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Delaying the Inevitable: An Investigation of Plastic Deterioration in Joseph Beuys Multiples

Abstract

Plastic objects in museum collections present unique and pressing conservation challenges. Although artworks incorporating these materials represent some of the newest pieces in museum collections, many are composed of inherently unstable formulations that deteriorate rapidly, producing dramatic and unanticipated alterations. This is the case for three Joseph Beuys multiples composed of polyvinyl chloride in the Harvard Art Museums' collection. Over the past decade, exudation of liquid plasticizer and progressive discoloration of the polymer have been observed and appear to be worsening.

This research aims to develop storage and display guidelines that will slow the deterioration and improve the accessibility of these significant pieces. The multiple *Phosphorous-Cross Sled* is a particular focus of this project because it is being considered for inclusion in an upcoming exhibit rotation of Beuys multiples. Technical study of this piece using pyrolysis-gas chromatography-mass spectrometry (pyGC-MS) and scanning electron microscopy-energy dispersive x-ray spectroscopy (SEM-EDS) has identified the materials and their degradation products, yielding insights into the deterioration mechanisms that underlie the observed changes. The potential for using cool storage, air-tight enclosures, and other measures to slow these processes and contain off-gassing is also discussed.

1. Introduction

Deteriorating plastic has been a growing problem for collecting institutions, especially those with large holdings of modern art and design objects. These plastic objects typically incorporate mass-produced materials and components that were not intended for long-term use. Until fairly recently, the poor ageing qualities of plastics were not widely known and considered, in part because their instability is not immediately evident. The resulting alterations to the material, which may take decades to develop, detract from the specific functional, aesthetic, and conceptual qualities for which these materials were selected.

These issues are confronted in the study of three polyvinyl chloride (PVC) objects by Joseph Beuys in the Harvard Art Museums' (HAM) collection: *Phosphorus-Cross Sled* (1995.265), *Stamp Sculpture* (1995.461.A), and *Postcards 1968-1974* (1995.295) (see fig. 1). These objects all show symptoms of advanced degradation, manifested by the migration of liquid plasticizer to the surface. This hazardous, sticky, and viscous substance has presented significant

barriers to routine viewing and handling of these objects.

The current planning for exhibit rotations of Beuys multiples in the new HAM facility has provided an ideal opportunity to undertake research on this important collection. These investigations, undertaken as a conservation fellowship project, have included examination, documentation, technical study, literature review, archival research, and correspondence with conservators and other experts. The information gathered has been used to produce a set of conservation recommendations for treatment, storage, and exhibition of these objects.

2. Polyvinyl Chloride: Background and Review of Previous Research

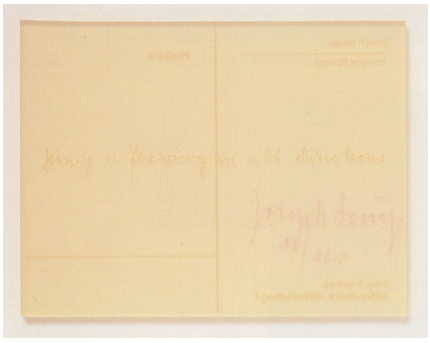
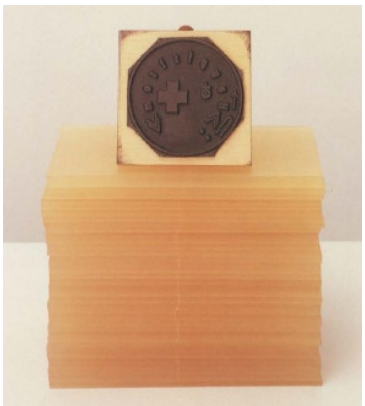
2.1 *Conservation of Plastics*

The preservation of plastics is still a relatively new frontier for the art conservation field. While effective inhibitive conservation approaches—those that slow the progression of deterioration processes—have been developed for plastics that are common in museum collections, the field lags in the development of techniques for more interventive treatments, such as cleaning and repair (Shashoua 2008). The Preservation of Plastic Artefacts (POPART) project, an international research collaboration for the advancement of plastics conservation, has made the latest and most comprehensive contributions towards testing and standardizing methods for the identification and treatment of plastics (Lavedrine, Fournier, and Martin 2012). However, because the techniques developed through this research are based largely on trials using unaged "model" plastic samples, there is still very little data available on treatments for plastics that have already entered an advanced state of degradation. These objects are typically more fragile and sensitive to the effects of mechanical action, water, and solvents.

2.2 *Deterioration of Plasticized PVC*

Plasticized PVC is made from complex formulations and, especially in its early years, was not made with long-term durability in mind. Compared to more traditional artists' materials, PVC came on the scene relatively recently. It was first polymerized in the 19th century, but was not produced on an industrial scale until the mid-20th century.

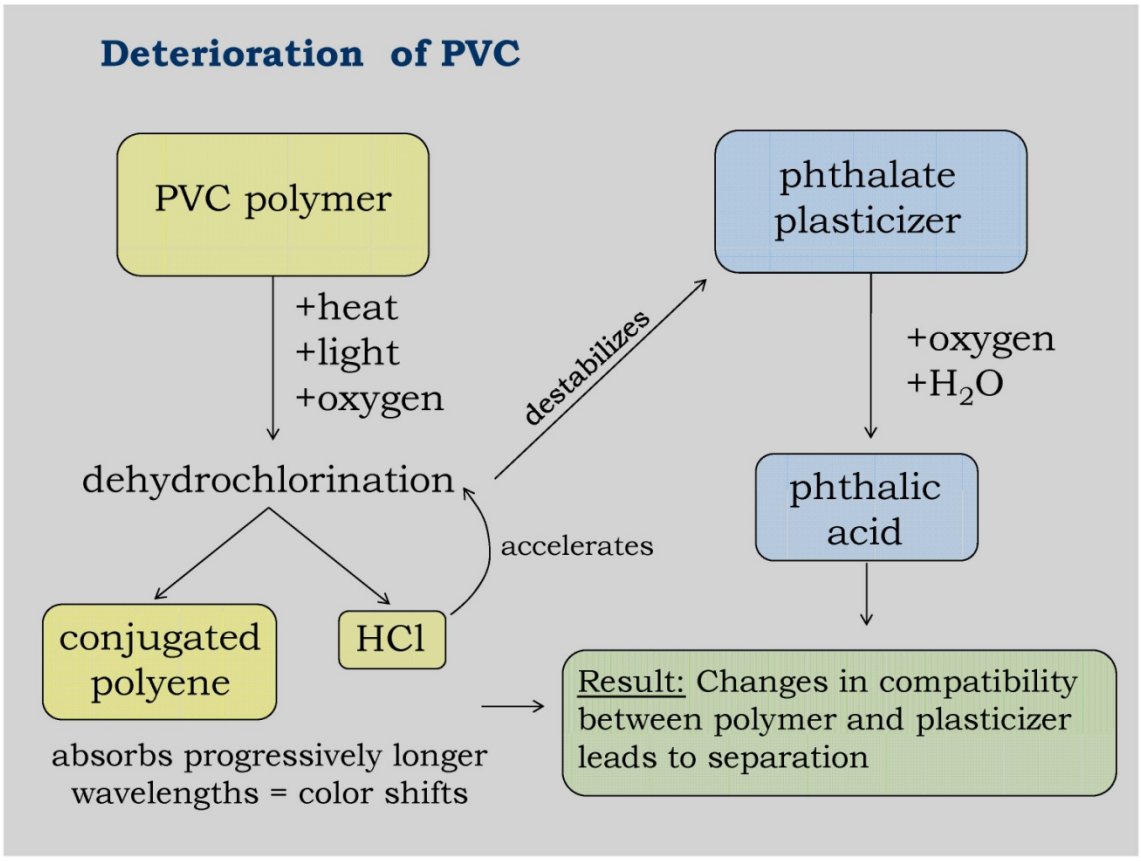
Fig. 1: Beuys PVC multiples at Harvard Art Museums, compared to catalog raisonné

Harvard Art Museums Edition	**Schellmann (1997) Catalog**
Phosphorus-Cross Sled	
	
HAM 1995.265 *2012*	45 x 45 x 0.6 cm (excluding clip)
Postcards 1968-1974	
	
HAM 1995.295 *2012*	10.5 x 15 x 0.3 cm (postcard)
Stamp Sculpture	
	
HAM 1995.461.A *2012*	19 x 19.5 x 45 cm (with stamp)

PVC can be produced in both plasticized and unplasticized formulations. Unplasticized PVC is hard and rigid, making it well-suited for products such as PVC piping. Plasticized PVC, by contrast, is softer and more flexible, and has been used for applications ranging from Barbie dolls to life support tubing in Apollo space suites (Shashoua, Schnell, and Young 2002). Plasticizers are semi-volatile solvents that make up 15-50% of PVC formulations by weight (Shashoua 2001). Plasticized PVC is the type used in the three Beuys multiples discussed herein.

In addition to large quantities of plasticizers, PVC formulations contain a complex mixture of additives which include stabilizers, lubricants, impact modifiers, processing aids, fillers, and colorants (Shashoua 2008; Waentig 2008). The interactions amongst specific compounds and their relative quantities ultimately determine the stability of the PVC product.

