Project Report

Salk Institute for Biological Studies Conservation Project: Teak Window Wall Assemblies

Phase 1: Research and Investigation Results and Preliminary Conservation Proposals

Sara Lardinois

The Getty Conservation Institute

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The Getty Conservation Institute (GCI) works internationally to advance conservation practice in the visual arts—broadly interpreted to include objects, collections, architecture, and sites. The Institute serves the conservation community through scientific research, education and training, model field projects, and the dissemination of the results of both its own work and the work of others in the field. In all its endeavors, the GCI focuses on the creation and delivery of knowledge that will benefit the professionals and organizations responsible for the conservation of the world's cultural heritage.

Cover: Installation of teak window wall asssemblies at the southern west office wing, March 1965.
Photo courtesy of the Louis I. Kahn Collection, University of Pennsylvania and Pennsylvania Historical and Museum Commission, scan 030.V.D.19.2_Mar 65.

Contents

CHAPTER 5

Treatment Recommendations

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Executive Summary

Completed in 1965, the Salk Institute for Biological Studies in La Jolla, California, is one of architect Louis I. Kahn's finest works and is widely considered to be a masterpiece of modern architecture with international significance. Kahn was commissioned by Dr. Jonas Salk, developer of the polio vaccine, to design an inspiring campus for his new scientific research institute on a coastal bluff overlooking the Pacific Ocean. Kahn's design consists of two nearly identical wings of laboratory, study, and office space that mirror each other on either side of a paved central plaza. The innovative, teak-clad window wall assemblies, set within the monolithic concrete walls of the studies and offices, are one of the major architectural elements of the site. After nearly fifty years in an exposed marine environment, the window walls have weathered to a non-uniform appearance and are deteriorated. Minor repairs at the window walls have been carried out over the years, largely following a maintenance-based approach. However, as the Salk Institute approaches its fifty-year milestone—the age at which many modern buildings typically are in need of a major conservation intervention—more serious repairs are needed at many of the 203 distinct window wall assemblies. Recognizing that such a major project has the potential to negatively impact the architectural significance of the site, the Salk Institute would like to transition toward a conservation-based approach to the long-term care of the window wall assemblies and other architectural elements of the site.

Project Scope and Methodology

The Salk Institute partnered with the Getty Conservation Institute (GCI) in Los Angeles in 2013 to develop the Salk Institute for Biological Studies Conservation Project: Teak Window Wall Assemblies, which follows international best-practice conservation methodologies. These practices recommend three basic steps to follow when developing a conservation project for cultural heritage sites: (1) understand the site before intervening; (2) develop conservation policies that both protect the significance of the site and integrate other considerations, such as owner objectives and legal requirements; and (3) select conservation treatments that best comply with the policies, then implement, maintain, and monitor. Building on this process, the scope of the Salk Institute project is divided into two distinct phases:

Phase 1: Research and Investigation

a) Historical research and assessment of significance.
b) Condition assessment, scientific research, and diagnosis.
c) Treatment recommendations.

Phase 2: On-Site Trial Mock-Ups

a) Perform on-site trials that involve mocking up identified treatments to further evaluate their suitability.
b) Monitor performance of mock-ups on site in the short, medium, and long term.
c) Refine treatment recommendations based on the results of the trial mock-up program.

This report presents the results of Phase 1 of the project, which was carried out from 2013 to 2014. An initial draft of this report was issued to the Salk Institute in August 2014, prior to the start of Phase 2. In preparing the final Phase 1 report for publication in 2017, minor content and copy edits were made; however, the report was not modified to reflect the enhanced understanding of the site gained during Phase 2 (2015–16) and the subsequent construction project (2016–17) or through the preparation of the conservation management plan (CMP) for the entire site by the Salk Institute's consultants (2014–17). Rather, a separate forthcoming report will present the results of Phase 2, including refinement of both the initial significance assessment and conservation policies based on additional research undertaken and the results of the trial mock-ups. This approach to publishing the reports reflects the iterative process utilized in the project.

Physical Description of the Window Wall Assemblies

The teak window walls are prefabricated assemblies that consist of a combination of horizontal sliding window sashes, louvers, and/or shutters, often with an internal pocket to accommodate these sliding components and, occasionally, built-in shelving. Prefabrication was selected as both a means of reducing project costs and increasing quality, as the units were partially assembled in a local cabinetmaker's shop prior to being transported to the site and lifted into place by crane. They are constructed using teak structural members and white fir wood (*Abies* spp.) stud framing and sheathed with a layer of asbestos-cement (transite) board on one or both sides of the studs. The exterior face of the wall is clad in teak, and the interior face is clad in oak paneling or gypsum board, all of which are attached to the transite board or studs with white fir or plywood furring strips. Several other tropical hardwoods are commonly referred to as teak; however, macroscopic and microscopic examination of the wood samples collected at the Salk Institute confirmed the presence of teak (*Tectona grandis*), a tropical timber species native to southeast Asia but now grown on plantations around the world. The original construction files for the project suggest that the teak was likely grown and/or milled in Thailand. Physical analysis of the samples indicates naturally grown teak is most predominantly used at the Salk, although some of the teak has characteristics consistent with plantation-grown wood.

Significance and Integrity Evaluation

The window wall assemblies are significant components within the larger context of building for a number of reasons. One of the key design features of the Salk Institute is the physical separation of the private study spaces, which Kahn referred to as the "architecture of the oak table and rug," from the collective workspace of the laboratories with their "architecture of cleanliness and area adjustability."[1] The use of individual window walls, clad in teak wood in the studies, in contrast to the large expanses of metal-framed window walls at the laboratories helps to further differentiate these spaces. The supremacy of the individual in the studies is further expressed in the functionality of the various sliding components: occupants are able to modulate light and ventilation within their work spaces. The design of these window walls are significant within Kahn's larger body of work, as it expands upon a language of custom exterior millwork established in his office and used in projects from the Dr. and Mrs. Norman Fisher House to the Class of 1945 Library at Phillips Exeter Academy. The particular use of prefabricated units at the Salk Institute is innovative in that it synthesizes industry and craft. Prefabrication is often thought of as an industrialized process, but at the Salk these units have a handcrafted quality due to the detailing of the teak wood by carpenters and the customization of the assemblies to fit the many different-sized openings. The very use of wood together with concrete, "often conceived of as materials of opposite character,"[2] results in a contrasting but complementary effect, with the fine-grained detailing of the window walls with narrow vertical tongue-and-groove (T&G) boards and horizontal trims set in multiple planes, contrasting with the larger expanses of relatively flat concrete walls. Teak was selected for the exterior wood as it was thought to be a durable, relatively maintenance-free material, requiring no finish coating, and that in its gray weathered appearance it would be compatible with the color of the adjacent concrete. It is important to note, however, that as wood is a natural material it weathers differentially depending on orientation and exposure to the environment. Thus, uniformity in this gray appearance could never be achieved across the building if the weathering process were left to occur naturally. It is difficult to ascertain if Kahn expected such a variation in appearance, but it is most certainly the result of his design.[3] Thus, subtle variations in appearance may be considered a feature of teak in this application and almost impossible to avoid. The orientation of the building facades will inevitably result in some variations in appearance.

As most of the components of the window wall assemblies remain unchanged from the time of their original construction, they can be said to retain a high degree of integrity in terms of location, design, materials, workmanship, and association. Integrity is a measure of the wholeness or intactness of a cultural heritage site and its ability to convey its significance.

The GCI carried out a significance assessment of the various components of the window wall assemblies, which has guided the development of conservation policies by providing an understanding of the components that are essential to retain and others that may be altered or removed without jeopardizing the overall significance of the assemblies. Components such as the overall prefabricated nature of the assembly and the teak cladding and window sashes were determined to be of exceptional significance, whereas interior stock components such as the wood stud framing and transite board were found to be only of moderate significance. Other components, such as later surface coatings—which were applied with the intent of protecting the wood but gave it a red appearance that strongly contrasts with the adjacent concrete and obscures its fine-grained texture—were found to be of little significance, detracting from the overall significance of the window walls. Thus, conservation treatments that reduce or remove these coatings should be considered.

Condition Assessment

The window wall assemblies have presented a number of maintenance challenges to the Salk's facilities staff almost since construction was completed. During construction, budgetary cutbacks such as the omission of window weather stripping and base flashing, and deficiencies such as sealants that failed to adhere to both the concrete and teak wood have resulted in ongoing and sometimes significant moisture infiltration through the window walls, which has proven to be difficult to correct in situ. Furthermore, the growth of a biofilm on the surface of the wood has given the teak a black appearance that varies significantly by exposure. Several cleaning campaigns have been undertaken in an attempt to remove this biofilm; however, none have produced long-lasting results.

The window wall assemblies currently exhibit a variety of conditions, including the following:

- Differential weathering in the teak cladding, which results in variations in the gray weathered appearance and different rates of erosion in the surface of the wood. The natural erosion process has been accelerated by past cleaning efforts. The rates of erosion vary from minimal at north-facing elevations, with 90% to 100% of the original board thickness remaining, to severe at the south-facing elevations, with less than 80% of the original board thickness remaining.
- Missing teak elements, often resulting from severe erosion or water or insect damage to the teak substrate.
- Moisture staining above and below horizontal elements and iron staining around and below exposed nail heads, both of which contribute to the varied appearance of the teak.
- The previously mentioned black fungal biofilm, which is concentrated on the surface of the teak and is composed of several types of fungi (order Capnodiales), most likely coming from the surrounding eucalyptus trees. The fungus thrives wherever there is a water source, and thus the heaviest growths appear on the north-facing elevations with limited sun exposure, just above horizontal sills and drips where moisture accumulates. As these are not decay fungi, they do not degrade the structural support of the wood. Laboratory analysis confirmed the overall integrity of the wood is good.
- Variation in color, most frequently the result of previous applications of Tip Top Teak Wood-Oil Sealer, which gave the wood a red appearance. This treatment has weathered at differential rates depending on exposure, and is most intact in those areas protected by overhead walkways.
- Minor insect damage in the teak cladding, which is superficial in nature and is limited to only a few elements, as observed during the preliminary visual condition survey.
- Variable drywood termite (*Incisitermes* spp.) damage to the interior white fir wood stud framing and furring strips to which the teak cladding is attached. Two investigative probes were carried out as part of this project: One, performed at a south-facing study (NL6), exhibited severe damage with loss of more than half of the sill plate. The other, carried out at a west-facing office (SO4), showed sound wood with no observable termite damage. Based on this limited number of openings, it is not possible to identify patterns or overall extent of damage at this time.

- Lack of flashing and failure of perimeter sealants, which allows for moisture infiltration into the wall cavities and also contributes to the development of previously noted moisture staining.
- Lack of effective weather stripping at windows, resulting in water and air infiltration.
- Presence of asbestos in the transite panels, which when disturbed must be handled according to special procedures for hazardous materials.

Prior to the start of the conservation project, it was thought that the extent of damage to the teak may require extensive, if not complete, replacement. The investigations carried out as part of this project show that a fair amount of teak remains in good condition, as do many of the other components in the window wall assemblies. The primary mechanism of the deterioration of teak is weathering. Termite damage does not represent a significant deterioration mechanism for the teak. The differential appearance of the teak and the presence of a fungal biofilm on its surface, while nonthreatening to the health of wood, presents an aesthetic problem, compromising the visual integrity of the site. Although some variation is to be expected due to the natural weathering process, the presence of the fungal biofilm and red appearance of the remaining Tip Top Teak treatment have resulted in a greater degree of variation. The black and red colors may also be considered incompatible with the natural gray weathered appearance of the teak.

Of all conditions observed, the drywood termite damage is of highest concern, as severe damage to the stud framing threatens the overall structural stability of the wall assembly, and damage to the furring strips can lead to detachment of the teak cladding, as demonstrated by the failure of a row of teak T&G vertical siding at the northwest office wing during a storm in February 2014. Severe erosion of the some of the teak cladding—most prevalent at south-facing elevations—is also of concern, as it can lead to failure of the joints between the T&G vertical boards, allowing air and water infiltration into the wall cavity and potential detachment of the boards themselves. Finally, the lack of flashings and failure of perimeter sealants reduces the overall performance of the window wall assemblies, which are an important element in the exterior envelope of the buildings.

Conservation Policies and Preliminary Treatment Recommendations

The development of treatment recommendations is guided by a series of conservation policies that integrate internationally recognized conservation principles with other factors such as owner objectives and legal requirements. These conservation principles seek to preserve significance by intervening at the minimal level necessary to meet the project objectives with the least damage to existing fabric, making like-for-like repairs, designing any new interventions to be compatible with the original materials and reversible, and selecting interventions that are durable in nature, with a constant and reliable performance over their lifetime. The Salk Institute's objectives for the project are to preserve significance and to develop long-term treatment solutions that have the longest expected life cycle possible, are logistically efficient (meaning they can be carried out with minimal interruption to the building occupants over a relatively short period of time), are cost efficient, provide a high degree of uniformity in terms of exterior appearance and treatment of concealed areas (including termite-resistant treatments and abatement of hazardous materials), and are ethical, particularly in the sourcing of replacement teak wood as needed. Furthermore, code-mandated requirements governing the structural performance of the wall assemblies and energy efficiency must also be considered.

Conservation Policies and Associated Treatments

The resulting policies and associated treatments are:

1. **Preserve the overall integrity of the wall assembly** by repairing damaged framing and improving resistance to future termite damage through spray treatment of existing framing with a low-toxicity chemical insecticide and/or replacement with pressure-treated wood framing. It should be noted that replacement of the wood framing will require the entire window wall assembly to be removed, rebuilt in a shop, and reinstalled. Limiting replacement to only those window walls exhibiting termite damage and in situ treatment of window walls with existing framing that is in good condition most closely adheres to the conservation principle of minimal intervention; however, an argument can be made for total replacement of the framing, as it allows a number of other issues to be addressed in a holistic way, such as abatement of hazardous materials and installation of flashings and a water-resistive barrier to improve the overall performance of the wall. At the present time, there is not sufficient information on the extent of termite damage to justify the unnecessary removal of original building material in good condition. Thus, the GCI recommends additional termite inspections be carried out to better understand the extent of damage before selecting one of these alternatives. It should also be noted that replacement of the internal framing does not necessarily merit replacement of the teak cladding; those teak elements in good condition can be salvaged and reinstalled.
2. **Preserve original teak structural members, cladding, and sliding windows, louvers, and shutters** to the greatest extent possible, as all are of exceptional significance to the overall window wall assembly. Teak exhibiting moderate to minor erosion has an estimated remaining service life of thirty to sixty years, depending on the extent of current erosion. This life span could be increased with the application of treatments to reduce moisture and weathering effects, such as an epoxy system applied to the end grains or a water-repellent preservative (WRP). Severely eroded teak has an expected remaining service life of up to twenty-five years and may be a good candidate for replacement with wood that matches the species and cut of the original. The selection of naturally grown teak will most closely match the original and provide the longest service life (up to 100 years); however, the market for this is volatile and ensuring the legality of the source material can be difficult. While plantation-grown wood is readily available, it is potentially less durable (estimated service life varies considerably due to growth variations). Thus, it is possible that replacement with plantation-grown teak will not provide a substantial overall increase in service life beyond retention and treatment of existing teak in good condition. Beyond the guiding conservation principles, there are economic and performance-based reasons as to why preference should be given to retaining existing naturally grown teak with adequate remaining service life.
3. **Reduce general variations in appearance** due to moisture and weathering effects by cleaning, brightening, and/or lightly sanding teak, with the understanding that some variation in appearance is inherent in the use of wood, and even in those areas where the teak is replaced with new material, variations in appearance are to be expected as the wood weathers. The appearance of the wood will never be uniform across the building or even a single elevation.

4. **Retard the growth of the fungal biofilm** by implementing treatments that reduce water sources through:
    a. In situ topical treatments, such as the application of a WRP or borate solution; and/or
    b. Modifications to the architectural details, such as the installation of flashings or treatment of end grains with an epoxy to limit moisture intake. Note that these treatments can be best implemented when the entire window wall assembly is removed from the wall opening and disassembled.
5. **Reduce the red appearance of later surface coatings** or remove altogether by sanding and/or stripping to achieve more uniformity in the appearance of the teak.
6. **Improve the overall performance of the wall assemblies** by correcting past construction deficiencies through the installation of flashings and building paper where possible, and through the repair of perimeter sealants.
7. **Retain the functionality of the horizontal sliding window sashes, improve their overall performance** by installing new weather stripping, and **address life safety concerns** by installing clear safety film over the existing plate glass or replacing with new clear tempered or laminated glass.
8. **Abate hazardous materials** as required by disturbance of material; **or, where not disturbed, manage in place.**

It must be noted that conservation-based approaches rarely result in a one-size-fits-all solution; rather, they are hybrid in nature, with a number of different solutions responding to different conditions present on site, with the goal of doing as much as necessary while also doing as little as possible.

Treatment Typologies

Based on the conditions extant at the Salk, three general levels of treatment are to be expected:

1. **Minor intervention**. In situ cleaning and repair of existing window wall assemblies exhibiting minor to moderate erosion at the teak cladding and no termite damage.
    a. Clean teak.
    b. Remove past surface treatments.
    c. Apply topical treatment to retard growth of biofilm.
    d. Spray-treat existing wood framing to increase resistance to future termite infestation.
    e. Install weather stripping at sliding windows and retrofit or replace glazing.
    f. Manage existing transite boards in place.
2. **Moderate intervention.** Off-site cleaning and repair of existing window walls exhibiting minor to moderate erosion and termite damage.
    a. Salvage existing teak, clean, and remove past surface treatments.
    b. Modify architectural details to retard moisture infiltration and growth of the fungal biofilm.
    c. Replace damaged wood stud framing with pressure-treated wood.
    d. Install weather stripping at sliding windows and retrofit or replace glazing.
    e. Replace transite boards.
3. **Major intervention.** Removal of existing window wall assemblies exhibiting both severe erosion and termite damage and reconstruction using in-kind materials.

a. Replace existing teak in-kind.
b. Modify architectural details to retard moisture infiltration and growth of the fungal biofilm.
c. Replace damaged wood stud framing with pressure-treated wood.
d. Install weather stripping at sliding windows and retrofit or replace glazing.
e. Replace transite boards.

While these types of treatments are tailored to the specific conditions present at an individual window wall, care must be taken to implement a similar treatment across an elevation or area of a building so as to maintain visual integrity, which is important in those architecturally significant sites with high aesthetic value. This will also satisfy owner objectives such as uniformity and logistical efficiency. For example, many of the south-facing window walls exhibit severe erosion in the teak cladding and have known moisture intrusion issues, which suggest a major intervention across part or all of the facade. However, many of the north-facing window walls exhibit minor erosion but significant growth of the black biofilm and a red color remaining from past surface treatments. Thus, a minor or moderate intervention is suggested, depending on the presence of termite damage. As the original teak cladding would be retained in either intervention, there should not be any concerns about exterior uniformity between these two treatments.

Next Steps

The suitability of different treatments shall be further evaluated through the trial mock-up program described in chapter 5 of this report. Following the completion of the mock-up program, the treatment recommendations will be refined. At that point, the GCI recommends that the Salk Institute retain the services of a licensed architect who has experience working with historic preservation projects, along with a structural consultant, to carry out a detailed condition survey and develop a full set of construction documents that expand upon the results of the trial mock-up program to guide a future implementation project.

Notes

1 Kahn 1961, 151.

2 Brownlee and DeLong 1991, 100.

3 In 2014, after Phase 1 of this project was completed, a book was published with transcriptions of Kahn in conversation with John W. Cook and Heinrich Klotz (1969–70). In a recording made on December 7, 1969, Kahn was asked about the weathering of the teak wood windows at the Salk Institute. He responded: “Depends on how much weather? The upper ones weather much more than the other ones. They were quite red when they got up there, but now they are sort of a grey and they look almost like the concrete, and they look more so later on when it gets to be really quite white. The walls will become very light” (Prown and Denavit 2014, 116).

CHAPTER 1

Introduction

Project Background

Completed in 1965, the Salk Institute for Biological Studies in La Jolla, California, is one of architect Louis I. Kahn's finest works and is widely considered to be a masterpiece of modern architecture with international significance. Kahn was commissioned by Dr. Jonas Salk, developer of the polio vaccine, to design an inspiring campus for his new scientific research institute on a coastal bluff overlooking the Pacific Ocean. Kahn's design consists of two nearly identical wings of laboratory, study, and office space that mirror each other on either side of a paved central plaza (figs. 1.1, 1.2).

The innovative, teak-clad window wall assemblies, set within the monolithic concrete walls of the studies and offices, are one of the major architectural elements of the site (figs. 1.3, 1.4). After nearly fifty years in an exposed marine environment, the window walls have weathered to a non-uniform appearance. Past surface treatments, carried out with the intention of addressing some of these issues, have inadvertently contributed to the non-uniform appearance of the wood. Furthermore, the teak wood and, perhaps more significantly, its underlying wood structural system are deteriorated. Minor repairs have been carried out at the window walls over the years, largely following a maintenance-based approach. However, as the Salk Institute approaches its fifty-year milestone—the age at which many modern buildings typically are in need of a major conservation intervention—more serious repairs are needed at many of the 203 distinct window wall assemblies.

Recognizing that such a major repair project has the potential to negatively impact the architectural significance of the site, the Salk Institute is ready to transition toward a conservation-based approach to the long-term care of the site. As a first step in this process, the Salk Institute has partnered with the Getty Conservation Institute (GCI) to develop the Salk Institute Conservation Project, which will study and evaluate the teak window wall assemblies to better understand their current condition and develop treatment recommendations for their long-term care and conservation, commensurate with international best practices for conserving modern architecture. The results of this work will be used by the Salk Institute to guide implementation of a future conservation project for the window wall assemblies. Additionally, the Salk Institute will be able to utilize the methodology established in this project when planning for the care of the site's other significant historic elements.

Scope and Methodology

The Salk Institute Conservation Project follows international best-practice methodologies, which recommend that three basic steps be followed when developing a conservation project for cultural heritage sites: (1) understand the site before intervening; (2) develop

FIGURE 1.1
View of the two wings of the Salk Institute flanking the main plaza, looking west toward the Pacific Ocean.
Image: J. Paul Getty Trust.

FIGURE 1.2
View of the two wings looking east across the main plaza, revealing the teak-clad window wall assemblies. Photograph predates the construction of the East Building in the early 1990s and buildings east of North Torrey Pines Road on the campus of the University of California, San Diego.
Image: Salk Institute for Biological Studies.

FIGURE 1.3
View of the west office wings, looking northeast. The teak-clad window wall assemblies are one of the major architectural elements of the site.
Image: J. Paul Getty Trust.

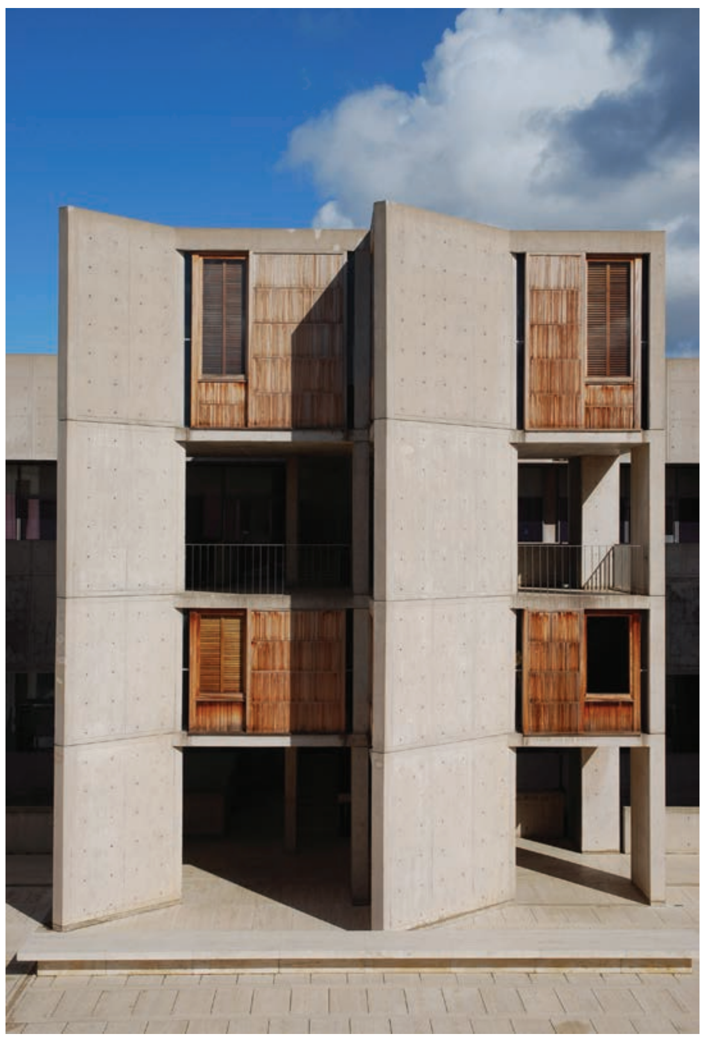

FIGURE 1.4
View of teak-clad window wall assemblies set within the concrete walls of a north study tower (tower 4, housing studies NL3, NL4, NU3, and NU4).
Image: J. Paul Getty Trust.

conservation policies that both protect the significance of the site and integrate other considerations, such as owner objectives and legal requirements; and (3) select a conservation treatment that best complies with the policies, then implement, maintain, and monitor.

The scope of the Salk Institute for Biological Studies Conservation Project for the teak window wall assemblies builds on this process and is divided into two distinct phases:

Phase 1: Research and Investigation

a) Historical research and assessment of significance:
   i. Carry out historical research to understand design, construction, and chronology of past treatments to better understand the window wall assemblies.
   ii. Assess significance.
b) Condition assessment, scientific research, and diagnosis:
   i. Perform a visual condition survey of all window wall assemblies to understand types of conditions extant on the site, as well as weathering and deterioration patterns and mechanisms.
   ii. Open up portions of the wall assemblies, through investigative probes, to better understand how the window walls are assembled and the condition of the internal elements.
   iii. Carry out wood analysis, including physical and laboratory analysis of wood samples to identify wood species and past surface treatments and to increase understanding of weathering and deterioration mechanisms.
   iv. Diagnose weathering and deterioration mechanisms.
c) Treatment recommendations:
   i. Develop conservation policies that integrate conservation principles with owner objectives and other factors.
   ii. Develop different treatments (cleaning, repair, and potential replacement) and evaluate against conservation policies.
   iii. Identify preferred treatments to be further explored during the trial mock-up phase.

Phase 2: On-Site Trial Mock-Ups

a) Perform on-site trials that involve mocking up identified treatments to further evaluate their suitability.
b) Monitor performance of mock-ups in the short, medium, and long term.
c) Refine treatment recommendations based on the results of the trial mock-up program.

Window Wall Assembly Naming Conventions

As part of this project, each of the 203 window wall assemblies was assigned a unique identification tag, with a prefix indicating the building area or room where the window assembly is located, followed by a letter for each assembly within that area or room. For example, window wall assembly NL1B is one of three windows (A–C) located in room NL1, which is a lower-level study at the north side of the central plaza. To the extent possible, building area or room names correspond to those already in use by the facilities department at the Salk Institute. The prefixes used in this project are as follows:

- NO2–NO6: Northern West Office Wing, floors 2 through 6 (ground level = 2)
- SO2–SO6: Southern West Office Wing, floors 2 through 6 (ground level = 2)
- NL1–NL9: North Study Towers, lower-level studies
- NU1–NU9: North Study Towers, upper-level studies
- SL1–SL9: South Study Towers, lower-level studies
- SU1–SU9: South Study Towers, upper-level studies

The assigned identification tags are shown on the floor plan and building elevation drawings in appendix D.

Relationship to Phase 1 Report to Subsequent Work of Phase 2

This report presents the results of Phase 1 of the project, the work of which was carried out from 2013 to 2014. An initial draft of this report was issued to the Salk Institute in August 2014, prior to the start of Phase 2. In 2017, while preparing the final Phase 1 report for publication, minor content and copy edits were made; however, the report was not modified to reflect the enhanced understanding of the site gained during Phase 2 (2015–16) and the subsequent construction project (2016–17) or through the preparation of the conservation management plan (CMP) for the entire site by the Salk Institute's consultants (2014–17). Rather, a separate forthcoming report will present the results of Phase 2, including refinement of both the initial significance assessment and conservation policies based on additional research undertaken and the results of the trial mock-ups. This approach to publishing the reports reflects the iterative process utilized in the project.

All photographs included as figures in this report were taken during Phase 1 of the project (2013–14) unless otherwise noted in the figure captions.

Acknowledgments

The GCI wishes to acknowledge the commitment of the Salk Institute to conservation and stewardship of their campus in La Jolla. We are grateful for the opportunity to be able to work in partnership with the Salk Institute on the conservation of this remarkable work of modern architecture. In particular we would like to thank former vice president of Scientific Services, Garry Van Gerpen, for his leadership and Tim Ball, senior director of Facility Services, for his early contributions to Phase 1 before managing the implementation of the mock-ups during Phase 2. Garry and Tim generously shared their knowledge of the site with us, provided both staff assistance and equipment, such as ladders and lifts, which facilitated the visual condition survey, and also allowed us to collect small samples of the teak and other building materials for laboratory analysis. Claire Grezemkovsky, former assistant director of Foundation Relations, proved to be an invaluable research partner, both at the Architectural Archives at the University of Pennsylvania, School of Design, home of the Louis I. Kahn Collection, and at the Salk Institute where she organized and indexed files related to construction and early maintenance of the site. She authored sections of this report, including the historical background and context section at the beginning of chapter 2 and the discussion of design intention in appendix C. Thanks to Amy Fouts-Wampler, director of Foundation Relations / External Relations, for her assistance with image permissions and other details necessary for the final publication of the report in 2017.

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Our research in the Architectural Archives at the University of Pennsylvania, School of Design would not have been possible without the assistance of William Whitaker. Thanks also to Bill for arranging visits to several Kahn residences in the Philadelphia area that have similar exterior wood detailing to window wall assemblies at the Salk Institute.

Finally, we wish to thank Cynthia Godlewski at the GCI for helping us to bring this report to publication, Dianne Woo for her thorough copyedit of the text, and Hespenheide Design for the design of the publication.

CHAPTER 2

Historical Background and Significance

Historical Background and Context of the Salk Institute

The following section was prepared by Claire Grezemkovsky.

Foundation of the Salk Institute

The Salk Institute for Biological Studies was founded in 1959 through a partnership between Dr. Jonas Salk, the famed inventor of the first successful polio vaccine, and the March of Dimes, under the leadership of Basil O'Connor. After considering several sites on the East Coast and West Coast, La Jolla, California, proved the ultimate draw for Salk, who chose Louis I. Kahn as the institute's architect. The development of a research industry in this area of San Diego reflected a national shift in innovation from the East Coast and Midwest to the West Coast, specifically California. In San Diego, these hubs included General Atomics, the Scripps Institute of Oceanography, and the University of California, San Diego.

Original Design and Construction

After their first meeting in 1959, Dr. Salk and Kahn formed a significant friendship and collaborated on the concept of the institute, which served to bring a community of scientists together while offering a place for individual contemplation on a serene, isolated campus set on a Western coastal bluff. Kahn had recently gained attention for his design of the Richards Medical Research Laboratories at the University of Pennsylvania (fig. 2.1), but it would be the Salk where Kahn's ideal laboratory community was ultimately realized.

Kahn's original design, developed during his site visits in the early 1960s, was a three-part plan including a research and study area, a meeting center, and residential quarters. Due to budget restrictions, only the first component—a central courtyard flanked by symmetrical laboratory and study complexes abutting west-facing administrative office buildings and facing the sea—was ever realized (fig. 2.2).

The architecture of the Salk embraces modernist materials, techniques, and forms, as well as Kahn's foundational training in the Beaux-Arts style. It also expresses Kahn's interest in the hierarchy of "served" and "servant" spaces. The outside perimeter of the complex includes service cores housing stairs, elevators, and bathrooms, with few apertures. The next level of enclosure is the laboratories—unobstructed and totally flexible spaces spanned by transverse Vierendeel trusses and surrounded by glass-and-steel curtain walls—sandwiched between full height interstitial spaces that contain all the building services and mechanics. This allows the laboratory environment to remain completely free of mechanical equipment and was important for meeting Dr. Salk's desire for an open, flexible, and unobstructed research space (fig. 2.3). Finally, at the perimeter of the internal courtyard stand the study towers, with individual cells that Kahn described as having an "architecture of the oak table and the rug" (fig. 2.4)[4] Open-air arcades below and between the lower- and upper-level studies provide sheltered circulation space for the institute (fig. 2.5). The inner

FIGURE 2.1
The Richards Medical Research Laboratories at the University of Pennsylvania, designed by Louis Kahn. Dr. Salk visited Richards prior to commissioning Kahn to design his new institute.
Image: J. Paul Getty Trust.

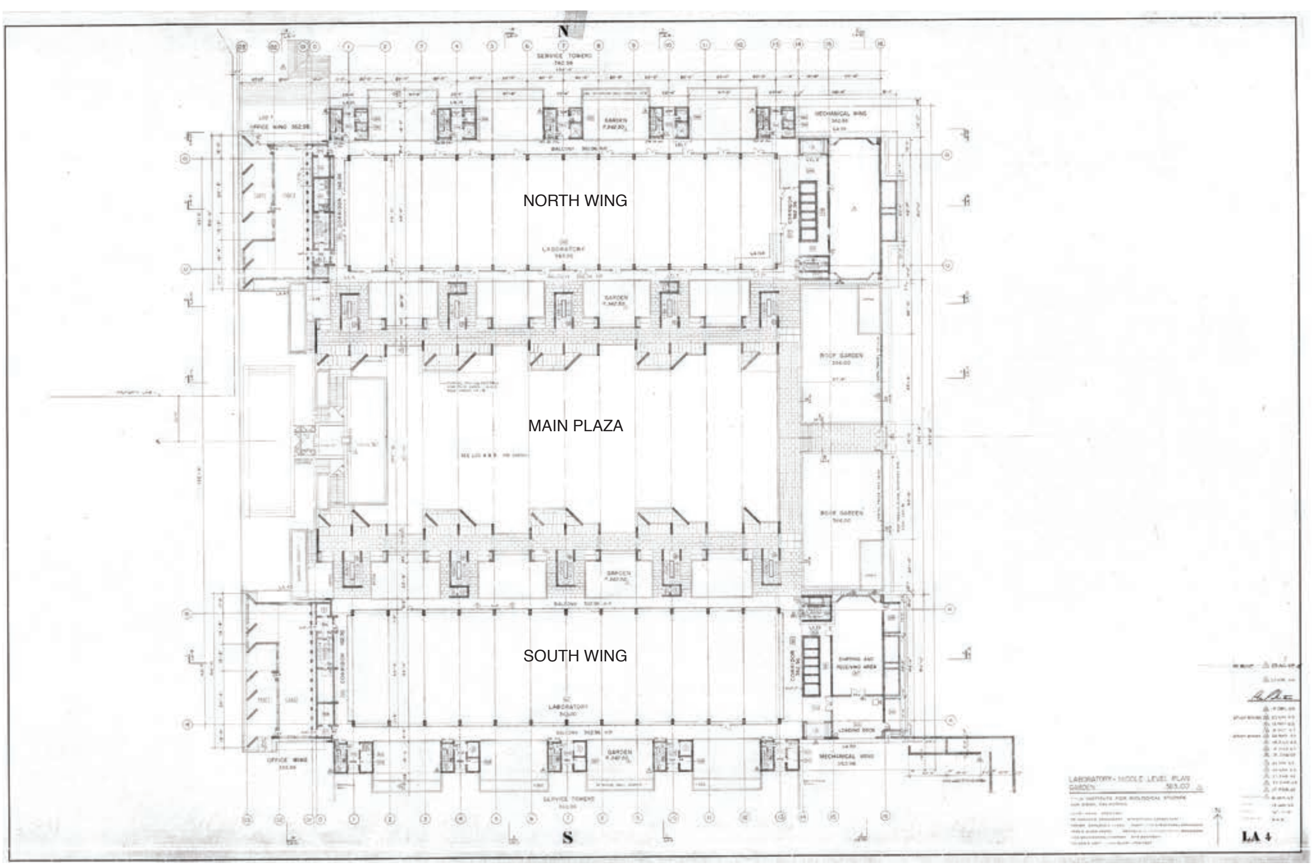

FIGURE 2.2
Intermediate- (or "middle") level floor plan of the Salk Institute, illustrating the near-symmetrical wings that lie to the north and south of the main plaza. Each wing is composed of the study towers, laboratories, and offices. Floor plan prepared by Kahn's office, initially dated January 17, 1963, with final as-built revisions dated July 23, 1965.
Image: Louis I. Kahn Collection, University of Pennsylvania and Pennsylvania Historical and Museum Commission.

FIGURE 2.3
Interior view of the laboratories. To meet Dr. Salk's specifications, the laboratories in both wings are designed as unobstructed, flexible spaces spanned by transverse Vierendeel trusses. Laboratory furniture and equipment divide the labs into smaller work spaces.
Image: J. Paul Getty Trust.

space is an open travertine courtyard bisected by a marble runnel that spills into a pool overlooking the sea and that recirculates in a constant fashion, a reference to the traditional design of Islamic gardens such as those of the Alhambra. Due to coastal building restrictions, the lowest laboratory level and service floor are sunken below ground level and serviced by deep wells that direct light underground and provide unique circulation and gathering spaces (fig. 2.6). These sunken gardens further separate the laboratories from the study towers. Light itself, while by no means a building material, is everywhere captured and manipulated by the Salk's architecture. The overall design demonstrates a deep observation and understanding of classical architecture and the promise of a contemporary modernist approach.

The complex, taut geometries that characterize the institute are manifested in an elemental but rich palate of materials finished to reveal the process of fabrication: pozzolanic concrete (a reference to ancient Roman building techniques), unfinished teak, lead, glass, Cor-Ten steel left to weather and rust, and a stainless steel/nickel alloy that frames the glass laboratory window walls.

Kahn's collaborators were essential to the building's architecture. Dr. Jonas Salk contributed his own view: that of a society of researchers, with spaces for connection and community as well as for singular contemplation. Kahn's structural engineer, August E. Komendant, made possible the construction of the poured-in-place concrete. And Mexican

FIGURE 2.4
Interior view of an individual study, with oak paneling and flooring and exposed concrete walls and ceilings.
Image: Salk Institute for Biological Studies.

FIGURE 2.5
Open-air arcades below and between the lower- and upper-level studies provide sheltered circulation space at either side of the plaza.
Image: J. Paul Getty Trust.

FIGURE 2.6
Sunken gardens separate the laboratories (left) and the study towers with individual cells (right), while allowing for natural lighting of the below-grade laboratory spaces. Bridges and staircases connect laboratories to the towers.
Image: J. Paul Getty Trust.

architect and engineer Luis Barragán, whom Kahn consulted as he hit an impasse while creating the design of the central courtyard, made the ultimate mark with his concept of a stark travertine plaza that would stand as a facade to the sky.

Later Alterations

In the early 1990s, in response to the need for increased scientific services and administrative support, as well as the importance of providing services included in the original but incomplete tripartite scheme (such as an auditorium), the Salk Institute commissioned the design and construction of the East Building. The building was designed to complement the original Kahn design, and it was undertaken by a team that included the firm of Anshen + Allen and David Rinehart and Jack MacAllister, who had served as Kahn's project architect on the original team. Construction resulted in the removal of the original eucalyptus grove, which had served as a screen allowing visitors to obliquely encounter the institute. This decision reflected the development of Torrey Pines Mesa from an isolated site to a highly developed area surrounded by numerous research institutes, corporations, and the massive University of California, San Diego, campus.

Between 1993 and 1998, the institute underwent a facility condition analysis to develop a deferred maintenance and capital renewal plan. As a result, the Salk undertook a complete mechanical and electrical systems renewal and expansion. Other projects identified in the plan have not yet been undertaken.

Current Historic Status

City of San Diego Register Historic Landmarks

The Salk Institute was listed as Historical Landmark #304 by the San Diego Historical Site Board (presently the Historical Resources Board) in 1991. In listing the institute, the board cited its association with both Louis I. Kahn and Dr. Jonas Salk; "its pivotal role in the metamorphosis of the economy of San Diego from near total dependence upon the military and aircraft manufacturing to a diverse one with a strong and growing medical and scientific research element"; and its architectural significance, notably its international renown as "an important work of modern architecture for both its dramatic siting atop with bluff with the ocean view framed by the paired buildings, and for its innovative design concepts, especially in the function of the laboratories and in the symbolism of the elegant central plaza." The designation specifically covers "all facades of both buildings, the view to the west which they frame, the upper terrace entryway with its ornamental grove concept, the central plaza with its watercourse, the lower terrace with its fountain, and the original amenities of these spaces such as steel gates and terrazzo seating areas."[5]

In addition to honorific recognition, the local landmark listing brings with it responsibilities. For example, proposed exterior alterations to the site, such as a project to conserve the teak window wall assemblies, are subject to review by city staff and the historical resources board for consistency with United States national standards for historic preservation. These standards are discussed in chapter 5, as are the alternative regulations of the *California Historical Building Code* that the Salk Institute is eligible to use as a local landmark.

California Register of Historical Resources and National Register of Historic Places

Currently, the Salk Institute is not listed in the California Register of Historical Resources or in the National Register of Historic Places, nor has its eligibility for listing in the National Register been formally evaluated.

In 2004, a coalition of neighbors of the Salk Institute prepared a National Register nomination for the site, which was reviewed by the California State Historical Resources Commission (SHRC). While the SHRC concurred with the neighborhood coalition and determined the parcel to be eligible for listing in the National Register, the property was not formally listed at the time. If the property obtains National Register listing in the future, it will automatically be listed in the California Register as well.[6]

Other Recognitions

American Institute of Architects

In 1992, the Salk Institute received a Twenty-five Year Award from the American Institute of Architects (AIA). Inaugurated in 1969, this award, "recognizing architectural design of enduring significance," is conferred on an annual basis to a single project designed by an architect licensed in the United States that has stood the test of time for twenty-five to thirty-five years.[7] The Salk and other recipients of the Twenty-five Year Award were subsequently featured in the AIA's traveling exhibition *Structures of Our Time: 31 Buildings That Changed Modern Life*, which premiered in 2002.

Significance and Integrity Evaluation of the Window Wall Assemblies

As previously noted, the local landmark designation for the Salk Institute found the site to be significant for its association with both historic events and individuals, as well as for its architectural qualities. Within that larger context, this project looked specifically at how the wood window wall assemblies contribute to the overall significance of the Salk.

Significance of the Window Wall Assemblies

One of the key design features of the Salk Institute is the physical separation of the singular "domestic" cells of the study towers—which Kahn often referred to as the "architecture of the oak table and the rug"—from the collective work space of the laboratories, with their "architecture of cleanliness and area adjustability."[8] The use of individual window walls, clad in teak wood at the studies (figs. 2.7, 2.8), in contrast to the large expanses of metal-framed window walls at the laboratories (fig. 2.9), is an exterior expression of these different spaces. The supremacy of the individual in the studies is further expressed through the functionality of the various sliding components: occupants are able to modulate light and ventilation within their work spaces.

The design of these window walls are significant within Kahn's larger body of work, as they expand upon a language of custom exterior millwork established in his office and used in projects from the Margaret Esherick House (1959–61) and the Dr. and Mrs. Norman

FIGURE 2.7
View of the window wall assemblies in the study towers at the north side of the main plaza.
Image: J. Paul Getty Trust.

FIGURE 2.8
Upper-level south-facing window (NU9C), north study towers. The sliding components of the window walls allow occupants to modulate light and ventilation within their own workspaces.
Image: J. Paul Getty Trust.

FIGURE 2.9
The use of large expanses of metal-framed window walls at the laboratories contrasts with the individual wood window walls at the studies and offices.
Image: J. Paul Getty Trust.

FIGURE 2.10
The Dr. and Mrs. Norman Fisher House, 1960–67, Hatboro, Pennsylvania, one of several Kahn projects with custom exterior wood detailing similar to the Salk Institute.
Image: J. Paul Getty Trust.

Fisher House (1960–67) (fig. 2.10), both in the Philadelphia area, to the Class of 1945 Library at Phillips Exeter Academy (1965–72) in Exeter, New Hampshire.

The use of prefabricated units at the Salk is innovative in that it synthesizes industry and craft. Prefabrication is often thought of as an industrialized process, but here these units have a handcrafted quality due to the detailing of the teak wood by carpenters and the customization of the assemblies to fit the many different-sized openings.

The very use of wood together with concrete, "often conceived of as materials of opposite character," results in a contrasting but complementary effect.[9] The fine-grained detailing of the wood window walls, with narrow vertical T&G boards and horizontal trims set in multiple planes, contrasts with the larger expanses of relatively flat concrete wall planes (figs. 2.11, 2.12).

Although research carried out to date as part of this project has not produced any statements directly attributable to Kahn on the choice of teak for the exterior cladding, the consensus among his design associates and scholars is that it was specified because it was thought to be a durable, relatively maintenance-free material requiring no finish coating, and that in its natural gray weathered appearance it would be compatible with the color of the adjacent concrete. During the design phase, several alternatives to the teak were considered as a means of reducing project costs. The only viable alternative, Honduras mahogany, was rejected by project architect Jack MacAllister because it "is very red in color and would create problems of appearance with the color of the concrete. It would also have to be treated periodically with a preservative or have to be varnished."[10] MacAllister urged that this substitution should be made only as a last resort. In April 1966, soon after the completion of construction, Kahn himself noted, "I think the tone now, the concrete and the wood, blends together much."[11] When asked about the color of the teak in 2013, MacAllister observed, "The marriage of—the consistency of—the total value of the building, from the concrete to the travertine to the grayed-out teak, I think is one of the really subtle beauties of the building. There's nothing that jumps forward of everything else. [The materials] all have that same kind of built-in patina, as it were, where they look like they are all related."[12]

FIGURE 2.11
Southern west office wing at the Salk Institute. The fine-grained detailing of the wood window walls contrasts with the relatively flat concrete wall planes.
Image: J. Paul Getty Trust.

FIGURE 2.12
Northern west office wing at the Salk Institute. The combination of concrete and teak creates a contrasting but complementary effect.
Image: J. Paul Getty Trust.

It is important to note that as wood is a natural material, it weathers differentially depending on orientation and exposure to the environment. Thus, uniformity in the expected gray appearance associated with the natural weathering processes could never be achieved across the building. It is difficult to ascertain if Kahn expected such a variation in appearance, but it is most certainly the result of his design.[13] Thus, subtle to moderate variations in appearance may be considered a feature of teak in this application and almost impossible to avoid. However, due to construction deficiencies (such as the lack of flashings and sealant failure) and the realities of the coastal environment, the teak exhibits much more variation with areas of moisture staining and the growth of a black fungal biofilm on the surface of the teak. The presence of this fungus was particularly troublesome to both Dr. Salk and his institute—in 1968, plant manager Carlos Johnson described it as giving the building "the appearance of a 5 o'clock shadow on all of the panels that do not get much sunlight."[14] Though maintenance staff initially employed a variety of cleaning methods to remove the fungus, leaving the wood "bare" as Kahn intended, in later years surface coatings were applied with the intent of protecting the wood. These coatings give the teak a red appearance that strongly contrasts with the adjacent concrete (fig. 2.13) and, in more recent years, has weathered away at differential rates, giving the building a more varied appearance. They also obscure, at least in part, the fine-grained nature of the wood detailing. Neither this high degree of variability nor the red color contributes to the significance of the window walls.

For further discussion of Kahn's design philosophy at the Salk and the environmental realities in La Jolla, refer to appendix C.

FIGURE 2.13
Surface coatings applied to the wood over the years have left a red appearance that is more visible in areas where the windows are recessed and protected from the ocean-facing exposure, such as these window assemblies protected by the terrace outside the library in the northern west office wing.
Image: J. Paul Getty Trust.

Integrity Evaluation

Most registries of cultural heritage sites, from the California Register of Historical Resources and the United States National Register of Historic Places to the UNESCO World Heritage List, stipulate not only that historic resources are significant, meeting well-established criteria, but also that they possess integrity. Integrity is the ability of a site to convey its significance. It is a measure of the wholeness or intactness of the site. In the United States, integrity is often evaluated with regard to the retention of location, design, setting, materials, workmanship, feeling, and association.

Most components of the window wall assemblies remain unchanged from the time of the Salk's original construction. Alterations to the window walls have been relatively minor and include the previously described application of surface coatings, which have altered the color of the teak; installation of films and other opaque materials to control light at the narrow sheets of glass flanking either side of the window walls; and conversion of a limited number of shutters to glazed sashes. Thus, the window walls can be considered to have a high degree of integrity in terms of location, design, setting, materials, workmanship, and association. Integrity of feeling may be considered slightly diminished by the changed color of some portions of the teak, but it remains very high.

Significance Assessment of Components of the Window Wall Assemblies

Different components of the window walls make different relative contributions to their overall significance. Loss of integrity or poor condition may diminish the relative importance of a component. Specifying the relative contribution of each component provides a framework for developing a conservation policy and for selecting conservation treatments that maintain the overall significance of the window wall assembly. Components with a higher level of significance should be retained or only minimally altered. Components with a lower level of significance may be able to undergo greater change without substantially impacting the overall significance of the assemblies. Table 2.1 identifies the different significance levels, or gradings, used to assess each component relative to overall significance.

Table 2.1. Significance grading categories.

Significance Grading	Definition
Exceptional (E)	*Rare* or *outstanding* component directly contributing to overall significance of the assembly. Includes major components that are original to the window wall assembly. May include some alterations that are minor in nature and do not detract from significance.
High (H)	Component that demonstrates a key aspect significance. Includes components that are original to the window wall assembly. May include some alterations that are of a more substantial nature than exceptional components but do not detract from significance.
Moderate (M)	Component that has little heritage value itself but contributes to overall significance of the window wall assembly. Includes additions or alterations to the original assembly.
Little (L)	Added or altered component that detracts from significance and/or may obscure more significant components.
Intrusive (I)	Added or altered component that damages the assembly's significance.

Table 2.2 provides the significance grading of each component of the window wall assemblies. It also analyzes the following key attributes of each component:

Table 2.2. Significance assessment of the components of the window wall assemblies.

Component	Significance Grading	Attribute (X if attribute embodies significance)				Other Considerations
		Form	Fabric	Location	Use	
Overall window wall assembly	E	x	x	x	x	
Exterior teak cladding (material)	E	x	x	x	x	Teak consumption raises environmental concerns (disappearance of old growth teak).
Wood framing	M	x		x	x	Poor condition, with some areas exhibiting severe termite damage.
Transite board (insulation)	M	x		x	x	Hazardous material (if disturbed).
Sliding sashes: • glazed sashes • louvers • shutters	E for all; except H for glass sheets and M for hardware.	x	x	x	x	Plate glass is a life safety risk and is less energy efficient than other types of glazing.
Sheets of glass at sides of window wall units	E	x	x	x	x	Plate glass is a life safety risk and is less energy efficient than other types of glazing.
Interior paneling: • oak • gypsum • other	E for oak; M for gypsum and other.	x for oak only	x for oak only	x for oak only	x for oak only	
Glass treatments (reflective films, etc.)	I					
Surface coatings at teak cladding	L					

Form: Design, configuration, details, scale, and character
Fabric: Physical material
Location: Original position versus relocated
Use: Original and current use

The table also notes other considerations beyond historic significance or integrity, such as material condition, environmental sustainability, or hazardous materials concerns, which may have a bearing on the selection of a future conservation treatment for the component.[15]

Notes

4 Kahn 1961, 151.

5 City of San Diego, Historical Site Board 1991, 1.

6 Page & Turnbull 2007, 7.

7 American Institute of Architects 2014.

8 Kahn 1961, 151.

9 Brownlee and DeLong 1991, 100.

10 Jack MacAllister, memorandum to the owner's representative, P. W. Roberts, December 9, 1963, Salk Institute for Biological Studies, Off-Site Storage and Archives.

11 Latour 1991, 216.

12 Van Gerpen et al. 2014, 4. It should be noted that much of the teak did not have a grayed-out appearance at the time that the interview of MacAllister was conducted.

13 In 2014, after Phase 1 of this project was completed, a book was published with transcriptions of Kahn in conversation with John W. Cook and Heinrich Klotz (1969–70). In a recording made on December 7, 1969, Kahn was asked about the weathering of the teak wood windows at the Salk Institute. He responded: “Depends on how much weather? The upper ones weather much more than the other ones. They were quite red when they got up there, but now they are sort of a grey and they look almost like the concrete, and they look more so later on when it gets to be really quite white. The walls will become very light” (Prown and Denavit 2014, 116).

14 Carlos Johnson, memorandum to Virginia White on “Sealing of Teak Panels,” July 31, 1968, Salk Institute for Biological Studies, Off-Site Storage and Archives.

15 The concept of assessing the key attributes of different components of an element of a historic building, the definition of these attributes, and the format of table 2.2 has been adapted from conservation policy section of the Draft Sydney Opera House: Conservation Management Plan, 4th ed. That section of the plan utilizes the concept of tolerance for change developed by Sheridan Burke in other conservation management plans prepared by GML Heritage in Australia.

CHAPTER 3

Window Wall Assembly Development History and Description

Chronology of Design, Construction, and Maintenance

The following chronology of design, construction, and maintenance is based on archival research carried out by the Salk Institute and the GCI in Philadelphia at the Louis I. Kahn Collection, the University of Pennsylvania and the Pennsylvania Historical and Museum Commission, and in the Salk's off-site storage facility and archives; a review of existing publications about Kahn's work at the Salk; an interview conducted with Kahn's project architect, Jack MacAllister (see appendix B); and various discussions with the Salk Institute's facilities and maintenance staff regarding care of the window walls over the years. A full timeline of design, construction, and maintenance with citations is provided in appendix A.

Design

Conceptual design work for the Salk Institute began around the time of Salk and Kahn's first visit together to the La Jolla site in early 1960. Kahn presented his initial concept in March 1960 on the occasion of the formal public announcement of the project.[16] Design work continued through 1963, when the construction documents were completed, although annotations on these drawings indicate that revisions were being made through 1964. Construction began prior to the completion of the design documents, with the first concrete poured in 1962.

According to the project architect, Jack MacAllister, while much of the detailed design work was completed by the team he had on site in La Jolla, the "teak walls were one of the few things that were actually detailed in Philadelphia in the office there."[17] This was likely a result of the expertise of the staff remaining in Philadelphia, who had worked on some of the residential projects in the Philadelphia area with similar exterior wood features. Detailing of the window wall assemblies was still under way as late as January 1963, as evidenced by a note from MacAllister accompanying the project specifications, indicating that millwork specifications were not included as the detailing was awaiting completion and approval.

Early outline specifications for the project, issued in January 1962, called for redwood lumber to be used for the millwork, with "grooved maple track inserts in the bottom rail of window frames"; however, by the end of that year the exterior millwork had been changed to teak and the interior millwork to oak. The preliminary specifications issued in March 1963 stipulated that the "exterior wood siding shall be approximately "1½ × 25⁄32" T&G teak boards set vertical and blind nailed between molded teak drips of profile indicated," and that white oak should be used for interior woodwork. The final project specifications, issued on December 9, 1963, provide insight as to the intended finish for the teak, noting "exterior teak to be solid stock teak with a rubbed finish." The teak has been referred to "Burmese teak" over the years, although none of the archival documents reviewed as part of this project substantiates this. An entry in the weekly job meeting minutes issued on March 24, 1964, suggests that the teak was likely grown and/or milled in Thailand.

Construction drawings issued on January 17, 1963, show a design for the window walls that is similar to what was actually built, with one or two rows of T&G vertical siding below the windows and four or five rows of vertical siding adjacent to the window openings (fig. 3.1). It appears that Kahn's office had not settled on this design, as a drawing produced by his office on July 15, 1964, shows a change in the millwork, with larger panels of vertical siding below and adjacent to the window openings (fig. 3.2). This alternative design was being prepared at about the same time Kahn's office was reviewing shop drawings prepared by the millwork subcontractor.

MacAllister noted that the window walls were designed as prefabricated assemblies as a means of both reducing project costs and increasing quality, as the units could be partially assembled in a cabinetmaker's shop prior to being transported to the site.

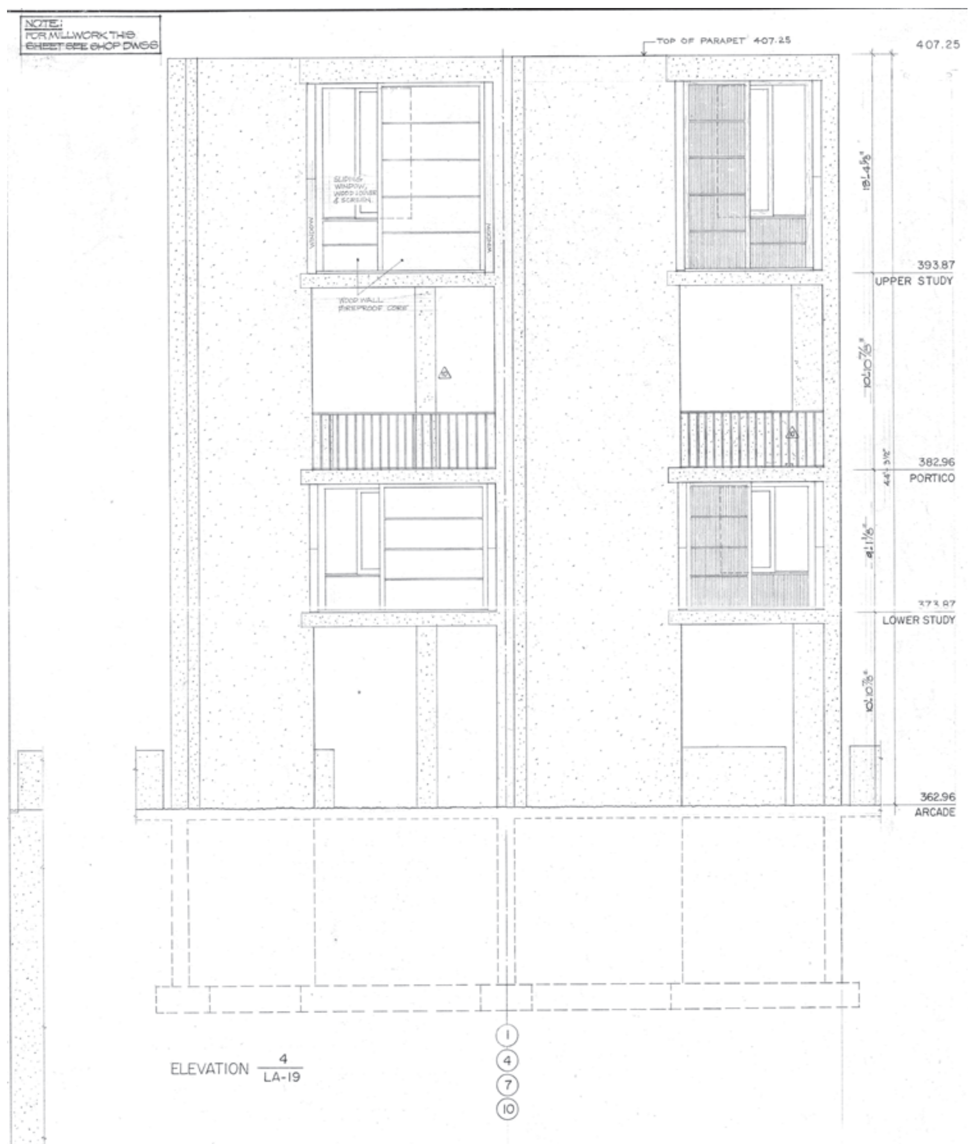

FIGURE 3.1
Elevation illustrating the design of the teak window walls. This elevation is from drawing sheet LA-19, which was part of a set of drawings issued by Kahn's office on January 17, 1963. Although this drawing sheet includes a number of different revisions—the last being issued on July 23, 1965—none of the revision tags are associated with the design of the teak window walls, suggesting that the design dates to 1963. The overall design of the window walls, including the rows of T&G vertical siding, closely matches what was built.
Image: Louis I. Kahn Collection, University of Pennsylvania and Pennsylvania Historical and Museum Commission.

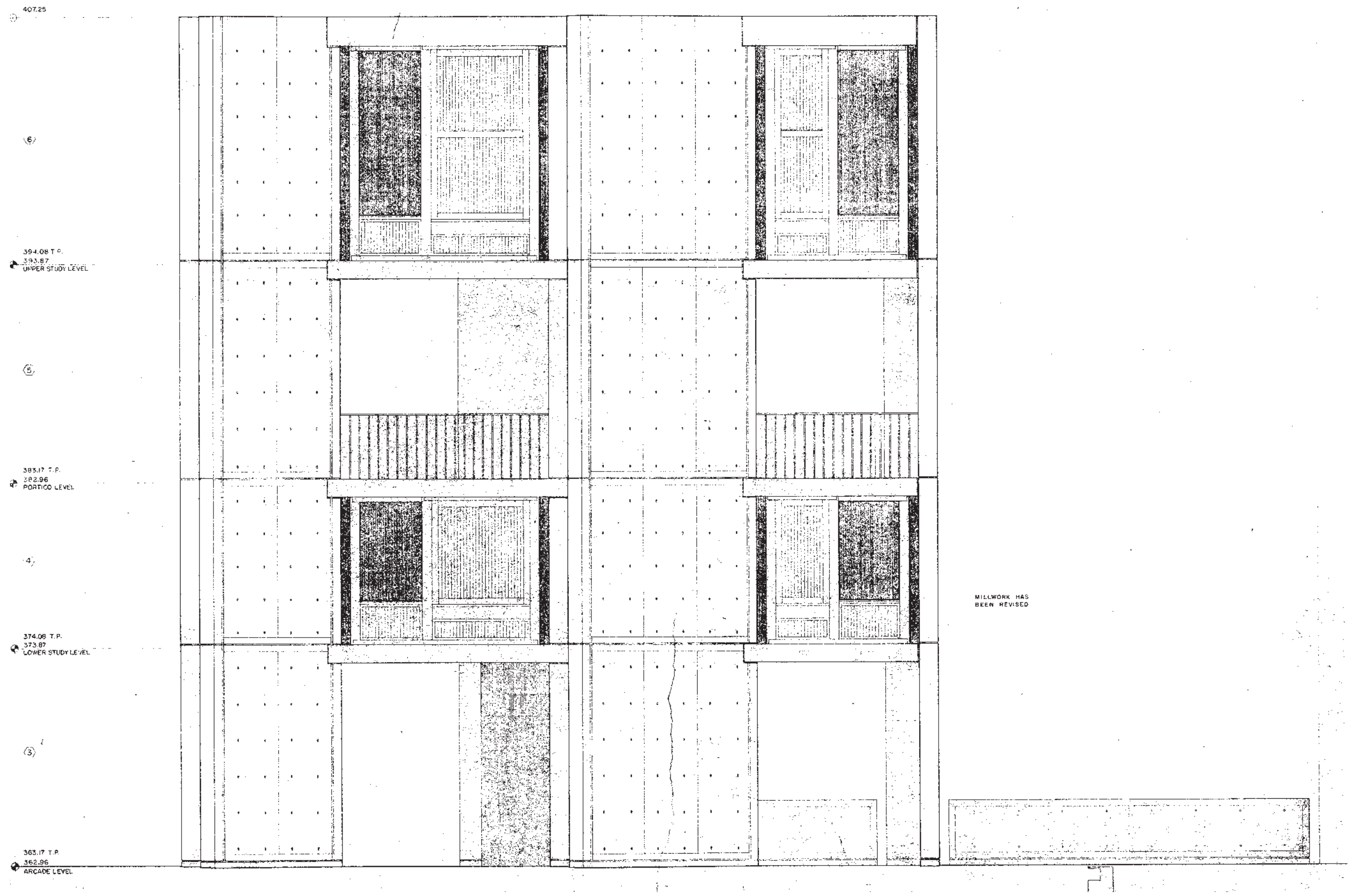

FIGURE 3.2
Elevation drawing (sheet LA-356N), issued by Kahn's office on July 15, 1964, shows an alternative design for the configuration of the T&G vertical siding panels. A note in the margin indicates that "millwork has been revised." This alterative design study was not pursued.
Image: Louis I. Kahn Collection, University of Pennsylvania and Pennsylvania Historical and Museum Commission.

Construction

The George A. Fuller Company, headquartered in New York, was selected as general contractor for the project. Bids for the millwork subcontract, which included the window wall assemblies, were obtained in the fall of 1963, and University Showcase & Fixture Corporation, based in nearby El Cajon, California, was eventually awarded the contract. During the bidding process, a number of alternative woods were considered for their cost-saving potential, including Japanese cypress, benge, Afromosia, and Honduras mahogany; however, the architect stood firm in his selection of teak and ultimately prevailed.

The shop drawings (figs. 3.3, 3.4) for the window walls were prepared between February and July of 1964. The monthly construction reports indicate that the teak was ordered in February and March of 1964, presumably from the mill in Thailand referenced in the March 24 weekly minutes mentioned previously. A full-size mock-up was installed in a north-facing opening of study NL8 (fig. 3.5), a lower study in north tower 10N, in late November 1964 and was approved by the architect. The full order of teak had presumably arrived by January 1965, when full installation of the window walls began in the north studies. Installation then moved on to the south studies and ended with the west office wings (fig. 3.6). Full installation was completed by May 31, 1965.

While the architect prevailed in the use of teak for the exterior cladding at the window walls, several other design items were deleted or deferred as a result of budget overruns, including the following:

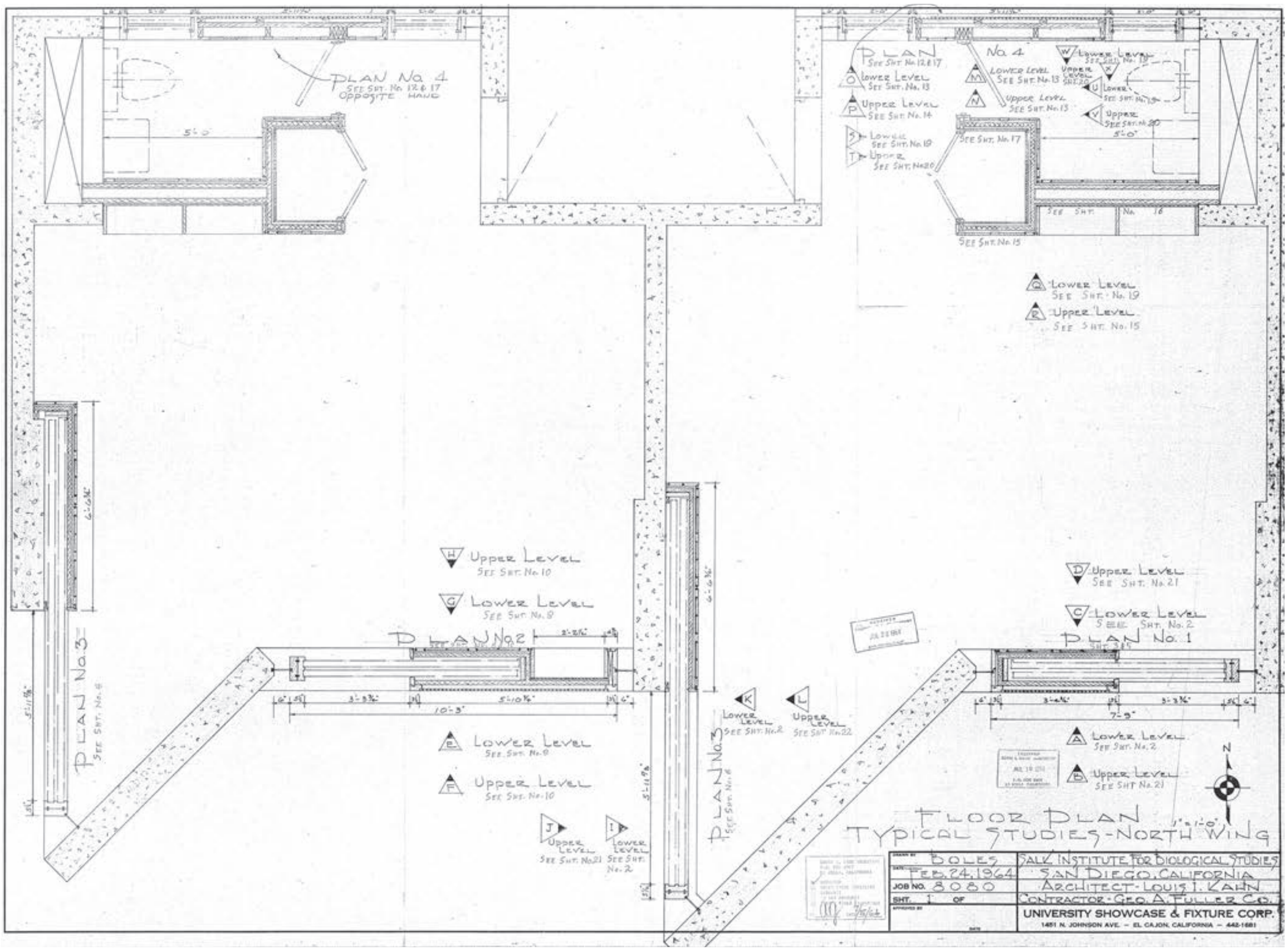

FIGURE 3.3

Floor plan illustrating the typical configuration of window wall assemblies and other millwork in a pair of studies in the north study towers. This plan was part of the shop drawing package prepared by the millwork subcontractor, University Showcase & Fixture Corporation, dated February 24, 1964, and approved by Kahn's office on July 22, 1964.

Image: Salk Institute for Biological Studies.

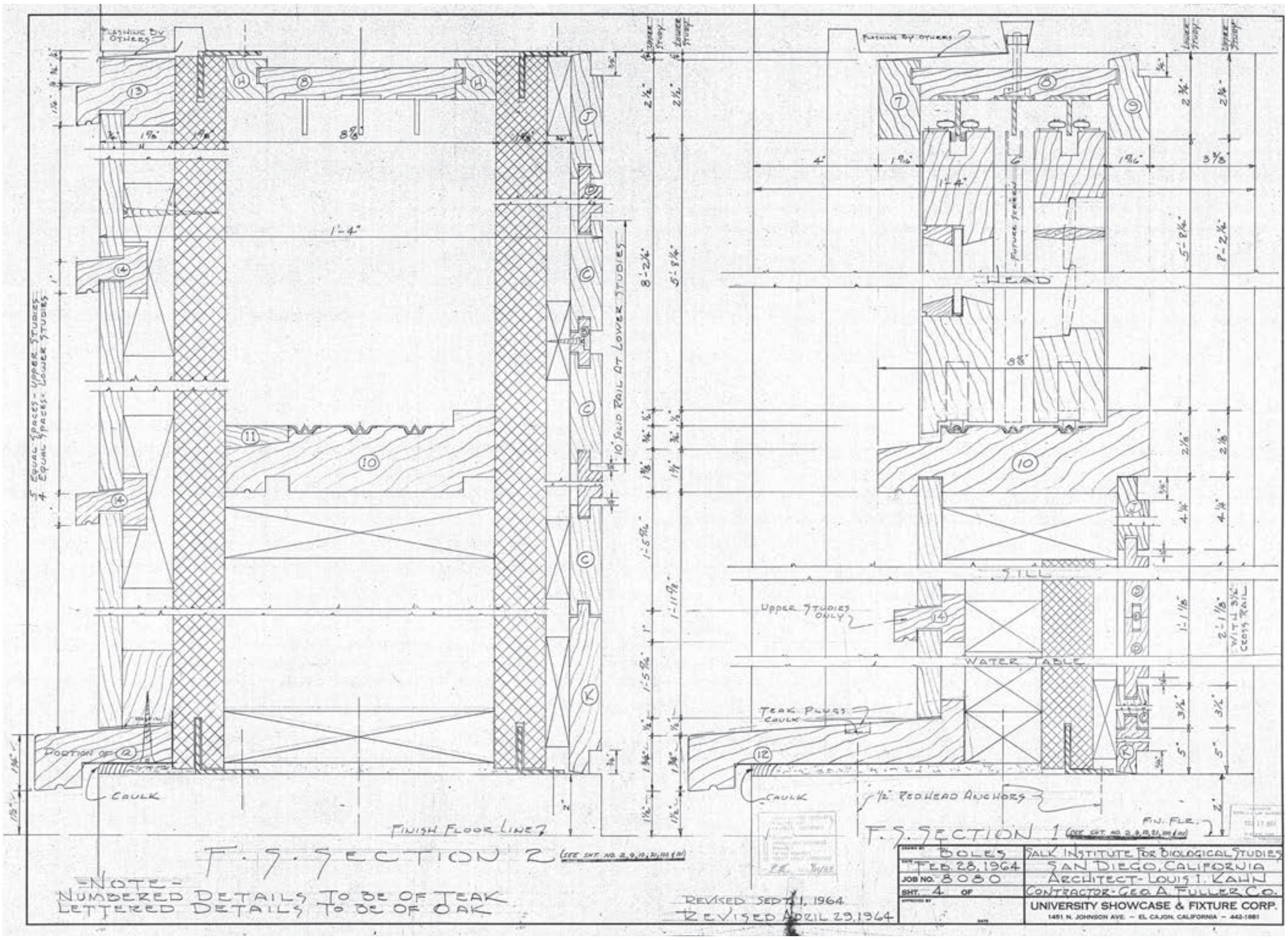

FIGURE 3.4

Typical cross sections of the plaza and west-facing window wall assemblies in the north study towers. The section on the right is cut through the window opening and the section on the left is cut through the adjacent pocket for the windows. This section is part of the shop drawing package prepared by University Showcase & Fixture Corporation and is dated February 28, 1964, with revisions on April 29, 1964, and September 1, 1964. It was finally approved by Kahn's office on September 16, 1964.

Image: Salk Institute for Biological Studies.

FIGURE 3.5

A full-size window wall assembly, referred to as a “pilot,” was installed in a north-facing opening of a lower-level study (NL8) in the north study towers for architect review and approval prior to proceeding with the fabrication of other assemblies.

Image: Salk Institute for Biological Studies.

FIGURE 3.6

Construction photograph, dating to March 1965, showing a crane being used to lift the prefabricated portion of window wall assemblies into place (left of center) in the southern west office wing. Construction workers within the building help to guide the assemblies into place. Interior finishes; sliding window, louver, and shutter sashes; and glazing at either side of the unit would be installed after the prefabricated portion of the assembly was bolted into place.

Image: Louis I. Kahn Collection, University of Pennsylvania and Pennsylvania Historical and Museum Commission, scan 03.V.D.19.2_ Mar 65.

- Screens at all windows, although the tracks for the screens were installed as designed
- The weatherproofing feature for the sliding windows, described as a "vertical strip"
- Sliding horizontal louvers and interior finishes at the southern studies and west office wing. These areas were later completed with a variety of finishes, including gypsum board and wood paneling, and horizontal blinds were installed for light control.

Early Construction Deficiencies and Remedial Actions

Almost immediately following completion of construction, a number of deficiencies were reported:

- Moisture infiltration at horizontal sliding window sashes and louvers:
  - — A June 1, 1965, memo on unsatisfactorily functioning items notes that due to the lack of a vertical strip at the window sashes that was eliminated in the 1963 cutbacks, there is a high potential for the windows to leak.
  - — By December 1966, all windows were identified as leaking. A memo from Salk maintenance staff indicates that once the water gets into the walls, "it runs to the bottom of the framework [and] here the caulking and flashing prevent it from running out," resulting in the water being diverted under the interior wood floors. It should be noted that while the presence of flashing is indicated both here and in the construction and shop drawings, no base flashing was observed in the two investigative probes carried out as part of this project.
  - — In an attempt to correct these leaks, various weatherproofing retrofits have been carried out by Salk maintenance staff at different windows over the years, including a bronze vertical strip channeled into the bottom of various sashes, interior angles installed on the interior side of the sill, and pile strip on the vertical edges of sliding sashes.
- Failure of the sealants installed between the concrete wall and the tops and bottoms of the window walls:
  - — The specified product (Dow sealant #780) did not bond to the teak. According to the architect, the product was recommended by Dow for this particular application; however, Dow blamed the architect for designing an unworkable system, saying that any sealant would have problems bonding to the teak due to the oils. There were numerous unsuccessful attempts, by Kahn's office and the Salk Institute, to get Dow to take responsibility; the ultimate resolution is unknown. The sealant failure resulted in significant water infiltration through the window walls, which led to "standing water under the floors" during a large storm in November 1965 and subsequent storms.
  - — The sealants in place today are largely modern replacements for the original product.
- Growth of the fungus, often referred to as "staining," on the teak surface:
  - — The presence of fungus was first reported in November 1966, less than eighteen months following the window wall installation.
  - — The panels were first washed in 1967; however, the fungus returned soon afterward. In 1968, the Salk contacted the United States Forest Product Laboratory regarding identification of the fungus and suggested treatments to remove it. The fungus was identified as "a heavy accumulation of dark-brown,

Schlerophoma-like hyphae on the wood surface,"[18] and cleaning with bleach solution and/or sanding was advised. The application of a water-repellent solution was also recommended.

— Over the years, the teak was cleaned approximately every two to three years. This cleaning treatment involved some combination of a bleach solution, tri-sodium phosphate (TSP), and wire brushes. The use of the wire brushes was discontinued after it was found to contribute to deterioration of the wood.

Additionally, early photographs of the site show moisture staining at the top and bottom of the vertical siding on many of the window walls (fig 3.7).

Ongoing Maintenance

In the mid-1990s, a two-part cleaner and brightener (TE-KA brand Scrubless Cleaner), along with a wood oil sealer (Tip Top Teak) was applied to the teak in an attempt to improve its appearance and retard further deterioration. The wood oil sealer gave the wood its red appearance, which is still visible in parts of the building today.

The teak continued to be cleaned and sealed on a four- to five-year cycle, with more focus given to the highly visible plaza-facing elevations than to other areas of the building. Around 2009, as the Salk Institute considered a more serious repair project for the window walls, this cleaning process was halted. As of 2014, the only cleaning being undertaken is the washing of the window glass several times a year. Salk maintenance staff report that the windows are regularly maintained, with the interior faces of the sashes sanded and sealed and the operating hardware cleaned and waxed to maintain functionality.

As the interior wood framing of the window walls is susceptible to insect damage, areas exhibiting such damage have reportedly been spot treated with sprays over the years. A preventive treatment was reportedly more systematically undertaken at the south studies in the 1980s, prior to installation of the deferred interior finishes.

FIGURE 3.7
Photograph of a window wall assembly in the lower study of the north wing, taken in October 1967. Note the moisture staining above the sloped teak sill, teak drips, teak T&G boards, and the teak jambs, and below the teak drip cap.
Image: The John Nicolais Collection, The Architectural Archives, University of Pennsylvania, scan aaup.260.I.D.36.12_ Oct 67.

FIGURE 3.8
Aerial view of the Salk Institute, showing the original 1965 construction to the west (left) and the early 1990s addition to the east (right). Both the original and later additions are aligned with the east-west axis of the main plaza.
Image: © 2014 Google, with overlay text by the GCI.

Site and Environmental Description

Location and Orientation

The Salk Institute is located at 10010 North Torrey Pines Road, La Jolla, California (lat 32°53’13” N; long 117°14’46” W). The original 1965 construction consists of two nearly identical buildings, each holding a west office wing, study towers, and a laboratory wing, mirrored on the north and south sides of an open-air plaza. Both the north and south buildings are sited on an axis that aligns with true north. The two buildings are connected by subterranean service spaces and corridors to the east of the plaza. A later addition, dating to the early 1990s, is located across the grove of trees to the east of the original complex (fig. 3.8). The main plaza is located at approximately 363 feet above sea level and approximately 2,250 feet from the coastal shoreline.[19] The teak-clad window walls are located in openings on the north, south, and west facades of the west office wings and study towers.

Environmental Conditions

The nearest weather station with official National Weather Service data is at San Diego International Airport (station 047740, alternatively identified as Lindbergh Field, San Diego WSO Airport), located 15 miles south of the Salk Institute. Immediately to the northwest of the institute, the weather station at Torrey Pines Gliderport (2800 Torrey Pines Scenic Drive) provides data on temperature, rain, humidity, barometric pressure, and wind direction, speed, and gusts. Data are readily available for the previous week, although historic data within the last year reportedly can be obtained through the gliderport weather station website (the GCI was not able to obtain more than two months of back data in its use of the website). According to Rich Parry, contact person for the gliderport weather station, the data meet the requirements for gliderport pilots; however, the data should not be considered official. In particular, Parry noted, the recorded barometric pressures are not accurate.

