatment. Vase, ca. 1550–1600 CE, diamond-point engraved and cold-painted glass, H 32.4 cm × Diam. 21 cm. The Metropolitan Museum of Art, Edward C. Moore Collection, Bequest of Edward C. Moore, 1891, 91.1.1460*

OBJECT DESCRIPTION

Manufacture and provenance

The vessel's form and decorative scheme are characteristic of *façon de Venise* glass production during the latter half of the 16th century in Innsbruck, Austria. Known as a *vasenpokal* (covered goblet), this type of vessel was fashionable for drinking wine at the end of the 16th century (Page 2004, 47). As is common with these objects, the cover to The Met's example is missing.

The free-blown glass vessel has a shouldered oviform body with a tall, gently flared neck and a furnace-finished rim. A trumpet-shaped foot with a folded edge is joined to the body by a molded ribbed knop via a merese. There is a pontil mark on the underside of the foot. The shoulder is decorated with two milled trails of glass and alternating impressed raspberry and mask prunts. The entire surface is ornately decorated: stylized cord-like bands, scroll borders, columns, arches, and alternating palmette and foliage motifs are delineated with diamond-point engraving. Areas left in reserve are filled with medallions and fruit swags painted in red, green, and gold. Select areas of the gilding are heightened with an orange glaze. The knop and applied hot-worked decorations are also painted gold.

The glass itself is nearly colorless, with a greenish-gray tinge and a few bubbles. In 2013, the vessel was included in a preliminary technical study of a selection of The Met's collection of cold-painted Venetian and *façon de Venise* glass objects. Analysis concluded the vessel's composition is consistent with *vitrum blanchum* that could have been manufactured in Austria or Venice in the 16th century; *vitrum blanchum* is a colorless glass that is slightly less refined than *cristallo*. The cold paints' pigments and mordants are also consistent with this date attribution. (Rizzo, Wypiski, and Pilosi 2013)

Condition and previous restorations

Approximately a third of the vessel's rim is missing, and there are two areas of damage to the body: a network of blind cracks on one side, and a network of breaks with two extant fragments and one area of loss (approximately 5 cm × 5 cm) on the other. The vessel entered the collection in this condition in 1891: an article describing the bequest of Edward C. Moore's collection notes, "A beautiful [glass] vase that unfortunately is badly broken, one side of the lip of the vase being gone, is decorated in gold and enamel with raised rosettes and masks and etched designs" (The Moore Collection 1892).

The vessel has undergone two documented treatment campaigns. In 1966, it was surface cleaned and losses were filled. In the treatment report, the conservator notes that "the gold, green and red will come off if rubbed" and describes the loss compensation techniques used: "waxed in missing area to make a pattern - cast in technovit, made a mold and pressed in plexie [sic] to make rim piece (universal cement)." Technovit 4004 is a two-part polymethyl methacrylate casting material; universal cement is likely a nitrocellulose adhesive. By 1977 the adhesive had failed, causing the two plastic fragments to "come away from the glass." At this time, the repairs to the original fragments were reversed, all adhesive residues removed, and the restorations and original fragments were secured back in place with cyanoacrylate adhesive. (Internal Treatment Records, The Metropolitan Museum of Art)

These brief reports omit a few details that are of particular interest. The plexiglass replacement piece demonstrates impressive craftsmanship: the repeating engraved palmette and foliage pattern was expertly replicated and incised on the new plastic fill. To mask the Technovit fill, the gilding and coldpaint were recreated with paint.

The vessel was reassessed in 2016 in preparation for a special exhibition. While in storage, the plexiglass replacement had warped, causing the adhesive holding it in place to fail. The adhesive repairs to the body of the vessel remained structurally stable but had yellowed. The Technovit fill to the body was likewise secure, but had darkened and discolored.

The vessel's surface remained in very good condition, save for a light accumulation of dust. The cold-painted decorations are abraded with pinpoint losses scattered throughout, but remain largely intact and stable. Cold paints are extremely susceptible to loss because they are applied to the slick surface of the glass after it has cooled, as opposed to enamels, which are fused to the glass through firing. As a result, many pieces from this period have lost nearly all of their decorations from use, handling, and cleaning over the centuries.