Fig. 2: Overview of PVC Deterioration Processes



The degradation of plasticized PVC can be described essentially as two parallel, but related processes (see fig. 2). Plasticizer molecules, especially phthalates—which are the most common—are weakly bound to the PVC polymer to begin with. Over time, the PVC degrades through a process of dehydrochlorination, in which the polymer is converted to a conjugated polyene system, releasing hydrochloric acid as a byproduct, which in turn accelerates the process. This conjugated polyene structure absorbs progressively longer wavelengths of light as the process continues, explaining some of the color shifts seen in PVC plastics over time. This degradation also tends to destabilize the plasticizer, which is also converted into new compounds—in the case of phthalates, producing phthalic acid. These changes reduce the already weak compatibility between the polymer and plasticizer components, resulting in their separation. The loss of plasticizer further destabilizes the whole system, eventually resulting in severe embrittlement (Shashoua 2002).

2.3 *Current Conservation Approaches for PVC-based Objects*

2.3.1 *Inhibitive Approaches*

Research by Shashoua (2001) examined how specific environmental conditions influence the degradation rate of various aged and unaged samples of plasticized PVC. Low temperature storage and air-tight enclosures were found to be most effective means of preservation.

Low temperature storage slows the rate of plasticizer evaporation and the deteriorative chemical reactions occurring within the polymer. According to research by Shashoua (2008), reducing the temperature by 5-10°C will slow the rate of chemical reactions by half, and placing PVC in freezer conditions has been shown to slow the rate of plasticizer migration by a factor of 15. However, it should be noted that cooling enhances the brittleness of PVC, and thus the chances of crack formation. Contraction and warping of the material may also occur, but will reverse upon warming. This transformation can pose risks to composite objects that incorporate materials with different responses to temperature changes. The thickness of the plastic is another important consideration. Because thicker plastics take longer to cool, there is a higher risk of condensation, which can displace the plasticizer. Therefore, low temperature storage is only recommended for plastics under 1 cm in thickness (Shashoua 2008).

Sealed enclosures also promote the preservation of PVC by slowing the rate plasticizer evaporation, and have been shown to extend the life of PVC under ambient conditions by more than 10 times (Shashoua 2008). This is desirable because the plasticizer stabilizes the polymer,

and its loss accelerates its degradation, resulting in warping and embrittlement. It also has the important secondary benefit of protecting nearby objects from acidic off-gassing produced by PVC. Despite the autocatalytic nature of PVC degradation, absorbents such as activated carbon, zeolites, oxygen scavengers, and silica gel all have been shown to promote further deterioration by absorbing plasticizer vapors, preventing the establishment of an evaporation-condensation equilibrium within the enclosure (Shashoua 2001). For this reason, enclosure materials must also be inert and non-absorbent. Both glass and Mylar (transparent polyester sheeting) are typically recommended for this purpose.

2.3.2 *Interventive Approaches*

Research into the treatment of plastic objects is still in its early stages, and the long-term effects of cleaning, consolidating, and adhering plastics are not well-understood. The recent POPART project (Lavedrine, Fournier, and Martin 2012) made significant contributions to this area through their comprehensive study of cleaning techniques, which produced a set of recommendations specific to each type of polymer and the nature of the soiling to be removed.

One of the greatest concerns in undertaking cleaning treatments on plastics is the risk of altering the surface chemically. Use of solvents carries the risk of dissolving, swelling, or crazing the plastic surface. Testing must always be carried out before employing a solvent-based cleaning method, especially because additives and degradation processes can change the solubility parameters of a polymer from their theoretical value. Since plastics tend to be soft and susceptible to scratching, mechanical cleaning alone also carries substantial risks.

For PVC, the removal of soiling is critical. Research published by the POPART project revealed that dirt and dust particles can migrate into the PVC within a matter of weeks. They recommend canned air for cleaning loose dust, while the removal of fixed particles may require using water with microfiber cloth, spectacle cleaning cloth, cotton swabs, or cotton cloth. Non-ionic detergent, ethanol, or isopropanol may be necessary in cases where soiling is oily or waxy. In general, surface scratching is reduced by a factor of five when aqueous media and solvents are used. Unfortunately, the cleaning of plasticizer exudates from the surface was not addressed by the POPART study because only unaged plastic samples were used in testing.

3. Joseph Beuys Multiples: Background

3.1 Joseph Beuys

Joseph Beuys was a German artist who was active during the post-war period until his death in 1986. Born in 1921 in Krefeld, he served in the Luftwaffe during World War II, during which he was wounded and held in a prisoner-of-war camp. After the war, he pursued his artistic training, and in 1961 was appointed a professor at the Kunstakademie Dusseldorf (Rothfuss and Carpenter 2005). During this period, he was influenced by the hybrid art forms produced by Fluxus artists and developed his concept of "social sculpture," which regards society and politics as an artistic medium. His artistic output bridges traditional boundaries of fine arts and blurs the line between art and everyday life. His works include sculpture, installations, performances, and lectures, as well as portable objects called multiples.

3.2 Multiples

Artists' multiples, defined in the broadest sense, are art objects issued in editions. Beuys created more than 500 different multiples in a twenty year span, of which Harvard has a nearly complete collection. Beuys' multiples are typically characterized by the presence of his signature and an edition number. However, this is not always a reliable indicator, as many lack one or both of these features. Further complicating matters, different editions of the same multiple can vary significantly in terms of materials and form, especially those editions that were released over the course of many years and through more than one publisher. Given these variables, the Schellmann (1997) catalog raisonné of Beuys multiples is widely regarded as the definitive list of multiples and its terminology and numbering scheme are used as universal identifiers in museums and private collections.

Most of the Beuys multiples were issued in predetermined edition sizes that range from less than ten to many thousands. This output was possible because Beuys worked with publishers to produce and distribute his works, and thus was not always directly involved in their fabrication. Beuys described his artistic motivations in a 1970 interview, where he states "I'm interested in the distribution of physical vehicles in the form of editions because I'm interested in spreading ideas" (Schellmann 1997). These "vehicles" came in many forms and in a rich diversity of materials: many incorporate found objects, others were relics of events in his life,

while others were manufactured on a large scale.

Beuys incorporated many unconventional and perishable organic materials into his multiples. He is perhaps best known for the frequent use of felt and fat throughout his work. Other uncommon materials include chocolate, margarine, fried fish bones, and sulfur. Unsurprisingly, these materials and their unusual combinations are very frequently unstable, presenting significant challenges to the storage, handling, and exhibition of these works.

3.3 Conservation Approaches

Beuys once stated "My sculpture is not fixed and finished. Processes continue in most of them: chemical reactions, fermentations, color changes, decay, drying up. Everything is in a state of change" (Beuys 2004, 9). While this statement provides some insights into Beuys' views on condition change, it is difficult to extrapolate how he would react to specific conservation interventions, especially given that no published interviews deal directly to this subject.

Barker and Bracker (2005) discuss ethical dilemmas in the conservation of Beuys' artworks using specific examples from the Tate's collection. In 1984, the Tate consulted directly with the artist about the condition of his sculpture *Fat Battery*. The fat component of this piece was dusty and had become somewhat liquefied, causing it to flow within the metal container and saturate the outer cardboard box. However, when shown the piece, Beuys responded that he was pleased with its current state, remarking on how it actually smelt like an old battery.

However, the approach taken was very different when the Tate consulted the artists' widow, Eva Beuys, about the condition of the multiple *Felt Suit* after it was extensively damaged by an insect infestation in 1989, three years after the artist's death. Because of the extent of damage, Mrs. Beuys deemed the object to be no longer displayable, and the object was subsequently deaccessioned from the Tate's collection.

Unfortunately, neither of these instances provides clear guidance in how to approach conservation of the PVC multiples because their situation differs in two important ways. Unlike the fat in *Fat Battery*, Beuys could not have anticipated the eventual changes to the PVC material that he selected, since the poor ageing properties of the material were not widely known at this time. And although the oozing liquid plasticizer presents significant challenges to displaying the PVC objects, the deterioration is an ongoing process resulting from inherent vice, as opposed to the single event of external origin that damaged the Tate's *Felt Suit.*

As part of her research, Ryf (2006) corresponded with Mrs. Beuys and other close associates of the artist about their thoughts on the condition of the PVC as it relates to artistic intention. Mrs. Beuys expressed her belief that the PVC material should not lose its original qualities. Beuys' friend Johannes Stüttgen also noted that the hazardous nature of the materials released by the degraded PVC would have run contrary to Beuys' strong environmentalist convictions. Based on this information, Ryf concludes that conservation interventions aiming to slow deterioration are consistent with preserving the artist's intention.

This position is further supported by the research of former Straus Center conservation fellow Craig Uram (2007). Through his fellowship project, Uram explored similar questions with respect to the Beuys multiples with metal components. Many of these objects have worn and corroded surfaces, and it is not always clear how to distinguish intentional or acceptable alterations from undesirable changes or damage. Uram contacted Eva Beuys with questions on this subject, and in her response, she stated that "what Joseph Beuys could not endure was that in a 'wrong, impolite way' an object was subjected to 'evident disregard'" (Uram 2007: 9).