Data on seasonal sun angles, temperature, and precipitation are provided in tables 3.1–3.3.

Fog is common, with 148.2 days of regular fog and 12.5 days of heavy fog per year for the reporting period from July 1996 to December 2008 at San Diego International Airport. The summer and early fall months are characterized by low clouds at night and in the early morning, which give way to sunshine later in the morning. This fog can be low-lying within the main plaza at the Salk Institute.

Wind speeds for this same period averaged 6 MPH, with an average peak wind gust of 59 MPH. The prevailing wind directions, as reported at the gliderport weather station, are from the southwest, west, and northwest.

Physical Description

A total of 203 wood window walls are extant at the north, west, and south elevations of both the study towers and the west office wings on the campus of the Salk Institute. The widths and heights of the window walls vary across the site, with the taller window walls located on the upper stories of both the study towers and west office wings, and the wider walls located at the west office wings. These window walls are prefabricated, wood-framed assemblies set directly into the concrete wall openings. They extend the full height of each floor and are directly bolted to the concrete roof/floor slab above and curb wall below; however, each side is separated from the adjacent concrete wall by a narrow sheet of glass. Each window wall typically consists of a combination of horizontal sliding window sashes, louvers, and/or shutters, often with an adjacent internal pocket to accommodate these sliding components and occasionally built-in shelving (figs. 3.9, 3.10, and 3.11). These various components allow the occupants to modulate the light and ventilation within their workspaces. Fixed louvers with bronze-framed screens are present in the elevations of the window walls facing the sunken gardens. The exterior faces of the window walls are clad in teak, the interior faces are clad with oak paneling or gypsum board, and the interior stud walls are sheathed with asbestos-cement panels (transite brand product, manufactured by Johns-Manville).

The exterior teak cladding consists of rows of T&G vertical siding separated by horizontal drips, vertical trim boards, a drip cap across the top of wall, and a sloped sill across the bottom. Depending on the overall height of the walls, there are one or two rows of vertical siding below the windows and four or five rows of vertical siding at the adjacent wall surface, in front of the sliding window pocket. At the first and second floors of the office wings, where window walls provide direct access to the adjacent walkway, the sliding sashes extend the full height of the opening, without any T&G vertical siding (fig. 3.12). The T&G siding is nailed to wood or plywood furring strips. In each row of siding, the last board to be installed (typically the second board from the left side of the row) is T-shaped to facilitate installation. Adhesive was applied to the sides of the board to secure it to the adjacent T&G siding boards. The horizontal drips originally had an overhanging lip, which

Table 3.1. Seasonal sun angles at the Salk Institute.

Date	Apparent Sunrise	Solar Azimuth / Elevation	Solar Noon	Solar Azimuth / Elevation	Apparent Sunset	Solar Azimuth / Elevation
Equinox (March 20, 2014)	06:53 PDT	89.57° / −0.3°	12:56:21 PDT	180° / 57.17°	19:01 PDT	270.77° / −0.54°
Summer Solstice (June 21, 2014)	5:41 PDT	61.1° / −0.47°	12:50:50 PDT	180° / 80.55°	20:01 PDT	298.95° / −0.56°
Winter Solstice (December 21, 2014)	6:48 PST	117.7° / −0.36°	11:47:12 PST	180° / 33.7°	16:47 PST	242.38° / −0.52°

Note: Data provided by the Earth System Research Laboratory (ESRL) Global Monitoring Division of the National Oceanic and Atmospheric Administration (NOAA) and available at: http://www.esrl.noaa.gov/gmd/grad/solcalc/, accessed March 9, 2014.

Table 3.2. General climate summary for the San Diego International Airport weather station.

SAN DIEGO INTERNATIONAL AIRPORT WEATHER STATION Period of General Climate Summary, 1914–2012											
	Monthly Averages			Daily Extremes				Monthly Extremes			
	Max	Min	Mean	High	Date	Low	Date	Highest Mean	Year	Lowest Mean	Year
	F	F	F	F	dd/yyyy	F	dd/yyyy	F	—	F	—
January	64.8	48.1	56.4	88	10/1953	29	04/1949	61.7	2003	47.8	1949
February	65.2	49.7	57.4	90	19/1995	36	02/1939	63.5	1980	52.4	1939
March	65.9	51.9	58.9	93	17/1978	38	12/1922	64.3	1978	54.5	1935
April	67.4	54.7	61.1	98	06/1989	41	07/1929	66.9	1992	56.3	1922
May	68.6	58.1	63.3	96	05/1953	45	03/1915	68.6	1997	58.1	1933
June	70.9	60.8	65.9	101	10/1979	50	14/1943	72.9	1981	61.5	1916
July	74.8	64.4	69.6	100	30/1930	55	05/1948	77.2	1984	65.0	1916
August	76.3	65.7	71.0	98	31/1955	57	07/1944	77.4	1983	66.0	1932
September	75.7	63.9	69.8	111	26/1963	51	26/1948	78.9	1984	62.7	1933
October	72.9	59.3	66.1	107	14/1961	43	30/1971	72.2	1983	59.3	1916
November	69.9	52.9	61.4	100	04/2010	36	28/1919	66.8	1976	56.4	1994
December	65.8	48.7	57.2	88	29/1963	34	08/1978	63.2	1977	52.4	1916
Annual	69.9	56.5	63.2	111	09/26/ 1963	29	01/04/ 1949	67.2	1984	59.5	1933
Winter	65.3	48.8	57.0	90	02/19/ 1995	29	01/04 1949	61.7	1980	51.4	1949
Spring	67.3	54.9	61.1	98	04/06/ 1989	38	03/12/ 1922	65.3	1984	56.6	1917
Summer	74.0	63.7	68.8	101	06/10/ 1979	50	06/14/ 1943	74.8	1981	64.5	1916
Fall	72.9	58.7	65.8	111	09/26/ 1963	36	11/28/ 1919	71.1	1983	60.0	1916

Note: Data compiled by the Western Regional Climate Center and available at: http://www.wrcc.dri.edu/egi-bin/cliGCStT.pl?ca7740, accessed March 9, 2014.

Table 3.3. Precipitation summary for the San Diego International Airport weather station.

SAN DIEGO INTERNATIONAL AIRPORT WEATHER STATION Average Total Participation (in inches), 1/1/1914–3/31/2013												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2.00	1.98	1.63	0.78	0.21	0.05	0.02	0.06	0.17	0.51	0.97	1.77	10.13

Note: Data compiled by the Western Regional Climate Center and available at: http://www.wrcc.dri.edu/egi-bin/cliGCStT.pl?ca7740, accessed March 9, 2014.

FIGURE 3.9
View of lower study (NL7), north wing study tower (10N). The exterior teak cladding consists of rows of T&G vertical siding separated by horizontal drips, vertical trim boards, a drip cap across the top, and a sloped sill across the bottom. At study windows facing the plaza, such as this one (NL7C), the pocket for the sliding sashes is also clad with T&G siding.
Image: J. Paul Getty Trust.

FIGURE 3.10
View of a west-facing window in an upper study (SU1B), south wing study tower (1S). The pocket for the sliding sashes is concealed behind the adjacent concrete wall.
Image: J. Paul Getty Trust.

covered the ends of the vertical siding boards; however, in some locations this has weathered away, leaving the drip flush with the faces of the siding boards and the end grains exposed.

The furring strips for the teak and the horizontal drips are either (a) nailed directly to the wood stud framing beneath the windows, or (b) nailed to a 1⅝-inch-thick transite board

FIGURE 3.11
View of a west-facing window (SO4F) in the southern west office wing. There is no pocket for the sashes, and the sliding window and shutter sashes are both exposed.
Image: J. Paul Getty Trust.

FIGURE 3.12
View of a north-facing assembly (SO2A) in the southern west office wing. Where the windows provide direct access to an adjacent walkway, the sliding sashes extend the full height of the opening without any T&G vertical siding.
Image: J. Paul Getty Trust.

at the adjacent pocket for the sliding components. The furring strip material varies by location, with both plywood and white fir observed during the investigative probes.

The width of the wall cavity at the internal framing varies. Narrower framing, generally 2½ to 6½ inches wide, is used beneath the window opening, and wider framing, generally varying from 7½ to 8⅝ inches wide, is used at the adjacent wall containing the internal pocket. White fir is used for both the sill plates and studs, while some of the vertical posts—

such as the window jambs—are made of teak. The sill plate is bolted to the concrete curb, and the wood head spanning the top of the window wall is also bolted to the wall above. Steel angles, nailed to the concrete curb and side of the sill plate, provide additional stability for the base of the internal wall framing (fig. 3.13).

An additional layer of 1⅝-inch-thick transite board is nailed to the inside face of the framing, both at the pocket and below the window, and wood furring strips are attached to the perimeter of each transite board. The interior finishes are then screwed to these furring strips. The north studies and northwest office wing are finished with oak paneling dating to the original construction; the interior finishes for the south buildings were deferred during the original construction period. Gypsum board and wood paneling finishes were installed at a later period in these areas. In Investigative Probe 2, carried out at the southwest office wing window wall number SO4B, building paper was observed attached to the interior face of the framing studs. As this was one of the areas finished at a later date, the building paper may have been installed as a response to earlier problems with moisture infiltration.

At either side of each window wall is a narrow sheet of glass approximately 6 inches in width. This glass sheet is both practical, in that it fills the gap between the rough concrete openings and the prefabricated units, and aesthetic, in that it allows light to spill across the

FIGURE 3.13
View of the internal wood framing at a window (NL6C) in the north study towers, after the internal oak paneling and transite panels were removed as part of Investigative Probe 1.
Image: J. Paul Getty Trust.

interior walls of the studies and offices. The gap between the tops and bottoms of the window walls and adjacent concrete wall is filled with a sealant. Although base and head flashing was called for in the original design and shop drawings, none was observed during the two investigative probes carried out as part of this project.

The hardware for the sliding sashes consists of a top guide (a brass angle screwed to the wood header), a groove in the top rail of the sashes, which engages with this guide, brush gaskets on either side of the groove, two rollers mortised into the bottom rail of each sash, and a recessed brass track recessed into the window sill, along which the rollers move (fig. 3.14). At least two different roller sizes are used, depending on the size of the sash, including a Grant #14 and #18, both of which have nylon wheels and metal housings (fig. 3.15).

Based on the archival research, oral histories, and investigative probes, the sequence of assembly of the window walls is understood as such (fig. 3.16):

1. A portion of the window wall units, including the wood framing, exterior transite board, window frame, head, and sill, and all exterior teak cladding are preassembled off-site in the millwork subcontractor's shop.

FIGURE 3.14
The wood header and hardware at the window openings—this one in north wing study tower 7N (NL6C). Brass angles screwed to the wood header act as guides for the window and louver sashes.
Image: J. Paul Getty Trust.

FIGURE 3.15
A louver sash, removed for maintenance in the shop at the Salk Institute maintenance shop. Note the two rollers mortised into the bottom rail of the sash.
Image: J. Paul Getty Trust.

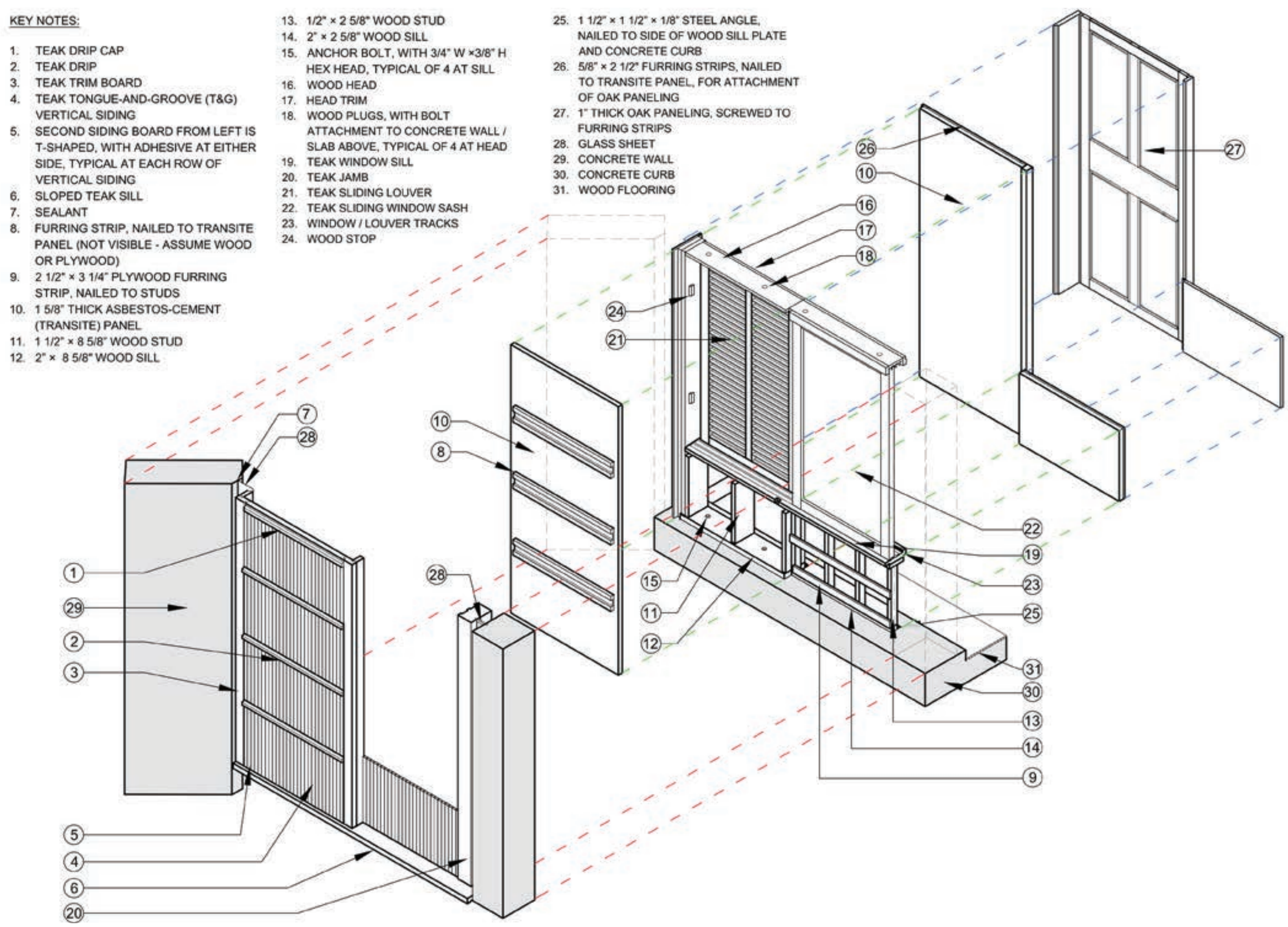

FIGURE 3.16
Exploded axonometric view of the window assemblies, illustrating the various components. Drawing was informed by Investigative Probe 1 carried out on the south-facing window in the lower study of the north wing.
Image: J. Paul Getty Trust.

2. The preassembled window wall units are delivered to the site in a flatbed truck and craned into position. Construction crew members shim each of the window wall units into place. The tops and bottoms of the window wall units are bolted to the concrete roof and floor slabs. A steel angle is nailed to the base of the wood sill plate and concrete wall to provide additional stability.
3. Interior transite board is nailed to the wood framing.
4. Six-inch-wide sheets of glass are installed on either side of the window wall units and grouted into a channel in the adjacent concrete walls.
5. Oak paneling is screwed to transite board, and wood plugs are installed to conceal screws (at the north study towers and northwest office wing only; installation of interior finishes at the south buildings was deferred during the initial construction as a cost-saving measure).
6. Horizontal sliding window sashes, louvers, and shutters are installed at guides and tracks already set within window head and sill.*
7. Fixed louver and bronze-framed screens are installed.*
8. Exterior sealant is installed between the tops and bottoms of the window wall units and the adjacent concrete walls.*

   *Note: The exact sequence of these items is unknown but most certainly occurred after the preassembled units were bolted in place.

The floor plans and elevations provided in appendix D illustrate the locations of all window walls and the assigned numbering system used for this project. The three-dimensional drawings and photographs of the investigative probes, provided in appendix E, illustrate the previously described details and sequence of assembly.

Notes

16 Brownlee and DeLong 1991, 330.

17 Van Gerpen et al. 2014, 10.

18 Letter from W. E. Eslyn, plant pathologist, fungus and insect investigations, Forest Products Laboratory, to Carlos Johnson, Salk Institute for Biological Studies, April 9, 1968, Off-Site Storage and Archives.

19 Vertical elevations are derived from data points provided in the original construction documents prepared by Kahn's office; measurements from the coastline were obtained through Google Earth.

CHAPTER 4

Condition Assessment

Existing Conditions and Observations

The window wall assemblies exhibit a range of conditions that were observed through a visual condition survey of all window walls conducted on site visits in October 2013, December 2013, and March 2014. Two investigative probes were undertaken in March and April of 2014; interior oak paneling and sheathing were removed to better understand the interior construction details and conditions of the window walls. The conditions and construction details were recorded on the drawings that appear in appendices D and E of this report and are further described in the text that follows.

Teak Wood Cladding

Weathering

Weathering of the wood is the result of the action of cyclic wetting and drying, exposure to ultraviolet (UV) light, and erosion through windblown debris, such as sand or other particles. The weathering process changes the appearance of the wood and gradually erodes the wood fibers. It is readily apparent from the silver-gray patina that develops on the surface of the wood and the small splits that develop, as well as from the rough surface texture. This patina and texture is often considered to be an aesthetically pleasing characteristic of wood. Rates of weathering vary by wood species and are greatly influenced by wood density, climate, and exposure to the elements; but the weathering process is typically quite slow. However, as a long-term process, it is a significant factor in the deterioration of wood exposed to the environment, although the wood is seldom damaged enough to require replacement.

Bleaching and Gray Patina

Both bleaching, or fading, and the development of a gray patina are the result of exposure to UV light. At the Salk Institute, the bleaching and patina vary considerably across the building, with those areas in direct sunlight being the most affected. The effect is most significant at the south-facing elevations of all buildings, with the degree of bleaching and gray patina increasing from the lower levels to the upper levels (fig. 4.1). It is noticeably reduced or absent in areas protected from exposure by overhead walkways or roof elements. The west elevations exhibit moderate to light bleaching, and no bleaching was observed at the north elevations. At both the west and north elevations, the gray patina appears in those areas that also exhibit moisture staining or a fungal biofilm. Across all elevations, the gray patina is more prevalent on the horizontal sills, drips, and vertical trim boards than it is on the vertical T&G siding boards (fig 4.2).

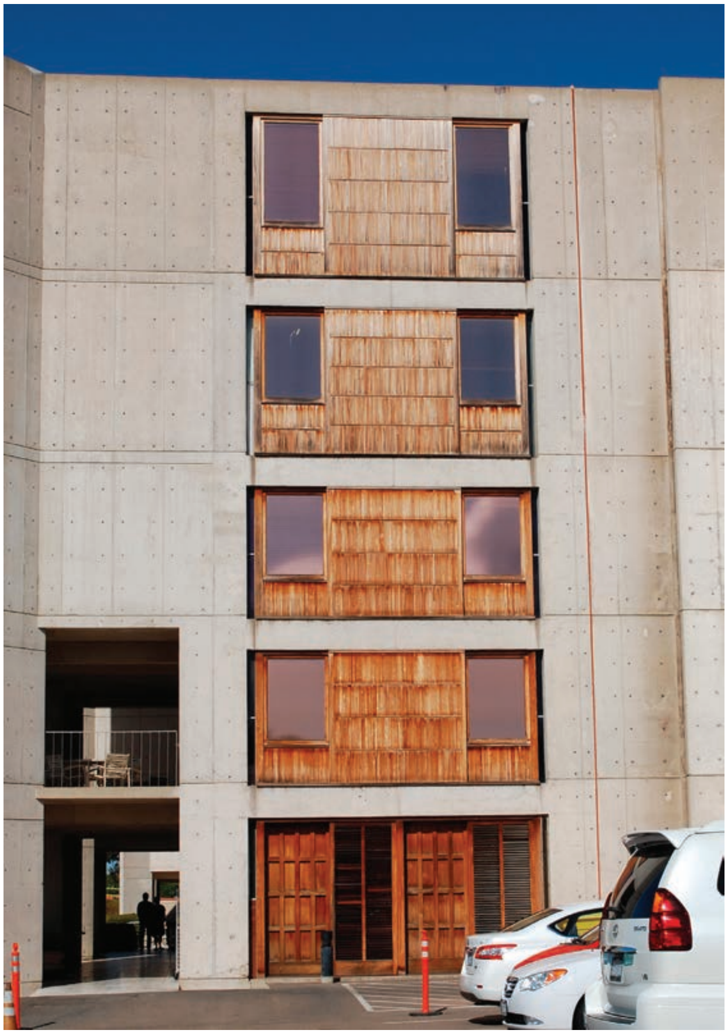

FIGURE 4.1
The degree of bleaching and gray patina increases from lower levels to upper levels at south-facing elevations, such as this one at the southern west office wing.
Image: J. Paul Getty Trust.

FIGURE 4.2
South study tower, lower level, north-facing window (SL4C). The gray patina is most prevalent on the horizontal sills, drips, and vertical trim boards. It also appears in those areas that exhibit moisture staining.
Image: J. Paul Getty Trust.

Erosion

Erosion of the wood surface occurs when individual wood fibers slough off or larger wood chips are lost as a result of the cyclic wetting and drying of the wood, which leads to swelling, shrinking, checking, and splitting. The exfoliation of small pieces of weathered wood exposes fresh surfaces which are then exposed to the weathering process. Additionally, windblown debris continuously erodes wood fibers. The erosion process can be accelerated through the use of aggressive cleaning practices, such as harsh bleach treatments or the use of wire brushes. Most of the teak at the Salk Institute has experienced some degree of erosion on its exposed face; however, as with the sun bleaching and gray patina, it varies greatly by orientation and degree of protection. Observed patterns of erosion are as follows:

- Severe erosion (loss of approximately 20% or more of surface depth) was observed at south-facing elevations of both the office wings and the north study towers (figs. 4.3, 4.4); these conditions increase from the lower levels to the upper levels. In these areas of significant erosion, the following was noted:
  — The outer portion of the groove of the vertical T&G boards has completely weathered away, giving the appearance of shiplap rather than T&G joint and leaving nail heads of the fasters exposed (fig. 4.5).
  — The outer face of the horizontal drip, which was designed to lap over the tops of the vertical boards, has eroded away, leaving the drip flush with the face of the boards and the end grains of these boards unprotected (fig. 4.6).
- Moderate erosion (80% to 90% of the original thickness remaining) was observed in the west elevations of all buildings; however, only minimal erosion was observed in portions of the elevations set in recessed wall pockets, such as window walls NO6G and NU2B, which offer a greater degree of protection from light and wind.

FIGURE 4.3
Northern west office wing, south-facing window, sixth floor (NO6K). The vertical siding and horizontal drips exhibit severe erosion.
Image: J. Paul Getty Trust.

FIGURE 4.4
Vertical T&G boards from window wall assembly NO6K, which were blown out of place during a February 2014 storm. Note the severely deteriorated surface of the teak.
Image: J. Paul Getty Trust.

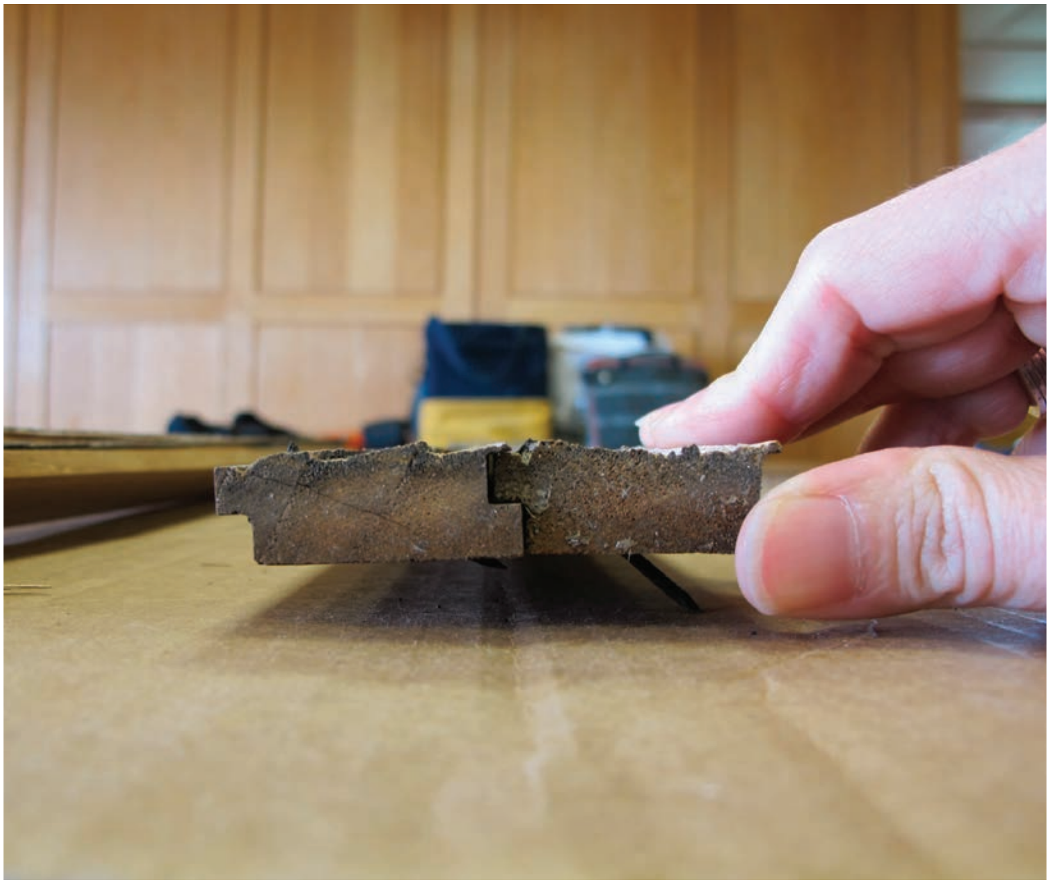

FIGURE 4.5
Vertical T&G boards from window wall assembly NO6K. The outer edge of the grooved piece has weathered away, giving the appearance of a shiplap rather than T&G joint.
Image: J. Paul Getty Trust.

FIGURE 4.6
Northern west office wing, south-facing window, sixth floor (NO6K). The outer face of the horizontal drip (top of image) has eroded away, leaving the drip flush with the face of the boards and the end grains of these boards unprotected.
Image: J. Paul Getty Trust.

FIGURE 4.7
North wing office, north-facing window, sixth floor (NO6A). The teak exhibits minimal erosion, and the horizontal drips still overlap the tops of the vertical T&G boards. Image: J. Paul Getty Trust.

- Minimal erosion (90% or more of the original thickness remaining) was observed in the north elevations of all buildings, with the least degree of erosion observed in those elevations that do not face the main plaza, such as the sunken garden–facing elevations of the north study towers and the northwest office building (fig. 4.7).

Moisture Staining

Moisture staining is the result of rain, moist ocean air, or fog accumulating on the horizontal surfaces of the sills and drips, which is then absorbed and deabsorbed through the end grains of the siding boards and other vertical elements (fig. 4.8). In the process, tannins and extractives in the wood leach out, leaving discolored lines at different heights where they were washed away. Areas exhibiting moisture staining frequently correspond to areas with a gray patina or fungal biofilm.

Iron Staining

Black stains are present around and below the rows of nails used to fasten the T&G vertical siding boards to the underlying furring strips (fig. 4.9). These stains are most noticeable where the teak is eroded to a depth at which the nail heads are exposed.

Although galvanized nails were originally used to fasten the exterior teak cladding, the galvanic coating has deteriorated over time as surface erosion of the teak exposed the nail heads to atmospheric conditions such as airborne salts. The metal-oxide staining observed is a result of a chemical reaction between the exposed iron in the

FIGURE 4.8
North wing office, north study tower (1N), north-facing upper study window (NU1A), showing moisture staining above the sill, above and below the drips, and below the drip cap.
Image: J. Paul Getty Trust.

FIGURE 4.9
North study tower (4N), west-facing lower study window (NL4B), showing iron stains around and below the rows of nails used to fasten the vertical T&G siding boards to the underlying furring strips.
Image: J. Paul Getty Trust.

nail core and the natural extractives in the wood. Staining of this nature often penetrates many cell layers into the wood surface and can be difficult to remove without aggressive sanding, which in turn reduces the overall remaining thickness of the wood.

Other Staining and Deposits

Calcite deposits were noted on some of the elevations of the study towers facing the sunken gardens (fig. 4.10), directly beneath those areas where concrete bridges interface with the study tower walls.

Fungal Biofilm

The fungal biofilm presents as a black, sooty material deposited on the surface of the teak or in cracks (fig. 4.11). The heaviest growths were observed on elevations with limited exposure to UV light, such as the north elevations of the west office wings (fig. 4.12) and in areas with moisture staining, such as the lower portions of the vertical T&G siding boards, just above the horizontal sills and drips. South-facing elevations, those elevations of the study towers that face the sunken gardens (north elevation of the north study tower and south elevation of the south study towers), and areas protected by roof overhangs or set in recessed wall areas exhibit little to no growth. At all elevations, the fungal biofilm deposits are heaviest at the upper levels of the walls, nearest to the ocean.

Past Surface Treatments with a Red Appearance

Portions of the teak have a red, somewhat shiny appearance that is associated with the application of a past surface treatment; however, this treatment has weathered differentially (fig. 4.13). Presently, the deepest and most consistent red appearance occurs at those window walls protected by the overhang of a walkway above, such as the west-facing window walls on the two lower levels of the west office wings. In areas that are only partially

FIGURE 4.10
South study tower, south-facing lower study window, showing calcite deposits at the top of the window wall assembly.
Image: J. Paul Getty Trust.

FIGURE 4.11
Detail view of a west-facing window in the northern west office wing (NO6J). The fungal biofilm presents as a black, sooty material deposited on the surface of the teak or in the cracks.
Image: J. Paul Getty Trust.

FIGURE 4.12
North elevation of the northern west office wing. The heaviest growths of the fungal biofilm occur on elevations with limited exposure to UV light.
Image: J. Paul Getty Trust.

FIGURE 4.13
North study tower (4N), north-facing lower study window (NL3A). The overhang of the walkway at upper left protects part of the fenestration from UV exposure, resulting in differential weathering of the later surface coatings.
Image: J. Paul Getty Trust.

covered by the roof, such as the lower-level window walls of the studies that face the gardens, there can be a dramatic shift in the red appearance across the exterior face of a single window wall as it weathers away.

Insect Damage

Although teak is considered naturally resistant to termites, minor insect damage was visually observed in some of the T&G vertical siding boards and vertical trims (fig. 4.14). Although superficial and limited in nature, the damage typically was observed in the upper levels of south-facing walls exhibiting severe levels of erosion.

Missing Elements

The visual condition survey noted several missing T&G vertical siding boards. The missing board was usually the second vertical board from the left in a row of boards, corresponding to the last T-shaped board installed in a row of T&G boards and secured in place with adhesive on the edges (fig. 4.15). The missing boards were most prevalent in the upper levels of south-facing elevations of the south study towers with severe levels of erosion. The loss of surface depth reduces the capacity of the joint and, coupled with UV degradation of the adhesive, leads to the board becoming loose and eventually falling to the ground. One notable exception to this pattern was the loss of three quarters of the boards in a row at NO6K during a severe storm in February 2014, revealing severe water and termite damage to the underlying furring strips (fig. 4.16).

FIGURE 4.14
North study tower, south-facing upper study window (NU7C). Insect damage is visible behind the furring strips behind the removed vertical siding member, as well as in some of the teak members.
Image: J. Paul Getty Trust.

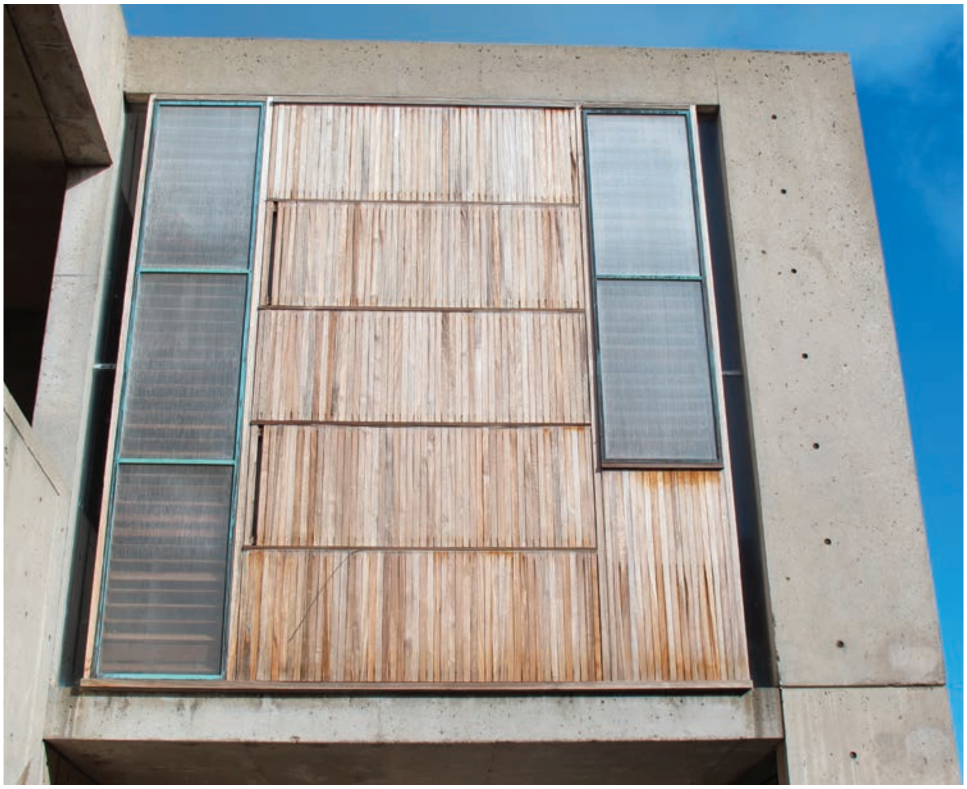

FIGURE 4.15
South study tower (7S), south-facing upper study window (SU6A). The second vertical siding member from the left has fallen out of place on both the second and fourth panels, due to surface erosion and failure of the adhesives that held this board in place.
Image: J. Paul Getty Trust.

FIGURE 4.16
North wing office, sixth floor, south-facing window (NO6K). The project team investigates failure of the vertical siding boards and furring strips following a storm in February 2014.
Image: J. Paul Getty Trust.

Salk maintenance staff have been diligent about reinstalling fallen boards or replacing in-kind at areas in public view or easily accessible by ladder or lift.

Internal Framing

Insect Damage

Insect damage was observed in exterior furring strips (to which the vertical T&G siding boards are nailed), as well at the internal framing of one of the two window walls opened for detailed investigation.

Probe 1, carried out at window wall number NL6C, a south-facing window on the lower level of the north study tower, revealed extensive insect damage in the sill plates, studs, window sill, and stops for the sliding windows and louvers (all white fir), as well as at the plywood furring strip for the vertical siding boards beneath the window opening (fig. 4.17). The damage was most significant in the sill plate, with a loss of approximately 50% of the area and two of the four anchor bolts no longer engaging with any wood, and in the lower portions of the studs. This is of great concern, as it impacts the overall structural stability

FIGURE 4.17
Probe 1, carried out at a south-facing window (NL6C) on the lower level of the north study tower, revealed extensive moisture infiltration and insect damage. Note the significant damage to the sill plate. The bolt in the bottom center of the image is no longer engaging with any wood.
Image: J. Paul Getty Trust.

FIGURE 4.18
Probe 2, carried out at a west-facing window in the southern west office wing (SO4B), revealed water damage but no insect damage.
Image: J. Paul Getty Trust.

of the units. Minor damage was noted in the upper portions of the framing, such as at the stops for the sliding windows and louvers. The area of damage also corresponds to an area exhibiting significant moisture staining along the base of the wall framing.

No insect damage was observed in Probe 2, carried out at window wall number SO4B, a west-facing, midlevel window in the southern west office wing (fig. 4.18). Water damage was noted; however, the presence of building paper and the possible application of a termite-resistant treatment in this area may partially explain the lack of damage in this location.

For additional discussion of the insect damage, including identification of the insects, refer the physical material condition analysis section of this chapter. Refer to appendix E for photographs illustrating conditions at the two probes.

Corrosion of Structural Fasteners

At Probe 1, which exhibited significant moisture staining, corrosion in the steel angle at the base of the wall and anchor bolts was also observed.

Internal Finishes

The internal finishes at the window walls, including the oak paneling and gypsum board, were not investigated as part of this study. However, the oak paneling that was removed to facilitate Probe 1 appeared to be in good condition, with limited water damage along the base of the panels.

Sliding Windows, Louvers, and Shutters

The sliding windows, louvers, and shutters, all constructed in teak, are original to the building, as is the operating hardware. The following modifications were observed during the preliminary condition survey:

- Removal of louvers and conversion of one shutter to a glazed sash at window walls NO4E and NO4F to provide unobstructed ocean views.
- Several of the sliding window sashes and louvers at the ground floor of the west office wings (level 02) have been fixed in place to accommodate interior programmatic needs.
- Installation of various films and reflective sheets at some south- and west-facing glazing to better control solar light and heat gain.

Although a detailed survey of each sliding window, louver, and shutter was not performed, many appeared to be generally sound, with the exception of south-facing window sashes on the upper levels of the office wings, which have open joints between the bottom rail and stiles, degraded sealants, and loose glazing. Additionally, some of the louver slats were cracked, eroded, or missing. Due to their solid teak construction and large dimensions, the window sashes, louvers, and shutters are heavy and can be difficult to operate. The operating hardware is regularly maintained (removed from the frames, taken to the shop and dismantled, and operating mechanisms waxed) by maintenance staff, which facilitates operation.

Moisture staining is extant on the sides and bottoms of some of the sashes and sills, as well as at interior finishes adjacent to the window openings, particularly at west-facing windows. Archival records indicate that the windows have been leaking almost since the completion of construction. Over the years, a variety of retrofits have been installed in an attempt to improve the performance of the windows. An extensive survey of these retrofits was not undertaken as part of this scope of work; however, the following types of retrofits were observed:

- At window wall SO4B, a small channel, created from two bronze angles, is attached to the sill, directly behind the bottom rail of the window sash (fig. 4.19). This is understood to have been one of the earliest retrofitting attempts to limit water infiltration below the bottom of the sash.
- At a number of windows throughout all buildings, a bronze metal strip has been installed at the exterior face of the track in the window sill, and a groove has been routed out of the bottom rail to accept this strip (fig. 4.20). As with the previous retrofit, the goal of this was to reduce water infiltration between the sash and sill. The groove for this strip is located very near to the exterior face of the rail, leaving a thin section of wood in front of it. In some locations, this strip of wood has eroded away, leaving the bronze strip exposed and visible from the exterior.
- At the west office wings, vertical weather stripping has been installed to prevent air and moisture infiltration through the adjacent window pocket (fig. 4.21). Typically, it is bronze weather stripping, screw-attached to the jamb, with a brush insert that closes the gap between the window stile and jamb. This retrofit is limited to those windows with an adjacent pocket and is not in use at those openings, such as NO6B, with side-by-side shutters and window sashes without a pocket.

Transite Panels

Transite panels are used as sheathing at both the exterior and interior faces of the stud wall framing. Investigative Probes 1 and 2 showed the transite panels to be in good condition, with limited areas of water damage; however, as transite contains asbestos, if disturbed it must be handled as a hazardous material.

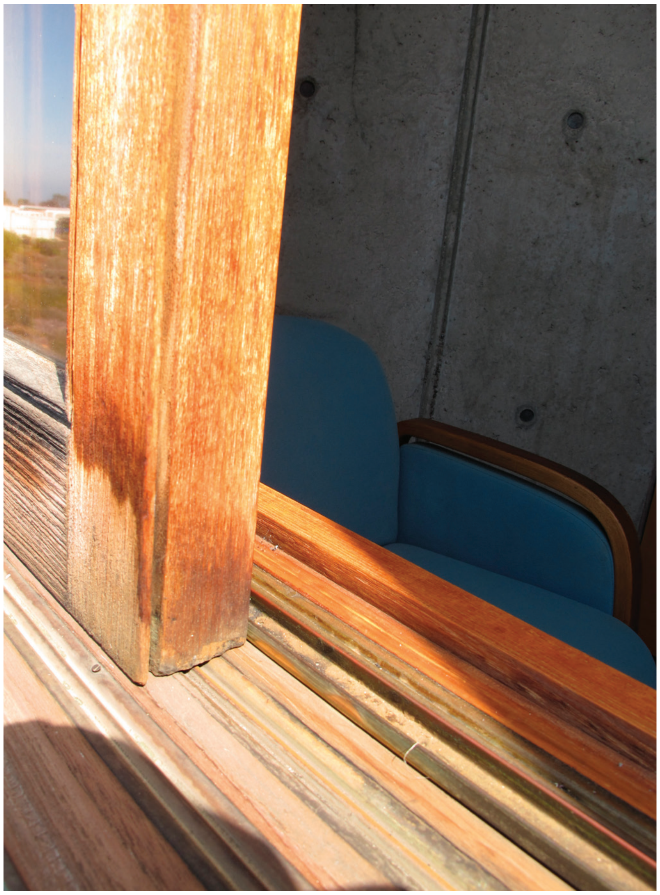

FIGURE 4.19 (TOP LEFT)
Southern west office wing, west-facing window (SO4B). Two bronze angles have been attached to the sill, directly behind the bottom rail of the window sash, in what is believed to be one of the earliest retrofits to improve the performance of the windows.
Image: J. Paul Getty Trust.

FIGURE 4.20 (TOP RIGHT)
South study tower (1S), north-facing lower study window (SL2C), showing the bronze metal strip installed at the exterior face of the track in an attempt to reduce water infiltration.
Image: J. Paul Getty Trust.

FIGURE 4.21 (BOTTOM)
Northern west office wing, south-facing window (NO6K). Vertical weather stripping has been installed at the right jamb in an attempt to prevent air and moisture infiltration.
Image: J. Paul Getty Trust.

Other Elements

Failure of the sealant in the joint at both the top and bottom of the window walls was observed in many locations (fig. 4.22). This condition occurred most often in the joint below the sloped sill.

Physical Material Condition and Laboratory Analysis

Physical and laboratory analysis of samples collected from the site was undertaken to identify wood species and past surface treatments and to increase understanding of the weathering and deterioration mechanisms (figs. 4.23, 4.24). Approximately seventy samples, including dust deposits and fungus removed to the surface of the wood and wood samples ranging in size from 1.5 mm diameter core samples to full-size vertical T&G siding boards, were analyzed (see appendix F for the complete sample log).

Physical Material Condition Analysis

The GCI's wood science consultant, Anthony & Associates, carried out a physical condition analysis of the wood to determine species, identify physical properties, and improve understanding of weathering and deterioration mechanisms. The analysis was based on on-site observations and the removal of twenty-two samples of both the teak and supporting furring strips and internal wood framing for more detailed study (fig. 4.25). A summary of key results follows; see appendix I for the full report.

FIGURE 4.22
Northern west office wing, west-facing window (NO5G), showing sealant failure between the top of the teak window wall assembly and the adjacent concrete.
Image: J. Paul Getty Trust.

FIGURE 4.23
Project team collecting small samples from the site for laboratory analysis of the fungal biofilm.
Image: J. Paul Getty Trust.

FIGURE 4.24
Project team collecting small samples from the site for laboratory analysis of the past surface treatments.
Image: J. Paul Getty Trust.

FIGURE 4.25
Project team conducting a visual condition survey of the window wall assemblies. Image: J. Paul Getty Trust.

Wood Identification

The original construction specifications for the Salk Institute identify the exterior millwork as "solid stock teak" with a rubbed finish; however, there are no other documents to confirm that teak was the wood species that was ultimately installed, beyond a reference in the weekly job meeting minutes to a mill location in Thailand. True teak wood is similar to many other tropical hardwood species, some of which are commonly referred to as "teak." Therefore, it is important to confirm the species of the teak for the purposes of analyzing its current condition, developing conservation treatments, and sourcing replacement material where needed for more serious repairs.

Nineteen samples of exterior wood, including vertical T&G boards, trims, and louvers were collected and identified through macroscopic and microscopic examination as teak (*Tectona grandis*). Of these samples, six were sent out for independent species verification, which confirmed teak (*Tectona grandis*) is extant at the Salk.

Tectona grandis is a tropical timber species native to Southeast Asia, although it is now grown on plantations around the world. Its typical characteristics include heartwood that is a golden or medium brown that darkens with age; a spicy, leather-like odor; and a coarse texture with medium-size open pores. The grain tends to be straight but can occasionally include wavy or interlocked grain. Freshly milled teak tends to have a slightly oily feel due to the presence of natural oils. Teak is considered to be naturally durable, resistant to decay fungi and insect attack.

Microscopic and macroscopic characteristics of the wood cannot be used to differentiate teak grown in Southeast Asia from plantations elsewhere. The GCI investigated the possibility of using DNA analysis to glean further information on the origin of the teak; however, we understand that there is not a sufficient database of information at this time to use DNA analysis to identify the region in which the teak was grown.

Based on an analysis of growth rates, specific gravity, and moisture content, most of the wood analyzed is consistent with naturally grown teak, although other samples fall within the expected ranges for plantation-grown teak.

The species of the softwood used for the internal wood framing and furring strips was also analyzed through the collection of three samples. The wood used at the internal framing was identified as softwood, white fir (*Abies* spp.). Both white fir solid stock pieces and plywood were used for the furring strips. None of these specimens showed evidence of any wood preservatives, which would protect against insect infestations.

Physical Characteristics Impacting the Performance of the Teak

A number of physical characteristics that contribute to the appearance of the teak and also have a bearing on its weathering and erosion mechanisms, including growth rate, orientation of the grain, tree center in relationship to exposed face, and specific gravity and moisture content, were also examined. The analysis showed the wood elements exhibit a variety of growth-ring counts and cuts, including flat vertical, rift-sawn cuts, with the majority of samples analyzed being rift-sawn. Flat-grain specimens have less surface texture than vertical-grain specimens, and samples with higher ring counts per inch have less erosion and surface texture. However, the erosion rate of the samples is more a factor of exposure conditions than of wood or ring count per inch.

This variability in cut and rings-per-inch count in teak elements of adjacent assemblies, or even within adjacent teak elements in the same assembly, means that differential weathering will occur even in panels with the same exposure.

Erosion Analysis

As part of the physical analysis, rates of erosion were quantified and remaining service life was estimated (table 4.1):

Table 4.1. Estimated remaining service life for eroded teak.

Rate of Erosion	Definition	Estimated Remaining Service Life
Minor	90% or more of original thickness remaining	30 to 60 years, depending on extent of current erosion
Moderate	80%–90% of original thickness remaining	30 to 60 years, depending on extent of current erosion
Severe	Less than 80% of original thickness remaining	Up to 25 years, depending on extent of current erosion

Insect Damage

The insect damage at the Salk Institute was the result of termites, which were identified as drywood termites (*Incisitermes* spp., likely *I. minor*). This species lives in small social colonies, ranging in size from fifty to three thousand insects per colony. They do not require contact with soil or sources of moisture within the wood and remain entirely above ground. They are easily identifiable by the frass, or fecal pellets, that accumulates at the base of infested wood members. Interior termite galleries in the wood tend to be broad pockets or chambers connected by smaller tunnels that cut across latewood. Irreparable damage to wood elements can be caused by drywood termites in two to four years' time, depending on the size of the wood element and the size of the infestation.

These termites are responsible for the damage to some of the white fir wood used for the internal wood framing of the window wall assemblies. This wood has no natural resistance to termites. Based on the two investigative probes carried out as part of this project, the framing in some wall assemblies has been severely compromised by infestations, while framing at other wall assemblies remains in good condition. Termite frass was observed on the floor directly below several other wood window walls throughout the complex, indicating other areas where termite infestations have occurred, although the extent of damage at these areas was not observed.

Some insect damage was observed in the exterior teak cladding. Based on the results of the preliminary visual condition survey, this damage was determined to be superficial and limited to only a few elements, and did not represent a risk to the long-term performance of the teak.

Laboratory Analysis

The GCI Organic Materials Laboratory carried out analyses to identify and better understand the fungal biofilm, materials used in past surface treatments of the teak, and other surface deposits on the wood. A summary of key results is provided below; see appendices G and H for the full reports.

Fungal Biofilm

The presence of a black fungus on the surface of the teak has been a recurring problem since the earliest years of the Salk Institute. Based on the results of DNA analysis, it can best be described as several different types of fungi that have evolved from a common ancestor, predominately from the order Capnodiales. It most likely comes from the surrounding environment, borne on either wind or water droplets, as the leaves from eucalyptus trees surrounding the institute were found to contain similar types of fungi. It is primarily a surface phenomenon, with deposits sitting on the surface of the wood, as a film, and penetrating no more than 1 mm. The fungus is not specific to teak—it has been observed on the surface of other wood buildings in La Jolla. Most importantly, it is not a wood-decay fungus, which breaks down the lignin that protects the wood cellulose. This is consistent with the physical material condition analysis conducted by Anthony & Associates—none of the teak samples examined were found to have wood decay fungi, and there was no evidence of active wood decay fungi at those window wall assemblies assessed in the field.

These fungi have adapted to living on a variety of substances, the result being that many different types of materials can serve as possible food sources, potentially even the drying oils used in past surface treatments. Eliminating or reducing water infiltration will be a critical part of any solution to retard growth, as fungi will thrive wherever there is water.

Past Surface Treatments

Laboratory analysis of past surface treatments detected the presence of Tip Top Teak Wood-Oil Sealer, both in areas that retain a red appearance and in areas where the red appearance has faded or weathered away. The treatment was found to be concentrated on the surface of the teak, with a penetration depth of 1.5 to 3 mm.

Acrylic polymers containing a fungicide/insecticide and an antioxidant were also found in several samples collected from the ground floor of the north office wing.

Adhesives and Fasteners

The glue applied to the sides of the vertical T&G siding boards was identified as urea formaldehyde and the original nails appear to have been galvanized, as zinc was identified through X-ray fluorescence (XRF) analysis of several samples.

Discussion

Prior to the start of the conservation project, it was thought that the extent of observable damage to the teak may require extensive if not complete replacement. The investigations carried out as part of this project show that a fair amount of teak remains in good condition, as do many of the other components in the window wall assemblies. The primary mechanism of the deterioration of teak is weathering, followed by mechanical damage from past cleaning methodologies. Termite damage does not represent a significant deterioration mechanism at the teak cladding nor does the presence of the fungal biofilm on the surface of the teak.

As is expected with a natural material, the teak has weathered differentially across the building depending on exposure and past maintenance practices. This weathering has both physical (loss of surface depth through erosion) and visual implications.

Degree of erosion in the teak varies considerably, with teak components at north-facing elevations remaining in good condition, exhibiting only minor loss of surface depth and retaining much of their original profiles. At other elevations, the vertical T&G boards and horizontal drips are more deteriorated, but the larger teak components such as sills and jambs often remain in fair to good condition.

The differential appearance of the teak, while not threatening to the health of the wood, presents an aesthetic problem, compromising the visual integrity of the site. While some variation is to be expected due to the natural weathering process, exposure, and variations in the cut and growth-ring density of the different teak elements, the presence of the fungal biofilm and remaining red appearance of the Tip Top Teak Wood-Oil Sealer application have resulted in a greater degree of variation. The black and red colors may also be considered incompatible with the natural gray weathered appearance of the teak.

The fungal biofilm, which has troubled the Salk Institute since the late 1960s, is primarily a visual problem. It is not a wood-decay fungus; however, numerous cleaning campaigns to remove it and later surface treatments to improve the appearance of the wood have prevented the teak from developing the gray patina that might have otherwise developed if it had been left alone. Some of the past cleaning techniques inadvertently damaged the teak; however, these practices were discontinued upon that discovery. Because the fungi that constitute the biofilm on the surface of the wood come from the surrounding environment, complete elimination is not possible. Thus, continued cleaning (by gentle means) will provide only a short-term solution. Reducing water sources in the teak window walls will likely prove to be more effective in retarding the growth of the biofilm, as the fungi will thrive wherever there is water. Fungicides may also help to retard its growth, but they will require ongoing maintenance and reapplication.

Of all conditions observed, the drywood termite damage to the internal framing is of highest concern, as severe damage and loss of material at the stud framing threaten the overall structural integrity and stability of the wall assembly. Furthermore, damage to the furring strips can lead to detachment of the teak cladding, as demonstrated by the failure of a row of teak T&G vertical siding boards at the northwest office wing during a storm in February 2014. This damage resulted from the use of untreated woods such as white fir, which are not naturally resistant to termites. Patterns of termite damage cannot be established at this point, as only two assemblies were opened up during Phase 1—one exhibiting extensive damage and the other showing no observable signs of termite damage. The extensive damage was observed in a south-facing window wall assembly along the plaza that exhibits severe erosion of the T&G vertical siding and horizontal drips. The failing T&G joints and horizontal drips allowed for additional water infiltration, beyond the typical paths of entry at the perimeter sealants and window sashes. That damp environment in the interior wall cavity coupled with the warmth of a south-facing exposure creates a microclimate conducive to drywood termite colonization. It is possible that extensive termite damage will be found in other window wall assemblies with similar exposures and conditions.

Air and water infiltration has reduced the overall performance of the window wall assemblies, with significant leaking reported through windows and wall cavities soon after the completion of construction. Lack of an effective moisture/air barrier and flashings, failed sealants, and inadequate weather stripping at the windows are the root causes. Severe erosion of some of the teak cladding—most prevalent at south-facing elevations—and missing teak elements further contribute to the problem. This severe erosion can lead to failure of the joints between the T&G vertical boards or, when the protective overhanging lip of the horizontal rail weathers away, exposed end grains at the tops of boards, both of which provide additional routes for water to enter the wall. Failure of the T&G joints may also lead to detachment of the T&G boards themselves.

CHAPTER 5

Treatment Recommendations

The proposed project to repair the teak-clad window wall assemblies is arguably one of the largest interventions in the architectural fabric of the original Kahn-designed buildings that the Salk Institute will ever undertake, in terms of scope and cost. Furthermore, as the window walls are one of the major elements composing the exterior of the building and retain a high degree of integrity, the proposed project could potentially have a large impact on the significance of the building and its appearance. As the Salk Institute is widely considered to be a masterpiece of modern architecture with international significance and is a site of architectural pilgrimage, what happens to the building is of great interest and any project of this scale would likely be subject to public scrutiny. Thus, following international best-practice conservation standards is critical to the success of the proposed project. These standards recommend the use of conservation policies, which integrate conservation principles for preserving significance with owner objectives and legal requirements, to guide the development of interventions or treatments. This chapter sets forward conservation policies for the window wall assembly conservation project, which follow the general conservation approach of doing as little as possible and only as much as is necessary to achieve a treatment that carefully balances preserving significance with factors such as physical condition, user needs, and code-mandated requirements. This chapter also assesses a number of conservation treatment alternatives against the policies and recommends preliminary conservation treatments to be explored further during Phase 2 of the project.

Conservation Policies

Guiding Conservation Principles

Background

Over the course of the last century, best-practice standards have been developed by the international conservation community to guide interventions in historically or culturally significant sites. Chief among these standards is the *International Charter for the Conservation and Restoration of Monuments and Sites* (The Venice Charter 1964). The Venice Charter sets forth principles of conservation based on the concept of authenticity and the importance of maintaining the historical and physical context of a site or building. It states that monuments are to be conserved not only as works of art but also as historical evidence. Nearly fifty years after its adoption, it continues to be an influential international conservation document and, although a number of principles in the charter have been critiqued, adapted, or superseded over the years, still guides much of contemporary conservation practice.

In the 1990s the conservation of modern heritage emerged as a distinct area of practice and with it came new publications and guidance documents addressing conservation challenges specific to modern sites. In 2011, the ICOMOS International Scientific Committee for Twentieth Century Heritage (ISC 20C) adopted the *Madrid Document: Approaches for the Conservation of Twentieth Century Architectural Heritage* (The Madrid Document) which provides guidance for conserving and managing modern heritage sites.

Many countries have adapted these international standards to their specific national needs. The United States national standards are set forth in *The Secretary of the Interior's Standards for the Treatment of Historic Properties* (The Standards), which were first developed by the National Park Service in 1977 and are influenced by the earlier work of the Venice Charter. Local historic review boards and planning agencies in the United States, including the City of San Diego, typically use the Standards and their associated practical guidelines when evaluating the appropriateness of proposed projects for historic resources.

Conservation Principles Applicable to the Salk Institute

The Standards, along with other international conservation texts, identify a number of different overall conservation approaches that can be adopted depending on the site's significance, physical condition, and proposed use. These approaches include preservation, rehabilitation, restoration, and reconstruction. For the planned repair of the teak window walls, an overall preservation approach would be most appropriate. Preservation is defined as "the act or process of applying measures necessary to sustain existing form, integrity, and materials of an historic property." Preservation focuses on maintenance and repair of existing historic materials, but it also allows for replacement of severely deteriorated features. Within the overall preservation approach, a restoration approach may be adopted for elements with little or intrusive significance, allowing for their removal. Restoration is defined as "the act or process of accurately depicting form, features, and character of a property as it appeared at a particular period of time by means of removal of features from other periods in its history and reconstruction of missing features from the restoration period."[20]

The following conservation principles are applicable to the preservation of the window wall assemblies at the Salk Institute:

- **Preserve significance:** No intervention shall be undertaken without ascertaining the likely benefit or harm to the building's significance. Furthermore, the removal of past interventions that damage the building's significance should be considered in order to reestablish significance.
- **Minimum intervention:** Each intervention shall be in proportion to the overall objectives of the project, providing the minimum necessary to meet those objectives and with the least damage to heritage values. No actions shall be undertaken without demonstrating that they are indispensable to meeting those objectives.
- **Like-for-like repairs:** When interventions are necessary, they should be made with the same materials and utilize the same techniques as found in the original construction.
- **Compatibility:** If new materials or techniques are introduced, they shall be aesthetically and technically compatible with the character of the original building. They shall not destroy the historic materials that characterize the building.
- **Reversibility:** When interventions are necessary, they should be designed and installed in a manner so that they may be removed in the future, should it prove possible to make improved repairs at that time, without impairing the authenticity or integrity of the building.

- **Durability:** The performance of the intervention over its expected lifespan should be constant and reliable.
- **Maintenance:** Ongoing maintenance of a building is essential to its conservation, as well as its overall performance. Thus, regular maintenance should be a first step, followed by other larger interventions.

Table 5.1 sets out in general terms how the preservation approach, with limited restoration, is applied to the different elements of the window walls, depending upon the significance grading assigned to each element (see table 2.1 in chapter 2).

Table 5.1. Significance gradings and associated treatment approaches.[21]

Grading	Associated Conservation Treatment Approach
Exceptional (E)	Preservation or restoration. In-kind replacement where significant form, elements, and/or fabric is severely deteriorated, altered, or missing.
High (H)	As for E, but with greater allowance for adaptation where this is in accordance with overall significance and integrity/authenticity can be maintained.
Moderate (M)	Retention and conservation where possible. Adaptation, alteration, or removal is also possible.
Little (L)	As for M, but with fewer constraints on removal, especially for those elements that detract from significance.
Intrusive (I)	Modify or remove to reduce adverse impacts on significance.

Owner Objectives and Other Requirements

Owner Objectives

The Salk Institute has identified the following owner objectives for the project:

- **Preserve Significance**
- **Longevity:** Those treatments providing the most long-term solution possible are preferred. A treatment with an expected life cycle of 100 years, if achievable, is preferred over a treatment with a fifty-year life cycle.
- **Logistical Efficiency:** Treatments can be carried out with minimal disruption to the building occupants over a relatively short period of time.
- **Cost Effective:** The number of different types of treatments should be minimized to reduce overall project costs. Furthermore, selection of those treatments with the longest expected life cycles is viewed as the wisest use of the institution’s funding.
- **Uniformity:** Treatments shall provide uniformity, in terms of both exterior appearance and treatment of concealed areas (such as improving the termite resistance of interior framing and abating hazardous materials). A “patchwork” approach is not desirable.
- **Ethical Approach:** As there is a large underground market selling illegal, naturally grown teak, the sourcing of replacement material for deteriorated teak may present ethical issues that are in conflict with the stated values of the owner.

Legal Requirements

The proposed project shall comply with all pertinent legal requirements governing:

- **Structural Performance:** The condition assessment found the structural connections between the window walls and adjacent concrete walls to be in poor condition in some locations. Depending upon the extent of a repair project for the window wall assemblies, the structural design may need to comply with the applicable requirements in the current adopted version of the *California Building Code, California Code of Regulations, Title 24,* particularly those governing seismic and wind lateral forces. As the Salk Institute is a designated local landmark, it is considered a "qualified historical building," and therefore the alternative regulations provided in the *California Historical Building Code* may be used for structural analysis and interventions. These alternative requirements often provide for more retention of historic fabric.
- **Energy Conservation**
- **Hazardous Materials Abatement and Management**

Discussion

The conservation principles and owner objectives share many of the same goals, including that of *preserving the significance* of the building; however, there may not be agreement as to how those shared goals are best achieved—through repair or in-kind replacement of the window wall assemblies.

Some of the conservation principles are highly compatible with the owner objectives, such as *durability* with *longevity,* as is *minimum intervention* with an *ethical approach.* There would appear to be a conflict between the conservation principles of *preserving significance* and *minimum intervention* and the owner objectives of *logistical efficiency* and *uniformity.* This is because conservation-based approaches rarely result in a one-size-fits-all solution—they are more often hybrid in nature, with a number of different solutions responding to different conditions, in order to achieve the goal of doing as much as necessary while doing as little as possible. However, even within a conservation-based approach, the development of different solutions needs to be balanced with the understanding that these treatments will be carried out at a very large scale across a building (as compared to the smaller scale of an object being conserved in a laboratory), as well as with the need to maintain a degree of visual integrity—to the extent that is possible and practical—in an architecturally significant site with high aesthetic value. Thus, at the Salk, it may be appropriate to apply the same solution to a particular area of the building or possibly across an entire elevation; however, such a possibility would require further assessment during the mock-up phase.

Resulting Conservation Policies

1. **Preserve the overall integrity of the wall assembly** by repairing damaged framing and improving resistance to future termite damage through spray treatment of existing framing with a low-toxicity chemical insecticide and/or replacement with pressure-treated wood framing. It should be noted that complete replacement of the wood framing will likely require the entire window wall assembly to be removed, rebuilt in a shop, and reinstalled. Limiting replacement to only those window walls exhibiting termite damage and in situ treatment of window walls with existing framing that is in good condition most closely adheres to the conservation principle of minimal intervention. However, an argument can be made for total replacement of the framing, as it allows a number of other issues to be addressed in a holistic way, such as the

abatement of hazardous materials and installation of flashings and a water-resistive barrier to improve the overall performance of the wall. Currently, there is not sufficient information on the extent of termite damage to justify the unnecessary removal of original building material in good condition. Thus, the GCI recommends that additional termite inspections be carried out to better understand the extent of termite damage before selecting one of these alternatives. It should also be noted that replacement of the internal framing does not necessarily merit replacement of the teak cladding; those teak elements in good condition can be salvaged and reinstalled.

2. **Preserve original teak structural members, cladding, and sliding windows, louvers, and shutters to the greatest extent possible,** as all are of exceptional significance to the overall window wall assembly. The condition of the teak varies across the building; however, a considerable quantity remains in reasonable condition, exhibiting minor to moderate deterioration. Teak exhibiting moderate to minor erosion has an estimated remaining service life of thirty to sixty years, depending on the extent of current erosion. This life span could be increased with the application of treatments to the teak to reduce moisture and weathering effects, such as an epoxy system applied to the end grains or a water-repellent preservative (WRP). Severely eroded teak has an expected remaining service life of up to twenty-five years and may be a good candidate for replacement with wood that matches the species and cut of the original. The selection of naturally grown teak will most closely match the original and provide the longest service life (up to 100 years); however, the market for this is volatile and ensuring the legality of the source material can be difficult. Although plantation-grown wood is readily available, it is potentially less durable (estimated service life varies considerably due to growth variations). Thus, it is possible that replacement with plantation-grown teak will not provide a substantial overall increase in service life beyond retention and treatment of existing teak in good condition. Beyond the guiding conservation principles, there are economic- and performance-based reasons as to why preference should be given to retaining existing naturally grown teak with adequate remaining service life.
3. **Reduce general variations in appearance** due to moisture and weathering effects by cleaning, brightening, and/or lightly sanding teak, with the understanding that some variation in appearance is inherent in the use of wood, and even in those areas where the teak is replaced with new material, variations in appearance are to be expected as the wood weathers. The appearance of the wood will never be uniform across the building or even a single elevation.
4. **Retard the growth of the fungal biofilm** by implementing treatments that reduce water sources through:
   a. in situ topical treatments, such as the application of a WRP or borate solution; and/or
   b. modifications to the architectural details, such as the installation of flashings or treatment of end grains with an epoxy to limit moisture intake. Note that these treatments can be best implemented when the entire window wall assembly is removed from the wall opening and disassembled.
5. **Reduce the red appearance of later surface coatings** or remove altogether by sanding and/or stripping to achieve more uniformity in the appearance of the teak.

6. **Improve the overall performance of the wall assemblies** by correcting past construction deficiencies through the installation of flashings and building paper where possible, and the repair of perimeter sealants.
7. **Retain the functionality of the horizontal sliding window sashes, improve their overall performance** by installing new weather stripping, and **address life safety concerns** by installing clear safety film over the existing plate glass or replacing with new clear tempered or laminated glass. Any new films or new glazing shall closely match the color and reflective qualities of the original glazing.
8. **Abate hazardous materials** as required by disturbance of material; or, where not disturbed, manage in place.

Preliminary Treatment Recommendations

Treatment Alternatives

Several treatment alternatives were developed to address the conditions present at the window wall assemblies and assessed against the conservation policies. These alternatives are presented in table 5.2. Additional information on some of these treatments can be found in appendix I. The GCI's recommended alternative at this phase of the project is also identified in table 5.2. These recommendations will be refined or revised following the results of the trial mock-up program in Phase 2.

Recommended Preliminary Conservation Treatments

Based on the range of conditions extant at the Salk Institute and the recommendations provided for specific components of the window walls in table 5.2, three treatment typologies, with varying degrees of intervention, have been identified at this phase of the project:

1. **Minor intervention,** involving in situ cleaning and repair of existing window walls exhibiting minor to moderate erosion at the teak cladding but with no termite damage:
   a. Clean existing teak and remove past surface treatments.
   b. Apply topical treatment to retard growth of biofilm on teak.
   c. Spray-treat existing wood framing to increase resistance to future termite infestation.
   d. Install weather stripping at sliding windows and retrofit or replace glazing.
   e. Manage existing transite boards in place.

2. **Moderate intervention,** involving off-site cleaning and repair of existing window walls exhibiting minor to moderate erosion and termite damage:
   a. Salvage existing teak, clean, remove past surface treatments, and reinstall.
   b. Modify architectural details to retard moisture infiltration and growth of the fungal biofilm on teak.
   c. Replace damaged wood framing with pressure-treated wood.
   d. Install weather stripping at sliding windows and retrofit or replace glazing.
   e. Replace transite boards with product that does not contain hazardous materials.

3. **Major intervention,** involving removal of existing window wall assemblies exhibiting both severe erosion and termite damage and reconstruction using in-kind materials:
   a. Replace existing teak in-kind.

b. Modify architectural details to retard moisture infiltration and growth of the fungal biofilm.
c. Replace damaged wood stud framing with pressure-treated wood.
d. Install weather stripping at sliding windows and retrofit or replace glazing.
e. Replace transite boards with product that does not contain hazardous materials.

While these types of treatments are tailored to the specific conditions present at an individual window wall, care must be taken to implement a similar treatment across an elevation or area of a building so as to maintain visual integrity. This will also satisfy owner objectives such as uniformity and logistical efficiency. For example, many of the south-facing window walls exhibit severe erosion in the teak cladding and have known moisture intrusion issues, which suggests a major intervention across part or all of that elevation. However, many of the north-facing window walls exhibit minor erosion but significant growth of the fungal biofilm and a strong red color. Thus, a minor or moderate intervention is suggested, depending on the presence of termite damage. As the original teak cladding would be retained in either of these interventions, there should not be any concerns about uniformity in the appearance of the teak.

Table 5.2. Treatment alternatives for the window wall assemblies at the Salk Institute

COMPONENT AND OBSERVED CONDITION	SIGNIFICANCE GRADING (see table 2.2)	RISK LEVEL*	RISK TYPE	POTENTIAL TREATMENT ALTERNATIVES	PROS	CONS	OTHER CONSIDERATIONS	GCI RECOMMENDATION (prior to Phase 2)
1. Wood Framing	**M**							
A. Insect damage at internal framing		H	Structural Integrity	i. Treat on a case-by-case basis: Inspect each window wall for damage through a video scope inserted into multiple small drill holes (approximately 3/8" in diameter) in each wall assembly. At areas exhibiting severe termite damage, remove window wall units from building, replace existing framing with pressure-treated wood (meeting American Wood Protection Association's Use Category UC3A for exterior protected wood), and reinstall salvaged exterior teak and interior finishes in good condition. At areas in good condition, spray treat existing wood in situ with a low-toxicity chemical insecticide and repair drill holes (as an alternative to drilling an inspection hole through the teak, consider making one vertical T&G board removable for inspections).	• Retains maximum amount of original fabric (both wood framing and teak cladding) in situ.	• Full scope of repair and replacement unknown until detailed inspection is undertaken. • Not a comprehensive, long-term solution; areas with chemical treatments have a life span of 5 years and will need to be periodically inspected and retreated. • The installation of performance-based improvements, such as base flashing and removal of hazardous materials can only be undertaken at those window assemblies removed from the building. • Inspection hole plugs/repairs may be visible.	> Specify corrosion-resistant materials for metal fasteners, flashings, and other items in contact with pressure-treated replacement wood. > Remove one damaged window wall assembly as a test to better understand potential damages incurred in the process.	Treatment Alternative 1.A.i most closely adheres to basic conservation principles; however, an argument can be made for pursuing alternative 1.A.iii, as it also allows a number of other conservation issues to be addressed in a holistic way. At the present time, there is not sufficient information on the extent of termite damage to justify the unnecessary removal of original building material in good condition. GCI recommends additional termite inspections to better understand the extent of termite damage before selecting one of these alternatives.
				ii. Same as alternative (i); however, carry out inspection and in situ treatment of wood by removing interior finishes and asbestos-containing transite panels and follow with replacement of transite panel and reinstallation of interior finishes.	• Retains maximum amount of original fabric (both wood framing and teak cladding) in situ. • Does not result in visible inspection hole plugs/repairs in exterior teak.	• Full scope of repair and replacement unknown until detailed inspection is undertaken. • Not a comprehensive, long-term solution; areas with chemical treatments have a life span of 5 years and will need to be periodically inspected and retreated. • The installation of performance-based improvements, such as base flashing, and removal of hazardous materials can be undertaken only at those window assemblies removed from the building. • Does not allow for inspection of exterior furring strips between teak cladding, as they will be obscured by exterior transite panel.	> Specify corrosion-resistant materials for metal fasteners, flashings, and other items in contact with pressure-treated replacement wood. > Remove one damaged window wall assembly as a test to better understand potential damages incurred in the process.	

COMPONENT AND OBSERVED CONDITION	SIGNIFICANCE GRADING (see table 2.2)	RISK LEVEL*	RISK TYPE	POTENTIAL TREATMENT ALTERNATIVES	PROS	CONS	OTHER CONSIDERATIONS	GCI RECOMMENDATION (prior to Phase 2)
				iii) Remove all window wall units from building, replace all existing framing with pressure-treated wood (meeting American Wood Protection Association's Use Category UC3A for exterior protected wood), reinstall salvaged exterior teak and interior finishes in good condition, and replace damaged teak in-kind.	• Comprehensive, long-term solution to termite control. • Removal of all window wall assemblies also provides an opportunity to install performance-based improvements, such as base flashing, and remove hazardous materials throughout the building. • Scope of project is understood at the current time.	• Unnecessarily replacing original building material that is in good condition.	> Specify corrosion-resistant materials for metal fasteners, flashings, and other items in contact with pressure-treated replacement wood. > Remove one damaged window wall assembly as a test to better understand potential damages incurred in the process.	
B. Corrosion of structural fasteners		H	Structural Integrity	i. Inspect fastener condition as part of termite inspections and replace only corroded fasteners with galvanized or stainless steel.			> Structural evaluation of size and spacing of fasteners is recommended.	Recommended approach dependent on selected treatment for Wood Framing 1.A.
				ii. Replace all fasteners with galvanized or stainless steel.			> Structural evaluation of size and spacing of fasteners is recommended.	
C. Insect and water damage at exterior furring strips (to which the teak is attached)		H	Structural Integrity	i. Treat on a case-by-case basis: Inspect furring strips as part of termite inspection and replace or spray treat with chemical insecticide as specified in Treatment Alternative 1.A.i.	• Retains maximum amount of original fabric (both wood framing and teak cladding) in situ.	• Full scope of repair and replacement unknown until detailed inspection is undertaken. • Not a comprehensive, long-term solution; areas with chemical treatments have a life span of 5 years and will need to be periodically inspected and retreated.	> Specify corrosion-resistant materials for metal fasteners, flashings, and other items in contact with pressure-treated replacement wood.	Recommended approach dependent on selected treatment for Wood Framing 1.A.
				ii. Replace all with pressure-treated wood as specified in Treatment Alternative 1.A.iii.	• Comprehensive, long-term solution to termite control. • Scope of project is understood at the current time.	• Not a comprehensive, long-term solution; areas with chemical treatments have a life span of 5 years and will need to be periodically inspected and retreated.	> Specify corrosion-resistant materials for metal fasteners, flashings, and other items in contact with pressure-treated replacement wood.	
2. Exterior teak wood	**E for all; except I for surface coatings**							

COMPONENT AND OBSERVED CONDITION	SIGNIFICANCE GRADING (see table 2.2)	RISK LEVEL*	RISK TYPE	POTENTIAL TREATMENT ALTERNATIVES	PROS	CONS	OTHER CONSIDERATIONS	GCI RECOMMENDATION (prior to Phase 2)
General - specifications for replacement teak as required by Observed Conditions 2.A and 2.B.				i. Replace with new, in-kind material, with a variety of cuts.	• Most closely matches original details.	• Less resistant to future growth of fungus (but may be offset by recommended surface treatments).	> Will continue to weather differentially, as it currently does.	Use of old growth teak in a variety of cuts most closely matches original teak; however, other considerations include: (1) Naturally grown teak markets are volatile and it can be difficult to ensure legality of purchase. Reclaimed naturally grown teak is an alternative to this, but it may be difficult to find quantities needed. Thus, it may be necessary to consider plantation-grown teak, but use of this material will likely result in a reduced expected service life. (2) While a variety of cuts most closely matches the original teak, consider use of all flat-sawn as a means of retarding the fungal biofilm growth. If this is to be considered further, a mock-up is needed to better understand any impacts to appearance.
				ii. Replace with new, in-kind material, but all flat-sawn.	• Less surface texture, provides fewer microenvironments suitable for mildew and other airborne biological spores.	• Less surface texture, resulting in a more uniform surface appearance which varies from the existing conditions.	> Erosion rates are similar between different cuts of wood.	
				iii. Use naturally grown teak.	• Most closely matches original details. • Longest service life.	• Sustainability/ethical concerns, depending on teak source. • Higher costs.		
				iv. Use plantation-grown teak.	• Fewer ethical questions. • Lower costs.	• Potential reduction in service life, due to growth patterns.		
A. Missing elements (vertical T&G siding boards)		H	Performance	i. Reuse existing boards from elsewhere on site (for example, in window walls with severe erosion that require replacement, it may be possible to salvage several boards for reuse elsewhere).	• Provides best match to existing adjacent wood.	• Dependent on availability of boards.		For the best match (aesthetic and estimated service life), the use of salvaged boards (Treatment Alternative 2.A.i) is preferable, but it will depend on the availability of salvaged boards.
				ii. Replace with new, in-kind material.		• Replacement wood may be noticeable until weathering process begins.		

COMPONENT AND OBSERVED CONDITION	SIGNIFICANCE GRADING (see table 2.2)	RISK LEVEL*	RISK TYPE	POTENTIAL TREATMENT ALTERNATIVES	PROS	CONS	OTHER CONSIDERATIONS	GCI RECOMMENDATION (prior to Phase 2)
B. Severe erosion		H	Perfor-mance	i. Replace with new, in-kind material only at severely eroded wall panels (rows of T&G boards and associated components), and retain ex-isting materials at wall panels with minor erosion. Note: Up to 25 years remain-ing service life for severely eroded boards; 30 to 60 years for boards with minor erosion.	• Preserves maxi-mum amount of origi-nal fabric.	• Variation in appearance with adjacent existing material or materials facing each other on each side of the plaza.		Treatment Alterna-tive 2.B.i.; however to maintain the visual integrity of site, the same treatment of the exterior teak wood (replacement or repair) should be considered for all window walls within an area of the site or across a portion of a facade.
				ii. Replace all T&G boards in-kind. Note: Up to 100-year service life with use of naturally grown teak.	• Potentially provides longest-term solu-tion, depending on type of wood used for replacement.	• Loss of historic fabric. • Sustainability issues: unnec-essarily replacing some teak that is in good condition.		
C. Minor to mod-erate erosion		M	Material Conserva-tion	i. Leave "as is" and let natural erosion process continue. Expected remaining service life is 30 to 60 years.			> Recommended treatments for the fungal biofilm (2.E) may extend life.	Treatment Alternative 2.C.i, as Alternative 2.C.ii raises a num-ber of issues; it is a short-term solution, requiring frequent maintenance, and may negatively impact the appear-ance of the teak. The service life of the teak may be ex-tended through other treatments, such as 2.E.iii or 2.E.iv.
				ii. Apply sacrificial coating to slow rate of erosion.		• Only film-forming coatings provide enough protection from weathering to restrict ero-sion. Clear coatings will alter the sheen and color and are not UV resistant, resulting in rapid breakdown of the coating and minimal protection of the substrate. Semitransparent, opaque, and other pigmented coatings offer more protection against weathering, but will alter the appearance more sig-nificantly than clear coatings. All will bubble or peel away, leaving a splotchy, uneven ap-pearance over time, and thus require regular maintenance/ reapplication. • Application of a coating is contrary to Kahn's original specifications.		
D. General variations in appearance due to moisture and weathering effects, including sun bleaching and moisture staining		- Visual Con-cern	Material Conserva-tion	i. Accept variations in appear-ance and let it continue to weather.		• No improvement to current condition. • Variations will increase, partic-ularly as compared to severely eroded areas requiring teak replacement.		Treatment Alterna-tive 2.D.ii, along with Treatment Alternative 2.D.iii, depending on the results of the trial mock-up program.

