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Encapsulation at Fifty Years: Results from a Survey of United States Paper Collections

Fünfzig Jahre Folientaschen: Ergebnisse einer Umfrage in Sammlungen in den USA

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Abstract: A survey of the document preservation technique referred to as encapsulation was conducted of United States institutions with catalogued archives and paper collections. The purpose of this survey was to inform: an estimation of the proportion and type of materials and documents encapsulated, the popularity of various methods and the materials used for encapsulation creation, and the condition of encapsulation materials and encapsulants in collections. The survey responses provided the first data pertaining to the state of encapsulation approximately fifty years after encapsulation for preservation was formally developed. Survey results suggest that: encapsulation is well-established and highly valued in the toolbox of preservation strategies yielded by conservators and collection managers; that most encapsulation construction materials used during the past fifty years evidence few deterioration problems such as yellowing or embrittlement; that it is not a frequent occurrence that conservation treatments like deacidification, washing or the introduction of pollution sorbents is common; and that there is general satisfaction with encapsulation as a preservation method for weakened paper, maps and posters, whether the encapsulation is used in an archival or exhibition environment. Several text responses from survey participants expressed that future research on polymeric material stability and permeability may alleviate some concerns regarding future use of encapsulation.

Keywords: encapsulation; survey; collections

Zusammenfassung: In amerikanischen Archiven und Sammlungen wurde eine Umfrage zu Folientaschen durchgeführt, die in den USA häufig zur Aufbewahrung

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und Stabilisierung von brüchigem Papier eingesetzt werden. Dabei werden die entsprechenden Papiere in einen Umschlag aus durchsichtigem Kunststoff lose eingelegt. Ziel der Umfrage war es, Informationen über folgende Aspekte zu erhalten: den Anteil und die Art der so behandelten Dokumente, die Beliebtheit der verschiedenen Arten von Folientaschen, die dafür verwendeten Materialien sowie den Zustand der behandelten Dokumente. Die Antworten auf die Umfrage lieferten erste Daten über den Stand der Verwendung von Folientaschen etwa fünfzig Jahre nach der Entwicklung des Verfahrens. Die Ergebnisse der Umfrage zeigen, dass Folientaschen gut etabliert sind und im Rahmen von Strategien zur langfristigen Erhaltung von Papierobjekten häufig eingesetzt wird, dass die meisten in den letzten fünfzig Jahren dabei verwendeten Materialien nur wenige Degradationsphänomene wie Vergilbung oder Versprödung aufweisen, dass konservatorische Behandlungen wie Entsäuerung, Wasserbäder oder das Einbringen von Schadstoffabsorbern nicht häufig in Kombination damit durchgeführt werden und dass der Einsatz von Folientaschen als Erhaltungsmethode für fragile Dokumente, Karten und Plakate im Allgemeinen gut geeignet ist, unabhängig davon, ob sie im Archivierungs- oder Ausstellungskontext eingesetzt wird. In mehreren Antworten der UmfrageteilnehmerInnen wurde zum Ausdruck gebracht, dass künftige Forschungsarbeiten zur Stabilität und Durchlässigkeit von Polymermaterialien einige Bedenken hinsichtlich der künftigen Verwendung von Folientaschen ausräumen könnten.

Schlüsselworte: Folientaschen; Umfrage; Sammlungen

1 Introduction

Encapsulation can be considered a preservation technique; it may have originated in England in the 1960s and it was developed with standardizations in the 1970s by the Library of Congress (Brown 1980; Library of Congress 1975; Minter 1983; Poole 1976a, 1976b) to address the important challenge of preserving physically weakened historic documents, archival material, and similar two-dimensional paper or cultural heritage materials, such as maps and posters. An encapsulation (Brown 1980; Poole 1976a, 1976b; Shahani 1986) is a protective envelope that is created to increase longevity of materials. The encapsulation envelope is generally made of a transparent polymer to allow for the inspection of contents, and the envelope may have side or corner openings to accommodate gas exchange. The use of polyethylene terephthalate (PET) films for encapsulation envelope creation has been recommended according to the 2009 Library of Congress Specification Number 500-500-16. The use of PET was implemented because PET, the most common thermoplastic polymer resin of the polyester family, is transparent, as well as mechanically and

chemically stable. Encapsulation was and is considered by many conservators to be more favorable than other physically supportive treatment methods that can include silking (Marwick 1964) lining (Zihrul 2010), and cellulose acetate lamination (Barrow 1939; McGath et al. 2015; Ormsby 2005; Poole 1976a, 1976b) because encapsulation is easily reversed (Brown 1980; Library of Congress 1975; Minter 1983) by simply cutting the envelope sleeve or capsule and removing the document.

Despite the extensive use of encapsulation in libraries and collections, there have been surprisingly few published studies of the materials and processes used in encapsulation, whether gases are indeed trapped in the encapsulate (Garside and Walker 2015; Hall et al. 2019; McGath et al. 2017a, McGath, Hall, and McGuiggan 2017b), and the long-term effects of encapsulation (Minter and Baty 2013; Shahani 1995). Therefore, this survey is the first known attempt to estimate the proportion of documents encapsulated, the method of encapsulation, and the condition of encapsulation materials in collections. Although the total number of encapsulated documents has not been recorded, there exists one estimate that 10 % of large unbound documents, maps, and posters in special collections have been encapsulated (O'Laughlin 2018). After roughly 50 years since encapsulation was introduced, there have been no published studies regarding the condition of naturally aged PET encapsulations, whether the PET is yellowing, and whether the document itself appears to have aged more or less rapidly than unencapsulated comparable material; consequently, these survey questions were designed to answer these questions.

2 Survey

2.1 Methods

This online encapsulation survey was modeled after a recent survey regarding cellulose acetate lamination (McGath et al. 2015). This encapsulation survey was distributed, with replies collected, via the online Qualtrics Survey Platform; it was self-administered, such that respondents completed the survey without assistance. The data collection and processing were anonymous and normalized to the number of complete responses. Participants were asked if their institution could be named in the final report data summary and some replies were affirmative, so these are highlighted with permission.

Survey dissemination was conducted in two phases. Initially, the survey was electronically sent to one hundred and eight institutions with paper-based collections on 17 April 2023; many of these institutions were also previously surveyed regarding cellulose acetate lamination (McGath et al. 2015; McGath et al. 2017a, McGath, Hall, and McGuiggan 2017b). This first survey phase stopped data

collection on 1 June 2023. This survey circulation included institutions representing every U.S. state and territory. Additionally, this first survey circulation phase included institutions that ranged in size from small collections at the local or county level with less than ten thousand catalogued items, to large collections with more than ten million catalogued items in federal depositories, state archives, and universities. Ultimately, a second solicitation for survey participation was distributed on 1 June 2023; this second survey phase utilized the Global Conservation Forum (GCF) for dissemination (https://www.culturalheritage.org/globalconservationforum), and all data recording ended twenty-one days following initial survey distribution. All survey results from phase one and phase two were combined for data processing and interpretation. Additional details concerning this survey administration are available by written request sent to the corresponding author. Participants could choose to leave any question blank, and most questions included a text-field so that participants could write answers or any appropriate clarifying comments. It should be noted that no limitations were given as to who would fill out the form, but survey instructions specified it was to be completed by a conservator, collections manager, archivist, or comparable professional. Most questions in the survey allowed only one response, with additional text answers available to clarify participant response. However, four of the questions allowed multiple answers, and these are identified in the text.