4. Beuys PVC Multiples at the Harvard Art Museums

According to the Schellmann (1997) catalog, there are four multiples made using 3 mm PVC board (see table 1). Three of these multiples (Schellmann #103, 105, and 417) contain the PVC in the form of screenprinted postcards. The other, *Phosphorus-Cross Sled* (Schellman #64), is larger and composed of two square PVC boards. HAM has three of these multiples in its collection: *Phosphorus-Cross Sled* (version 64B)*, Postcards 1968-74,* and *Stamp Sculpture*.

Based on the dimensions and edition sizes of these multiples, the total amount of PVC board used by Beuys would be at least 100 m^2 (Ryf 2006). The source of the PVC material is unknown, but the similarities in appearance and properties suggest that it originated from a single manufacturer. However, tracing the source is complicated by the fact that the first multiple to incorporate this material (*Phosphorus-Cross Sled,* 1972) was published by Marian Verlag, which fell into bankruptcy just a few years later, leaving no records pertaining to its purchase of this material (Ryf 2006). This PVC material was likely purchased all at one time, and passed on to subsequent publishers (Schellmann 1997).

Table 1: Beuys Multiples Incorporating Plasticized PVC Board (information from Schellmann 1997)

Multiple Title	German Title	Schell-mann #	Year Published	Edition Size	Publisher	HAM Accession Number	Size (cm)	Description
Phosphorus-Cross Sled	*Phosphor-Kreuzschlitten*	64A	1972	100	Edition Merian, Krefeld	n/a	L: 45 W: 45 H: 0.6	Composed of two square PVC boards. This version does not have a clip.
		64B	1977	100	Kunstverein Braunschweig	1995.265	L: 45 W: 45 H: 0.6 (+ clip)	This version is the same as above, with the addition of a signed clip.
Postcards 1968-1974	*Postkarten 1968-1974*	103	1974	120 plus 20 supplementary	Edition Staeck, Heidelberg	1995.295	L: 18 W: 12.5 H: 6	Each edition includes one signed *Honey is Flowing* postcard
Honey is Flowing	*Honey is Flowing*	105	1974	Approximately 800 signed postcards	Edition Staeck, Heidelberg	n/a	L: 15 W: 10.5 H: 0.3	Screenprinted PVC postcard, also incorporated into Schellmann #103 and #417
Stamp Sculpture	*Stempelplastik*	417	1982	35 plus 3 supplementary	Edition Staeck, Heidelberg	1995.461. A	L: 10.5 W: 15 H: 19 (stacked)	Each edition includes 37 unsigned *Honey is Flowing* postcards

4.1 ***Phosphorus Cross-Sled (HAM 1995.265)***

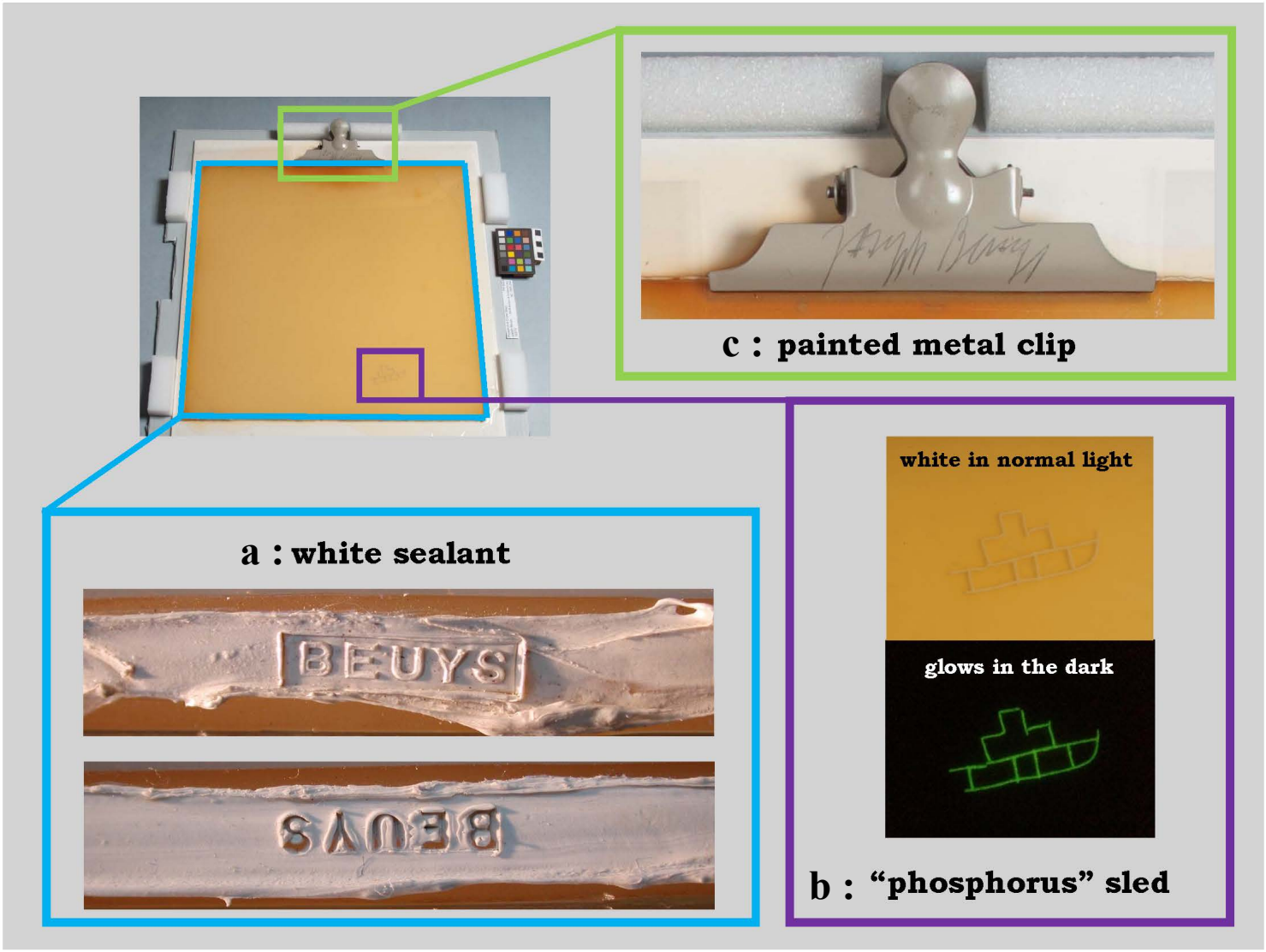
This multiple is a composite object, consisting of two stacked PVC boards sealed together at the edges with a white sealant material, into which Beuys' name (in all capital letters) is stamped twice using two different stamps (fig. 3a). Between the board, in the lower proper left corner, there is a half-cross and sled symbol, created using an applied phosphorescent material which glows in the dark (fig. 3b). At the top of the PVC board, there is a metal clipboard clip attached (fig. 3c). Though the total edition size *of Phosphorus-Cross Sled* was two hundred, only one hundred of them include this clip, which Beuys signed on the front. A transparent coating on the front of the clip is likely a fixative applied to protect the signature. It is unclear whether this would have been applied by the artist, publisher, or a collector.

Phosphorus-Cross Sled incorporates many of the symbols and concepts that recur throughout Beuys' oeuvre. In particular, the sled and the half-cross are recognizable symbols that clearly link the piece to Beuys, serving as a kind of personal insignia. According to Kunstverein Braunschweig's advertisement for this multiple, the yellow color and transparency of the PVC is meant to evoke honey (*Phosphor-Kreuzschlitten* 1977). The disorder represented by flowing honey serves as a counterbalance to the order implied by the square form of the PVC board. As in many of Beuys' stacked works, the multi-layered structure of the piece as a whole conveys the concept of energy, and the phosphorescent properties of the half-cross and sled symbol further reinforces this idea (Wismer 2013).

4.1.1 *Condition*

The history of Harvard's edition of this multiple has been fairly well-documented photographically, allowing us to roughly track the progression of the deterioration. The earliest photographs date to before the piece was accessioned by the museum in 1995. Unfortunately, these are very small, and not high in quality. In 1996, the piece was put on exhibit, suggesting that there were no major concerns for its condition at that time. However, by 2005, the problem of plasticizer migration was well underway. The piece was documented again in 2007. At this time, sheets of Mylar were placed in contact with the top and bottom surfaces.

Fig. 3: Materials and construction of Phosphorus-Cross Sled (1995.265)



While this Mylar has prevented dirt and dust particles from accumulating on the surface, it did not cover the area where the clip contacts the PVC. This has allowed the edge of the metal clip to remain in prolonged contact the acidic plasticizer liquid, resulting in the development of corrosion along the clip's edge (fig. 4). It also did not stop the plasticizer from migrating to the surface. When the Mylar is lifted, a pool of plasticizer is revealed and built-up volatile components are released (fig. 5). Given the potentially hazardous nature of these components, ventilation is always used when examining the object.

We know from our prior documentation that the red discoloration evolved in the period between 2007 and 2012 (fig. 6). This redness is concentrated around the metal clip, and also along the top edges, suggesting that the redness is related to the corrosion of the clip. Another visible condition feature is the presence of bubbles between the two PVC boards, created by the migration of liquid plasticizer into the narrow void in between (fig. 7).