COMPONENT AND OBSERVED CONDITION	SIGNIFICANCE GRADING (see table 2.2)	RISK LEVEL*	RISK TYPE	POTENTIAL TREATMENT ALTERNATIVES	PROS	CONS	OTHER CONSIDERATIONS	GCI RECOMMENDATION (prior to Phase 2)
				ii. Clean, brighten, and/or lightly sand to reduce variations in appearance.	• Can be done in situ or with panels removed. • Significant moisture staining and areas of distinct surface texture will be minimized; however, metal oxide stains and some surface texture will remain.	• Cleaning can slow weathering processes and mitigate extreme color variations, but will require regular maintenance. • Metal oxide stains and some surface texture will remain.		
				iii. Clean as in alternative 2.D.ii and apply epoxy system to end grains of T&G boards to minimize color changes due to moisture and weathering effects. (Estimated service life of teak T&G boards with this intervention is 20 to 50 years, depending on the current thickness of the boards.)	• Potentially retards growth of fungal biofilm.	• Boards need to be removed to apply treatment (or trimmed in place to allow a brush application below): difficult to remove boards unless entire window wall unit is removed for repair.	> Must test through mock-up to see if epoxy has any unintended effects on appearance of the teak.	
				iv. Where window wall assemblies are removed, wood framing is replaced, and other performance improvements are installed, reinstall T&G vertical board siding with original unweathered interior faces to exterior. An epoxy treatment, similar to alternative 2.D.iii may also be applied to the end grains. (Estimated service life of teak T&G boards with this intervention is 20 to 50 years, depending on the current thickness of the boards.)	• Boards have a freshly milled appearance: considered a pro or con?	• Boards have a freshly milled appearance: considered a pro or con? • Boards need to be removed to apply treatment: difficult to remove boards unless entire window wall unit is removed for repair.	> To reduce significant variations in appearance, reverse all boards across the site or within a distinct area of the building(s).	
				v. Apply bleach and weathering product to untethered areas to create an overall, uniform weathered appearance.	• Available products can mimic the look of weathered wood and accelerate the natural weathering processes. • Products require little maintenance: product wears away over time, exposing the wood to natural weathering processes.	• Attempt to artificially weather may not produce the desired effect. • May reduce remaining service life of teak.		

COMPONENT AND OBSERVED CONDITION	SIGNIFICANCE GRADING (see table 2.2)	RISK LEVEL*	RISK TYPE	POTENTIAL TREATMENT ALTERNATIVES	PROS	CONS	OTHER CONSIDERATIONS	GCI RECOMMENDATION (prior to Phase 2)
E. Black fungal biofilm		- Visual Concern	Material Conservation	i. Let fungal biofilm continue to grow, without cleaning, to see if areas will eventually develop a more uniform gray patina.	• Biofilm remains in place, potentially protecting wood from future UV degradation.	• The expected results are unknown and a patina may take an extremely long time to develop.		Treatment Alternative 2.E.ii, along with Treatment Alternative 2.E.iii, iv, or v, depending on the results of the trial mock-up program.
				ii. Clean annually, but with improved cleaning procedures and no other improvements: mild detergent or oxygen-bleach and soap formula and natural bristle brush, rubbing gently across the grain, with some light sanding.	• Consistent with Kahn's original specifications to leave the teak uncoated and subsequent cleaning recommendations by his office staff.	• Short maintenance cycle: 1 to 2 years to prevent fungal build-up. Maintenance cycle may be longer (4 to 5 years), where other coatings are applied to the teak (see alternative iv). • Regular cleaning process also removes the gray patina, which is understood to be part of Kahn's intentions for the weathering of the teak.	> Specified cleaners should not provide a food source for the fungus (i.e., sugars).	
				iii. Clean and then modify architecture details to reduce water infiltration (treat end grains with a marine-grade epoxy, cut back bottom of boards by less than 1/8", and/or install flashing).	• Reduces moisture source which directly contributes to growth of fungus.	• Can only be implemented where window walls are removed for replacement of interior framing. • Flashing or cuts may be minimally visible, altering the appearance of the window walls.	> Assess effectiveness through mock-ups.	
				iv. Clean and then apply a topical treatment, water-repellent coating, to dry wood to retard growth of fungus.	• Retards growth of fungus with minimal color change to teak.	• Requires frequent maintenance: WRP treatment typically last 6 months to a year. • May darken wood slightly, but this effect will diminish over time. • Potential impact on adjacent concrete.	> Coating should not provide a food sources for the fungus (i.e., sugars). > Assess effectiveness and any changes in appearance to the teak or impacts to the adjacent concrete through mock-ups and accelerated weathering tests.	
				v. Clean and then apply a topical treatment, borate solution (low-level toxicity fungicide) to wet wood to retard growth.	• Retards growth of fungus with minimal color change to teak. • Allows gray patina to develop.	• Requires frequent initial maintenance, with initial applications on a semiannual or annual basis; but subsequent applications may need to occur with diminishing frequency over time. • May darken wood slightly, but this effect will diminish over time. • Potential impact on adjacent concrete.	> Assess effectiveness and any changes in appearance to the teak or impacts to the adjacent concrete through mock-ups and accelerated weathering tests. > Effectiveness of borates in treating the fungus on site to be trialed during Phase 2.	

COMPONENT AND OBSERVED CONDITION	SIGNIFICANCE GRADING (see table 2.2)	RISK LEVEL*	RISK TYPE	POTENTIAL TREATMENT ALTERNATIVES	PROS	CONS	OTHER CONSIDERATIONS	GCI RECOMMENDATION (prior to Phase 2)
F. Red appearance, indicative of past surface treatment		- Visual Concern	Materials Conservation	i. Leave "as is."		• No improvement to current condition.	> Cleaners or brighteners specified under 2.E may help to even out color variations.	Treatment Alternative 2.F.ii, depending on results of trial mock-up program.
				ii. Remove with mild solvents and sanding.	• Potential improvement in varied appearance of teak. Test as part of trial mock-up program.	• Can be harsh on wood fibers and cause additional erosion, so care must be used in application.	> Select a single solution that will work for all situations (Tip Top Teak Wood-Oile Sealer and other finishes).	
				iii. Flip boards, to expose back side.			> Backsides of boards viewed during investigative probes appeared to be in good condition, but exhibited moisture staining. The condition of the backside of trim boards is unknown. Detailing of the boards (both joints and profiles) may not permit the boards to be flipped.	
G. Moisture stains		- Visual Concern	Materials Conservation	i. Leave "as is."		• No improvement to current condition.		Treatment Alternative 2.G.ii, depending on results of trial mock-up program.
				ii. Cleaning, brightening, and application of an epoxy treatment to treat the black fungal biofilm may also reduce appearance of moisture stains.	• Potential improvement in appearance. Test as part of trial mock-up program.			
I. Iron staining, below exposed nail heads at teak T&G vertical siding boards		- Visual Concern	Materials Conservation	i. Leave as is, as staining penetrates many cell layers into the wood surface and is difficult to remove without aggressive sanding, which will further reduce the thickness of already eroded teak siding boards.		• Stains remain and will continue to develop.	> Brighteners have also been used with limited success to remove iron stains, but they rely on chemical reactions between the ferrous metal and the wood cell components; these stains tend to be very deep in the wood and the color may leach back out to the surface even after the surface stain is removed and fastener is removed.	Combination of all three treatment alternatives, depending on selected treatment recommendation for teak (2.A, 2.B, and 2.C).

COMPONENT AND OBSERVED CONDITION	SIGNIFICANCE GRADING (see table 2.2)	RISK LEVEL*	RISK TYPE	POTENTIAL TREATMENT ALTERNATIVES	PROS	CONS	OTHER CONSIDERATIONS	GCI RECOMMENDATION (prior to Phase 2)
				ii. Where teak siding boards are removed and reinstalled as part of another scope of work, replace nails with stainless steel.	• Will prevent development of future staining.	• Stainless steel nails more expensive than galvanized nails.		
				iii. Where teak siding boards are replaced in kind, as part of another scope of work, use stainless steel nails for attachment to furring strips.	• Will prevent development of future staining.	• Stainless steel nails more expensive than galvanized nails.		
3. Sliding Sashes: Glazed Sashes, Louvers, and Shutters	**E for all; except H for glass sheets**							
A. Perimeter air/ water leaks at sashes		H	Performance	i. Install new weather stripping at sides and bottoms of sashes.	• Improved performance of window.	• Depending on selection of weather stripping, small visual impact.	> Test during trial mock-up phase.	Treatment Alternative 3.A.i.
B. Plate glass (very large panes of glass, particularly at west-facing studies)		H	Life Safety	i. Install clear safety film at inside face of existing glass and conserve wood sashes.	• Retains maximum amount of original fabric. • Some films may also provide protection against UV light and improve energy efficiency. • Lower costs.	• Altered appearance; slight color shift. • Maintenance issue: films can bubble, etc., requiring replacement every 7 to 10 years.	> Test during trial mock-up phase.	Treatment Alternative 3.B.i preserves original fabric; however, Alternative 3.B.ii will not significantly impact overall significance, so long as the new glazing is similar in appearance to the color and reflectivity of the original. Evaluate during the trial mock-up phase.
				ii. Replace with tempered or laminated glass and conserve wood sashes.	• Improved performance. • Requires less maintenance than Treatment Alternative 3.B.i.	• Loss of original fabric. • Sustainability issues: removal/ recycling of a large quantity of glass. • Altered appearance. • Laminated glass may be slightly thicker than original glazing: requires further study to determine if it could be accommodated within the original sash width. • Higher costs.	> Test during trial mock-up phase.	

COMPONENT AND OBSERVED CONDITION	SIGNIFICANCE GRADING (see table 2.2)	RISK LEVEL*	RISK TYPE	POTENTIAL TREATMENT ALTERNATIVES	PROS	CONS	OTHER CONSIDERATIONS	GCI RECOMMENDATION (prior to Phase 2)
4. Transite board (insulation)	**M**							
A. Asbestos-containing material; must be abated when disturbed or managed in place.		H	Hazardous Material	i. Replace with non-asbestos-containing material at only those areas that are disturbed.	• Less disturbance to other adjacent fabric in good condition.	• Results in a hybrid solution, with only partial removal of hazardous materials.	> Potential replacement products, such as exterior-grade cement board sheathing and glass-mat sheathing, have a typical maximum thickness of 5/8”. Thus, multiple layers will be required to maintain existing overall wall thickness. Additional research of replacement products required.	Recommended approach dependent on selected treatment for Wood Framing 1.A.
				ii. Replace all with non-asbestos-containing material.	• Consistent approach across the site, facilitating future maintenance and investigations.	• Disturbance of original components in good condition (may not be able to replace transite board with damaging surrounding materials).	Same as 4.A.i.	
5. Overall window wall assembly	**E**							
A. Perimeter sealant failure		H	Performance	i. Replace all sealants.	• Prevents additional infiltration into wall.	• No back-up system if/when sealants fail.		5.A.i.
B. Lack of flashing		H	Performance	i. Leave as is, unless removing window wall assemblies for replacement of framing.		• No improvement to current situation.		Treatment Alternative 5.B.i and/or 5.B.ii, depending on selected treatment for Wood Framing 1.A.
				ii. Install base flashing.	• Prevents additional infiltration into wall.	• Potential visual impact if flashing is visible from exterior.		
				iii. Install base flashing and flashing at all horizontal rails.	• Prevents additional infiltration into wall and potentially helps to retard growth of fungal biofilm.	• Potential visual impact if flashing is visible from exterior.		
C. Lack of moisture/air barrier		M	Performance	i. Install moisture/air barrier where wall assemblies are removed for other treatments.	• Prevents additional infiltration into wall.	• Not a consistent treatment across site if all wall assemblies are not removed.		5.C.i.

* Risk levels are as follows: H = high; M = medium; and L = low.

Trial Mock-Up Program

The GCI recommends that that the following three full-size mock-ups be carried on site during Phase 2. Following discussion and agreement with the Salk Institute about the scope and location of the mock-ups proposed below, the GCI will provide additional protocols for their mock-up.

Trial Mock-Up 1: Minor Intervention

This mock-up involves in situ cleaning and repair of an existing window wall.

Objectives and Scope

- Test the efficacy of cleaning methods to remove fungal biofilm and generally improve the appearance of the exterior teak cladding:
  — Lightly sand wood to facilitate removal of the fungal biofilm, and/or
  — wet wood surface and clean with a mild oxygen-bleach and soap formula using a natural-bristle brush, rubbing gently across the grain, and/or
  — apply wood brightener.
- Test methods for reducing the red appearance of past surface treatments or removing the coating altogether:
  — Lightly sand wood and/or
  — apply mild solvent-based stripper.
- Test the effectiveness of topical treatments in retarding the growth of the biofilm and understand any other impacts they may have, such as changing the appearance of the wood:
  — Use a WRP and/or
  — a borate-based solution.
- Test the effectiveness of the videoscope for inspecting insect damage to the internal framing and the feasibility of spray-treating internal framing:
  — Drill a ⅜-inch hole in each row of vertical T&G boards and transite panel to allow for insertion of videoscope into wall cavity, or explore feasibility of removing one vertical board for inspection;
  — test feasibility of applying low-toxicity chemical insecticide through drill holes; and
  — after completion, install plug in drill hole or reinstall removed vertical board with screws (to facilitate future inspections).

Suggested Area for Implementation

- North-facing window wall assembly, with minor erosion, significant growth of fungal biofilm, and remains of past surface coatings. For fungal biofilm retarding treatments, it will be important to test three different options (no surface treatment, WRP, and borate-based solution) in close proximity to one another, so they are exposed to similar environmental conditions and the results can be compared. This could be done within a single window wall assembly or at three adjacent assemblies. One possible location is the north elevation of the northwest office wing, window wall numbers NO2A, NO2B, NO3A, NO4A, NO5A, or NO6A.

Trial Mock-Up 2: Moderate Intervention

This mock-up involves off-site cleaning and repair of an existing window wall.

Objectives and Scope

- Better understand the process for removing the existing window walls, including any damages that may be incurred in the removal process, and reinstalling repaired assembly.
- Demonstrate the process of replacing the internal framing and transite panels:
  - — Replace existing framing with new pressure-treated wood framing and stainless steel bolts.
  - — Replace transite with exterior-grade cement board sheathing with a moisture/air barrier as required or glass-mat sheathing with a gypsum core and fiberglass face and back. Note that most available sheathing products have a maximum thickness of 5/8 inches, so multiple layers or thicker furring strips will be required to maintain the overall wall thickness.
- Test the efficacy of new performance-based improvements:
  - — Install moisture/air barrier.
  - — Install base flashings.
- Demonstrate the process of reinstalling salvaged teak after replacement of internal framing:
  - — Utilize the same methods of cleaning, stripping, and applying a topical treatment, as per Trial Mock-Up 1; however, processes may prove to be more effective when carried out in the repair shop rather than in situ.
- Test efficacy of design modifications to reduce water infiltration and retard growth of fungal biofilm and understand any other impacts they may have, such as changing the appearance of the wood:
  - — Reduce length of existing vertical boards to provide a gap between horizontal elements and the bottom of the boards.
  - — Treat end grains of boards with a marine-grade epoxy.
  - — Apply a WRP and compare performance to that of wood without a WRP treatment.
- Test the appearance and effectiveness of clear safety film with UV protection installed on the inside face of the existing glazing.
- Test installation of weather-stripping retrofits at existing sliding sashes:
  - — New weather stripping installed at side of window opening
  - — New weather stripping installed at the bottom rail of the window sash, either to the bottom or to the side

Suggested Area for Implementation

- West-facing window wall, with minor to moderate erosion of the teak, moderate growth of the fungal biofilm, and termite damage

Trial Mock-Up 3: Major Intervention

This mock-up involves replacement of window wall assemblies with in-kind materials.

Objectives and Scope

- Better understand the process for removing the existing window walls, including any damages that may be incurred in the removal process, and installing reconstructed assemblies.
- Demonstrate the process of replacing the internal framing and transite panels:
  - — Construct with new pressure-treated wood framing and stainless steel bolts.
  - — Replace transite with exterior-grade cement board sheathing with a moisture/air barrier as required or glass-mat sheathing with a gypsum core and fiberglass face and back. Note that most available sheathing products have a maximum thickness of 5/8 inches, so multiple layers or thicker furring strips will be required to maintain the overall wall thickness.
- Test the efficacy of new performance-based improvements:
  - — Install moisture/air barrier.
  - — Install base flashings.
- Assess options for replacement teak: naturally grown, plantation-grown, and reclaimed material. Consider material sourcing issues, physical and visual compatibility with existing material to remain, and long-term durability.
- Test efficacy of design modifications to reduce water infiltration and retard growth of fungal biofilm and understand any other impacts they may have, such as changing the appearance of the wood:
  - — Reduce length of new vertical boards to provide a gap between horizontal elements and the bottom of the boards.
  - — Treat end grains of boards with a marine-grade epoxy.
  - — Apply a WRP and compare performance to that of new wood without a WRP treatment.
- Test installation of new laminated glass in existing window sashes and assess appearance.
- Test installation of weather-stripping retrofits at existing sliding sashes.
  - — New weather stripping installed at side of window opening
  - — New weather stripping installed at the bottom rail of the window sash, either to the bottom or side

Suggested Area for Implementation

- A window wall assembly with known termite damage and severe erosion of the teak, such as NL6C (where Investigative Probe 1 was carried out). As this study is not regularly occupied, a mock-up in this location could be carried out with minimal disruption to building occupants. This location is highly visible from the main plaza and may be considered undesirable as a result, since the reconstructed window wall will contrast with the adjacent untreated window walls. Alternatively, carrying out the mock-up in this location will provide an opportunity to highlight the work of the conservation project. Alternative locations to be considered include the window walls located on the south elevations of the west office wing or the upper levels of the south elevations of the south study towers. Before selecting a final location, the presence of termite damage should be confirmed.

Other Recommended Actions during the Trial Mock-Up Phase

- Investigate the condition of the internal wood framing at an additional five to ten window wall assemblies—representing approximately 5% of the total number of window walls on site—in different areas of the building(s) to better understand the extent of termite damage and potentially identify any patterns of damage.

Evaluation and Refinement of Treatment Recommendations

- The performance of the mock-ups should be monitored in the short, medium, and long term.
- The results of the trial mock-up program shall be used to assess and refine the treatment recommendations and typologies and identify preferred treatment(s) and the best way forward.

Next Steps[22]

Coordination with Forthcoming Conservation Management Plan

In 2014, the Salk Institute engaged Wiss, Janney, Elstner Associates, Inc. (WJE) and consultant Peter Inskip + Peter Jenkins Architects to prepare a conservation management plan (CMP) for the entire architectural ensemble. A well-known tool internationally, the CMP will bring together historical documentary and oral evidence, physical analysis of the existing fabric, and knowledge of its performance to inform a long-term strategy for the care and conservation of the site. As part of this preparation, the significance of the entire site, including the window wall assemblies and many other elements such as the concrete structure and travertine-paved plaza, will be evaluated and policies established to manage future work. It is possible that the significance assessment and policies provided in this report may have to be slightly adjusted to reflect the outcomes of the CMP, which will look at the window walls in a larger context.

Peer Review

Coordination with the CMP will provide an opportunity for peers in the conservation field (WJE and Inskip + Jenkins) to review the conservation treatment approach for the window walls and either validate this approach or make suggestions for improving upon it. Given the international significance of the Salk Institute and the scope of the project, the GCI feels such a peer review is critical. The Salk Institute may also wish to proactively engage with the architectural community by including representatives as part of a larger peer review process. However, if this is pursued, architectural peer reviewers should be carefully selected and well managed.

Design Development and Implementation

The GCI recommends that the Salk Institute retain the services of a licensed architect who has experience working with historic preservation projects, and the services of a structural consultant, to carry out a detailed conditions survey and fully develop/design the conservation treatments based on the GCI recommendations and results of the trial mock-up program, and to prepare construction documents. These construction documents serve several purposes, including (1) providing clear and detailed professional direction to the contractor who will carry out the work; (2) meeting submittal requirements for any necessary historical resource board or planning commission review or required building department permits; (3) a means of refining the project budget and obtaining competitive bids; (4) a means of enforcing quality control during construction; and (5) a means of documenting conservation actions for ongoing monitoring and any future conservation activities. As part of this process, the architect should also develop a maintenance strategy to guide the Salk Institute's care of the window walls following the implementation of the project.

The Salk Institute may pursue a number of different options for implementing the work, from competitive to negotiated bids with contractors. The GCI recommends that the Salk select a contractor with previous experience in historic preservation. This is particularly important for any contractor or millwork subcontractor who will be responsible for cleaning, repair, and replacement of the teak wood cladding and sliding windows.

Notes

20 National Park Service, United States Department of the Interior 2001.

21 Significance grading categories and associated treatment approaches in table 5.1 adapted from those utilized in the Sydney Opera House Draft Conservation Management Plan, fourth ed., 2015.

22 As noted in chapter 1, this report was prepared in 2014 (although not widely published until 2017). Thus, the work recommended in this Next Steps section has already taken place. The text here has not been updated to reflect what occurred after 2014; rather, that will be discussed in the forthcoming Phase 2 project report.

Glossary

Annual ring
A ring representing one year of growth in a woody plant, made up of one band of earlywood and one band of latewood. Also known as a growth ring. (EH)

Bleaching
A reaction that whitens or removes color from a surface. (DAC)

Cambium
A band of living cells just under the bark of a tree that produce sap wood (secondary xylem) and inner bark (phloem) as the tree's diameter increases. (EH)

Cellulose
A polysaccharide (complex carbohydrate) consisting of a long, unbranched chain of glucose units; it generally forms 40% to 50% of the cell walls of woody plants (also found in some algae and fungi) and is responsible for the cell's rigidity. (EH)

Decay fungi
Wood-decay fungi excrete enzymes that break down wood fibers, which can ultimately lead to the inability of the wood to perform its intended function. Most wood-decay fungi are able to grow only on wood with a moisture content greater than 20% and are unable to damage adjacent dry wood. (A&A)

Earlywood
Wood formed in the first part of a growth year, during spring. The cells of earlywood have thin walls and large interiors to maximize conduction. (EH)

Flat sawn (plain sawn)
Flat-sawn lumber is wood that has been cut parallel to the tangential face of the log. This results in a pleasing characteristic U- or V-shaped grain pattern on the wide faces of boards and lumber. This cut is common because it maximizes the amount of usable material from the log. (A&A)

Heartwood
The inner part of the woody stem that develops when the tree's optimum sapwood content is maintained through the death of the inner sapwood cells, as more are added just underneath the inner bark by cambium. Heartwood is composed of dead cells that are no longer used for storage or conduction. They may contain the various metabolic products (extractives) that are responsible for color, smell, and durability. (EH)

Latewood
Wood formed in the latter part of a growth year. In ring-porous hardwoods such as oak, the vessels produced during the latter part of the year are much smaller than those of earlywood, with the extra space being taken up with fibers. In softwoods, the cell walls of latewood are thickened and the cell aperture (lumen) is reduced. (EH)

Lignin
A highly complex organic polymer deposited in the cellulose of plant cells during growth (lignification). Lignin content of hardwoods is typically 18% to 25% (in softwoods, 25% to 35%). With cellulose, it is the main structural material in wood. (EH)

Rift sawn
Timber obtained from a quarter-sawn log that is cut into planks with a slight variation in angle at each cut, so that every plan is sawn exactly perpendicular to the growth rings. It is a costly and wasteful procedure but produces straighter grain and greater dimensional stability than either crown sawing or quarter sawing. (EH)

Sapwood
The outer part of a tree's woody stem, containing live cells (parenchyma). It is here that sap is transported from the roots to the crown of the tree. Sapwood is produced by a band of cells (vascular cambium) just under the bark as the tree grows. (EH)

Shiplap
Wood boards whose edges are rabbeted to make an overlapping joint. (DAC)

Pith
The central tissue of a plant stem, composed of the thin-walled live cells (parenchyma) important during early growth. In timber, the phenomenon of "wandering" (or eccentric) pith, which affects wood compression and occurs in certain growth conditions, may cause twisting or other defects in sawn timber. (EH)

Tongue-and-groove (T&G) joint
A joint formed by the insertion of a tongue (a projecting member, either as a continuous ridge along the edge of a board or plan, or as a tenon on the end of a wood member) of one member into the corresponding groove of another. (DAC)

Tyloses
Foam-like growths in live cells (parenchyma) that bulge through the bordered pits of vessel members and block water movement. (EH)

Vertical sawn (quarter sawn)
Timber produced by sawing a log lengthwise into quarters that are then sawn into boards roughly perpendicular to the tree rings. This produces boards with an even, parallel grain and greater dimensional stability than crown-sawn timber. (EH)

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APPENDIX A

Timeline of Teak Window Wall Assembly Design, Construction, Reported Conditions, and Implemented Treatments

PREPARED BY SARA LARDINOIS

SALK INSTITUTE FOR BIOLOGICAL STUDIES   The Getty Conservation Institute

Salk Institute Conservation Project: Teak Window Wall Assemblies

Timeline of Teak Window Wall Assembly Design, Construction, Reported Conditions, and Implemented Treatments

Changes in the appearance of the teak window walls over time are illustrated by the historic photographs that follow this timeline (drawing sheets TL-1 through TL-4).

Date	Event	Source(s) / (Timeline Entrant)
1960	Jonas Salk selects San Diego as his preferred site for a collaborative research center. The City of San Diego donates a 27-acre site. The Salk Institute for Biological Studies is incorporated. The National Foundation/March of Dimes provides funds for the building. Salk chooses Louis Kahn as architect to collaborate on designing an ideal environment for research.	http://www.salk.edu/about/discovery_timeline.html (Sara Lardinois, SL)
Jan. 17, 1962	Outline specifications for millwork call for redwood lumber with, unless otherwise noted, "grooved maple track inserts in bottom rail of window frames."	Louis I. Kahn Collection, call no. 030.II.A.108.11 (SL)
June 1962	Groundbreaking.	http://www.salk.edu/about/discovery_timeline.html (SL)
Oct. 8, 1962	Typewritten specification "Section 12. Carpentry and Millwork" indicates teak woodwork in studies.	Louis I. Kahn Collection, call no. 030.II.A.108.27 (SL)
Dec. 1962	First concrete poured.	http://www.salk.edu/about/discovery_timeline.html (SL)
Dec. 7, 1962	Unsigned memo, "Salk Institute for Biological Studies, Window, Door and Finish Schedule," notes: "The Owner has requested that the Architect not proceed with final development of the Laboratory window design until Laboratory planning is fully developed. At a later date, however, the Architect was requested to proceed with the design of the windows for budget purposes. Written clarification is requested." *(Unclear whether metal-framed windows in labs or wood windows in studies are being referenced, as "labs" is sometimes used to refer to the entire complex, in comparison to "meeting house".)*	Louis I. Kahn Collection, call no. 030.II.A.108.17 (SL)
Dec. 27, 1962	Letter from Kahn to Dale Harvey, owner's representative for Salk, indicates that interior millwork in studies has been changed from teak to oak.	Louis I. Kahn Collection, call no. 030.II.A.9.21 (SL)
Jan. 28, 1963	Project specifications are complete, although handwritten cover letter by John E. "Jack" MacAllister (JEM) indicates: "Section #14 'Millwork' will be expanded after detailing is complete and approved." No wood species identified in specifications.	Louis I. Kahn Collection, call no. 030.II.A.108.27 (SL)
March 1963	Preliminary specifications for "Laboratory Building." Section 14-11 (f) on installation indicates: "Bed exterior wood sills in elastic caulking	Louis I. Kahn Collection, call no. 030.II.A.108.27.2 (SL)

Note: Red text highlights the key items related to the teak window wall assemblies.

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1

SALK INSTITUTE FOR BIOLOGICAL STUDIES — The Getty Conservation Institute

Salk Institute Conservation Project: Teak Window Wall Assemblies

Timeline of Teak Window Wall Assembly Design, Construction, Reported Conditions, and Implemented Treatments

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Date	Event	Source(s) / (Timeline Entrant)
	compound as specified under Section 18." Section 14-14 on "Exterior Siding" indicates: "Exterior wood siding shall be approximately 1 ½" x 25/32" T&G teak boards set vertical and blind nailed between molded teak drips of profile as indicated. Lay out work so that no board is less than full width. Use special wide boards at ends if necessary." Interior woodwork is specified as white oak. Section 14-18 indicates: "Provide silicone treated wool pile weatherstrip for sliding glass doors."	
June 10, 1963	Architectural drawing prepared by Louis Kahn's office, entitled "Studies – Millwork Details" provides sections through the window walls. Detailing is similar to what was ultimately built. The exterior wood is identified as "teak t&g," and the interior wood is identified as oak.	Scanned architectural drawing, LA-110, provided by Tim Ball and Adam Ames of the Salk Institute (SL)
Aug. 15, 1963	Memo on status of general construction subcontracts, authored by JEM, indicates that millwork is "scheduled to be bid by 1st June, 1964. Architect has recommended that bids be taken two or three months sooner, due to long lead time necessary to buy teak of large dimensions required."	Louis I. Kahn Collection, call no. 030.II.A.108.40 (SL)
Sep. 23, 1963	Meeting minutes authored by JEM, item #10, "Pre-bid conference on the millwork will be held on or about October 1st. University Showcase and Murray Mills of San Diego have been visited by the builder and the Architect. Los Angeles Millwork Company and one additional local bidder will be visited."	Louis I. Kahn Collection, call no.030.II.A.107.18 (SL)
Nov. 16, 1963	Memo prepared by JEM on potential changes to reduce construction budget estimate of Nov. 15, 1963, suggests changing "all teak millwork to Japanese Cypress."	Louis I. Kahn Collection, call no. 030.II.A.108.37 (SL)
Nov. 26, 1963	Greenheart, Inc., a wood importer/distributor based in Fort Lauderdale, FL, sends technical product information on Greenheart, Basra Locus (also known as Guiana Teak), and Purpleheart woods sent to Kahn's office per phone request of "Friday last." *(This would seem to indicate they are looking for alternatives, following the high construction bids obtained.)*	Louis I. Kahn Collection, call no. 030.II.A.108.25 (SL)
Dec. 9, 1963	Specification Section 14 Millwork 14-07 – Interior millwork species to be solid stock oak with wax finish; exterior millwork to be solid stock teak with rubbed finish.	Salk Institute, off-site storage (SL)
Dec. 18, 1963	Memo from JEM to P. W. Roberts, owner's rep, on "Salk Institute Millwork" indicates that	Salk Institute, off-site storage (SL)

Note: Red text highlights the key items related to the teak window wall assemblies.

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SALK INSTITUTE FOR BIOLOGICAL STUDIES — The Getty Conservation Institute

Salk Institute Conservation Project: Teak Window Wall Assemblies

Timeline of Teak Window Wall Assembly Design, Construction, Reported Conditions, and Implemented Treatments

Changes in the appearance of the teak window walls over time are illustrated by the historic photographs that follow this timeline (drawing sheets TL-1 through TL-4).

Date	Event	Source(s) / (Timeline Entrant)
	the architect has completed his investigation of methods to reduce the cost of the millwork, comparing physical properties, cost, and availability of commercially available woods in the US against the technical requirements. "The results of the investigation indicated that only three woods had the required physical properties. They are 'Benge,' 'Afromosia,' and 'Honduras Mahogany.' Of the three, on Honduras mahogany could be supplied in the quantities required and within the time schedule. Honduras mahogany is very red in color and would create problems of appearance with the color of the concrete. It would also have to be treated periodically with a wood preservative or would have to be varnished…the Architect, the Builders, and the millwork subcontractor agree that this substitution should be made as a last resort only." Other deletions/cost savings are recommended, including the deletion/deferment of all sliding screens in all areas and sliding shutters in the south studies and south office wing.	
1963	Construction document drawings completed, with revisions dated through 1964.	Per dates that appear on scans of original construction drawings provided by Tim Ball and Adam Ames (SL)
Dec. 31, 1963, and Jan. 31, 1964	Millwork budget jumps from $263,420 to $478,500, with $473,675 pending.	Salk Institute, off-site storage (Claire Grezemkovsky, CG)
Feb. through March 1964	Shop drawings for window walls in studies prepared by University Showcase & Fixture Corp.; submitted in batches, with revisions ongoing through April 1964.	Per dates that appear on scanned shop drawings provided by Tim Ball and Adam Ames (SL)
Feb. 29, 1964	Millwork section reads partial shop drawings submitted; teak ordered; sample pending.	Salk Institute, off-site storage, Report #17 [alternately called Report #14] (CG)
March 11, 1964	Weekly Job Meeting Minutes, new item #2: "Millwork sub-contractor is preparing to purchase all material, and that it would be [*sic*] for the owner if the material for the partitions at the west office wings could be purchased at the same time. Drawings and partition layout and details to be issued sometime between March 16, 1964, and March 31, 1964."	Louis I. Kahn Collection, call no. 030.II.A.108.26 (SL)
March 18, 1964	Weekly Job Meeting Minutes, old item #12: "Millwork shop drawings for studies almost complete. Subcontractor to meet with Architect next week. Office wing drawings will be available on specified dates."	Louis I. Kahn Collection, call no. 030.II.A.108.46 (SL)
March 24, 1964	Weekly Job Meeting Minutes, old item #10: "Millwork Subcontractor met with Architect	Louis I. Kahn Collection, call no. 030.II.A.108.46 (SL)

Note: Red text highlights the key items related to the teak window wall assemblies.

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Salk Institute Conservation Project: Teak Window Wall Assemblies

Timeline of Teak Window Wall Assembly Design, Construction, Reported Conditions, and Implemented Treatments

Changes in the appearance of the teak window walls over time are illustrated by the historic photographs that follow this timeline (drawing sheets TL-1 through TL-4).

Date	Event	Source(s) / (Timeline Entrant)
	3/23/64. Submitted preliminary shop drawings for Studies. Architect requests a sample of teak wood 12" x 36" x 1" be airmailed from Bankok [*sic*]. Also location of mill in Thailand."	
March 31, 1964	Partial shop drawings submitted; teak ordered; sample pending.	Salk Institute, off-site storage, Report #18 (CG)
April 1, 1964	Weekly Job Meeting Minutes, old item #7: "Balance of Millwork shop drawings in process."	Louis I. Kahn Collection, call no. 030.II.A.108.46 (SL)
April 30, 1964:	Partial shop drawings submitted; teak ordered; sample pending.	Salk Institute, off-site storage, Report #19 (CG)
May 1, 1964	Weekly Job Meeting Minutes, old item #5: "A review of the millwork schedule indicates that the millwork can be completed with the rest of the work and will not overrun the construction schedule."	Louis I. Kahn Collection, call no. 030.II.A.107.18 (SL)
May 31, 1964	Shop drawings submitted; teak en route; sample panel made; $550 pending millwork charge.	Salk Institute, off-site storage, Report #20 (CG)
May through July 1964	Shop drawings for window walls in office wings prepared by University Showcase & Fixture Corp.; submitted in batches, starting with the lower levels and ending with the upper levels.	Per dates that appear on scanned shop drawings provided by Tim Ball and Adam Ames (SL)
June 18, 1964	Meeting minutes prepared by JEM: Item #15 provides a complete estimate of all known change estimates, including #6, "Delete flashing at Millwork. {C.E. #46}"	Louis Kahn Collection, 030.II.A.107.18 (SL)
July 15, 1964	Architectural elevation of the studies, drawing prepared by Louis Kahn's office, shows a design for the window walls with vertical T&G siding; however the size of T&G panels varies from what was ultimately built. A note on the drawing indicates "millwork has been revised."	Scanned architectural drawing, S-7 north, provided by Tim Ball and Adam Ames (SL)
July 31, 1964	Millwork 0% complete; oak material delivered; partial shipment of teak delivered.	Salk Institute, off-site storage, Report #22 (CG)
Aug. 31, 1964	Millwork section reads "shop fabrication."	Salk Institute, off-site storage, Report #23 (CG)
Sep. 30, 1964	Shop fabrication millwork 0% complete.	Salk Institute, off-site storage, Report #24 (CG)
Oct. 31, 1964	Millwork 0% complete.	Salk Institute, off-site storage, Report #25 (CG)
Nov. 27, 1964:	George A. Fuller Company construction progress photo illustrating "study millwork pilot exterior." (First window to be installed. Black-and-white photo appears to show variations	Salk Institute, off-site storage (SL)

Note: Red text highlights the key items related to the teak window wall assemblies.

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4

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Salk Institute Conservation Project: Teak Window Wall Assemblies

Timeline of Teak Window Wall Assembly Design, Construction, Reported Conditions, and Implemented Treatments

Changes in the appearance of the teak window walls over time are illustrated by the historic photographs that follow this timeline (drawing sheets TL-1 through TL-4).

Date	**Event**	**Source(s) / (Timeline Entrant)**
	in the color/appearance of vertical teak slats.) Fuller daily Log indicates University Showcase was on-site 11/23, 11/24, and 11/27 installing this mock-up at "column line 10 at elev. 373, north study."	
Nov. 31, 1964	Millwork 29% complete; fabricated and installed millwork for pilot study @N line 10 elev. 372.	Salk Institute, off-site storage, Report #26 (CG)
Dec. 1964	By this date, University Showcase received the contract.	Salk Institute, off-site storage (CG)
Dec. 30, 1964	Millwork 29% complete.	Salk Institute, off-site storage, Report #27 (CG)
1964/1965	Per JEM, "the teak exterior walls…were completely prefabricated in a cabinet shop, I believe at El Cajon. Everything was finished. Windows were mounted, hardware [was installed], and they were lifted by crane into place and simply bolted onto the concrete frame. And the slit glass windows at either end of those were used to make up [the difference]. In other words, they were frameless and the glass was cut to fit, which allowed us to have all the components the same size [even if] the opening varied by some inches or fractions of inches." *Later, when asked if the window walls were sprayed in the shop with a treatment or arrived bare, JEM responded:* "They came bare. They may have been protected with whatever Visqueen was in those days, I don't remember. But they came standing up in a flatbed truck, and then a crane lifted them into place. There were very few bolts to hold them in. It went in very quickly."	Written transcription of conversation with John E. MacAllister, Dec. 5, 2013 (SL)
Jan. 31, 1965	Received material for study panels and north office panels. Started to erect teak panels at the 354 level of north office wing.	Salk Institute, off-site storage, Report #28 (CG)
Feb. 28, 1965	Received set and plumbs exterior teak panels for all of the north studies and the entire north office wing. Working on interior panels for all levels of the north office wing. Received and set 75% for the south study exterior teak panels. (In this report, the millwork budget jumps from $478,500 to $501,154. Awarded $500,604 and cost to date is $416,192.)	Salk Institute, off-site storage, Report #29 (CG)

Note: Red text highlights the key items related to the teak window wall assemblies.

Prepared August 2014; copyedited March 2017 5

SALK INSTITUTE FOR BIOLOGICAL STUDIES

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Salk Institute Conservation Project: Teak Window Wall Assemblies

Timeline of Teak Window Wall Assembly Design, Construction, Reported Conditions, and Implemented Treatments

Changes in the appearance of the teak window walls over time are illustrated by the historic photographs that follow this timeline (drawing sheets TL-1 through TL-4).

Date	Event	Source(s) / (Timeline Entrant)
March 25, 1965	Memo from P. W. Roberts to G. S. Conn on millwork – south wing – proposal by J. Marinello, president of University Showcase (millwork subcontractor) describes deferral of south building's millwork, with offer of University Showcase to finance the full cost of manufacturing and installation of the millwork in the south building (both studies and west office wing) and charge no interest over the first year. *Salk does not pursue this offer.*	Salk Institute, off-site storage (SL)
March 31, 1965	Fuller Company Monthly Report: installation of millwork 95% complete. "Completed installation of exterior teak panels for the south studies and south office wings. Installing teak and oak interior panels and bookcases for upper and lower levels for all north studies. Hang doors and install hardware for pilot study. Install louvers and screens for north studies. Work of north office interior panels, door jambs, sash, etc."	Louis Kahn Collection, 030.II.A.26.49 (SL)
April 30, 1965	Fuller Company Monthly Report: installation of millwork 96% complete. "Completed all millwork except for interior partitions in North Office Wing. Framed study walls and hung sheetrock for these partitions to receive oak veneer panels."	Louis Kahn Collection, 030.II.A.26.49 (SL)
May 31, 1965	Fuller Company Monthly Report: installation of millwork 100% complete.	Louis Kahn Collection, 030.II.A.26.49 (SL)
June 1, 1965	**Reported Condition:** Memo to files re "Permanent Building – Fuller Contract Items Functioning Unsatisfactorily." "The following items have been orally reported to the Architect as functioning in an unsatisfactory manner and whose responsibility it is to solve to the satisfaction of the Institute: 1. Sliding windows and louvers, west Office Wing & Studies: The lack of a tight seal between the vertical surfaces of the sliding windows and louver frames may result in leakage during heavy or horizontal rain conditions. In addition, the latches are fragile and several have been broken as of this writing." **Proposed Treatment:** "The Architect recommends that a vertical strip be installed as a test. This item was eliminated in the 1963 cutback."	Roberts, P. W. 1965. Written memo to files, June 1, 1965. Salk Institute, off-site storage (SL)

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Prepared August 2014; copyedited March 2017

6

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Salk Institute Conservation Project: Teak Window Wall Assemblies

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Date	Event	Source(s) / (Timeline Entrant)
Nov. 17, 1965	**Reported Condition:** Letter from P. W. Roberts to George A. Fuller reports on period of heavy rain from Nov. 15 to 17, in which 2.65 inches of rain was recorded. Substantial building leaks described included "water entering Studies U4 and U3 and collecting under the floors and working through the flooring, as well as entering the electrical system and flowing through the conduits."	Louis I. Kahn Collection, call no. 030.II.A.107.17 (SL)
Nov. 24, 1965	**Reported Condition:** Letter from P. W. Roberts to Louis Kahn reports on period of heavy rain from Nov. 15 to 17, and again from Nov. 20 to 23. Substantial amounts of water entered the building on both occasions, including the following: "4. More than half the studies have standing water under the floors. The water is working through the flooring… 6. Water is entering the south-west end of the [sixth level of the west office wing], passing under the floors and into light fixtures on the fifth level and dripping on the floor in the Fellows Room."	Louis I. Kahn Collection, call no. 030.II.A.107.17 (SL)
1966	First laboratories in new north building are occupied.	http://www.salk.edu/about/discovery_timeline.html (SL)
1966	**Reported Condition:** Letter from R. E. Nordstrom of George A. Fuller Company to Center Glass Company regarding the millwork caulking, dated Jan. 26, 1966, describes a number of conversations following the Nov. 1965 rains and an observation of "water penetrating through daylight areas under millwork water table of upper study No. 4, north wing." **Proposed Treatment:** On Jan. 5, 1966, Center Glass Company removed the existing caulking at upper study no. 4 and re-caulked the millwork at the juncture with the concrete. A hose test on Jan. 14, 1966, proved the re-caulked joint to be "impervious to water penetration." On Jan. 19, 1966, U. M. Linder (architect's rep) and Nordstrom visited the re-caulked area to test it and found that the "caulking material bonds properly where primer has been used. Mr. Waldman (Center Glass) concluded that the surfaces receiving caulking at this project were not adequately	Louis Kahn Collection, 030.II.A.107.17 and 030.II.A.108.31; Salk Institute, off-site storage (SL)

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Salk Institute Conservation Project: Teak Window Wall Assemblies

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Date	Event	Source(s) / (Timeline Entrant)
	primed." Nordstrom recommends Center Glass take corrective action on the defective work. Letter from Nordstrom to JEM, dated March 18, 1966, describes the failure of the caulking to bond to the teak. Indicates that Dow Corning is recommending "a different primer as surface preparation to overcome the bonding failure" and that "Center Glass Company will replace window wall putty where this glazing compound has adopted amorphous characteristics." Letter from Robert Huhnke of Dow Corning, dated May 10, 1966, and attached to letter from Nordstrom to Louis Kahn (May 19, 1966), says Dow is "disclaiming any responsibility for failure of the #780 product to bond to the teakwood." Huhnke writes, "Some types of teakwood contain more oil than others, although teakwood is generally loaded with it. There is nothing that will stick to oil. About the only thing left to be done is to get the oil out of the wood, which is nigh on impossible. Center Glass would have the same trouble with any other kind of sealant. It appears that this puts it right back in the architect's lap since he has designed an unworkable system depending totally on the sealant's adherence to the teakwood to keep out the water." Letter from U. M. Linder to G. Conn, Sep. 19, 1966, indicates that "Dow Corning has so far not shown any indication to cooperate." However, Kahn's office feels the responsibility is theirs (Dow Corning), as they recommended this specific application. Suggests that some "higher up" pressure from the Institute may help resolve this matter.	
Aug. 18, 1966	Letter from Louise M. Badgley, secretary to Kahn, responding to Drucilla B. Boit's request for information on exterior wood preservatives used at the Salk Institute: "I have asked Mr. John MacAllister of our office for this information and he states there was no finish used on the exterior wood, since the type of wood used was Teak and did not, therefore, require a finish coating."	Louis I. Kahn Collection, call no. 030.II.A.107.17 and 030.II.A.108.25 (SL)
Nov. 11, 1966	**Reported Condition:** List of Items Requiring Attention (Not Conclusive) – no author listed: 2. Woodwork in Studies: We know the cause of the bowing and cracking. A solution should be detailed and priced. 12. Teak staining: no action taken yet. 13. All windows not waterproof: no action taken yet.	Salk Institute, off-site storage (SL)

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Prepared August 2014; copyedited March 2017

SALK INSTITUTE FOR BIOLOGICAL STUDIES

The Getty Conservation Institute

Salk Institute Conservation Project: Teak Window Wall Assemblies

Timeline of Teak Window Wall Assembly Design, Construction, Reported Conditions, and Implemented Treatments

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Date	**Event**	**Source(s) / (Timeline Entrant)**
Dec. 7, 1966	**Reported Condition:** Memo from Carlos Johnson to A. Kinzel on Building Malfunctions: 1. All windows in the studies and west office wings are reported to be leaking water. “The winds which frequently pelt the building drives the water into the window framework around the rabbeted mouldings and creates funnel-like spouts for the water to get behind the paneling. Then it runs to the bottom of the framework. Here the caulking and flashing prevent it from running out. Instead, the water is diverted into the building and runs down the cork strips and under the oak flooring and eventually finds its way—in the Fellows Room as an example—through the cement openings along electrical conduit lines and drips on to the furniture and floor beneath. The results are water-stained panels of oak on the inside of the window frames. Exterior weathering is evident since no sealer is on this wood either inside or outside.” **Proposed Treatment:** Letter recommends the following: a. Sealing of the rabbeted joints and seams. b. Sealing the ends of the brass guide rails on which the glass frame and louvered frames slide. c. Correcting the caulking under the window framework so moisture can drain out. d. Caulking on the inside panels to prevent moisture from flooding into the building. e. Weatherproof bronze extrusions installed in the window frames. Memo indicates that the study and office caulking issue has not yet been resolved with Dow Corning. Johnson recommends that “the matter of the caulking should be accomplished and possible clear sealer should be coated on the window sill. Further sealing of the louvered frames may be done by some techniques of weather-stripping.” Letter from Johnson to U. M. Linder, dated Dec. 29, 1966, inquires about the progress of “the design for weather-proofing the windows in the dining area? It was my understanding that if this model window was successful after the weather test, this same technique would be used for weather-proofing all of the windows in the west office wing.”	Salk Institute, off-site storage (SL)

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The Getty Conservation Institute

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Date	Event	Source(s) / (Timeline Entrant)
	Letter from Johnson to Zero Weather Stripping Company, dated March 9, 1967, asks for assistance in this matter. Johnson indicates that the areas in need of weatherstripping are ¼ inch wide, but due to warping in the marine environment, the area can be as small as 3/16 inch wide. Johnson asks if Salk's solution of a nylon pile with 3/8-inch bristle mounted similarly to Zero's part #54M single screw of #39 single screw will work. He notes material will have to be bronze to match the decor of the building. He closes by saying "the problem is reaching a critical point."	
1967	Completion of core building construction.	http://www.salk.edu/about/discovery_timeline.html (SL)
Aug. 9, 1967	**Implemented Treatment:** Letter from U. M. Linder to Johnson provides a list of items accomplished since Nov. 1966 and items yet to be done. Linder is concerned about addressing these issues with the inclement weather months just ahead. Items include: "2. Woodwork in studies: The cause for warping and splitting has been largely reduced. We should now think about repairing the wood panels." (A 9/27/67 list from Johnson suggests this work will move forward; a 10/17/67 letter from Linder says the woodwork shall not be repaired until the respective studies are occupied.) "12. Teak staining Completed 70% - recommend that entire woodwork be washed. 13. All windows not waterproof: Proposal to G. Conn by C. Johnson in May 1967. No action since." A 9/27/67 list from Johnson suggests this work will cost $13,000.)	Salk Institute, off-site storage (SL)
Aug. 23, 1967	**Proposed Treatment:** Johnson, memo to files, Walk Through of Laboratories: "6. The study area leaks are due to improper construction of the teak panels according to Dr. Komendant. He suggested that these panels be sealed with creosote. Earl Walls and Dr. Komendant both suggested that this creosote would be plain and would not change the color of the paneling. It was further observed that this type of wood paneling is for interior woodwork and not intended for exterior finishes."	Salk Institute, off-site storage (SL)
Oct. 30, 1967	**Implemented Treatment:** Letter from Johnson to U. M. Linder re "Preserving the Teak Panels" indicates: "The teak panels which are part of the studies facing the center of the garden area have been washed down and cleaned of mildew by A. P. McCune and Cloies Hudspeth. The process	Salk Institute, off-site storage (SL)

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The Getty Conservation Institute

Salk Institute Conservation Project: Teak Window Wall Assemblies

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Date	Event	Source(s) / (Timeline Entrant)
	has been effective; the panels are clean and give a very fine appearance. The panels that were washed first have begun to show signs of mildew reappearing." Johnson goes on to say that Linder's suggestion of washing the panels each year (with no applied protective coating) will not be effective, as the problem will become greater with each washing: "the mildew would go deeper into the pores of the wood. Eventually, this appears to be a problem that could not be completely resolved by this method alone." Thus, the plant engineer recommends a coating of water seal or bleach or preservative be applied immediately after washing to preserve the wood surface, prevent the grain from rising, and keep mildew from penetrating deeper into the wood. Indicates that the plant engineer has some samples of teak wood under experiment for the purposes of checking weathering and preventing fungicide buildup and appearance, but will require another six months before the results are fully known.	
Dec. 1967	Architectural historian and journalist Esther McCoy on her visit to the site with Dr. Salk: "We had been talking in his office on the next to top floor at the west end of the north block. His desk was placed far back into the room, and he faced windows shielded from the glare of the sky and sea by louvered teak screens streaked with rain marks. Before he left to change from his white lab coat to an olive tweed jacket, he paused to comment on the materials and the windows. He would have liked windows lower. He allowed that they composed well on the exterior but inside they were so high he lost some of the view. As for the wood panels, frames, and screens of the window elements, 'Wood posed some problems of jointing. It isn't watertight. The wood wasn't installed with a healthy respect for rains. The first year the building was up was the heaviest rainfall, and for economy we had left out the weather stripping. It was unwise, there is no tight seal.'"	McCoy 1967, 32–34 (MD)
April 3, 1968	**Proposed Treatment:** Memo from JEM to J. Hunt regarding "M. Cohn Memo dated 29 March, 1968" (*a copy of this original memo has not been located)*: 3. Water entering under the study floors is due to two conditions: a. Failure of Dow 780 silicone caulking material; Dow has not yet addressed this failure. b. "All weatherstripping in the studies and office wings was deferred to bring the initial construction cost in line with the budget. We have already made recommendations for the installation of proper weatherstripping."	Salk Institute, off-site storage (SL)

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SALK INSTITUTE FOR BIOLOGICAL STUDIES — The Getty Conservation Institute

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Date	Event	Source(s) / (Timeline Entrant)
April 9, 1968	**Reported Condition:** Letter from W. E. Eslyn, plant pathologist, fungus and insect investigations, Forest Products Lab, to Carlos Johnson: "We have examined the stained piece of teak wood which you forwarded here for inspection and noted the presence of a heavy accumulation of dark-brown, Sclerophoma-like hyphae on the wood surface." **Proposed Treatment:** "To correct this condition, we recommend you first rid the panels of this growth either by scrubbing the affected surface with a Clorox [bleach] solution or by light sanding. We tried both methods with success on the sample you provided us. If the scrubbing method is used, you should rinse the wood well afterwards and then allow it to dry out thoroughly before further treatment. When the surface has been cleaned to your satisfaction, paint or spray the wood with a water-repellent solution of 5 percent pentachlorophenol in light oil, making sure that the wood is thoroughly soaked in the process. To maintain the panels free of fungi, it will probably be necessary to repeat the application of this preservative about every 2 to 3 years."	Salk Institute, off-site storage (SL)
July 31, 1968	**Reported Condition:** Memo from Johnson to Virginia White, Salk Institute secretary, re "Sealing of Teak Panels": The fungus growth on the teakwood panels "give the appearance of a 5 o'clock shadow on all of the panels that do not get much sunlight. All of the west exposure of both the North and South Building and the study towers of the South Building are particularly affected." **Proposed Treatment:** "I could have the panels cleaned and the wood sealed. We have several samples of sealer on teak and these have been exposed to the weather for several months. Jack MacAllister has noted these samples and so has Ullie Linder. Some of them have been acceptable. The panels could be treated with a wood preservative, or they could be treated with a DuPont epoxy resin…the treating of the exterior panels could be done in three different phases" at a total cost of $2,750.	Salk Institute, off-site storage (SL)

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Date	Event	Source(s) / (Timeline Entrant)
March 4, 1969	**Implemented Treatment:** Memo from Johnson to Virginia White: 4. Corrected leaks in studies: "Only one-half of Dr. Cohn's Study has had leaks corrected. However, the exterior was not sealed; only two window units of three have been sealed and weather-stripped from the inside. Seventeen studies on the north side remain to be done. The cost as estimated by Salk Institute is $5,334.00." 5. Status of teakwood waterproofing: North study windows: Dr. Cohn's study is one-half complete; 35 units remain to be completed. South study windows: outside only 18 studies to be completed. North study windows: exterior cleaning fungus and sealing. South study windows: exterior cleaning fungus and sealing. West office wing – north building: Mr. Slater's office completed; 25 units to be completed. West office wing – south building: 26 units remain to be completed.	Salk Institute, off-site storage (SL)
1970s and 1980s	**Implemented Treatment:** The bleach cleaning treatment recommended by the Forest Products Lab in 1968 was undertaken approximately every 2 to 3 years on all sides of the building. Treatment was done at the time of year when the Santa Ana winds are blowing and the weather is warm and dry. Wood was washed and cleaned, working from top to bottom at all elevations except the plaza-facing elevations. At some point, wire brushes began to be used in the cleaning process—most likely to improve the efficacy of the cleaning, as the fungus became more difficult to remove. The use of wire brushes was discontinued in the 1990s after it was found to contribute to the deterioration of the wood. The use of trisodium phosphate (TSP) and a wood preservative was also reported.	As verbally conveyed by Salk staff to Sara Lardinois during site visit, Dec. 4–5, 2013 (SL)
Late 1980s	**Implemented Treatment:** Wood framing at south studies was treated for termites prior to installing interior finishes, primarily at the garden-facing elevations (south elevations).	As verbally conveyed by Salk staff to Sara Lardinois during site visit, Dec. 4–5, 2013 (SL)

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Date	Event	Source(s) / (Timeline Entrant)
January 1993	A facility condition analysis of the Salk Institute was performed by ISES Corporation of Lilburn, Georgia. The results of this work are contained 1999 update report submitted to the Salk. **Reported Condition of the Window Walls in 1993:** Project Title: Exterior Teak and Window Restoration. Building Name: North Tower. Project Class: Deferred Maintenance. Project Date: 1/25/93. Project Location: Building Wide: Floor(s) 1,2, 3, 4, 5, 6. Project Description: "The exterior window units are in need of general maintenance. The slide tracks are very dirty and in need of lubrication in order to improve operation. Also, the exterior teak wood that surrounds the windows has developed a fungus in the areas that are not exposed to direct sunlight. All the windows should be restored to the original manufacturer's specifications for the operation. All of the teak should be cleaned and sealed with weather protectant." Building Name: South Tower. Project Class: Deferred Maintenance. Project Date: 1/26/93. Project Location: Building Wide: Floor(s) 3, 4, 5, 6. Project Description: "The exterior window units are in need of general maintenance. The slide tracks are very dirty and in need of lubrication in order to improve operation. Also, the exterior teak wood that surrounds the windows has developed a fungus in the areas that are not exposed to direct sunlight. Most of the teak on this building faces to the north so the extent of the fungus problem is a little larger in scale than the problem on the North Tower. All the windows should be restored to the original manufacturer's specifications for the operation. All of the teak should be cleaned and sealed with weather protectant."	Salk Institute, off-site storage (SL)

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Date	Event	Source(s) / (Timeline Entrant)
1994/1995 +/-	**Implemented Treatment:** Following the advice of a yacht/marine specialist, TE-KA "scrubless" two-part teak cleaner was applied to some/all? of teak on-site for the first time (previous cleaning was done with bleach). TE-KA formula A is described as the cleaner and formula B as the brightener. Following cleaning and brightening, Tip Top Teak Wood-Oil Sealer was applied to the teak. This process was repeated approximately every five years until 2009 +/-. Salk staff provided a container of Tip Top Teak Wood-Oil Sealer stored on the site to the GCI Science Department for laboratory analysis.	As verbally conveyed by Salk staff to Sara Lardinois during on-site meeting, Dec. 4, 2013 (SL)
2009 +/-	**Implemented Treatment:** According to staff, the last time the teak was cleaned was approximately four years ago (2009?). During this cleaning effort, the main focus was on the plaza-facing elevations.	As verbally conveyed by Salk staff to Sara Lardinois during on-site meeting, Dec. 4, 2013 (SL)
2013	**Implemented Treatment:** At the current time, washing windows a couple of times a year; nothing has been done to the teak for several years in anticipation of a more comprehensive solution and project at the window wall assemblies.	As verbally conveyed by Salk staff to Sara Lardinois during on-site meeting, Dec. 4, 2013 (SL)
2014	**Proposed Treatment:** Area of vertical teak board at window NO6K fell to the ground during storm on Feb. 28. 2014. Exposed furring strips exhibit moisture and termite damage. **Implemented Treatment:** Replaced with new teak boards.	As observed on-site (SL)

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15

SALK INSTITUTE FOR BIOLOGICAL STUDIES

The Getty Conservation Institute

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ARCHIVES

Louis I. Kahn Collection, University of Pennsylvania and Pennsylvania Historical and Museum Commission.

Salk Institute for Biological Studies, Off-Site Storage and Archives.

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OFFICES - WEST ELEVATIONS

030.V.D.18.13_Feb 65

February 1965
- Preassembled window wall units being installed; sliding windows, sashes, louvers, and shutters not yet installed
- Color differences in adjacent vertical sidings

aaup.260.I.D.37.9_Oct 67

October 1967
- Moisture stains on lower portion of vertical siding panels
- Dark gray appearance on sloped teak sills
- Dark gray appearance on teak windowsills
- Dark red, varied appearance on shutters

aaup.260.I.D.40.9_1972

September 1972
- Water marks on lower portion of vertical siding panels
- Black fungus growth heavier on upper window wall assemblies
- Gray appearance (weathering) on vertical siding panels and frames
- Varied red appearance on shutters and frames

aaup.260.I.D.47.3_Mar 77

March 1977
- Fungi appear to be less dense than in previous years
- Gray appearance (weathering) on window wall assemblies
- Varied red appearance on window wall assemblies

aaup.260.I.D.44.8_May 76

May 1976
- Fungi appear to be heavier at the south office building west-facing windows than at the north office building west-facing windows
- Increase in black fungus growth
- Moisture stains on window wall assemblies

aaup.260.I.D.42.17_Mar 73

March 1973
- Black fungus growth heavier on upper window wall assemblies
- Moisture stains on window wall assemblies
- Varied red appearance on adjacent vertical sidings and vertical trims

Note: Photos beginning with aaup.260 (tag at right side of image) courtesy of The John Nicolais Collection, The Architectural Archives, University of Pennsylvania.
Photos beginning with 030 (tag at right side of image) courtesy of the Louis I. Kahn Collection, University of Pennsylvania and Pennsylvania Historical and Museum Commission.

SALK INSTITUTE CONSERVATION PROJECT
Teak Window Wall Assemblies

SALK INSTITUTE FOR BIOLOGICAL STUDIES
The Getty Conservation Institute

Drawing Name:
TIMELINE OF OBSERVED CHANGES IN APPEARANCE OF WOOD WINDOW WALLS
Salk Institute for Biological Studies
La Jolla, CA

Drawing Issued: 5/2014, updated 3/2017
Drawn By: MD

Sheet No.: TL-1

OFFICES - NORTH ELEVATIONS


aaup.260.I.D.33.6b_July 65


aaup.260.I.D.42.17_Mar 73


aaup.260.I.D.49.1_Apr 77

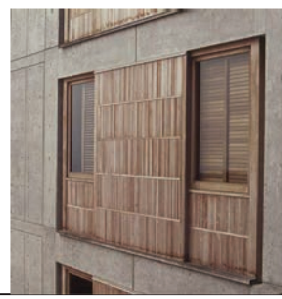
July 1965
- Gray appearance on sloped teak sills

March 1973
- Color of teak lightens

April 1977
- Moisture stains on lower part of widow wall assemblies
- White phenomenon on the windowsill
- Varied red appearance on shutters and trims

OFFICES - SOUTH ELEVATIONS


aaup.260.I.D.33.11_July 65


aaup.260.I.D.35.20_Oct 67


aaup.260.I.D.39.3_Apr 72


aaup.260.I.D.45.3_Dec 76

July 1965
- Color differences in adjacent vertical sidings
- Moisture stains on lower part of window wall assemblies
- White phenomenon on sloped teak sill
- White phenomenon on teak windowsill

October 1967
- Black fungus growth on sloped teak sill
- Gray appearance (weathering) on vertical siding panels, teak drip cap, teak drips, and teak sliding window sashes
- Moisture stains on bottom of window wall assemblies and vertical trims

April 1972
- Moisture stains on bottom of window wall assemblies and vertical trims

December 1976
- Moisture stains above and below teak drips

Note: Photos beginning with aaup.260 (tag at right side of image) courtesy of The John Nicolais Collection, The Architectural Archives, University of Pennsylvania.
Photos beginning with 030 (tag at right side of image) courtesy of the Louis I. Kahn Collection, University of Pennsylvania and Pennsylvania Historical and Museum Commission.

SALK INSTITUTE CONSERVATION PROJECT
Teak Window Wall Assemblies

SALK INSTITUTE FOR BIOLOGICAL STUDIES — The Getty Conservation Institute

Drawing Name:
TIMELINE OF OBSERVED CHANGES IN APPEARANCE OF WOOD WINDOW WALLS
Salk Institute for Biological Studies
La Jolla, CA

Drawing Issued: 5/2014, updated 3/2017
Drawn By: MD

Sheet No.: TL-2

NORTH AND SOUTH STUDIES - WEST ELEVATIONS

aaup.260.I.D.33.5_June 65

aaup.260.I.D.35.9_Oct 67

aaup.260.I.D.39.10_Apr 72

June 1965
- Installation of window wall assemblies complete
- Minor color differences in adjacent vertical sidings

October 1967
- Moisture stains on lower portion of window walls
- Black fungus growth on sloped teak sill, windowsill, sliding window sashes, and teak trim boards
- Gray appearance on sloped teak sills and windowsills

April 1972
- Moisture stains on lower portion of vertical siding panels
- Varied red appearance on teak drips with darker area above drips

aaup.260.I.D.54.9_May 77

aaup.260.I.D.45.1_Nov 76

aaup.260.I.D.43.5_Mar 73

May 1977
- Black fungus growth on sloped teak sill and sliding window sashes
- Weathering on window walls
- Moisture stains on window walls

November 1976
- Weathering at vertical siding panels and frames
- Moisture stains rise on window walls; it appears height of the moisture stain is rising
- Varied red appearance on adjacent vertical sidings and vertical trims
- Black fungus growth on sloped teak sill and sliding window sashes

March 1973
- Teak has sunbleached appearance
- Gray appearance (weathering) on sloped teak sill and sliding window sashes
- Moisture stains on lower portions of window walls
- Varied red appearance on adjacent vertical sidings and vertical trims

Note: Photos beginning with aaup.260 (tag at right side of image) courtesy of The John Nicolais Collection, The Architectural Archives, University of Pennsylvania.
Photos beginning with 030 (tag at right side of image) courtesy of the Louis I. Kahn Collection, University of Pennsylvania and Pennsylvania Historical and Museum Commission.

SALK INSTITUTE CONSERVATION PROJECT
Teak Window Wall Assemblies

SALK INSTITUTE FOR BIOLOGICAL STUDIES
The Getty Conservation Institute

Drawing Name:
TIMELINE OF OBSERVED CHANGES IN APPEARANCE OF WOOD WINDOW WALLS
Salk Institute for Biological Studies
La Jolla, CA

Drawing Issued: 5/2014, updated 3/2017
Drawn By: MD

Sheet No.: TL-3

NORTH STUDIES - PLAZA-FACING (SOUTH) ELEVATIONS

aaup.260.I.D.33.2_June 65

June 1965

- Installation of window wall assemblies complete; note that windows have not yet been installed
- Color differences at adjacent vertical sidings
- White appearance on sloped teak sill and teak drip cap; sunlight reflection or deposit?

aaup.260.I.D.36.12_Oct 67

October 1967

- Moisture stains above sloped teak sill and teak drips and below drip cap
- Black fungus growth on sloped teak sill and windowsill
- Gray appearance on sloped teak sills and teak trim board

aaup.260.I.D.38.10_Apr 72

April 1972

- Dark red appearance below drips and windowsill

aaup.260.I.D.53.5_May 77

May 1977

- Black fungus growth on sloped teak sill and teak trim board
- Moisture stains above sloped teak sill
- Varied red appearance on teak, with dark red areas below drips and windowsills

aaup.260.I.D.45.2_Dec 76

December 1976

- Moisture stains above sloped teak sill
- Black fungus growth on sloped teak sill and teak trim board
- Varied red appearance, with dark red areas below drips and windowsills

aaup.260.I.D.43.5_Mar 73

March 1973

- Teak has sunbleached appearance

Note: Photos beginning with aaup.260 (tag at right side of image) courtesy of The John Nicolais Collection, The Architectural Archives, University of Pennsylvania.
Photos beginning with 030 (tag at right side of image) courtesy of the Louis I. Kahn Collection, University of Pennsylvania and Pennsylvania Historical and Museum Commission.

SALK INSTITUTE CONSERVATION PROJECT Teak Window Wall Assemblies SALK INSTITUTE FOR BIOLOGICAL STUDIES · The Getty Conservation Institute	Drawing Name: TIMELINE OF OBSERVED CHANGES IN APPEARANCE OF WOOD WINDOW WALLS Salk Institute for Biological Studies La Jolla, CA	Drawing Issued: 5/2014, updated 3/2017 Drawn By: MD	Sheet No.: TL-4

APPENDIX B

Transcription of Conference Call with Jack MacAllister, FAIA, Regarding the Teak Fenestration System

TRANSCRIBED BY MESUT DINLER

The Getty Conservation Institute
Buildings and Sites Department
1200 Getty Center Drive, Suite 700
Los Angeles, CA 90049

Conference Call Transcription

Salk Institute for Biological Studies Conservation Project: Teak Window Wall Assemblies Conversation with Jack MacAllister, FAIA

Call conducted from the Salk Institute for Biological Studies, La Jolla, California
December 5, 2013

Participants:
John E. "Jack" MacAllister, FAIA, via telephone from the San Francisco Bay Area

Garry Van Gerpen, former Vice President, Scientific Services, Salk Institute
Claire Grezemkovsky, former Assistant Director, Foundation Relations, Salk Institute
Kyle Normandin, former Senior Project Specialist, Getty Conservation Institute
Sara Lardinois, Project Specialist, Getty Conservation Institute
Herant Khanjian, Assistant Scientist, Getty Conservation Institute
Joy Mazurek, Assistant Scientist, Getty Conservation Institute
Mesut Dinler, former Graduate Intern, Getty Conservation Institute
Ronald Anthony, Wood Scientist, Anthony & Associates, Inc.
Kim Dugan, former Wood Specialist, Anthony & Associates, Inc.

INTRODUCTION

The following is an edited transcript of a conference call between Jack MacAllister, FAIA, and the Salk Institute for Biological Studies Conservation Project team, which included Salk Institute staff and Getty Conservation Institute staff and consultants. MacAllister was a project architect in Louis Kahn's office. He played a significant role in the design of the Salk Institute and oversaw construction in the field in La Jolla. He, along with David Rinehart, later design the East Building addition to the Salk in the 1990s. During Phase 1 of the conservation project, the team conducted a telephone interview with MacAllister to better understand the original design and construction of the teak window wall assemblies. They discussed the early maintenance of the assemblies—in particular, past cleaning efforts to remove the black fungus that began to appear on the teak wood soon after completion of construction. MacAllister also provided his opinion on the appropriateness of different potential conservation solutions, which had yet to be developed. Sadly, MacAllister passed away less than a year after this interview was conducted, in October 2014, at the age of eighty.

TRANSCRIPTION

Transcribed by Mesut Dinler; reviewed and edited by Sara Lardinois, January and February 2014; copyedited by Dianne Woo, April 2017.

KYLE NORMANDIN: [To begin,] I'd like to give you a couple of sentences on the project. This project is falling under our new initiative launched in March 2012, which is part of the

Conserving Modern Architecture Initiative. The GCI started this program in an effort to look at architecture from the twentieth century and at different approaches to this period of architecture. Our involvement with the Salk Institute now is to take a close look at the teak wood. We are carrying out an investigation and survey to help the Salk and to provide some recommendations for how we might take care of the wood in the future, repair it, or apply treatments that would extend the longevity of the wood. We are just getting started with that process now, and this project is new. Our other field project as part of this initiative is the Eames House Conservation Project, which is the house that Charles and Ray Eames lived in which is located in Pacific Palisades.

JACK E. MACALLISTER: I know it well. I've been there many times.

KN: We have two very important projects, iconic works in California that fall under this initiative, and we're really excited about this opportunity to work here.

JEM: I am excited that you are helping us. It's terrific. Shall I run through my thoughts, Garry, as a way of starting, or do you have another plan?

GARRY VAN GERPEN: No, that would be a good way to start. That way we can know what you are thinking.

JEM: […] Let me give you a little bit of history, first of all. When we started the construction of Salk, the contractor that was chosen was George A. Fuller Company from New York. Their background was entirely in high-rise commercial buildings and not in institutional buildings, so there was kind of an ongoing fight from the beginning about the cost of the project and Fuller's desire to apply the technologies that they knew from high-rise buildings to Salk. The initial fight was, would it be a structural steel building, which Fuller was an expert in, or a concrete building, which was what we wanted? We had to constantly find ways of beating their prices by being more clever than they were. One of the strategies that I devised was to do prefabrication of as many building components as we could, both to make the quality better, since the work would be done in a factory setting, and to make them cheaper, because the field labor would be cut down. There were four areas where we accomplished that, and in every case we were able to beat Fuller's alternatives.

One was the teak exterior walls, which were completely prefabricated in a cabinet shop, I believe at El Cajon. Everything was finished. Windows were mounted, hardware [was installed], and they were lifted by crane into place and simply bolted onto the concrete frame. And the slit glass windows at either end of those were used to make up [the difference]. In other words, they were frameless and the glass was cut to fit, which allowed us to have all the components the same size [even if] the opening varied by some inches or fractions of inches.

[Two was that] doors and frames are done the same way.

[Three] the formwork.

[Four] the ceilings slots in the labs.

After I moved back to Philadelphia and was back at Kahn's office—I think the building must have been in place two years—I got a call from Jonas [Salk]. He said, "Jack, the teak is all turning black and we're very alarmed about it. What do you know about it?" I said, "Nothing. I'll come out."

I flew to La Jolla, and I got on a ladder, scraped some of what looked like black mold to me into an envelope, and mailed it to Forest Products Laboratory in Wisconsin and asked them if they knew what it was. For some reason I didn't tell them where it was from. I got a note back from them saying, is there any chance that this building is on the sea and are there kelp beds anywhere near the building? I wrote back and said you are right on both [counts]—we're in La Jolla, we're adjacent to the sea, and there are serious kelp beds right offshore. They then wrote back that the material was a spore that came from kelp beds, and if we treated it with a mild bleach solution every couple of years it should not be a problem. My understanding was that's what we did. I wasn't aware that we were also using wire brushes on it, which I would have stopped, certainly.

Now, that's the history. You can ask me questions about other things. But the potential problems that I see, and I'm sure you see, are these: One is the presence of asbestos. I have a lot of experience with buildings and projects where we've had asbestos. I know how expensive it is [to mitigate]. Two, if we replace the whole unit, the building authorities may want us to upgrade the glazing to conform to today's building code, which could [mean] double-glazing and low-e glass, and so forth. The window and shutter hardware is shot. Every time I've been there I noticed that. So that should be replaced.

Another problem from the prefabrication is that, I believe, all the exterior teak is blind fastened from the back, from the inside. This means that there is no way to get it out from the outside without taking the inside skin off as well, which complicates the matter.

I wouldn't go ahead with anything until we know how we're going to protect it in the future and, if it is new, is there a way of pressure treating it without changing the color that would protect it from these spores? There needs to be a plan.

There are several historic listings the building has, and I am not sure what they are—I haven't kept up with that. We need to be careful that we're not stepping on anyone's toes. I think the biggest problem of all is [implementing] the wrong solution and having the wrath of the worldwide architectural community come down on all of this. Obviously, you are not replacing with Formica or oil cloth or whatever, but whatever we do, it has to be something that preserves what people see as value in the building.

The last thing is fundraising. This is a building that's valued by architects worldwide. I think I can help raise funds. I'm at a high point in my career right now. I was given the AIA [California Council] Lifetime Achievement Award this year in fact, which is the highest honor they give to any architect. I also just gave a keynote address at the Monterey Design Conference which, for reasons that escape me, was very well received. […] I'm also very identified with the Salk Institute worldwide by architects, so I'd like to be part of the solution in two ways: One, to be a filter that you all use to pass solutions through, to see if I think they are appropriate. […] And two, I would like to have a role in raising money for it.

[…]

One last thought: the teak is fifty years old. Not many materials last fifty years without resurfacing, repainting, what have you. So it is not too shocking that it would need some treatment. The other thing you should be aware of is that of all the science buildings built in the sixties—and many of them were built at the University of California—this is the only one that is still being used as a research building. The others are all obsolete and have been abandoned or rebuilt for softer uses. I think that's the remarkable thing about the building that people should know.

KN: That's a good point. That certainly adds to the significance of this place.

[…]

KN: Jack, I think a lot of our questions focus on the themes you just presented. We'd like to have an informal discussion with you and go through those questions, and if there are more that come up, have an open discussion about it.

SARA LARDINOIS: We wanted to ask you to talk in more detail about the design intent, in terms of color and appearance and what you had hoped for. [Was the intent for the teak to develop] a uniform gray appearance?

JEM: Yes, that's a good point. One of the things I immediately thought of was a solution that would put a shiny finish on it or keep it dark would be inappropriate. The marriage of—the consistency of—the total value of the building, from the concrete to the travertine to the grayed-out teak, I think is one of the really subtle beauties of the building. There's nothing that jumps forward of everything else. [The materials] all have that same built-in patina, as it were, where they look like they are all related. I think it would be a mistake to do anything that suddenly made the teak look brand new and kind of like a perfect material. Its weathering was something we welcomed and knew would happen. So I think a solution has to allow the teak to still be a natural material and not some super material that never changes.

KN: There are different interpretations about the weathering of teak. Certainly, in a lot of historic photos [of buildings] where the material has been used extensively, say in places like Southeast Asia, there is a more uniform grayness to the material, but that aging of the material or that weathering over time is in a different geographic location than what we have here, next to the ocean. I think what we're seeing at the Salk is representative of what would happen quite quickly to the aging of the teak based on its exposure to the ocean. I wonder if you have any sense of what the intent was at the beginning for how the teak would look over time. Was there a sense to that? What was the gauge?

JEM: Let me back up a little bit. Lou did not like to use any materials that required repainting over time or refinishing. He always made a joke that the next janitor might have bad taste and paint everything pink. So we tried to use materials that required no maintenance and no painting. In fact, the only painted surface in the original building, in the entire building, is the fire doors. The doors that had ratings—because no one had ever burned a stainless steel fire door in a test—we had to use baked-on enamel for those. Other than that, there is no paint in the entire building. The teak was consistent with that—it would be a long-lived material that required no refinishing. I have owned several fairly large sailboats with teak decks, so I am very familiar with living with teak. Aircraft carriers, by the way, have teak decks on them, or they used to. It is an incredible wood, and it just stands (?), which ultimately led to its downfall, but I am not sure of that either.

The monotone look of the teak, the travertine, and the concrete and stainless steel I think is very important to the preservation of what people see as a value in that building and its architecture.

RONALD ANTHONY: So Jack, with something like a boat or aircraft carrier deck, one of the components that gives that patina to the teak is fairly regular maintenance on an annual basis or every other year. You are doing something to clean that material. Here at the Salk, I don't think it was ever anybody's intention to do maintenance annually or every couple of years, the consequences [being that] the teak has weathered to a differential color pattern. Some of the material is that nice silver-gray patina you envisioned, some of it is more of a yellow, brownish look, and then we've got the black spores, that's a separate issue. But from the color alone, we do not have at this point a uniform gray color to the teak panels.

JEM: I know, and I think that is something Lou would have said [in response], "OK, that's just what happens with nature." I don't think that's in and of itself a problem, as long as the dominant color is the gray. If you saw [the 2003 documentary film] *My Architect*, in that I said—Nathaniel [Kahn] and I were looking at the concrete—"imperfections." I said, "Lou liked those." And then I said I just had a thought I never had before—that maybe it had something to do with the imperfections of his own face that he likes things that are less than perfect. And maybe even with the teak that would carry over. He wasn't a person who looked for perfection in finishes or materials; rather, he used to say, "I like to see the evidence in something of how it was made." When we extruded the handrails in stainless steel, for instance, you could see the drag marks of stainless steel being pushed through the dies because nobody before that have even tried to extrude stainless steel. And he said, "I quite like that because it is evidence of the struggle the material went through to get its form." So I don't think that the variations in themselves—I mean, I haven't seen them lately, but they never bothered me before. The last time I had been there was four years [ago], but before that I never noticed anything that I found disturbing.

GVG: My understanding was that it was the faculty and the people here who kept saying that we need to turn it back to the red color. They are the ones who did not want to turn it into gray color.

JEM: That may be. There are always going to be people like that. But that's OK.

RA: Jack, along with the color, there's texture. As you know, as wood is exposed over time, it develops a surface texture—some of the less dense parts of the boards weather away through UV light exposure and sandblasting from airborne debris. Is that quality, that textured nature of the wood, is that in your opinion consistent with what Kahn would have wanted over time, as well as the color issue?

JEM: Absolutely.

KN: It's interesting that that point is raised, because when you look at some of the plank boards, you can still see evidence of all the saw cut marks if you get up close on those boards, and there is very much a rough finish to that. The weathering that has occurred over time—it's been difficult to comment on that because we don't know the history of it. But the weathering certainly adds to that character of craftsmanship of the wood that has been used on those locations.

JEM: I think that would be very consistent with the way Lou saw materials.

KN: It fits with what you just described.

RA: You mentioned that his intent was not to have maintenance and to allow the material to weather naturally. But all things, as you know, have problems over time. With these prefab panels, did you anticipate the ability to do repairs? Is it something you thought ahead and said, "If something goes bad where we will lose some pieces, some of the slats, the intent is to pull the entire panel out and repair, or to repair individual pieces in situ"? Did you have an idea of how that would be done in the future?

JEM: I am embarrassed to say, but no.

RA: No need to be embarrassed. We didn't want to recommend a treatment and a repair that would have been inconsistent, had that been something that was thought of.

JEM: I think we saw the teak as being as permanent as any other component in the building. The longest we hoped for the building to be around was a hundred years, and that was rather an optimistic point of view in itself.

KN: Half way there [to one hundred years]. To take a step back, Jack, in addition to the Salk Institute, this is the challenge of this period of architecture. There were a lot of prefabricated components used and experimented with in the twentieth century. […] There were a lot of different materials that were put together and fabricated and brought to the site for ease of erection and cost saving in construction. Here we are fifty years later, trying to take a different approach to—

JEM: In my era of practice, prefabrication and factory-built components were very much on my mind. It was a postwar phenomenon, and that's why the Eichler houses happened up here and a lot of things in architecture. We were looking for new ways of doing things.

RA: A couple of questions specific to the teak. You must have specified the teak. Were you more specific in terms of identifying that you wanted, say, Burmese teak?

JEM: I believe we were. I think that the notion of sustainable teak came in long after we chose that teak. I don't think it was an issue at the time. But my recollection is that it was Burmese teak. I was told at the time that when it was shipped, it was the largest single shipment of teak ever to come into the country.

RA: So you spec'd Burmese teak.

JEM: I believe, but Garry can check on that because he has copies of the original specifications.

GVG: It is Burmese teak.