TREATMENT GOALS AND LIMITATIONS

Conversations with the curator focused on replacing the aged fills to bring the vessel to the museum's standards for exhibition. Inconsistencies in the previous restoration—notably, that different aspects of the surface decorations were recreated on each replacement piece—prompted a discussion about the extent to which new restorations should be integrated. A middle-ground approach to treatment was selected: the vessel's form would be made whole with epoxy fills tinted to match the glass body, leaving absent any imitation of the elaborate surface decorations. Completing the vessel's profile would focus the viewer's eye on its design and form, and minimize (rather than mask) the appearance of the distracting losses. This approach kept the scope of treatment work more manageable, while respecting the object's condition and collecting history; Moore had purchased the piece as an excellent example of *façon de Venise* production, undeterred by its compromised condition.

In The Met's lab, the preferred technique for casting epoxy resin fills for glass objects is the vacuum-formed PVC foil mold technique outlined by Stamm, Lemajič, and Pilosi (2013). PVC foil molds allow for a high level of control throughout the casting process (e.g. monitoring and eliminating air bubbles, checking the color match of the tinted resin before it cures) and significantly reduce the effort required to obtain a glass-like finish. These were critical considerations for filling the Austrian vessel's missing rim, as any internal or surface finish flaws would be readily visible in such a large expanse.

Casting epoxy resin fills in situ ensures that the fill is flush to the original surface and minimizes the visual disruptions at the fill-break edge interface. However, the highly-sensitive cold paints posed a number of limitations. Casting in situ requires securing the molds to adjacent surfaces, and includes the risk of epoxy leaking from the mold as the fill sets. This was quickly eliminated as an option because the vessel's cold-painted decorations extended right up to the break edges.

The safest option was to cast and finish the fills separately from the object, later securing them in place. This approach had the added benefit of minimizing both handling and the stresses placed on the historic glass during finishing work. However, this posed another set of challenges: the fills needed to fit the shape of the losses, conform to the jagged contours of the break edges, and remain flush to both the interior and exterior profiles of the vessel. This final consideration highlighted another constraint created by the cold paints: molds could only be taken of the vessel's interior profile.

CONSERVATION TREATMENT

The vessel was selectively surface cleaned, primarily on the interior and avoiding the cold paints, using ethanol on cotton swabs. The Technovit body fill and adjacent repairs were dismantled and adhesive residues removed with acetone applied on cotton swabs and cotton pad poultices. In advance of rejoining the two extant fragments with HXTAL NYL-1 epoxy resin, a tiny dot of epoxy was first introduced into the network of blind cracks directly connected to the join lines and allowed to cure completely. This prevented excess epoxy from flowing into and filling the cracks during rejoining. Blind cracks can extend as a result of the different expansion properties of adhesive and glass; additionally, any future efforts to reverse the epoxy could cause swelling and pressure, with the same unwanted result.

A new body fill was modeled on the Technovit fill, which was a fairly good match in shape and profile. A two-part silicone rubber mold was taken from the old fill to cast a plaster positive, which was then refined and polished to improve the fit and surface finish. A two-part GI-1000 silicone rubber and vacuum-formed PVC foil mold was made from the finished plaster positive; the PVC was formed using a Pro-Form Dual Chamber Dental Vacuum Former.

The new fill was cast in HXTAL NYL-1 tinted to match the color of the glass body using Vantico epoxy paste colorants. The procedure for casting fills using a PVC foil mold is detailed by Lemajič (2006). In short: one hole was made at each corner of the PVC mold wall using a PrecisionGlide 20 gauge by 1 inch syringe needle, creating an injection site and an air exit hole. The beveled edge of the needle was then trimmed off. The tinted epoxy resin was placed inside a vacuum chamber to remove air bubbles before transferring it to the syringe. The epoxy was introduced slowly into the mold at the injection site.