4.1.2 *Treatment and Exhibition History*

The object was treated in 1996 in preparation for its display in the exhibition "Joseph Beuys: The Sled as Symbol" in Werner Otto Hall between June 2 and July 14, 1996. The condition report notes the presence of a "waxy-like material in an interrupted semi-circular pattern and in a few spots on the front surface," which could represent the earliest signs of plasticizer migration to the surface, though it was not identified as such at the time. The 1996 treatment consisted of the removal of dirt and smudges from the surface using cotton swabs and Multilith cotton pads dampened with distilled water. Additional photodocumentation and cleaning, which involved wiping the surface, was performed by conservation staff in 2005. The photos of the object dating to 2007 likely correspond to the object's rehousing in preparation for transit to off-site storage in Somerville.

Fig. 4: Rust and red-stained plasticizer along front edge of metal clip on 1995.265.

Fig. 5: Images showing pooled plasticizer below Mylar on front surface of 1995.265

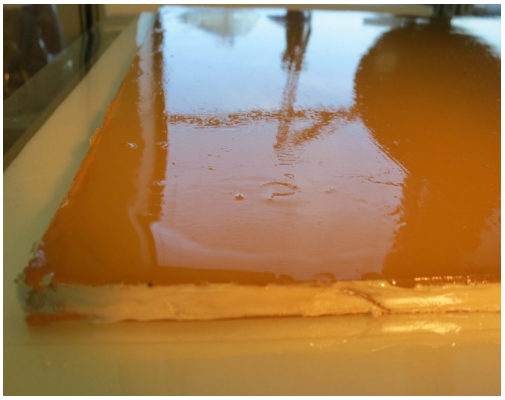
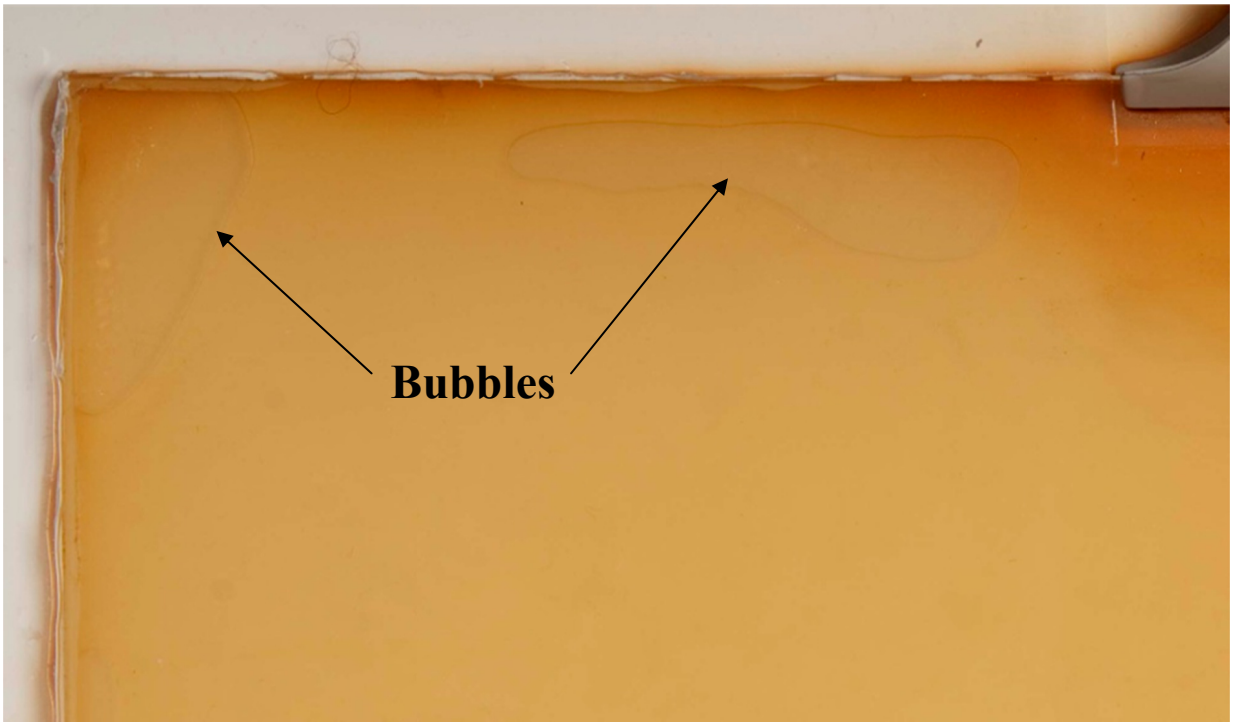


Fig. 6: Comparison 2007 and 2012 photos of 1995.265, showing evolution of red staining.

2007 **2012**

Fig. 7: Bubbles between the PVC boards of 1995.265.



4.2 *Postcards 1968-1974* (HAM 1995.295)

This multiple consists of a collection of postcards contained within a cardboard box. One of the postcards is a screenprinted and signed PVC postcard, which is identical to the multiple *Honey is Flowing*.

4.2.1 *Condition*

Like *Phosphorus-Cross Sled*, the PVC is exuding liquid plasticizer. However, because the piece has not been covered with Mylar, the plasticizer has taken the form of droplets on the top surface (fig. 8). The bottom surface of the PVC is in direct contact with a wooden postcard, and it appears that the plasticizer has soaked into the wood. Fortunately, the paper postcards were previously removed from the box and are housed separately. The visible areas of the cardboard box do not appear to be affected by the plasticizer.

The screenprinted text on the postcard appears to be intact. However, a reddish smudge on the upward-facing side is likely what remains of Beuys' signature, which has been dissolved by the plasticizer. Though the photo quality is very poor, the collector's photo of this multiple dating to before 1995 shows what appears to be an intact signature, though it is difficult to determine if it was still legible at that time.

There is no record of previous treatment or exhibition of this piece.

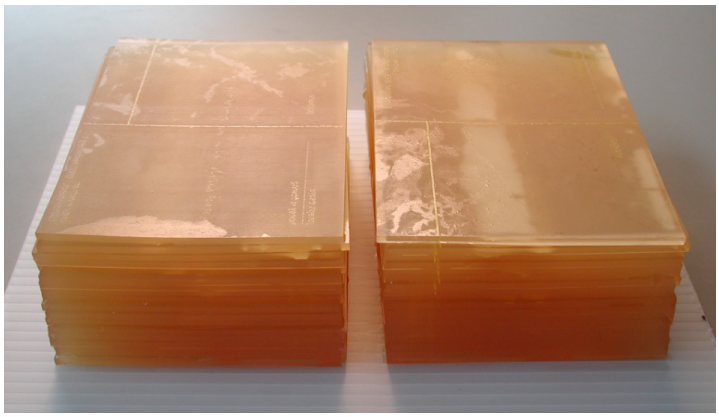
Fig. 8: Photo of PVC postcard (1995.295) taken in 2012, in box with black print on wooden postcard showing through.

4.3 *Stamp Sculpture* (HAM 1995.461.A)

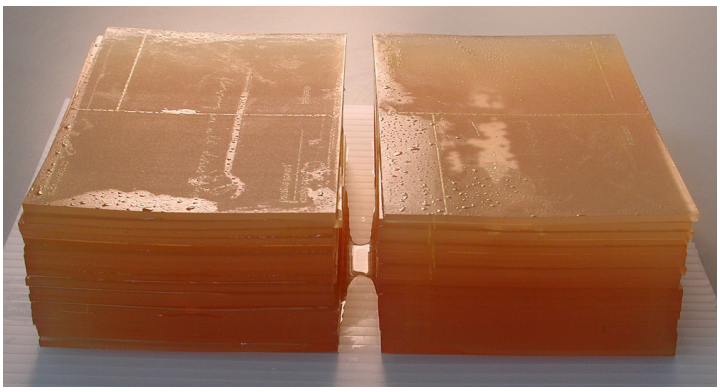
This multiple consists of 37 screenprinted PVC postcards in a stack. The postcards are the same as the postcard in *Postcards 1968-1974*, but do not appear to be signed. This multiple also includes a rubber stamp with a wooden handle, which is housed separately.

Fig. 9: Photos of *Stamp Sculpture* (1995.461.A) from HAM records

a : 2005



b : 2007



4.3.1 *Condition*

The postcards are currently stored as two stacks of roughly equal height. However, the earliest photo of this piece dating to before 1995 indicates that the postcards were originally in one stack. There are droplets of liquid plasticizer on the top surface of each stack and along the sides of the stack as well. The screenprinted text appears intact.

The piece is currently stored on a corrugated plastic support within a lidded plastic container. In general, there appears to be significantly more plasticizer on the surface currently than in the photos taken in 2005 (fig. 9a) and 2007 (fig. 9b). Even though the container is permeable and does not have an air-tight seal, plasticizer gasses have built up within the container. For this reason, examination can only be done safely inside a fume hood, thus limiting a more extensive examination and condition assessment.

4.3.2 *Treatment and Exhibition History*

There is no record of this multiple being treated previously, with the exception of its transfer to the closed plastic container in 2007. Prior to this date, the condition of the object was photodocumented in 2005 by HAM conservators. It was also displayed as part of the Busch-Reisinger Museum exhibition "In/Tuition: A Seminar's Engagement with Joseph Beuys" between September 20 and December 7, 1997. Presumably, the plasticizer was not migrating out at this time.