RA: So you know how construction projects work. You spec'd Burmese teak. What do you think you got?

JEM: I don't know. You're so right. It may have come from the Caribbean, who knows? I found teak in Trinidad, believe it or not, when I was there.

[…]

RA: So we got one shipment of teak that we believe is all Burmese teak. We're taking samples of various pieces to see if that is indeed the case, in part because of the differential behavior. I am sure one of the reasons you selected that is its high degree of natural durability.

JEM: I knew a lot about it from my sailing and also navy experience. I knew a lot about teak but not like you do today…

RA: We have some deterioration today that is unusual. When you've got, whatever it is, twenty thousand sticks of wood on the structure, some of them are not going to behave very well. We're looking at the possibility that there's some other species, tropical species, that was mixed in.

JEM: Going back to my original statement, the problem is that because it was built in a factory, those pieces were probably all fastened from the back. So piecemeal replacement is probably not possible without huge expense. Do you see what I mean?

RA: Yes, but it is not as difficult as you are picturing because some of the teak has weathered to the point where the heads of the nails in the shiplap of the slats are exposed, and it would be easy to pull the nails and pop a slat out.

JEM: Are boards T&G?

RA: We believe that they are shiplapped.[1]

JEM: Shiplapped. At 50%.

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[1] Wood investigations carried out after this interview was conducted showed that all of the vertical teak boards or slats had tongue-and-groove (T&G) joints, with the exception of the last board to be installed in a row, which was T-shaped to facilitate installation. As these T-shaped boards were secured in place with adhesive at the sides, they were often the first boards to fall out in a deteriorated row of boards. As these fallen T-shaped boards were the first pieces to be examined by the conservation project team, the initial assumption was that the boards or slats were installed with shiplap joints.

Transcription of Conference Call with Jack MacAllister
December 5, 2013
Page 8

RA: Correct. Some of the pieces have eroded on the face, the exposed face, down almost to that lap.

JEM: Are the nails galvanized, or are they stainless steel?

RA: That's a good question. They are not stainless steel, but we have a lot of iron stains on the face where the nail heads have been exposed to the elements. Now we're getting a lot of iron stains.

JEM: They must be mild steel, which means they'll go too.

RA: We are going to pull some nails and take a look at the extent of the corrosion. It is not good to have the wood in good shape for another fifty years and the nails fail in ten and the pieces fall off.

[…]

[Discussion of original construction costs, preliminary cost estimates for the planned teak window wall assembly conservation project, and inflation.]

JEM: At the time a lot of architects who were, I guess, jealous said, "Well, spending that kind of money [$10.8 million[2]], I could have built a great building too." When we went to NIH [National Institutes of Health], which I headed, to get matching funds for the outfitting of the labs, they had a rule that they would not fund buildings that were extravagant. They kept a database of the costs of research buildings to make sure that if they gave money to a particular project, it was not an exorbitant project. Salk finished in the fiftieth percentile of all laboratory buildings built in that period. So it wasn't the most expensive—it was right in the middle, which people didn't believe was true.

RA: When the teak was brought over, was it in rough-sawn boards or logs?

JEM: I don't know. I never went out to the shop. Garry, were you able to find out who the contractor was?

GVG: I think it is Showcase.

SL: Yeah, it is on the corner of the shop drawings. Let me pull them up.

KN: And they were located locally, right?

JEM: I believe the man's name was Al. I don't remember his last name.

[2] Original construction costs for the building(s), according to MacAllister.

Transcription of Conference Call with Jack MacAllister
December 5, 2013
Page 9

SL: University Showcase and Fixture Corporation.

GVG: And they are not in business anymore.

JEM: They're not. The reason I couldn't remember is that the plumbing contract was University Plumbing and I thought maybe my mind was . . .

GVG: No. Exactly.

JEM: It was University Showcase. Well, there might be someone around who worked for them who would know.

KN: Obviously, the shipment of the wood went straight to their shop and everything was fabricated there and then, as you have pointed out, brought to the site and lifted into openings. Is that correct?

JEM: Yes. At the time it was very elegant.

KN: They were all custom-made windows then?

JEM: Everything, yes. Even the drinking fountains in that building are custom. The door hardware, the lever handles are custom. There is nothing at Salk that is out of a catalog.

KN: They are windows, but they are really window walls, aren't they?

JEM: That's exactly right.

KN: We've been trying to anticipate how that was done and how those [windows] were installed, but I guess the fabrication of windows pretty much stayed ahead of the construction of each wing. Is that correct?

JEM: It falls right behind. Well, they waited until [all the openings were] ready and they brought all [the windows] out at once. They didn't do it piecemeal.

KN: So when the window walls were fabricated, were they actually sprayed in the shop with a treatment, or did they come to the site bare?

JEM: They came bare. They may have been protected with whatever Visqueen was in those days, I don't remember. But they came standing up in a flatbed truck, and then a crane lifted them into place. There were very few bolts to hold them in. It went in very quickly.

GVG: So what you're saying is "Don't lean on them too hard." *[Laughter]*

Transcription of Conference Call with Jack MacAllister
December 5, 2013
Page 10

JEM: Well, no. They are probably as easy to take out as they were to [put in]. Maybe the solution is to take the whole unit out rather than trying to do it in situ. It may be difficult in order to replace them on site. It might be easier to unbolt them and do all that one at a time in a factory setting.

KN: That's been thought of. The interesting thing for me is, how did the office come to select this particular cabinet maker to make these window walls?

JEM: It was me, and I don't remember if we took bids or whether it was somebody who was recommended to us. I know what happened on the window walls, the stainless steel ones and the doors. I remember the whole process. I don't remember the whole process on the teak. The teak walls were one of the few things that were actually detailed in Philadelphia in the office there; everything else was detailed on site by the group I had on site.

SL: Since we are talking about the windows and we talked a little bit about the budget before…One of the files that Garry came across was a memo to the file written in 1965, talking about the lack of a tight seal between the vertical surfaces of the windows and the louver frames. It was a detail that was left out due to budget cutbacks in 1963. Do you recall that?

JEM: I don't remember. I thought we weather-stripped everything. There are three panels: the glass, the solid panel, and the louvered panel.

SL: [The memo] says, "The architect recommends that a vertical strip be installed as a test. This item was eliminated in 1963 cutback."

JEM: No, I don't remember that.

SL: Were there any other things, maybe budgetwise, that were altered or changed that may, in your mind, have had an impact on the performance of—

JEM: No, but when initial bids came in, the project was $12.5 million and everybody was ready to abandon it. I remember saying at the time, "Give me three days to think about it." I went into my office and I stayed there for three days without going home, with a red marker, and I marked up a set of drawings and got it down to the budget in three days by myself.

SL: Bravo.

JEM: By just red-marking things to take out.

KN: That's 20%.

JEM: So I may have taken something out. Every page looked like somebody bled on it.

KN: Since the window walls were being designed in Philadelphia and fabricated out here, was there precedence for the window system being used somewhere else?

JEM: No, except attitudinally. Kahn's was an office where we used a hell of a lot of custom woodwork, so we had a lot of knowledge about how to properly design cabinetwork as well as exterior woodwork. Some of the houses that Lou did before Salk probably are related in the general attitude about millwork and how it is detailed. Panel doors, for instance—we knew how to make floating panels, so if there was shrinkage from temperature changes it wouldn't ruin the doors. Then there was the house—I can't remember the name—that was done with apitong in Chestnut Hill [Margaret Esherick House]. All the doors and windows—that would be worth looking at. The thing went to hell when it weathered—it swelled. Apitong is a Philippine wood the navy used to build piers. It was cheaper than teak. It all shrank and cracked, it ruined itself. This is an interesting story—you are all too young, but the Museum of Modern Art at some point, in the fifties I think, had a Japanese house built in the museum by a craftsman who came over from Japan and built it right in the museum. Well, we found him and we moved him to Chestnut Hill, and over a year's period, with Japanese hand tools, he repaired all the woodwork in the entire house. It was stunning.

CG: That is so fascinating. I've never read that before. That's such an iconic (moment?), that exhibit.

JEM: It was an astounding thing to watch. This man worked with tools that had been designed five hundred years ago, and when he was finished you couldn't tell that anything had ever been repaired.

KN: Maybe we should find some of his relatives to come and help us here. *[Laughter]*

RA: Let me go back to the bleach [solution]. You said you got the call about two years after construction was completed about the black on the teak. You took samples and sent them to Forest Products Lab in Madison. That may have been to George Garrett—I think he was at the lab at that time doing most of that kind of work.

JEM: I don't remember any names, but I was astounded that they guessed that [the building] was on the water with kelp nearby right away.

RA: George Garrett had that kind of capability. But he recommended, which Forest Products Lab for decades recommended, using a diluted solution of bleach to clean mildew off the wood. Do you know if that was done right away? This was two years after construction, we've got a lot of black on the teak. Did they start to do that based on the recommendations right away? And was it done annually or every few years, or they did it once and went back?

JEM: It was done right away and it worked perfectly. And it was done as long as I was still at Salk. My guess is every three to maybe five years. It was done pretty religiously.

RA: At some point, according to Garry, they started to use the wire brushes.

JEM: I know, and I never knew that. I would have screamed if I had known that.

GVG: That was the first thing I saw when I got here. They were actually doing that. I immediately put a stop to it.

JEM: That's one of those things where the maintenance man had his own idea. But it certainly was not a good idea. Maybe a bristle brush would have worked, or a toothbrush, but not a wire brush. Jonas was a very fussy man. He liked perfection. If he came from his car and he saw the teak was turning black, he would have immediately gone to Garry's predecessor and said, "Do something about it. I can't stand looking at that."

KN: Do you think that Jonas preferred a more pristine look to the wood?

JEM: Jonas would have liked a more pristine look than Lou, yes. Jonas is the one who pushed us on the concrete, to make it more and more perfect. When we did—I don't know if you've been through the East Building that David Rinehart and I did—but the concrete there is exactly what Jonas always wanted. We weren't quite able to achieve it in the original building, but did in the East Building.

KN: It is quite smooth. It is perfection.

JEM: That's the best concrete in the world. There's nothing like it anywhere.

CG: Did they argue about that—perfection versus imperfection—when they were going through construction? Jonas and Lou?

JEM: Oh, yes. Constantly. We built sample panel after sample panel. Even the first one, Lou was ready to accept and Jonas wouldn't—he wanted it perfect.

KN: Well, he's footing the bill.

RA: We talked a little bit about attic stock, any material that would have been left over for repairs. Our understanding is there wasn't any. Would you know of any material from the original construction, any teak, that would be somewhere? Some of the original material that has not been placed in service anywhere.

SL: [Such as] an approved sample.

JEM: I can get you a piece of the original travertine because everybody got coffee tables out of the spares, but I do not remember any teak coffee tables. […] I do not know if samples [of the teak] were kept, but there certainly would have been a sample in the file somewhere, or there should have been. I don't recall. […] It is a good question, though.

Transcription of Conference Call with Jack MacAllister
December 5, 2013
Page 13

RA: You never know. I have pieces from projects that were not necessarily official samples, but it's the same material that went into the structure after the fact, and it would take someone asking that exact question for me to say, "Oh, yes, I happen to have a piece of that beam." […]

GVG: That's all the questions we have for now, but we are definitely going to get back to you as we go through the process and start taking pieces off and doing research on them.

JEM: Let me know any way I can help and call me anytime. I am usually here.

KN: We appreciate your offer to include you in the decision-making process, because as we move further along with the Salk, we'd love to bring you in.

JEM: I appreciate that. If Jonas were alive and you made a decision, the first question he would ask is, "Did Jack approve of this?"

KN: Point well taken.

GVG: I learned that early on here.

JEM: You did? You know what I mean.

[Thank-yous and goodbyes]

APPENDIX C

Louis Kahn's Design Approach, Teak Window Wall Assemblies, Salk Institute for Biological Studies

PREPARED BY CLAIRE GREZEMKOVSKY

Louis Kahn's Design Approach, Teak Window Wall Assemblies, Salk Institute for Biological Studies

Prepared by Claire Grezemkovsky, Salk Institute for Biological Studies, 2014

Introduction

In the final project specifications for the Salk Institute for Biological Studies, La Jolla, California, approved by the architectural offices of Louis Kahn in 1963, the entry on millwork is intriguingly spare: *Exterior Millwork Species: Teak solid stock; Finish: rubbed*. What did *rubbed* mean? The answer would not come until three years later, in a letter of response to a Boston firm seeking advice on wood preservation from the Kahn offices. After consulting with project architect John E. "Jack" MacAllister, Kahn's secretary, Louise M. Badgley, wrote to the Boston firm in the summer of 1966 that "there was no finish used on the exterior wood, since the type of wood used was Teak and did not, therefore, require a finish coating" (Louis I. Kahn Collection, call no. 030.11.A.108.25).

Carlos Johnson, the Salk Institute's manager of plant engineering, doubtless would have objected to this assessment that the wood was fine on its own. In an undated memo to Salk secretary Virginia White, likely written around the same time, he wrote that "the teakwood panels on the Institute are subject to fungus growth," which "gives the appearance of 5 o'clock shadow on all of the panels that do not get very much sunlight" (Salk Institute, Off-site Storage and Archives). The problem of black fungal growth was noted within a year after completion of the millwork at the Salk Institute, and Johnson and others, including Jack MacAllister, had attempted to correct the problem by developing strategies to clean and preserve the wood.

The documentation of this process expresses the difficulty that the stewards of the Salk Institute encountered in preserving the design intention of Kahn and his patron Jonas Salk. As all parties involved in the care and maintenance of the building came to understand, leaving the wood to weather "naturally" and unmolested clashed with the environmental realities of a damp coastal climate and value engineering in the building process which had left the teak window systems without the weatherproofing necessary to keep them dry.

This report delineates Louis Kahn's design intention behind unfinished wood so that stewards of the Salk Institute can weigh the wishes of architect and patron against the realities of how the teak has aged over the last fifty years. A clear understanding of why Kahn intended the wood to age "naturally" and remain unfinished informs strategies for preservation of the Salk Institute.

Kahn's Design Philosophy

Hierarchy, separation, and order are major tenets of Kahn's modernist design philosophy. Kahn refined these concepts over decades through his monumental work as well as his comparatively small domestic projects. Kahn articulated these concepts in regularly held planning meetings regarding the Salk, which included the leads for the general contractors who built the Institute. At these meetings, the contractors contributed concrete directives, as documented in the minutes, and Kahn expressed his design philosophy. In the minutes from a meeting on October 18, 1963, the architect commented that "one must discover about each space, the way of life it demands as differentiated from the way of life another space demands," and that "one must know the 'reality of belief' before one knows the 'reality of means.'"

Landscape

This insight into the principles guiding Kahn, gleaned from the collaborative design and construction process, hints at the role of landscape in the architecture of the Salk Institute. Landscape was a primary element of hierarchy for Kahn. In his draft of the Salk program, under the section titled "Site," Kahn wrote of a "presence of nature rather than an urban environment in the presence of abstractions of man's activities." He continued:

> The choice of the site of Torrey Pines, La Jolla, San Diego, overlooking the sea and protected by surrounding park and University property is the first inspiring act towards creation of the environment for the Institute of Biology. From the presence of the unin-

> terrupted sky, the sea and the horizon, the clear and dramatic configuration of weather-beaten land spare of foliage, the buildings and their gardens must find their position in deference to Nature. (Louis I. Kahn Collection, call no. 030.II.A.27.16)

The position of the Salk campus standing in "deference to Nature" is schematically hierarchical: Nature is at the fore, and the architecture draws from it. This ideal is revealed in examples of Kahn's domestic architecture as well. In 1930, Kahn met and eventually formed a partnership with the Philadelphia modernist George Howe, who would have a profound influence on the young architect. During the 1930s, while Kahn was involved in creating mass housing, he had been carefully following the development of Fortune Rock, a cantilevered residence designed by Howe in Somes Sound, Maine. Constructed by Maine craftspersons, the house featured natural elements of stone and cedar left to gray and weather, elements that merged naturally with the surroundings, as do the vernacular fishermen's houses tucked into the surrounding Atlantic coastline. Kahn further developed his sense of architectural "agreement" in landscape in sketches and paintings he made during a number of trips he made to the North Atlantic Canadian coast in the late 1930s. He would continue to develop his approach to the placement of architecture in landscape (Marcus & Whitaker 2013, 29).

"The oiled cedar clapboards, the silver-gray shingles and the stone used for the chimney and base wall (gleaned from the site itself) merge seamlessly with the natural surroundings," William Whitaker and George H. Marcus wrote of Fortune Rock (Marcus & Whitaker 2013, 29), an ideal relationship that Kahn cultivated early in his career working alongside George Howe and continued to seek out in his coastal excursions, during which he observed and processed vernacular architecture in nature.

Once one understands Kahn's hierarchical placement of architecture in landscape, in which the conditions of the environment set the agenda for the material reality of the buildings, one can understand why Kahn specified that the wood at Salk remain unfinished and left to age naturally. To seal and preserve the wood would separate the material reality of the buildings from the material reality of the landscape.

Domesticity

Although the Salk comprises a research institute, the distinct separation of its spaces includes the cordoning off of distinct studies, which stand as the domestic counterpoint to the collective workspace of the laboratories. A central aspect of hierarchy in Kahn's architecture pertains to the division of spaces based on distinct uses. Unlike his contemporaries, who espoused open planning and flexible multiuse spaces, Kahn was a structural modernist who insisted on spatial division and separation as the basis of architectural and social integrity. The studies and offices that feature teak fenestration at the Salk are delineated as singular domestic cells separated and removed from the collaborative workspaces of the middle zone of flexible laboratories and the outer layer of service structures. Kahn described the studies, again in the building program, as the "architecture of the oak table and rug," which can strengthen the overall mission of the Institute by "providing an environment for meditation and study which is separate and distinct from the environment of research experimentation" (Louis I. Kahn Collection, call no. 030. II.A.27.16).

The use of wood in the design of the studies underscores the studies' domestic categorization. In addition, the teak millwork relates directly to Kahn's domestic architecture, including especially the Norman and Doris Fisher House (completed 1967) and the Steven and Toby Korman House (completed 1973). As Pierson Booher argues in his research on Kahn, the fenestration of the Salk has a great deal in common with these two Philadelphia projects (for example, two different species of wood are used for the interior and exterior, and on the exterior are primarily vertical members with horizontal members to hide joints). These houses, like the studies of the Salk, were also intended to have their wood gray like the houses on the coast, in perfect balance with nature. To understand what Kahn intended for the teak at the Salk, we must understand this design feature as an extension of his domestic architecture.

Environmental Realities

Kahn's observations of rustic vernacular houses represented an ideal of architecture in landscape that deeply impacted his design approach. However, the reality of Kahn's ideal of architecture standing in deference to Nature has taken on a distinct form thanks to water infiltration and the development of black spore growth of the kind Carlos Johnson and others have grappled with since the Institute's completion. Previous sections of this report have offered suggestions for the design intent for the teak in terms of aging. There is no explicit statement from Kahn stating that the wood should be gray and weathered. However, as members of the Salk's maintenance staff struggled to contend with the pigmentation surfacing on the wood, their correspondence and record keeping bears evidence of a continuous attempt to allow the wood to gray according to Kahn's intention.

August E. Komendant, the Salk's structural engineer, visited the Institute in August of 1967 to inspect his workmanship had fared over the past two and a half years. He made note of water infiltration issues in the studies, which he attributed to improper construction, and recommended, along with laboratory designer Earl Walls, that the teak panels be sealed with creosote. He insisted that creosote "would be plain and would not change the color of the paneling," a statement that suggests a sensitivity to the coloration of the wood (Salk Institute, off-site storage). Carlos Johnson expressed similar concern in two letters written in October of that year to Ullie Linder of Earl L. Walls Associates. In these letters, Johnson argued that the current approach to cleaning the mildew from the wood adversely affected the wood; after washing without sealing or treating, the panels immediately turned black with "fungus," and each subsequent yearly washing could make the problem worse by causing the "mildew" to penetrate further into the wood. His recommendation followed that, after washing, a "coating of water seal or bleach or preservative would be applied. This would preserve the wood surface, prevent the grain from rising, and keep the mildew from penetrating deeper into the wood. The appearance of the teak wood would then be kept in first class condition" (Carlos Johnson to Ullie Linder, October 30, 1967, Salk Institute, Off-Site Storage and Archives).

To this end, Johnson and his staff set about preparing various product samples "for the purposes of checking weathering, prevention of fungicide build-up and appearance." Continuing his argument against the status quo, Johnson reassured Ullie Linder that "it is reasonable to believe from demonstrations that some of the preservatives that could be used might appear to discolor the panels, but this would be for a period of 6–9 months," after which "the wood would take on the appearance of the concrete; the panels would be preserved against deterioration by the elements" (Carlos Johnson to U. M. Linder, October 30, 1967, Salk Institute, Off-Site Storage and Archives).

The methodical argument Johnson puts forth—to treat the wood in such a way that it would eventually return to the same gray of the concrete—speaks to a larger discussion that was no doubt taking place, particularly among the Salk stakeholders who knew of Kahn's wishes and among the new guard charged with maintaining the building going forward. Matching the teak to the color of the concrete was no doubt what Jack MacAllister had in mind when he advised the Boston firm that in the case of the Salk teak, it was not necessary to preserve the wood, even though a short time later he was in La Jolla, examining the wood preservative samples that Johnson's plant engineering staff were preparing (Salk Institute, off-site storage). The discussion continued into the following year, when Johnson sent a sample of the teak "stained" with the fungus to Forest Products Laboratory and received a diagnosis in April 1968 confirming a "dark-brown, Schlerophoma-like hyphae" and recommending treatment to "rid the panels of this growth either by scrubbing the affected surface with a Clorox solution or by a light sanding." Once this was completed, the letter continued, "paint or spray the wood with a water-repellent solution of 5 percent pentachlorophenol in light oil" (Salk Institute, Off-Site Storage and Archives). This is likely the protocol that was implemented, since traces of "penta" were found in analysis of the teak in 2014.

The sensitivity Johnson expressed in his letters, and the effort very early on to develop a maintenance protocol that would satisfy the need to allow the wood to "take on the appearance of the concrete" and the wood surface to remain intact and free of fungal discoloration, points to a tension that has existed since the completion of the Salk Institute. This tension must be addressed when considering the maintenance of the building according to the ideal specifications of its architect and patron, in an environmental reality that constantly challenges that ideal.

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Boother, Pierson William. 2009. Louis I. Kahn's Fisher House: A Case Study on the Architectural Detail and Design Intent. Master of Science in Historic Preservation thesis, University of Pennsylvania. http://repository.upenn.edu/cgi/viewcontent.cgi?article=1122&context=hp_theses

Marcus, George H., and William Whitaker. 2013. *The Houses of Louis Kahn*. New Haven, CT: Yale University Press.

Archives

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Salk Institute for Biological Studies, Off-Site Storage and Archives.

APPENDIX D

Preliminary Condition Survey Drawings

PREPARED BY MESUT DINLER AND SARA LARDINOIS

Note: Image © 2013 Google, with overlay text by GCI.

N

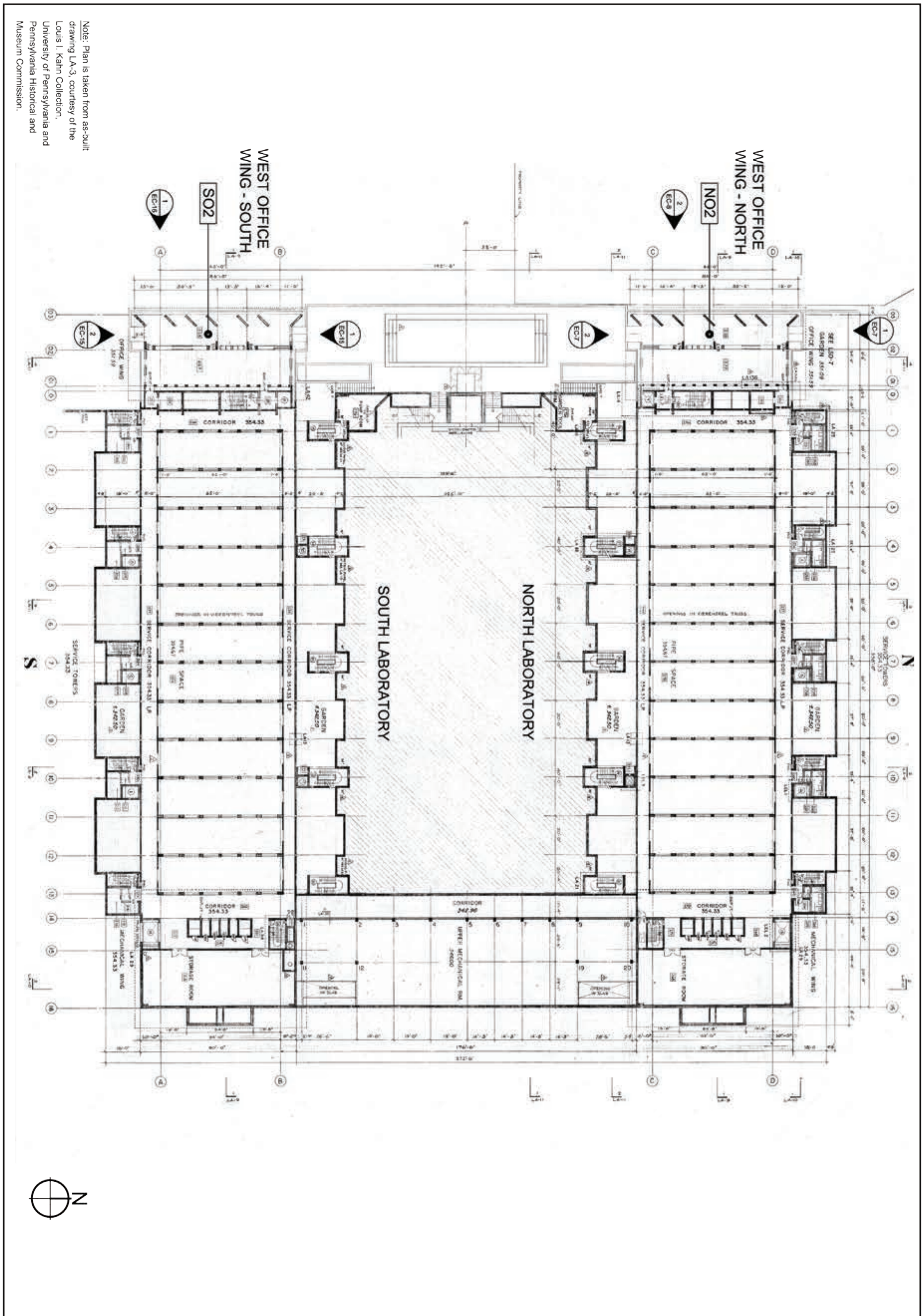
SALK INSTITUTE CONSERVATION PROJECT
Teak Window Wall Assemblies

SALK INSTITUTE FOR BIOLOGICAL STUDIES
The Getty Conservation Institute

Drawing Name:
PRELIMINARY CONDITION SURVEY
SITE PLAN
Salk Institute for Biological Studies
La Jolla, CA

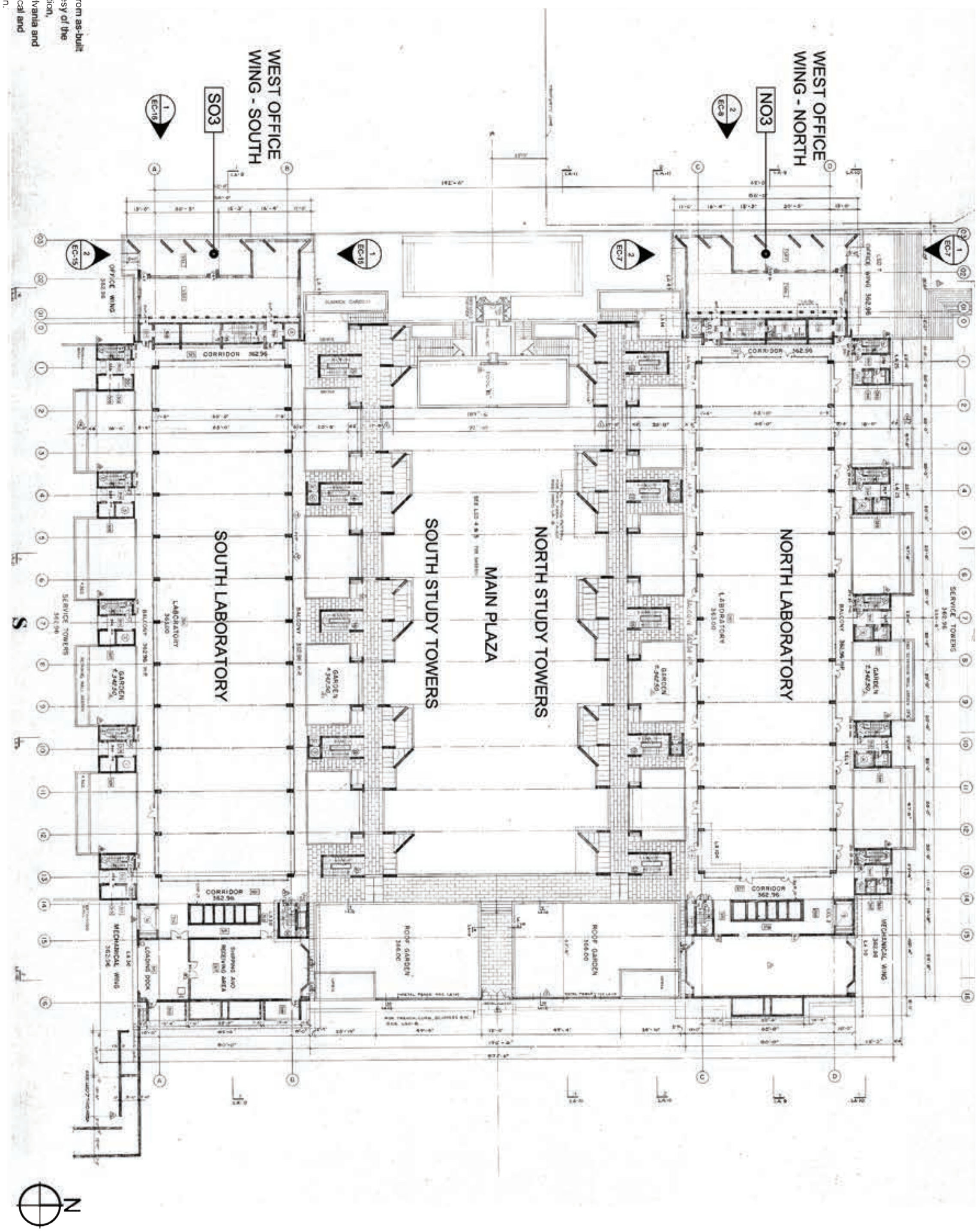
Survey Date(s): October 2013, March 2014
Drawing Issued: 4/2014, updated 5/2017
Drawn By: MD, SL

Sheet No.: EC-1

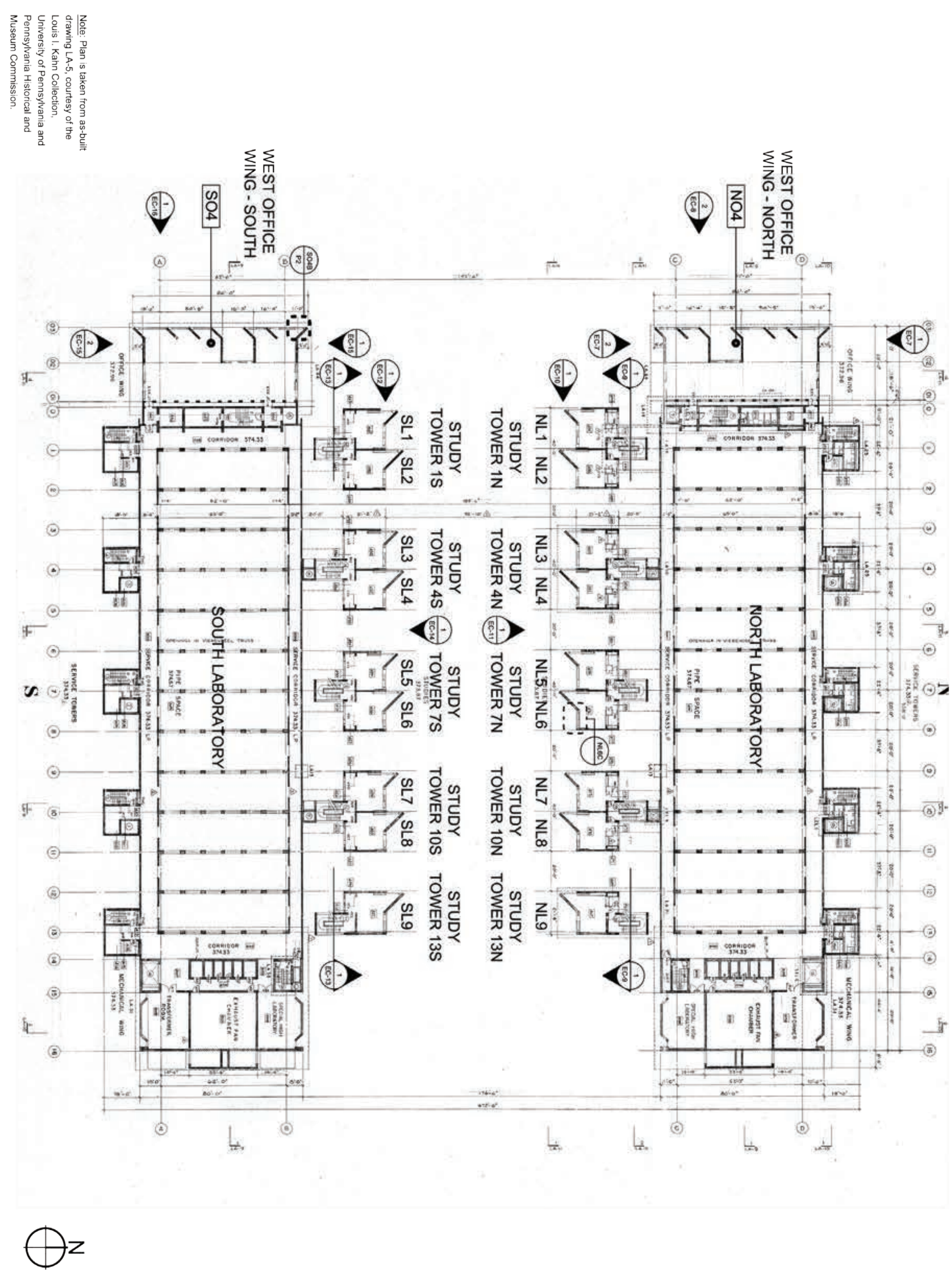


SALK INSTITUTE CONSERVATION PROJECT Teak Window Wall Assemblies SALK INSTITUTE FOR BIOLOGICAL STUDIES — The Getty Conservation Institute	Drawing Name: PRELIMINARY CONDITION SURVEY 2ND FLOOR PLAN Salk Institute for Biological Studies La Jolla, CA	Survey Date(s): October 2013, March 2014 Drawing Issued: 04/2014, updated 5/2017 Drawn By: MD, SL	Sheet No.: EC-2

Note: Plan is taken from as-built drawing LA-4, courtesy of the Louis I. Kahn Collection, University of Pennsylvania and Pennsylvania Historical and Museum Commission.



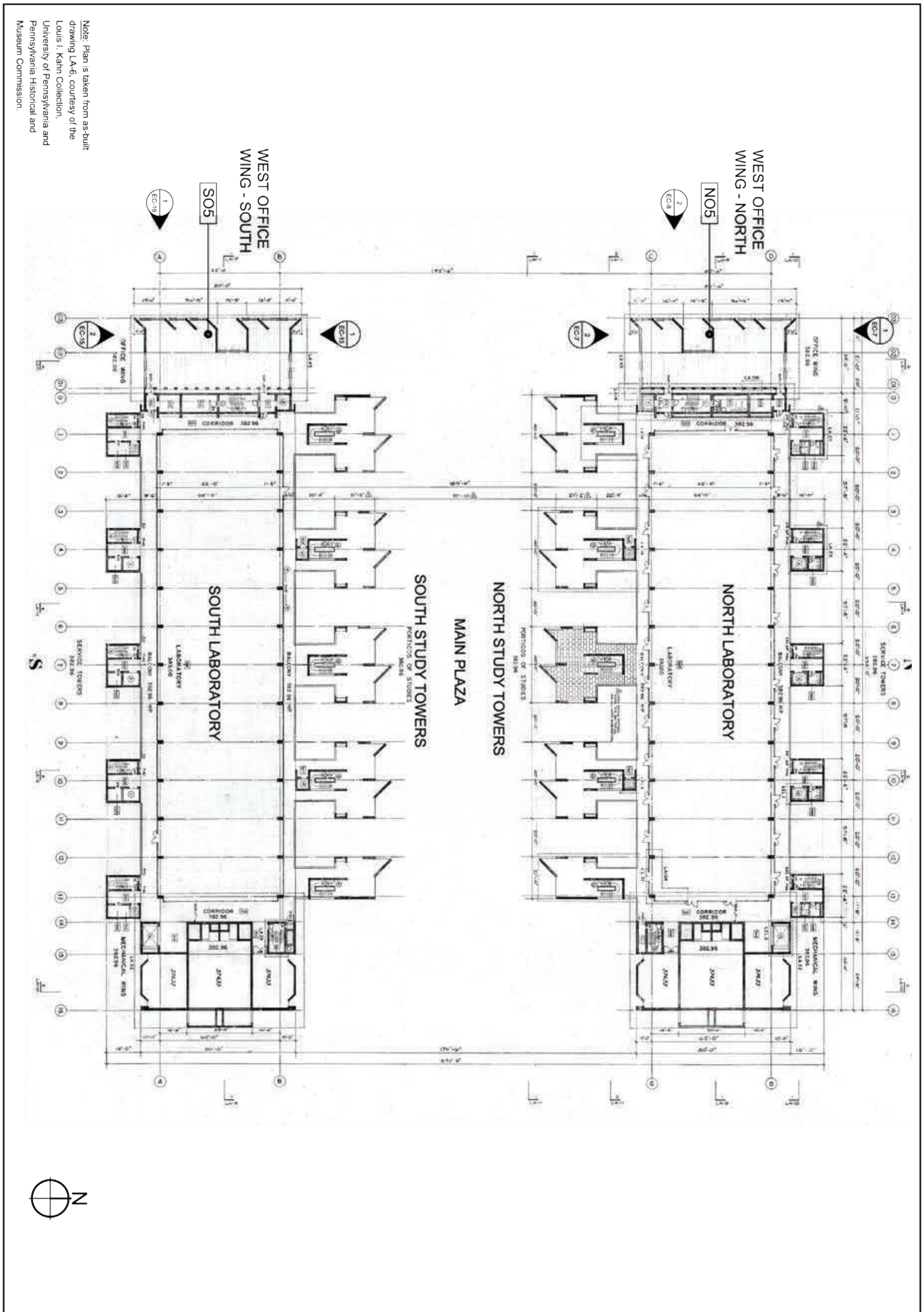
SALK INSTITUTE CONSERVATION PROJECT Teak Window Wall Assemblies SALK INSTITUTE FOR BIOLOGICAL STUDIES · The Getty Conservation Institute	Drawing Name: PRELIMINARY CONDITION SURVEY 3RD FLOOR PLAN (PLAZA LEVEL) Salk Institute for Biological Studies La Jolla, CA	Survey Date(s): October 2013, March 2014 Drawing Issued: 04/2014, updated 5/2017 Drawn By: MD, SL	Sheet No.: EC-3



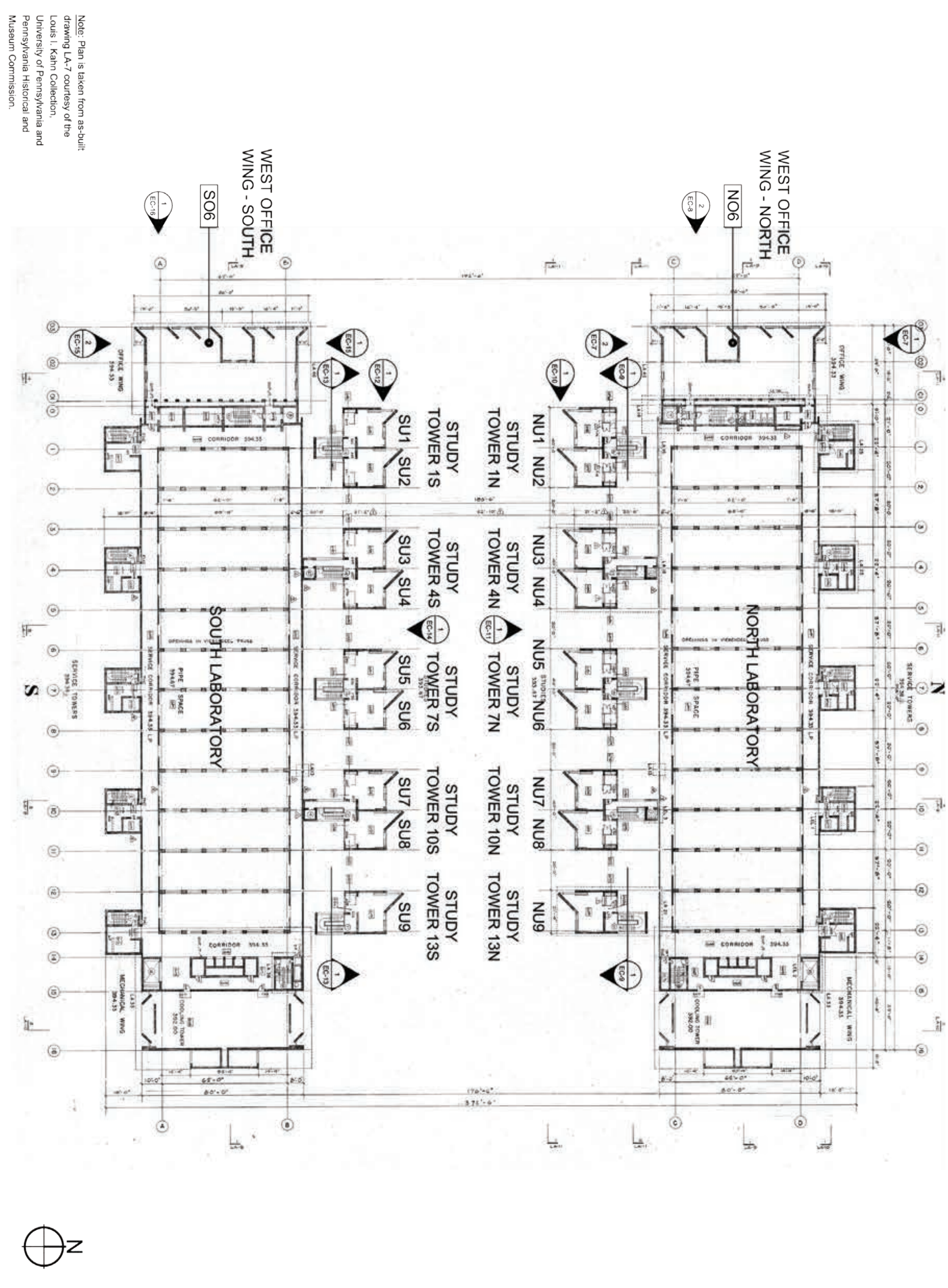
SALK INSTITUTE CONSERVATION PROJECT
Teak Window Wall Assemblies

SALK INSTITUTE FOR BIOLOGICAL STUDIES · The Getty Conservation Institute

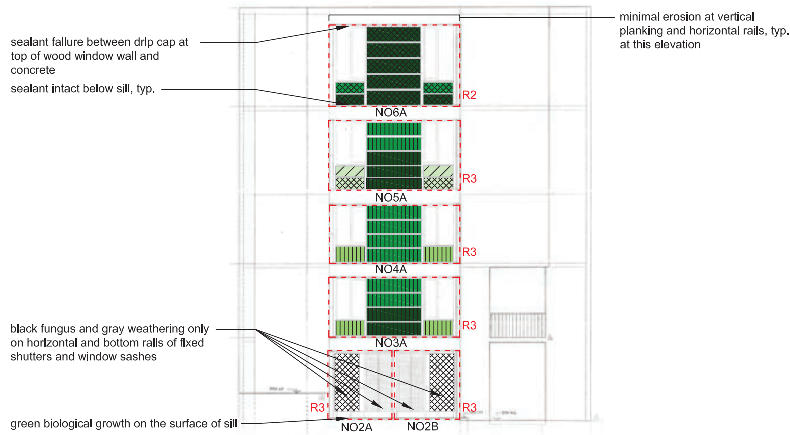
Drawing Name:	Survey Date(s):	Sheet No.:
PRELIMINARY CONDITION SURVEY 4TH FLOOR PLAN (LOWER STUDIES) Salk Institute for Biological Studies La Jolla, CA	October 2013, March 2014 Drawing Issued: 04/2014, updated 5/2017 Drawn By: MD, SL	EC-4

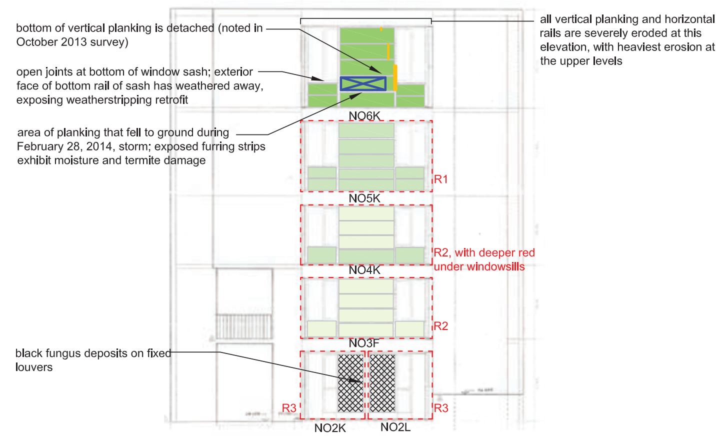


SALK INSTITUTE CONSERVATION PROJECT Teak Window Wall Assemblies SALK INSTITUTE FOR BIOLOGICAL STUDIES · The Getty Conservation Institute	Drawing Name: PRELIMINARY CONDITION SURVEY 5TH FLOOR PLAN Salk Institute for Biological Studies La Jolla, CA	Survey Date(s): October 2013, March 2014 Drawing Issued: 04/2014, updated 5/2017 Drawn By: MD, SL	Sheet No.: EC-5



SALK INSTITUTE CONSERVATION PROJECT Teak Window Wall Assemblies SALK INSTITUTE FOR BIOLOGICAL STUDIES · The Getty Conservation Institute	Drawing Name: PRELIMINARY CONDITION SURVEY 6TH FLOOR PLAN (UPPER STUDIES) Salk Institute for Biological Studies La Jolla, CA	Survey Date(s): October 2013, March 2014 Drawing Issued: 04/2014, updated 5/2017 Drawn By: MD, SL	Sheet No.: EC-6





LEGEND

Gray Weathering (% of the area): 1-5, 6-19, 20-49, 50-89, 90-100

Black Fungus (% of the area): 1-5, 6-19, 20-49, 50-89, 90-100

Insect Damage: Visible from the exterior face of the teak

Missing Element:

Past Surface Treatment: Area of red coating
R1: Light red coating
R2: Medium red coating
R3: Dark red coating

Other: Ⓢ Exterior screen with bronze frame

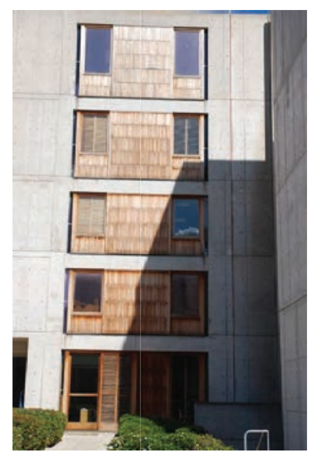
1A NORTH OFFICE BUILDING - NORTH ELEVATION
PRELIMINARY CONDITION SURVEY

5 4 3 2 1 0 5 10 Feet

2A NORTH OFFICE BUILDING - SOUTH ELEVATION
PRELIMINARY CONDITION SURVEY

5 4 3 2 1 0 5 10 Feet

1B NORTH OFFICE BUILDING - NORTH ELEVATION EXISTING PHOTOGRAPHS



2B NORTH OFFICE BUILDING - SOUTH ELEVATION EXISTING PHOTOGRAPHS

Note: All elevation drawings on sheets EC-7 through EC-16 taken from as-built drawings, courtesy of the Louis I. Kahn Collection, University of Pennsylvania and Pennsylvania Historical and Museum Commission.

SALK INSTITUTE CONSERVATION PROJECT
Teak Window Wall Assemblies

SALK INSTITUTE FOR BIOLOGICAL STUDIES
The Getty Conservation Institute

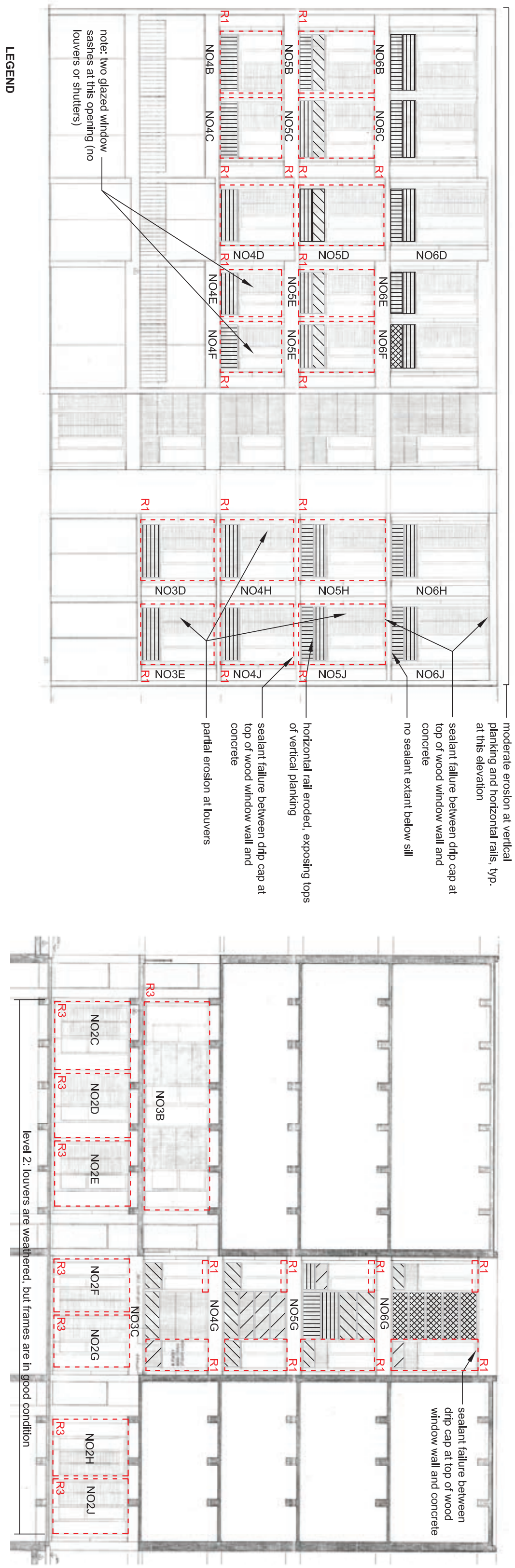
Drawing Name:
PRELIMINARY CONDITION SURVEY
NORTH OFFICE BUILDING
Salk Institute for Biological Studies
La Jolla, CA

Survey Date(s):
October 2013, March 2014

Drawing Issued:
4/2014, updated 5/2017

Drawn By:
MD, SL

Sheet No.:
EC-7



1A NORTH OFFICE BUILDING - WEST ELEVATION PRELIMINARY CONDITION SURVEY

LEGEND

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1-5 | 6-19 | 20-49 | 50-89 | 90-100

Black Fungus (% of the area):
1-5 | 6-19 | 20-49 | 50-89 | 90-100

Insect Damage:
Visible from the exterior face of the teak

Missing Element:

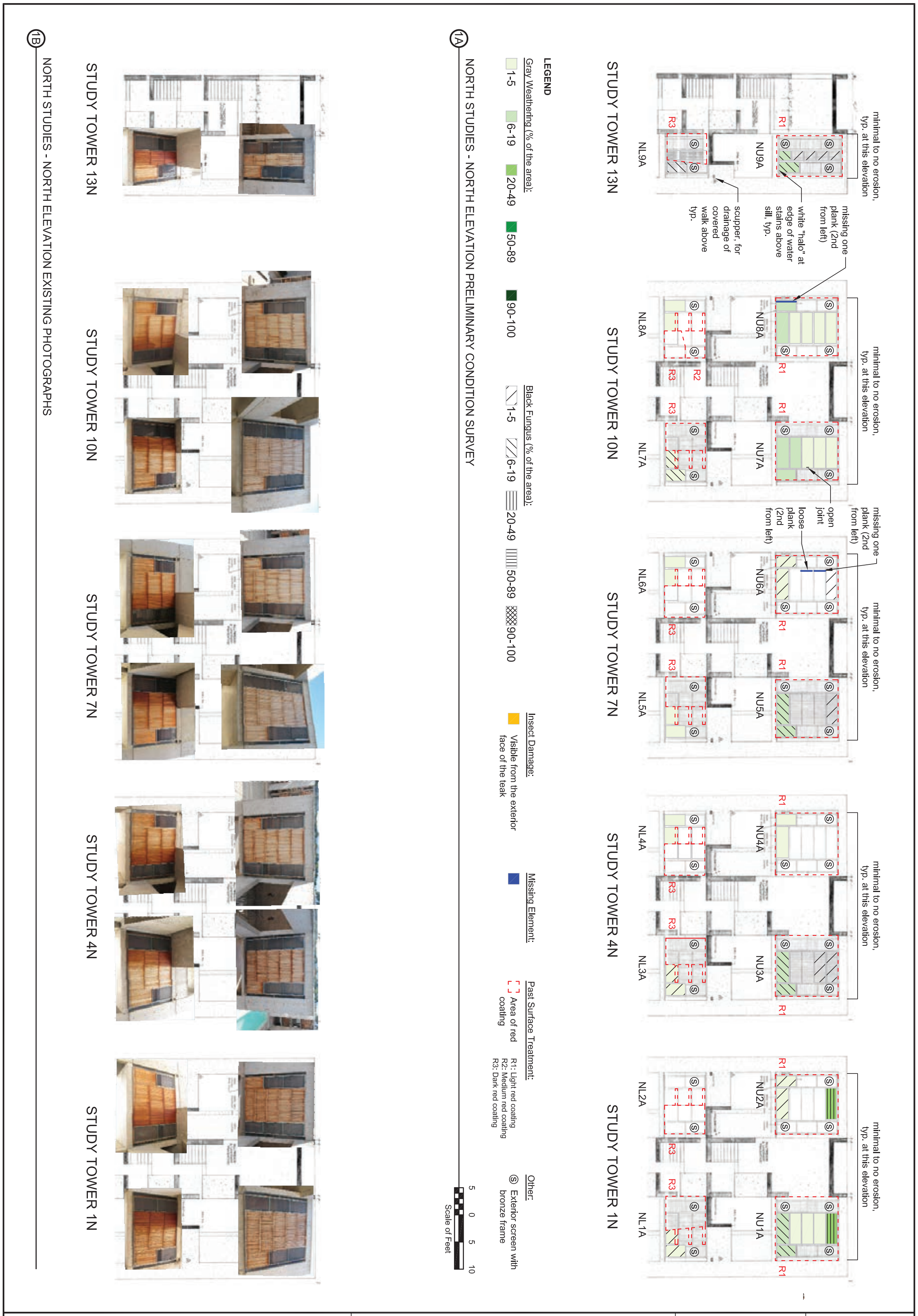
Past Surface Treatment:
Area of red coating
R1: Light red coating
R2: Medium red coating
R3: Dark red coating

Other:
Ⓢ Exterior screen with bronze frame

5 4 3 2 1 0 5 10 Feet

1B NORTH OFFICE BUILDING - WEST ELEVATION EXISTING PHOTOGRAPHS

SALK INSTITUTE CONSERVATION PROJECT Teak Window Wall Assemblies SALK INSTITUTE FOR BIOLOGICAL STUDIES · The Getty Conservation Institute	Drawing Name: PRELIMINARY CONDITION SURVEY NORTH OFFICE BUILDING Salk Institute for Biological Studies La Jolla, CA	Survey Date(s): October 2013, March 2014 Drawing Issued: 4/2014, updated 5/2017 Drawn By: MD, SL	Sheet No.: EC-8



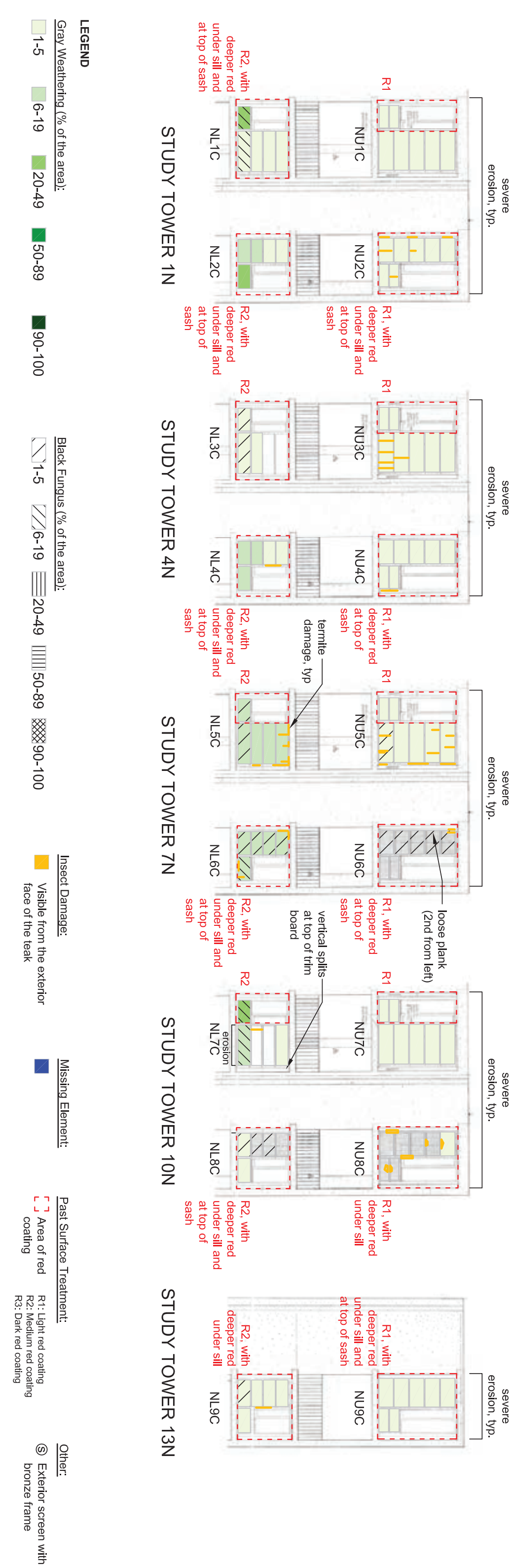
SALK INSTITUTE CONSERVATION PROJECT
Teak Window Wall Assemblies

SALK INSTITUTE FOR BIOLOGICAL STUDIES | The Getty Conservation Institute

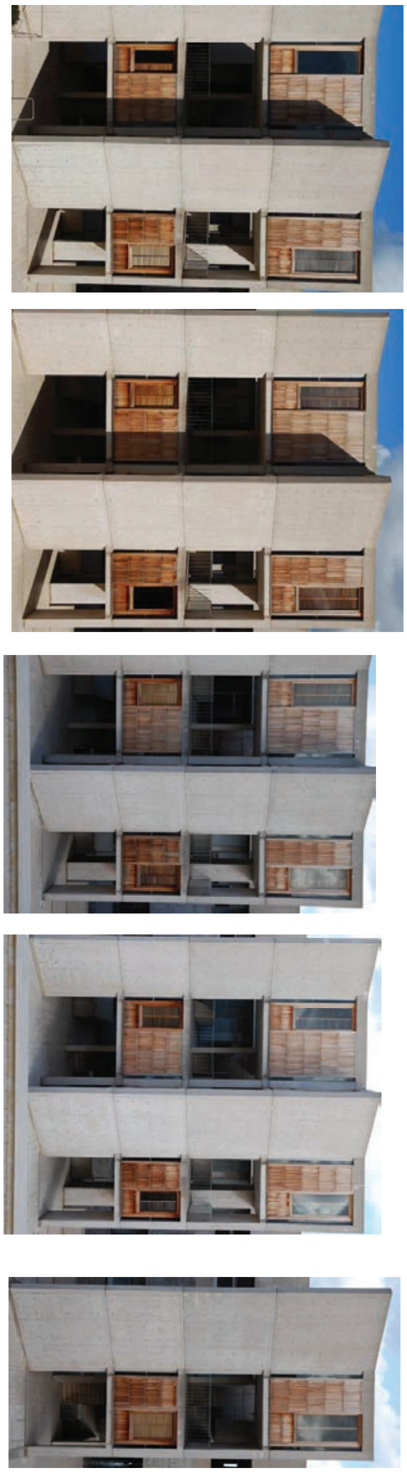
Drawing Name:
PRELIMINARY CONDITION SURVEY
NORTH STUDIES
Salk Institute for Biological Studies
La Jolla, CA

Survey Date(s): October / Decmeber 2013
Drawing Issued: 4/2014, updated 5/2017
Drawn By: MD, SL
Sheet No.: EC-9

SALK INSTITUTE CONSERVATION PROJECT Teak Window Wall Assemblies SALK INSTITUTE FOR BIOLOGICAL STUDIES / The Getty Conservation Institute	Drawing Name: PRELIMINARY CONDITION SURVEY NORTH STUDIES Salk Institute for Biological Studies La Jolla, CA	Survey Date(s): October / December 2013 Drawing Issued: 4/2014, updated 5/2017 Drawn By: MD, SL	Sheet No.: EC-10



1A NORTH STUDIES - SOUTH ELEVATION PRELIMINARY CONDITION SURVEY



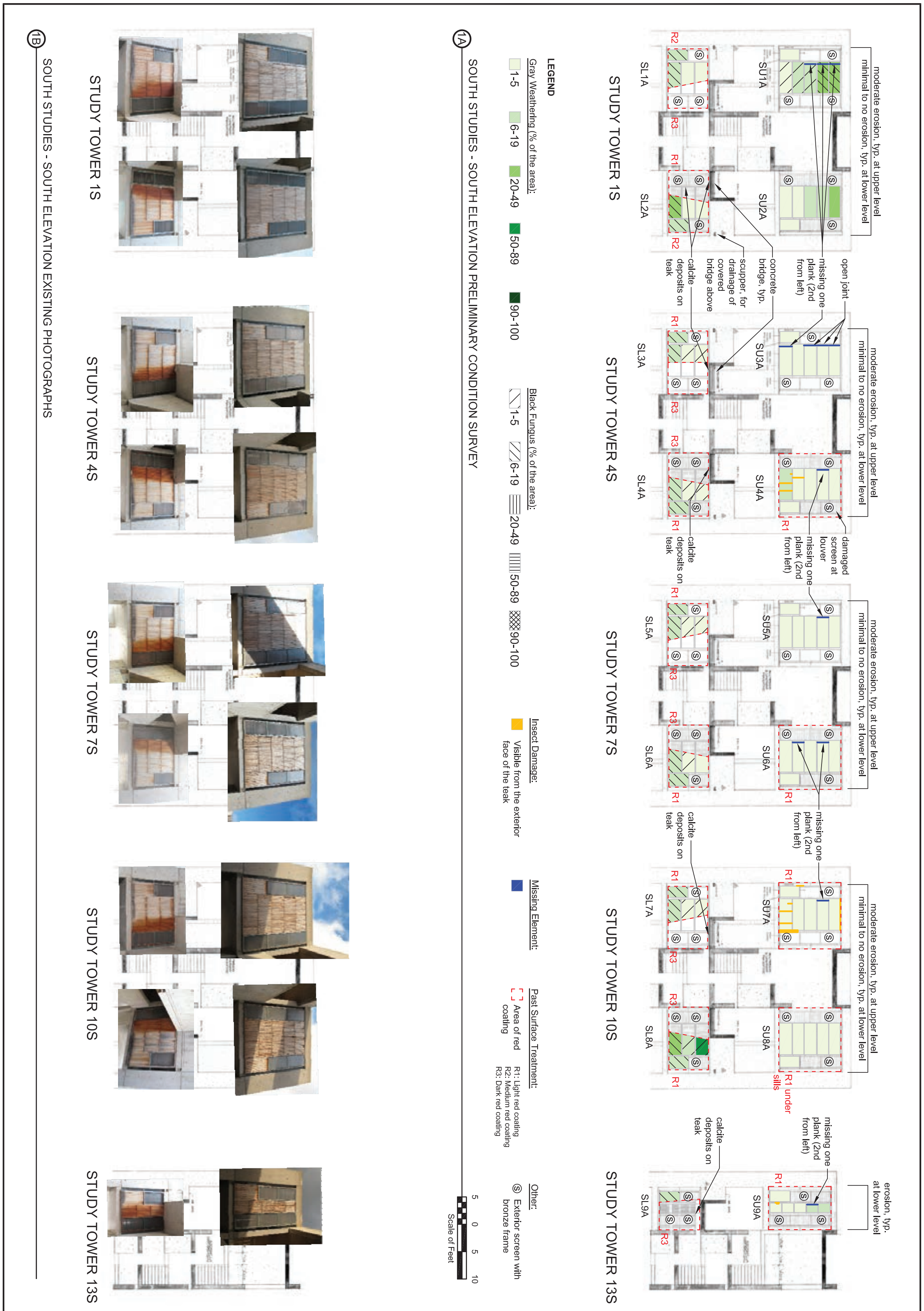
1B NORTH STUDIES - SOUTH ELEVATION EXISTING PHOTOGRAPHS

SALK INSTITUTE CONSERVATION PROJECT
Teak Window Wall Assemblies

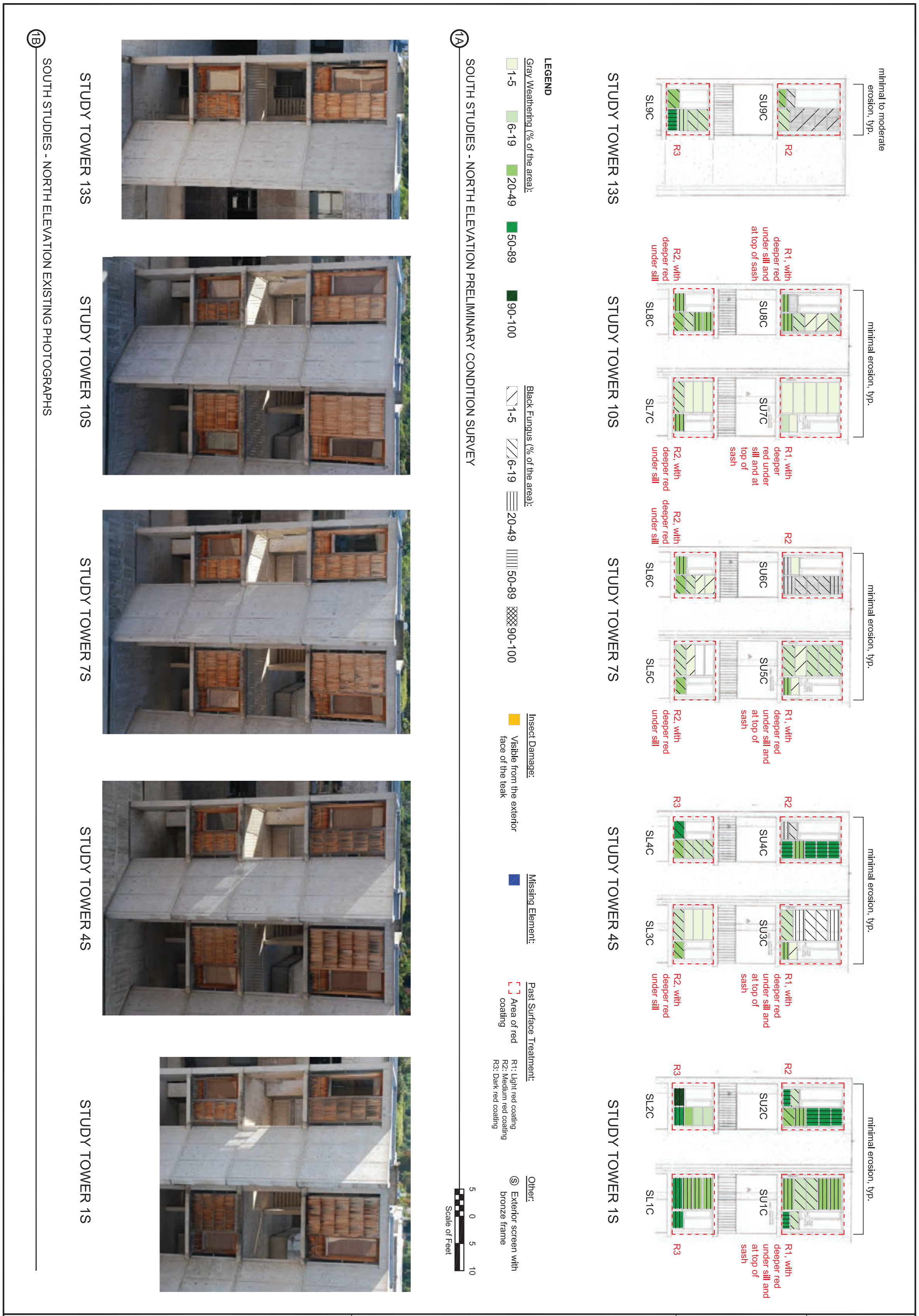
SALK INSTITUTE FOR BIOLOGICAL STUDIES — The Getty Conservation Institute

Drawing Name:	Survey Date(s):	Sheet No.:
PRELIMINARY CONDITION SURVEY NORTH STUDIES Salk Institute for Biological Studies La Jolla, CA	October / December 2013 Drawing Issued: 4/2014, updated 5/2017 Drawn By: MD, SL	EC-11

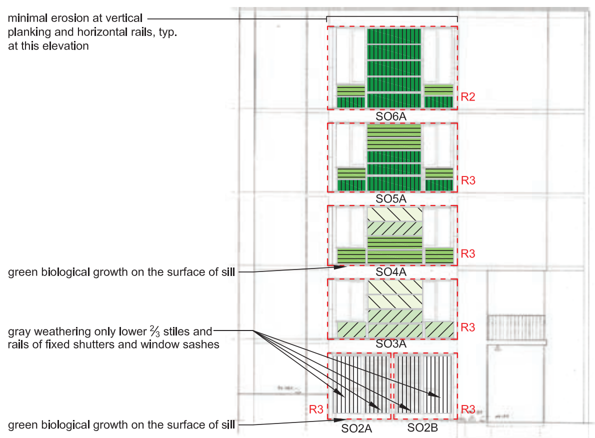
SALK INSTITUTE CONSERVATION PROJECT Teak Window Wall Assemblies SALK INSTITUTE FOR BIOLOGICAL STUDIES · The Getty Conservation Institute	Drawing Name: PRELIMINARY CONDITION SURVEY SOUTH STUDIES Salk Institute for Biological Studies La Jolla, CA	Survey Date(s): October / December 2013 Drawing Issued: 4/2014, updated 5/2017 Drawn By: MD, SL	Sheet No.: EC-12

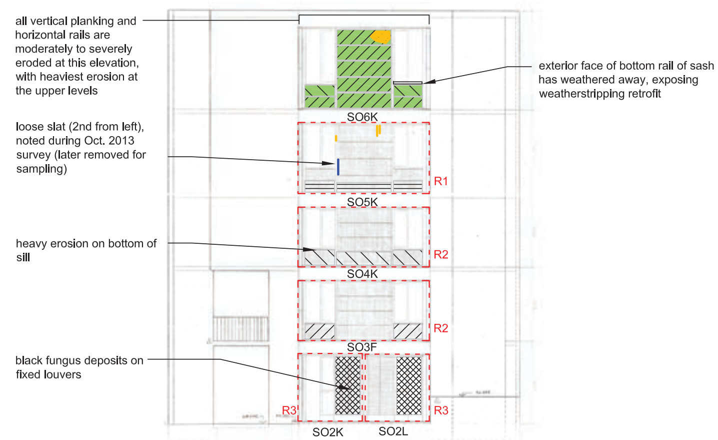


SALK INSTITUTE CONSERVATION PROJECT Teak Window Wall Assemblies SALK INSTITUTE FOR BIOLOGICAL STUDIES · The Getty Conservation Institute	Drawing Name: PRELIMINARY CONDITION SURVEY SOUTH STUDIES Salk Institute for Biological Studies La Jolla, CA	Survey Date(s): October / December 2013 Drawing Issued: 4/2014, updated 5/2017 Drawn By: MD, SL	Sheet No.: EC-13



SALK INSTITUTE CONSERVATION PROJECT Teak Window Wall Assemblies SALK INSTITUTE FOR BIOLOGICAL STUDIES / The Getty Conservation Institute	Drawing Name: PRELIMINARY CONDITION SURVEY SOUTH STUDIES Salk Institute for Biological Studies La Jolla, CA	Survey Date(s): October / December 2013 Drawing Issued: 4/2014, updated 5/2017 Drawn By: MD, SL	Sheet No.: EC-14





LEGEND

Gray Weathering (% of the area): 1-5 | 6-19 | 20-49 | 50-89 | 90-100

Black Fungus (% of the area): 1-5 | 6-19 | 20-49 | 50-89 | 90-100

Insect Damage: Visible from the exterior face of the teak

Missing Element:

Past Surface Treatment: Area of red coating
R1: Light red coating
R2: Medium red coating
R3: Dark red coating

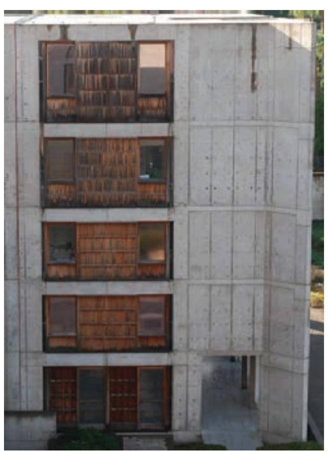
Other: (S) Exterior screen with bronze frame

1A SOUTH OFFICES - NORTH ELEVATION
PRELIMINARY CONDITION SURVEY

5 4 3 2 1 0 5 10 Feet

2A SOUTH OFFICE BUILDING - SOUTH ELEVATION
PRELIMINARY CONDITION SURVEY

5 4 3 2 1 0 5 10 Feet



1B SOUTH OFFICE BUILDING - NORTH ELEVATION EXISTING PHOTOGRAPHS

2B SOUTH OFFICE BUILDING - SOUTH ELEVATION EXISTING PHOTOGRAPHS

SALK INSTITUTE CONSERVATION PROJECT
Teak Window Wall Assemblies

SALK INSTITUTE FOR BIOLOGICAL STUDIES
The Getty Conservation Institute

Drawing Name:
PRELIMINARY CONDITION SURVEY
SOUTH OFFICE BUILDING
Salk Institute for Biological Studies
La Jolla, CA

Survey Date(s): October 2013, March 2014
Drawing Issued: 4/2014, updated 5/2017
Drawn By: MD, SL

Sheet No.: EC-15

SALK INSTITUTE CONSERVATION PROJECT Teak Window Wall Assemblies SALK INSTITUTE FOR BIOLOGICAL STUDIES · The Getty Conservation Institute	Drawing Name: PRELIMINARY CONDITION SURVEY SOUTH OFFICE BUILDING Salk Institute for Biological Studies La Jolla, CA	Survey Date(s): October 2013, March 2014 Drawing Issued: 4/2014, updated 5/2017 Drawn By: MD, SL	Sheet No.: EC-16

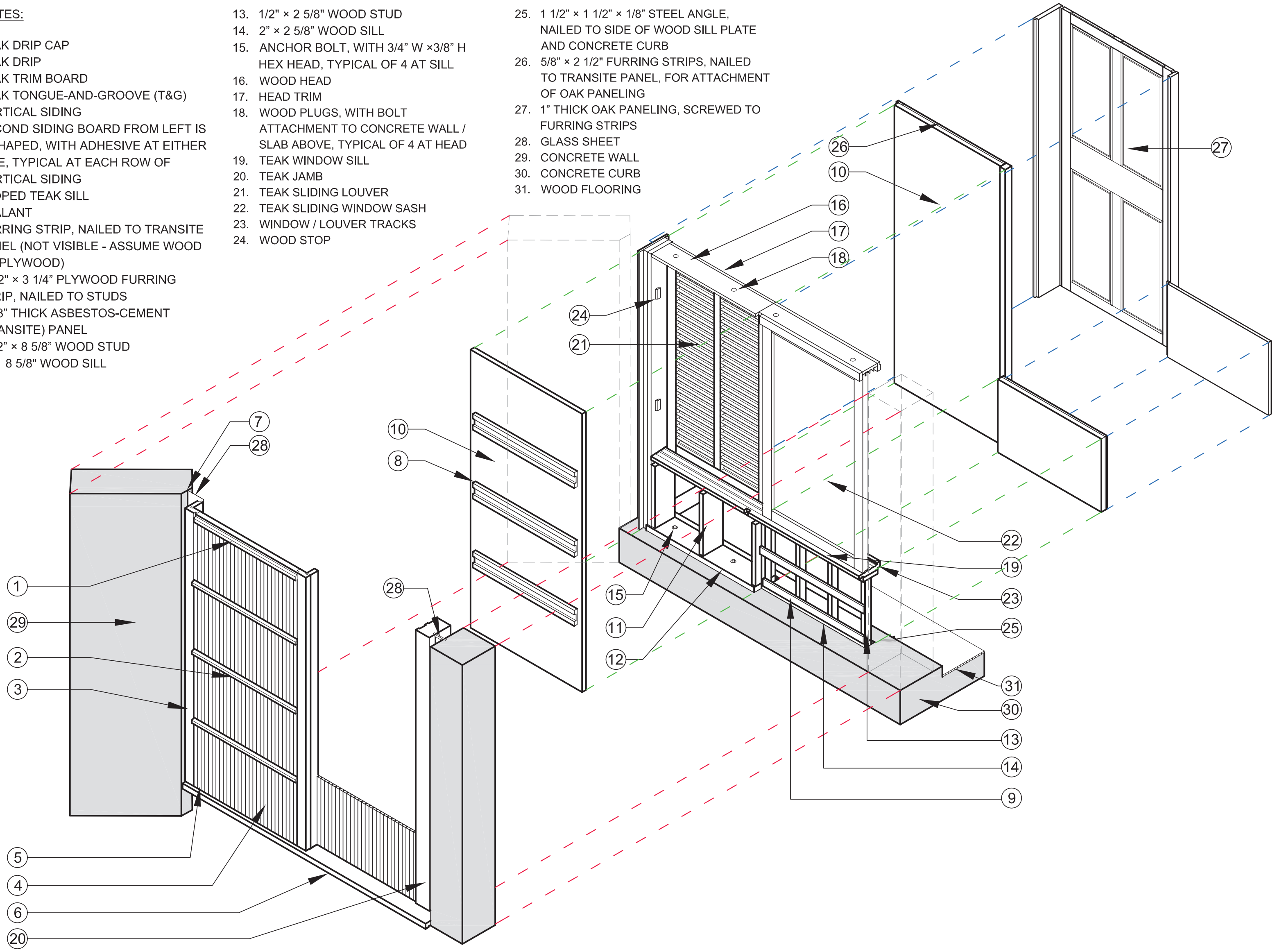
APPENDIX E

Investigative Probe Drawings

PREPARED BY MESUT DINLER

KEY NOTES:

1. TEAK DRIP CAP
2. TEAK DRIP
3. TEAK TRIM BOARD
4. TEAK TONGUE-AND-GROOVE (T&G) VERTICAL SIDING
5. SECOND SIDING BOARD FROM LEFT IS T-SHAPED, WITH ADHESIVE AT EITHER SIDE, TYPICAL AT EACH ROW OF VERTICAL SIDING
6. SLOPED TEAK SILL
7. SEALANT
8. FURRING STRIP, NAILED TO TRANSITE PANEL (NOT VISIBLE - ASSUME WOOD OR PLYWOOD)
9. 2 1/2" × 3 1/4" PLYWOOD FURRING STRIP, NAILED TO STUDS
10. 1 5/8" THICK ASBESTOS-CEMENT (TRANSITE) PANEL
11. 1 1/2" × 8 5/8" WOOD STUD
12. 2" × 8 5/8" WOOD SILL
13. 1/2" × 2 5/8" WOOD STUD
14. 2" × 2 5/8" WOOD SILL
15. ANCHOR BOLT, WITH 3/4" W ×3/8" H HEX HEAD, TYPICAL OF 4 AT SILL
16. WOOD HEAD
17. HEAD TRIM
18. WOOD PLUGS, WITH BOLT ATTACHMENT TO CONCRETE WALL / SLAB ABOVE, TYPICAL OF 4 AT HEAD
19. TEAK WINDOW SILL
20. TEAK JAMB
21. TEAK SLIDING LOUVER
22. TEAK SLIDING WINDOW SASH
23. WINDOW / LOUVER TRACKS
24. WOOD STOP
25. 1 1/2" × 1 1/2" × 1/8" STEEL ANGLE, NAILED TO SIDE OF WOOD SILL PLATE AND CONCRETE CURB
26. 5/8" × 2 1/2" FURRING STRIPS, NAILED TO TRANSITE PANEL, FOR ATTACHMENT OF OAK PANELING
27. 1" THICK OAK PANELING, SCREWED TO FURRING STRIPS
28. GLASS SHEET
29. CONCRETE WALL
30. CONCRETE CURB
31. WOOD FLOORING

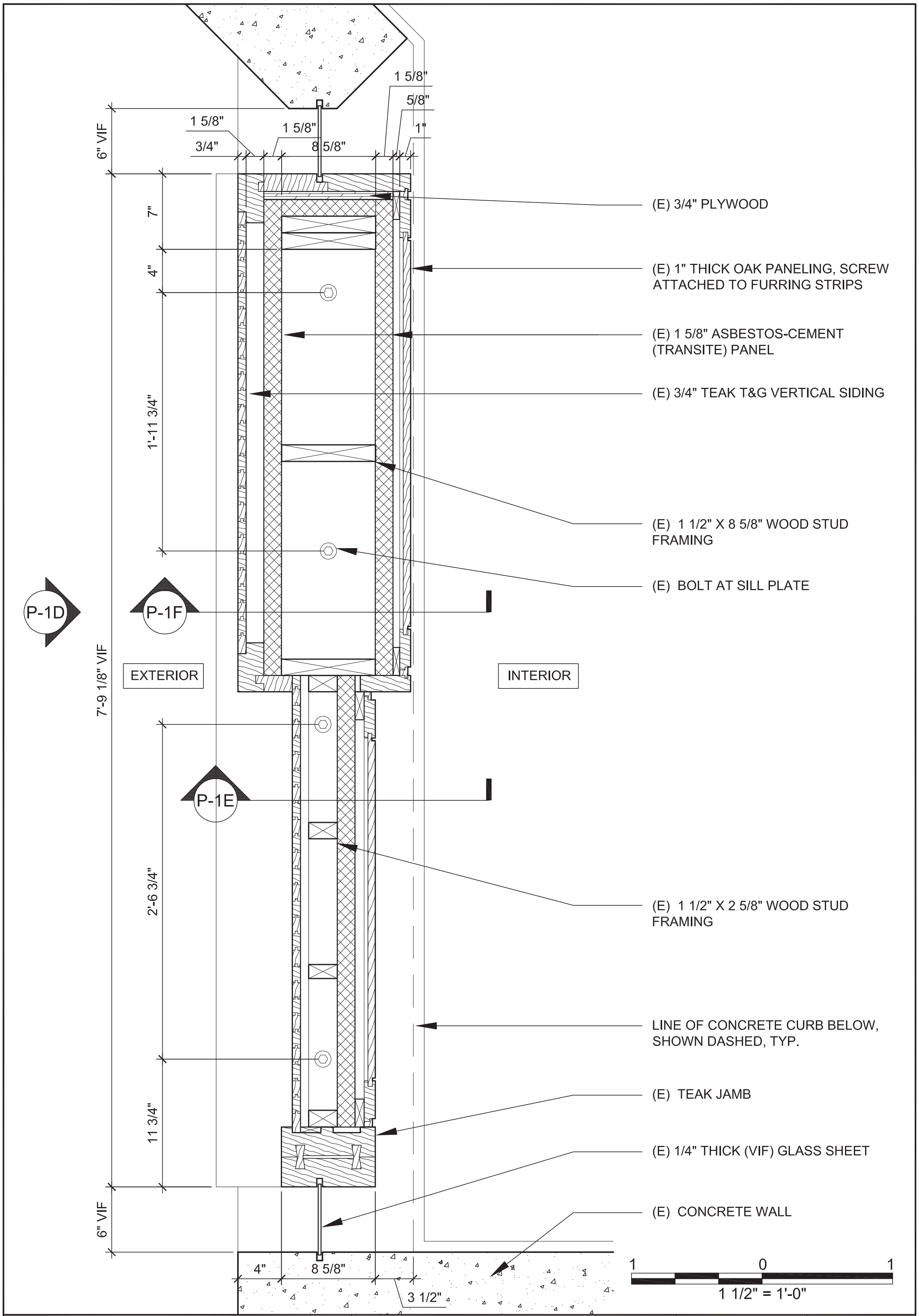


SALK INSTITUTE CONSERVATION PROJECT
Teak Window Wall Assemblies

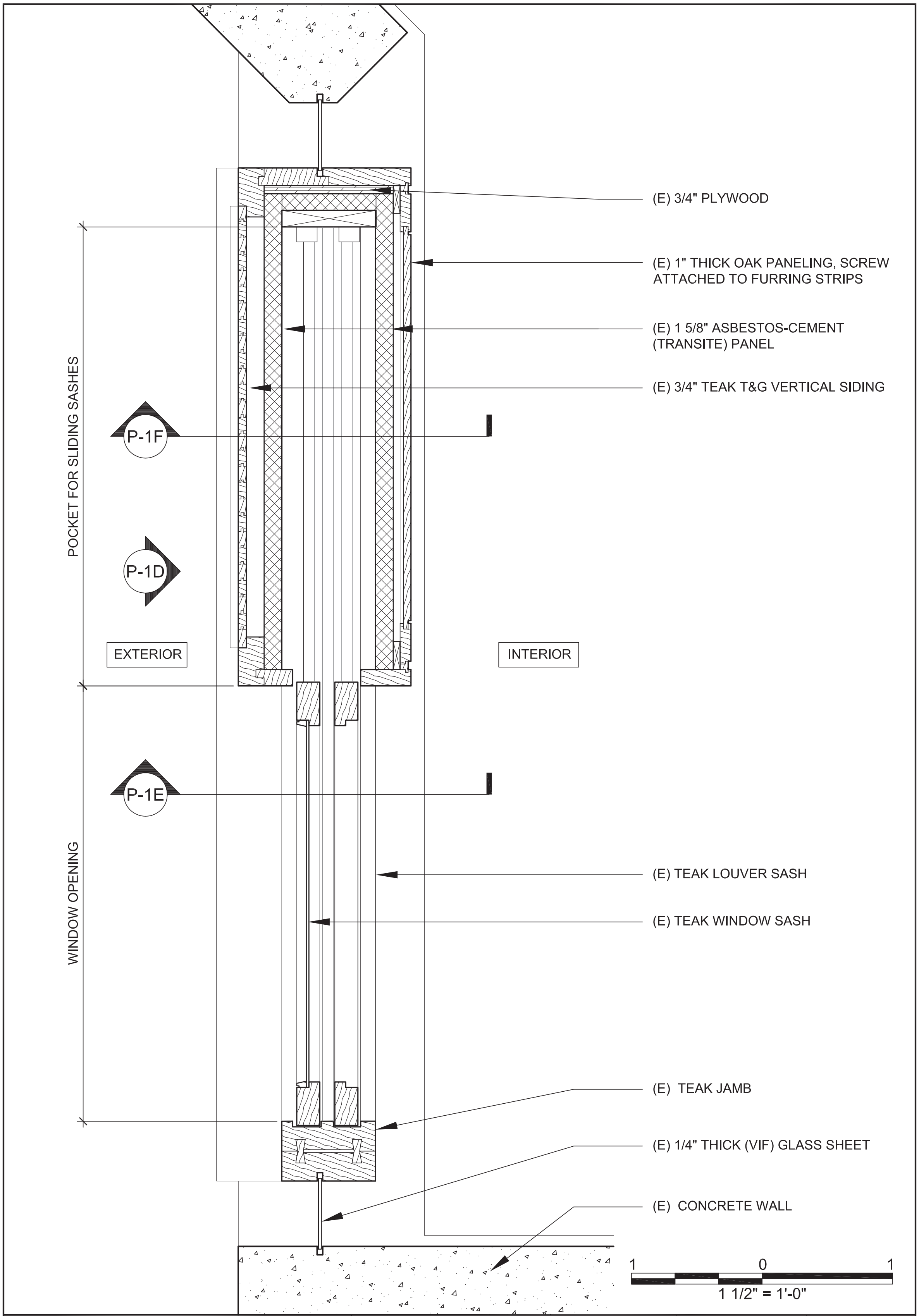
SALK INSTITUTE FOR BIOLOGICAL STUDIES
The Getty Conservation Institute

Drawing Name:
INVESTIGATIVE PROBE 1 - NL6C
TYPICAL WINDOW WALL - EXPLODED VIEW
Salk Institute for Biological Studies
La Jolla, CA

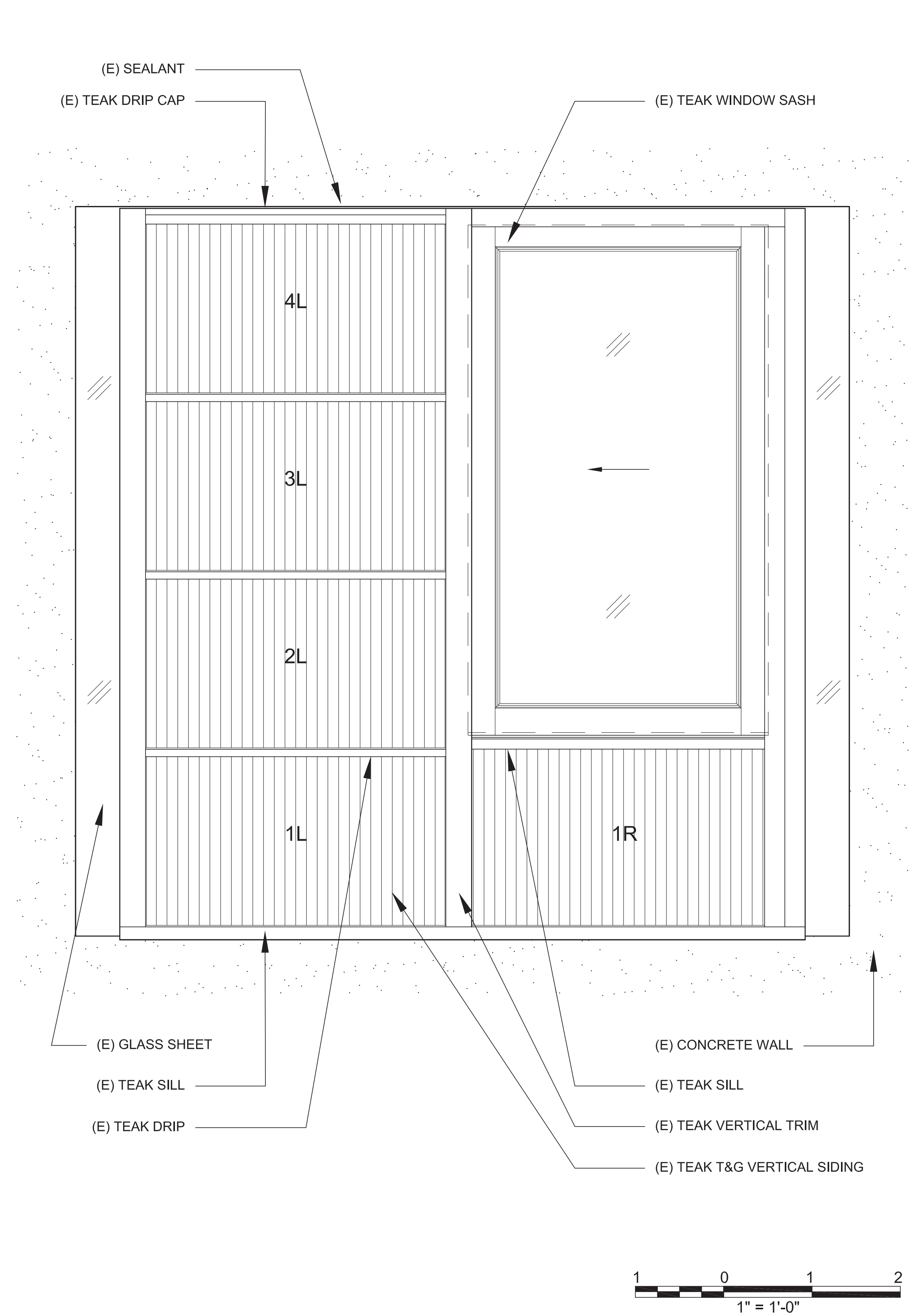
Drawing Issued: 5/2014, updated 3/2017
Drawn By: MD, SL
Sheet No.: P-1A



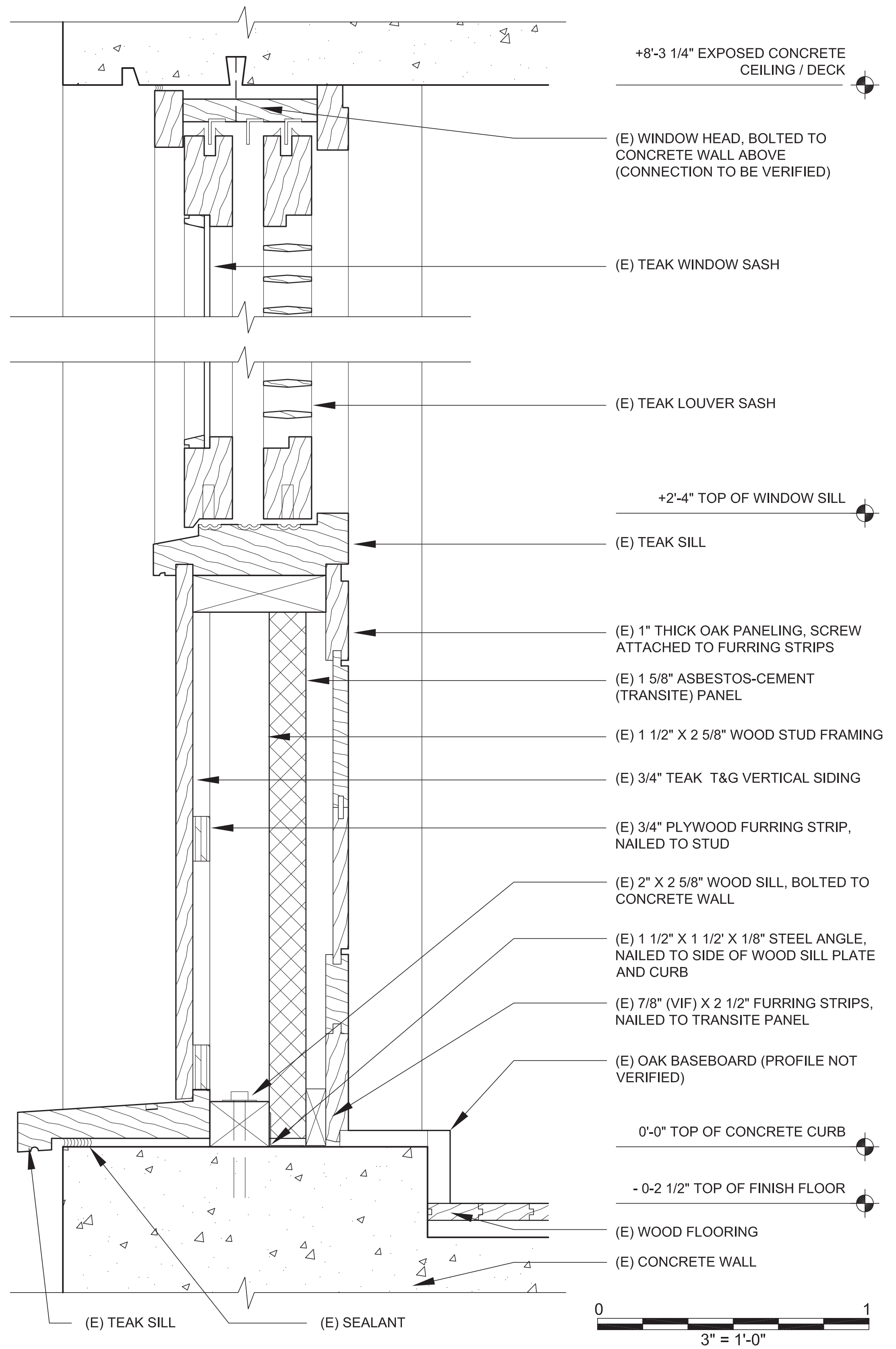
SALK INSTITUTE CONSERVATION PROJECT Teak Window Wall Assemblies SALK INSTITUTE FOR BIOLOGICAL STUDIES — The Getty Conservation Institute	Drawing Name: INVESTIGATIVE PROBE 1 - NL6C TYP. WINDOW WALL - PLAN BELOW WINDOW Salk Institute for Biological Studies La Jolla, CA	Scale: 1 1/2" = 1'-0" Drawing Issued: 5/2014, updated 3/2017 Drawn By: SL, MD	Sheet No.: P-1B



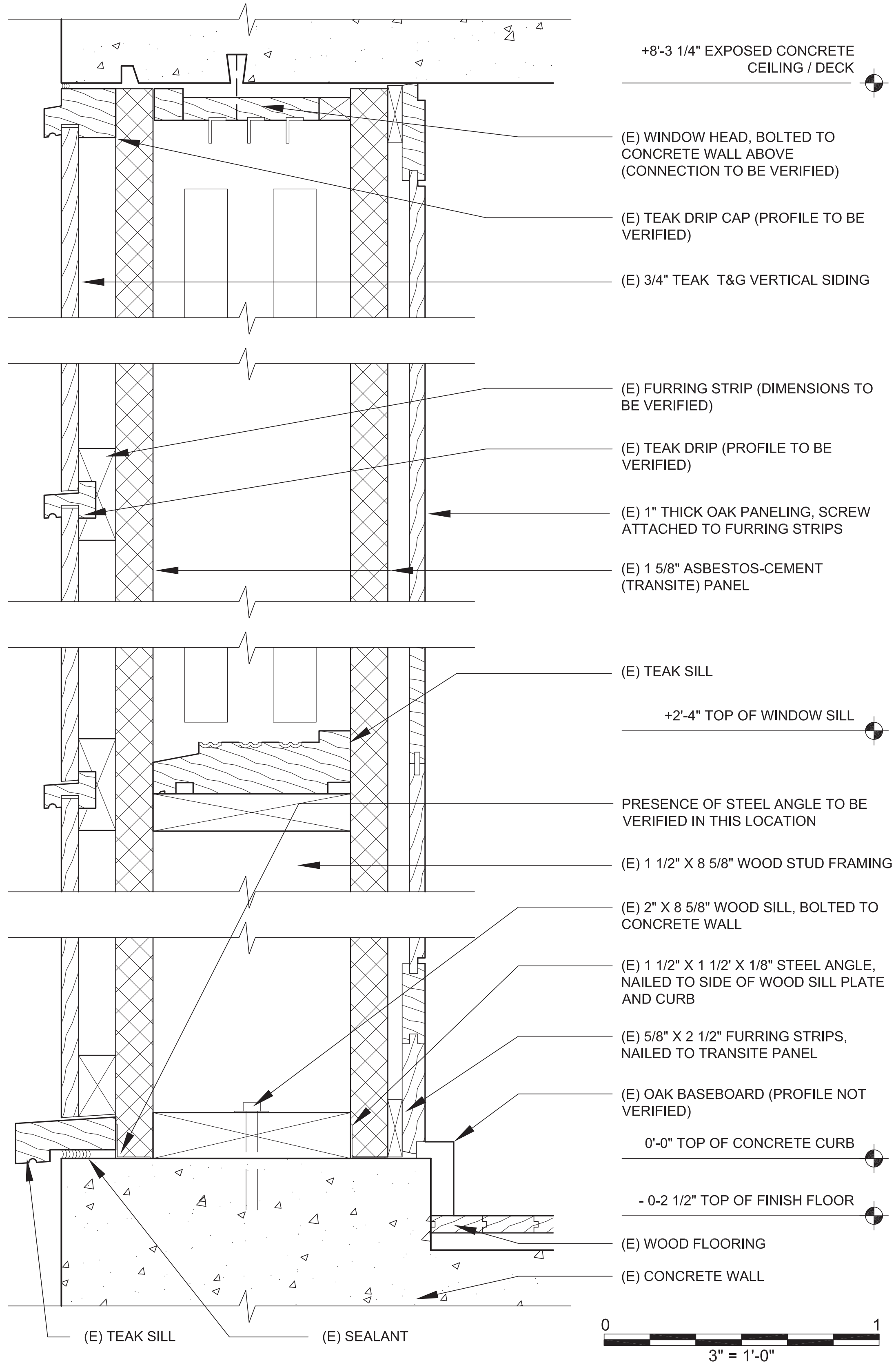
SALK INSTITUTE CONSERVATION PROJECT Teak Window Wall Assemblies SALK INSTITUTE FOR BIOLOGICAL STUDIES · The Getty Conservation Institute	Drawing Name: INVESTIGATIVE PROBE 1 - NL6C TYP. WINDOW WALL - PLAN AT WINDOW Salk Institute for Biological Studies La Jolla, CA	Scale: 1 1/2" = 1'-0" Drawing Issued: 5/2014, updated 3/2017 Drawn By: SL, MD	Sheet No.: P-1C



SALK INSTITUTE CONSERVATION PROJECT Teak Window Wall Assemblies SALK INSTITUTE FOR BIOLOGICAL STUDIES · The Getty Conservation Institute	Drawing Name: INVESTIGATIVE PROBE 1 - NL6C TYP. WINDOW WALL - EXTERIOR ELEVATION Salk Institute for Biological Studies La Jolla, CA	Scale: 1" = 1'-0" Drawing Issued: 5/2014, updated 3/2017 Drawn By: SL	Sheet No.: P-1D



SALK INSTITUTE CONSERVATION PROJECT Teak Window Wall Assemblies SALK INSTITUTE FOR BIOLOGICAL STUDIES / The Getty Conservation Institute	Drawing Name: INVESTIGATIVE PROBE 1 - NL6C TYP. WINDOW WALL - SECTION AT WINDOW Salk Institute for Biological Studies La Jolla, CA	Scale: 3" = 1'-0" Drawing Issued: 5/2014, updated 3/2017 Drawn By: SL, MD	Sheet No.: P-1E



SALK INSTITUTE CONSERVATION PROJECT Teak Window Wall Assemblies SALK INSTITUTE FOR BIOLOGICAL STUDIES · The Getty Conservation Institute	Drawing Name: INVESTIGATIVE PROBE 1 - NL6C TYP. WINDOW WALL - SECTION AT POCKET Salk Institute for Biological Studies La Jolla, CA	Scale: 3" = 1'-0" Drawing Issued: 5/2014, updated 3/2017 Drawn By: SL, MD	Sheet No.: P-1F


NL6C, PRIOR TO REMOVAL OF INTERIOR TRANSITE PANEL

NL6C, AFTER THE REMOVAL OF INTERIOR TRANSITE PANEL

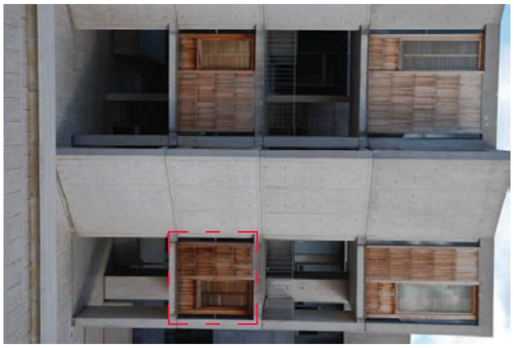

DETAIL 1


DETAIL 3


DETAIL 2

DETAILS OF NL6C

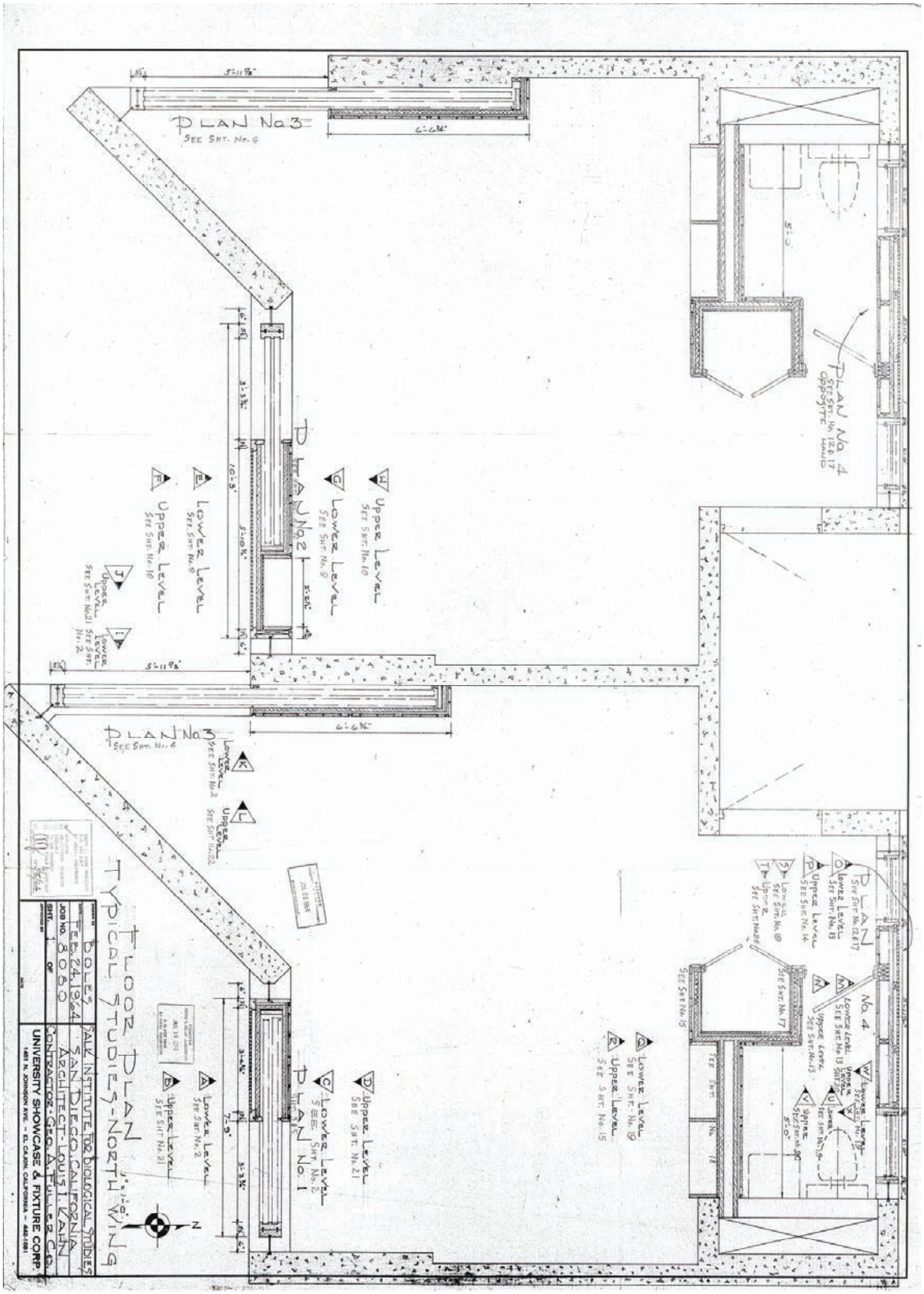

VIEW OF NORTH STUDIES FROM PLAZA, SHOWING STUDY TOWER 7N


STUDY TOWER 7N, SHOWING THE PROBE LOCATION


NL6B, ADJACENT WINDOW WITH OAK PANELING IN PLACE

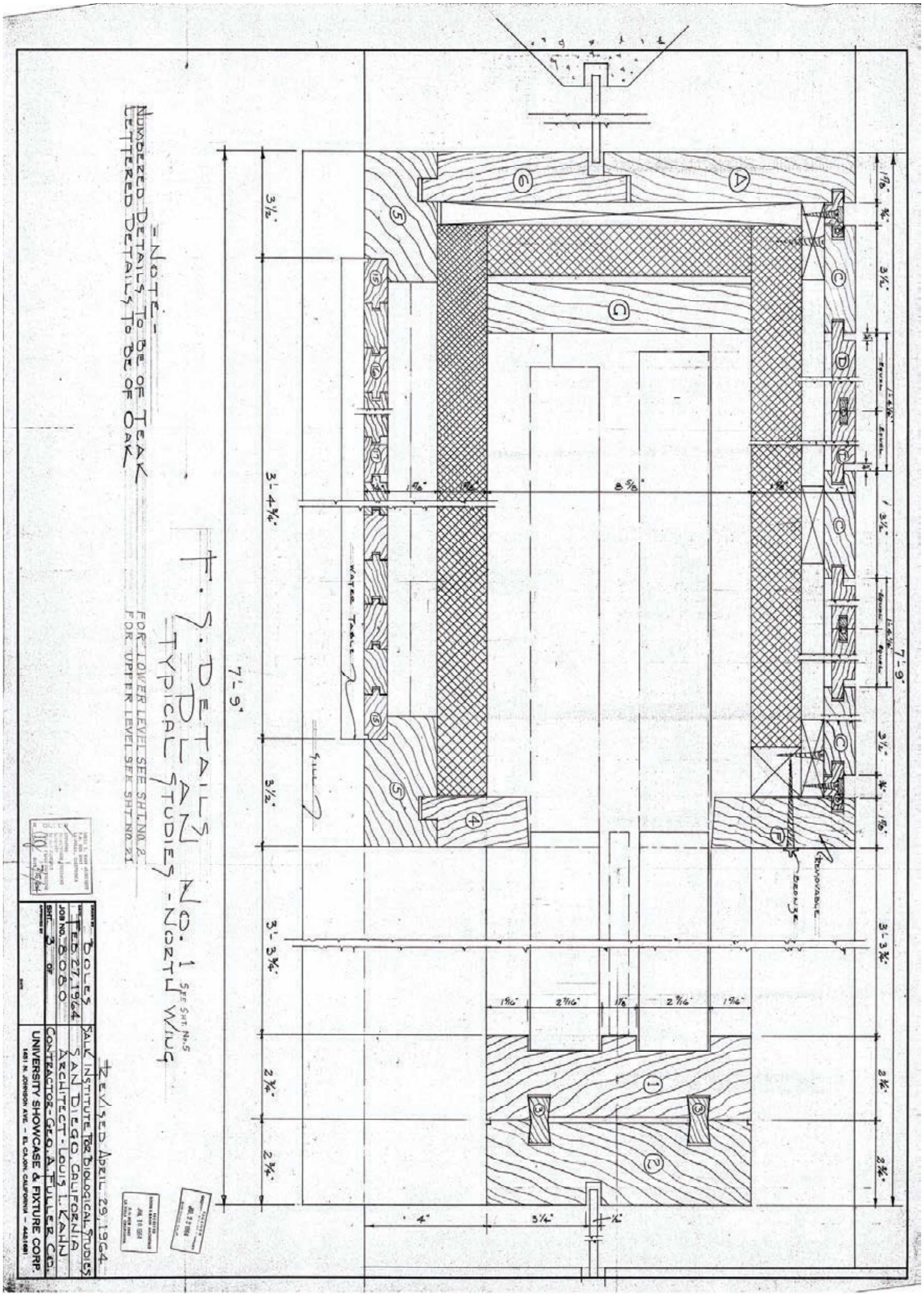
SALK INSTITUTE CONSERVATION PROJECT Teak Window Wall Assemblies SALK INSTITUTE FOR BIOLOGICAL STUDIES — The Getty Conservation Institute	Drawing Name: INVESTIGATIVE PROBE 1 - NL6C PHOTOGRAPHS Salk Institute for Biological Studies La Jolla, CA	Drawing Issued: 5/2014, updated 3/2017 Drawn By: MD	Sheet No.: P-1G

Note: Scan of shop drawing courtesy of the Salk Institute for Biological Studies.



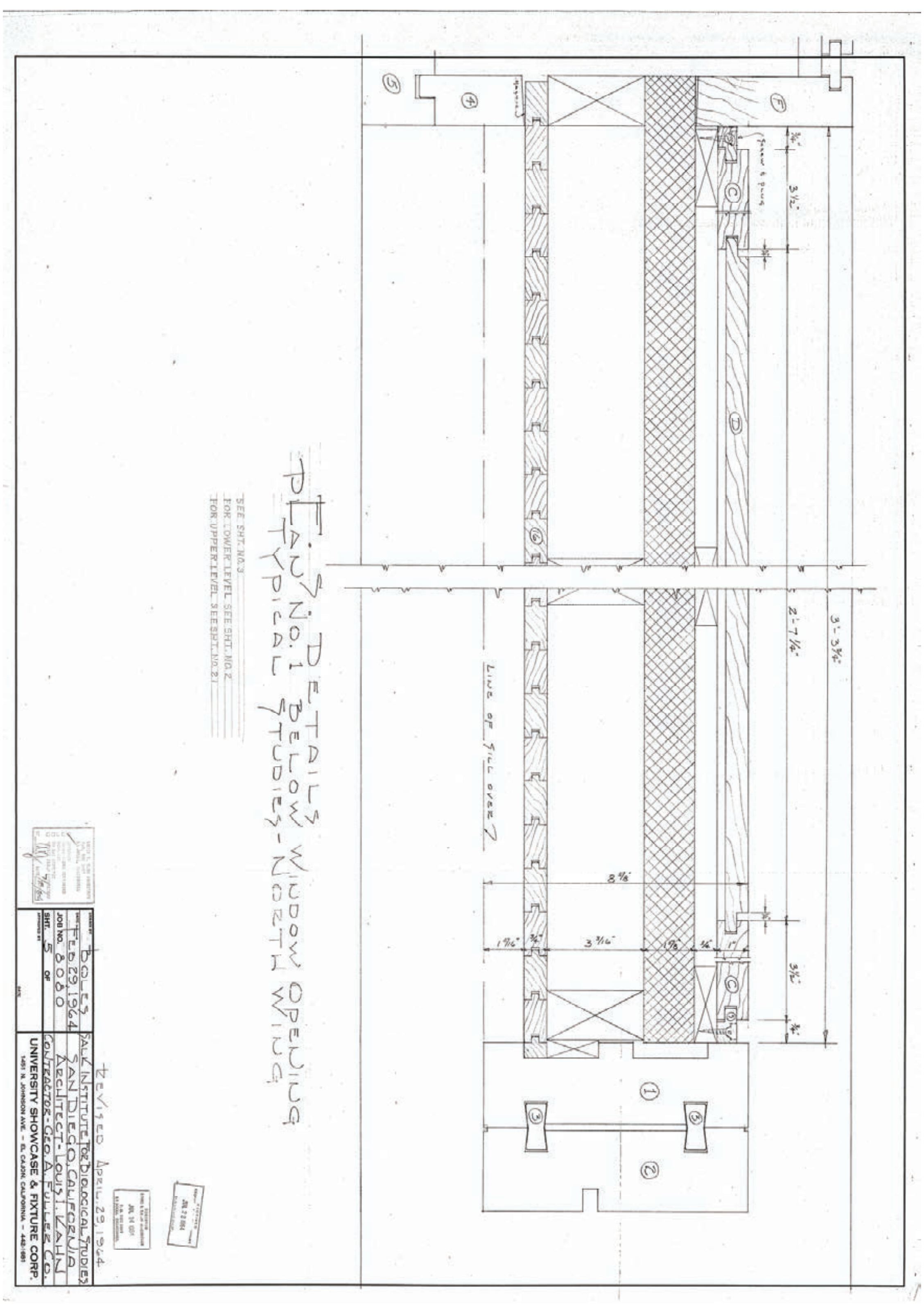
SALK INSTITUTE CONSERVATION PROJECT Teak Window Wall Assemblies SALK INSTITUTE FOR BIOLOGICAL STUDIES · The Getty Conservation Institute	Drawing Name: INVESTIGATIVE PROBE 1 - NL6C SHOP DRAWINGS / FLOOR PLAN Salk Institute for Biological Studies La Jolla, CA	Drawing Issued: 5/2014, updated 3/2017 Drawn By:	Sheet No.: P-1H

Note: Scan of shop drawing courtesy of the Salk Institute for Biological Studies.



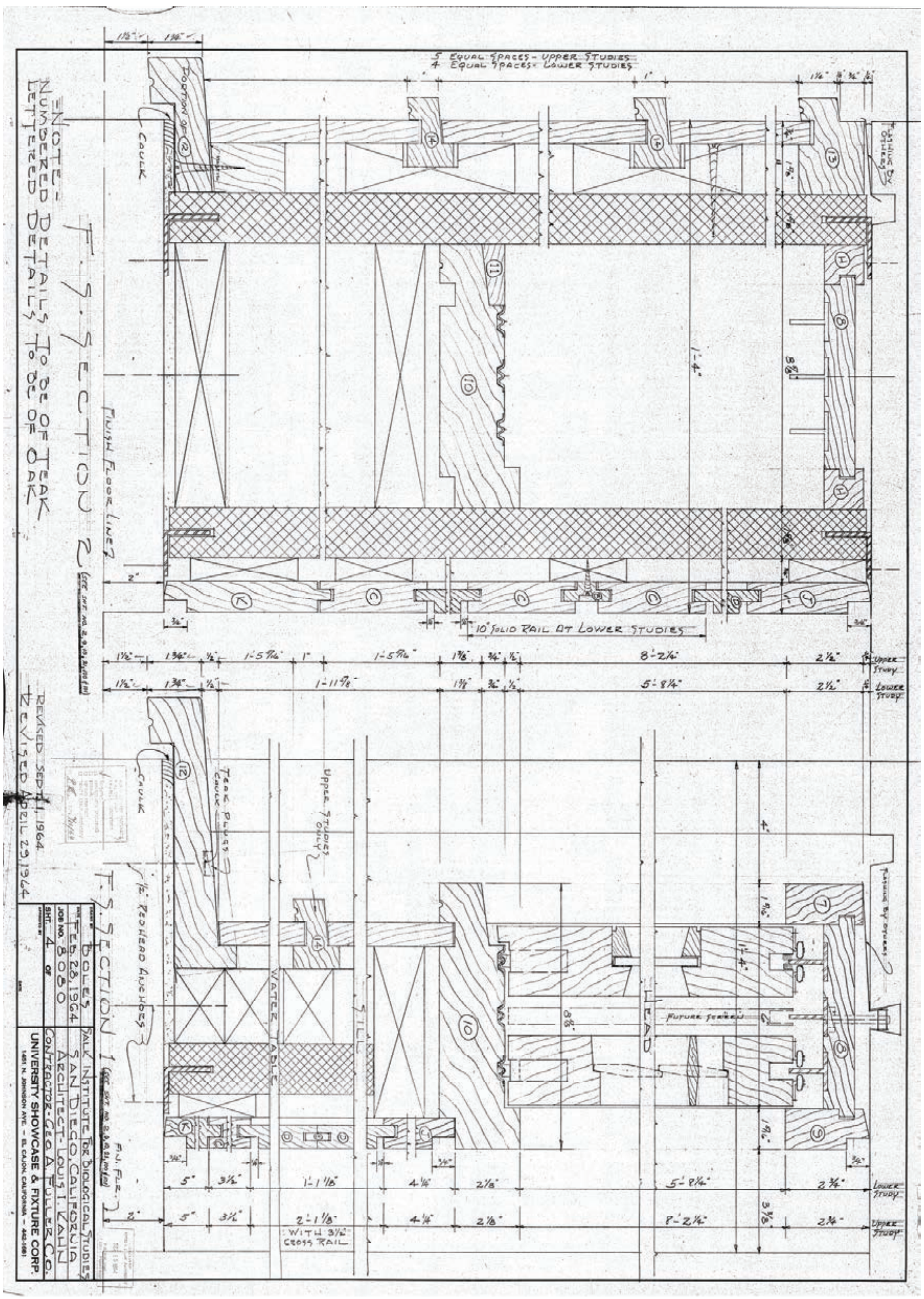
SALK INSTITUTE CONSERVATION PROJECT Teak Window Wall Assemblies SALK INSTITUTE FOR BIOLOGICAL STUDIES · The Getty Conservation Institute	Drawing Name: INVESTIGATIVE PROBE 1 - NL6C SHOP DRAWINGS / FLOOR PLAN Salk Institute for Biological Studies La Jolla, CA	Drawing Issued: 5/2014, updated 3/2017 Drawn By:	Sheet No.: P-1I

Note: Scan of shop drawing courtesy of the Salk Institute for Biological Studies.



SALK INSTITUTE CONSERVATION PROJECT Teak Window Wall Assemblies SALK INSTITUTE FOR BIOLOGICAL STUDIES · The Getty Conservation Institute	Drawing Name: INVESTIGATIVE PROBE 1 - NL6C SHOP DRAWINGS / FLOOR PLAN Salk Institute for Biological Studies La Jolla, CA	Drawing Issued: 5/2014, updated 3/2016 Drawn By:	Sheet No.: P-1J

Note: Scan of shop drawing courtesy of the Salk Institute for Biological Studies.



SALK INSTITUTE CONSERVATION PROJECT
Teak Window Wall Assemblies

SALK INSTITUTE FOR BIOLOGICAL STUDIES
The Getty Conservation Institute

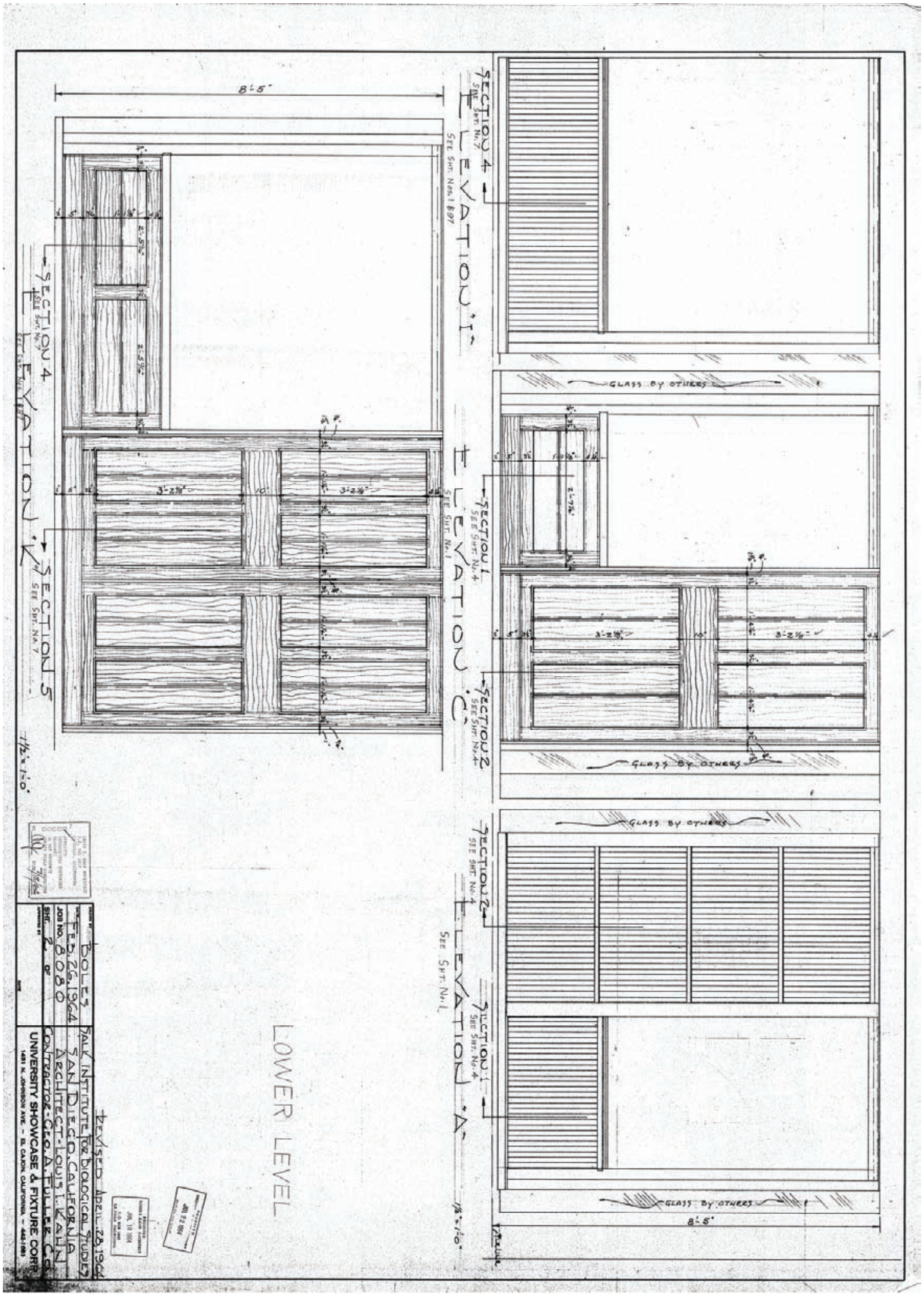
Drawing Name:
INVESTIGATIVE PROBE 1 - NL6C
SHOP DRAWINGS
Salk Institute for Biological Studies
La Jolla, CA

Drawing Issued:
5/2014, updated 3/2017

Drawn By:

Sheet No.:
P-1K

Note: Scan of shop drawing courtesy of the Salk Institute for Biological Studies.



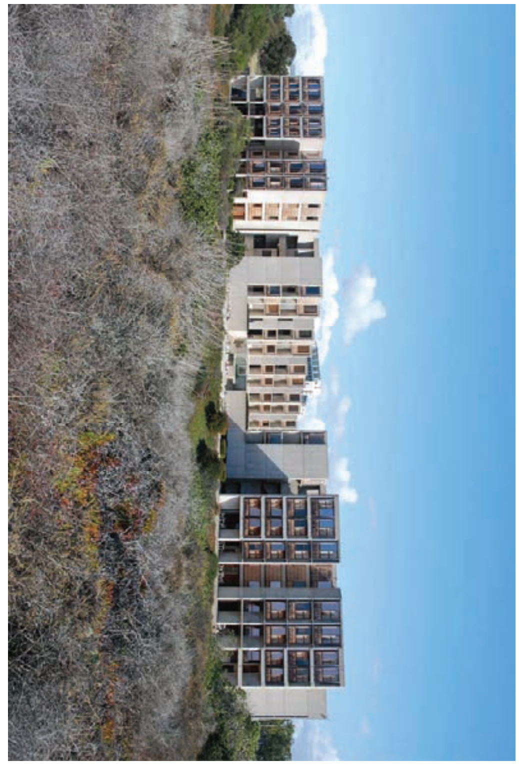
SALK INSTITUTE CONSERVATION PROJECT Teak Window Wall Assemblies SALK INSTITUTE FOR BIOLOGICAL STUDIES The Getty Conservation Institute	Drawing Name: INVESTIGATIVE PROBE 1 - NL6C SHOP DRAWINGS Salk Institute for Biological Studies La Jolla, CA	Drawing Issued: 5/2014, updated 3/2017 Drawn By:	Sheet No.: P-1L

SO4B, AFTER REMOVAL OF OAK PANELING, SHOWING BUILDING PAPER AT INSIDE FACE OF FRAMING

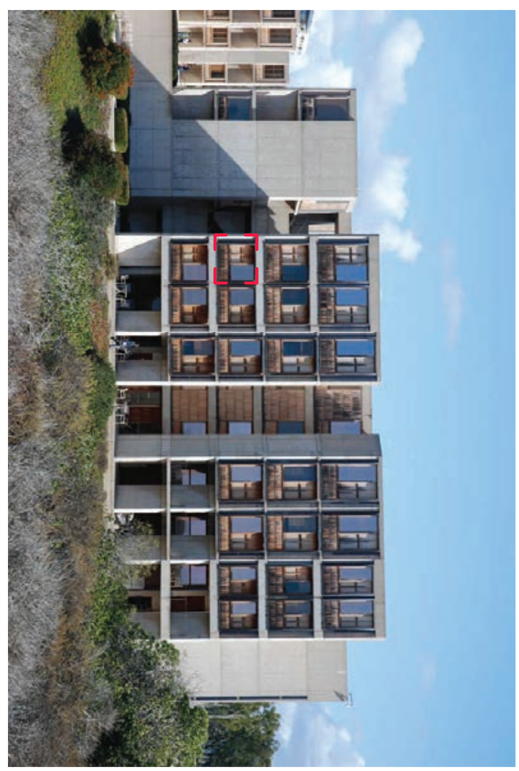
SO4B, AFTER REMOVAL OF BUILDING PAPER

DETAIL 2
DETAILS OF SO4B

DETAIL 1



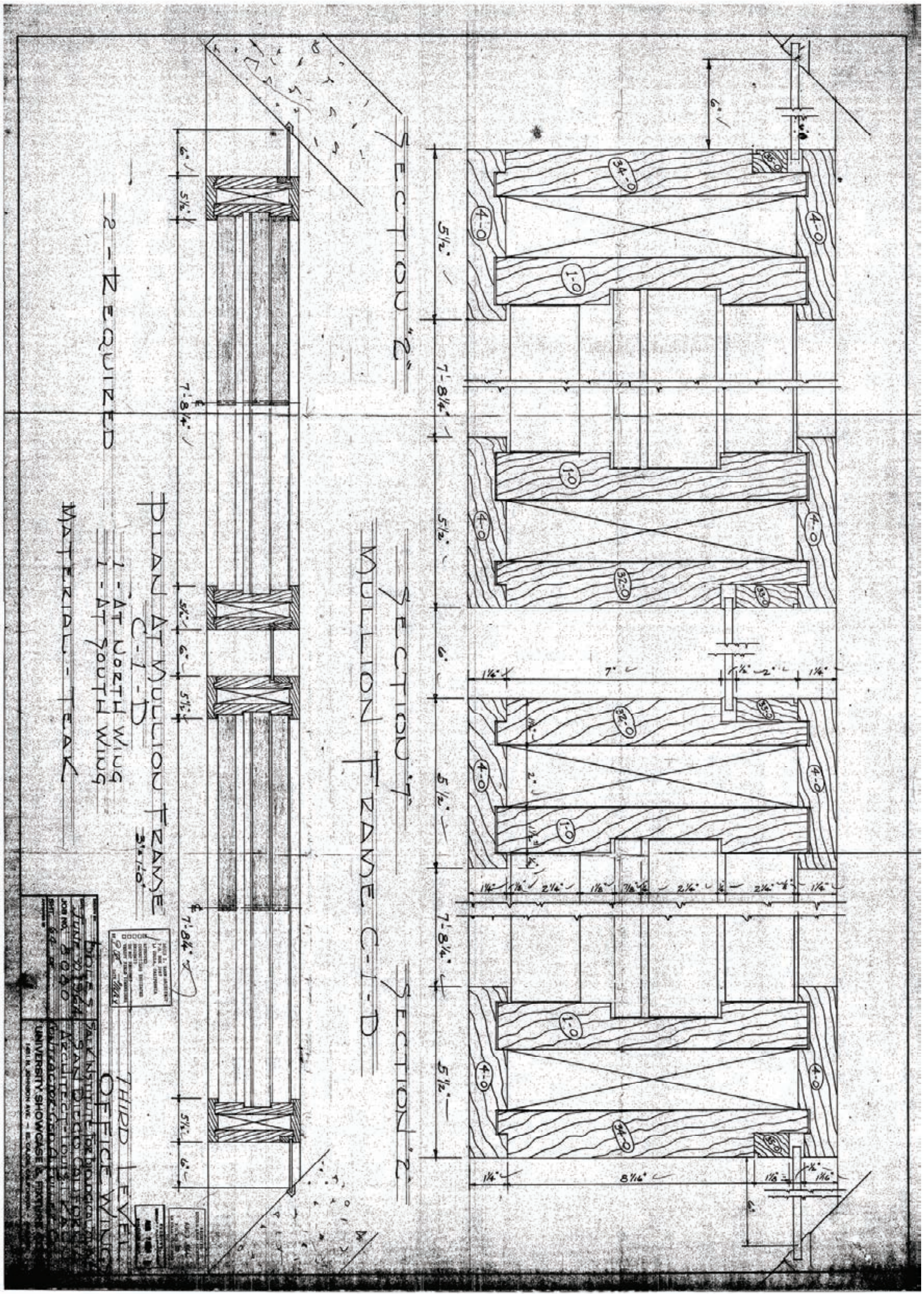
VIEW OF THE CAMPUS FROM WEST



VIEW OF SOUTHERN WEST OFFICE WING, SHOWING THE PROBE LOCATION

SALK INSTITUTE CONSERVATION PROJECT Teak Window Wall Assemblies SALK INSTITUTE FOR BIOLOGICAL STUDIES / The Getty Conservation Institute	Drawing Name: INVESTIGATIVE PROBE 2 - SO4B PHOTOGRAPHS Salk Institute for Biological Studies La Jolla, CA	Drawing Issued: 5/14, updated 3/2017 Drawn By: MD	Sheet No.: P-2A

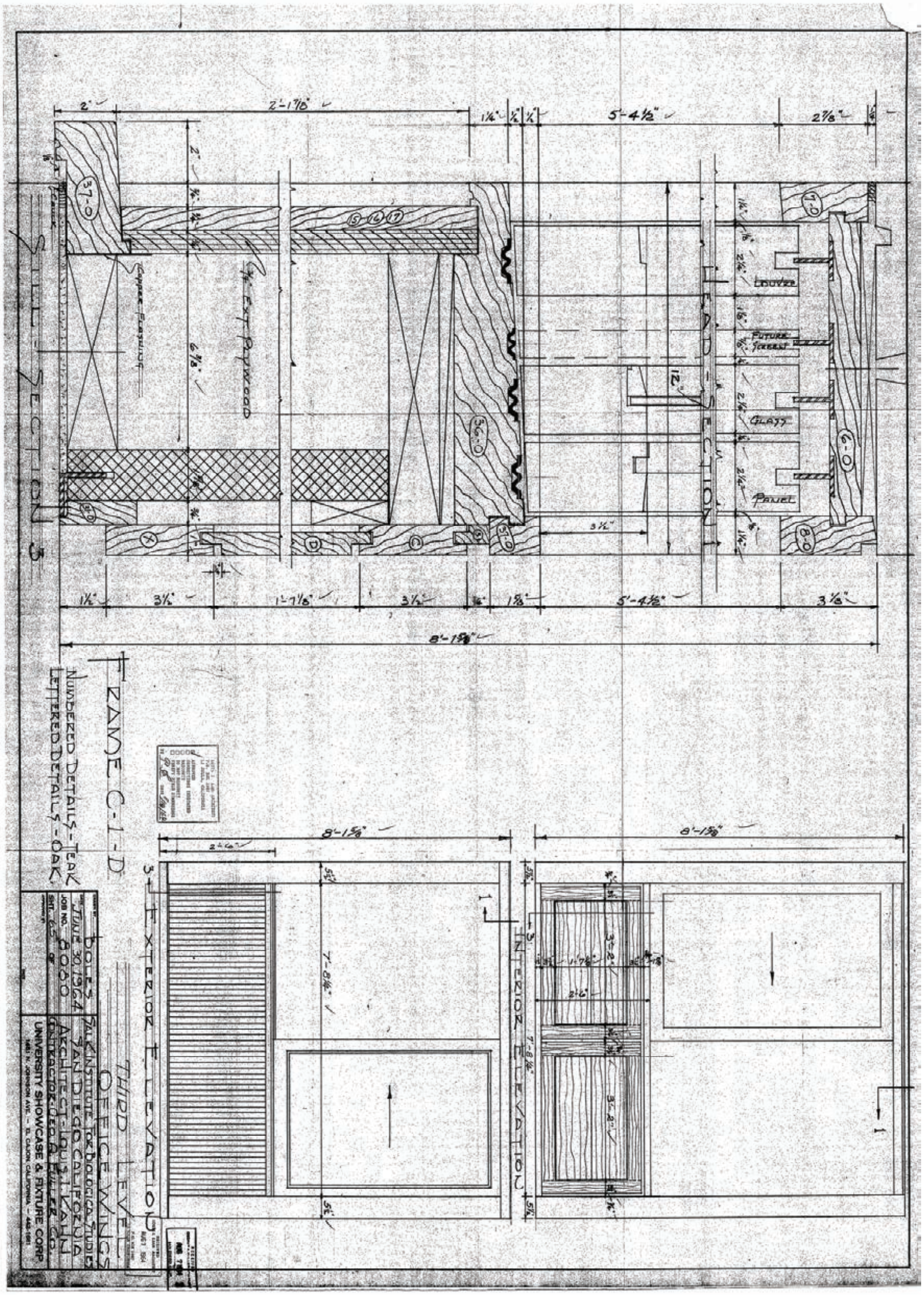
Note: Scan of shop drawing courtesy of the Salk Institute for Biological Studies.



SALK INSTITUTE CONSERVATION PROJECT Teak Window Wall Assemblies	Drawing Name: INVESTIGATIVE PROBE 2 - SO4B SHOP DRAWINGS Salk Institute for Biological Studies La Jolla, CA	Drawing Issued: 5/2014, updated 3/2017 Drawn By: MD	Sheet No.: P-2B

SALK INSTITUTE FOR BIOLOGICAL STUDIES · The Getty Conservation Institute

Note: Scan of shop drawing courtesy of the Salk Institute for Biological Studies.



SALK INSTITUTE CONSERVATION PROJECT
Teak Window Wall Assemblies

SALK INSTITUTE FOR BIOLOGICAL STUDIES — The Getty Conservation Institute

Drawing Name:		Sheet No.:
INVESTIGATIVE PROBE 2 - SO4B SHOP DRAWINGS Salk Institute for Biological Studies La Jolla, CA	Drawing Issued: 5/2014, updated 3/2017 Drawn By: MD	P-2C

APPENDIX F

Sample Log

PREPARED BY MESUT DINLER

SALK INSTITUTE FOR BIOLOGICAL STUDIES

The Getty Conservation Institute

Salk Institute for Biological Studies Conservation Project: Teak Window Wall Assemblies Wood Sample Log			
Sample	**Element**	**Location**	**Description**
Collected by GCI Field Projects and Anthony & Associates, Inc., December 4 and 5, 2013, with additional smaller samples taken from the larger samples by GCI Science in Los Angeles, December 20, 2013 (indicated with subnumber, such as C.1)			
A	Small louver (interior)	From Salk facilities dept. workshop	Specific location of removal unknown
B	Large louver (exterior)	From Salk facilities dept. workshop	Sspecific location of removal unknown
C	Vertical shiplap slat	NL6C	West panel, slat row 1, 2nd slat from west
C.1.	White residue		
C.2.	Glue		
D	Furring strip	NL6C	Assumed 2 × 4 bottom furring strip, west panel, slat row 1, in area where slat was removed
E	Furring strip	NU7C	East panel, slat row 3, lower strip behind 2nd-4th slat from west
F	Vertical shiplap slat	NU7C	East panel, slat row 3, 2nd slat from west
G	Vertical shiplap slat	NU7C	East panel, slat row 3, 3rd slat from west
H	Tongue-and-groove vertical slat	SL8B	Slat row 1 under window, 5th from north, multiple pieces
H.1.	Thin section to investigate depth of biological deterioration		
H.2.	Second thin section of H		
I	Tongue-and-groove vertical slat	SL8B	Slat row 1 under window, 6th from north, small portion only

SALK INSTITUTE FOR BIOLOGICAL STUDIES

The Getty Conservation Institute

Salk Institute for Biological Studies Conservation Project: Teak Window Wall Assemblies Wood Sample Log			
Sample	**Element**	**Location**	**Description**
J	Tongue-and-groove vertical slat	SL8B	Slat row 1 under window, 4th from north
J.1.	Red coating		
K	Large louver (exterior)	SO2K	21st louver from bottom, western-most row of louvers
K.1.	Black spore		
L	Vertical shiplap slat	SO5K	Center panel, slat row 2, 2nd slat from left/west
L.1.	Glue		
M	Vertical shiplap slat	SO5K	Center panel, slat row 1, 2nd slat from left/west
M.1.	Loose black deposit		
M.2.	Glue		
M.3.	Deteriorated wood		
N	Framing sill plate	SL8B	2 × 4 horizontal bottom framing member exposed by sample removal of H, I, and J
Requested by Anthony & Associates, Inc., and collected by the Salk Institute, December 6 and 9, 2013			
O	Slat	SL8C	West panel, slat row 3, 2nd or 3rd slat from west (taken on 12/9/2013)
P	Slat and two nails	SL7C	east panel, slat row 3, 3rd or 4th slat from west – confirm, as photo is unclear (taken on 12/6/2013)
P.1.	Sample of wood in good condition		

SALK INSTITUTE FOR BIOLOGICAL STUDIES

The Getty Conservation Institute

Salk Institute for Biological Studies Conservation Project: Teak Window Wall Assemblies Wood Sample Log			
Sample	**Element**	**Location**	**Description**
P.2.	Sample of wood (from shiplap) in good condition		
Q	Slat	NL8A	Center panel, slat row 2, 4th or 5th slat from the west (taken on 12/9/2013)
Q.1.	Red coating		
Q.2.	Seemingly non-coated part of the slat		
R	-	-	Sample identification letter not used
S	Slat	NO3E	Slat row 1 under window, 1st or 2nd slat from the west (taken on 12/9/2013)
S.1.	Coating		
Collected by GCI Field Projects and Anthony & Associates, Inc. (A&A), March 12, 2014			
T	Sill	NO6J	Core sample of top face of bottom sill, left-hand (north) side
U	Vertical trim board	NO6H	Core sample of vertical trim piece, far right-hand (south) side of opening, approximately 10–12” above the bottom sill
V	Tongue-and-groove slat	NO6K	Center panel, slat row 2 (row of slats that fell out during Feb. 28, 2014 storm and salvaged by Salk)
W	Tongue-and-groove slat	NO6K	Center panel, slat row 2 (row of slats that fell out during Feb. 28, 2014 storm and salvaged by Salk)

Salk Institute for Biological Studies Conservation Project: Teak Window Wall Assemblies Wood Sample Log			
Sample	**Element**	**Location**	**Description**
-	Termite frass	NL6C	Collected after interior finishes removed for investigative work

Notes:

1. Blue font indicates samples taken by A&A from Salk directly to Colorado offices (did not come back to the GCI).
2. Yellow highlighted letters have been assigned to the samples by the GCI.

SALK INSTITUTE FOR BIOLOGICAL STUDIES

The Getty Conservation Institute

Salk Institute for Biological Studies Conservation Project: Teak Window Wall Assemblies Wood Sample Log			
Sample	**Element**	**Location**	**Description**
Collected by GCI Field Projects and GCI Science, December 4 and 5, 2013			
1		NO2B	White phenomenon
2	Middle ledge	NO2A	Gray patina
3	Vertical framing	NO2A	Gray patina
4		NO2A	Red stain / varnish
5	Vertical framing	NO2A	Fungi
6	Panel	NO2C	Red stain/lacquer photo no. #1829, 1830, 1831, 1832
7	Panel	NO2C	Photo no. #1835, 1836, 1837, 1838
8	Black spore	NO2F, NO2G	
9	Panel	NO2K	Photo no. #1854, 1853
10	Panel	NO2K	Photo no. #1855, 1856
11	Louver	NO2K	Photo no. #1859
12	Bottom sill	NO2K	Photo no. #1857, 1858
13	Louver	NO2D	Dust on the surface photo no. #1826, 1827, 1828
14	Panel	SO2B	White deposit photo no. #1862, 1863, 1864, 1866, 1870

SALK INSTITUTE FOR BIOLOGICAL STUDIES

The Getty Conservation Institute

Salk Institute for Biological Studies Conservation Project:
Teak Window Wall Assemblies
Wood Sample Log

Sample	Element	Location	Description
15	Panel	SO2K	Probable coating photo no. #1875, 1876, 1877, 1878, 1879, 1880, 1881, 1882, 1883
16	Beneath sample #15	SO2K	
17	Window casing	SO2K	Rust stain photo no. #1884
18	Louver	SO2K	Black sticky coating
19	Bottom sill of the window	SL5C	Gray patina
20	Vertical slat	SL5C	Water stain
21	Debris behind the slat taken off	NU6C	
22	Sill	NU6C	Interior wood chip behind the slat
23	Side of slat	NU6C	Glue
24	Windowsill	SL5C	Black spore
25	Beneath sample #24	SL5C	Green coloration
26	Concrete	SL4A	Salt
27	Windowsill	SL4A	Salt
28	Slat	SL4A	Red coating
29	Blue copper corrosion	SL4A	

SALK INSTITUTE FOR BIOLOGICAL STUDIES

The Getty Conservation Institute

Salk Institute for Biological Studies Conservation Project: Teak Window Wall Assemblies Wood Sample Log			
Sample	**Element**	**Location**	**Description**
30	Inside the panel behind the slat taken as sample	NL8B	
Collected by GCI Field Projects and GCI Science, February 19, 2014			
31	Slat	NO3E	17th slat from north; area with black fungal growth
32	Slat	NO3E	17th slat from north; area with black fungal growth
33	Slat	SO4K	Comparison past treatments
34	Slat	NL6C	Top of 4th slat from east; coating sample
35	Slat	NL6C	Top of 4th slat from east; coating sample
36	Vertical frame	NL8A	Taken from vertical post; coating sample
37	Slat	SL6C	Taken from top of 9th slat from left
38	Slat	SL6C	Taken from middle of 9th slat from left
39	Slat	SL6C	Taken from bottom of 9th slat from left
40	Vertical frame	SL4A	Taken from vertical post by the walkway; sample also included salt
41	Panel	SO2A	Resampling of sample 3, as it was lost in mounting and preparation process
Collected by GCI Field Projects and GCI Science, March 11 and 12, 2014			
42	Vertical trim (face)	NO6H	Black crust

SALK INSTITUTE FOR BIOLOGICAL STUDIES

The Getty Conservation Institute

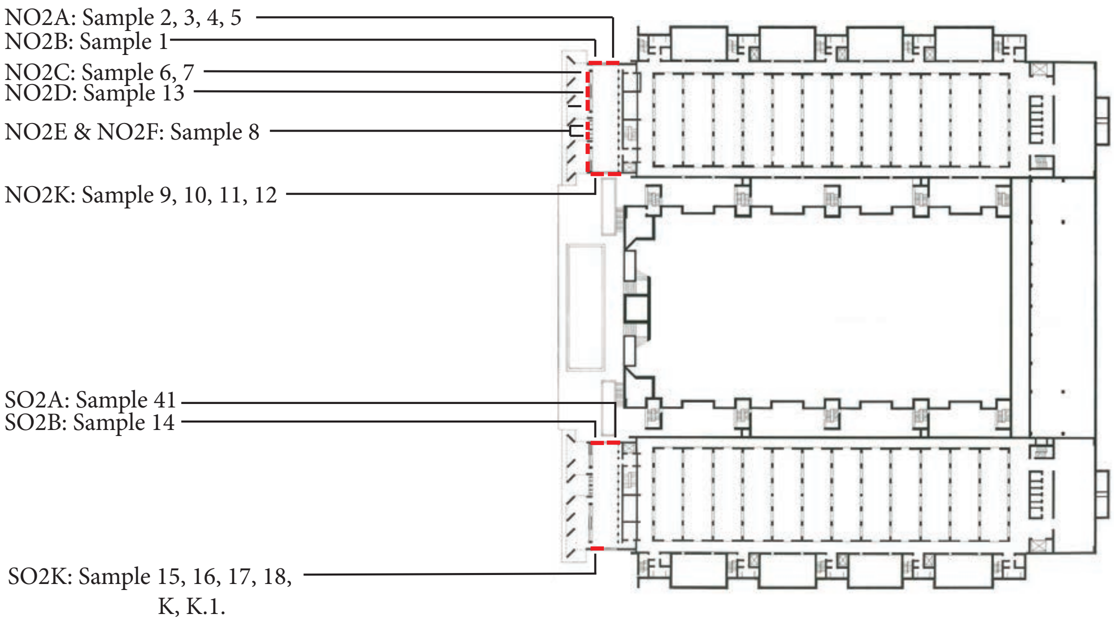
Salk Institute for Biological Studies Conservation Project:
Teak Window Wall Assemblies
Wood Sample Log

Sample	Element	Location	Description
43	Vertical trim (side/return)	NO6H	White efflorescence
44	Vertical trim	NO5H	Black crust
45	Horizontal rail	NO5H	Loose piece of rail (center of span), between slat rows 1 and 2
46	Slat	SO5D	Bottom of 4th slat from left (north), slat row 1
47	Slat	SO5D	Bottom of 5th slat from left (north), slat row 1

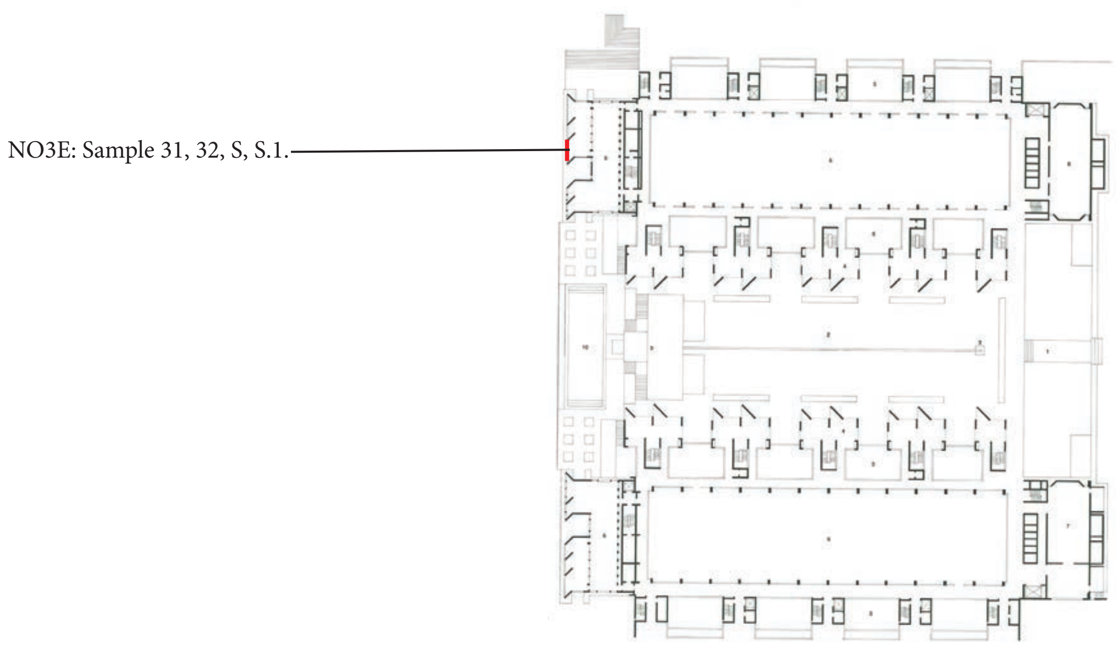
Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

Reference Plans Showing All Samples Collected

Level 2



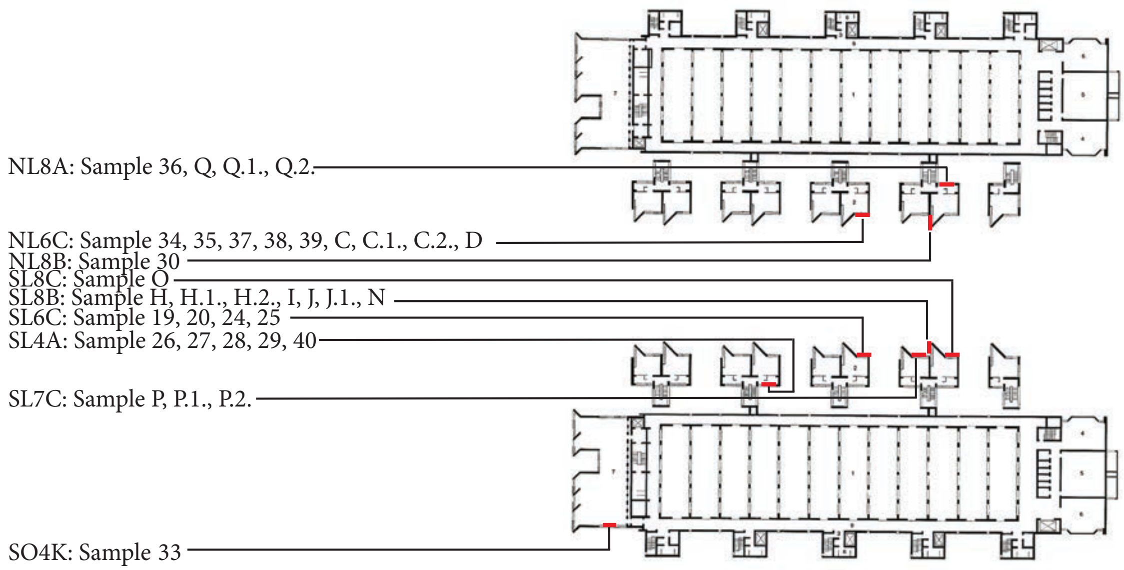
Level 3



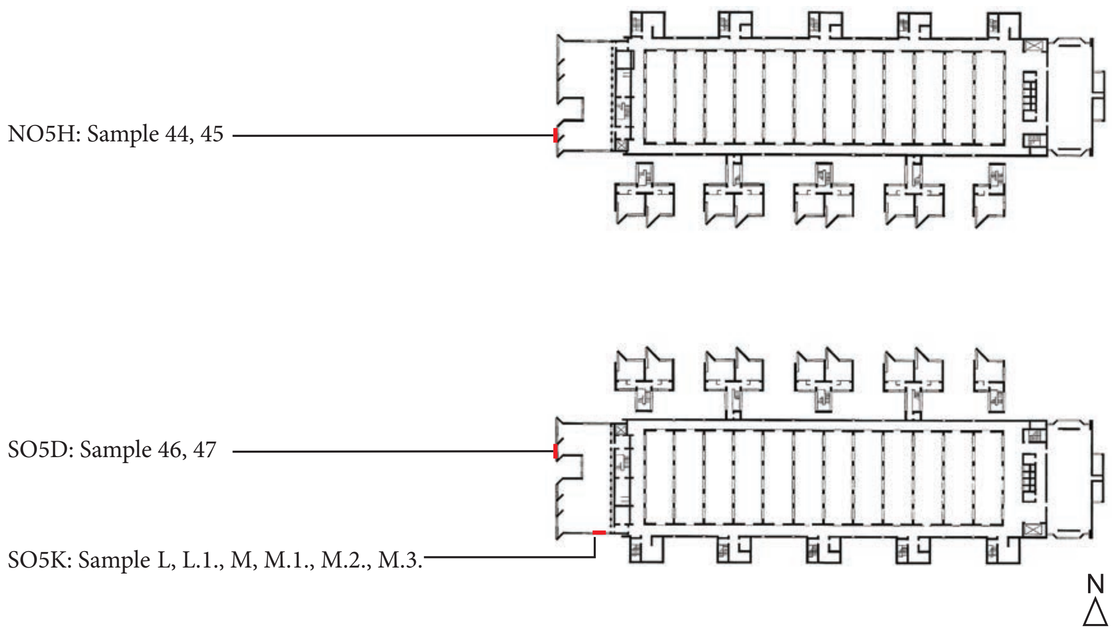
Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

Reference Plans Showing All Samples Collected

Level 4 (Lower Studies)



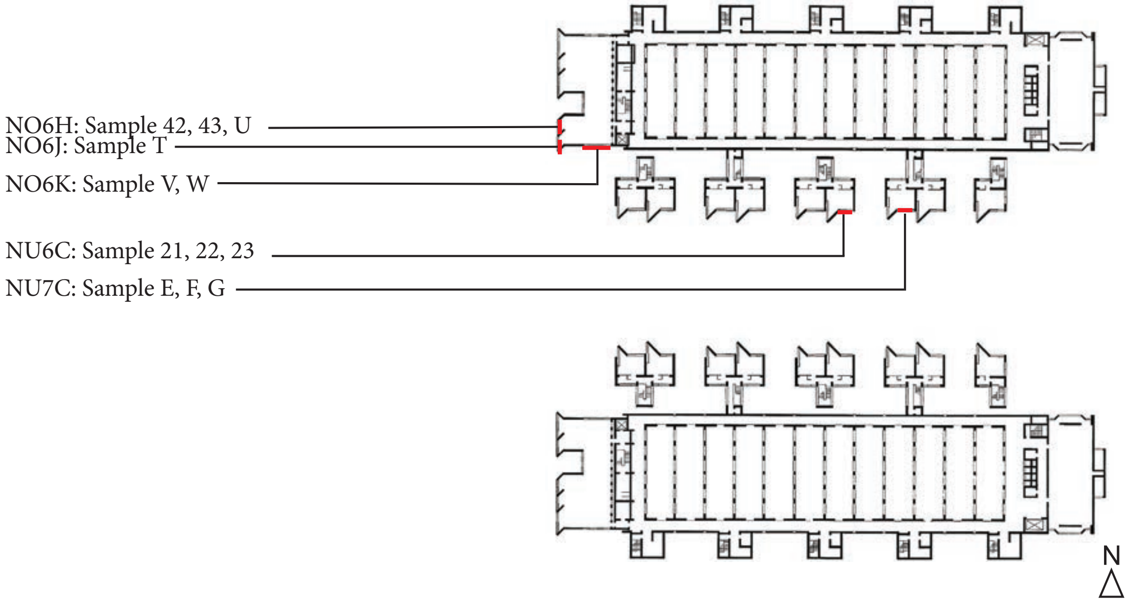
Level 5



Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

Reference Plans Showing All Samples Collected

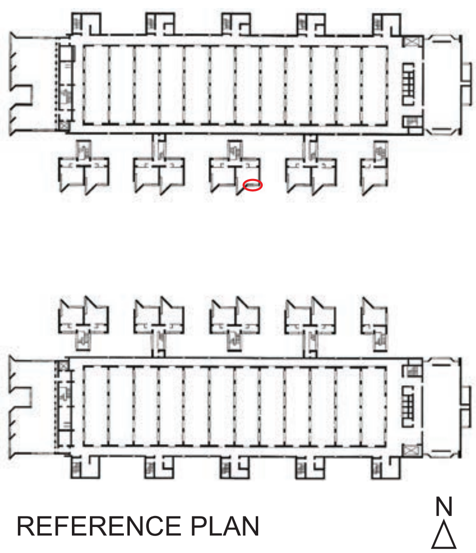
Level 6 (Upper Studies)



Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

Collected by GCI Field Projects and Anthony & Associates, Inc., December 4 and 5, 2013

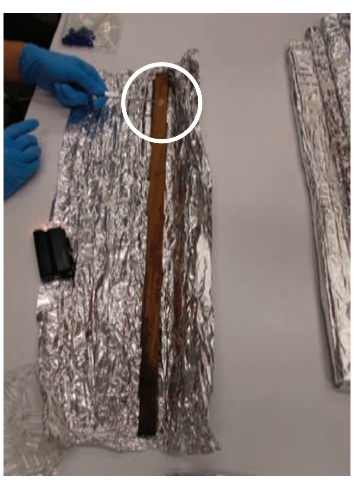
Study Tower 7N | NL6C | Sample C



SAMPLE C

vertical shiplap slat: west panel, slat row 1, 2nd slat from west

Additional Samples Collected by GCI Science, Los Angeles, December 20, 2013



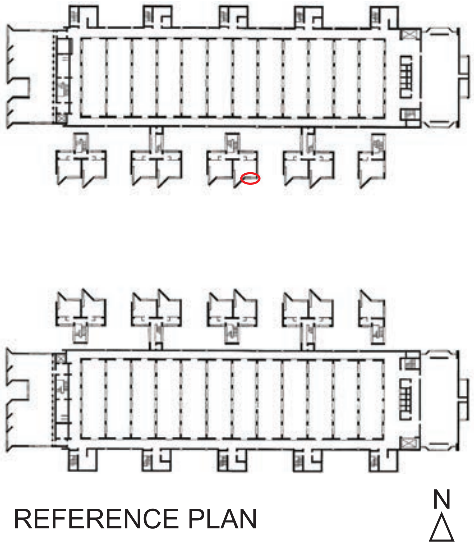
Sample C.1.
white glue-like material

Sample C.2.
glue

Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

Collected by GCI Field Projects and Anthony & Associates, Inc., December 4 and 5, 2013