2.2 Response

After one month following initial distribution in April 2023, fourteen surveys were completed with answers to both the first and last survey content question, (Q#33). Within this group of fourteen survey completions in phase one, some survey questions were not answered in most returned surveys, and some survey questions were answered by selecting more than one of the survey choices. Additional phase one surveys were supplied by four respondents that answered just 70, 30, 21, and 9 % of the questions, and three additional surveys were returned with just the first question answered concerning the institution's size. A bar chart that relates each survey question to the total number of total responses for both phase one and phase two combined is presented in Figure 1. The survey response for phase two resembled that for phase one: sixteen surveys were returned in phase two with both the first and last survey question answered. Five more surveys were included in phase two that completed 64, 45, 42, 39, and 6 % of the survey content questions. In total, thirty surveys were returned with the first and last survey question answered, although some questions in between may not have been completed; six more surveys were returned with more than 30 % of the questions answered and six surveys were returned with 21 % or less of the survey questions answered.

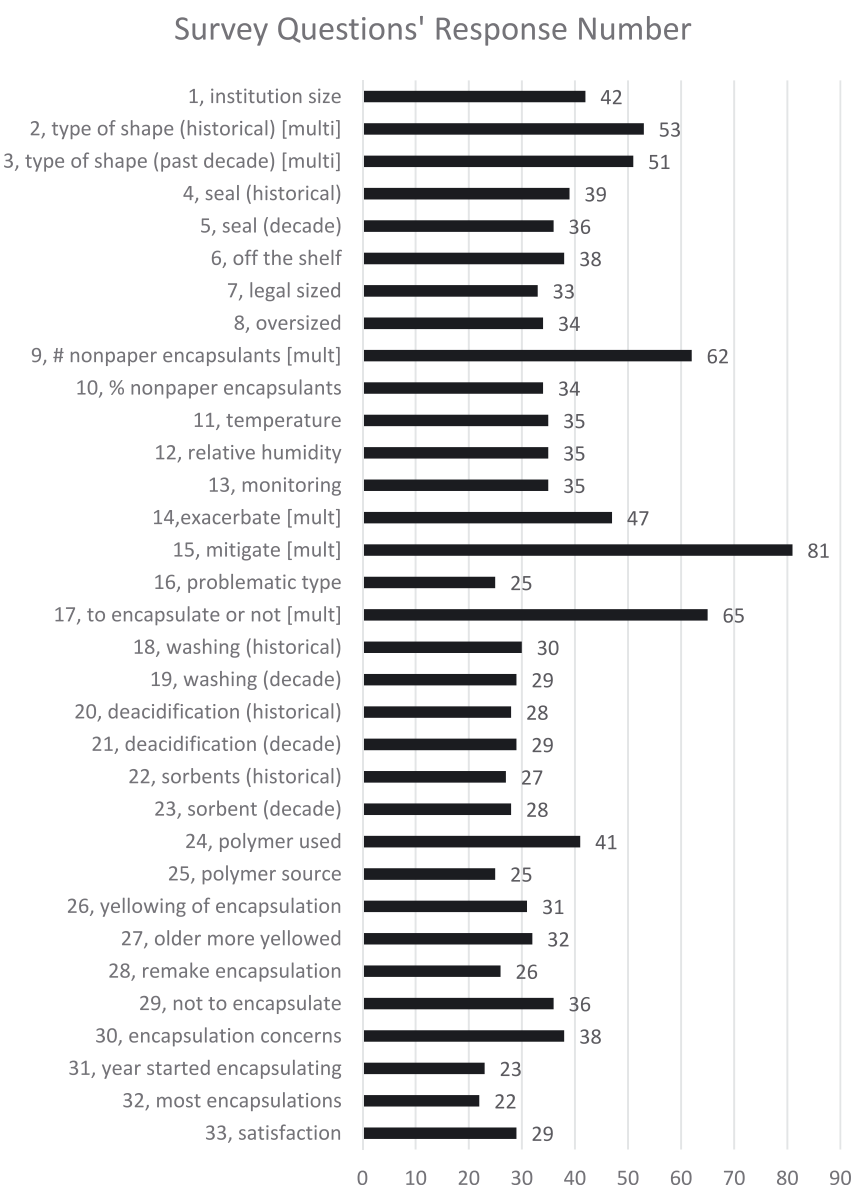

Figure 1: A bar chart that correlates the total number of responses to each survey question; note that for questions 9, 14, 15, 17 multiple selections were possible, indicated above using [mult], so these four questions have the highest number of responses. Also, survey questions #2 and #3 did receive multiple responses [mult].

The sizes of institutions represented by all survey respondents (n = 42) that answered the first survey question are shown in Figure 2. Seven largest institutions that returned a survey, having collections of more than ten million catalogued items, represented 17 % of all responses; the Library of Congress was in this group of largest institutions, referred to in this paper as the "A" group or $A_{>10^{\wedge}7}$. The most common size of responding institution represented total catalogued items between one and ten million (n = 17, 40 %); seventeen such institutions replied to this survey and are referred to as the "B" group or $B_{>10^{\wedge}6}$. These two largest categories of responding institutions established many of the data trends revealed by statistical analyses of the whole data set, which also includes: the nine replying institutions (21 %) with collection sizes between one million and one hundred thousand referred to as the "C" group or $C_{>10^{\wedge}5}$, and the eight replying institutions (19 %) with collection sizes between one hundred thousand and ten thousand as the "D" group or $D_{>10^{\wedge}4}$. Only one institution with less than ten thousand catalogued items responded, representing 2 % of respondents, and is referred to as the "E" group, the smallest institution represented by this survey, or $E_{<10^{\wedge}4}$.

Regarding the persons that were surveyed and chose to describe their capacity of employment (n = 27), the greatest number (n = 15, 55 %) were self-described as "conservator" "paper conservator" or "library conservator." The second most popular self-description (n = 6, 22 %) was "chief conservator" or "head conservator." Finally, there were six respondents that used either "archivist" or "librarian" or "preservation technician," representing 22 % of self-described respondents. Twenty-two respondents also named their institution.