5. Materials Analysis

The analytical component of this research has aimed to gather information about the composition and structure of the PVC and adjacent materials, in order to better understand the specific processes acting on the Beuys PVC. Pyrolysis GC-MS analysis was used to identify the composition of the plastic and its deterioration products, as well as the plasticizer and other compounds contained within the liquid exudates. SEM-EDS was used to image the PVC samples and to determine the source of the red discoloration.

5.1 *Review of Previous Technical Research*

The only previous in-depth technical study of the PVC material used in the Beuys multiples was completed by Ryf (2006) as a Masters thesis project at the Department of Conservation and Restoration at the Hochschule der Kunst in Bern, Switzerland. This research

used unsigned *Honey is Flowing* PVC postcards, loaned to the university by Eva Beuys, for sampling and compositional analysis, as well as experimental trials of stabilization and cleaning treatments. Using FTIR, the plastic was identified as PVC and the main plasticizer in the exudates as an adipate plasticizer. Waentig (2008) also identifies the plasticizer composition of *Phosphorus-Cross Sled* as dioctyladipate, though it is not stated which edition of this multiple was tested and where this analysis was carried out.

5.2 *Methods*

Pyrolysis GC-MS is an analytical technique frequently employed in the compositional analysis of organic polymers. By separating a sample into its constituent compounds, this technique is capable of identifying the polymer, plasticizers, additives, and their degradation products.

SEM produces high-magnification images of samples, providing information about surface features and compositional structure of the materials. When coupled with an EDS instrument, it is possible to detect and map the presence of specific elements of interest.

5.3 *Samples*

Five samples were taken from *Phosphorus-Cross Sled* (see fig. 10 and table 2)

5.4 *Results*

5.4.1 *pyGCMS*

The results of pyrolysis GC-MS analysis (see table 2) confirmed that the polymer is PVC. The exudate was found to contain primarily phthalate plasticizer. Adipic acid was also detected, indicative of adipate plasticizers which had been detected in other studies of this material. However, unlike the results published for other editions, the concentration of the adipate-type plasticizer appears to be less than the phthalates. Other components detected in the exudate include bisphenol-A, pentachlorophenol, and other minor unidentifiable components.

Fig. 10: Samples and Locations

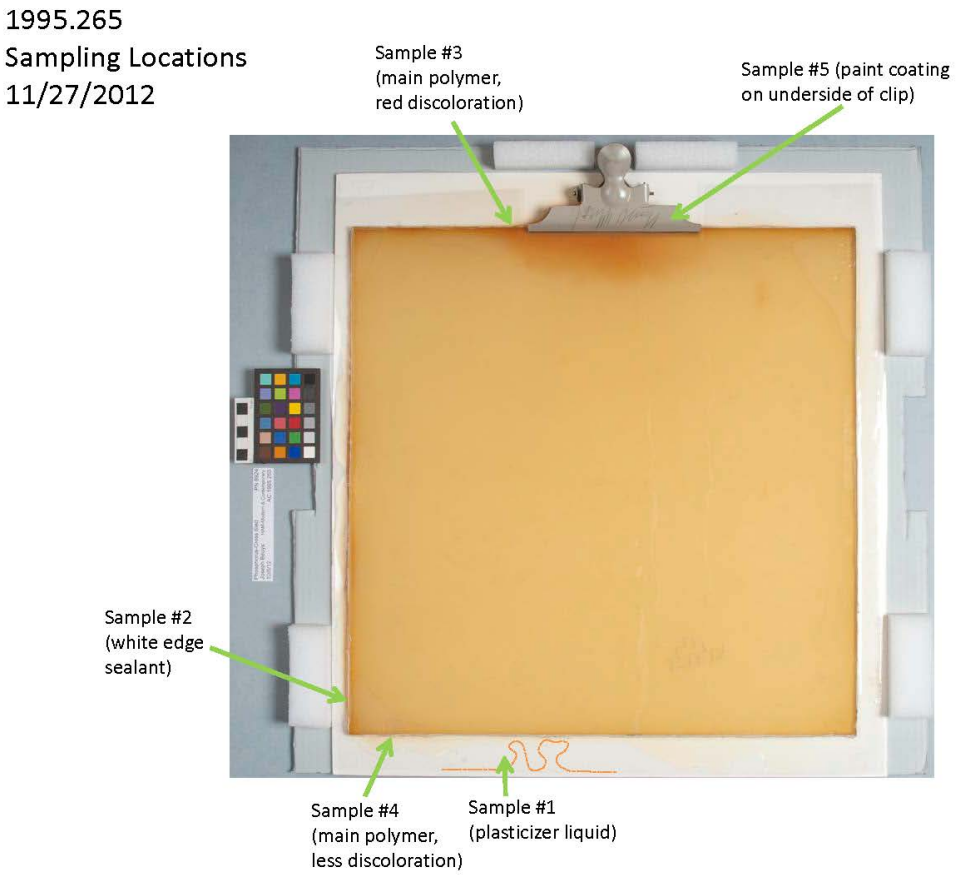


Table 2: pyGC-MS Results

Material	**Sample(s)**	**Composition**
Exudate	#1	Phthalates, adipic acid, bisphenol-A (BPA), pentachlorophenol (PCP), and other components
Edge Sealant	#2	Polyvinyl chloride (PVC)
Polymer	#3 and #4	Polyvinyl chloride (PVC)
Clip Paint	#5	Alkyd

Another important finding is that the white sealant around the edges of the PVC board is also composed of PVC, combined with pigments to produce the white, opaque color. The catalog raisonné describes this material in non-specific terms as a "heat seal" (Schellmann 1997: 440). Finally, the paint covering the metal clip was identified as an alkyd-based paint.