Study Tower 7N | NL6C | Sample D



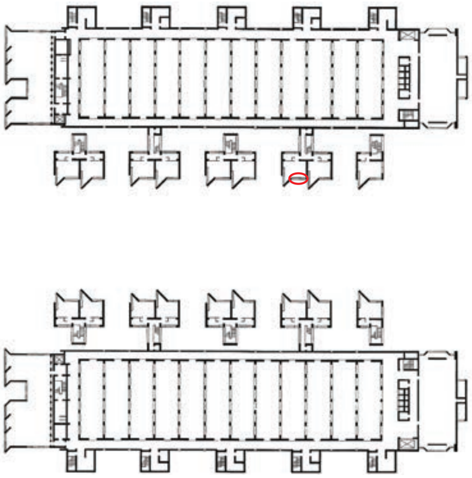
SAMPLE D

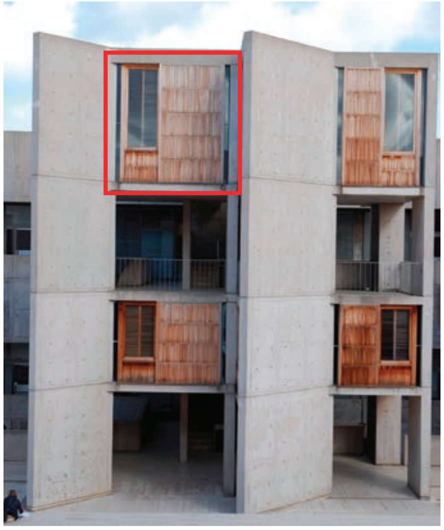
furring strip: assumed 2 x 4 bottom furring strip, west panel, slat row 1, in area where slat was removed

Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

Collected by GCI Field Projects and Anthony & Associates, Inc., December 4 and 5, 2013

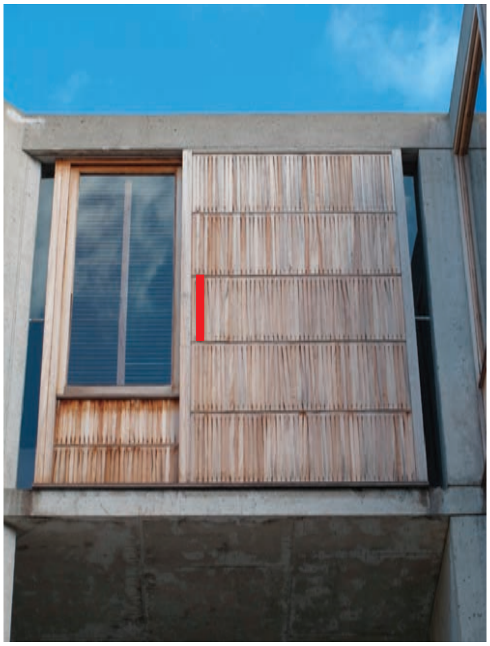
Study Tower 10N | NU7C | Sample E, F, G





REFERENCE PLAN

N



After removal of slats

SAMPLE E

furring strip: east panel, slat row 3, lower strip behind 2nd to 4th slat from west

SAMPLE F

vertical shiplap

slat: east panel, slat row 3, 2nd slat from west

SAMPLE G

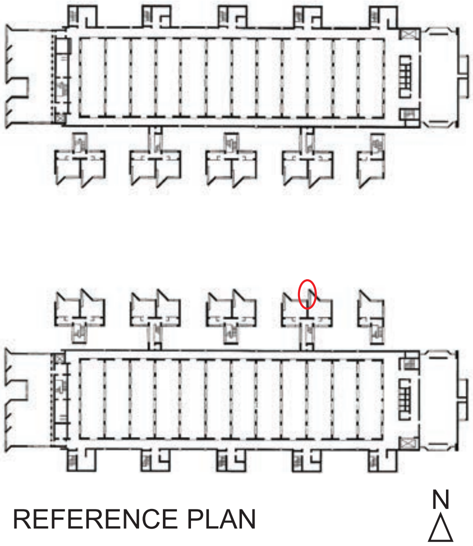
vertical shiplap

slat: east panel, slat row 3, 3rd slat from west

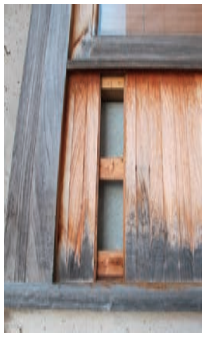
Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

Collected by GCI Field Projects and Anthony & Associates, Inc., December 4 and 5, 2013

Study Tower 10S | SL8B | Sample H, I, N




Before removal of slats


After removal of slats

SAMPLE I

<u>tongue-and-groove vertical slat:</u>
slat row 1 under window, 5th from north, multiple pieces

SAMPLE H

<u>tongue-and-groove vertical slat:</u>
slat row 1 under window, 6th from north, small portion only

SAMPLE N

<u>framing sill plate:</u>
2 x 4 horizontal bottom framing member exposed by removal of samples H, I, and J

Additional Samples Collected by GCI Science, Los Angeles, December 20, 2013

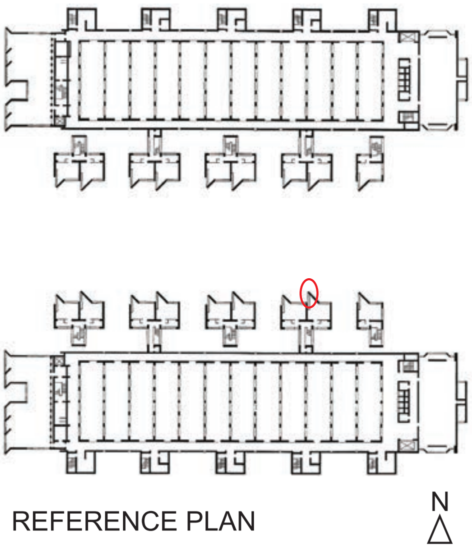
<u>Sample H.1.</u>
thin section to investigate depth of biological deterioration

<u>Sample H.2.</u>
thin section to investigate depth of biological deterioration

Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

Collected by GCI Field Projects and Anthony & Associates, Inc., December 4 and 5, 2013

Study Tower 10S | SL8B | Sample J

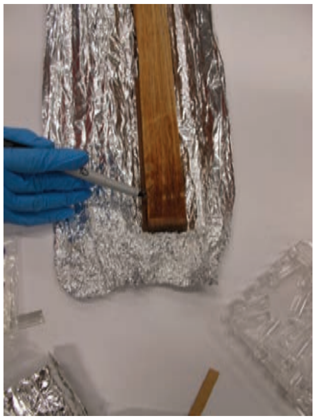


REFERENCE PLAN

SAMPLE J

tongue-and-groove vertical slat:	slat row 1 under window, 4th from north

Additional Samples Collected by GCI Science, Los Angeles, December 20, 2013

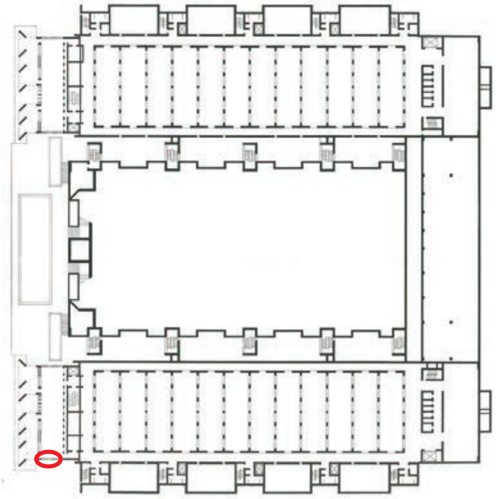


Sample J.1.
red coating

Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

Collected by GCI Field Projects and Anthony & Associates, Inc., December 4 and 5, 2013

South Office Buildings | SO2K | Sample K



REFERENCE PLAN

N

SAMPLE K

large louver (exterior): 21st louver from bottom, westernmost row of louvers

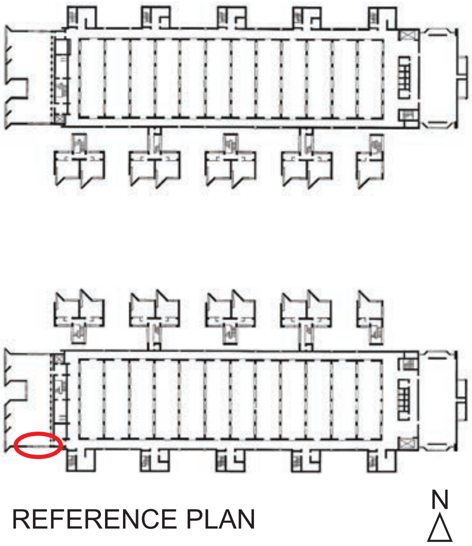
Additional Samples Collected by GCI Science, Los Angeles, December 20, 2013

Sample K.1.
black spore

Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

Collected by GCI Field Projects and Anthony & Associates, Inc., December 4 and 5, 2013

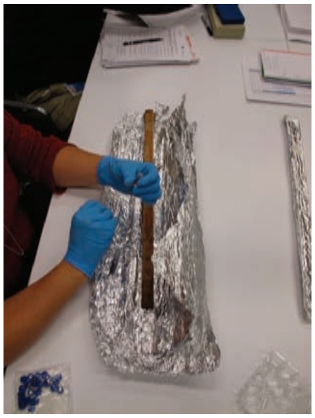
South Office Building | SO5K | Sample L



SAMPLE L

vertical shiplap slat: center panel, slat row 2, 2nd slat from left/west

Additional Samples Collected by GCI Science, Los Angeles, December 20, 2013

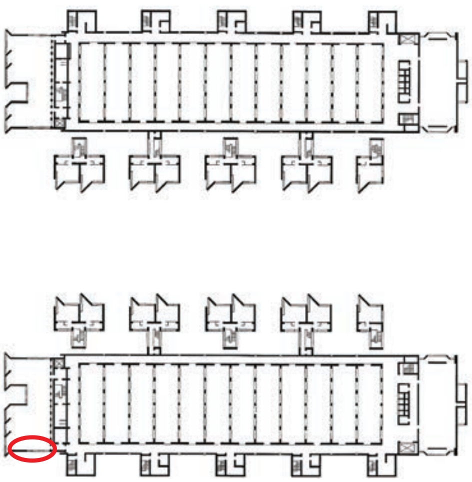


Sample L.1.
glue

Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

Collected by GCI Field Projects and Anthony & Associates, Inc., December 4 and 5, 2013

South Office Building | SO5K | Sample M



REFERENCE PLAN

N

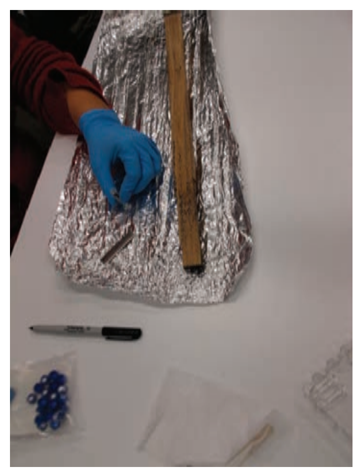
SAMPLE M

vertical shiplap slat: center panel, slat row 1, 2nd slat from left/west

Additional Samples Collected by GCI Science, Los Angeles, December 20, 2013

Sample M.1.
loose black deposit

Sample M.2.
glue

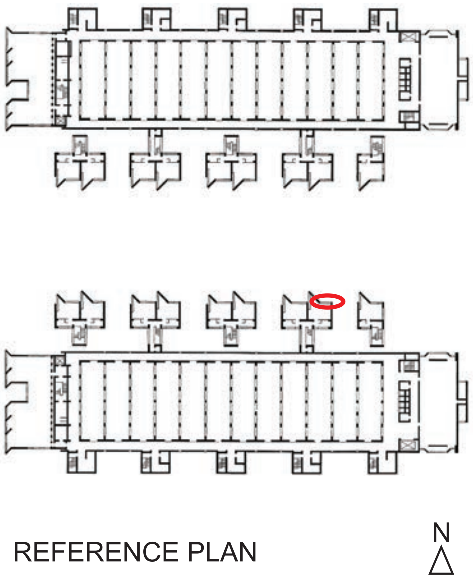


Sample M.3.
deteriorated wood

Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

Requested by Anthony & Associates, Inc., and Collected by the Salk Institute, December 6 and 9, 2013

Study Tower 10S | SL8C | Sample O



SAMPLE O

vertical shiplap slat: west panel, slat row 3, 2nd or 3rd slat from west

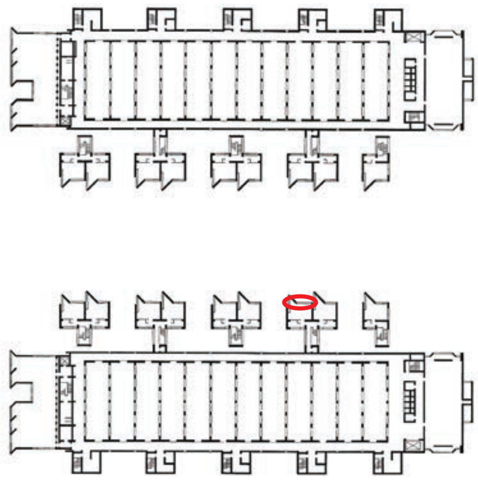
Before removal of slats

After removal of slats

Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

Requested by Anthony & Associates, Inc., and Collected by the Salk Institute, December 6 and 9, 2013

Study Tower 10S | SL7C | Sample P



REFERENCE PLAN

N

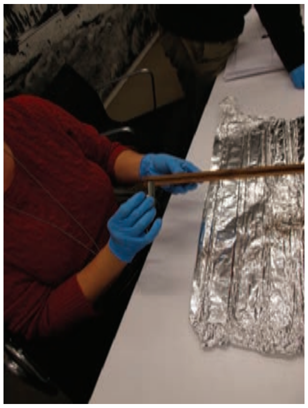
SAMPLE P

slat and two nails:	east panel, slat row 3, 3rd or 4th slat from west

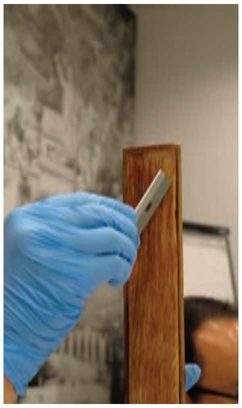
Before removal of slats

During removal of slats

Additional Samples Collected by GCI Science, Los Angeles, December 20, 2013



Sample P.1.
sample of wood in good condition

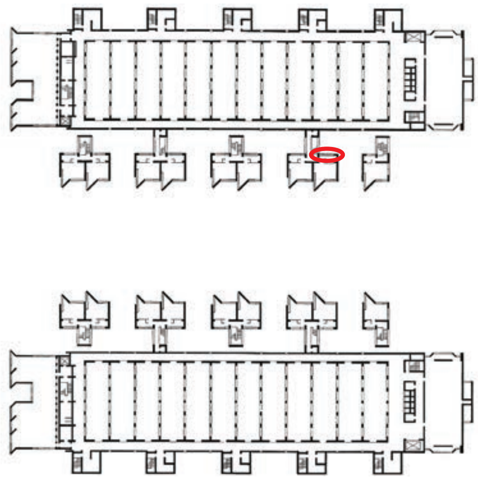


Sample P.1.
shiplap sample of wood in good condition

Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

Requested by Anthony & Associates, Inc., and Collected by the Salk Institute, December 6 and 9, 2013

Study Tower 10N | NL8A | Sample Q



REFERENCE PLAN

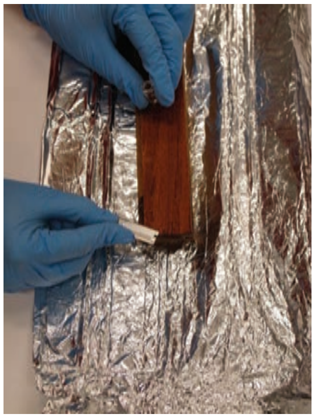
N

After removal of slats (with patches installed by Salk)

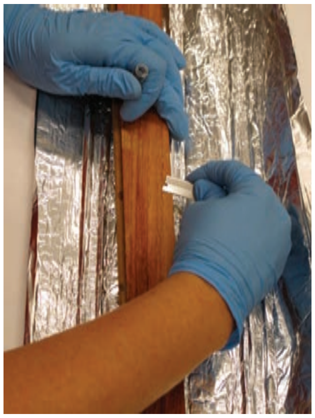
SAMPLE Q

slat: center row, slat row 2, 4th or 5th slat from west

Additional Samples Collected by GCI Science, Los Angeles, December 20, 2013



Sample Q.1.
red coating

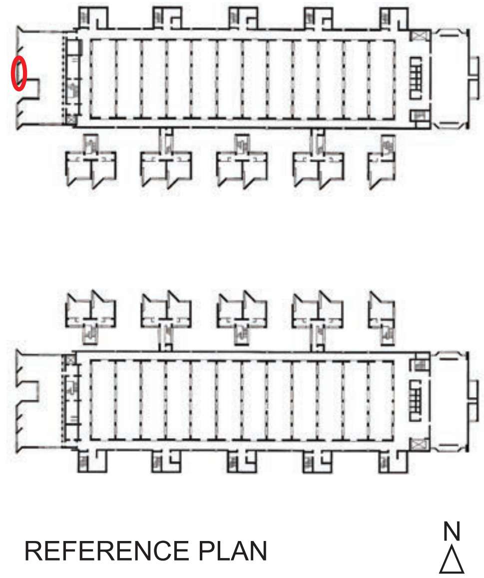


Sample Q.2.
seemingly non-coated

Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

Requested by Anthony & Associates, Inc., and Collected by the Salk Institute, December 6 and 9, 2013

North Office Building | NO3E | Sample S



SAMPLE S

slat: slat row 1 under window, 1st or 2nd slat from west


After removal of slats

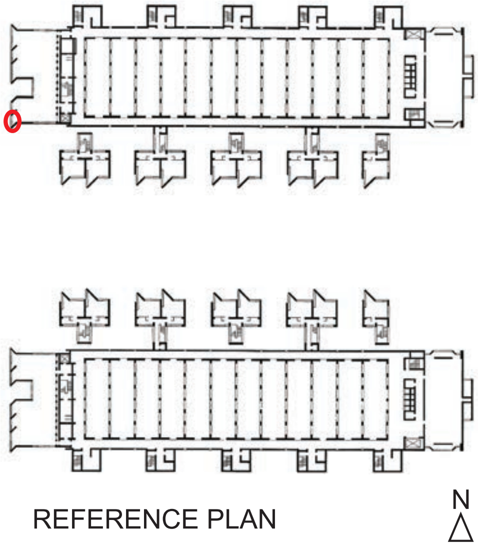
Additional Samples Collected by GCI Science, Los Angeles, December 20, 2013

Sample S.1.
coating

Salk Institute for Biological Studies, Teak Fesnestration Conservation Program
Wood Sample Log

Collected by GCI Field Projects and Anthony & Associates, Inc., March 12, 2013

North Office Building | NO6J | Sample T



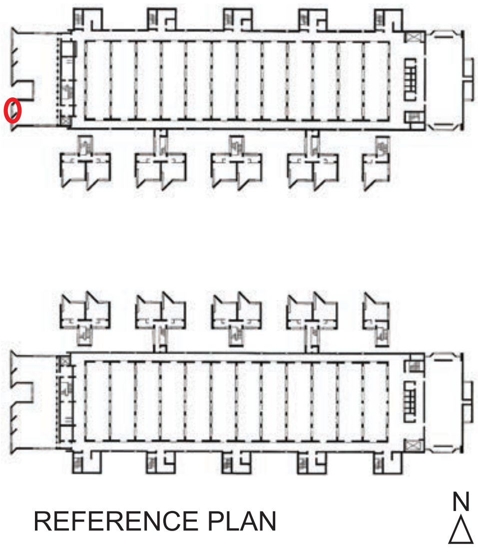
SAMPLE T

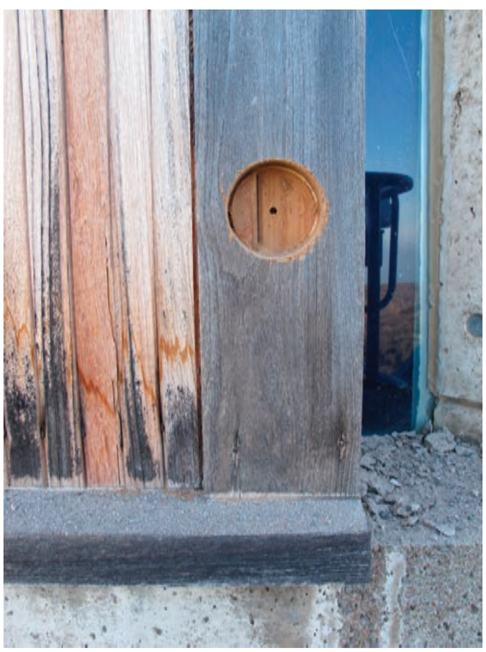
sill: core sample of top face of bottom sill, left-hand (north) side

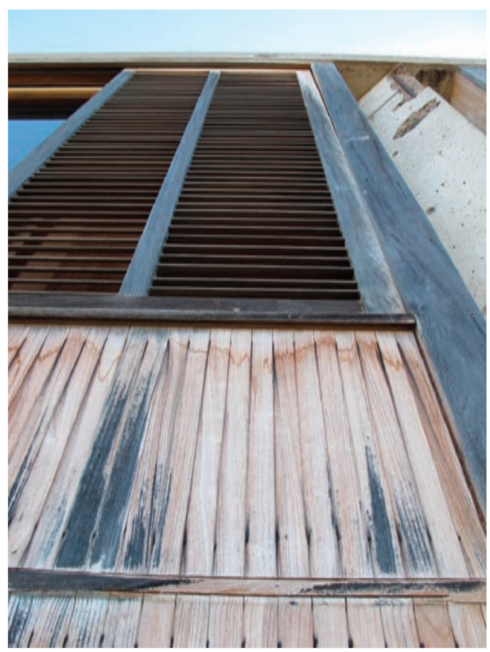
Salk Institute for Biological Studies, Teak Fesnestration Conservation Program
Wood Sample Log

Collected by GCI Field Projects and Anthony & Associates, Inc., March 12, 2013

North Office Building | NO6H | Sample U







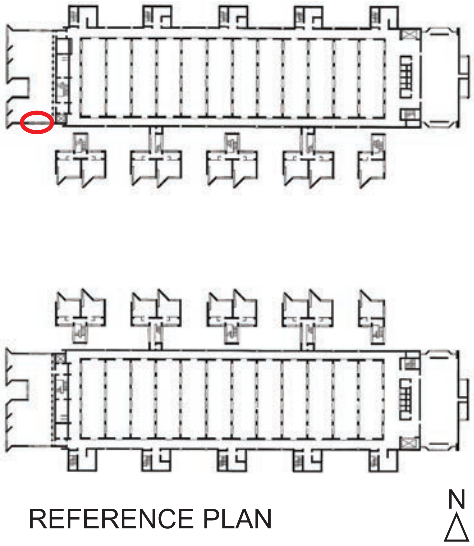
SAMPLE U

vertical trim board: core sample of vertical trim piece, far right-hand (south) side of opening, approximately 10” to 12” above the bottom sill

Salk Institute for Biological Studies, Teak Fesnestration Conservation Program
Wood Sample Log

Collected by GCI Field Projects and Anthony & Associates, Inc., March 12, 2013

North Office Building | NO6K | Sample V, W



SAMPLE V

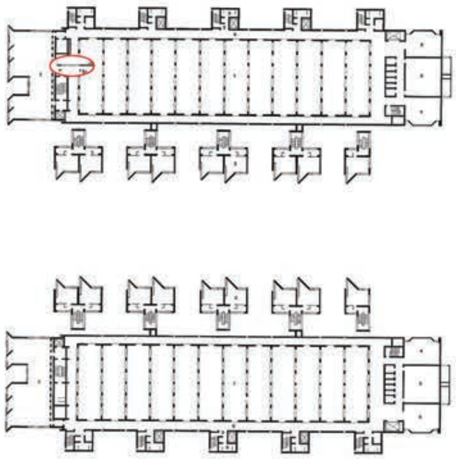
<u>tongue-and-groove slat:</u> center panel, slat row 2 (row of slats that fell out during Feb. 28 storm and salvaged by Salk)

SAMPLE W

<u>tongue-and-groove slat:</u> center panel, slat row 2 (row of slats that fell out during Feb. 28 storm and salvaged by Salk)

Salk Institute for Biological Studies, Teak Fenestration Conservation Program Wood Sample Log
Collected by GCI Science, December 4 and 5, 2013

North Office Building | NO2A & NO2B
Sample 1, 2, 3, 4, 5



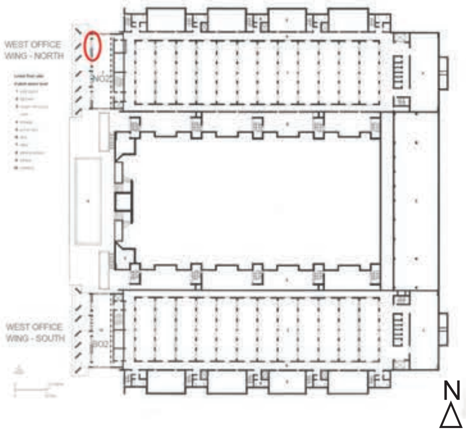
REFERENCE PLAN

N

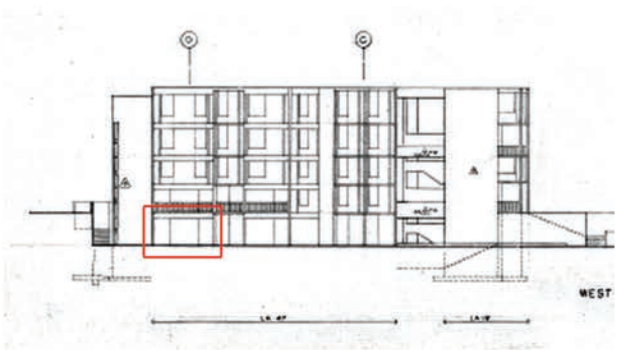
Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

Collected by GCI Science, December 4 and 5, 2013

North Office Building | NO2C & NO2D | Sample 6, 7, 13



REFERENCE PLAN



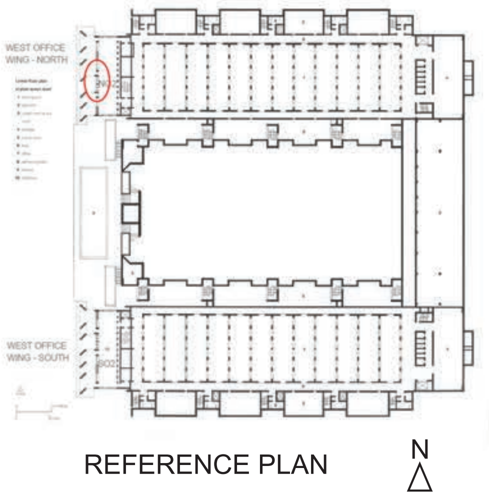
NO2C
samples #6 and #7 are taken from the panel behind the louvre

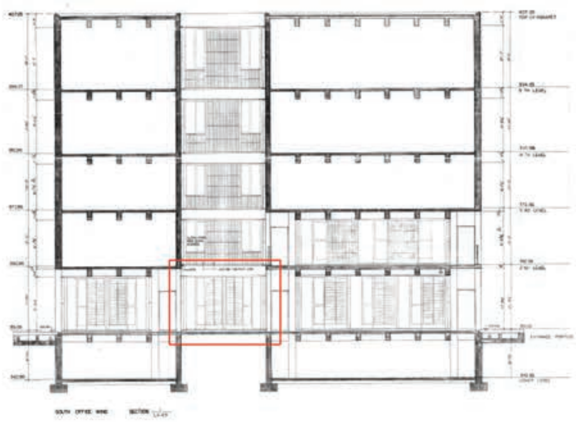
NO2D

Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

Collected by GCI Science, December 4 and 5, 2013

North Office Building | NO2F & NO2G | Sample 8



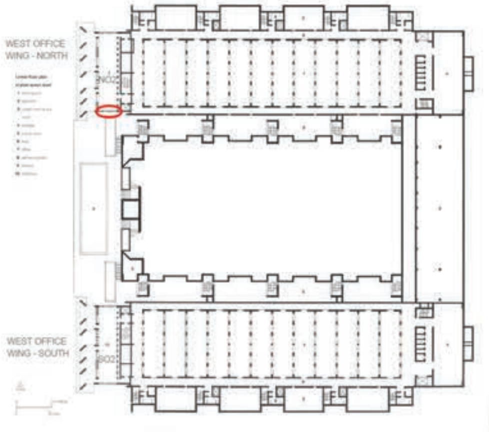


Sample #8:
black spore

Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

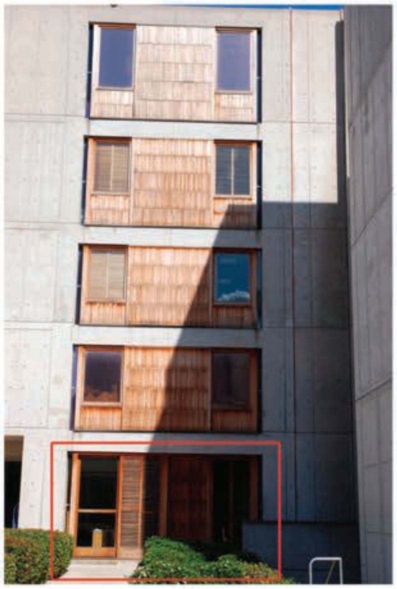
Collected by GCI Science, December 4 and 5, 2013

North Office Building | NO2K & NO2L | Sample 9, 10, 11, 12



REFERENCE PLAN

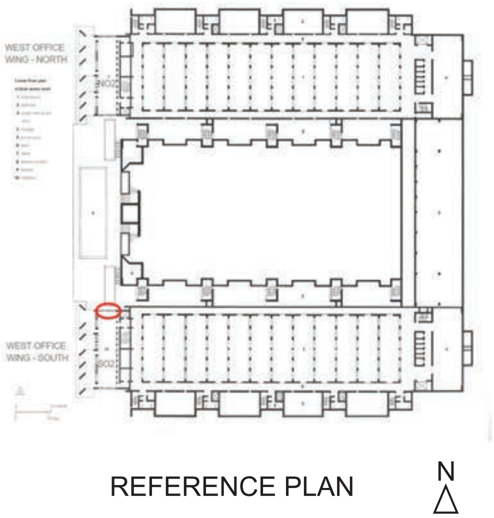
N



Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

Collected by GCI Science, December 4 and 5, 2013

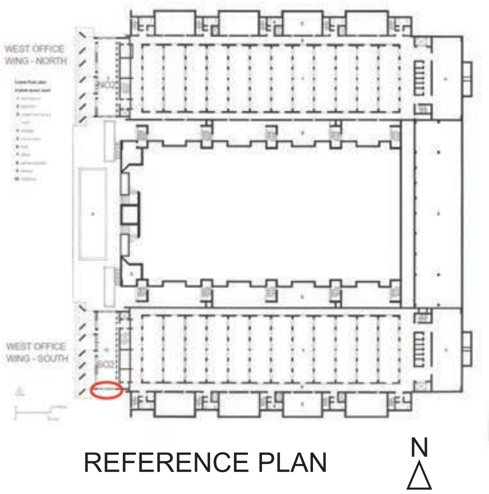
South Office Building | SO2B | Sample 14

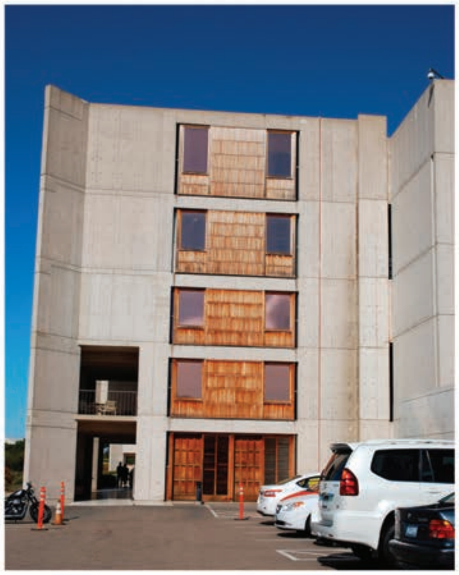


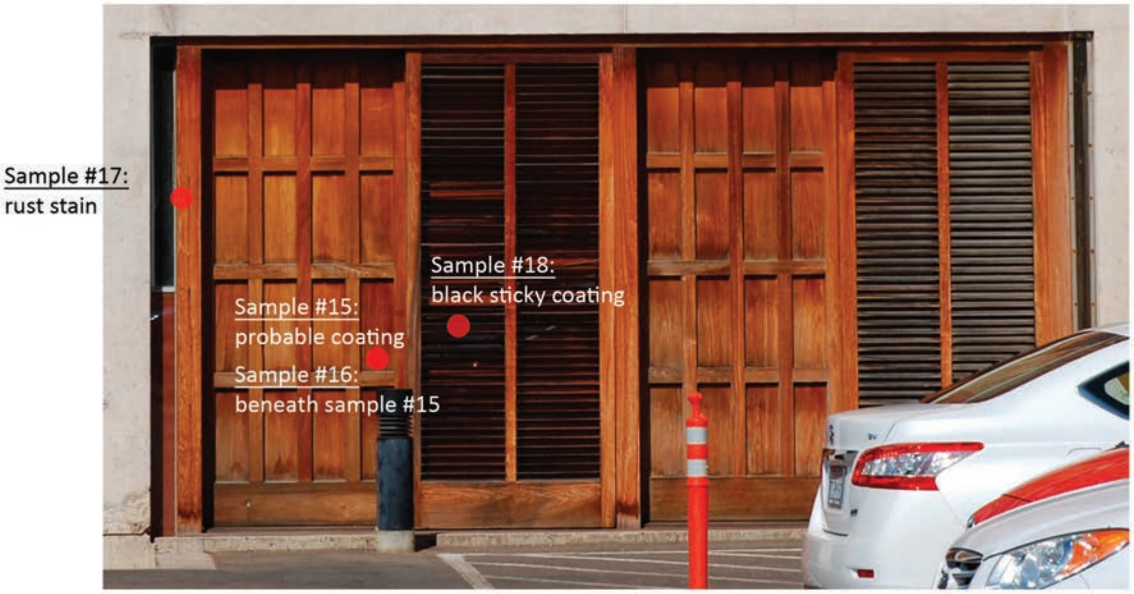
Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

Collected by GCI Science, December 4 and 5, 2013

North Office Building | SO2K | Sample 15, 16, 17, 18



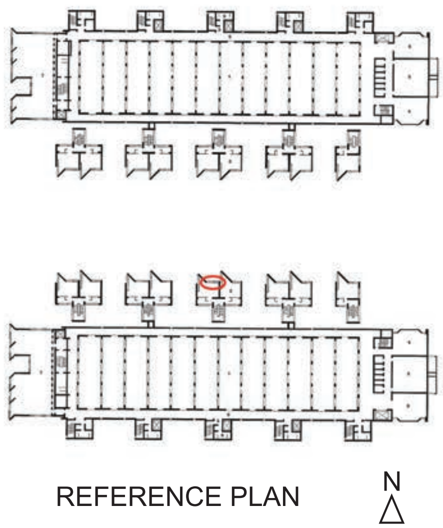




Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

Collected by GCI Science, December 4 and 5, 2013

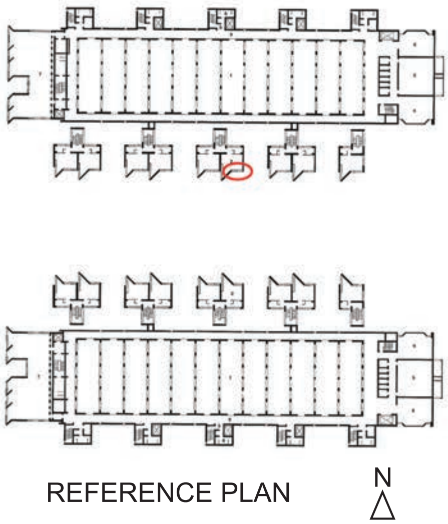
South Studies | SL5C or SL6C (confirm) | Sample 19, 20, 24, 25

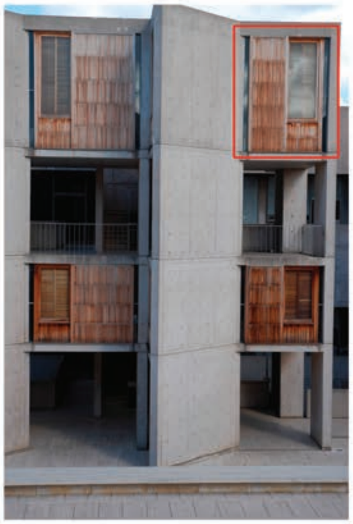


Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

Collected by GCI Science, December 4 and 5, 2013

South Studies | NU6C | Sample 21, 22, 23



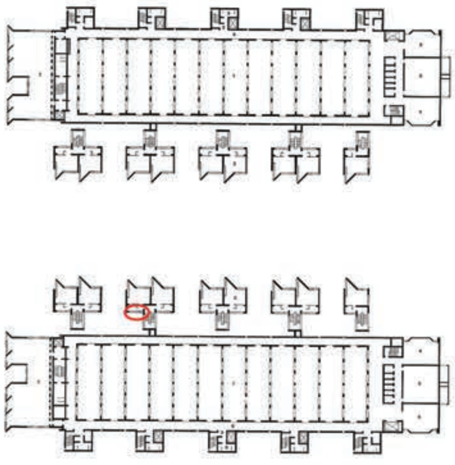


Sample #21:
Debris behind the slat
Sample #22:
Interior wood chip
Sample #23:
Glue on the slat

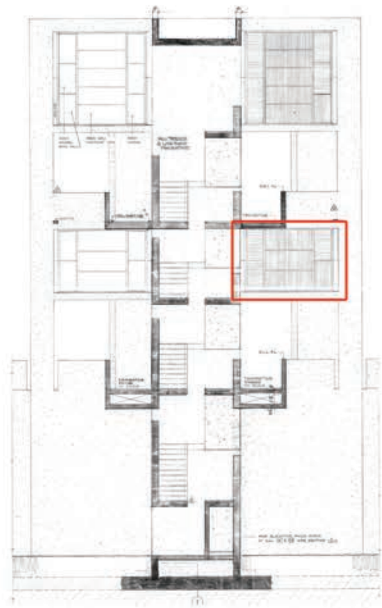
Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

Collected by GCI Science, December 4 and 5, 2013

South Studies | SL4A | Sample 26, 27, 28, 29



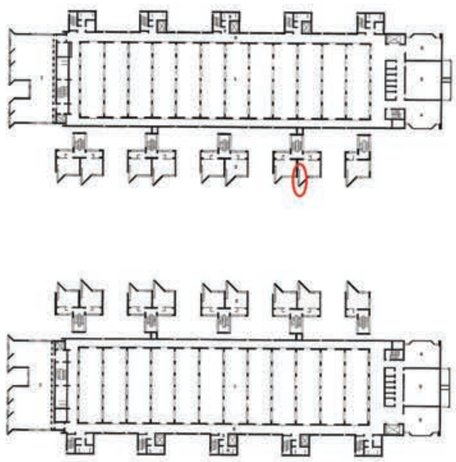
REFERENCE PLAN N



Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

Collected by GCI Science, December 4 and 5, 2013

South Studies | NL8B | Sample 30

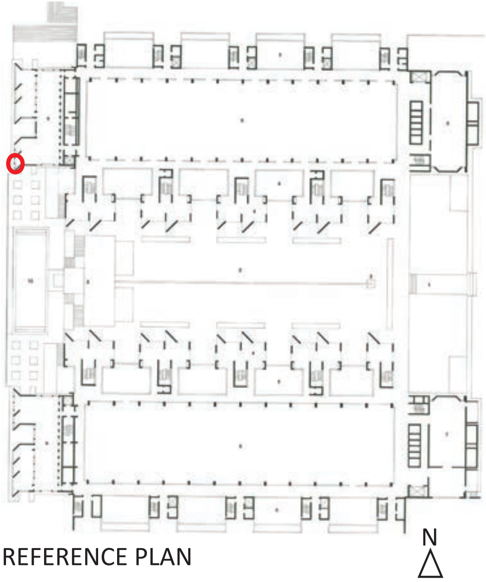


REFERENCE PLAN N

Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

Collected by GCI Science, February 19, 2014

North Office Building | NO3E | Sample 31, 32



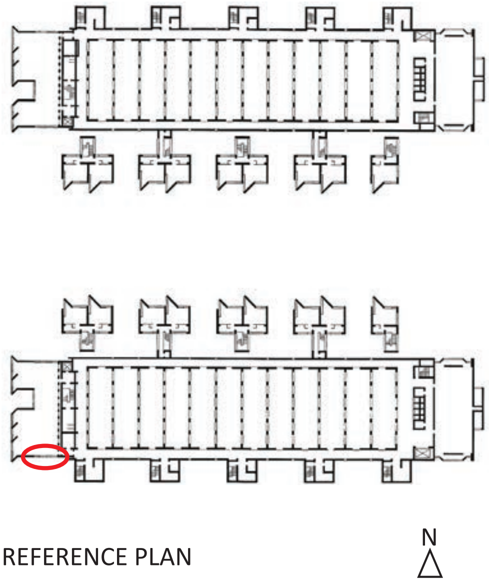
REFERENCE PLAN

Sample #31 & 32: 7th slat from north;
area with black fungal growth

Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

Collected by GCI Science, February 19, 2014

South Office Building | SO4K | Sample 33



REFERENCE PLAN

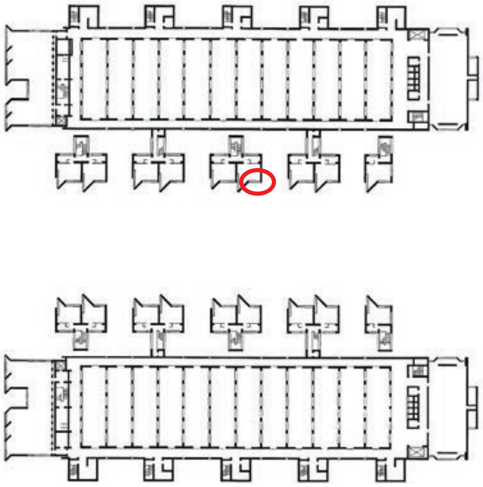
<u>Sample #33:</u>

2 samples from 3rd slat from east. To determine if treatment/coating stratigraphy at upper levels is different from that at lower levels.

Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

Collected by GCI Science, February 19, 2014

North Study Tower 7N | NL6C | Sample 34, 35



REFERENCE PLAN

N

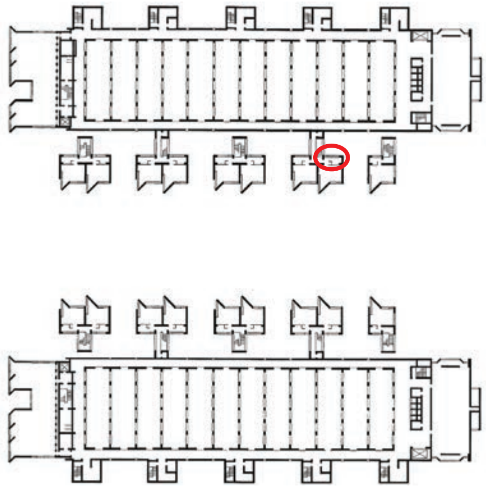
Sample #34:
top of 4th slat from east;
coating sample

Sample #35:
bottom of 4th slat from east;
to compare coating with Sample #34

Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

Collected by GCI Science, February 19, 2014

North Study Tower 10N | NL8A | Sample 36



REFERENCE PLAN

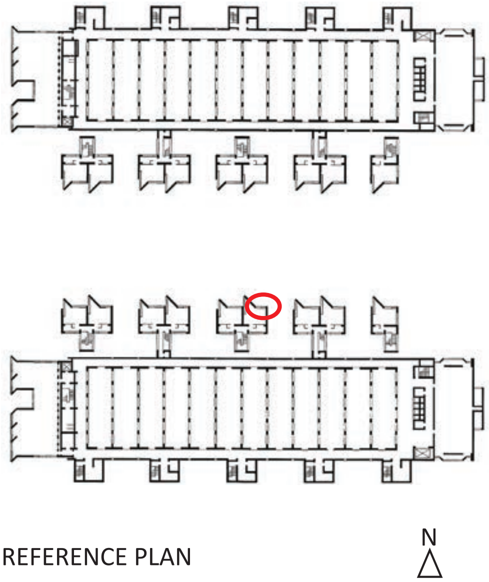
N

Sample #36:
taken from post; coating

Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

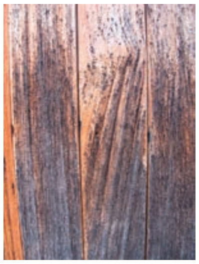
Collected by GCI Science, February 19, 2014

South Study Tower 7S | SL6C | Sample 37, 38, 39



REFERENCE PLAN

Sample #37:
taken from top of 9th slat from left



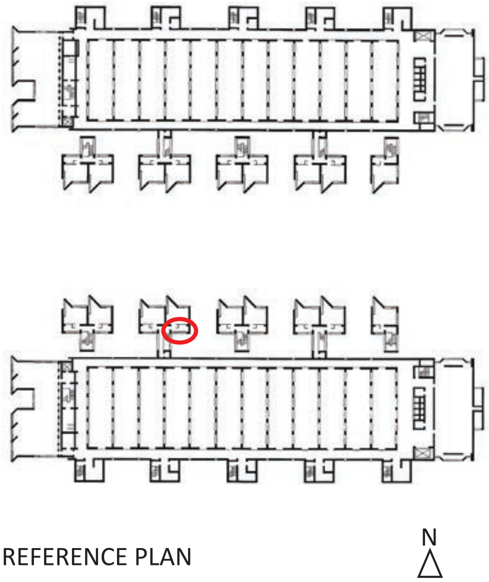
Sample #38:
taken from middle of 9th slat from left

Sample #39:
taken from bottom of 9th slat from left

Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

Collected by GCI Science, February 19, 2014

South Study Tower 4S | SL4A | Sample 40



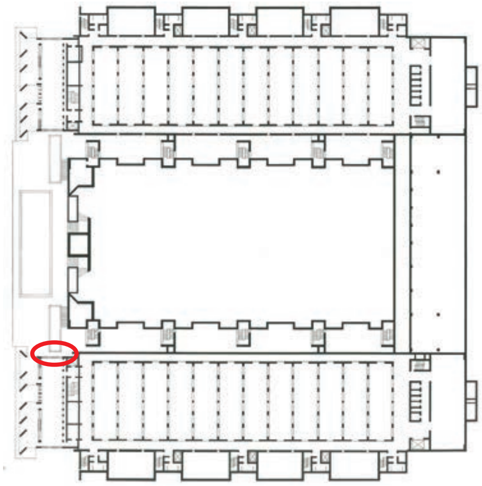
REFERENCE PLAN

Sample #40: taken from post by walkway;
sample included salt as well as coating

Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

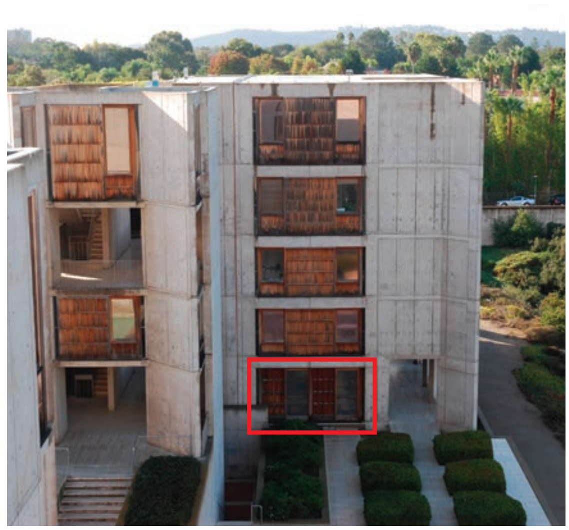
Collected by GCI Science, February 19, 2014

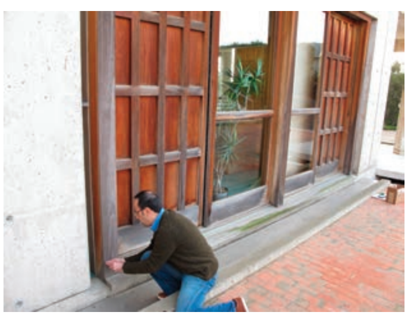
South Office Building | SO2A | Sample 41

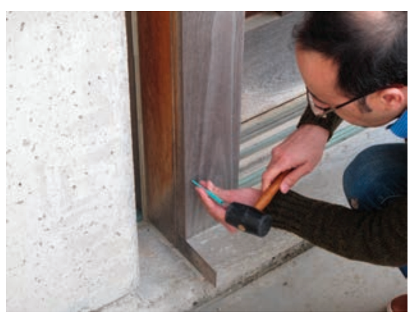


REFERENCE PLAN

N





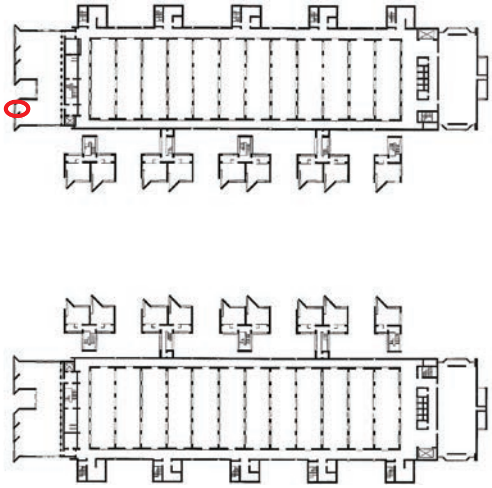


<u>Sample #41:</u>
resampling of original Sample #3, as it was lost in mounting/preparation process

Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

Collected by GCI Field Projects and GCI Science , March 11 and 12, 2014

North Office Building | NO6H | Sample 42, 43



REFERENCE PLAN

N

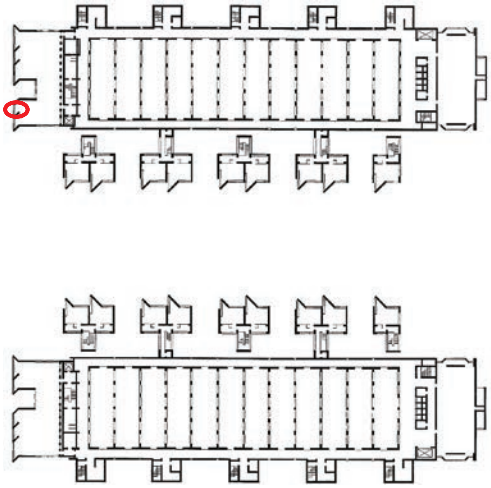
Sample #42:
vertical trim (face); black crust

Sample #43:
vertical trim (side/return);
white efflorescence

Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

Collected by GCI Field Projects and GCI Science , March 11 and 12, 2014

North Office Building | NO5H | Sample 44, 45



REFERENCE PLAN

N

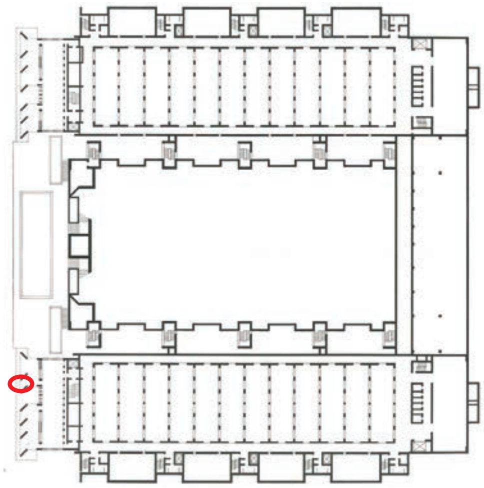
Sample #44:
vertical trim; black crust

Sample #45:
loose piece of rail (center of span) between slat rows 1 and 2

Salk Institute for Biological Studies, Teak Fenestration Conservation Program
Wood Sample Log

Collected by GCI Field Projects and GCI Science , March 11 and 12, 2014

South Office Building | SO5D | Sample 46, 47



REFERENCE PLAN

N

Sample #46:
slat; bottom of 4th slat from left (north), slat row 1

Sample# 47:
slat; bottom of 5th slat from left (north), slat row 1

APPENDIX G

GCI Organic Materials Laboratory Analysis Report I

PREPARED BY JOY MAZUREK

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Analysis Report

Organic Analysis Laboratory

Date: April 7, 2014

Site: Salk Institute for Biological Studies, designed by Louis Kahn, 1962

Address: 10010 N. Torrey Pines Rd., La Jolla, CA 92037

Project: Salk Institute for Biological Studies

Prepared for: Kyle Normandin and Sara Lardinois

Prepared by: Joy Mazurek, Assistant Scientist

Salk Institute Wood: Scientific Investigation and Analytical Results

1.0 Introduction

This report summarizes the scientific investigation, conducted by Joy Mazurek of the Science Department of the Getty Conservation Institute (GCI), of wood samples taken during a December 2013 sampling campaign at the Salk Institute for Biological Studies. Approximately thirty samples were selected in order to answer three main questions: (1) What is the black sooty deposit found on wood all over the site in variable environmental conditions? (2) What are the materials that were used previously to treat the wood? and (3) What are the other surface deposits that are different or stand out from the surrounding wood?

2.0 Black Surface Deposits on the Wood

We observed several different types of black material on the wood at the Salk Institute. The simplest to identify by eye are the black deposits shown in figure 1 (Salk, undocumented location). These are iron and tannin reactions that occur when iron comes into contact with wood. The deposits are easily distinguished by the long trail of black below the nails. Other black deposits were found in some areas that were primarily composed of dust and dirt.

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Analysis Report
Organic Analysis Laboratory
CMAI – Salk Institute Teak Conservation Project

Figure 1

The photo below was taken outside windows NO4E and NO4F in Francis Crick's former office in the northern west office wing (fig. 2). It is representative of the ubiquitous black color found on the wood throughout the Salk Institute. It is a sooty material deposited on the surface or in the deep longitudinal grooves of the wood.

Figure 2

Figure 3 shows a microscopic image (100x oil immersion) of the sooty black material. It was positively identified as a microorganism (probably yeast) that was actively budding, dividing, and growing. It is highly pigmented with melanin, cells are between 5 and 10 micrometers in diameter, and groups of clusters or chains are clearly visible.

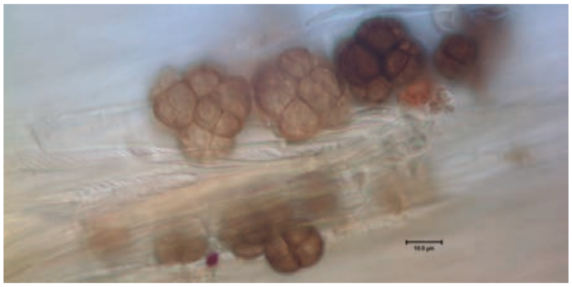

Figure 3

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Science Department

A cross section of wood with the black sooty microorganism on its surface is shown below (100x oil immersion). The microorganisms are the dark-brown specks or brown rice grains (see arrow, fig. 4). The growth of microorganisms on the surface of an object or substrate is defined as a biofilm and is often encapsulated in an extracellular matrix, most often a polysaccharide (long chain of sugars), in order to adhere to the substrate. The biofilm on the Salk wood is seen in figure 4 as brown clusters and penetrates to about 1000 µm or less.

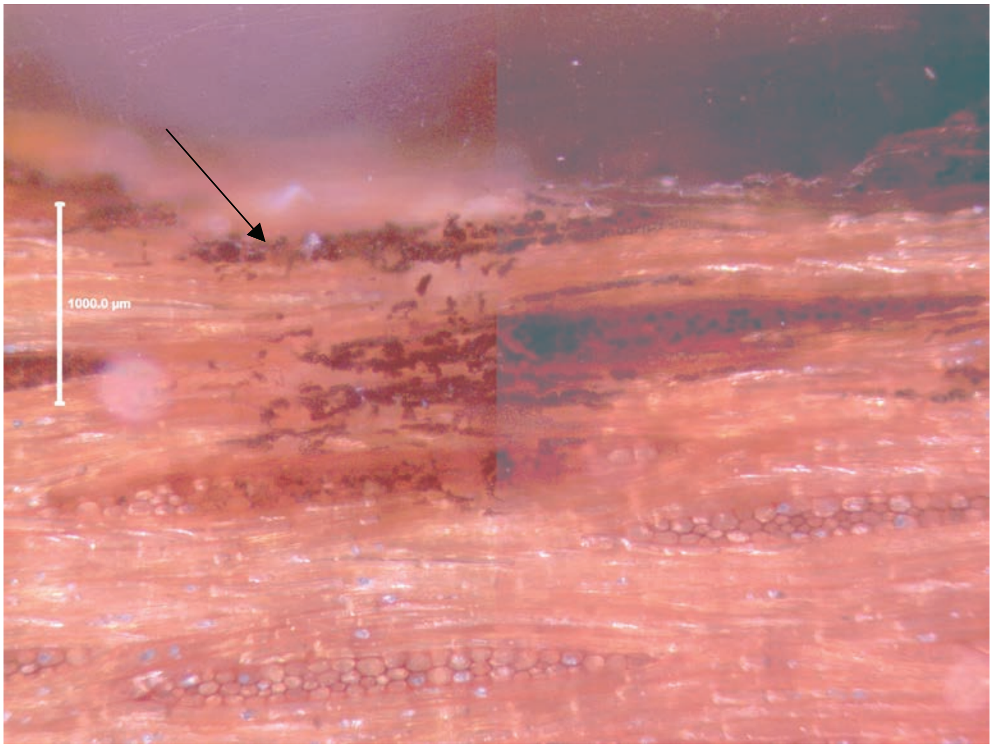


Figure 4

A sample of the black biofilm (sample #8, windows NO2F and NO2G[1]) was collected and placed in sterile water. Fungal hyphae grew in two days, strongly indicating that the fungus is actively growing (fig. 5). The hyphae were stained with lactophen cotton blue (see arrows).

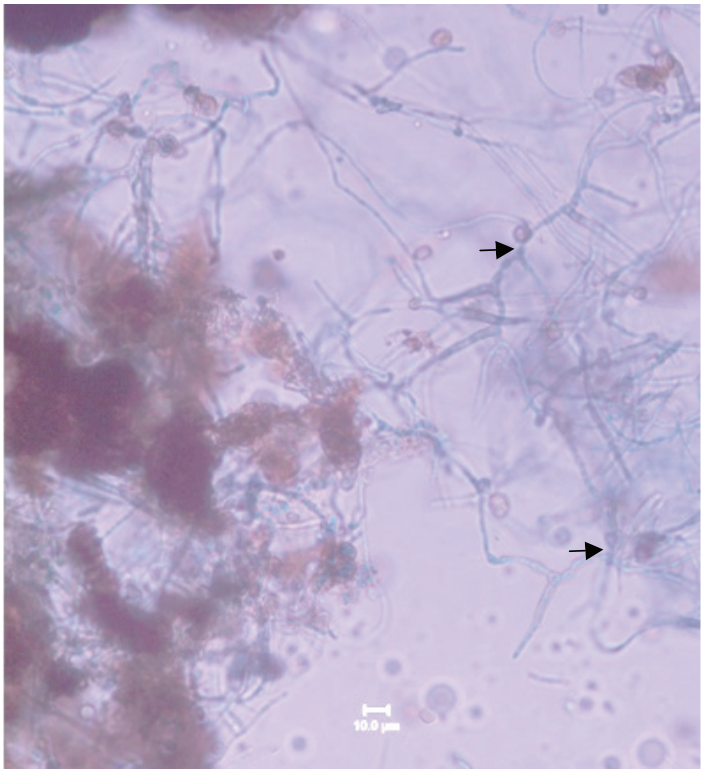


Figure 5

2.1 Identification of Fungal Biofilm Using DNA Analysis

Four samples of the biofilm were sent to Microbial Insights, University of Knoxville, Tennessee, for fungal DNA analysis. The first two samples were collected by scraping the black material directly off the wood on-site (#8 NO2F and NO2G and #24 SL5C); the third sample contained the combined wood and scrapings with black material from two different Salk window wall locations (#J SL8B, #H SL8B, and #S NO3E); and the fourth sample was black material scraped off eucalyptus leaves on-site. These

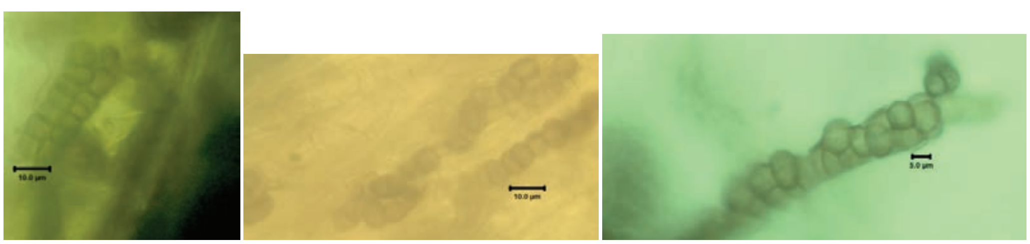
[1] A log of all samples collected, including drawings and photographs indicating the exact sample collection location, is provided in the related appendix F of the main project report, *Salk Institute for Biological Studies Conservation Project: Teak Fenestration and Wall System, Phase 1: Research and Investigative Results and Preliminary Conservation Proposals*.

samples were selected specifically to detect the community of organisms that may be present in decaying wood and leaf matter in the environment. A summary of the results is shown in table 1.

Table 1. Summary of DNA analysis results.

Sample(s)	**DNA Results**
#8 black biofilm (windows NO2F and NO2G)	*Phaeothecoidea* spp. (order Capnodiales)
#24 black biofilm (window SL5C)	*Toxicocladosporium* spp. (order Capnodiales)
#J, #H, and #S, wood and biofilm (windows SL8B and NO3E)	Order Capnodiales: could not identify to species level
Eucalyptus leaves, black biofilm	Order Dothideales and phylum Ascomycota: could not identify to species level

DNA analysis showed that the dominant organism in the biofilm from sample #8 (windows NO2F and NO2G) is *Phaeothecoidea* spp.; it is a fungus commonly found on dead and decaying fauna and is the causal agent for leaf spot disease in eucalyptus and other trees. *Phaeothecoidea* spp growing on leaf matter is similar in appearance to the black material on the Salk wood because it is also encased in a black shiny exudate. The biofilm from sample #24 matched *Toxicocladosporium* spp.; these type of fungi are able to degrade cellulose and are visually similar to *Phaeothecoidea* spp. (black shiny exudate growing on leaf matter). As samples #J, #H, and #S are microscopically similar to each other, they were analyzed as a mixture. DNA analysis showed they belong to the order Capnodiales (fig. 6). Most importantly, DNA analysis of the fungi from Salk wood showed all to be within Capnodiales, an order that is also known as “sooty mold fungi” and is responsible for important crop and tree diseases.



Sample #J Sample #H Sample #S

Figure 6

Lastly, black material found on the eucalyptus leaves from trees found on the Salk property were also sent for DNA analysis. The black sooty mold samples were scraped from leaves that had black raised areas. The microorganism is similar under the microscope to the black deposits on the Salk wood (fig. 7). The DNA analysis identified two matching markers, order Dothideales and phylum Ascomycota. Dothideales contains fungi that are plant pathogens and Ascomycota is the larger group of fungi that includes Dothideales and Capnodiales. Even though DNA analysis did not identify the fungi to species level, phylum Ascomycota is probable because it contains many fungal plant pathogens.

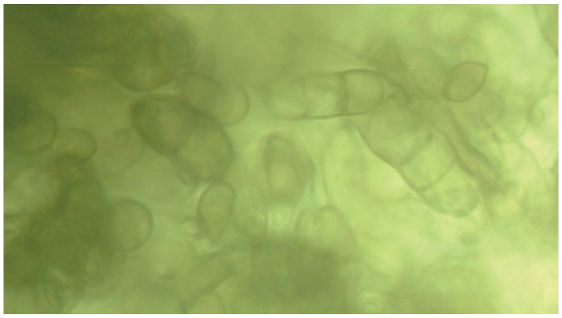


Figure 7. Eucalyptus leaf fungus growing on-site.

In the past, scientists attempted to identify the black sooty organisms growing on the wood at the Salk Institute. Reliable identification of these diverse fungi that grow on leaves, fruit, and wood has eluded scientists in the past because the fungi are a challenge to isolate and grow in pure cultures and they have a lack of spores (fruiting bodies). A letter from Forest Products Lab, dated April 9, 1968, states that lab staff had examined a sample of black sooty material growing on the Salk wood, and they found "the presence of a heavy accumulation of dark-brown, Schlerophoma-like hyphae," or, in other words, septate mycelium (similar to the divided cells shown in fig. 7). Forest Products Lab's visual observations corroborate the GCI's microscopic analysis.

Fungi that divide with septate mycelium and grow on plant material exhibit similar phenotypes or visual characteristics, so that only with the advent of DNA sequencing can the huge variety of species within the orders Capnodiales and Dothideales (and many others) become known. The biofilm on the wood at the Salk Institute can best be described as several different types of fungi that have evolved from a common ancestor, predominately from Capnodiales, and can utilize cellulose or wood extractives from a carbon source.

2.2 Food Source for the Fungal Biofilm

Based on the identification of the order Capnodiales by DNA, the likely food source for the biofilm is cellulose and hemicellulose; these are polysaccharides, or long chains of sugars. Fungal biofilm also exudes different types of polysaccharides in order to adhere to substrates, and it selectively breaks down cellulose into free sugars with the enzyme cellulase. Sugar alcohols are used as storage carbohydrates and/or intermediates in sugar metabolism.

Gas chromatography–mass spectrometry (GC/MS) was used to analyze for free sugars and sugar alcohols in three samples of wood with and without biofilm (#H, #J, and #O), and in samples of black fungi scraped off eucalyptus leaves from the Salk site. Results are summarized in table 2.

Table 2. Summary of GC/MS analysis results for sugars and alcohols.

Sample	% Free Sugars	Xylitol and Glucitol
#H wood with biofilm	0.1	Yes
#H wood	ND	ND
#J wood with biofilm	1.0	Yes
#J wood	ND	ND
#O wood with biofilm	.05	Yes
#O wood	ND	ND
Fungi on eucalyptus	0.27	Yes

In all cases, the wood with the biofilm contained free sugars and alcohols, and the plain wood did not (ND<0.1%). The biofilm contained comparably larger amounts of free sugar alcohols, tentatively identified as xylitol and glucitol. These results support the hypothesis that sugar metabolism is occurring by the degradation of cellulose, as sugar alcohols are described as intermediates in sugar metabolism.

2.3 Lignin Degradation

Cellulose in wood is protected by lignin, and fungi cannot utilize the cellulose until the lignin is broken down. It takes highly specialized fungi to metabolize lignin, and these were not identified by DNA or microscopic techniques. Lignin on the surface of wood can be bleached and degraded by UV and/or variable environmental conditions (fluctuating humidity, salt, wind, and bleach), making the cellulose available to the fungi at the surface of the wood. This is consistent with the depth of penetration of the fungi in microscopic imaging, showing the biofilm is located in the top 1 mm of the wood. The black pigment in the biofilm is melanin, and it provides protection for the fungi by absorbing UV. It is possible that melanin inhibits the degradation of lignin beneath it, thus preserving the wood.

3.0 Extractives, Coatings, and Deposits

Extractives in the wood were removed by heating the sample with chloroform at 60°C for one hour, and analyzed by GC/MS. Drying oils were detected by treating the sample with Meth Prep II reagent in toluene (1:2).

3.1 Tip Top Teak Wood-Oil Sealer

Two GC/MS chromatograms are shown in figure 8. The chromatogram on bottom is from a wood treatment material called Tip Top Teak Wood-Oil Sealer that was found on-site at the Salk Institute and analyzed as a reference material. The chromatogram on top is from sample #15 SO2K coating. Tip Top Teak was identified in several samples due to this wide set of peaks; it displays a variety of high-molecular-weight hydrocarbons (perhaps a hydrocarbon-based wax) and fatty acids from a drying oil (results not shown). Figure 9 summarizes all of the samples tested using GC/MS that match Tip Top Teak.

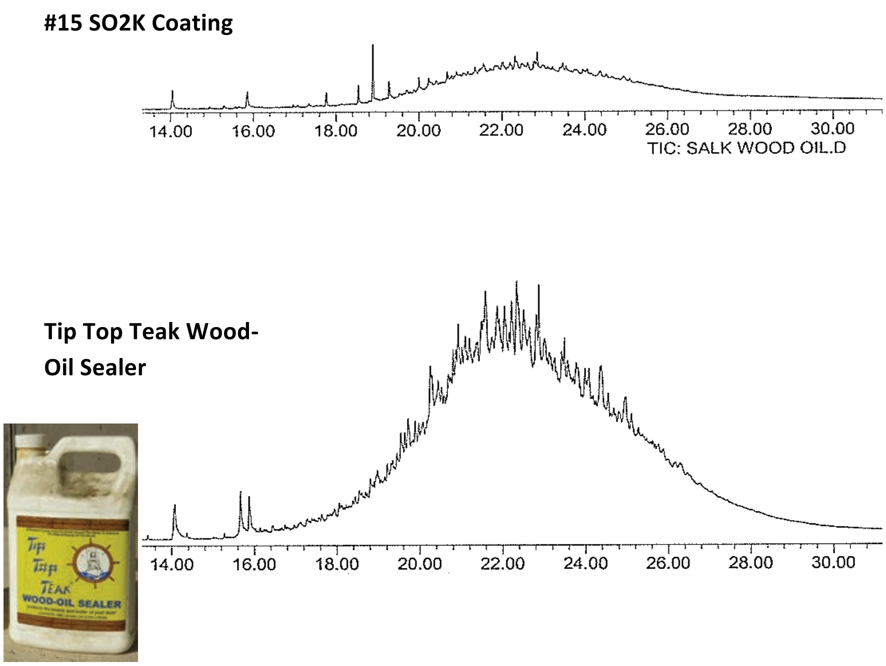


Figure 8

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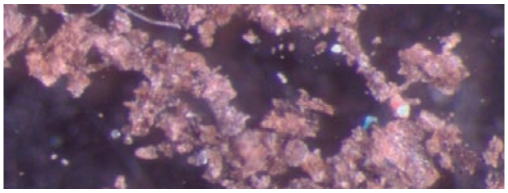
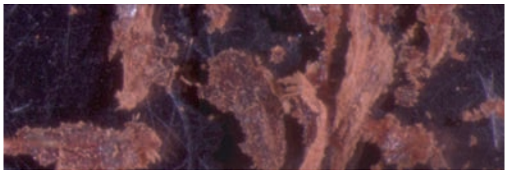
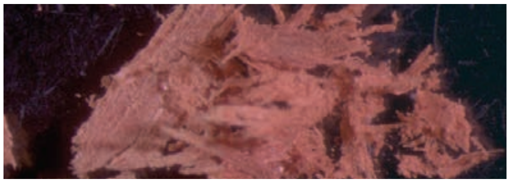
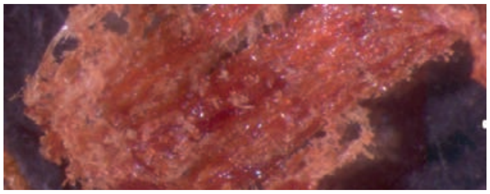
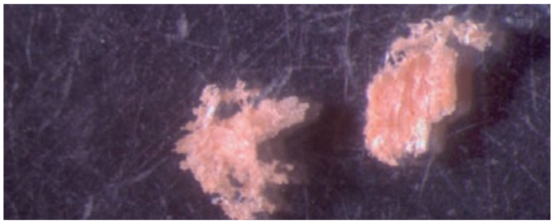
Tip Top Teak Wood-Oil Sealer Sample and Description	Image of Sample
#4 NO2A red stain/varnish and (right) #5 NO2A black biofilm on vertical framing	
#15 SO2K coating	
#16 SO2K beneath sample #15	
#28 SL4A slat red coating	
#Q1 NL8A slat red coating and (right) #Q2 NL8A slat seemingly non-coated	

Figure 9

3.2 Acrylic Polymers

Acrylic polymers were also identified in several samples by pyrolysis GC/MS, based on the presence of ethyl acrylate, methyl methacrylate, ethyl methacrylate, and butyl methacrylate (fig. 10). This indicates a modern formulation, as it is a complex mixture of acrylic monomers. Diisooctyl phthalate was present in the GC/MS chloroform extracts as well as phenol, pentachloro- (an herbicide, fungicide, and insecticide), and oxybenzone (a UV inhibitor).

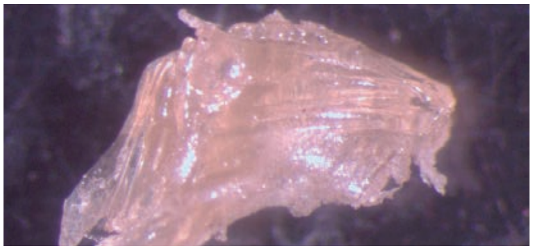
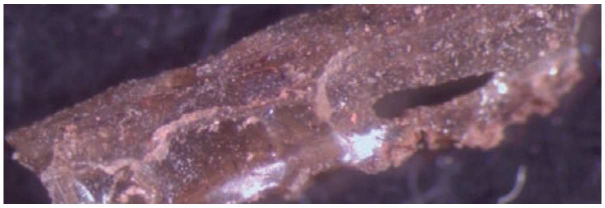
Acrylic Polymer	Image of Sample
#6 NO2C panel red stain lacquer	
#9 NO2K panel (right) and #10 NO2K panel	

Figure 10

3.3 Urea Formaldehyde

Urea formaldehyde was identified as the glue used to hold the wood panels together; #23 NU6C, #C2 NL6C, #L1 SO5K, and #M2 SO5K all tested positive for urea formaldehyde.

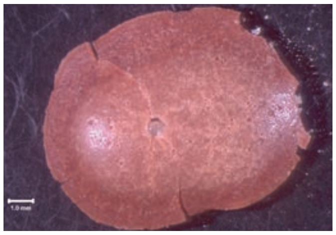


Figure 11. Sample #23 NU6C, one of four samples that tested positive for urea formaldehyde.

3.4 Drying Oils

Lipids such as drying oils and animal fats are identified on the basis of fatty acid composition. Palmitic (P), stearic (S), and azelaic (A) acids are used to identify different types of drying oils; for example, the P/S ratio for walnut is around 3; for poppy, around 5; and for linseed, around 1.5. A/P ratios around 1 or higher also indicate the presence of a drying oil. Ratios of suberic (Sub) relative to azelaic (A) (0.3 and above) indicate the presence of a heat-bodied oil. Table 3 shows a summary of the results from GC/MS analysis of oils. Most of the oils have a P/S value close to that of linseed, but with outdoor treatments the oils are difficult to identify and the data must be interpreted with caution as mixtures of oils may have been used. Some of the samples were previously identified by GC/MS to contain Tip Top Teak.

Table 3. Summary of GC/MS analysis results for oils.

Sample	P/S	A/P	Sub/A	Comments
#J1 SL8B	1.1	2.5	0.6	Heat-bodied oil
#K1 SO2K	1.3	4.9	0.4	Heat-bodied oil
#L1 SO5K	1.2	1.9	0.3	Heat-bodied oil, urea formaldehyde
#M1 SO5K	1.9	1.7	0.4	Heat-bodied oil
#Q1 NL8A	0.6	4.0	0.4	Heat-bodied oil, Tip Top Teak
#Q2 NL8A	1.0	2.6	0.5	Heat-bodied oil, Tip Top Teak
#5 NO2A	1.7	3.9	0.5	Heat-bodied oil, Tip Top Teak
#7 NO2C	1.2	4.1	0.5	Heat-bodied oil
#11 NO2K	1.3	5.9	0.4	Heat-bodied oil
#13 NO2D	1.7	1.5	0.5	Heat-bodied oil
#15 SO2K	1.5	3.6	0.5	Heat-bodied oil, Tip Top Teak
#16 SO2K	1.6	4.1	0.4	Heat-bodied oil, Tip Top Teak
#19 SL5C	1.5	1.5	0.6	Heat-bodied oil
#21 NU6C	1.7	1.3	0.4	Heat-bodied oil
#28 SL4A	0.9	4.0	0.5	Heat-bodied oil, Tip Top Teak

3.5 Other Materials

Deposits such as calcite stalagmites were found in sample #26 SL4A, and sample #29 SL4A contains a blue copper corrosion product identified as copper chloride. Sample #18 SO2K contains a sticky (and fishy-smelling) black coating that is not a drying oil but rather a fatty acid, probably animal or vegetable lipids.

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4.0 Metallic Composition of the Nails

Nails from the Salk Institute were analyzed by Lynn Lee (assistant scientist, GCI) for metals using X-ray fluorescence (XRF) to determine if the galvanized coating (Zn) was still present. An ARTAX XRF spectrometer was employed, and the 65 µm spot size was on scale to the nail-exposed interior area size. Zinc was identified as a major element in the nails, indicating they are galvanized. A summary of the results is shown in table 4.

Table 4. Summary of XRF analysis results for metals.

Sample	Elements*
Sample O nail head interior	**Fe**, **Zn**, Mn, Cu, Pb, *Cr*
Sample O nail body interior	**Fe**, **Zn**, Mn, Cr, Cu, *Pb*
Sample O nail tip interior	**Fe**, **Zn**, Mn, Cr, Cu, *Pb*
Sample O nail surface I	**Fe**, **Zn**, Mn, Cr, Cu, *Pb*
Sample O nail surface II	**Fe**, **Zn**, Mn, Cr, Cu, *Pb?*
Sample J nail surface	**Fe**, **Zn**, Mn, Cr, Cu, *Pb*
Sample P nail surface	**Fe**, **Zn**, Mn, Cr, Cu, *Pb*
Sample S nail surface	**Fe**, Mn, Cr, Cu, *Zn*, *Pb*

*Boldface indicates major elements, lightface indicates minor elements, and italics indicate trace amounts. Relative amounts are estimated based on peak intensity and are intended only as a guide. Relative amounts are not quantitative. Samples analyzed by Lynn Lee, assistant scientist, GCI. ARTAX XRF spectrometer (Bruker AXS) employed for all work presented here. The Rh-target tube was fitted with a polycapillary lens, providing a nominal spot diameter of 65 µm. An accelerating voltage of 400 kV and a current of 400 µA were used with an acquisition time of 60 seconds in ambient conditions

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Analysis Report

Organic Analysis Laboratory

5.0 Conclusions

Tip Top Teak Wood-Oil Sealer was found on several samples due to the presence of drying oils and/or a high-molecular-weight hydrocarbon material. The glue used to attach the wood was identified as urea formaldehyde, and an acrylic polymer was found in several locations that contained a fungicide/insecticide and antioxidant. The nails from the Salk wood appear to be galvanized, as zinc was identified by XRF.

The ubiquitous black sooty biofilm on the Salk wood is composed of fungi from order Capnodiales and penetrates the wood to a depth of about 1 mm. These fungi can degrade cellulose but cannot degrade lignin; thus they are not degrading the structural support of the wood. Most importantly, DNA analysis did not identify the type of fungus that can degrade lignin. The black sooty mold found on the Salk wood likely originates from the nearby leaves of the eucalyptus trees, spreading by wind or water droplets.