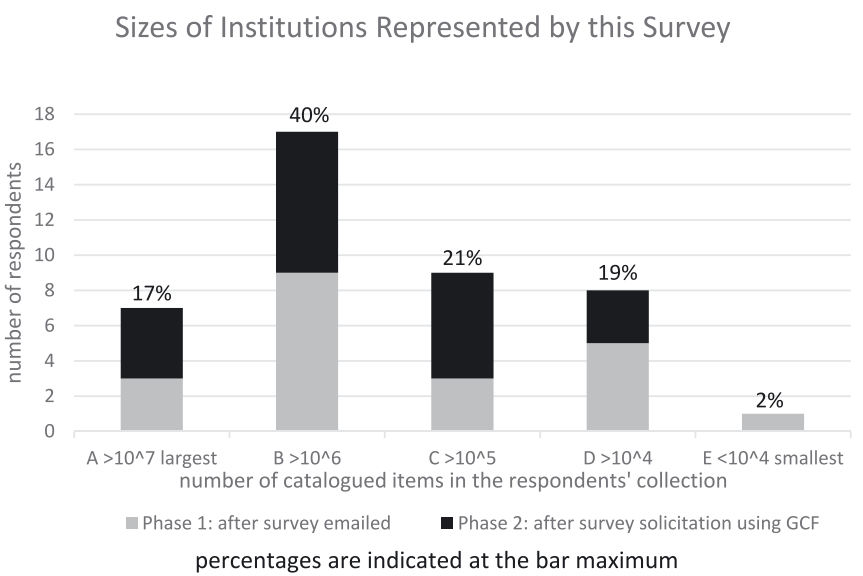

Figure 2: A bar chart describing the distribution of sizes of institutions represented by this survey.

3 Survey Results and Discussion

3.1 Enclosure Shape Type, Questions #2 and #3

Participants were queried about the most common type of enclosure used at their institution historically, to include these five options: a four-sided join with, and without, a gap to facilitate gas exchange, a three-sided U-shaped join, a two-sided L-shaped join, or a folded sheet with just one edge joined. Of all (n = 53) responses, the four-sided join was the most common historically (n = 23, 43 %) with corner air gaps (n = 12) slightly more common than not (n = 11), see Figure 3. Next historically popular in this survey is the two-sided join (n = 18, 34 %), followed by the three-sided U-shape join (n = 9, 17 %) and the single side join (n = 3, 6 %). The four text replies from participants are summarized: (1) methods and approaches have changed over the last fifty years; (2) The majority of encapsulation is accomplished using U-shaped protector envelopes but maps have four sided encapsulations; (3) encapsulation in conservation is four sided without a gap but collection managers employ commercial L-shaped polyester enclosures; (4) moldy items are encapsulated with a gap, but for support, items are put in U-shaped or L-shaped sleeves (more common). This survey question highlighted the implementation of gaps in encapsulations: of the institutions historically encapsulating using four-sided joins, half include gaps for gas or vapor exchange, but half do not.

When this question changed from the past 50 years to the most common shape of an encapsulation used in the past decade, to include purchased and/or produced polymeric envelopes, the responses (n = 51) were similar to the responses for the historic enclosures, see Figure 3. The four-sided encapsulation is the most common (n = 23, 45 %) with gaps (n = 6, 12 %) less common than no gaps (n = 17, 33 %). Similar to the historic responses, results from considering just the past decade of encapsulations revealed the L-shape encapsulation is the second most institutionally used (n = 16, 31 %) followed by the U-shape (n = 9, 18 %) and the single sided or folded sheet (n = 3, 6 %). The text replies included these clarifications: (1) corner gaps in the encapsulation easily get caught during handling so were abandoned; (2) the collection has minimal handling, so a roll of Mylar® is purchased to make single-join folded sleeves that provide sufficient support; (3) small non-circulating items have L-shaped encapsulations, but increasingly, especially for circulating maps, a four-sided join without gap is used.

These two questions did reveal a curiosity as shown clearly in Figure 3: for four-sided encapsulations, the use of a small gap to increase gas circulation is much less common in the most recently passed decade, compared to all decades previous. However, considering the entire past fifty-year history of encapsulating documents for

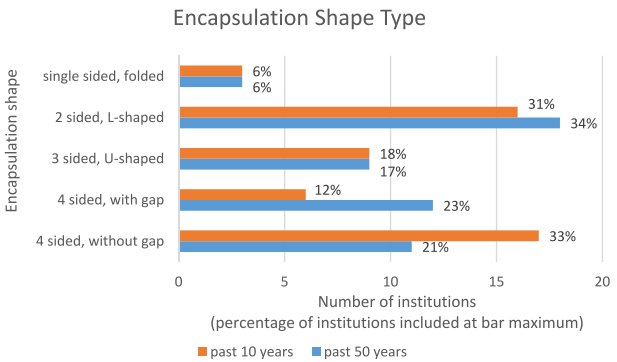

Figure 3: Bar chart showing the most popular encapsulation shape type at surveyed institutions since the technique was introduced in blue color, compared to the most popular shape type during the past decade, represented by orange color.

preservation purposes, the use of a corner gap on a four-sided encapsulation is approximately the same as the use of a four-sided encapsulation without a corner gap.

3.2 Encapsulation Seal, Questions #4 and #5

Regarding how the encapsulation seal was historically made, most survey replies (n = 39) suggest that a continuous seal such as a heat or ultrasonic weld was by far the most common (n = 29, 74 %). A discontinuous seal, such as one made using periodic or interrupted stitching, perhaps achieved using ultrasonic stitch, was reported by only three respondents (n = 3, 8 %). Pressure sensitive adhesive (PSA) tape encapsulation seals, such as 3M 415 double sided PSA tape, were also reported (n = 7, 18 %) to be used; sewn attachment was not reported. Text clarifications to the answers were: (1) we purchase sleeves rather than make them, but if making them, double-sided tape is used; (2) there were decades of sewing and tapes; (3) a heat seal has been used for 25 years, but before, it was tape; (4) we are replacing drawings in encapsulations that have tape. These results did not really change if the respondent (n = 36) was asked to focus on just the past decade. Continuous seal by heat or ultrasound was most reported (n = 31, 86 %) with only one (n = 1, 3 %) response confirming a discontinuous seal, and four (n = 4, 11 %) responses confirming the continued use of tape to seal an encapsulation. These data indicate that PSA tape seals are still used, yet rarely; such may be more common at institutions with minimal financial resources, for example, to invest in specialized encapsulation equipment. The discontinuous seal, such as that made using periodic ultrasonic stitching, is also comparatively unpopular; this seems consistent with minimal concerns with creating encapsulations that have air

exchange through gaps. This finding seems consistent with the reduction of gaps on four-sided encapsulations in the past decade, as revealed by institutions' responses to the previous survey questions.