Fig. 11: Sample 3 (Polymer, Red) SEM Images

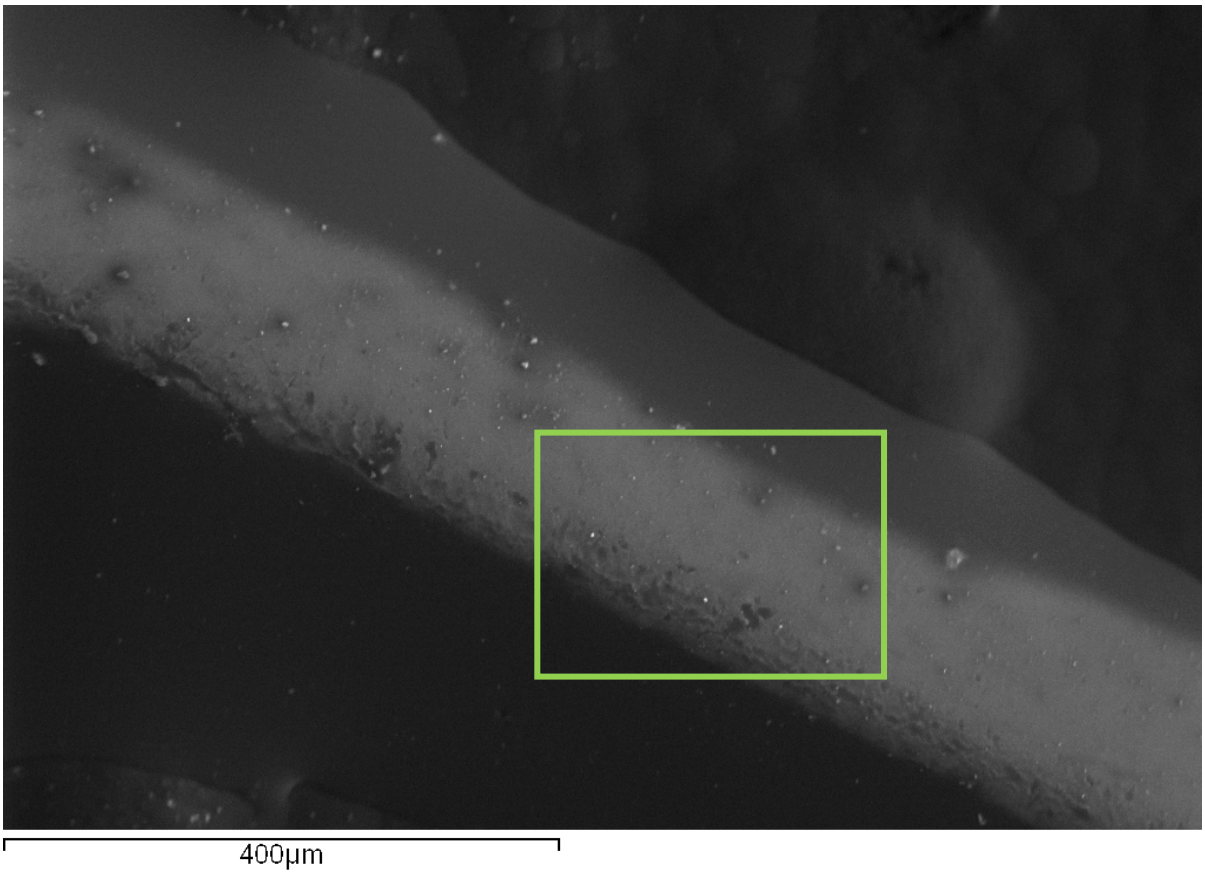
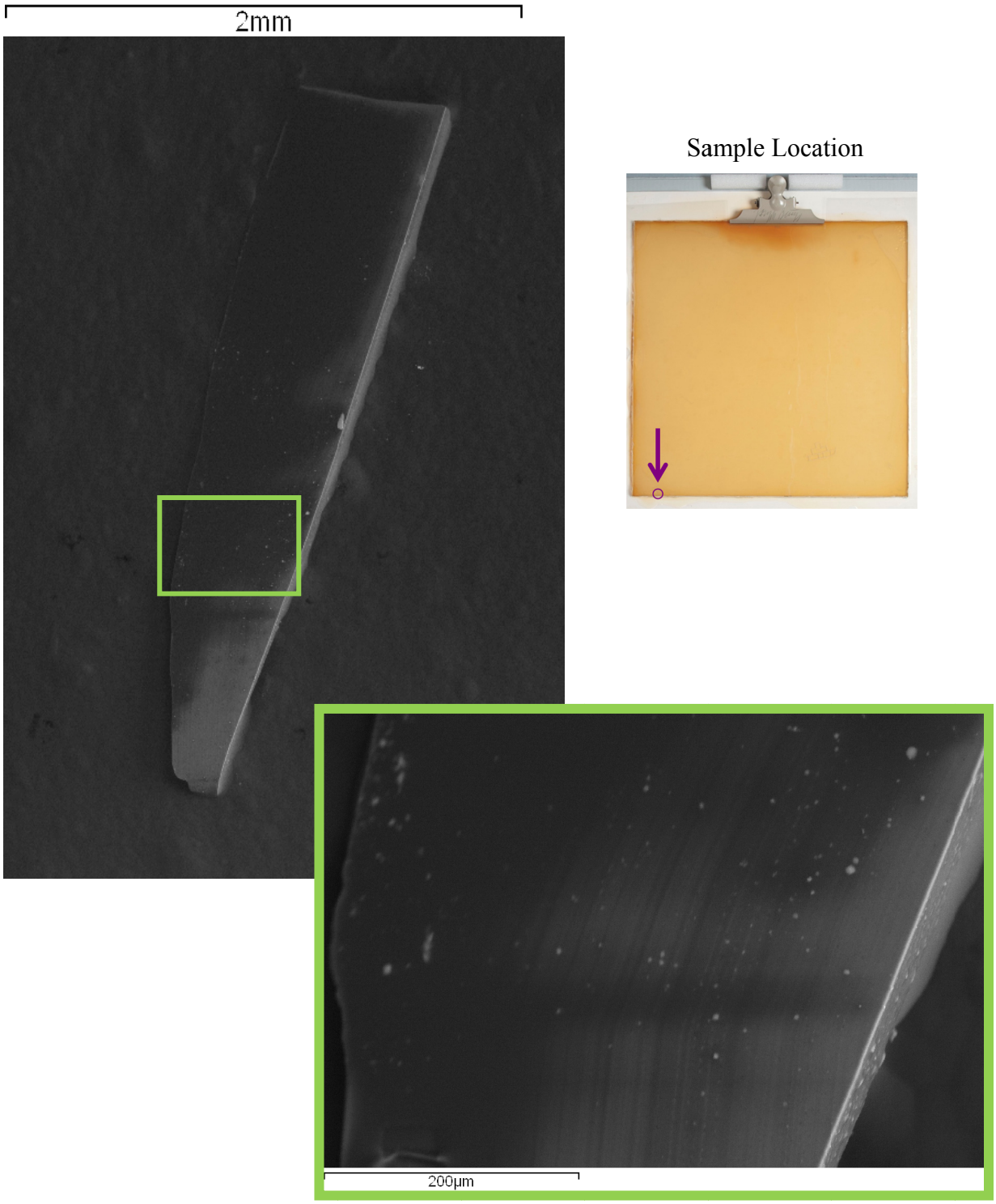


Fig. 12: Sample 4 (Polymer, Not Red) SEM Images



5.4.2 *SEM-EDS*

The results of SEM-EDS analysis provided information about the structure of the PVC surface and confirmed the source of the red staining. Fig. 11 shows the PVC polymer sample taken from the top edge of the piece, where the red discoloration is present. Elemental analysis performed on the large, bright white particles in the image confirmed the presence of iron.

Iron was not detected in the polymer sample taken from the bottom edge of the piece, which lacks the red discoloration (see fig. 12). However, this image revealed differentiated layers that correspond to different chlorine concentrations, with the darker portions representing chlorine-depleted areas. The interpretation of this unexpected feature will require additional sampling to determine the orientation of the banded structure.

5.5 *Discussion*

The identification of the plastic as PVC confirms that the composition of the boards matches the descriptions given in the multiples catalog raisonné and other literature. The detection of high levels of phthalates in the exudates was a more surprising finding, but it seems likely that this is due to contamination from the sheet of Mylar on the surface, which has degraded while in prolonged in contact with the acidic plasticizer. However, this conclusion can only be confirmed by sampling another Beuys PVC multiple that has been stored in this way.

The identification of the white sealant as PVC was another interesting and unexpected finding. It raises questions about what type of PVC-based product was used for the seal and how it was applied. The catalog raisonné refers to this as a "heat seal" (Schellmann 1997, 440). However, this claim is difficult to evaluate based on examination. Ridges left by a smoothing tool are well-preserved, suggesting that the material was applied in a viscous state. The two Beuys name stamps must have also been applied when the material was moldable and soft. These characteristics and the sealant's appearance are consistent with some type of commercial caulking material, but unfortunately, no PVC-based product with these properties has been identified.

The identification of alkyd paint on the metal clip is an important result because it will inform future conservation approaches to the clip. Alkyd paints were developed in the early 20th century for industrial and household applications. The binding medium is composed of a polyester modified by fatty acids, which produce a more flexible polymer by minimizing the amount of polyester cross-linking (Ploeger and Chiantori 2012).

The results of SEM-EDS analysis confirm that the source of red staining is the corrosion developing along the edges of the clip. This is problematic, not only because the stain is disfiguring, but also because the presence of iron accelerates the process of dehydrochlorination in PVC (Waentig 2008).

The layering structure observed in the SEM imaging of the PVC remains a question to be investigated in future work if the opportunity for further sampling arises. It is possible that this structure is related to the chlorine-depletion of the polymer as it degrades, or could be an artifact of the manufacturing process. A follow-up core sample would likely reveal more information about these features.

6. Recommendations

The following section provides a set of recommendations for the treatment, display, and storage of the three Beuys PVC multiples in HAM's collection. These recommendations are based on the information gathered through this study, as well as the current theoretical understanding of PVC ageing properties described in the reviewed conservation literature. However, because PVC formulations and their extent of deterioration are highly variable, it is difficult to make predictions about future ageing behavior without performing real-time testing. Constant close monitoring of the piece post-treatment, while in storage, and during exhibition will be essential, and may provide important information resulting in revisions to these proposed guidelines.

6.1 *Treatment*

6.1.1 *Phosphorus-Cross Sled*

With confirmation that the liquid plasticizer is causing the corrosion of the clip and associated red staining, the most immediate recommendation is to release the metal clip from the PVC board and store it separately. It is also advisable to remove large corrosion particles and reduce the red-stained exudates on the surface to prevent further absorption of the iron into the PVC polymer matrix. This is the only course of action that would guarantee that the metal does not contact the acidic exudates and its volatile acidic vapors. It also has the additional benefit of relieving mechanical stress on the PVC board, which may also contribute to plasticizer loss (Shashoua 2008). Furthermore, it will eliminate complications associated with placing this object

into low temperature storage, where the different dimensional responses of metal and PVC to temperature changes could give rise to new mechanical stresses.

Since preventing plasticizer loss is of primary importance in preservation strategies for PVC, cleaning the plasticizer from the surface is not advisable until the piece is placed on exhibit. Pooled plasticizer on the surface is disfiguring to the object, messy, and presents a hazard to the handler during movement and installation. However, complete removal of the plasticizer may not be feasible, or even desirable. The surface underneath the plasticizer is degraded and has likely lost its original surface characteristics. Leaving some plasticizer on the surface may serve to saturate and visually integrate the unevenness in surface quality.

When cleaning is undertaken, it should follow the method described by Ryf (2006) using glassine (German: *Pergaminpapier*) to lift away the liquid. This is the only published method that has been previously tested on Beuys PVC with success. The liquid exudate adheres to glassine pressed lightly against its surface, and is lifted off when the glassine is peeled away. The main advantage of this technique is that it will not pull plasticizer out of the PVC. It is also a very controllable process, and does not involve potentially abrasive materials or cleaning agents.

Cleaning of the white sealant around the edges of PVC can be undertaken using more standard dry cleaning methods, as this component is in good condition and does not suffer from plasticizer migration. Cleaning the front of the metal clip should not be undertaken without further study and curatorial input. This side of the clip has a fixative over the surface that may have been applied to prevent Beuys' pencil signature from smudging. Cleaning the interior and back surfaces of the clip, which have been exposed to the plasticizer, should only be undertaken as necessary, using cotton swabs lightly dampened with ethanol to gently to dissolve plasticizer residues.

6.1.2 *Postcards 1968-74*

Cleaning the liquid plasticizer from the surface of this piece is not recommended due to the risks that cleaning may pose to the screen-printed text and dissolved remains of Beuys' signature. However, the PVC postcard should be removed from the cardboard box and separated from the wooden postcard directly below it. The PVC postcard should be transferred to an inert, impermeable support, such as glass or Mylar. If possible, PVC plasticizer should be removed from the surface of the wooden postcard.