At the outset of treatment, the decision was made to create a double-walled vacuum-formed PVC foil mold to cast the new rim fill. Unlike with the body fill, the old restoration could not be repurposed because it had warped. As the vessel is free-blown—and therefore is not a perfect circle—and more than a third of the rim was missing, it was critical to custom fit the mold walls to the area of loss rather than modelling them on the extant portion of the rim. This could be accomplished more easily with thin sheets of rigid PVC foil than with thicker pieces of flexible silicone rubber. Additionally, PVC mold walls would provide a glass-like finish on both sides of the large fill, approximately 22 cm at its widest point.

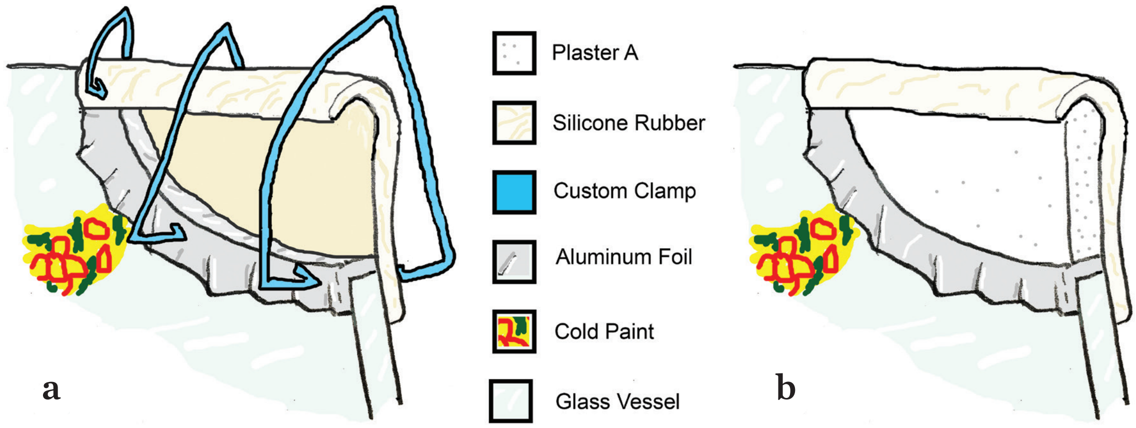

Figure 2. *Cross-section diagram showing preparation of Plaster A: a) metal clamps securing silicone rubber mold behind the loss; b) the loss filled with plaster*

Creating a double-walled PVC foil mold

A mold was first taken from the vessel's interior, directly across from the loss, using two layers of compatible silicone rubbers: a thin layer of GI-1000 to capture surface finish, followed by a thicker layer of thixotropic XT-493. This flexible mold captured the interior profile of the neck and extended just over the rim's curved top edge.

Next, a system was devised to secure the silicone rubber mold behind the loss area safely. Custom metal clamps, made of low-carbon steel welding wire, were placed strategically in areas of undecorated glass to hold the mold closely against the interior surface (Figure 2a). Cut pieces of confectionery foil (approximately 0.01 mm gauge aluminum foil) were folded over the break edges to protect the adjacent cold paint decorations. The foil was pressed tightly against the break edges to serve as a release layer and tacked down with small pieces of low-tack blue painter's tape in areas of undecorated glass. The mold was secured in place with GI-1000, thinly applied by a brush along the inside edge of the break, and the clamps were removed once the silicone rubber had cured.