3.3 Encapsulation Fabrication, Question #6

Survey results that compare all sizes of institutions suggest that the in-house fabrication of encapsulations is by-far more popular compared to purchased envelopes, see Figure 4. Of all survey replies (n = 38), most survey participants (n = 22, 58 %) make at least 75 % of encapsulations in-house, with half that number of respondents (n = 11, 29 %) making in-house at least 90 % of encapsulations. Of the remaining (n = 16) reporting institutions, seven reported at least 50 % of their encapsulations are made in-house (n = 7, 18 %), and five institutions reported at least 25 % of their encapsulations are made in-house (n = 5, 13 %), with just a few institutions (n = 4, 10 %) making only 10 % of encapsulations in-house and purchasing the rest. In-house manufacture dominates purchased products at two institutions for every one institution that favors premade encapsulation purchases. However, if only replies are considered from the largest institutions (n = 7) that have catalogued more than 10 million items, then there is a clear bimodal distribution of results: three reporting institutions make at least 75 % encapsulations in house, and four reporting institutions make between 10 and 25 % of encapsulations in-house, with none of these largest institutions reporting around 50 % (Figure 4).

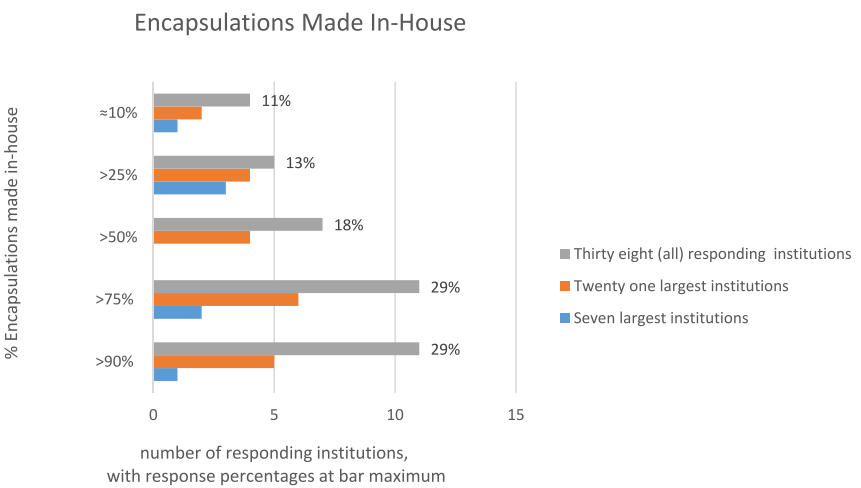

Figure 4: This bar chart shows the propensity to make encapsulations in-house; note the bi-modal distribution in blue, representing only the largest seven institutions responding institutions.

3.4 Encapsulations of Items the Size of Legal-Sized Paper or Smaller, Question #7

Several questions were asked to quantify the proportion or extent (x_E) of encapsulations at responding institutions. These questions divided encapsulations into two sizes for interrogation: items equal to or smaller than legal sized paper were queried separately from larger, oversized-paper items such as maps and posters, see Figure 5. Of the largest collections responding ($A_{>10^{\cdot}7}$), with catalogues greater than ten million (n = 6 respondents), the most common response for catalogued, encapsulated paper less than legal size was $1{,}000 < x_E < 10{,}000$ reported by two institutions. The other three largest institutions' responses were distributed evenly, with one institution having less than 1,000 encapsulations, one institution having more than 100,000 encapsulations, and one institution having between $10{,}000 < x_E < 100{,}000$. Only one of the largest institutions did not report an answer to this survey question. These results for the largest responding collections ($A_{>10^{\cdot}7}$) show the proportion of encapsulations of legal sized paper or smaller materials is surprisingly well distributed: at least one institution having a large, catalogued collection of greater than ten million catalogued items reported less than 1,000 encapsulations.

This trend was strongly amplified as slightly smaller, ($B_{>10^{\cdot}6}$), but still large institutions all having more than one million catalogued objects (n = 24 respondents from $A_{>10^{\cdot}7}$ plus $B_{>10^{\cdot}6}$ sized institutions), were considered: the most common response was again between $1{,}000 < x_E < 10{,}000$ encapsulated catalogued objects of less than legal-sized paper, see Figure 5. The remaining large-sized institutions' responses ($A_{>10^{\cdot}7}$ plus $B_{>10^{\cdot}6}$) were equally distributed, with just two or three institutions representing each remaining category: >100,000 encapsulations, <1,000 encapsulations and the median $10{,}000 < x_E < 100{,}000$ number of catalogued collections.

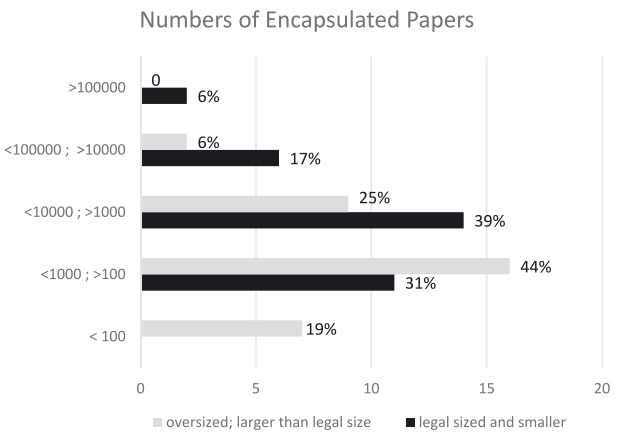

Figure 5: The number of reported encapsulations: oversized compared to legal-sized and smaller papers.

Considering all institutional sizes, the most common extent of catalogued encapsulations of legal size or less remained between 1,000 and 10,000 (n = 14 respondents total) with respondents reporting less than 1,000 catalogued encapsulations at eleven institutions, see Figure 5. Unfortunately, respondents were not asked if they had access to an ultrasonic or heat-sealing apparatus; this would be useful to know to help clarify these results. However, these survey data do suggest it is not the size of the institution that dictates the extent of encapsulated catalogued objects, but rather, an institutional propensity to encapsulate or not, which may relate to the type of catalogued objects. Only two respondents could not answer the question, explaining such data were unavailable.

3.5 Larger Oversized Encapsulations, Question #8

The follow-up question interrogated the number of encapsulated, oversized items catalogued, or specifically items larger than legal sized paper, such as maps and posters. There were thirty-four responses in total, with two responses as "information unavailable." Considering only the six largest replying institutions, each having greater than ten million catalogued objects, ($A_{>10^{\cdot}7}$), there is a clear bimodal distribution of response data: none of the largest respondents selected between 1,000 and 10,000 encapsulations, see Figure 5. Either the largest institutions, ($A_{>10^{\cdot}7}$), reported less than 100 encapsulations (n = 1) or 100 < x_E < 1,000 encapsulations (n = 2), with two of six respondents having >10,000 encapsulations. If the largest and second largest sized institutions are only considered, ($A_{>10^{\cdot}7}$ plus $B_{>10^{\cdot}6}$), with each respondent representing an institution with more than one million catalogued objects, then the most common response remained 100 <x_E < 1,000 oversized encapsulations (n = 9), and 1,000 < x_E < 10,000 oversized encapsulations was the second choice (n = 7). Finally, considering all responses, the final data distribution appears bell-curve shaped: the most popular response being between 100 and 1,000 (n = 16, 44 %) with roughly equal distributions for institutions with less than 100 encapsulations (n = 7, 20 %) and between 10,000 and 1,000 encapsulations (n = 9 or 25 %). With this question's response, it was revealed that some huge paper collections have remarkably few oversized encapsulations.