6.1.3 *Stamp Sculpture*

Cleaning the liquid plasticizer from the top surfaces of the postcard stacks is not recommended due to the risk this could pose to the screen-printed text. The postcards should remain stacked as-is and no attempt should be made to separate them at this time. Since the corrugated plastic support (likely polyethylene) is not an ideal support material, the stacks should eventually be transferred to a glass support and enclosed within an impermeable, air-tight container.

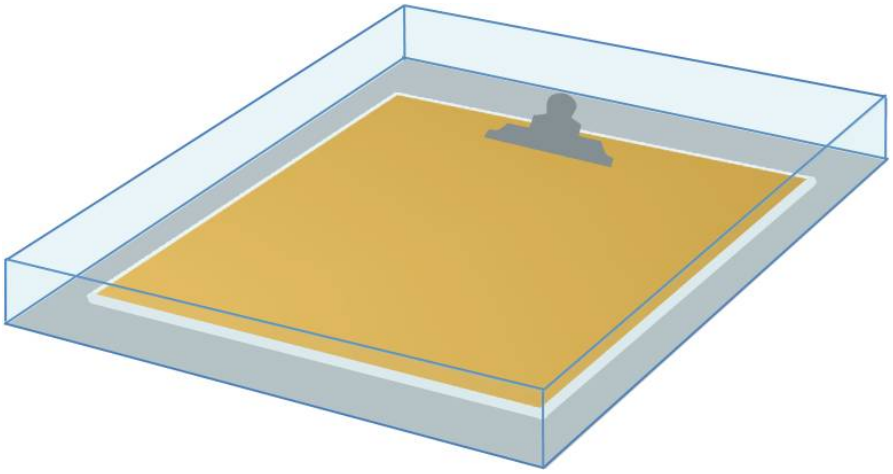
6.2 Exhibition

Currently, the only PVC multiple that is slated for future exhibition is *Phosphorus-Cross Sled*. This piece will be displayed in 2016 as part of the fourth rotation of Beuys multiples to be installed at the new museum facility. Unless this object can be placed by itself within a sealed glass vitrine, it will require its own impermeable, air-tight enclosure. The main function of this enclosure is to prevent volatile acidic components from contacting other art objects inside the case. It also eliminates any concerns about damaging the case materials, since there is a possibility that plasticizer vapors could condense on the case interior, fogging the glass and damaging metal components and painted finishes.

Another important benefit to the enclosure is that it will prevent the loss of volatiles, slowing the evaporation rate of the plasticizer from the surface, and thus the migration rate of the plasticizer. A gasketed air-tight box made of glass would be ideal because it is both inert and impermeable (see fig. 14). Acrylic substitutes, such as Plexiglas, are unsuitable because the plasticizer will cause crazing (Zycherman 2013). This display box could also serve as a permanent storage container.

Placement of the clip is another important display consideration. The back of the clip can be isolated and protected from the back of the PVC board by encasing the contacting area in Mylar. A small spacer of inert material can be inserted just in front of the clip's spring mechanism to prevent the clip from clamping down on the PVC, allowing for a small amount of clearance between the two materials. This spacer and the small gap between the top of the PVC and the bottom edge of the clip will not be readily visible to viewers. As an additional safeguard, a narrow strip of Mylar can be laid onto the PVC directly below the front clip edge.

Fig. 15: Possible Design for Glass Exhibit Enclosure



The planned duration of the exhibition including *Phosphorus-Cross Sled* is six months. This rotation length is based on the scheduled rotation frequency for the gallery. While there is no doubt that exposure to light and typical museum temperatures will accelerate the degradation of the PVC, these risks must be balanced against the benefits of making the object accessible for public viewing while it still has physical integrity. The planned Beuys exhibit provides a unique opportunity for this piece to be viewed by a wide audience and in the context of other works by Beuys and his contemporaries. Until the difference in deterioration rates under gallery conditions versus optimal storage conditions can be quantified, the six-month rotation should be considered as a real-time test-period in which the piece will be monitored closely. If at any time the piece's stability is visibly compromised, the object should be deinstalled and the future exhibit recommendations revised. When the period of exhibition is over, any changes in condition should be thoroughly documented and the exposed metal on the clip should be cleaned with ethanol to ensure that any condensed plasticizer on the surface is removed.

6.3 Storage

6.3.1 *Housing Materials*

Despite strong indications that Mylar degrades in the presence of the acidic exudate, there are various reasons why it should not be excluded as a housing material for the PVC multiples.

First, the Mylar in contact with *Phosphorus-Cross Sled* was not visibly altered after more than five years, and proved very effective at protecting the surface from dust accumulation. Second, while the Mylar did not prevent the plasticizer from migrating, it may have helped to limit the rate of migration. Finally, the Mylar facilitates viewing of the piece by limiting the off-gassing of plasticizer vapors, and also causes the plasticizer droplets on the surface to merge into a continuous liquid film that improves the evenness and legibility of the surface.

Glass is also recommended as an inert, impermeable storage material for PVC (Shashoua 2008). However, glass is heavier, more expensive, and more difficult to seal than Mylar, and acrylic substitutes are ineffective due to their demonstrated incompatibility with the plasticizer vapors (Zycherman 2013). Another risk with glass is that the PVC board will stick to the surface and may be challenging to remove. Mylar, by contrast, is flexible. It conforms to undulations in the PVC board and peels away from the sticky surface.

However, given the evidence that Mylar degrades in the presence of the plasticizer, it should be monitored and replaced with a fresh sheet periodically. The Mylar's release of phthalic acid into the plasticizer exudates is unlikely to pose a threat to the PVC, since it is already acidic and phthalates are already present in the exudates.

6.3.2 *Low Temperature Environments*

Storage in a low temperature storage facility is recommended for long-term storage of *Phosphorus-Cross Sled* and the PVC postcard from *Postcards 1968-74.* Despite the risks associated with possible embrittlement and distortion, the benefit of slowing the degradation process offers the best prognosis for these pieces.

HAM currently has two low temperature storage chambers set at different temperatures: a "cool" storage room at 55°F and 40% RH and a "cold" storage room is 40°F and 30% RH. This provides the opportunity for a very controlled, gradual temperature transition. Even though low temperature storage is expected to significantly slow the migration rate of the plasticizer, the PVC objects placed into these conditions will still need to be enclosed. The enclosure will help to protect the piece from dust and damage, and also may help to buffer the temperature transition. A sealed glass case or Mylar enclosure would be suitable for this purpose.

Low temperature storage is not recommended for *Stamp Sculpture* due to the thickness of the postcard stacks. According to Shashoua (2008), PVC that is over 1 cm thick risks the formation of condensation because the center of the polymer will take longer to cool.

The clip from *Phosphorus-Cross Sled* should not be placed into low temperature storage. This component should be stored separately, attached to a Mylar-lined padded mount, in normal museum storage conditions. The exposed metal should be monitored to ensure that it is not actively rusting.

7. Treatment

As of spring 2014, the only PVC object to be treated as part of this project is *Phosphorus-Cross Sled.* For this piece, immediate actions were taken to halt the progression of the rusting clip and associated staining.

7.1 Removal of Metal Clip

After careful consideration of many options, which included coating the edge of the metal clip and inserting a Mylar barrier, the decision was made, in consultation with the curator, to remove the clip entirely. Because the clip is clamped to the PVC, and not permanently attached, it is unlikely that its current position corresponds to the original placement by Beuys or the publisher. While it is always placed at the center of the top edge of the PVC, the distance of the clip from the edge varies from edition to edition. There is no evidence that its precise position is important to the artwork.

A padded support board was constructed for this purpose and was applied to the front of the piece, leaving a cut-out for access to the front of the clip (see fig. 15). To prevent movement and flexing of the object during flipping, the new front support was secured tightly to the back support with cotton twill tape. The piece was then flipped, and the back support and Mylar lining were carefully lifted, offering the first glimpse of the back since it was last examined in 2007. Fume extractors were used from this point forward to prevent the inhalation of vapors from the exposed plasticizer on the back surface.

The back of the clip was found to be submerged in pooled plasticizer (fig. 16), and unfortunately this had caused the alkyd paint to swell and blister where it had been in direct contact with the exudates, becoming softened and rubbery. This blistering was associated with ruptures in the paint surface and small scattered paint losses. However, this did not interfere with the spring mechanism of the clip, and the clip was released and removed with ease (fig. 17). A

padded clamp was used to hold the clip in an open position so that the condition could be further assessed and the plasticizer cleaned from both the interior and exterior surfaces of the clip.