This set up an open-faced mold for casting a rough plaster positive of the loss. Working on the object against the silicone rubber mold, the loss area was filled with a thin layer of plaster (Figure 2b). The resulting plaster positive (Plaster A) captured the contour of the break edge, the shape and profile of the loss, the rounded top edge of the rim, and the approximate thickness of the vessel wall. After setting, the plaster was released from the mold, removed from the vessel, and any surface and wall thickness irregularities were minimized with sandpaper and MicroMesh polishing papers. During the initial stages of this finishing work, a small break appeared in the thin plaster form. It was first consolidated with 10 percent PARALOID B-72 in acetone and then backed with a thin piece of Reemay (a polyester spunbonded fabric) with 20 percent PARALOID B-72 in acetone. A 2.5 cm margin of Reemay was left along all sides. A rigid support was formed from Apoxie Sculpt (a proprietary epoxy putty by Aves) by gently pressing it against the plaster to conform to its curve and shape. The edges of the Reemay backing were adhered to the epoxy putty support with 20 percent PARALOID B-72 in acetone (Figure 3a). The final finishing work was completed with the plaster secured to this rigid support, which prevented further breakage from the pressures of sanding and polishing and minimized the handling of the plaster's delicate edges.

Next, a second plaster positive (Plaster B) robust enough to withstand the pressure of the PVC vacuum-forming process was fabricated from Plaster A. First, a 1 to 2.5 cm margin of Klean Klay (a non-drying modeling clay) was added all around the edges of Plaster A while it was attached to the epoxy putty support. The Klean Klay was smoothed out with a silicone rubber tool to "extend" the curved profile in all directions (Figure 3b). Another two-layer silicone rubber mold, with a supportive plaster mother mold, was taken from this in order to cast Plaster B. The back of Plaster B was built up to approximately