3.6 Encapsulants, Questions #9 and #10

Survey participants were asked about the non-paper materials that receive encapsulation at their institution, and survey options included: papyrus, palm, parchment, textiles, tree bark, tapa, and photographs, with a write-in possibility. Photographs

are encapsulated at thirty-one responding institutions. Parchment and textiles are the next most encapsulated material, each having eleven responding institutions. Papyrus and tree bark were the next popular items to encapsulate, with three and one institutions responding respectively. Three write-in responses included hair as an encapsulated material. One lengthy write-in response added encapsulated materials at their institution include: coins, pressed flowers, tobacco leaves, political buttons, and pins. No institutions report encapsulating palm leaf or tapa for this survey.

Regarding the estimated amount of non-paper encapsulated materials at participating institutions, less than 1 % encapsulated non-paper materials was the most common reply provided by 56 % of responding institutions (n = 19). Ten institutions representing 30 % of the total respondents have encapsulation between 1 and 5 % of catalogued materials. Three institutions, corresponding to close to 10 % of responses, report more than 25 % of the collection is encapsulated; these institutions are not the largest having more than 10 million catalogues ($A_{>10^{\cdot}7}$). Only one institution reported encapsulations between 5 and 10 % or between 10 and 25 % of the catalogued collection, each reply representing a 3 % response rate. Quite clearly, the quantity of encapsulations depends on collection needs, and encapsulations usually represent a small fraction of catalogued materials.

3.7 Storage Conditions, Questions #11 and #12

The next survey questions pertained to environmental maintenance, specifically, the strictness of temperature and humidity conditions of encapsulant storage. The six largest reporting institutions ($A_{>10^{\cdot}7}$) evidence an equally split response between the strictest control at ±5 °C or less, independent of the season, and moderate control between 5 and 15 °C, independent of season, see Figure 6. This trend continued as smaller institutions were considered in the entire data set. For the top two largest categories of catalogued objects, ($A_{>10^{\cdot}7}$ plus $B_{>10^{\cdot}6}$), representing twenty institutions, 50 % have moderate temperature control and 40 % have strict temperature control; only 10 % of collections greater than one million objects (n = 2) have seasonal temperature fluctuation with the summer significantly higher than in winter. Examining all data (n = 35 responses to these questions), independent of institutional size, yielded comparable results: 30 institutions have moderate temperature fluctuation between 5 and 15 °C; four institutions have minimal control manifesting significantly higher summer temperature. Interpreting these data set in its entirety suggests all institutions queried have some form of temperature maintenance, a small number of institutions around 10 % evidence seasonal fluctuation of more than 15 °C but most (85 %) fall into categories of stricter temperature control.

The trends for reporting institutions that address humidity control at respective institutions mirror the trends for temperature, see Figure 6. In the largest sized group ($A_{>10^{-7}}$), three institutions have the strictest control (±<5 % RH), and three have moderate control between 5 and 15 % RH. Concerning all (n = 35) reporting institutions, 30 % have the strictest relative humidity control (n = 11), while 45 % have moderate control (n = 15) keeping relative humidity fluctuations between 5 % RH to 15 % RH, and 20 % of reporting institutions (n = 7) report minimal humidity control with summer having significantly higher humidity fluctuation than winter, with a few (n = 2, just 5 %), of reporting institutions allow high fluctuations of relative humidity in excess of 15 % RH independent of season.

3.8 Encapsulation Monitoring, Question #13

Participants were queried about the frequency of encapsulation inspection or condition monitoring. The most common response was that there is no monitoring, expressed by 50 % of respondents (n = 17). The second most common response from participants, 43 % (n = 15), was that there is no routine monitoring, but unplanned inspection occurs approximately once every decade. Two institutions, i.e., 5 % of responses, reported approximate monitoring approximately alternating decades but

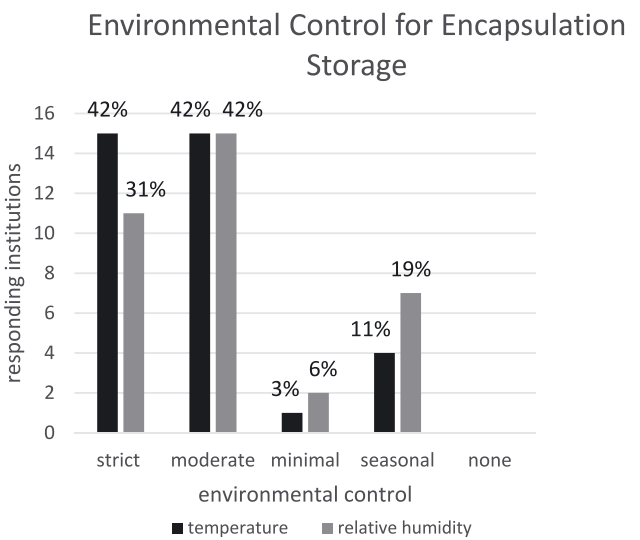

Figure 6: Results from survey questions that interrogated encapsulation storage temperature and relative humidity control.

without scheduling or regularity, and only one institution reported a regular, rotating inspection of encapsulations approximately every decade. The results show most paper collections are monitored without regularity but inspected, if possible, roughly every decade or alternate decades.

3.9 Encapsulation Mitigation and Exasperation Effects, Questions #14 and #15

Participants were asked if any of the following were noticeably exasperated by encapsulation: (1) foxing, (2) loss of paper material, (3) paper yellowing or discoloring/darkening, (4) ink fading or flaking, (5) affixed pressure sensitive adhesive (PSA) tape deterioration, (6) applied colors changing, (7) wrinkling/planar distortion/dimensional change, (8) crack propagation, (9) mold or bacterial activity, (10) paper embrittlement, or (11) slumping of encapsulants when vertical; results are summarized in Figure 7. The most popular response, with 15 % of respondents (n = 7), was that PSAs affixed to encapsulated papers deteriorate with encapsulation; the second most popular response, with 11 % of respondents (n = 5) reporting slumping of