Fig. 15: 1995.265 prepared for flipping

Fig. 16: Images of discolored (reddish) pooled plasticizer on back clip

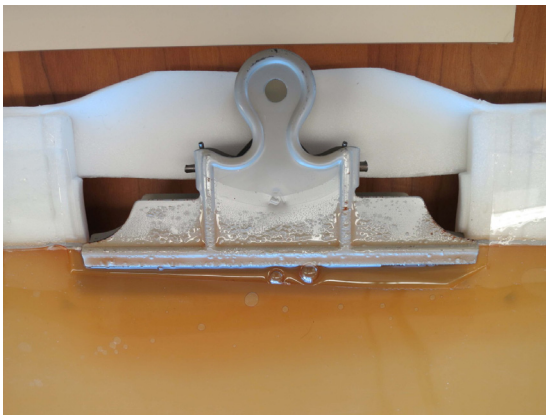
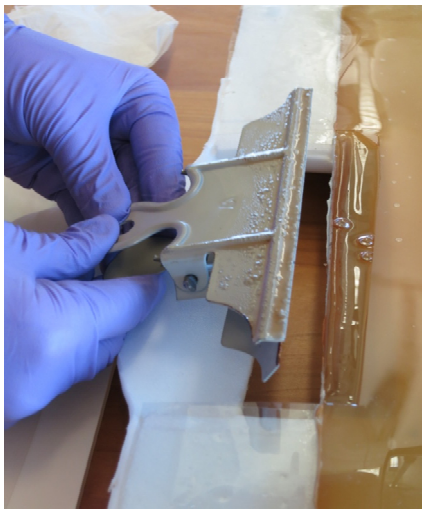


Fig. 17: Removal of clip



7.2 Localized Removal of Corrosion Products from PVC Surface

The large pool of reddish-colored plasticizer that surrounded the back of the clip was reduced by absorbing with dry cotton swabs, avoiding direct contact with the PVC surface as much as possible. A small amount of this plasticizer was saved for future compositional analysis.

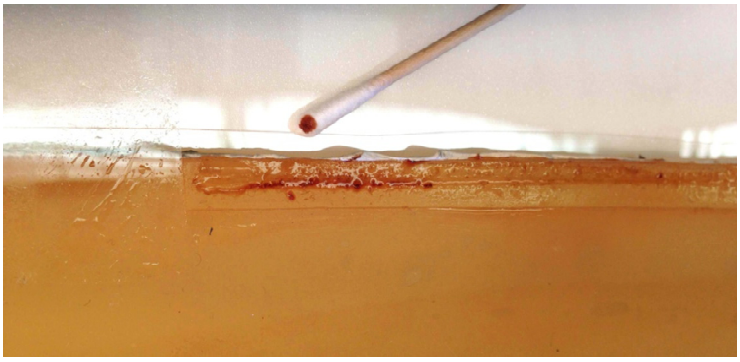
A new sheet of Mylar was applied to the back of the piece and a new padded support was constructed. The object was then flipped using the same procedure as before so that the front could be reexamined without the clip. The area where the front edge of the clip had previously clamped down on the PVC board left behind a line of corrosion particles and red-stained plasticizer, which was gently removed by dabbing with dry swabs (fig. 18a), being careful to lift the corrosion particles rather than drag them across the PVC surface. The clip also left behind a linear impression in the PVC surface (fig. 18b).

The old Mylar lining the front was removed from the PVC, and the large drips and droplets along the white edge sealant were removed carefully using dry cotton swabs. A new sheet of Mylar, covering the entire area of the PVC board, was placed on the top surface.

These treatment steps reduced much of the red discoloration and greatly enhanced the overall appearance of the PVC board (fig. 19). This suggests that much of the red staining was present in the exudates that had welled up in the void behind the clip, and had not yet penetrated into the PVC.

Fig. 18: Corrosion (a) and impression (b) left by metal clip

a



b

Fig. 19: Front of 1995.265before and after clip removal

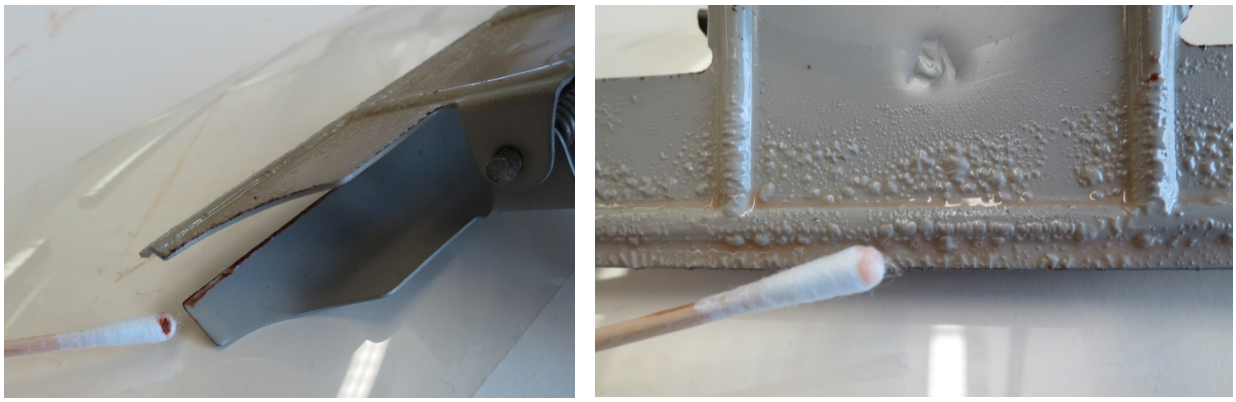
Before (October 2012)

After (April 2013)

7.3 Cleaning the Metal Clip

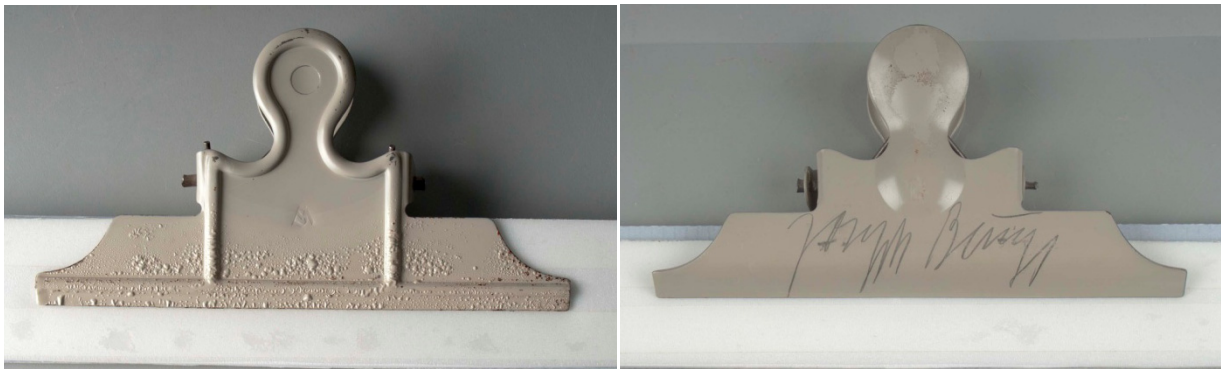
The plasticizer accumulations on the interior, edges, and back sides of the clip were removed with cotton swabs moistened with ethanol (fig. 20). Ethanol facilitated the cleaning process by solubilizing the exudates, and did not appear to swell the alkyd paint film when applied sparingly to the surface. An especially gentle approach was taken to the blistered areas on the back and interior of the clip. Ruptured paint blisters were lightly pressed with a cotton swab to drain out the plasticizer. The clip was then left to dry and checked every few days to monitor the surface condition. For several weeks, reddish plasticizer continued to ooze slowly out of the ruptured paint blisters and the edges of paint losses, and was promptly removed.

Fig. 20: Images of cleaning metal clip



Eventually, the oozing subsided and the paint film regained its firmness. However, the paint blisters did not flatten (see fig. 21), and there are likely dried residues of the plasticizer exudates remaining below the paint surface. For this reason, the condition of the clip should continue to be monitored to ensure that these residues do not promote more corrosion. The stability of this paint surface should also be evaluated periodically, especially prior to display.

Fig. 21: Metal clip after cleaning



Back **Front**

7.4 Future Treatment Work

Much of the remaining treatment work on *Phosphorus-Cross Sled* will be undertaken just prior to its exhibition in 2016. At that time, an overall cleaning to reduce the amount of plasticizer on the surface should be performed, as it will improve its appearance and facilitate the handling of the piece for installation. Consolidation of the blistered paint on the back of the clip should also be considered prior to exhibition. Until that time, the PVC component should be enclosed and transferred to low temperature storage.

8. Conclusion

This research project has brought together information and data from many sources to produce a more complete understanding of the three Beuys PVC multiples in the HAM collection. It is hoped that this information, and the resulting recommendations, will provide helpful guidelines to HAM and other institutions as they make plans for the future storage, exhibition, and treatment of these objects. If these important preventive and remedial steps are taken, there is a better chance that these pieces will remain accessible and exhibitable for decades to come.

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Acknowledgements

I would like to thank the following institutions and individuals for their support and important contributions to this fellowship research project:

Samuel H. Kress Foundation

Harvard Art Museums/Busch-Reisinger Museum:

Lynette Roth
Maja Wismer

Straus Center for Conservation and Technical Studies:

Henry Lie
Angela Chang
Tony Sigel
Georgina Rayner
Narayan Khandekar
Kathy Eremin
Francesca Bewer

Antje Janssen, *Kunstmuseum Bonn*

Lynda Zycherman, *Museum of Modern Art, New York*

Vicki Gambill, *Broad Art Foundation, Los Angeles*

Maike Grün, *Pinakotheke der Moderne, Munich*

Sandra Ryf and Marc Egger, *Hochschule der Künste Bern*