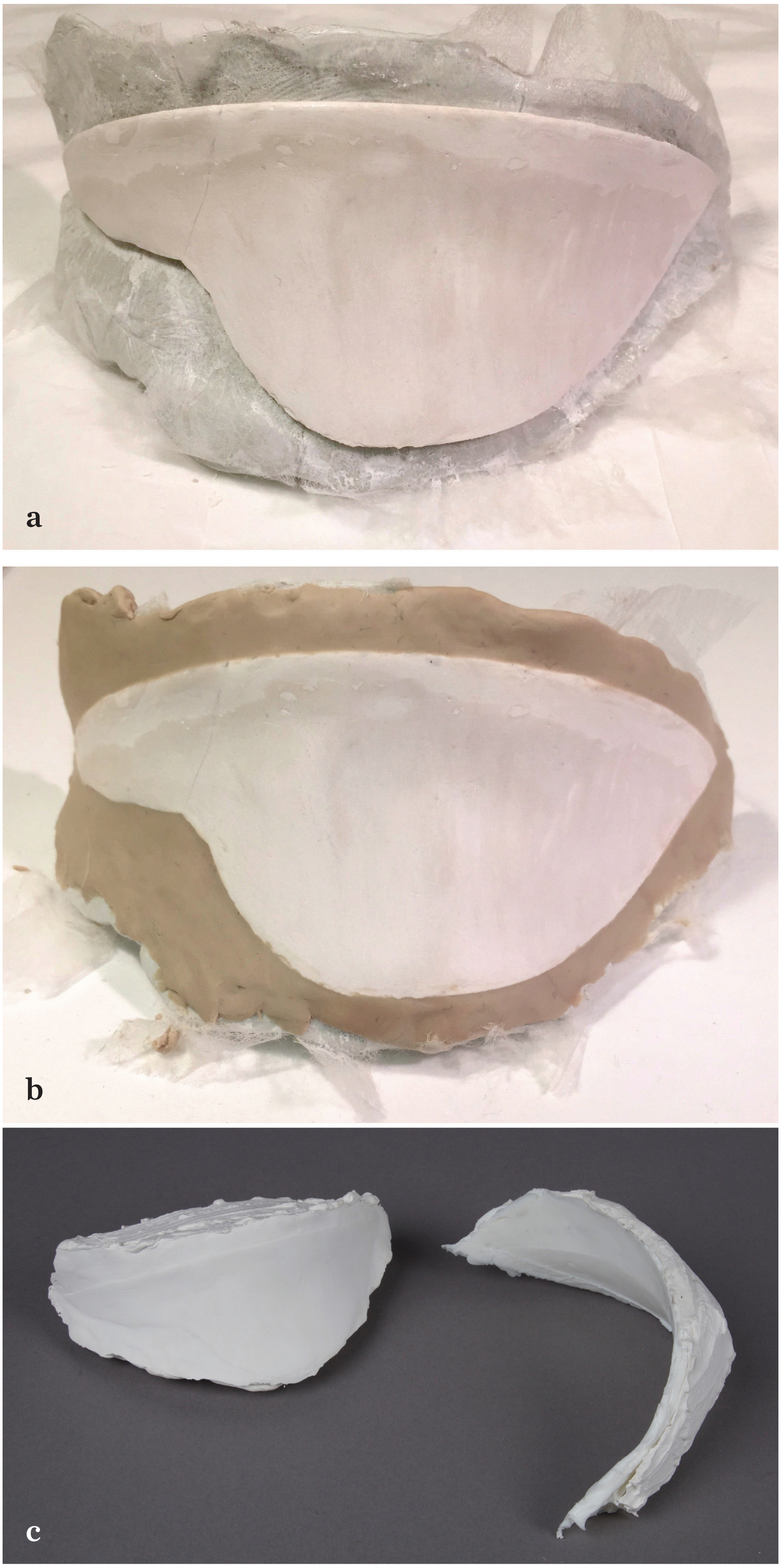

__Figure 3.__ Steps to fabricate Plaster B: a) Plaster A secured to epoxy putty support with Reemay interleaving; b) Plaster A profile extended with Klean Klay; c) Plaster B (left) cast from a silicone rubber mold of Plaster A (right)

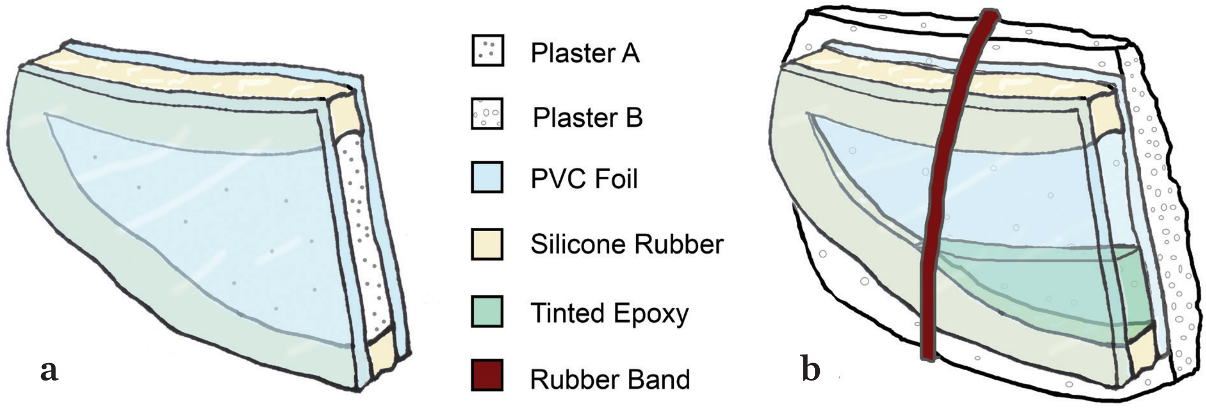

Figure 4. *Cross-section diagram showing preparation of double-walled PVC foil mold: a) Plaster A temporarily secured between two vacuum-formed PVC foils; b) the resulting mold package held against Plaster B with rubber bands*

5 cm thick to create a solid plaster positive against which PVC could be vacuum-formed (Figure 3c). The top surface was polished smooth to remove toolmarks. A slight impression of Plaster A's edges was left intact to serve as registration marks for the next steps in the mold-making process.

Two pieces of PVC foil were formed over Plaster B using an EZFORM SV 1217 tabletop vacuum-former: one to serve as the exterior profile mold wall and another to serve as the interior profile. It was possible to use the same form for both profiles because the vessel walls are fairly consistent throughout, approximately 3 mm thick, and are thin relative to the vessel's overall size. The PVC pieces were trimmed down, leaving a 1 cm margin around all sides of the slightly indented registration marks.