In the future, when selecting treatment materials for the wood, any possible food sources for the fungi should be eliminated. Because fungi are adapted to live on a variety of substances, many different types of materials can serve as possible food sources, such as the drying oils found in Tip Top Teak. Eliminating or reducing water infiltration is a mandatory part of the solution, as fungi thrive with water. The biofilm is likely deriving energy from the sugars of cellulose and hemicelluloses, but it can do this only after lignin is degraded by harsh environmental conditions. It is excellent news for the health of the Salk wood that specialized lignin-degrading fungi were absent in the samples sent for DNA analysis and were not observed microscopically.

APPENDIX H

GCI Organic Materials Laboratory Analysis Report II

PREPARED BY HERANT KHANJIAN

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Analysis Report

Organic Materials Laboratory

Date: May 6, 2014

Site: Salk Institute for Biological Studies

Address: 10010 N. Torrey Pines Rd., La Jolla, CA

Project: Salk Institute Conservation Project: Teak Window Wall Assemblies

Prepared for: Conserving Modern Architecture Initiative

Prepared by: Herant Khanjian, Assistant Scientist

Summary

A group of samples removed from the teak wood fenestrations at the Salk Institute for Biological Studies were investigated to determine their composition and further the understanding of prevailing surface conditions. The samples were photographed with a visible and ultraviolet light microscope and analyzed using Fourier-transform infrared spectroscopy (FTIR) to help establish the factors that may contribute to their appearance. Both visual and chemical information revealed the omnipresent black fungal layer and various other deposits to be mainly concentrated on the surface. The identified surface coatings included urea-formaldehyde adhesive as well as layers containing acrylic resin, drying oils, and long-chain aliphatic hydrocarbons. Other efflorescent deposits, such as carbonate minerals, were found in samples collected from areas located in elevations facing the campus laboratories.

1.0 Introduction

The study of the teak wood window fenestrations at the Salk Institute was initiated to determine the surface makeup prior to preparation of a treatment strategy and formulation of a long-term conservation plan. A group of representative surface and core samples were collected during three visits, from December 5, 2013, through March 11, 2014. The samples were first examined under a light microscope, then photographed with visible and ultraviolet (UV) light. The photodocumentation procedure was used to help guide the selection of core samples for subsequent analysis using FTIR. The core samples ranged approximately 1.5 to 3 mm in depth and 1.5 mm in diameter. A point-by-point linear attenuated total reflectance (ATR) mapping was performed on the core samples using a Bruker Hyperion 3000 FTIR microscope.

2.0 Range of Conditions

A wide range of surface conditions was observed on the exterior of teak wood depending on orientation and window elevations.

2.1 Black and Gray Deposits

The ubiquitous black accumulations found on the teak wood surface ranged in color from light gray to very thick black sooty deposit (fig. 1). The buildup was more evident on the north- and west-facing elevations. The light-gray patinas were mainly observed on the lower parts of the vertical slats in contact with the windowsills and various horizontal dividing pieces. The deposits were likely the result of capillary movement of water containing dissolved salts and various organic matter.

Figure 1

2.2 Red and White Deposits

Other areas showed a wide spectrum of surface deposits ranging from white powdery layers on vertical slats and trims to red coatings resulting from previous treatment applications. Figure 2 illustrates the reddish coatings seen frequently on the upper and more protected areas of the windows. Figures 3 and 4 show the gray patina that usually forms on the lower part of the slats due to the aforementioned capillary migration of water-soluble salts and other components that may promote the growth of the fungal biofilms. White and black deposits were also observed on vertical window trims.

Figure 2

Figures 3 and 4

3.0 Characterization of Surface and Core Samples

A group of representative surface and core samples were removed from slats and window-frame trims showing a variety of surface coating appearance. Dermal biopsy punches from Miltex, Inc. (1.5 mm diameter), were used to extract core samples from the wood. The punches were gently tapped into the wood using a rubber mallet, then removed and stored in their original packaging. Later, the punches were cut open in the laboratory with a circular hobby saw and the cores pushed out with a rigid hand-held needle.

3.1 Single Slat Variations

To assess surface variations along a single slat, sampling was carried out on three areas where visual differences were apparent (top, middle, and bottom). Figure 5 illustrates the core sampling step on the black middle part of the slat. Figures 6–8 show close-up images of the holes left on the wood surface in the three areas after sampling.

Figure 5

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Analysis Report
Organic Materials Laboratory
Salk Institute Conservation Project

Figure 6 (top)

Figure 7 (middle)

Figure 8 (bottom)

Close inspection of the sampled slat shows the top part to be in good condition and containing the previously applied treatment wood sealer. In contrast, the middle area reveals a significant change in the wood surface through loss of coloration and appearance of the black fungal deposit. The lower part shows a more uniform gray layer, likely containing higher concentration of salts as well as a similar fungal layer as observed in the middle area. The visual contrast of the three areas illustrates the widespread surface variation and evolutionary process afflicting the teak wood.

Figures in the sections that follow show visible and UV light photomicrographs of top and cross sectional views of the core samples. All photographs highlight the superficial presence of the black fungal layer and various other deposits.

3.1.1 Top red part

Figures 9 and 10 show core samples removed from the top part of the single slat discussed in section 3.1. Both visible and UV illuminated images show the top deposits concentrated on the surface. FTIR analysis of the surface composition indicated the presence of oil, acrylic, and oxalate material. The presence of the first two components was likely the result of previous surface applications, while the occurrence of oxalate is a likely the result of biological and environmental interactions.

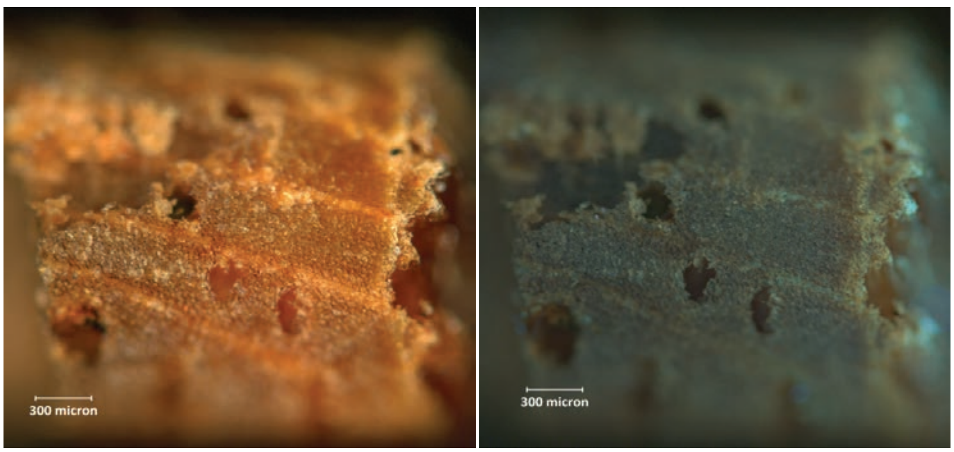

Figure 9. Sample 37 from SL6C, cross sectional view under visible (left) and UV illumination.

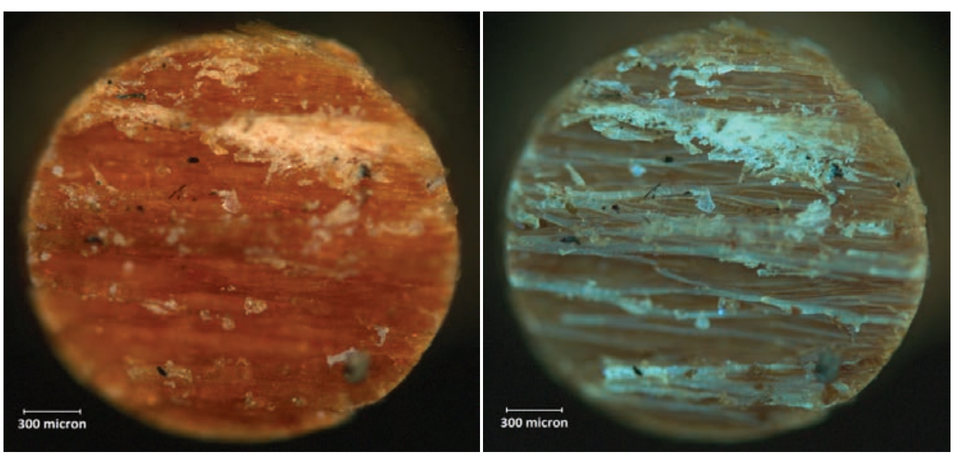

Figure 10. Sample 37 from SL6C, surface area under visible (left) and UV illumination.

3.1.2 Middle white and black part

Figures 11 and 12 show core samples removed from the middle area of the slat. Both visible and UV illuminated images again show the top fungal layer to be concentrated on the surface. The presence of acrylic from artificial surface treatments and protein originating from the fungal layer was confirmed.

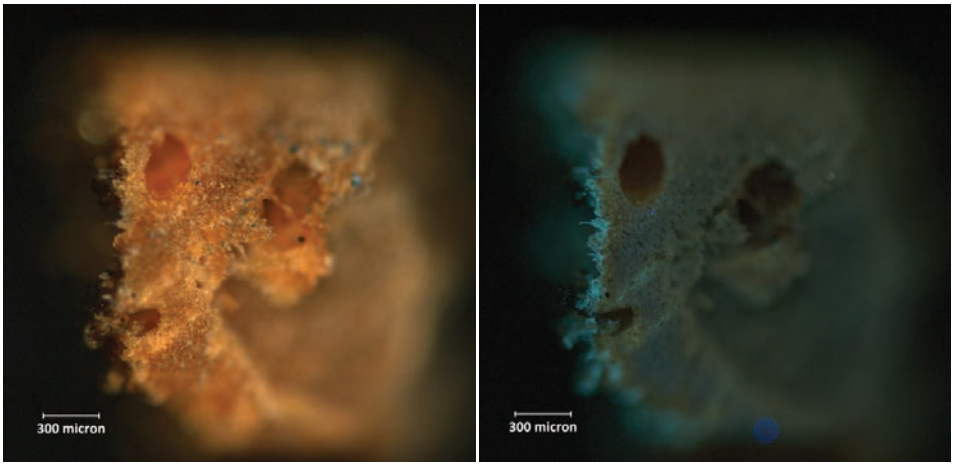

Figure 11. Sample 38 from SL6C, cross sectional view under visible (left) and UV illumination.

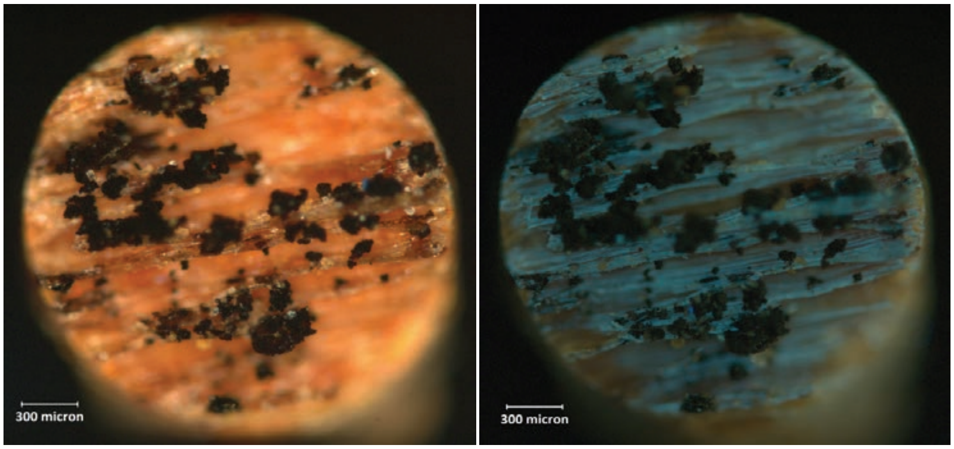

Figure 12. Sample 38 from SL6C, surface area under visible (left) and UV illumination.

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Science Department

Analysis Report
Organic Materials Laboratory
Salk Institute Conservation Project

3.1.3 Lower gray patina part

Figures 13 and 14 show core samples removed from the lower part of the slat. Both visible and UV illuminated images show the top gray layer to be concentrated on the surface but different in color and texture when compared with the middle layer. This is likely due to the presence of water-soluble material wicking up the wood. FTIR analysis of the top layer show the presence of oil and oxalate.

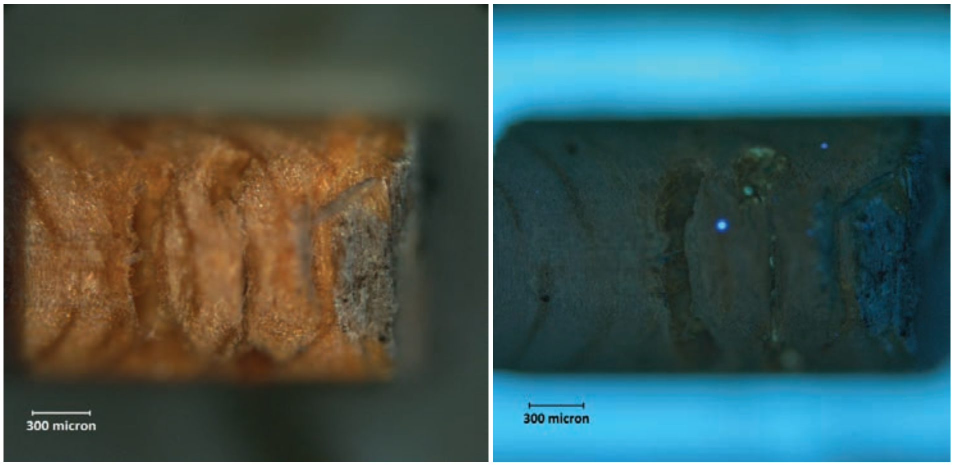


Figure 13. Sample 39 from SL6C, cross sectional view under visible (left) and UV illumination.

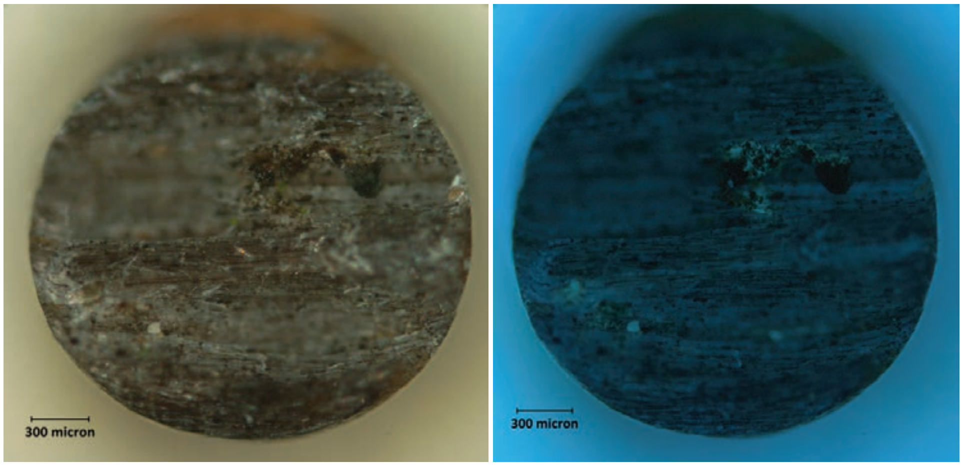


Figure 14. Sample 39 from SL6C, surface area under visible (left) and UV illumination.

3.2 Adjacent Slats with Varying Appearance

Adjacent divergent slats were present in different areas of the Salk Institute. Photographs taken from the west elevation of the south office building show large areas of biological growth, with few slats showing lack of infestation (figs. 15 and 16).

Figure 15

Figure 16

3.2.1 Red coating

The photomicrographs in figures 17 and 18 clearly show the lack of fungal infestation on the red-coated slat. However, the teak wood exhibited weathering patterns on the uneven surface. Analysis results indicated the presence of resinous material, likely applied as a surface coating.

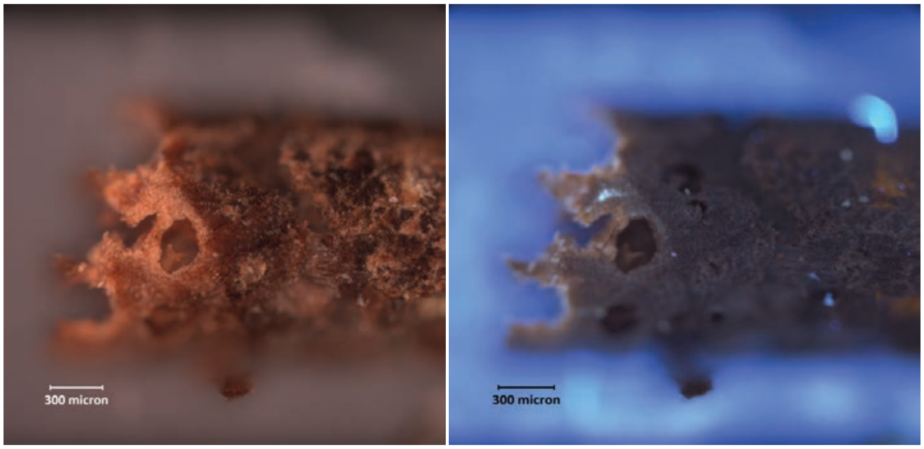


Figure 17. Sample 46 from SO5D, cross sectional view under visible (left) and UV illumination.

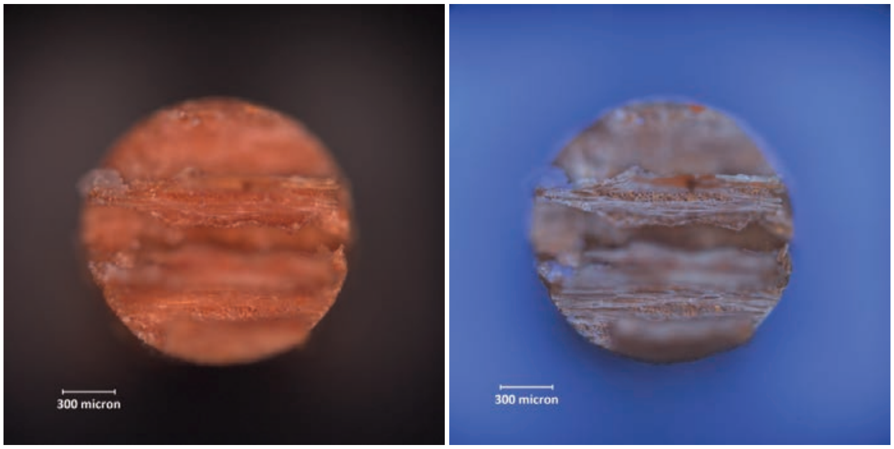


Figure 18. Sample 46 from SO5D, surface area under visible (left) and UV light illumination.

3.2.2 Black deposit

The photomicrographs in figures 19 and 20 show a black crust on the surface of the core sample. Analysis results indicated the presence of inorganic carbonates and wax.

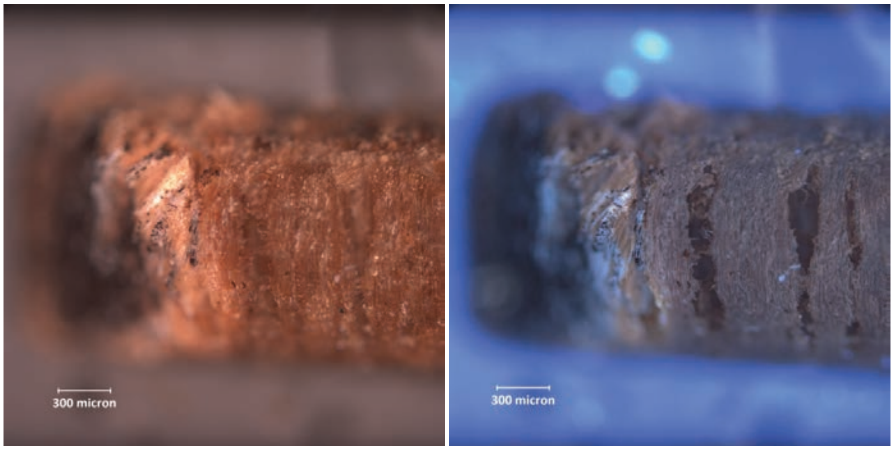


Figure 19. Sample 47 from SO5D, cross-sectional view under visible (left) and UV illumination.

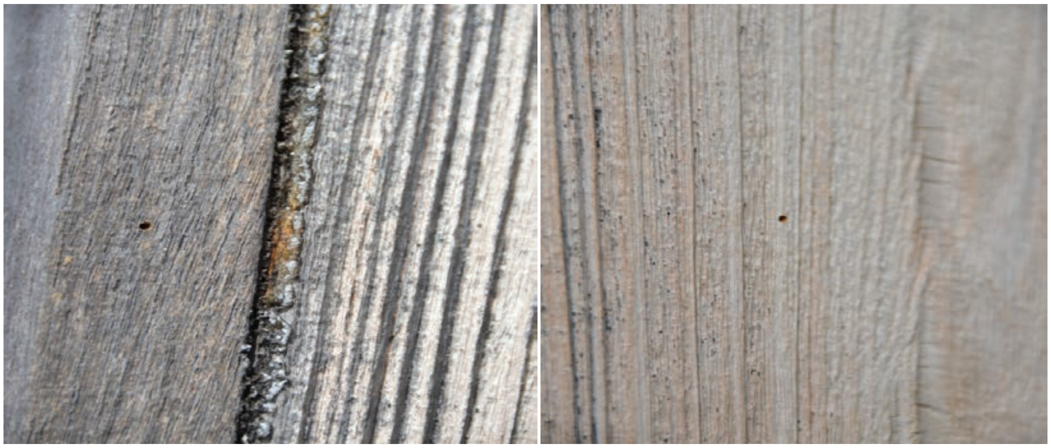
Figure 20. Sample 47 from SO5D, surface area under visible (left) and UV illumination.

3.3 Vertical Trim Variations

The west elevation of the north building showed different coatings on the same vertical trim. The west-facing trim contained a black crust, while the adjacent south-facing trim exhibited white efflorescence. Figure 21 illustrates the visual differences between the west and south sides. Figure 22 shows tiny holes created by the sampling biopsy punches on the south side.

← West (front) → ← South (side) →

Figure 21



← South (side) →

Figure 22

3.3.1 Black crust

A black crust layer appears to be concentrated on the top thin surface of the wood (figs. 23 and 24). The core sample contains a larger number of vacuoles, or holes, when compared with the core taken from the adjacent south-facing trim. This variation may be attributed to the inherent differences in the source of the teak wood (plantation vs. old growth) or the cut angle of the wood lumber. The layer of black crust contained proteinaceous material, likely produced by the fungal material, as well as other minor components that were difficult to identify.

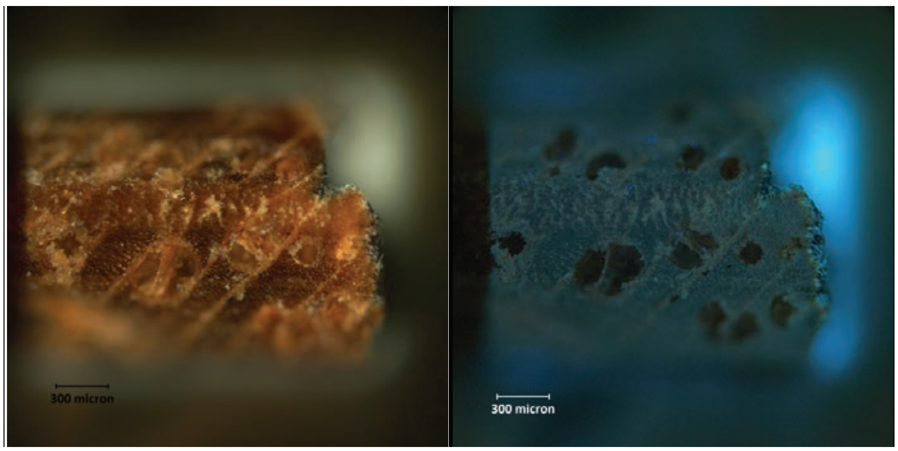


Figure 23. Sample 42 from NO6H, cross sectional view under visible (left) and UV illumination.

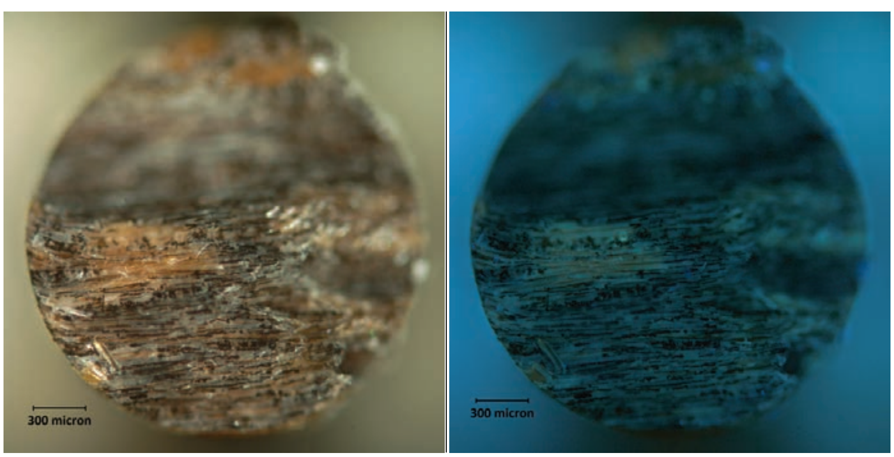


Figure 24. Sample 42 from NO6H, surface area under visible (left) and UV illumination.

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Analysis Report
Organic Materials Laboratory
Salk Institute Conservation Project

3.3.2 White efflorescence

The white coating appears very thin but is layered on the surface of the core sample (figs. 25 and 26). In comparison with the wood in the west-facing sample, the wood in the core sample contains a smaller number of holes. The white efflorescence showed the presence of oxalate, a product that may be the result of various environmental influences.

Figure 25. Sample 43 from NO6H, cross sectional view under visible (left) and UV illumination.

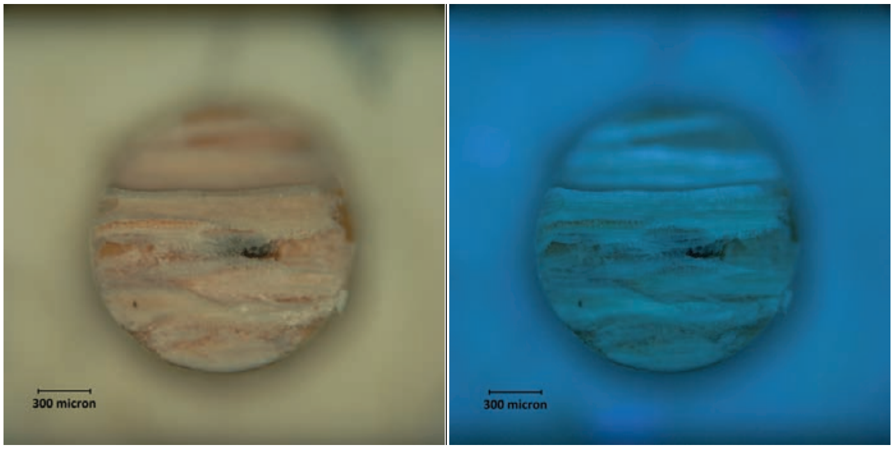

Figure 26. Sample 43 from NO6H, surface area under visible (left) and UV light illumination.

3.4 Chemical Analysis

Individual fragments were scraped from the surface, and point-by-point linear ATR mapping was performed on the core samples using a Bruker Hyperion 3000 FTIR microscope. The identified surface coatings included urea-formaldehyde adhesive as well as layers containing acrylic resin, drying oils, long-chain aliphatic hydrocarbons, and oxalates (table 1). Other efflorescent deposits, such as carbonate minerals, were found in samples collected from areas located in elevations facing the campus laboratories.

Table 1. Summary of analytical results.

Sample	Description/Color Layer	FTIR Analysis
#23NU6C Brown coating on the side of slat	Original brown adhesive	Urea-formaldehyde adhesive
#6 NO2C	Red stain lacquer	Acrylic resin
#28 SL4A	Red coating	Oil
#26 SL4A	Wood efflorescence	Calcium carbonate
#37 SL6C	Red coating, collected from top of same vertical slat as #38 & #39	Acrylic, calcium oxalate
#38 SL6C	Black and white coating, collected from middle of same vertical slat as #37 and #39	Acrylic, protein
#39 SL6C	Gray coating, collected from bottom of the same vertical slat as #37 and #38	Oil, calcium oxalate
#42 NO6H	Black crust	Protein
#43 NO6H	Gray coating	Calcium oxalate, oil

#44 NO5H	Black crust	Protein, acrylic
#46 SO5D	Red coating	Resinous material
#47 SO5D	Black crust	Carbonate, wax?

Figures 27 - 29 show the chemical mapping of the three core samples removed from the same single slat described in section 3.1. The colored dots in the top diagram of each figure represent the FTIR analysis points. The top dot is the one nearest the outer surface of the core sample. The red and pink colors represent areas where a good contact was achieved between the ATR crystal and the sample. The spectra at the bottom of each figure are overlaid comparisons and correspond to the color of the dots. Analysis results show the spectra to be similar at various points. There appears to be no significant difference through the 1.5 to 3 mm depth of the core sample. Samples 42 and 43 NO6H, originating from the west elevation of the north building, and samples 46 and 47 SO5D, from the west elevations of the south office building showed similar behavior. It is important to note that components present in low concentration (below 5%) could not be identified due to the more qualitative strength of the FTIR method.

3.4.1 FTIR mapping of top red area

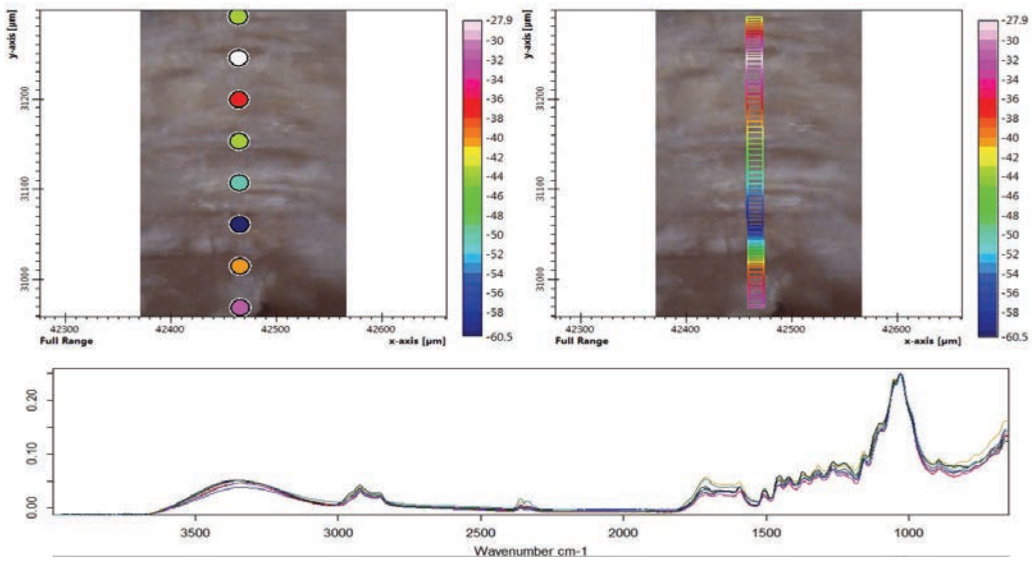

Figure 27. Sample 37 from SL6C, FTIR mapping of cross section.

The Getty Conservation Institute
Science Department

Analysis Report
Organic Materials Laboratory
Salk Institute Conservation Project

3.4.2 FTIR mapping of middle black area

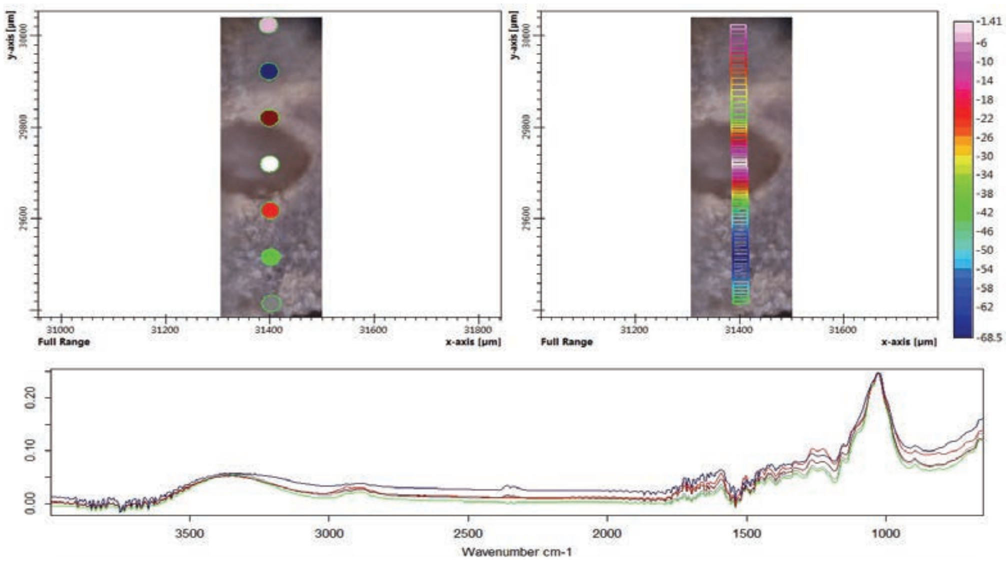

Figure 28. Sample 38 from SL6C, FTIR mapping of cross section.

3.4.3 FTIR mapping of lower gray area

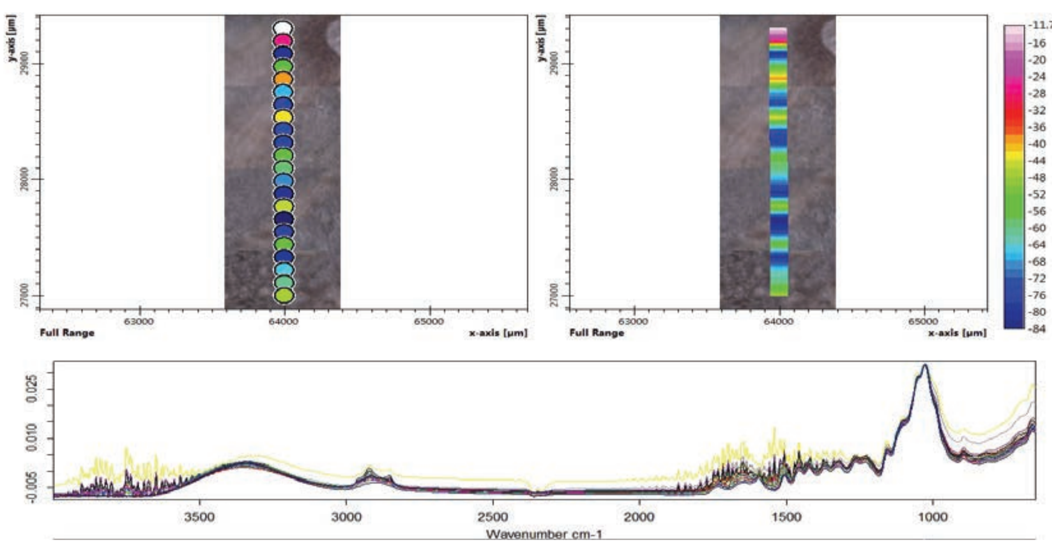

Figure 29. Sample 39 from SL6C, FTIR mapping of cross section.

4.0 Discussion

A wide range of surface conditions is observed on the surface of window fenestrations. The variations extend from dark black to neutral gray, caused by fungal activity as well as migration of water and aqueous soluble material. Additional conditions ranging from a red appearance resulting from previous surface treatments, to a white efflorescence associated with various salts and oxalates were also detected. The light-gray patinas were observed mainly on the lower parts of the vertical slats in contact with the windowsills and various horizontal dividing pieces.

There are indications that certain elevations are more prone to biological infestation and weathering due to orientation of the window. The buildup of the black deposit was more evident on the north- and west-facing elevations, while the influence of water and sunlight may play an important role in the growth and propagation of biological activity. The possible presence of both plantation and old-growth teak wood may have also contributed to the selective erosion of the surface. In addition, previous harsh and uneven cleaning treatments have exaggerated the rough, streaky appearance of the wood.

A short-term treatment strategy and formulation of a long-term preservation road map should be recommended. The following suggestions for a conservation proposal may be considered:

1. A new regular cleaning program should be implemented. This cleaning should include a gentle washing with mild detergents to remove existing biological activity.

2. The removal of previous coatings should be considered. This will require consultation with conservators and testing mild cleaning solvents applied to the teak wood surface.

3. A viable short- and long-term efficacy treatment plan to control growth of biological activity should be considered. The best approach may be to test four or five different applications based on historical treatments of similar types of wood.

4. Uniform substrate prepping may be an important step prior to any invasive treatment.

5. Conservation-grade reversible coatings should be applied to protect the surface of the wood and retard the infiltration of water and airborne pollutants.

6. The preservation protocol should maintain a reasonable cost for the short- and long-term treatment plan.

5.0 Conclusion

Both visual and chemical information revealed the omnipresent black fungal layer and various other deposits to be concentrated mainly on the surface. Identified surface coatings included urea-formaldehyde adhesive as well as layers containing acrylic resin, drying oils, and long-chain aliphatic hydrocarbons. FTIR mapping showed the chemical differences to be minor between the inner and outer parts of the core samples. Although mapping was conducted only on the top few millimeters, there should be no reason to doubt that the same properties extend throughout the wood thickness.

For the most part, the integrity of the wood appears to be good, as supported by the lack of major differences in the photomicrograph records of the core samples. This may be indicative of the wood's durability and reliability in the formulation of a long-term treatment plan. Reduction of water infiltration should also be considered as it may have a long-term effect on the permanency of protective coatings and growth of microorganisms. For long-term treatment strategy and formulation of a long-term conservation plan, a new regular cleaning program should be implemented. The treatment should include gentle cleaning of the teak wood to preserve the integrity of the tropical hardwood. The best approach may be to test cleaning solvents and protective coatings on mock-ups for evaluation of their short- and long-term efficacy.

APPENDIX I

Salk Institute for Biological Studies: Wood Investigation of the Teak Window Wall Assemblies

PREPARED BY ANTHONY & ASSOCIATES, INC.

Salk Institute for Biological Studies:
Wood Investigation of the Teak Window Wall Assemblies

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June 2014

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CONTENTS

EXECUTIVE SUMMARY

In 2013, Anthony & Associates, Inc. (A&A), was contacted by the Getty Conservation Institute (GCI) to conduct a wood investigation of the teak fenestration panels at the Salk Institute for Biological Studies in La Jolla, California (the Salk). The Salk, designed by Louis Kahn and completed in 1965, is composed of twenty-nine separate buildings and includes study towers, offices, and laboratories. The original buildings of the Salk Institute were designated by the San Diego Historical Resources Board as a historical landmark in 1991, and the California State Historical Resources Commission determined the entire 27-acre site to be eligible for listing on the National Register of Historic Places in 2006. Concerns have been expressed by the Salk staff about the condition of the teak window wall assemblies, which are character-defining elements of the structures, due to fading, bleaching, moisture staining, insect damage, and weathering of the panels. This report represents A&A's findings, in collaboration with the work of the GCI, on the field and laboratory investigation of the teak assemblies.

This report identifies A&A's scope of work and provides a summary of the findings, which were based on site visit observations and detailed examination of specimens removed for analysis. Each specimen was digitally photographed, weighed, measured, and traced to scale prior to destructive testing. Small sections of each specimen were examined under a stereomicroscope and a light microscope to identify species and types of wood deterioration. The wood species results were based on examination of twenty-two specimens removed from various fenestration panels and structural framing members that support the panels. Three samples removed from structural framing members supporting the teak panels were identified as white fir (*Abies* spp.), commonly found in the spruce-pine-fir species group of commercially available lumber. Nineteen specimens were removed after consultation with the GCI and the Salk staff, including slats, louvers, and samples of large window-framing members. All were identified as teak (*Tectona grandis*) based on macroscopic and microscopic examination. A third-party expert in species identification of tropical hardwoods verified the findings for six of the specimens. Finally, growth ring density and orientation were recorded to gain additional insight into patterns of weathering, erosion, and discoloration of individual teak slats that produce the irregular color (stain) pattern of the panels. Specific gravity and moisture content were also determined following ASTM test standards to aid in determining wood quality for purposes of identifying suitable replacement material, if needed.

The most significant threat to the teak window wall assemblies is the damage done to structural (non-teak) framing members by drywood termites (*Incisitermes* spp.). Although teak is considered naturally resistant to termites, minor damage due to insects was noted on a few teak slats and some of the large teak elements supporting the fenestration systems. This damage is superficial and limited to only a few of the elements and does not represent a risk to the long-term performance of the teak. The insect borings that were observed may have been present in the teak when the panels were fabricated and installed. However, the softwood lumber framing that supports the window wall assemblies is at risk of termite infestation, and through limited probes, a number of framing members were found to be significantly damaged by drywood termites. This structural damage is severe enough to impact the performance of the teak assemblies, as demonstrated through the failure of a panel during a high-wind event in January 2014. Addressing the structural damage to the framing lumber caused by termites is critical to the long-term serviceability of the teak assemblies in the window wall system.

The primary cause of concern expressed by the Salk staff was differential discoloration of the teak. The project team identified multiple forms of discoloration, including fading/bleaching, moisture staining, metal oxide staining, black biological fungal spore growth (generically called mildew), natural weathering, and calcium carbonate staining. Weathering processes were identified as having the most widespread effect on the visual appearance and long-term physical performance of the teak fenestration panels.

Bleaching or fading is caused by exposure to ultraviolet light, as is the silver-gray patina commonly associated with weathered wood. Moisture stains were identified as caused by moisture absorption and desorption through the end grain of vertically oriented elements. Tannins and extractives subsequently leached out of the wood through this process, leaving discolored lines at different heights, where they were washed away.

Metal oxide stains have formed on the teak due in large part to the process of erosion (both mechanical and natural) that has occurred for approximately fifty years. As the thickness of the teak slats has been reduced due to erosion associated with weathering and physical abrasion, the heads of the metal fasteners have become exposed (particularly on the tongue-and-groove slats). Although the fasteners were galvanized at the time of construction, the atmospheric conditions of the site (located close to the Pacific Ocean, with a high percentage of airborne salts) have degraded the galvanized finish, allowing the iron in the fastener cores to interact with oxygen and salts in the air. Combined with exposure to moisture, this chemical reaction interacts with natural chemicals in the teak to form black stains at fastener locations. This type of staining is typically difficult to remove without aggressive sanding that further reduces the thickness, as it often penetrates many cell layers into the wood surface.

Black biological fungal spore growth has been a reoccurring problem for the teak panels at the Salk since shortly after its construction. The spores may be from a variety of fungal organisms but are not wood-decay fungi that degrade the cellular structure of the wood. They are primarily surface phenomena that are part of the natural weathering processes that cause color changes in the wood. Spores tend to grow on surfaces with a food source (the wood cells, in this instance) and favorable temperature and moisture conditions. It is difficult to control the growth of these organisms, as they can be carried by air/wind currents and can survive in a relatively wide range of environmental conditions. Because of this, it may not be possible to prevent the growth of the black spores; however, options to control the rate of spore growth can be considered.

Calcium carbonate staining has resulted in some areas. This may be due to a combination of microclimatic conditions and runoff/drainage conditions from the concrete. Teak does contain some mineral inclusions (primarily silica) but does not include calcium carbonate.

Weathering of the exposed faces of the teak has occurred since the teak panels were installed. Weathering is the result of a combination of factors, including exposure to ultraviolet light, moisture, cyclic wetting and drying, and the action of windblown debris. In addition to color changes to the wood surface, weathering erodes the wood surface, creating a rough texture. The severity of the erosion depends on a number of factors, including environmental conditions, density of the wood, and type of cut. In the case of the Salk, erosion of the teak has also occurred due to cleaning techniques that were implemented shortly after construction and continued into the 1990s. Metal bristle brushes and frequent cleaning with bleach solutions, in combination with natural surface weathering from environmental factors, have led to significant surface texture and erosion of some of the teak. In some cases, severe erosion has led to failure of the teak tongue-and-groove slats.

Based on the data collected from two site visits as well as additional laboratory analysis, the primary mechanism of deterioration of the wood is weathering, followed by mechanical damage (from past cleaning methodologies identified by the Salk maintenance employees). Termite damage does not represent a significant mechanism of deterioration for the teak members; however, termite damage to the white fir structural framing lumber is severe in some locations.

I. BACKGROUND AND SCOPE OF WORK

Background

Anthony & Associates, Inc. (A&A) was contracted by the Getty Conservation Institute (GCI) to collaborate on a Conserving Modern Architecture Initiative (CMAI) project at the Salk Institute for Biological Studies (the Salk). Based on discussions with the Salk staff, there are concerns regarding the condition of the existing wood window wall assemblies and their suitability for continued use. The panels are showing signs of distress, including erosion of the wood surface and discoloration due to biological growth, weathering, and ultraviolet (UV) light exposure. Termite activity has been noted as well. In some locations, the erosion of the wood surface has become severe enough to cause individual teak slats and sections of panels to come loose.

In December 2013 and March 2014, A&A staff, in conjunction with the GCI, conducted fieldwork at the Salk to document conditions and remove specimens for analysis. The two site visits and subsequent specimen analysis form the basis of this report.

Scope of Work for the Field and Laboratory Investigation

A&A's scope of work included four investigation tasks: identification of mechanisms of deterioration; identification of past cleaning and surface treatments; identification of wood species; and analysis of erosion and weathering mechanisms. The identification of past cleaning and surface treatments was researched primarily by GCI staff and is described in their report. An outline of each task is given below.

1. **Identification of mechanisms of deterioration**
   - Mildew, stain, and decay fungi
   - Insect damage
   - Mechanical damage
   - Establish patterns of deterioration

2. **Identification of past cleaning and surface treatments (researched primarily by GCI staff)**
   - A&A identified samples with possible prior treatments based on stereomicroscopic and light-microscopic inspection of samples removed from the site. The same samples were used to identify species, type of deterioration, and specific gravity. A&A provided samples with possible prior treatments to GCI to conduct gas chromatograph and/or mass spectrometry analyses to determine the chemicals used in prior cleaning or treatment.

3. **Identification of wood species of various components in the teak fenestration system**
   - Sample locations were identified by A&A and GCI during the initial site investigation. Removal of the samples was conducted by the Salk staff and documented by GCI. Samples were shipped to A&A for laboratory analysis.

4. **Analysis of erosion and weathering mechanisms**
   - Using stereomicroscopy and visual assessment, the extent and mechanism of erosion were determined.

Scope of Work for the Treatment Recommendations

A&A's scope of work for treatment recommendations was limited to providing guidance and suggestions on options proposed by the GCI. A&A's role in treatment recommendations is supplemental to the recommendations provided by the GCI and discussed in their report. An outline of A&A's tasks for treatment options is given below.

1. **Provide recommendations on approaches to investigative procedures to identify the severity of termite infestations**
   - Define parameters for a phased approach to the investigation
   - Make recommendations on the methods of inspection and treatment

2. **Provide recommendations on the repair and replacement of deteriorated teak and structural elements**
   - Comment on feasibility of locating replacement teak and provide potential sources for teak suppliers
   - Provide recommendations on the suitability of replacement material for structural elements
   - Provide recommendations on altering construction details to improve the performance of the teak window wall assemblies

3. **Provide recommendations on the control of biological growth and minimizing color changes**
   - Provide recommendations on treatment options to control black spore growth
   - Provide recommendations on cleaning and treatment options to reduce the impact of natural weathering on color changes and/or variation of the teak window wall assemblies

II. WOOD AS AN EXTERIOR ARCHITECTURAL MATERIAL

Wood Characteristics

Successful conservation of the teak window wall assemblies at the Salk to extend the service life of the wood begins with an understanding of the issues that can affect the performance and aesthetics of wood in an exterior environment. Such an understanding will enable GCI and the Salk to make informed decisions for conservation, repair, and replacement of the wood elements.

Because all wood comes from trees, a basic understanding of tree physiology is essential to understanding the properties of milled lumber (and therefore the teak used in the window wall assemblies at the Salk). Trees have a protective layer of bark, composed of dead wood cells, surrounding their trunks and branches. Just inside the bark is a very thin layer of cells called the cambium, which creates new wood cells. The new cells created on the inside of the cambium are a zone of living cells referred to as sapwood. Sapwood serves to store the nutrients of the tree and transfer sap up from the roots to the leaves. The size of the sapwood zone varies depending on tree species and the size of the tree. At the inner edge of the sapwood there is a transition into the heartwood. Heartwood is not "living" wood in that it is not involved in the transfer of nutrients throughout the tree, but it does contribute to its structural strength. Finally, at the very center of the trunk is the pith. The pith of the tree is a small core of weak cells generated from the first years of growth.

Viewed under a low-powered microscope, a section of wood resembles a bundle of straws packed tightly together. These "straws" are the tubular sapwood and heartwood cells whose long axes run parallel to the long axis of the tree trunk. The cells are made primarily of cellulose and bonded together by lignin, a cementing substance. The direction of these tubular cells is referred to as the grain of the wood; grain direction is important to understanding how a piece of wood behaves when subjected to various environmental conditions because the properties of wood parallel to the grain (along the length of the piece) differ significantly from the properties perpendicular to the grain (across the width of the piece). Most hardwood and softwood trees in the US exhibit a pattern of concentric circles when viewed in cross section; these circles are bands of light and dark wood and represent the annual growth rings of the tree over the course of its life. The dark rings, called latewood, are denser and thinner than the light-colored rings, as they represent the growth of the tree in the fall and winter. The light-colored rings are generally much wider than the dark rings and represent the faster growth that occurs in spring and summer. This earlywood is typically less dense and weaker in structure than latewood growth. The growth rings of tropical hardwoods are influenced by seasonal fluctuations in rainfall rather than identified seasons (e.g., summer and winter), and some species of hardwoods, depending on their environment, have no distinguishable growth rings. Teak is a tropical hardwood that typically does have readily identifiable growth rings.

The teak slats and timbers used at the Salk were produced from milled lumber. Trees can be milled a number of ways, and each piece of lumber will have different properties based on the orientation of the grain and how it was cut from the log. Varying grain orientations can cause pieces of lumber to distort differently as the wood dries. Additionally, living trees contain significant amounts of water, and after a tree is cut, the water starts to evaporate. As the wood dries, it changes dimension; that is, it shrinks in cross section and along its length; sometimes resulting in warp. Warp can include cupping, twisting, bowing, checking, and splitting. Furthermore, the manner in which a slat or timber was milled (discussed in detail in section IV) will affect its durability when exposed to weathering. There are many sources for additional information on the nature of wood; an excellent reference is *Understanding Wood* by R. Bruce Hoadley, which discusses the fundamentals of wood physiology.

Wood Deterioration

There are many causes of wood deterioration, and often multiple types of degradation can interact to affect the performance of the material. Appropriately selected conservation or remedial treatments can be effective in preventing or retarding some types of degradation, but only if the cause of the deterioration is correctly identified and mitigated. Accordingly, some understanding of the causes of wood deterioration is necessary when considering the need for repair or replacement of wood substrate materials. Common causes of wood deterioration are discussed below.

Weathering

Weathering is a primary mode of deterioration for wood used in exterior architectural applications because it is typically exposed to precipitation and direct UV light. Weathering is readily apparent from the gray and brown surfaces of the wood and the small checks and splits that develop during the weathering process.

Weathering of wood is the result of the action of cyclic wetting and drying, exposure to UV light and erosion of the wood through windblown debris (a process similar to sandblasting). Weathering is a long-term process and a significant factor in the deterioration of wood exposed to the environment. The weathering process changes the appearance of wood and gradually erodes wood fibers, but the process is quite slow. Weathered wood is often considered aesthetically pleasing because of the silver-gray patina the wood can achieve with weathering, and, unlike decay or insect attack, it seldom damages the wood enough to require replacement.

Initially, the wood grays or darkens, and small seasoning checks and splits begin to develop on the wood surface that allow for moisture penetration. These turn into longer

splits due to cyclic wetting and drying of the wood (and to freeze-thaw action in cold climates). As moisture is absorbed into the wood, the wood expands, generating more splits and establishing a favorable environment for active wood decay.
In addition to the graying from UV exposure and the swelling, shrinking, checking, and splitting due to moisture intrusion, wind-blown debris facilitates the weathering process by continually eroding fibers on the exposed wood surface. Windblown debris can also collect in crevices, inhibit moisture evaporation, and serve as a growth medium for windblown plant spores and seeds. As the weathering process continues, individual wood fibers on the surface begin to slough off. The lighter-colored earlywood in the growth rings erodes faster than the darker, denser latewood bands, resulting in a rough surface texture (fig. 2.1). This process can be accelerated by aggressive cleaning practices such as bleaching and/or using wire brushes to clean exposed wood surfaces (fig. 2.2).

Figure 2.1. Example of an uncoated wood substrate with natural erosion of the lower-density earlywood due to weathering.

As checks and splits extend from cyclic wetting and drying, individual fibers slough off and small wood chips are lost. The exfoliation of small pieces of weathered wood exposes fresh surfaces that are then exposed to the weathering process. This process is slow and varies by wood species and the amount of environmental exposure. Some softer coniferous woods can lose up to a quarter inch of thickness per century of exposure, depending on the wood species. In addition to exposure, the weathering rate is greatly influenced by wood density, climate, exposure to the elements, and building elevation. Weathering of the wood over time may enable decay fungi to enter the wood through even minute checks and splits.

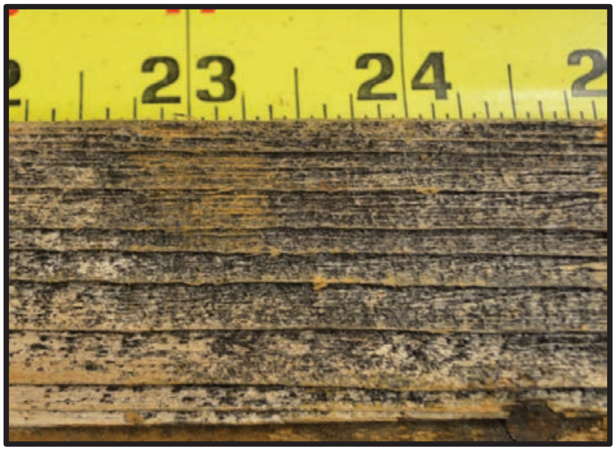


Figure 2.2. Detail of the bottom of specimen S from the Salk with erosion of the earlywood, likely due to a combination of natural processes and aggressive cleaning practices.

Where moisture can penetrate the wood, shrink-swell and freeze-thaw cycles can loosen the connections between wood fibers to the point where gaps develop. As the gaps increase in size with cyclic moisture effects, more wood surface is exposed to ultraviolet light and contact with moisture, thereby accelerating the rate of deterioration. Decay fungi will eventually find their way into the exposed wood. Weathering of the wood over time (decades) will make it possible for decay fungi to enter the wood through the many checks and splits. Eventually, the decay process, which is much more rapid than weathering, can become the dominant means of deterioration, particularly for larger timbers that absorb and retain moisture longer than thinner elements, thus providing a suitable environment for wood decay fungi to proliferate.

Moisture

Moisture is not so much a mechanism of deterioration as it is the means for forms of deterioration to develop and progress. Moisture serves as a catalyst for many forms of deterioration and is an integral component of weathering, decay, and insect attack. Moisture stains are not an indication of damage to the wood but a record of the wood being exposed to water either repeatedly throughout its life or for an extended period of time. Moisture can cause nails and screws to rust, causing additional staining of the wood (fig. 2.3). As previously mentioned, moisture aids in the weathering process by causing wood to swell or shrink, thus generating checks and splits as the wood fibers expand or contract. Wood that is not exposed to environmental weathering or in contact with a source of moisture can remain stable for decades or centuries. Wood that reaches a moisture content of 20% or more is at risk for decay fungi and insect attack. Wood with a moisture content higher than 30% has a high probability of decay and insect infestation.

Figure 2.3. Stains on teak slats caused by a combination of moisture and a chemical reaction between extractives in the wood and the exposed metal fasteners after significant weathering occurred.

Mold and Mildew

Mold and mildew are types of fungi that do not deteriorate wood substrates or coatings but can cause discoloration of the coating surface and exposed wood surfaces. Most molds are green, orange, or black, and mildews are typically black; both are powdery in appearance. Spores can grow quickly on moist surfaces or on exterior surfaces in humid conditions. Since the conditions that are favorable for growth of mold and mildew are the same as for more destructive wood-decay fungi, mold and mildew should be considered as warning signs of potential problems but do not necessarily indicate that deterioration of the wood substrate has occurred. The source of the moisture should be identified and corrected when possible.

Biological growth other than decay can be removed with careful cleaning (fig. 2.4), but unless the favorable underlying conditions are altered, the growth will return. Biological growth can be controlled in a number of ways, including chemical treatments, cleaning, and altering construction details and/or microclimatic conditions. The simplest means of controlling biological growth includes reducing the amount of available moisture and trimming trees and vegetation to increase sunlight exposure to enhance drying.

There are other types of organisms, such as lichens and moss, that can be found growing on wood substrates. However, no lichens or mosses were found on the teak at the Salk.

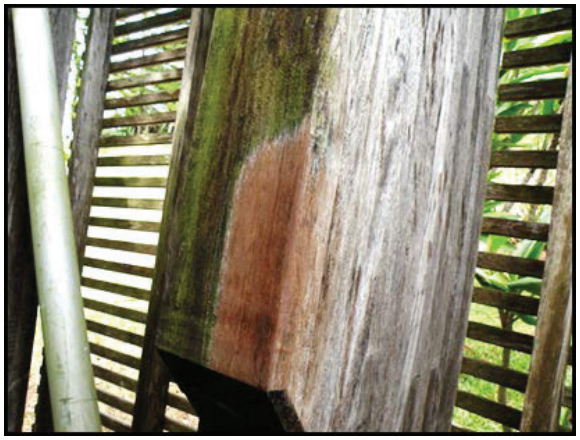


Figure 2.4. Example of biological growth and weathered patina, both of which can be removed through careful cleaning.

Decay Fungi

All wood is subject to a variety of deterioration mechanisms, the most destructive of which is wood-decay fungi. Wood-decay fungi excrete enzymes that break down wood fibers, which can ultimately lead to the inability of the wood to perform its intended function. Most wood-decay fungi are only able to grow on wood with a moisture content greater than 20 percent and are unable to damage adjacent dry wood. Evidence of typical decay of wood products can be identified by the dry, cubicle cracking that occurs in the wood substrate and/or by fungal fruiting bodies visible on the wood surface, although other patterns of deterioration can occur.

Wood with mold or mildew on the surface remains firm and sound. Wood that has been attacked by decay fungi at or just below the surface loses this firmness and is easily penetrated with a blunt awl. Deterioration through decay is a particular concern where the wood is in contact with the ground or other materials, such as porous stone, that may facilitate moisture absorption into the wood. None of the teak specimens removed from the Salk were found to have wood-decay fungi, and there was no evidence of active wood-decay fungi of the teak window wall assemblies identified during the field investigations.

Insects

Insect attack is generally a minor contributing factor to the deterioration of wood, as most insects seek out wood that has already been compromised by high-moisture-content levels. However, there are a number of wood-boring insect species that can cause significant damage to exposed architectural and structural wood. In the southeastern US and other humid coastal regions in particular, insects are more likely to be an issue than in other parts of the country. The diversity of insect species that can damage wood is quite broad; only the most common and most damaging of these insect pests are discussed here.

Termites or other wood borers will reduce the cross section of a wood member by either digesting or tunneling through the wood. With decay, there is usually a gradual transition from sound wood to punky wood to a total loss of wood fiber (a void). Unlike decay, insect damage tends to have an abrupt transition from unaffected to affected areas of the wood. The mechanism of deterioration is different for insect attack, but as with decay fungi, moisture is generally required and the result is a loss of integrity of the wood.

As termites are the primary cause of wood failure due to insect attack, special attention should be paid to monitor and identify potential infestations by closely examining wood for bore holes, frass (insect excrement), mud tubes, and/or live insects or other evidence of wood-boring activity. A number of termite species can damage wood used in architectural and structural applications. These species include subterranean termites, Formosan termites, drywood termites, and dampwood termites. Although termite species can be difficult to distinguish from one another, especially when swarming, each species has specific identifying characteristics. It is important to identify the species of termite because each species requires different environmental conditions to thrive as well as different approaches to control and/or eliminate infestations.

The termite species identified at the Salk are drywood termites (*Incisitermes* spp., likely *I. minor*). Drywood termites do not require contact with soil or sources of moisture within the wood. Colonies can reside in non-decayed wood with low moisture contents. Drywood termites live in small social colonies, with as few as fifty insects, to more than three thousand insects in a mature colony. They remain entirely above ground and do not connect their nests to the ground with mud tubes or galleries. Typically, the first sign of a drywood termite infestation is fecal pellets collecting at or near the base of wood members. The fecal pellets are hard, angular, abd less than 1 mm in length. and vary in color from light gray or tan to very dark brown (figs. 2.5 and 2.6). Interior galleries tend to be broad pockets or chambers connected by smaller tunnels that cut across latewood. Irreparable damage to wooden elements can be caused by drywood termites in two to four years, depending on the size of the element and the size of the infestation.

There is no definitive means to identify specific reasons as to why drywood termite colonies have populated some of the window wall assemblies at the Salk. Some of the assemblies have drywood termite infestations and others do not; this may be a function of the condition of the teak (i.e., heavily weathered teak has provided openings for access into the interior of the wall assembly and the untreated structural members) or environmental conditions (i.e., microclimatic temperature and moisture conditions conducive to drywood termite colonization).

Figure 2.5. Example of typical drywood termite galleries discovered after breaking through a thin shell of sound-looking wood. Note the collection of frass. Awl handle in foreground is shown for scale.

Figure 2.6. Frass found behind a teak slat removed for specimen analysis, study tower 10, NU7C.

Other wood-boring insect species include the carpenter ant and carpenter bees, both of which can cause damage to structural and architectural wood. Unlike termites, however, carpenter ants and carpenter bees do not feed on wood but rather burrow into wood to make nests. Damage from carpenter ants or carpenter bees was not identified at the Salk during the field investigations.

III. FIELD PROCEDURES AND LABORATORY INVESTIGATION

The approach to the field and laboratory investigation began by establishing a system of nomenclature to allow for the research team and the Salk to identify where samples were removed and various conditions were exhibited. Elevations and as-built drawings (or construction documents) were used to establish sitewide patterns of wood conditions. Site visits centered on data collection. Between A&A, GCI staff, and Salk staff, the range of teak conditions, the environmental conditions at the Salk, the maintenance practices used by Salk staff, and sample requirements were identified. Fieldwork was intended to provide data and samples (1) to identify wood species to make it possible to identify compatible material for repairs and suitable treatments for preservation of the wood, and (2) to establish the types and extent of deterioration.

Nomenclature

The locations of the teak fenestration panels are referenced by identifiers provided by GCI and by cardinal direction. For example, N7LC, west panel, identifies the west panel of the teak window wall assembly within the north study towers (N), from the lower study 7 (7L), and from elevation C (facing the courtyard). Teak slat rows are numbered from bottom to top (e.g., NL7C, west panel, slat row 2). Figures 3.1 and 3.2 show labeled examples. Individual slats as a general rule are not numbered; however, when referencing individual slats, typically they are numbered from west to east for south-facing elevations, from north to south for west-facing elevations, and from east to west for north-facing elevations. Specimens removed for species identification and other analyses were assigned alphabetical identifiers (A, B, C, etc.). Additional information on the nomenclature is available in the appendix.

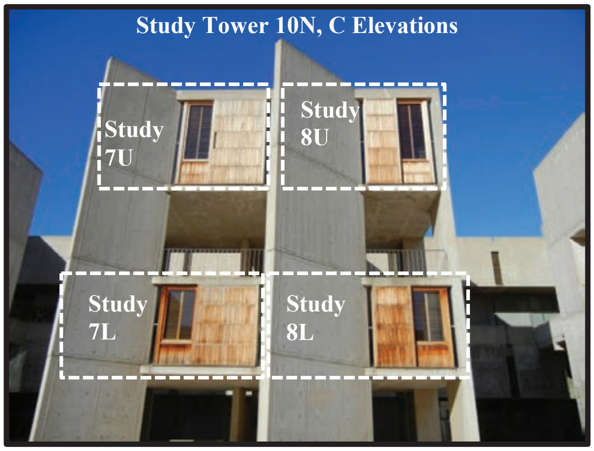


Figure 3.1. C (courtyard-facing) elevations of study tower 10N.

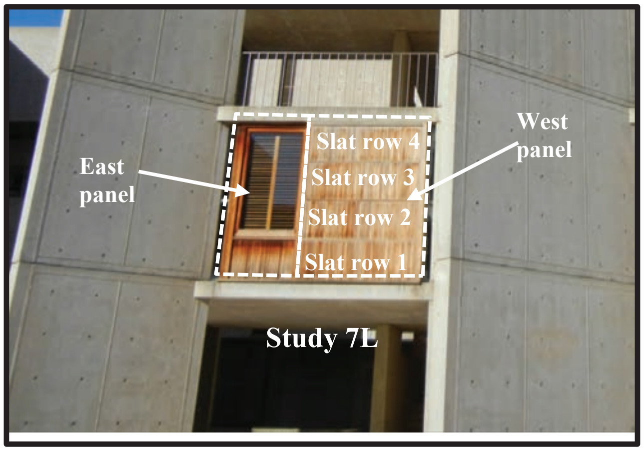


Figure 3.2. Study 7L with labeled panels and slat rows.

Field Procedures

The assessment used a combination of visual inspection and probing, videoscope inspection, and specimen removal for analysis, including species identification. These techniques are described below.

Visual Inspection and Probing

Visual examination of the wood allows for identifying components that are missing or broken or in an advanced state of deterioration. Missing components are those that have been removed or have fallen away, frequently due to extensive deterioration. If missing components were originally intended to provide structural support or protection from the elements (e.g., prevent moisture intrusion), their replacement may be essential to prevent long-term damage to the structure. Visual inspection also allows for the detection of past or current moisture problems, as evidenced by moisture stains on the exposed surface of the wood. Further, visual inspection enables detection of external wood-decay fungi or insect activity, as determined by the presence of decay fruiting bodies, fungal growth, insect bore holes or wood substance removed by wood-destroying insects. Visual inspection provides a rapid means of identifying areas that may need further investigation (fig. 3.3).

Figure 3.3. Visual inspection of a panel with significant weathering and erosion.

Remote Visual Inspection

Remote visual inspection equipment allows imaging of wood that is inaccessible for normal visual inspection. Remote visual inspection involves the use of a videoscope—a device with a small camera mounted at the end of a long, flexible tube—and a monitor that displays the transmitted images from the camera. The camera is then inserted into gaps, holes, or crevices too small for other forms of inspection to access. A 6-mm-diameter videoscope was inserted into the fenestration cavities, and still images were captured as necessary to depict interior wall conditions (figs. 3.4 and 3.5).

Figure 3.4. Use of the videoscope to determine wall cavity conditions.

Figure 3.5. Videoscope image of interior fenestration cavity showing termite frass.

Sample Removal for Species Identification

The fenestration systems make extensive use of small-dimension slats and larger-dimension lumber. Identifying wood species makes it possible to identify compatible material for repairs for both structural and architectural elements. Small samples of wood were removed from key structural elements and larger samples from slat and louver specimens (fig. 3.6). From these samples, the wood species or species group was identified under microscopic examination.

Figure 3.6. Slat removal for species identification and analysis of wood deterioration.

Laboratory Procedures

General Observations

Each specimen removed for analysis by A&A was documented in detail prior to conducting any destructive testing or sampling. Table A-1 in the appendix provides rough dimensions (the specimens were not uniform in dimension due to weathering), weights, and physical descriptions. The exposed faces, back faces, partial profiles, and end grains of the specimens were digitally photographed and the surfaces of the specimens were examined under a stereomicroscope (where additional digital images were captured) prior to sanding the end grains and rephotographing to document growth rate, as calculated in rings per inch, and examine type of cut (flat-sawn, vertical-sawn, or rift-sawn). Table A-2 in the appendix provides information on the number of rings per inch, type of cut, and surface conditions. The following sections describe the tasks and summarize the findings of the documentation process.

The wood specimens removed from the Salk were examined for evidence of deterioration: weathering (broken up into three classifications: graying of the wood surface, surface texture, and erosion), moisture staining, biological growth (mold, mildew, lichens, and moss), decay fungi, and insect damage. Detailed descriptions by specimen are given below. The findings are summarized in Table A-2 in appendix A.

Definitions of General Conditions

Each specimen was visually assessed for surface texture, erosion, graying of the exposed face, bleaching of the exposed face, and black spore growth. Surface texture is defined as the difference between maximum thickness and minimum thickness, measured at the bottom end of vertical slat specimens only (louver specimens were not included in the quantitative analysis for surface texture or erosion). Erosion is defined as the difference between the assumed original nominal thickness of 0.75 inch and the mid-width thickness measured at the (typically) thinner bottom end of the vertically oriented slats. Surface texture and erosion are based on quantitative data. Graying, bleaching, and spore growth were visually assessed and are therefore based on qualitative data. For each condition classification, a rank of *minor*, *moderate*, or *severe* was assigned based on either actual or visually estimated percentages.

The term *minor* is used to describe conditions such as graying of the wood surface, bleaching, and black spore growth that covers less than approximately 20% of a specimen's exposed face. Surface texture was determined to be minor if the difference between maximum and minimum bottom thickness did not exceed 5%. Slats with an original thickness remaining of 90% or more were classified as having minor erosion.

Moderate is used to describe graying of the wood surface, bleaching, and black spore growth that covers 20% to 35% of a specimen's exposed face. Surface texture was determined to be moderate if the difference between maximum and minimum bottom thickness was between 5% and 10%. Slats with 80% to 90% of the original thickness remaining were classified as having moderate erosion.

Conditions were classified as *severe* if graying of the wood surface, bleaching, and/or black spore growth covered more than 35% of a specimen's exposed face. Surface texture was determined to be severe if the difference between maximum and minimum bottom thickness exceeded 10%. Slats with less than 80% original thickness remaining were classified as having severe erosion.

Digital Photography

The exposed face, back face, and ends of each specimen were photographed, along with a partial right-side profile (based on the exposed face). The photographs of the ends were taken before and after sanding with 200-grit sandpaper to enhance the visibility of the growth rings and the ring orientation. After sanding, one end (typically the top) was photographed. Examples of the photographs are shown in figures 3.7 through 3.11.

Figure 3.7. Specimen C, exposed face.

Figure 3.8. Specimen C, back face.

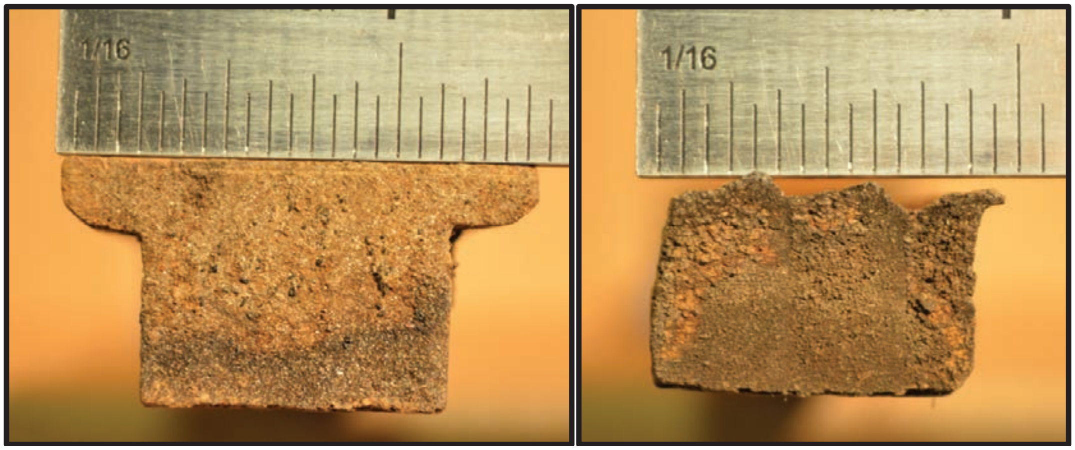


Figure 3.9. **(**Left) Specimen C, top end grain prior to sanding; (right) Specimen C, bottom end grain prior to sanding.

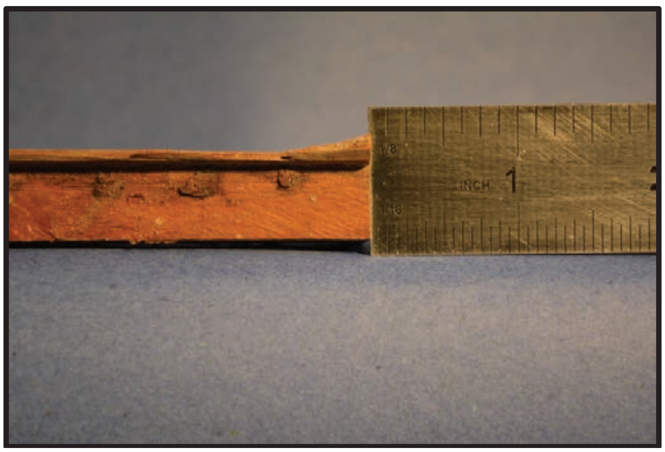


Figure 3.10. Specimen C, right partial profile.

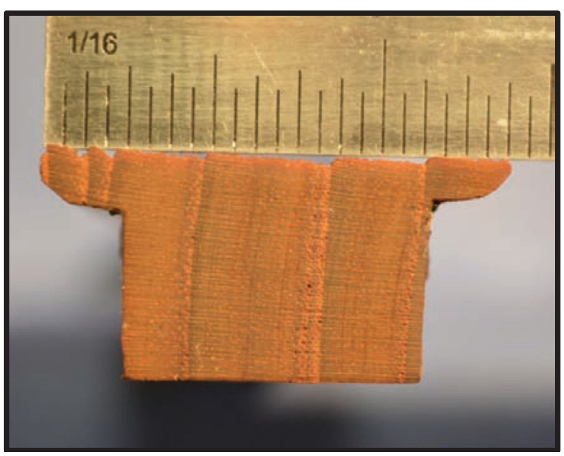


Figure 3.11. Specimen C, top end grain, after sanding.

Specimen Descriptions

Specimen A

Specimen A is a small louver procured from the workshop by maintenance staff at the Salk. Its original location when in use is unknown. It exhibits moderate weathering and erosion of the wood surface, as well as moderate black spore growth and minor bleaching.

Specimen B

Specimen B is a larger louver that, like specimen A, was procured from the workshop by maintenance staff at the Salk. Its original location when in use is unknown. It exhibits only minor erosion of the wood surface, black spore growth, and bleaching. Specimen B does not exhibit any graying of the wood surface.

Specimen C

Specimen C was originally described as a shiplap slat. Subsequent analysis of the specimens by GCI indicates that those initially interpreted as shiplap slats are actually tongue-and-groove slats that exhibit severe surface erosion (additional information on tongue-and-groove vs. shiplap slats appears in subsequent sections). Specimen C was the second slat from the west in slat row 1 on the west panel of NL6C. In the panels examined, the second slat from the west (depending on cardinal orientation) in every slat row is a T-shaped slat that was glued into the panel rather than nailed. Because of the lack of fasteners and failure of the adhesive over time, these T-shaped slats tend to be easily removed. Specimen C exhibits significant erosion and bleaching of the wood surface, minor black spore growth, and minor graying of the wood surface.

Specimen D

Specimen D is a structural framing lumber sample; it was removed from an assumed 2 x 4-inch bottom furring strip from the west panel of NL6C, where specimen C was removed.

Specimen E

Specimen E is a structural framing lumber sample; it was removed from an assumed 2 x 4-inch bottom furring strip from the east panel of NU7C, where specimen F was removed.

Specimen F

Specimen F was originally described as a shiplap slat. Specimen F is a T-shaped slat (second slat from the west) located in slat row 3 on the west panel of NU7C. It exhibits significant bleaching, moderate erosion, and minor black spore growth. Specimen F does not exhibit graying of the wood surface.

Specimen G

Specimen G was originally described as a shiplap slat but has subsequently been recategorized as a tongue-and-groove slat. Specimen G is the third slat from the west in slat row 3 on the west panel of NU7C. It exhibits significant bleaching of the wood surface, moderate erosion, and minor black spore growth. Specimen G does not exhibit graying of the wood surface.

Specimen H

Specimen H is a tongue-and-groove slat and was the fifth slat from the north in slat row 1 on the SL8B panel. It was removed in several pieces by Salk maintenance staff. It exhibits moderate bleaching of the wood surface, moderate erosion, moderate black spore growth, and moderate graying of the wood surface.

Specimen I

Specimen I is a small portion of a tongue-and-groove slat and was the sixth slat from the north in slat row 1 on the SL8B panel. It exhibits moderate bleaching of the wood surface and moderate black spore growth. As specimen I is only a small sample removed from the tongue of a slat that remains in the extant panel, there is no graying of the wood surface.

Specimen J

Specimen J is a tongue-and-groove slat and was the fourth slat from the north in slat row 1 on the SL8B panel. It exhibits moderate bleaching of the wood surface, moderate erosion, moderate black spore growth, and moderate graying of the wood surface.

Specimen K

Specimen K is a larger louver. It was the twenty-first louver from the bottom on the westernmost shutter panel. It exhibits significant erosion of the wood surface, moderate black spore growth, and graying. Specimen K does not exhibit any bleaching of the wood surface.

Specimen L

Specimen L was originally described as a shiplap slat. Specimen L is a T-shaped slat (second slat from the west) located in slat row 2 on the center panel of SO5K. It exhibits significant bleaching and erosion and moderate black spore growth. Specimen L exhibits minor graying of the wood surface.

Specimen M

Specimen M was originally described as a shiplap slat. Specimen M is a T-shaped slat (second slat from the west) located in slat row 1 on the center panel of SO5K. It exhibits significant bleaching and erosion and moderate black spore growth. Specimen M exhibits minor graying of the wood surface.

Specimen N

Specimen N is a structural framing lumber sample; it was removed from an assumed 2-inch x 4-inch lumber sill plate from panel SL8B, where specimens H, I, J, and K were removed.

Specimen O

Specimen O is a tongue-and-groove slat (second or third slat from the west) located in the west panel, slat row 3 of SL8C. It exhibits significant black spore growth and graying of the wood surface, moderate erosion, and minor bleaching.

Specimen P

Specimen P is a tongue-and-groove slat (third slat from the west) located in the east panel, slat row 3, of SL7C. It exhibits minor black spore growth and no graying of the wood surface, moderate erosion, and minor bleaching.

Specimen Q

Specimen Q is a tongue-and-groove slat (fourth slat from the west) located in slat row 3 of panel NL8A. It exhibits only minor erosion, with no black spores, graying, or bleaching.

Specimen S

Specimen S is a tongue-and-groove slat (first or second slat from the west) located in slat row 1 under the window of panel WOW N3. It exhibits moderate erosion and bleaching, moderate graying of the surface, and moderate black spore growth.

Specimen T

Specimen T is a cored sample removed from the top face of the bottom sill of panel NO6J. It exhibits significant graying of the wood surface, minor erosion, and no bleaching or black spore growth.

Specimen U

Specimen U is a cored sample removed from the south vertical trim piece of panel NO6H. It exhibits significant graying, minor erosion, no bleaching, and no black spore growth on the wood surface.

Specimen V

Specimen V is a tongue-and-groove slat that was removed from slat row 2, center panel of the window wall assembly NO6K. It exhibits significant bleaching and erosion, minor black spore growth, and minor greying of the wood surface.

Specimen W

Specimen W is a tongue and groove slat removed from slat row 2, center panel of the window wall assembly NO6K. It exhibits significant erosion and bleaching, minor black spore growth, and no graying of the wood surface.

Other Tests

After digital photography and description of the specimens were completed, additional laboratory analyses and tests were done on each specimen. These included stereomicroscope inspection, species identification, analysis of growth ring density and orientation, determination of moisture content, and determination of specific gravity. These procedures are described in the next section, together with the findings for each procedure.

IV. LABORATORY FINDINGS

Stereomicroscope Inspection

Prior to destructive testing, each specimen was examined under the stereomicroscope for evidence of deterioration, weathering, mold or mildew growth, coatings, and insect damage. Findings were noted and digitally photographed. Figures 4.1 through 4.5 provide examples of the images. Surface fungal growth in the form of mold and/or mildew was identified, as were grit (possibly sand) particles that likely are contributing to the weathered appearance of the wood, and remnants of both adhesives and finishes. Weathered surfaces showed broken cellular bonds, cellular bleaching, and an open, porous structure.