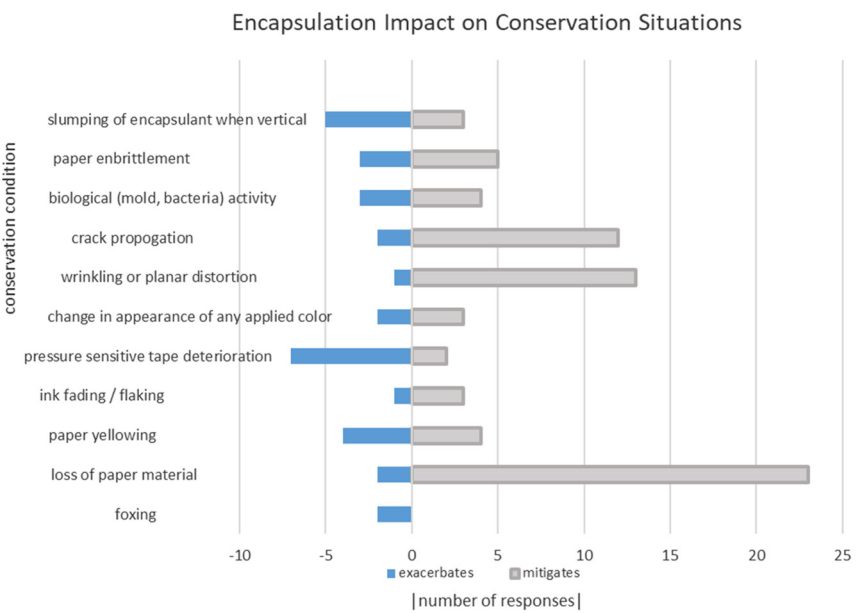

Figure 7: Responses interrogating how encapsulation affects conservation concerns of the encapsulated materials.

encapsulants when vertical. The third most popular (9 %, n = 4) response confirmed yellowing or darkening of encapsulants; all other options garnered three or less (<7 %) of respondents' confirmation of exasperation by encapsulation. By text reply, participants added that encapsulation also exacerbates friable pencil or other abrasion-applied media, and changes specifically "Duoshade" media used by editorial cartoonist Herblock. Participants also added there was danger when: (1) encapsulations slide in flat storage drawers ending up curled in the back of the drawer, or when (2) encapsulations are mixed with unencapsulated paper resulting in abrasion, or when, (3) PSAs that are used as joining materials creep and stick to the encapsulated material. One text reply specifies full encapsulations are avoided, and instead, a gap is introduced into the seal for air exchange to avoid acid build-up.

Conversely, participants were asked next if any of the above same conditions were noticeably mitigated by encapsulation, see Figure 7 for survey results. Loss of paper was the most popular (n = 23) response with 30 % of participants confirming mitigation, and both the mitigation of dimensional changes (n = 12 or 15 %) and the mitigation of crack propagation (n = 13) were reported. Five responses report mitigation of paper embrittlement, and four responses report mitigation of both mold issues and paper yellowing/discoloration. Text replies to this question provide much clarity, including these quotes: (1) encapsulations are particularly helpful handling brittle paper since the added support mitigates tearing and subsequent paper loss; (2) encapsulation helps with handling issues that concern fragile items; (3) encapsulated maps reduce wear and tear formation or propagation; (4) and one respondent wrote that the main benefit of encapsulation is ease of handling and transport, not storage.

Survey data clearly revealed that there is a general acceptance by conservators that encapsulation mitigates the loss of paper material and planar distortion, while it is less clear if encapsulation mitigates or exacerbates yellowing or biological activity. Additional research is necessary for increased clarity regarding these questions.

3.10 Problematic Encapsulations, Question #16

Survey participants were asked if there was a problematic type of encapsulated paper that would manifest age differently from non-encapsulated paper, and 72 % responded negatively (n = 23), clarifying that there was an aging equivalency between encapsulated and non-encapsulated paper. The opposite was reported by just two participants, representing 6 % of respondents with some clarification by text: (1) engineering drawings on heavy wood pulp paper are embrittled and have darkened/yellowed; (2) original pastels and charcoal drawings are not encapsulated because the propensity to lose colorant within the encapsulation; (3) if problematic materials are encapsulated in polyester, it is done so with an alkaline backing sheet

but static attraction can be an issue complicating extraction; (4) folded encapsulations embrittle at the fold; and finally, (5) encapsulation is still a relatively new technique and no problems have been observed. Seven respondents (21 %) report that it is unknown if there are problematic types of materials for encapsulation at their respective institution.

3.11 Encapsulation Justification, Question #17

The justification for encapsulation, "to encapsulate or not?" was interrogated with these optional responses for participant selection: (1) physical or structural added support, (2) chemical protection from pollutants or temperature/humidity swings, (3) biological reduction of mold/bacteria, (4) handling ease or transport, or (5) to satisfy an out-of-house requirement, for example, a traveling exhibition or a protective material mandate. Any of these options could be selected by the participant, allowing multiple selections, unlike for most questions in the survey that allowed only one response, with additional text answer available to clarify participant response; survey results are presented in Figure 8. Therefore, about thirty-five individuals completed this survey but there are sixty-five (n = 65) responses to this question. By far the main justification to encapsulate paper is physical: to support weakened paper (n = 30). The next most popular selection is to mitigate future physical damage and encourage careful handling (n = 19). These results are roughly the same, whether the largest or smallest institutions replied. The chemical justification had few (n = 3) affirmations, representing 5 % of responses. Similar low participant response was obtained for confirming encapsulation justification based on biological deterioration (n = 2, 3 %) or for the option of satisfying of a requirement for travel or exhibition

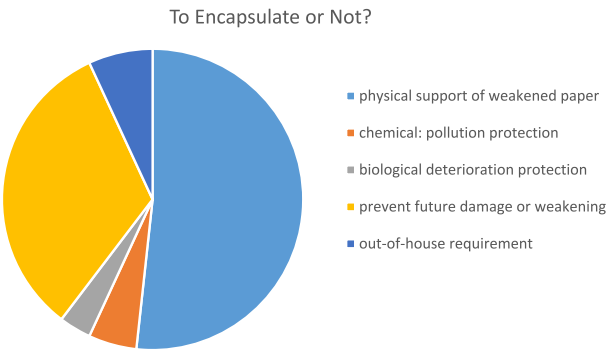

Figure 8: A pie chart relating the justification to encapsulate or not, to responding institutions.

(n = 4, 6 %). The text clarification provided by participants include: (1) by far the majority of encapsulations were created for physical support of fragile objects especially for handling; (2) many encapsulations were created to mitigate the spread of mold; (3) encapsulations are removed after exhibition; (4) encapsulations minimize fading; (5) encapsulations serve as containers for item fragments, like historic labels, previous bindings, frame elements, or textile fragments; and (6) polyester encapsulations are created for photographs because glove use is difficult to enforce.

3.12 Encapsulation and Conservation Treatment, Questions #18, #19, #20, #21, #22, and #23

The next group of survey questions interrogated the application of three conservation treatments, washing, deacidification, and the addition of chemical sorbents; these treatments were interrogated for the immediate past ten years of encapsulation production, separate from the entire history of encapsulation at the respondents' institution, to create six separate questions; survey results are included in Figure 9. The specific results and trends suggested by the most recent ten years of encapsulation practice are essentially the same as if the entire history of encapsulation were considered regarding pre-encapsulation washing, deacidification and pollution sink additions. Washing prior to encapsulation was reported to be a rare event; 60 % of respondents (n = 24) confirmed less than 10 % of encapsulants are washed before encapsulation. Only five institutions wash the encapsulant less than 50 % of the time, but more than 10 % of the time encapsulation is conducted. One institution reports more than 90 % of encapsulants are washed, independent whether the time queried was the past decade or the entire institutional history. The text replies are that: (1) washing is not common; (2) washing occurs less than 1 % of the time; (3) washing is never done on site; (4) washing was more common two decades ago when the staff was larger; (5) historically, drawings were encapsulated without washing; (6) prior to encapsulation, erasers are used for surface cleaning and paper is de-acidified using Bookkeeper®.