Plaster A was then released from its Reemay and epoxy putty support with the application of acetone, and placed between the pieces of formed PVC, using the registration marks for alignment. The whole package was temporarily secured together with rare earth magnets. The outline of Plaster A was lightly scored onto the exterior PVC with a scalpel. The remaining margin around Plaster A was filled with GI-1000 silicone rubber, encasing the plaster form between the two PVC foils. In effect, this silicone rubber margin became a mold that captured the contour of the break edge, the shape and profile of the loss, the rounded top edge of the rim, and the approximate thickness of the vessel wall (Figure 4a).

The exterior PVC was peeled off, leaving the silicone rubber margin secured to the interior PVC, and Plaster A was carefully removed and set aside. Using the light score marks for alignment, the exterior PVC was then secured back in place with a thin layer of GI-1000 applied by brush. The double-walled PVC package was sealed around all edges with GI-1000 and secured to Plaster B using rubber bands (Figure 4b). This provided a rigid support for the flexible mold package, keeping it in alignment and allowing for easy repositioning during the casting process, without touching the mold package itself.

Casting and finishing the rim fill

The fill was cast in tinted epoxy using the same method outlined above, with the injection hole and air hole made in the exterior PVC at opposite corners of the mold package. Due to the size of the fill, the casting was completed with two major pours on successive days, necessitating the creation of a new injection hole on the second day. On the third day, the fill was topped up to account for shrinkage of the epoxy resin as it cured.

The fill was removed from the PVC foil mold for final finishing work once the epoxy was fully cured. Thin strips of Elite Double 8, a semi-translucent pink silicone rubber by Zhermack sPA, were cast out on a watch glass. Small surface imperfections around the injection and air holes and along the rim edge were filled locally with tinted epoxy, cured against strips of the silicone rubber to achieve a glass-like finish.

Figure 5. *After treatment*

The curvature of the final fill was slightly too wide, resulting in one "sprung" corner that did not perfectly align with the break edge. Working away from the object, adjustments were made by slowly warming the fill until it was slightly soft, holding it in place on the vessel, manipulating it by hand to become flush with the surface, and allowing it to cool in this new position. This was accomplished with either a heat gun for larger areas or a Willard Conservation Equipment UK hot air pen, a hand-held hot air tool with variable airflow and temperature control, which allows for finer control. Similarly, some small final adjustments to the fit and shape of the body fill were made using a scalpel and the Willard tool.

Tinted epoxy was used to adhere both fills in place and to fill small gaps along the break edges (Figure 5). The epoxy was fed into the joins from the interior side of the vessel to avoid contact with the cold-painted decorations.

PRACTICAL TREATMENT CHALLENGES

Several challenges arose when fabricating and finishing the rim fill, which should be considered for future applications of this technique.

A significant advantage of casting fills in situ is that the conservator can ensure the final fill will be flush with the original surface. As anticipated, working away from the object presented more of a challenge; it was difficult to assess the fills' thicknesses and alignments with both the interior and exterior surfaces. Despite various precautions taken to prevent stepped joins, the final rim fill was slightly thicker than the original vessel walls. This is directly linked to a major challenge in this treatment: working with a very thin and delicate plaster positive (Plaster A), which served as the "original" in the casting and mold-making process. Due to its shape, size, and thickness, the plaster had to be secured to an auxiliary support to prevent damage during sanding and polishing work. This hindered easy access to one side of the plaster and the ability to check it against the object as work progressed.

Such auxiliary supports were created ad hoc as treatment progressed. Although PVC foil is a relatively stiff mold wall material—especially compared to many silicone rubbers—it could not hold its shape across the large width of the rim fill with the added weight of the silicone rubber margin securing the two PVC walls together. Fortunately, Plaster B could be repurposed as a rigid support to hold the mold in the desired shape during casting.

Despite this, there were some minor distortions in the final fill. As with any casting process, there is increased risk of distortion or inaccuracy with each additional step removed from the original via a mold or intermodel. The "sprung" corner likely resulted from imperfect alignment of the final PVC mold and Plaster B during final casting, and/or the small break that developed in Plaster A during finishing work.