Deacidification was interrogated separately, and the extent of deacidification applied prior to encapsulation for the past decade is indistinguishable from the entire institutional history of encapsulation in all responses, see Figure 9. Deacidification seems to be applied more commonly than washing, and perhaps this can be attributed to the minimal infrastructure required to spray deacidification compared to the extensive paper washing equipment and requisite personnel. The most common response was that deacidification is a rare event, with <10 % encapsulants deacidified prior to encapsulation confirmed by 50 % of responding institutions

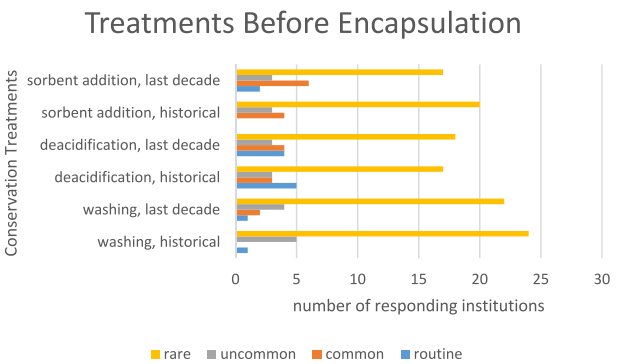

Figure 9: This bar chart of conservation pretreatments applied to encapsulants shows that they are rare events historically, and in the most recent decade.

(n = 17). Five institutions (15 %) report deacidification is routine with >90 % of encapsulations deacidified. The remaining responses are split equally between three institutions that report deacidification is uncommon with an estimate between 10 and 50 % deacidified before encapsulation, and an equal number (n = 3) reporting it is common, with an estimate between 51 and 90 % of encapsulants deacidified before encapsulating. Text responses to this question are: (1) deacidification is unnecessary when a backing sheet is used; (2) encapsulated items are never deacidified (three similar text replies were received); (3) Bookkeeper® build-up of white residue (maybe attributable to too heavy application) seems to scratch the polymer films used to encapsulate so Bookkeeper® is no longer used.

The addition of sorbing pollution sinks to encapsulations is also a rare event, according to survey results from responding institutions (n = 33), see Figure 9. The separate addition of adsorbents or buffering materials occurred with less than 10 % of encapsulations produced at 60 % of responding institutions (n = 20). No institution response was reported for adsorbent or buffer additions that were routinely added to more than 90 % of all institutional encapsulations. The remaining responses are split equally between three institutions that report sorbent addition is uncommon with an estimate between 10 and 50 % using a sorbent introduced before encapsulation, and an equal number (n = 3) reporting it is common, with an estimate between 51 and 90 % of encapsulants have sorbents. Text replies to this query are very clear concerning the addition of sorbing materials: (1) this did not happen; (2) not a common practice; (3) never; (4) buffered paper backing is preferred to sorbent addition; (5) if encapsulation was performed through preservation, then adsorbent addition was routine, however if performed by an archivist, then it is rare to have adsorbent with encapsulant.

3.13 Encapsulation Polymer, Questions #24 and #25

Concerning the specific polymer used for encapsulation, all six largest institutions, by catalogued items, report using only 100 % Mylar® polyester. Considering the twenty-seven largest institutions responding to this survey, Melinex® polyester was reported by 22 %. This 3:1 distribution between Mylar® and Melinex® was the same for all forty-one reporting institutions. Three respondents (7 %) report use of polyester without a trademark, but clarify by text this is Gaylord archival polyester, with one respondent specifying: "DuraLar (Melinex®) from Grafix near Cleveland Ohio." Also, three respondents (7 %) report using non-polyester polymer, specifying: various 3-hole punched page protectors are used (polymer not specified); and three different respondents specify the thickness of their polyester as 4, 3 and 2 mil corresponding to 0.1, 0.08 and 0.05 mm; and one respondent reports Demco® Durafold™ II book jacket covers are made using 2 mil or 0.05 mm thick polyester roll.

3.14 Encapsulation Film Yellowing, Question #26

Survey respondents reported that the polymeric materials used to make encapsulations are rarely observed to be significantly yellowing. For all responses (n = 31), only one institution reports some yellowing in less than 50 % of institutional encapsulations. Most respondents (n = 23, 75 %) report some yellowing of the polymeric encapsulation envelope occurring in less than 10 % of institutional encapsulations. The respondent's seven text clarifications are: no yellowing was reported by three; three respondents report "unknown;" and one reply specifies yellowing by interaction with PSA tape seals.

3.15 Encapsulation Remaking, Question #27

When survey participants were asked whether older, historic encapsulations produced in the 1970s and 1980s are degrading more rapidly, compared to encapsulations more recently produced, there seems to be little consensus. For all reporting institutions (n = 35), half explain there was no encapsulation production during this period, and by text, one respondent notes an institutional preference for lamination during the 1960s and 1970s. The second most popular selection (n = 9, 25 %) was neither agreement nor disagreement that older polymeric envelopes degrade faster. Four respondents (11 %) do agree that older polymers are yellowing quicker; one respondent disagreed, representing 3 % of surveyed institutions. Two text replies clarify that early available films delivered to preservation professionals

to satisfy orders of "Dupont Mylar® Type D" may not have been the particularly specified product, so some suppliers provided cheaper products, but this activity has decreased. One final text clarification provided by a respondent recognizes higher quality polymers are produced more recently as manufacturing improves over the past four decades.

3.16 Encapsulation Remaking, Question #28

The survey responses (n = 39) to the question that probed the frequency of remaking old encapsulations that may have deteriorated in any manner suggest that this is not a major problem. Of the largest eight institutions participating, three (38 %) report that less than 1 % of encapsulations were remade out of necessity due to failure of the encapsulation; three respond "unknown." One largest institution, within the $A_{>10^{\wedge}7}$ group, reports a frequency between 1 and 5%, and another one of the largest $A_{>10^{\wedge}7}$ group institution reports 5–10 % of encapsulations remade. This trend continues as all institutions are considered; 36 % (n = 14) report remaking old encapsulations less than 1 % of the time, remarkably similar to the largest $A_{>10^{\wedge}7}$ institutions' data. Five institutions (12 %) report remaking between 1 and 5%; three institutions report between 5 and 10 %; and two institutions each report between 10 and 20 % and more than 25 %. Thirteen participants (33 %) respond "unknown." By text response, some failure mechanisms are reported: (1) encapsulations need to be remade primarily because the ultrasonic or heated seal has failed; (2) encapsulations sealed with PSA are replaced. Additional text clarification provided by one response is: encapsulations need to be remade following digitization of contents, but no failure of the encapsulation was observed nor deterioration of contents, and items are returned to L-seals with alkaline backing sheets. Final text responses are: five write "unknown;" and that most lignin documents are removed from encapsulations, but no deterioration of the encapsulation observed.