The final stages of treatment did include some exacting finishing work, as detailed above. Mold seam lines on the rim fill's top edge and gaps along the break edges required minor surface or gap filling in situ. Preventing the development of air bubbles in gap fills along the break edges was particularly difficult. Despite this, the overall time spent on finishing work was relatively minor because of the glass-like surface finish imparted by the PVC foil mold walls.

POTENTIAL APPLICATIONS

The adaptation of the vacuum-formed PVC foil mold method presented here expands the uses for this material and technique. In some instances, it may be necessary or desirable to cast a fill separately so it can be more readily detached from an object (e.g. using PARALOID B-72 to secure the fill in place, rather than epoxy resin) or to minimize direct work on the object due to structural concerns. This method can also be used to create fills for areas with limited access, such as closed forms or narrow-necked vessels; this has been done successfully for small fills completed at The Met.

CONCLUSION

This case study presents a successful adaptation of the vacuum-forming method for fabricating transparent PVC foil molds: in order to protect sensitive cold-painted surface decorations, a double-walled mold was used to cast a large epoxy resin fill separately from the object, and the fill was adhered in place after finishing work was complete. This approach expands the potential applications for this material and mold-making technique to scenarios in which a detachable fill is required or access to the loss area is limited.

REFERENCES

Internal treatment records, 1966 and 1977. The Sherman Fairchild Center for Objects Conservation, The Metropolitan Museum of Art, New York.

Lemajič, G. 2006. Transparent PVC mould: Replacing missing pieces on hollow glass objects. *Icon News* 3: 46–48.

Mertik, N. and G. Lemajič. 2007. Conservation of a glass cup using a transparent mould technique. In *Glass and Ceramics Conservation 2007: Preprints of the Interim Meeting of the ICOM-CC Working Group, 27-30 August 2007, Nova Gorica, Slovenia*, ed. L. Pilosi, 83–84. Nova Gorica: Goriski Muzej Kromberk.

Page, J-A. 2004. *Beyond Venice: Glass in the Venetian style, 1500-1750*. Corning: The Corning Museum of Glass.

Rizzo, A., M. Wypiski, and L. Pilosi. 2013. Insights into the materials of cold painted Venetian glass / *façon de Venise* glass objects in The Metropolitan Museum of Art. Presented at the 5th International Symposium Painting Techniques, History, Materials and Studio Practice, Rijksmuseum, Amsterdam, 18–20 September 2013.

Stamm, K., G. Lemajič, and L. Pilosi. 2013. Vacuum-formed PVC moulds for casting epoxy resin fills in glass objects. In *Recent Advances in Glass, Stained-Glass, and Ceramics Conservation 2013: Preprints of the ICOM-CC Glass and Ceramics Working Group Interim Meeting and Forum of the International Scientific Committee for the Conservation of Stained Glass (Corpus Vitrearum-ICOMOS),* eds. H. Roemich and K. Van Lookeren Campagne, 69–75. Zwolle: SPA Uitgevers.

The Moore Collection. 1892. *The Sun* [New York] 6 March 1892.

SELECTED MATERIALS

EZFORM® SV 1217: Centroform. www.centroform.com/ (accessed 24 February 2019)

GI-1000 and XT-493: Silicones Inc. High tear strength, tin-catalyzed (condensation cure) RTV-2 (Room Temperature Vulcanized - 2 component) silicone rubbers. For this treatment, both were mixed with GI-UFC, or Ultra Fast Catalyst. www.silicones-inc.com (accessed 24 February 2019)

Pro-Form Dual Chamber Dental Vacuum Former: Keystone. https://dental.keystoneindustries.com (accessed 24 February 2019)

Note: Vantico epoxy paste colorants are no longer manufactured.

ALL IMAGES AND DIAGRAMS

The Sherman Fairchild Center for Objects Conservation, The Metropolitan Museum of Art.