3.17 Whether to Encapsulate, Question #29

Concerning the reasoning or justification to not encapsulate, for all survey responses (n = 37), by far the majority (n = 25, 68 %) make it clear that the most common reason not to encapsulate is because it is simply not needed. Three respondents each (8 %) cited prohibitive cost, and three cited unavailable staffing. Only one respondent (3 %) cites the justification that the encapsulating equipment is unavailable. Four respondents (11 %) justify not encapsulating because the microenvironment

created may accelerate degradation. No text replies or clarifications why encapsulation is not done were provided by respondents.

3.18 Encapsulation Concerns, Question #30

Regarding encapsulation concerns, for all replies (n = 38) to the survey question asking what is of greatest concern about encapsulation that exists at the responding institution, the most selected concern (n = 16, 42 %) was that chemicals are trapped within the encapsulation and could accelerate deterioration. The second most popular response (n = 8, 21 %) was concern about light reflecting off the polymeric film of the encapsulation, consequently obscuring an encapsulant during exhibition conditions, for example. Small numbers of reporting institutions (n = 3, 8 %) also selected concern about coating or slip agents on polymers that could interact with material encapsulated, and two respondents (5 %) were most concerned about the deterioration of the polymers used for the encapsulation. Many text clarifications regarding the greatest encapsulation concern were reported, including: (1) media stability; (2) changes in handling or 'the feel' of fully encapsulated objects; (3) when PSA is the only attachment material available (like at small institutions); (4) expense, added weight and bulk; (5) encapsulations require four times storage space compared to unencapsulated items; (6) drying encapsulated paper after a water inundation event; (7) the protection from encapsulation outweighs the issue of light reflection; and finally, (8) our institution does not have any concerns related to encapsulation.

3.19 Encapsulation History, Questions #31 and #32

Survey responses (n = 32) to the question asking in what decade did encapsulation begin at the reporting institution, are well-distributed in bell-shape from the 1960s to now, with the most common decade being 1990s (n = 13, 41 %) see Figure 10. The 1980s was the second most popular selection (n = 5, 16 %); the 2000s was the third most common selection (n = 2, 6 %), and one institution (3 %) selected each 1970s, 1960s, and 2010s or later. This seems consistent with a respondent's comment previously discussed that during the 1960s and 1970s, lamination was popular yet fades in popularity by the late 1970s. Text replies were absent, but nine participants (28 %) selected "unknown."

When participants were asked in what decade were the most encapsulations performed, there is a progressive increase in encapsulations by decade from 1960 to 2010, see Figure 10. While ten participants (31 %) answered "unknown," an equal number reported the most encapsulations in the most recent decade. Only one

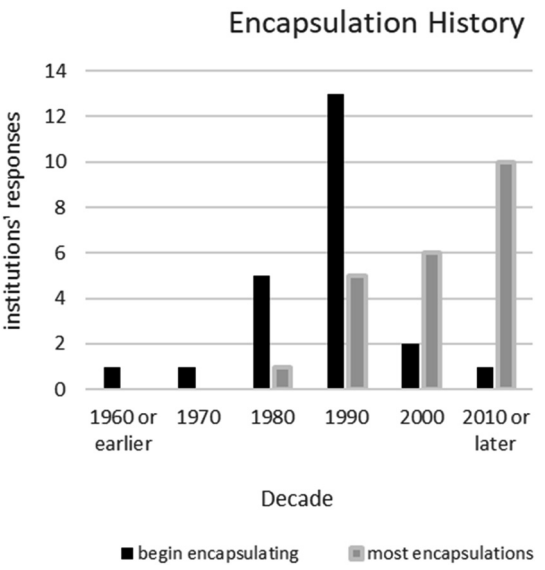

Figure 10: Encapsulation history institutional start decade and the decade of most encapsulations. There is a trend of increasing encapsulations suggested for the future.

institution reported the most encapsulations were completed in the 1980s, which increased to five institutions (16 %) reporting the most encapsulations were completed in the 1990s, which increased to 6 institutions (19 %) answering 2000s. Text replies were not an option with this question.

3.20 Encapsulation Satisfaction, Question #33, Final

The survey interrogation of encapsulation concluded with a question regarding overall satisfaction, and with all (n = 32) responses considered, 'highly satisfied' was the most frequent selection (n = 22, 70 %), with less than 10 % of encapsulations evidencing conservation or preservation issues. The second most popular selection was 'very satisfied' (n = 4, 13 %); one institution reported 'moderately satisfied' with encapsulation. The text replies were: (1) highly satisfied with encapsulation but space, cost and limited staff allow for less encapsulating than desired; and (2) I don't encapsulate much but when I do then I am satisfied.

4 Conclusions

The results of this survey on encapsulation suggest there is high regard, acceptance, and use within the conservation community for this paper preservation technique.

However, many related concerns were communicated, especially using the text-reply option included for most survey questions, to specify primarily the concern of trapped, noxious chemicals accelerating the deterioration of the encapsulated material. While this concern is certainly valid, survey results do suggest that the introduction of gaps within the four-sided encapsulation – gaps intended to increase gas exchange and consequently reduce trapped, noxious gases – has decreased in the past decade, compared to the preceding fifty years. Another finding from this survey is that during the past five decades, it seems rare, as opposed to routine, to use washing or deacidification prior to encapsulation; this may contrast with some early research on encapsulation (Shahani 1986). When asked why one would not encapsulate, only 11 % of respondents replied that the encapsulation materials or microenvironment accelerates deterioration, whereas the most popular response was that encapsulation was simply not needed (68 %), or prohibitive cost/staff (16 %) were the more popular justifications to not encapsulate. An additional finding from this survey is that respondents did not generally report observing yellowed, discolored-polymeric encapsulations, nor the need to remake deteriorated encapsulations. Certainly, there exist rich avenues for future research to explore the interrelationship between encapsulation construction and encapsulation microenvironment.

Concerning the number of encapsulations in U.S. collections, the results from a recent survey on lamination (McGath et al. 2015) suggest that a survey might not be the best way to obtain such absolute numbers since respondents may not be aware of historical practices, or the survey does not interrogate appropriate representatives. Consequently, this survey focused on informing the proportion of encapsulations in collections, with survey data consistent with one estimation provided by a conservator that approximately 10 % of large unbound documents, maps, and posters are estimated to be encapsulated (O'Laughlin 2018). For encapsulated items smaller than legal-sized paper, quantified, proportional estimates have a great distribution, suggesting much depends on the specialization of the collection itself, but an estimation around 10 % for most collections does seem consistent with the survey data. One concern expressed repeatedly in survey responses was that the reflective encapsulation surface was problematic for exhibition, suggesting the merit of exploring the use of matte encapsulating materials.

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