Figure 4.1. Specimen F, viewed under the stereomicroscope, showing weathered wood surface, open cellular structure, and weak cellular bonds. Note biological growth (center).

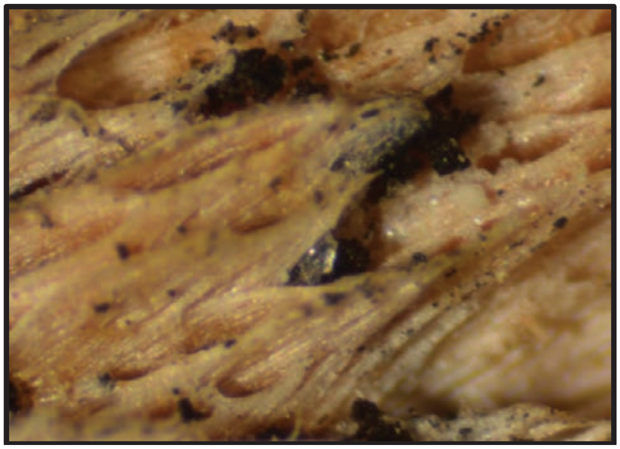


Figure 4.2. Specimen F showing a particle of sand and biological growth on the weathered surface.

Figure 4.3. Specimen I showing a weathered wood surface and biological growth that appears to be clustered around a debris particle.

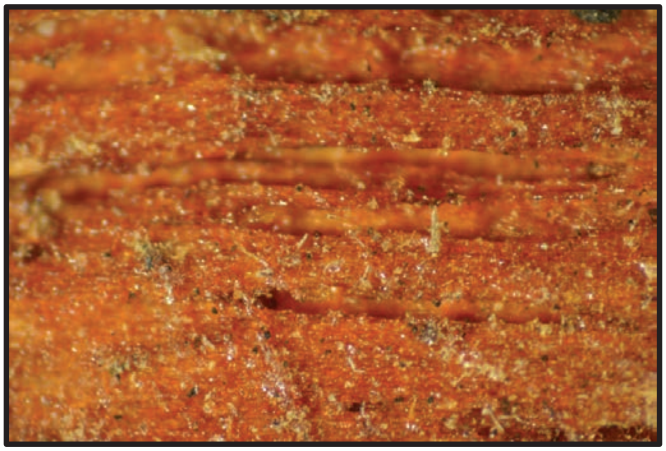


Figure 4.4. Specimen H showing remnants of a protective wood finish.

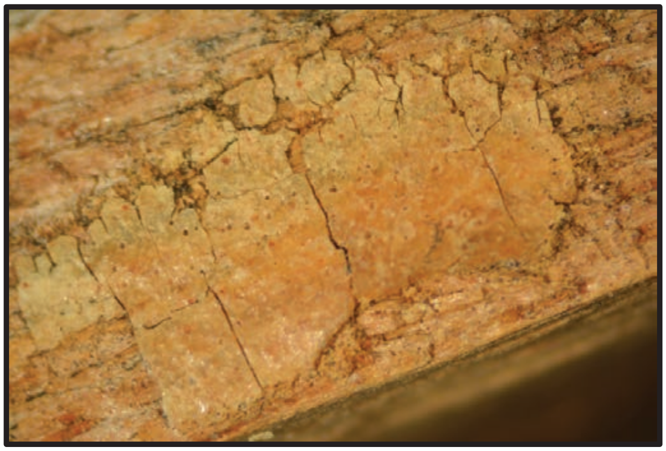


Figure 4.5. Specimen G showing remnants of an adhesive on the side face.

Following inspection using the stereomicroscope, small sections of the specimens were removed for species identification and examination of biological growth under a light microscope. Photographs of the biological growth on a microscopic scale indicate that the growth tends to be a surface phenomenon and does not appear to be wood-decay fungi (figs. 4.6 and 4.7). Sand particles and adhesive fragments were also identified using the light microscope (figs. 4.8 and 4.9).

Figure 4.6. Biological growth on a wood fiber, 400x magnification.

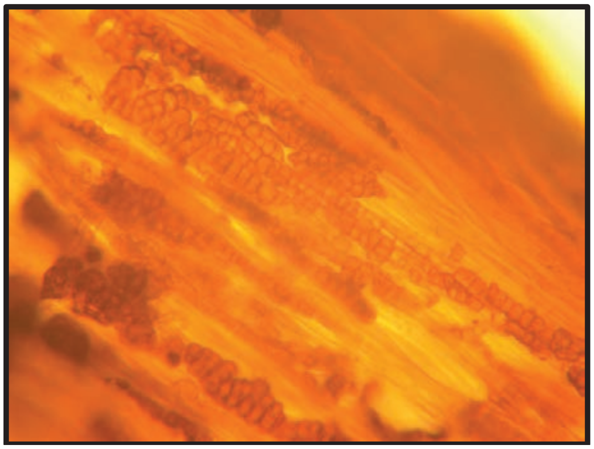


Figure 4.7. Biological growth on or in the wood cells, 400x magnification.

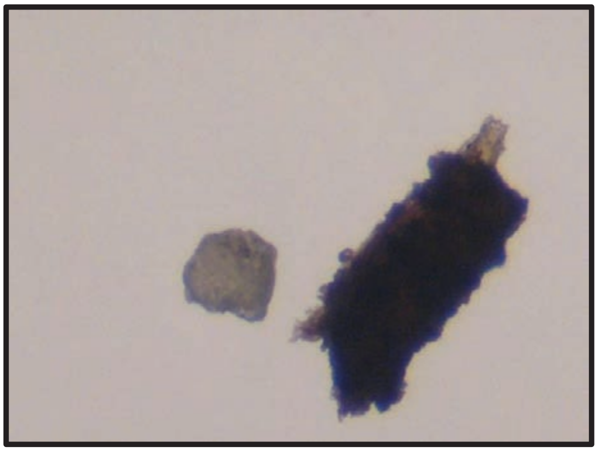


Figure 4.8. Grain of sand next to a small wood fragment covered in biological growth, 400x magnification.

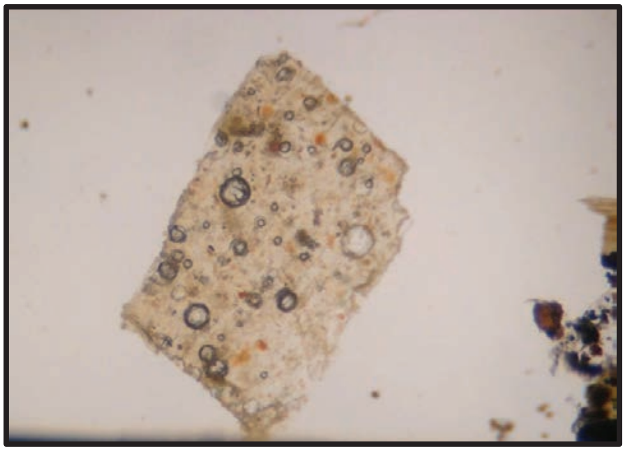


Figure 4.9. Small fragment of adhesive, 400x magnification.

Species Identification

Eighteen specimens were removed from the Salk during the initial site visit in December 2013 by A&A personnel or Salk maintenance staff for purposes of species identification and additional analysis. The specimens were assigned alphabetical identifiers (A through S; the letter R was not assigned). Four additional specimens (T through W) were removed during the March 2014 site visit.

Identifying wood species makes it possible to identify compatible material for repairs. Small samples were removed from structural members and whole or partial slats from the architectural window panels. From these samples, the species or species group was identified under microscopic examination (fig. 4.10).

Figure 4.10. Location of specimens H, I, J, and N, panel SL8B on study tower 10S.

Three specimens were removed from structural framing supporting the exposed wood panels; all three (specimens D, E, and N) were identified as belonging to the white fir species group (*Abies* spp.) due to the presence of macroscopic characteristics such as a lack of resin canals on the transverse face and microscopic characteristics including taxodioid cross-field pitting and crystalline structures in the ray cells (fig. 4.11). None of the specimens showed any evidence of wood preservatives on a macroscopic or microscopic level. One of the specimens (specimen E) had substantial drywood termite (*Incisitermes* spp.) damage (fig. 4.12).

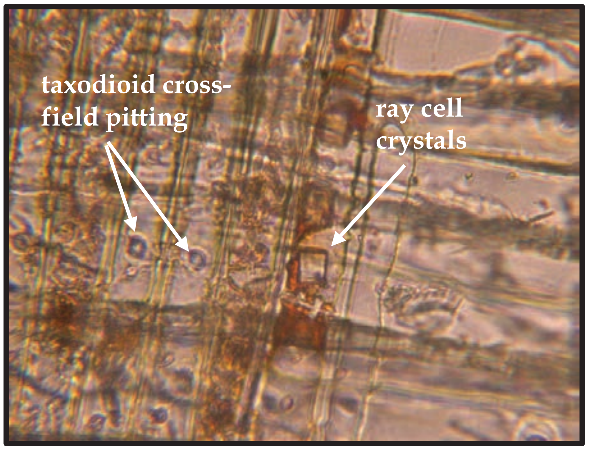


Figure 4.11. Radial section of specimen D at 400x showing taxodioid cross-field pitting and crystals in the ray cells.

Figure 4.12. Location of specimen E and the surrounding teak slats showing superficial drywood termite damage.

The fifteen remaining specimens were all identified by A&A as teak (*Tectona grandis*) based on macroscopic and microscopic characteristics. Six specimens (C, G, K, L, O, and Q) were sent to the Forest Products Laboratory (FPL) for independent species verification. All six specimens were confirmed as *Tectona grandis*. According to FPL research botanist Alexander Wiedenhoeft, “Of the 6, specimen K shows a slow growth rate that could be interpreted as indicative of natural-grown material. The other 5 are faster-grown and would be consistent with plantation material, or unusually fast-grown native forest material” (personal communication, 2014).

Teak is a tropical timber species native to southeast Asia, although it is now grown on plantations around the world. It is important to note that species identification of teak cannot provide information on country of origin (i.e., based on macroscopic and microscopic characteristics, there is no way to differentiate between teak grown in South America from teak grown in Thailand. GCI research indicates the teak used at the Salk may have come from Thailand. There are two *Tectona* subspecies—*T. hamiltoniana*, endemic to Myanmar, and *T. philippinensis*, endemic to the Philippines—that are not grown on plantations elsewhere or widely marketed. A number of wood species are referred to as “teak,” such as Brazilian Teak (Cumaru - *Dipteryx odorata*), African Teak (Iroko - *Milicia excelsa* or *Cholorophora excelsa*), and Rhodesian Teak (*Baikiaea plurijuga*), therefore distinction must be made regarding genus and species.

Teak is considered to be naturally durable (i.e., resistant to decay fungi and insect attack), although it is only moderately resistant to marine borers and powder post beetles. It has been used for centuries for boat building and in exterior and interior applications, both architecturally and structurally. Teak is generally easy to work with; however, it has a high silica content that rapidly dulls cutting edges. The high oil content may necessitate application of a solvent prior to gluing, although it typically glues and machines well. Most of the *T. grandis* available today is plantation-grown, with an average tree age at harvest of fifteen to twenty-five years. Old growth teak can be difficult to source; reclaimed teak is often the best source for old growth timbers.

The wood characteristics of *T. grandis* include heartwood that is a golden or medium brown that gets darker with age; a characteristic spicy' leather-like odor; and a coarse texture with medium-size open pores. The grain tends to be straight but can occasionally include wavy or interlocked grain. The wood, when freshly milled, tends to have a slightly oily feel due to the presence of natural oils. When viewed in cross section, the cellular structure can be seen to be ring-porous or semi-ring-porous with large, solitary earlywood pores and solitary or radial multiples of two or three medium-to-small latewood pores. Tyloses and other mineral deposits are common. Growth rings tend to be distinct.

The macroscopic and microscopic characteristics that identify *T. grandis* from other similar tropical wood species include a characteristic spicy odor, ring-porous or semi-ring-porous distinct growth rings, large earlywood pores, vessels with tyloses or yellowish or whitish deposits, distinct rays, simple perforation plates, and alternate, medium intervessel pitting. Microscopy images are shown in figs. 4.13 through 4.17.

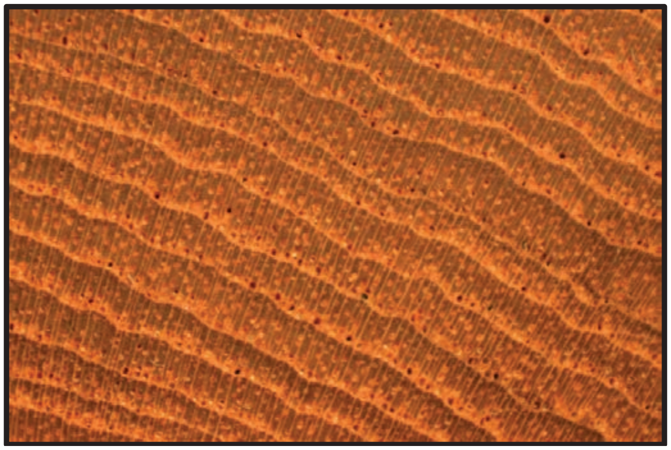


Figure 4.13. Cross section of specimen P, after sanding with 200-grit sandpaper, showing typical macrocellular characteristics of *T. grandis,* including distinct growth rings, a ring-porous structure, and visible rays.

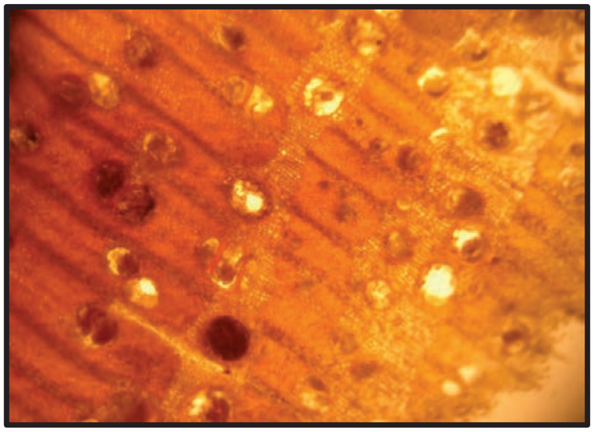


Figure 4.14. Cross section (transverse) of specimen F showing large, solitary earlywood cells at 100x magnification.

Figure 4.15. Tangential section of specimen H showing rays with 1 to 5 (but typically 3 to 4) cells in width at 100x magnification.

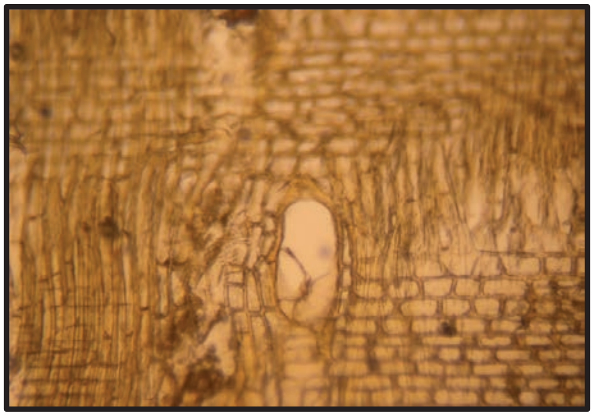


Figure 4.16. Radial section of specimen H showing a simple perforation plate and ray cell structure at 100x magnification.

Figure 4.17. Alternate intervessel pitting, specimen F, 400x magnification.

Analysis of Growth Rings

Growth Rate – Rings-per-Inch Count

The number of rings per inch is a measure of the rate of growth. Rings per inch can potentially indicate whether some of the material used in the window wall assemblies came from plantation-grown or natural forest trees. Plantation-grown material grows - quickly in general, resulting in wide growth rings composed predominantly of less-dense earlywood. Natural forest trees tend to grow much more slowly because of greater competition for sunlight and moisture; therefore, natural forest trees tend to have narrow growth rings, with a larger proportion of dense latewood than plantation-grown trees have. Rings per inch can also affect density and specific gravity (which, in turn, affects the rate of erosion of the wood due to weathering). Rings per inch was measured perpendicular to the ring orientation; many are, therefore, approximate because several of the specimens are not thick/wide enough to measure a full inch. Additionally, in some cases, such as the end grain of specimen B, the growth rings are not distinct (fig. 4.18). Depending on where the dark latewood bands are counted, there are twenty-five to thirty-one rings across the thickness of the specimen (0.625 inch). Assuming a similar growth rate for a full 1.00-inch specimen, then, would result in a range of total growth rings of forty to forty-nine rings in one inch. These two factors prevent the rings-per-inch count from being exact. The rings-per-inch tally is meant to show the range of growth rates of the specimen material and to provide information that may facilitate conclusions about weathering patterns based on the growth rate of the wood.

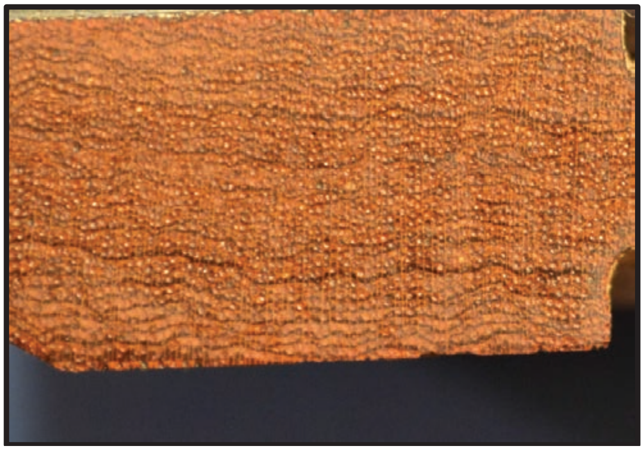


Figure 4.18. Indistinct growth rings, specimen B, end grain.

Results for most of the specimens are included in table A-2 in the appendix. The table also includes information on weathering patterns. As specimens A, B, and K are taken from moveable louvers, their weathering patterns are distinct from the stationary vertical slats and larger exterior teak elements. For this reason, specimens A, B, and K were excluded from the table. Additionally, the original locations of specimens A and B are unknown, as is the length of time they were in service. However, for the purposes of this discussion regarding rings per inch, specimen A had fourteen rings per inch; specimen B had forty-nine rings per inch; and specimen K had forty rings per inch.

For the remaining sixteen specimens from fixed vertical or horizontal elements, the rings-per-inch count ranges from two to forty. Eight of the sixteen specimens have ring counts of less than ten rings per inch, seven of the specimens have ring counts between eleven and sixteen rings per inch, and one specimen (specimen T) has forty rings per inch.

It is often assumed that a low rings-per-inch count is associated with a preponderance of less-dense earlywood and therefore an accelerated rate of weathering than specimens that have higher rings-per-inch tallies and therefore exhibit slower growth patterns and a larger percentage of dense latewood. Weathering is considered to be the combined effect of erosion (overall loss of exposed material), surface texture (differential loss of earlywood and latewood), black spore growth, and color changes including bleaching and graying. In this instance, a low rings-per-inch count alone does not predict the weathering rate of the specimen. However, when considered in combination with the orientation of grain and the location of the specimen on the building facade, the rings-per-inch count does in fact have some correlation with surface texture and rate of erosion.

In general, specimens with a higher rings-per-inch count (between eleven and forty) had minor to moderate surface texture, whereas specimens with lower rings-per-inch counts (two to nine) had moderate to significant surface texture.

Orientation of Grain

The cut of the wood can affect movement in service and weathering rates. Wood is an anisotropic material; that is, it has different material properties and physical characteristics depending on grain orientation. Therefore, the way in which the wood is cut from the log impacts how it behaves both structurally and architecturally. It should be noted that terminology associated with the type of cut varies considerably and can be quite confusing. There are two primary cuts: flat sawn (or flat grain, also called plain sawn) and vertical sawn (or vertical grain, also called quarter sawn). Typically, material is considered flat sawn if the growth ring angle is 0° to 45° across the thickness of the piece. Material is generally considered vertical sawn if the growth ring angle is 45° to 90° across the thickness of the piece. For the purposes of this analysis, however, more restrictive definitions were applied to allow for three types of cut: flat sawn, vertical sawn, or rift sawn. Flat-sawn material was defined as wood that has predominantly no growth ring angle (i.e., the growth rings parallel the exposed face). Vertical-sawn material was defined as wood that has predominantly a 90° growth ring angle. Rift-sawn material was defined as wood that has predominantly a growth ring angle of approximately 45°.

Flat Sawn

Flat-sawn lumber is wood that has been cut parallel to the tangential face of the log (fig. 4.19). This results in a pleasing characteristic U- or V-shaped grain pattern on the wide faces of boards and lumber. This cut is common because it maximizes the amount of usable material from the log. However, wood shrinks and swells the most in a tangential direction; therefore, having large surface areas cut from tangential faces of logs leads to boards and lumber that tend to cup, crown, bow, warp, and twist more than other cuts.

Figure 4.19. Flat-sawn softwood board with typical U-shaped grain pattern (material not from the Salk).

Specimens B and G removed from the Salk are flat sawn. Specimen B is a large louver retrieved from the Salk maintenance shop (fig. 4.20); its original location is unknown. Specimen G is a vertical shiplap slat from study tower 10N, NU7C (fig. 4.21).

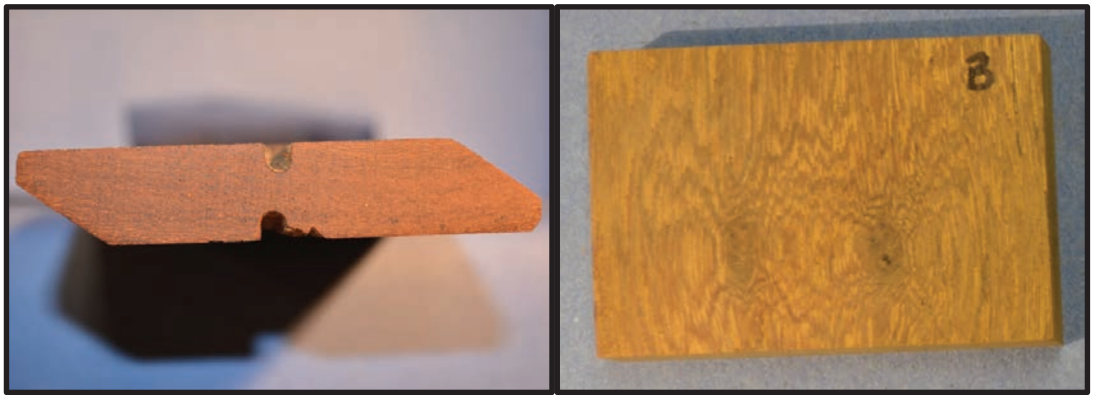


Figure 4.20. (Left) End grain of Specimen B; (right) wide face of a small portion of Specimen B showing the characteristic flat-sawn pattern.

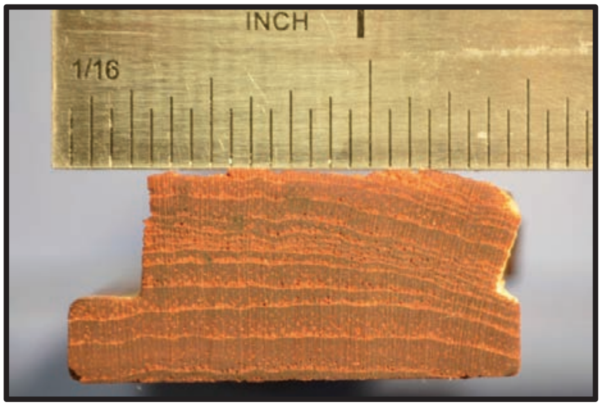


Figure 4.21. Specimen G, top end grain, after sanding.

Vertical Sawn

Vertical-sawn lumber is cut to be as close as possible to the radial face of the log (the wide face is in a radial line from the center of the log to the outer edge). This results in growth ring bands that are nearly perpendicular to the wide face of the element and a minimization of tangential wood. Vertical-sawn wood exhibits the least movement due to shrinkage and swelling in service. Vertical-sawn lumber is the most expensive type of cut because it is the least efficient use of the log. Weathering rates between earlywood and latewood can vary considerably with this type of cut because earlywood tends to be less dense and erode at a faster rate than latewood, which can result in a striped, textured appearance over time.

Specimens C and S are vertical-sawn slats (figs. 4.22 through 4.25). Both specimens have significant surface texture, but specimen C is significantly eroded while specimen S exhibits minor erosion. This difference may possibly have to do with the number of growth rings per inch (specimen C has three growth rings per inch; specimen S has seven growth rings per inch) or the location of the specimen on the building (specimen C was originally located on the south elevation of NL6C, facing the courtyard; specimen S was located on NO3E, facing the ocean), or a combination of thesefactors.

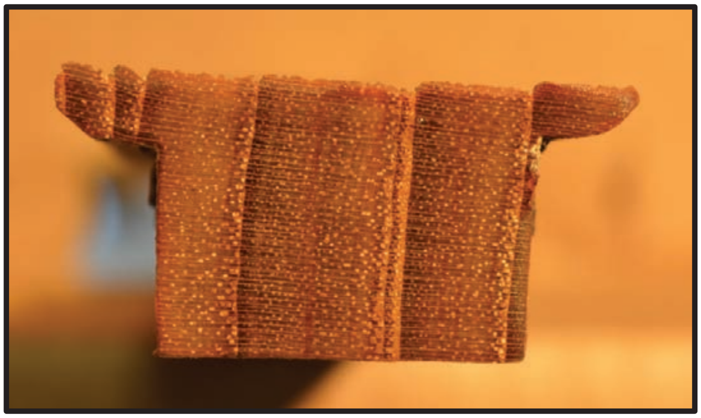


Figure 4.22. Specimen C, top end grain, showing vertical grain orientation and erosion of the earlywood.

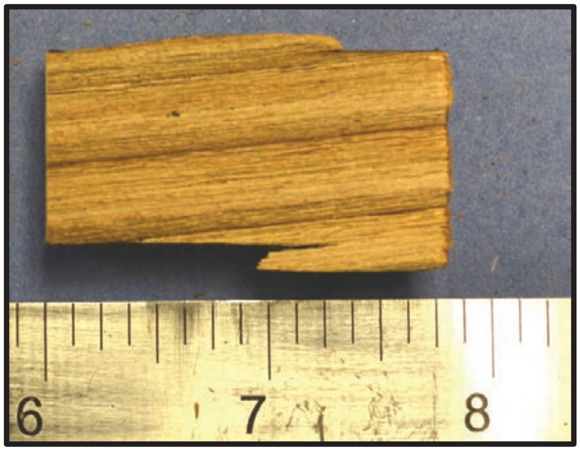


Figure 4.23. Small portion of specimen C showing extensive erosion of the earlywood on the exposed face.

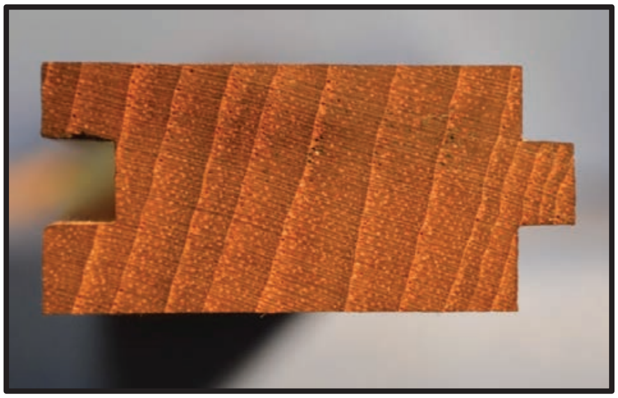


Figure 4.24. Specimen S, top end grain, showing predominantly vertical grain orientation.

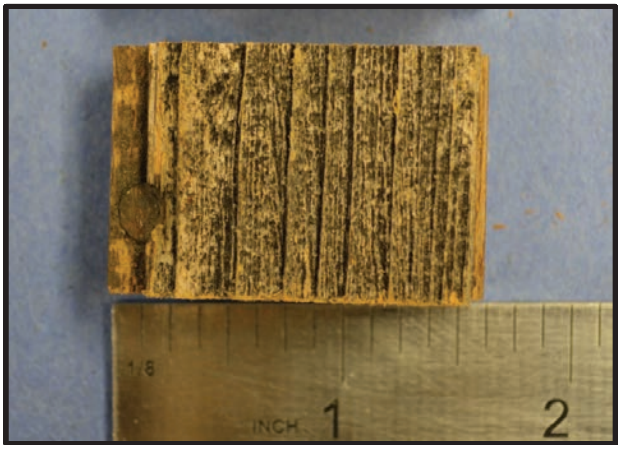


Figure 4.25. Small sample from the bottom of the exposed face of specimen S showing typical grooved weathering pattern of vertical grain elements.

Rift Sawn

Rift-sawn lumber is wood that generally has both flat-sawn and vertical-sawn elements (although the term *rift sawn* is sometimes used interchangeably with *vertical sawn*). The growth ring orientation in this type of cut is diagonal to the width of the piece. This type of cut commonly intergrades into vertical-sawn and flat-sawn cuts within the same board. Rift-sawn lumber tends to have more limited movement in service than flat-sawn lumber, but greater movement in service than vertical-sawn lumber.

The majority of specimens removed during the December 2013 site visit to the Salk (specimens A, F, H, J, K, L, M, O, and Q) are rift sawn. An example is shown in fig. 4.26.

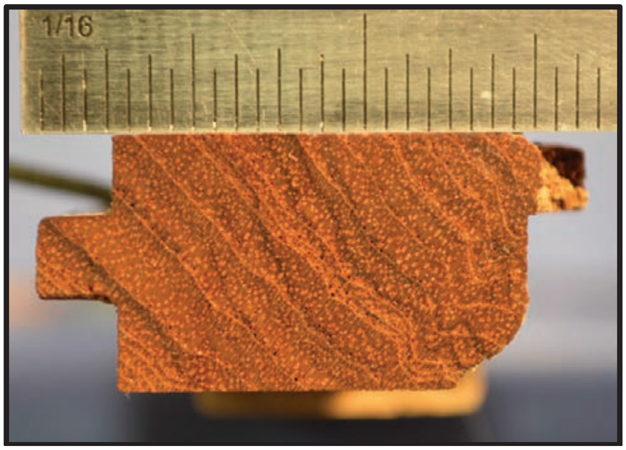


Figure 4.26. Specimen H, top end grain, showing rift-sawn grain pattern.

Tree Center in Relationship to the Exposed Face

As previously discussed, growth ring orientation plays an important role in movement in service and weathering characteristics. Another important aspect of growth ring orientation is the location of the pith, or tree center, in relationship to the exposed face of the piece. This relationship also has an impact on wood movement in service. For example, wood cut along the tangential face tends to shrink and swell more with changes in moisture content. In flat-sawn boards, this results in cupping or crowning because the face with the largest portion of tangential wood (and thus the face farthest away from the tree center) moves the most (fig. 4.27). This relationship was identified for all of the teak specimens and can be found in table A-2 in the appendix.

Figure 4.27. Flat-sawn deck board that has crowned due to differential shrinkage and swelling (material not from the Salk).

Specific Gravity and Moisture Content

Specific gravity of wood is the ratio of the density of the wood to the density of water at 4° C and 1 atmosphere of pressure. Reference-specific gravity values for wood are based on volumes measured typically at either 12 percent moisture content or in a saturated condition (fiber saturation point). Once the volume is measured, the moisture is driven from the samples to establish the oven-dry weight of the wood substance (because moisture can dramatically influence the weight). Thus, specific gravity is based on a wet volume but a dry weight.

There are two primary reasons that specific gravity is of interest to A&A's work on the Salk. One reason is that specific gravity of the wood affects rate of erosion due to weathering; lower-density wood erodes more readily than higher-density wood. The second reason is that lower-density material of the same species may be indicative of plantation-grown material, whereas higher-density material of the same species is usually indicative of naturally-grown timber.

Specific gravity was determined for eleven of the specimens (B, C, F, G, H, J, L, O, P, Q, and S. Specimens I, K, and M were not thick enough in cross section to conduct specific gravity tests in accordance with ASTM D 2395, Standard Test Methods for Specific Gravity of Wood and Wood-Base Materials. Small samples were cut from various specimens removed from the Salk and sanded to be uniform in dimension (fig. 4.28). The dimensions of each sample were measured and the samples were weighed on a balance in accordance with ASTM D 2395.

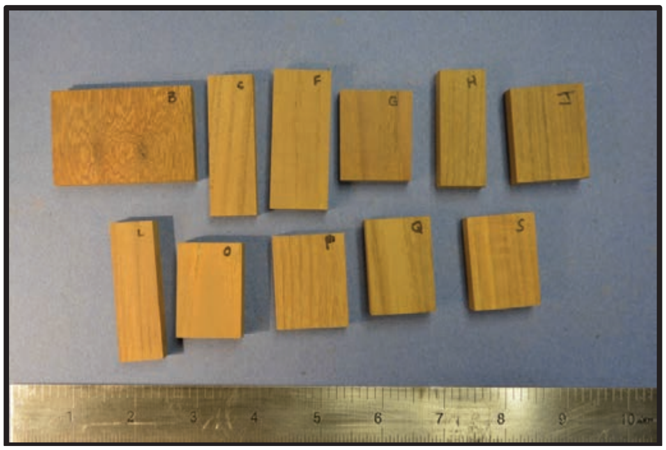


Figure 4.28. Samples after preparation for specific gravity testing.

Moisture content of each sample was determined in accordance with ASTM D 4442, Standard Test Methods for Direct Moisture Content Measurement of Wood and Wood-Base Materials, Method A. Weights of the samples were taken at twenty-four-hour intervals until the weights were stable, indicating that the moisture in the sample had been driven off (oven-dry). The oven-dry weight was used to calculate the specific gravity at the initial moisture content. Because the specimens were removed from the Salk and stored in the laboratory until the samples were cut, the moisture content was less than the typical reference value. This is not of any significant consequence to the teak analysis other than recognizing that the specific gravity values calculated are slightly higher than they would have been if they were based on the volume of the samples at 12 percent moisture content.

Table 4.1. Moisture Content and Specific Gravity for Salk Samples

Sample	MC (percent)	Specific Gravity MC = 0
B	7.2	0.56
C	6.6	0.54
F	6.8	0.58
G	7.1	0.64
H	8.1	0.61
J	8.2	0.61
L	6.6	0.54
O	8.0	0.57
P	8.2	0.57
Q	8.2	0.55
S	8.0	0.67

Specific gravity and moisture content values for the samples are given in table 4.1. The specific gravity values for the eleven teak samples ranged from 0.536 to 0.665. This range is consistent with that of naturally grown teak, although the lower end of the range overlaps with that of plantation-grown teak.

Interestingly, the specific gravity data do not correlate to number of growth rings per inch, rate of erosion, or degree of surface texture. It is generally assumed that a low growth ring count would result in a lower specific gravity value and that specimens with lower specific gravity values would have greater rates of erosion and more surface texture due to lower densities, but no clear-cut correlations can be identified from the specimens that were tested.

Prior Treatments

The Salk staff identified that the following treatments that had been applied to the teak.

- Abrasive cleaning (bleach and wire brush cleaning)
- TE-KA, two-part teak cleaner (manufactured by ITW Polymers Coatings North America; according to the available material safety data sheets (MSDS), part A contains 5% to 10% sodium hydroxide and part B contains 10% to 30% phosphoric acid)
- Oil/varnish or other treatments (most visible in areas with a deep red appearance)

Analysis of wood samples by GCI staff confirmed that multiple chemical residuals from these treatments were found, and the treatments were likely used at various times over the life of the structure. An oral interview with John E. "Jack" MacAllister, the architect who worked with Louis Kahn during construction of the Salk, also confirmed that these treatments were likely used.

For a detailed review of the treatments and their chemical components, please refer to GCI scientific reports.

V. ANALYSIS OF EXISTING CONDITIONS

Identification of Mechanisms of Deterioration

General Observations

It is helpful to examine the teak fenestration panels as a whole to gain perspective on general patterns of weathering and discoloration that can be identified. Figures 5.1 through 5.8 are composite images of the various elevations that show general trends of black spore growth, bleaching, and weathering.

Figure 5.1. North office tower, all elevations.

Figure 5.2. North study towers, north (A) elevations.

Figure 5.3. North study towers, west (B) elevations.

Figure 5.4. North study towers, south (C) elevations.

Figure 5.5. South office tower, all elevations.

Figure 5.6. South study towers, north (C) elevations.

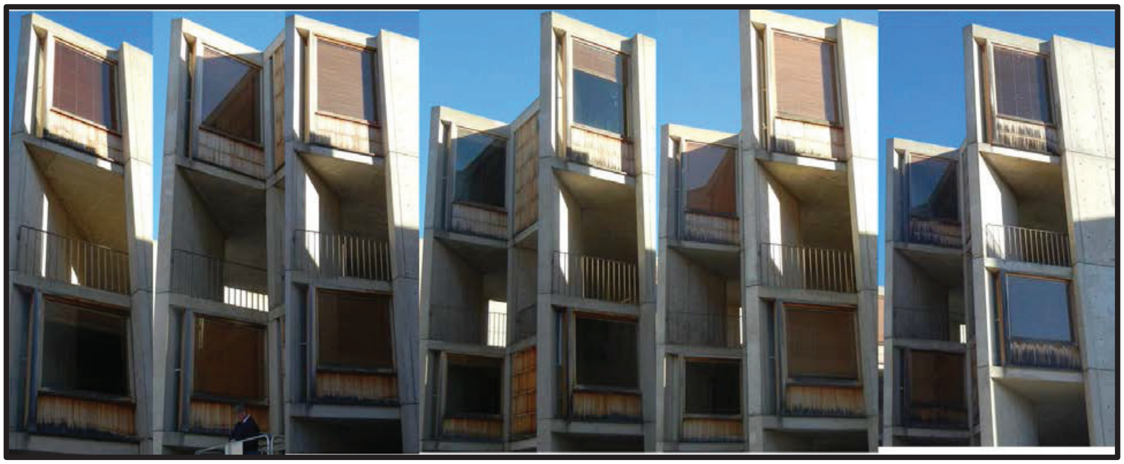


Figure 5.7. South study towers, west (B) elevations.

Figure 5.8. South study towers, south (A) elevations.

Visual Assessment

In general, based on visual observations, the orientation of the panel and the degree of protection (in the form of overhangs) have a significant impact on the weathering and discoloration of the teak. North, unprotected elevations (north office, north elevation, and south office, north elevation) do not show significant bleaching overall but do show that graying of the wood surface and black spore growth increases as the elevation (height) increases, with the top floor panels exhibiting the most severe spore growth and graying.

South, unprotected elevations (north study towers, C elevations facing the courtyard, unprotected south study towers facing the laboratories, the south elevation of the north office tower, and the south elevation of the south office tower) show significant bleaching that increases with elevation (height). Areas protected by overhangs retain more of the orange color associated with past surface treatments (see fig. 5.8).

West-facing teak panels show increasing black spore growth with increasing proximity to the ocean. The west-facing panels on the office towers show a combination of weathering, including graying of the wood, erosion, and surface texture, bleaching/fading, and black spore growth, all of which increase with increase in elevation (height).

Erosion and Surface Texture

Many of the vertical slats exhibit signs of weathering, including erosion of the exposed face. In order to understand the rate at which the teak is being eroded, and to understand its remaining service life, various dimensions of the slats were recorded and compared to original nominal dimensions. Only the slats were analyzed, not the louvers. Of the three louvers included as specimens for analysis, only one was removed from an extant window wall assembly. The others were removed from the Salk maintenance staff workshop and their original locations and length of service are unknown, so any efforts to define rates of erosion and surface texture would be inconclusive.

Erosion of the entire exposed face of the slats results in a loss of material. This impacts the service life of the teak and is distinguished from surface texture (or roughness), which is the result of differential weathering of softer earlywood and denser latewood. This surface texture can impact the rate of erosion. Field conditions, particularly for the slats on the north study towers facing the courtyard (C elevations), indicate that a significant amount of thickness has been lost due to erosion of many of the slats.

A&A and GCI staff made initial assumptions that some of the slats were half-lap/shiplap and some were tongue and groove, based on the profiles of the specimens that were removed for analysis. Subsequent investigations indicate that it is likely all of the slats were originally tongue and groove, and those that appear to be shiplap have lost enough thickness to cause failure of the upper groove rail or to eliminate the upper rail entirely under severe weathering down to the tongue. Figures 5.9 through 5.11 illustrate the surface profiles of various specimens when viewed from the end.

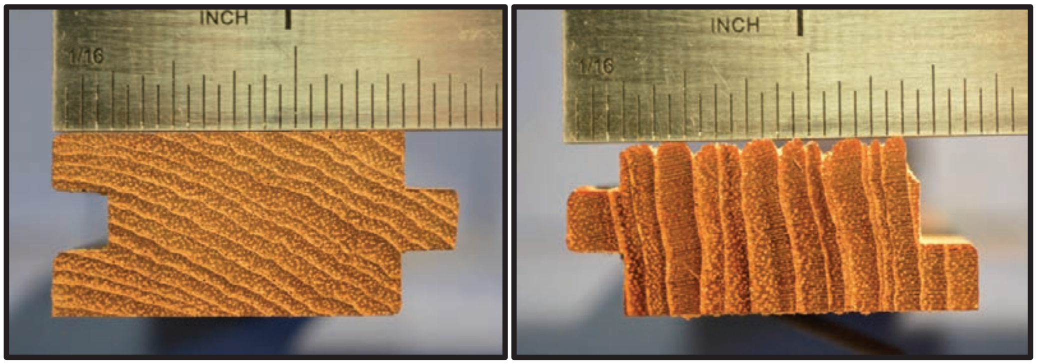


Figure 5.9. (Left) Specimen P, view of top, tongue-and-groove profile; (right) specimen W, view of top, apparent shiplap profile that erosion due to weathering has resulted in failure and loss of the top groove rail.

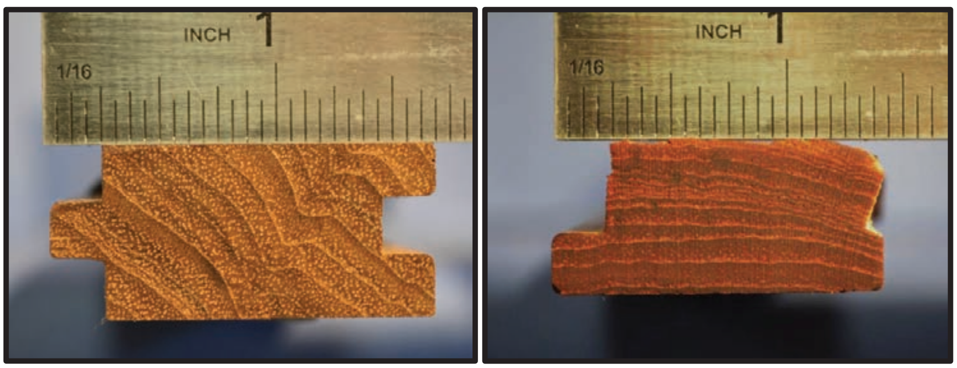


Figure 5.10. (Left) Specimen J, view of top, tongue-and-groove profile; (right) specimen G, view of top, apparent shiplap profile that erosion due to weathering has resulted in failure and loss of the top groove rail.

Figure 5.11. End grain of tongue-and-groove slats from panel that fell during a January 2014 storm. Note the loss of the upper groove rail on the slat, second from right.

To determine the amount of erosion, slat specimens were measured with calipers to measure the loss of thickness on the bottom of the slat, where the specimens typically were the thinnest. Because the bottom thickness was typically irregular due to surface texture, the mid-width thickness was used. This was compared to the assumed original nominal thickness of 0.75 inch. For slats, a remaining thickness between 90% and 100% was classified as minor erosion, while a remaining thickness of 80% to 90% was classified as moderate erosion. Specimens with less than 80% thickness remaining were classified as having severe erosion. Slats with severe erosion, under similar conditions of weathering since construction, would have a remaining service life of up to twenty-five years, depending on the extent of current erosion. Slats with minor erosion, under similar conditions of weathering since construction, would have a remaining service life of thirty to sixty years, depending on the extent of current erosion.

Most specimens were classified as having moderate to severe erosion, with values ranging from 0.03 to 0.27 inch of thickness lost. All the samples with severe erosion come from either south-facing or west-facing elevations. It should be noted, however, that specimens C, F, L, and M are T-shaped slats that are assumed to have been inserted last during construction of the panels and were glued in place. As such, they may not have had the same original thickness as the tongue-and-groove slats.

Surface texture (or roughness) was calculated using maximum and minimum bottom thickness. Based on the percentage difference between the two, the quantitative surface texture categories can be defined as minor (less than 5% difference), moderate (between 5% and 10% difference), and severe (more than 10% difference). Most specimens were classified as having only minor surface texture, with values ranging from less than 1% to over 16%. Surface texture, a function of the orientation of the grain in the slat, has a minor impact on rate of erosion of the entire slat but a significant impact on appearance. This is discussed in the next section.

Impact of Orientation of Grain and Tree Center in Relationship to the Exposed Face

Although there are no clear visual indicators, such as wire brush marks, that would give clues as to the impact prior cleaning programs have had on erosion rate of the teak, it is possible to draw some conclusions onerosion and surface texture of the slats based on orientation of grain and type of saw cut. Table A-2 in the appendix shows the growth ring orientation of the tongue-and-groove slat specimens.

There are thirteen tongue-and-groove slat specimens. Eight slats are rift sawn, three are flat sawn, and three are vertical sawn. Only one of the specimens (specimen F) was identified as having the tree center located toward the exposed face. All other rift-sawn or flat-sawn slats have the tree center located toward the back face. Vertical-sawn slats have the tree center located toward the left or right side. Based on the limited number of analyzed specimens, the location of the tree center in relationship to the exposed face is not useful for explaining weathering performance of the wood.

However, the grain orientation can be used to explain some weathering patterns. Vertical-sawn specimens generally exhibit the most significant surface texture, and in many cases the most significant erosion, depending on exposure and elevation (height). This type of weathering pattern makes sense, particularly for areas that were cleaned with wire brushes along (following) the grain. In rift-sawn and flat-sawn wood, pockets of soft earlywood on the exposed face will have dense latewood behind or underneath it; thus, once the earlywood wears away, due to either natural weathering processes or mechanical processes, erosion rate slows because dense latewood is exposed.

Vertical-sawn wood has dense latewood and softer earlywood in vertical bands that extend the width of the slat; because there is no overlap between earlywood and latewood due to the type of cut, the earlywood bands will erode at a much faster rate than the latewood bands, leaving ridges or striations of heavy surface texture. Table 5.1 shows the type of saw cut and location and orientation of the slats in their original locations.

Table 5.1. Saw Cut and Exposure of Specimens

Sample	Location	Saw Cut	Orientation
C	NL6C	vertical	south
F	NU7C	rift	south
G	NU7C	flat	south
H	SL8B	rift	west facing on north elevation
J	SL8B	rift	west facing on north elevation
L	SO5K	rift	south
M	SO5K	rift	south
O	SL8C	rift	north
P	SL7C	flat	north
Q	NL8A	rift	north
S	NO3E*	vertical	west
V	NO6K	rift	south
W	NO6K	vertical	south

*Possibly NO5K

Past Cleaning and Surface Treatments

As discussed in section IV, the specimens were examined under the microscope for evidence of past cleaning (scrubbing with a wire brush and a bleach solution) and surface treatments. Figures 4.4 and 4.5 show stereomicroscope images of the teak with a past surface treatment and an adhesive, respectively. Visible evidence of wire brush cleaning has not conclusively been identified under the stereomicroscope. This may be due to the fact that aggressive cleaning practices on the teak were reportedly halted in the 1990s and natural weathering processes have continued eroding the wood. As a result, striation marks or other indicators of wire brush cleaning cannot be distinguished from other weathering processes.

Specimens were examined for evidence of past surface treatments such as protective coatings. Remnants of surface treatments were identified on specimens H, I, J, Q, and S. Evidence of surface treatments was found on the exposed faces of the specimens but not on the protected top edge (fig. 5.12). Analyses of prior surface treatments are discussed in detail in GCI reports.

Figure 5.12. Specimen J showing the uncoated, protected top edge (left) and the surface treatment on the exposed face (right).

In summary, the differential weathering and discoloration of the teak, based on visual observations and analyses of removed specimens, is a function of the following:

- **Exposure conditions.** Orientation, elevation, and height of the teak assemblies exposes the wood to different conditions that are conducive to fading/bleaching, erosion, and growth of black spores. Wood in protected locations such as the A elevations of the north studies and under overhangs such as the panels outside the library have better retention of finishes and color, and less erosion, than those in other, less protected locations. Wood that is exposed to moist ocean air or fog, such as that on the north elevation of the office wings, tends to have greater potential for biological growth than wood in protected locations or in locations where the sun can quickly dry accumulated moisture.

- **Cut of the wood and number of rings per inch.** In general, flat grain specimens have less surface texture than vertical grain specimens, and samples with a higher rings-per-inch count have less erosion and surface texture. However,erosion rate of the specimens is more a factor of exposure conditions than cut of wood or rings-per-inch count.
- **Degree or severity of past mechanical cleaning.** Based on visual observation, the teak assemblies facing south or west on the north studies within the courtyard exhibit the most severe erosion. It seems likely that assemblies within the courtyard were cleaned more frequently than assemblies that cannot be seen from the courtyard. Additionally, chlorine bleach (used in the cleaning process) degrades wood cellular bonds. The combination of high UV exposure, stiff metal brushes that removed softer earlywood, and chlorine bleach has likely greatly accelerated natural weathering processes.
- **Metal oxide staining.** This type of staining has occurred due to the use of galvanized metal fasteners in a high slat environment and erosion of the teak, which has led to the exposure of the nail heads. This type of discoloration is difficult to remove due to the depth of penetration of the stain; however, it can be prevented through the use of stainless steel fasteners.

It bears mention that wood is a natural product with inherent variability. Some differential weathering and coloration is to be expected, and no wood, if left untreated, will achieve an entirely uniform appearance over time. Wood with different environmental exposures will exhibit differential coloring and weathering because of the impact that exposure has on biological growth, bleaching/fading, and erosion. Differences in appearance in new construction can be minimized through tightly controlled specifications for material. The variability in cut and rings-per-inch count in the existing teak material in the window wall assemblies means that even in panels with the same exposure, differential weathering will occur.

VI. CONSIDERATIONS FOR ESTABLISHING TREATMENT RECOMMENDATIONS

The GCI is providing treatment recommendations for the teak window wall assemblies at the Salk. However, A&A is providing technical information for consideration in establishing and selecting a treatment option. The considerations are grouped below under four primary subheads. The first two subheads address the primary issues impacting the teak: long-term performance issues, including deterioration of the plywood and lumber framing, termite activity, and erosion of the teak panels; and appearance issues, including patina, bleaching, biological growth, cleaning, and coating. The third subhead outlines an inspection protocol to prioritize repairs to treatments, and the final subhead addresses repairs and replacement of the teak window wall assemblies.

Long-Term Performance Issues

Deterioration of Framing Lumber and Plywood by Termites and Wood Decay

Although the initial concern at the Salk was the condition of the teak window wall assemblies, during the field investigation it became apparent that a more pressing concern is the condition of the structural lumber and plywood securing the assemblies to the buildings. Due to a combination of construction details and the effects of aggressive cleaning and weathering, some of the assemblies have allowed for moisture intrusion into the wall cavities, which has led to wood decay and aided termite infestation and deterioration of the structural framing lumber and plywood in some locations.

Drywood termites can survive in wood with very low moisture contents, but wood that has even slightly higher moisture contents than the surrounding material is susceptible to drywood termite activity. As the teak slats have weathered, small gaps have opened in some of the panels, allowing for water in the form of precipitation or fog to penetrate into the wall cavity and, in some cases, allowing termites to access the untreated framing lumber.

Teak is naturally resistant to termites, including drywood termites, but the framing lumber that supports the assemblies is not, nor are the solid wood furring strips to which the teak slats are fastened (some furring strips may be teak plywood, which has greater natural resistance to termite attack). Samples removed from the framing lumber were identified as white fir (*Abies* spp.), a native softwood species group that has no natural resistance to termites. White fir is sold as the commercial group spruce-pine-fir (SPF).

Erosion of the Teak

Modifications to prolong the service life of the exterior teak are primarily independent of treatments intended to address air and water infiltration. Ultimately, the severely weathered and eroded teak slats will allow for moisture and air penetration unless modifications are made to the construction details or the eroded material is replaced with new teak slats. However, it is important to note that even if the weathered slats were replaced with new material, the wall cavities would remain susceptible to moisture and air penetration due to the method of construction and the lack of an effective moisture/air barrier within the wall cavity.

Determining a suitable treatment for the exterior teak depends largely on the priorities and intent of the Salk. While severely eroded teak slats that no longer form a tight joint with surrounding slats may require replacement, determining the need to replace slats that remain serviceable is a function of priorities as identified by the Salk (see “Inspection Protocol,” below). For example, if a certain appearance is desired (e.g., that the teak assemblies maintain the color and texture of freshly milled wood), then recommendations for replacement, treatment, and maintenance will differ significantly from recommendations for treatment of the teak necessary only to address air and water infiltration.

To preserve as much of the original teak as possible, the teak panels could be disassembled and retrofitted with a vapor barrier backer board and shims behind the teak slats. The details of such an assembly should be established by a licensed architect. In this instance, severely weathered teak can remain in service even though the slat may allow water or air penetration; the vapor barrier backer board would prevent additional infiltration into the wall cavity. The backer board and wood shims should be made from pressure-treated wood or alternative materials to prevent termite activity. Corroded metal fasteners should be replaced with stainless steel fasteners, and the teak slats may be cleaned, brightened, and/or lightly sanded to reduce variation in surface texture and color. A treatment, such as a water-repellent preservative or mildewcide, may be applied to slow the growth of biological organisms; long-term maintenance requirements of such a treatment should be considered prior to application.

Additional levels of intervention may include application of an epoxy system applied to the end grain of the teak slats to minimize color changes due to moisture and weathering effects, but some color variation and the surface texture of the weathered slats would remain. The overall appearance would be similar to the existing appearance of the panels, as it would not be possible to remove all of the metal oxide staining nor remove all of the surface texture from the slats; however, significant moisture staining and areas of distinct surface texture would be minimized. The estimated service life of the teak slats with this type of intervention is twenty to fifty years, depending on the current thickness of the slats.

A similar, alternative method to preserve the existing teak while creating a more uniform appearance in color and texture would be to disassemble the slat panels, install the vapor barrier backer board and shims, and reinstall the teak slats with the interior (unweathered) faces on the exterior. The slats would likely not be sufficiently watertight or airtight to use without the backer board, but the interior faces of the slats have, in essence, a freshly milled appearance. End grain treatments, such as trimming the bottom end grain slightly and/or applying a marine-grade epoxy, may be used to reduce the development of moisture stains and discoloration. The estimated service life of the teak slats with this type of intervention is also twenty to fifty years.

While a sacrificial coating could, theoretically, be applied to the teak assemblies to slow the process of erosion, the practical challenge of finding a suitable product makes this an unlikely option. Only film-forming coatings (pigmented paints) provide enough protection from weathering to restrict erosion; these include clear coatings and pigmented coatings. Clear coatings typically alter the sheen and color of the wood and are not UV resistant, resulting in rapid breakdown of the coating and minimal protection of the wood substrate. Semitransparent, opaque, and other pigmented coatings offer more protection against weathering but alter the appearance of the assemblies even more significantly than clear finishes, as the natural wood color would not be visible. Most film-forming coatings will fail at the bonding surface without regular maintenance, meaning that the coating will bubble or peel away from the wood rather than wear away gradually, leaving a splotchy, uneven appearance over time.

Appearance Issues

One option regarding the appearance of the assemblies is to accept variations in the appearance and let the teak continue to weather naturally. Through research conducted by GCI and A&A, it appears that this was the intent of Louis Kahn when designing the building and specifying the use of teak for the window wall assemblies. However, because the wood is exposed to different microclimatic conditions, it will continue to experience differential weathering and will never appear uniform on all facades of the buildings. Bleaching from the sun and the gray patina that develops are natural parts of the weathering process and cannot be prevented. Surface treatments and cleaning can slow the process and mitigate extreme color variations, but such an approach requires regular maintenance and, potentially, considerable cost.

Another option may be to apply a bleaching and weathering product designed to create a more uniform, weathered appearance. These products can mimic the look of weathered wood while accelerating the natural weathering process and are intended to require little additional maintenance, as the product wears away over time, exposing the wood to natural weathering processes. Use of these products has been met with mixed results.

Biological Growth Cleaning and Control

In the cleaning approach discussed in the “Replacement Details” section below, low-pressure hoses are used to wet the wood surface, followed by cleaning with a mild oxygen-bleach and soap formula using a natural bristle brush and rubbing gently across the grain (without following the grain ridges). Light sanding may facilitate some removal of the fungal spores as well as reduce the surface texture and the available microclimates that encourage fungal growth. However, aggressive sanding will result in additional loss of section and should not be used. In some instances, this may mean that all of the black biological growth cannot be removed. In those instances, if the appearance is not acceptable, the slat should be replaced.

Cleaning will be necessary on a short maintenance cycle (two to four years) to prevent fungal growth buildup. It should be noted that cleaning, even with low pressure and natural bristle brushes, will likely remove the gray, weathered patina in addition to the fungal growth. Thus, the color of the panels may remain irregular for the foreseeable future and will not develop a uniform silver-gray patina (as may be desired). If cleaning is used alone without a chemical treatment to inhibit biofilm growth, an annual or biannual maintenance cycle should be expected. Alternatively, the assemblies may be thoroughly cleaned, and a product designed to inhibit biofilm growth may then be applied; this approach may eventually extend the maintenance cycle to every four or five years.

To retard the growth of black biofilm, a water-repellent preservative (WRP) may be applied. These treatments typically last six months to a year and require regular maintenance/reapplication to remain effective. Alternatively, a borate-based solution may be applied. Borates are a low-level-toxicity fungicide that can inhibit fungal growth while allowing a silver patina to develop. Initial applications of a borate solution may require semiannual or annual application, but subsequent applications may need to occur with diminishing frequency over time.

With either a WRP or a borate solution, the wood should be thoroughly cleaned before application. Borate solutions may be applied when the wood is still damp; WRPs should be applied when the wood has dried (following specific manufacturer’s instructions). With either product type, there should be minimal color change to the teak. Both products may darken the wood slightly, but this effect will diminish over time. As with any chemical application, the potential impact on the concrete and the surrounding environment should be assessed before application.

Topical treatments offer relatively short-term solutions to the issue of black biofilm on the teak assemblies. One primary cause for the growth of these fungi is the environment. These spores are naturally occurring in the air and need only a food source, adequate temperatures, and water to survive; there is no realistic way to eliminate the growth of the biofilm entirely. Another primary cause involves the teak panels themselves, which serve as a substrate through the accumulation of organic wind-blown debris and water in the crevices of the weathered wood surface. In order to mitigate the growth of the biofilm, either the food source must be removed, access to water must be prevented, or the temperature must be altered such that the environment is no longer conducive to fungal growth. Unfortunately, there is no realistic approach for the Salk that will completely prevent biofilm growth over the long term. However, modifications can be made to limit the amount of moisture that the spores have access to, as well as limit the easy availability of a food source.

Modifications can be made to the construction details to inhibit black biofilm growth. These include mitigating color changes by sanding and/or trimming vertical slats and applying a marine-grade epoxy to the end grain to inhibit moisture absorption. The primary goal would be to limit moisture intake through the end grain of the slats, thus providing an environment less conducive to the growth of the spores.

Modifications can be made to the teak, as described above, by applying a topical treatment to the wood that makes it a less conducive environment for the growth of black biofilm. The approaches may be combined to attempt to provide the most comprehensive mitigation possible.

Removal of Existing Coatings and Stains

Existing coatings (the orange patina of TE-KA or other treatments) can be removed through chemical stripping or sanding. If all panels are to be systematically removed and repaired, the surface treatments can be safely removed inside the appropriate containment system in a workshop. If the panels are to remain in place, they can be chemically stripped using an environmentally safe product that will not damage the concrete, or they may be sanded if they are tented and vacuum equipment is used to control the sanding dust.

Previously applied products may be chemically stripped, lightly sanded, or left as is to eventually weather away. It may be possible to even out color variation using brighteners and cleaners, but these products tend to be harsh on the wood fibers and can cause additional erosion; care must be used in their application.

Moisture stains can be mitigated with a brightener and cleaner; sealing the end grain (top and bottom) to inhibit moisture uptake and/or trimming the teak slats so that the bottom end grain is not in contact with horizontal surfaces/pooling water will prevent new moisture stains from developing.

Iron stains from corroded metal fasteners are difficult to remove because of the depth of the stains. Brighteners have had limited success, but they rely on chemical reactions between the ferrous metal and the wood cell components; these stains tend to be deep in the wood and the color may leach back out to the surface even after the surface stain and the fastener are removed. Possible options include leaving as-is, trying a cleaner/brightener, reassembling the panels with the interior wood on the exterior face, or replacing the slats with stains.

Inspection Protocol

Structural integrity of the framing lumber is critical for ensuring long-term public safety, and inspection and repair of deteriorated lumber should be considered a high priority. Although outside the scope of the initial wood investigation, the project team has determined that this issue cannot be overlooked and has outlined the steps for necessary inspection and treatment of the termite infestation and damage. The inspection protocol described below is intended to allow for the Salk to establish priorities for the teak panels so that repairs can be done in phases.

Every window wall assembly should be inspected, as there may be little or no visible evidence of termite activity. Additionally, due to the lack of a wood preservative, the framing lumber (and, in some cases, plywood) will remain susceptible to wood decay and termite attack; even if no termites are currently present in an assembly, they may gain access to and deteriorate the wood in the future. However, because there is clear evidence that some of the teak window wall assemblies are in distress while others appear to be in good condition, the inspection and repairs can be classified as high-, medium-, and low-priority assemblies.

Each assembly could be assigned a priority ranking based on a combination of field investigation results and internal information from the Salk maintenance staff on reported moisture intrusion locations. All assemblies with identified active termites or termite damage should be assigned the highest priority and inspected soon, as well as those with heavily weathered teak panels and evidence of moisture intrusion into the wall cavity due to gaps between slats. Next, those assemblies with weathered panels but no visible or reported evidence of moisture intrusion should be inspected, followed by those that appear sound or have tight joints between the teak slats, are predominantly not weathered, and/or are in protected locations. This priority list can be generically summed up as follows:

1) Any assemblies with identified termite damage (highest priority)
2) South-facing panels with known moisture intrusion issues and heavily weathered teak slats (high priority)

3) Exposed west- and north-facing panels with known moisture intrusion issues and heavily weathered teak slats (high priority)
4) South-, west-, and north-facing panels with no evidence of moisture intrusion but heavily weathered teak slats (medium priority)
5) South-, west-, and north-facing panels with teak slats with no evidence of moisture intrusion, in good condition with minimal weathering (low priority)

Inspection and remedial preservative treatment can occur simultaneously. The inspection should involve the use of a small-diameter videoscope. A hole will need to be drilled into every row of slats of each assembly from the exterior; care must be taken to avoid drilling into the asbestos panel. A ⅜-inch hole should be directly above the horizontal structural member and could be drilled near the center of the panel to allow for inspection of the entire length of the structural member inside the wall cavity. The hole needs to be only slightly larger than the diameter of the videoscope insertion tube. The videoscope can then be used to inspect for termite damage and/or deterioration due to moisture intrusion.

If the structural members are sound with no visible evidence of deterioration from termites or moisture, a chemical treatment specific to drywood termite control could be inserted into the wall cavity to deter potential termite activity. The hole should then be plugged with either a teak plug or a threaded plastic plug that will allow for subsequent inspections in the future. Treatment should involve the use of a low-toxicity chemical insecticide.[1] Additional wood preservative chemicals are not necessary and would do little to inhibit additional deterioration of the structural members due to wood decay, if present. Photographs should be taken with the videoscope to document conditions at the time of the inspection and provide a baseline for identifying potential changes over time.

For assemblies that have been identified as having active termites, the chemical treatment can be inserted into the wall cavity through the inspection hole to inhibit additional damage before repairs can be made. The severity of the termite damage and/or moisture deterioration may provide an additional means of assigning repair priorities; however, any amount of deterioration, whether due to termites or moisture, should be considered a high priority for repair.

Inspection of the teak window wall assemblies can occur primarily from the exterior to avoid disrupting study tower residents. However, in some cases, it may be desirable to inspect and insert a chemical treatment into the interior wall cavities as well. To prevent additional termite damage to the interior woodwork, any window wall assembly with

[1] See V.R. Lewis, A.M. Sutherland, and M.I. Haverty, “Drywood Termites,” *Pest Notes*, Publication 7440 (Davis: University of California, Aug. 2014, http://ipm.ucanr.edu/PDF/PESTNOTES/pndrywoodtermites.pdf) for chemical treatments allowed in California.

active termite infestation identified on the exterior should also be inspected and treated on the interior.

All of the window wall assemblies should be periodically reinspected to verify the efficacy of the treatment and to identify potential future deterioration from moisture intrusion.

Other Nondestructive Techniques

There are no nondestructive investigative techniques that have been shown to reliably detect drywood termite activity. Infrared thermography has been shown to detect subterranean termite activity when there is sufficient moisture present to support the termites and the colony is sufficiently large. Drywood termites have neither the moisture requirement nor the colony size of typical subterranean termite infestations; thus, infrared thermography is not a suitable technology for the identification of drywood termite activity or colony locations.

Detection of deterioration in the structural framing lumber is possible using resistance drilling; however, due to the sporadic and random colonization habits of drywood termites, several tests on every panel would be necessary in order to establish significant confidence that damage has been detected. Resistance drilling is a quasi-nondestructive technique for determining the relative density of wood. It is best suited for determining internal problems in wood components that do not show obvious signs of deterioration, such as surface decay. Any internal voids due to decay or insect damage at the location drilled can be detected by determining the relative density of the wood. The bit used for this type of drilling is a small, flexible needle with a ⅛-inch-wide paddle on the end; therefore, the damage can be quantified only at the drilling location, making an investigation conducted with resistance drilling extremely time-consuming. This technique would not be appropriate for investigating the teak window wall assemblies.

Other techniques used to assess the condition of wood, including digital radioscopy, ground-penetrating radar, and stress waves, have limitations that preclude them from being useful in this situation. Visual examination using the videoscope has the greatest probably of detecting either termite activity or deterioration in the framing lumber.

Teak Window Wall Assembly Repairs and Replacement

The teak window wall assemblies use tongue-and-groove slats of wood. Based on field inspection results, the slats are composed of flat-sawn, vertical-sawn, and rift-sawn material. The vast majority of the slats were cut as rift-sawn material, that is , the grain angle through the thickness of the piece is between 30 and 45°. The remaining slats were cut approximately equally from vertical-sawn and flat-sawn material.

Some of the performance characteristics of the slats can be linked to the type of cut. For example, flat-sawn material tended to have significantly less surface texture than vertical-sawn or rift-sawn material (fig. 6.1). Erosion rates may be similar; however, because flat-sawn slats have less surface texture (due to the manner in which the earlywood and latewood are exposed to weathering agents), the overall visual effect of the flat-sawn slats is of wood with a more uniform textural appearance than the vertical-sawn or rift-sawn slats.

Figure 6.1. Vertical-sawn and rift-sawn slats on the left show a rough, ridged surface texture, while flat-sawn slats on the right show a smoother, more uniform appearance. The black stains are due to corrosion of the nails, not to the cut of the wood.

Additionally, because of the general reduction in surface texture, flat-sawn slats tend to provide fewer microenvironments suitable for mildew and other airborne biological spores. The deep crevices created by erosion of the earlywood on vertical-sawn and some rift-sawn slats can allow for moisture and windblown debris to collect in these areas; the rate of evaporation in these crevices is slower than the rate of evaporation on smoother, exposed surfaces. Thus, the valleys on the wood surfaces of vertical-sawn and rift-sawn slats tend to accumulate more organic debris and biological growth than the valleys on flat-sawn material (fig. 6.2).

Based on the field investigation and analysis results, one repair/replacement option may be to consider replacement of severely weathered vertical-sawn and rift-sawn slats with flat-sawn material. Doing so would reduce the visual appearance of surface texture variation and color variation related to biological growth.

Figure 6.2. Two flat-sawn slats with minimal biological growth adjacent to rift-sawn and vertical-sawn material with more concentrated biological growth.

Replacement Details

For panels designated a high priority for repair, the deteriorated framing lumber should be replaced with pressure-treated material of similar or better quality than the existing wood. Specifying replacement SPF lumber in accordance with Western Lumber Grading Rules would be appropriate. Additionally, to provide for long-term durability, the wood should be pressure-treated with a preservative in accordance with the American Wood Protection Association's Use Category UC3A. This level of treatment is intended to protect exterior wood should it become wet. Although protected by the teak panels, this treatment level provides additional protection to the framing lumber and limits future concerns and maintenance requirements.

On the interior, the asbestos insulation panel should be removed. Alterations may be made to the construction details to prevent moisture intrusion into the wall cavity. Teak slats with erosion severe enough to expose the metal fasteners and cause metal oxide staining should be replaced. This staining cannot be removed without aggressive sanding and would erode the slat even further, thus making the slat too thin to have an effective tongue-and-groove connection.

Slats with moisture staining may be repaired by disassembling the window wall component, thoroughly cleaning the slat panel to remove biological growth and moisture stains (the tongue-and-groove slats do not need to be individually disassembled), sanding the top end grain of the slat panel slightly to prepare the surface for a protective coating, sanding or trimming the bottom edge of the slat panel slightly (less than ⅛ inch), and applying a marine-grade epoxy to the end grain (both top and bottom) only.

As discussed above, the panels can be cleaned with an environmentally safe oxygen bleach and water; the slat panels should be hosed with water (not by pressure spray), and the oxygen-bleach-and-water solution should be applied with a soft natural bristle brush. The brush should be used across the grain (not up and down following the grain) to limit removal of less-dense earlywood. This approach should remove surface stains and biological growth without significant additional damage to the slats. The slat panels should then be allowed to dry to equilibrium moisture content (EMC), typically less than 8% moisture content.

The moisture content of the wood should be checked prior to epoxy application to make sure the slats have reached EMC. Trimming the bottom of the slats to make them slightly shorter will prevent direct uptake of moisture through the end grain of the wood. Once the epoxy has cured, it will provide a protective barrier that should effectively inhibit any additional moisture uptake into the vertical slats, thus mitigating moisture staining, biological growth, and other color changes associated with the weathering process. This treatment will not prevent weathering from occurring but should prevent the types of color variation currently seen on the window wall assemblies.

For teak slat panels that need to be replaced, new material should be milled to current specifications (although modifications may be made to the construction details as explained above to mitigate color changes) and a new panel should be fabricated. Stainless steel fasteners (rather than galvanized material) should be used due to the highly corrosive saltwater environment; galvanized fasteners will eventually corrode in such a harsh environment. To reduce surface erosion, flat grain slats should be used; however, these replaced panels will appear visually distinct from the original panels and will have a distinct patina as they age.

Replacement Material

There are three possibilities for replacement material: (1) naturally grown teak, which was predominantly used in the original construction of the Salk and can be obtained; however, this market is the most volatile and ensuring the legality of the source material is difficult; (2) reclaimed teak lumber, likely harvested from natural forests and possible to obtain, but supply and volume change rapidly; and (3) plantation-grown teak, which is readily available.

The market for Southeast Asian-grown teak is currently quite volatile. In April 2014, a ban was implemented on the export of raw teak from Myanmar, the only country in the world that still exports raw teak. There is a large black market that continues to sell teak illegaly in the surrounding region, making teak lumber from Thailand, China, Laos, and Bangladesh suspect, as it may be sourced from Myanmar forests. Nonetheless, it is possible to purchase naturally grown teak legally, although it is unlikely that it will be certified by the Forest Stewardship Council (FSC). While naturally grown (nonplantation) teak lumber may be the preferred choice for historical accuracy and long-term durability, alternative sources of teak were explored.

The advantages of using naturally grown teak are primarily historical accuracy and durability. The disadvantages are availability, potential difficulties with importing the lumber, potential ethical issues that may conflict with the stated values of the Salk, verifying the legality of the source material, and cost. The advantages of using reclaimed teak are the same as those for naturally grown teak, provided that the "reclaimed" lumber was not recently harvested. Certification of authenticity is important when purchasing reclaimed lumber. The disadvantages of reclaimed teak are supply and, potentially, cost. The advantages of plantation-grown teak are availability and cost; the disadvantages are a potential lack of historical accuracy and potentially less durability due to the growth pattern of plantation-grown timber.

Regardless of the source, the request should be for rough-sawn 4/4 (1 inch thick) or 8/4 (2 inches thick) boards. Width can vary since the boards can be resawn to produce the 1 ½-inch by ¾-inch-thick slats. When requesting a bid on teak, it is imperative to specify *Tectona grandis* to ensure that true teak is supplied, not one of the many wood species currently marketed as teak. Additionally, the moisture content should be specified not to exceed 12% to limit warp or movement in service that may develop as the lumber dries and acclimates to the conditions in La Jolla. Additional specifications on the material may include a limit on the size and/or frequency of knots, a range of acceptable growth rings per inch, and requirements on the orientation of the grain. Sources of teak that could be potentially used for repairs on the Salk panels include the following:

Reclaimed and possibly naturally grown teak:

Burma Chindits Co.
Sanchaung Township, Yangon, Myanmar
Contact: Jamie Humphries
jamie@burmachindits.com
http://www.burmachindits.com/

Reclaimed, plantation-grown, and possibly naturally grown teak:

Bear Creek Lumber
Contact: Merle Kirkley
mjk@bearcreeklumber.com
Toll free: 866.457.3007
Office: 509.997.3007
Fax: 509.997.2040
Mobile: 509.668.8141
www.bearcreeklumber.com

Reclaimed teak:

TerraMai
Tel: 541.973.2301
Tel: 800.220.9062
Fax: 541.973.2308
info@TerraMai.com
http://www.terramai.com/

FSC plantation-grown teak:

Pacific Coast Teak
2111 Golden Hill Rd.
Paso Robles, CA 93446
Contact: don@pacificcoastteak.com
Office: 805.237.2100
Fax: 805.237.2122
http://pacificcoastteak.com/

VII. OTHER USE OF EXTERIOR TEAK BY LOUIS KAHN

Louis Kahn designed the Library at Phillips Exeter Academy (the Academy) in Exeter, New Hampshire, in 1966. Construction began in 1969 and was completed in 1971, after the Salk had been built. The building has a brick masonry exterior and teak fenestration panels at the windows fig. 7.1). The Academy campus is located about 8 miles from the coast, so ocean-related weather events are common. However, they do not get sea fog like the Salk.

A brief summary of the history of the Library teak fenestration panels is useful because of similarities to the performance and appearance issues regarding the Salk. The treatment option selected for the teak at the Library (outlined below) raises potential appearance and maintenance considerations for the Salk. While the initial intent of the Academy was to provide a uniform appearance on all teak fenestration panels, it became apparent that both elevation (aspect) and floor (height above ground) influenced appearance even in a relatively short period of time. To retain the "uniform" appearance, a maintenance program was implemented in which the treatment was to be reapplied on an approximately four- to five-year cycle. The treatment is typically applied to one elevation each year. The discussion that follows shows that attempting to retain a uniform appearance is both difficult and maintenance intensive.

Figure 7.1. North (left) and west (right) elevations of the Library at Phillips Exeter Academy.

In early 2014, A&A contacted the facilities staff at the Academy to discuss the teak fenestration units. Gary Tuttle has been working at the Academy for more than twelve years. He identified the construction of the panels as framing using 2 x 4-inch lumber, plywood sheathing, and, originally, felt paper over the plywood. This backing behind the teak boards is a more closed construction than that of the Salk panels, likely an attempt to prevent moisture intrusion into the wall cavities. Eight-inch-wide (by an estimated ⅝-inch to ¾-inch thick) teak boards with half-lap joints were nailed over the felt paper at the top and bottom and at the half-lap joint.

For decades after construction was completed, leaks at the roof and fenestration units resulted in deteriorated framing lumber. The Academy considered and made numerous minor modifications, but no significant modifications or treatments were conducted on the teak panels until approximately 1990. "Several major renovations have occurred, primarily in the last 15 years. Substantial work was done from June through October 1990 on the roof, attempting to resolve persistent problems with leaking at the windows. As this work ultimately proved unsuccessful, a major renovation effort from March 2002 through February 2003 addressed the leakage problems" (Changes and Renovations: Class of 1945 Library, Phillips Exeter Academy, https://www.exeter.edu/libraries/553_4380.aspx, accessed June 2014).

Gary Tuttle described the renovations of the teak panels, which involved the removal of the teak, removal of the felt paper, replacement of deteriorated plywood and 2 x 4-inch framing lumber, and reinstallation of the teak boards with neoprene strips under the half-lap joints to prevent moisture penetration at the joint. He did not recall any evidence of insect damage or deterioration of the teak other than the discoloration and splitting of a few boards during the restoration process. Once the teak was refastened, it was sandwiched against the neoprene to form a seal to prevent moisture penetration into the wall. There was a fair amount of decay in the plywood and framing lumber supporting the teak, but the vast majority of teak boards were able to be reused (approximately 98 percent; a few split during removal and were replaced).

It is A&A's understanding that the teak fenestration panels were left unsealed and untreated from the completion of construction until 2002. They had weathered to a gray patina, which was a point of controversy on campus: many people loved the color, and many hated the color. Ultimately, during the 2002-2003 repairs, the Academy decided to try to restore the panels to their original color. A contractor was hired to lightly sand the panel surfaces, clean and brighten the wood, and apply a teak oil to preserve the original color of the freshly milled teak. Tuttle indicated that the color of the oiled wood is darker than the natural teak was originally. The products used were supplied by West Marine products, including the cleaner and brightener, as well as the teak oil (Premium Gold Teak Oil). A bristle brush (not metal but possibly plastic) was used to clean the teak. The cleaning did raise the grain a bit at first, but the heavier ridges were sanded down.

The Academy has maintained a regular cleaning, brightening, and oiling schedule since the renovations in 2002-–2003. Approximately every year, the exterior teak panels on one elevation are cleaned, brightened, and reoiled; each elevation receives treatment approximately every four years. The cleaning started with the east/northeast elevation, as that is where the weathering effects are most severe.

In April 2014 Ron Anthony from A&A visited the Library and met with facilities staff and the library archivist to review the effectiveness of the periodic cleaning, brightening, and oiling procedure used by the Academy. Figure 7.2 shows the north elevation, which was treated during the summer of 2013 (approximately nine months before to the photograph was taken). Figures 7.3 through 7.5 show the condition of teak fenestrations on the first, second, and third floors, respectively, of the north elevation. Note that from a distance the overall appearance of the treated teak panels and trim is uniform in color and texture. However, in areas where the teak is protected from direct exposure to UV and precipitation, the color change is more pronounced as a function of the degree of exposure, as is shown just below the flashing in figure 7.6. Additionally, close examination revealed that some of the treatment has already begun to weather despite being applied less than a year earlier (fig. 7.7).

Figure 7.2. North elevation, Library at Phillips Exeter Academy.

The south elevation, which was treated in 2011, is shown in figure 7.8. Figures 7.9 through 7.11 show the condition of teak fenestration units on the first, second, and third floors, respectively, of the south elevation. Note that from a distance the overall appearance of the treated teak panels and trim is weathered and less uniform in color and texture than the more recently treated north elevation. The fenestration units have also differentially weathered with height (i.e., the teak on the first floor has weathered less than the teak on the second floor, which has weathered less than the teak on the third floor). Close examination revealed that some of the treatment has weathered severely and that the treatment has been largely ineffective (fig. 7.12).

Figure 7.3. First floor, teak fenestration units, north elevation.

Figure 7.4. Second floor, teak fenestration unit, north elevation.

Figure 7.5. Third floor, teak fenestration unit, north elevation.

Figure 7.6. The relatively protected teak just below the flashing has retained a much lighter color after treatment than the more exposed teak.

Figure 7.7. North elevation, first-floor teak fenestration unit. The arrows indicate where that the treatment has begun to fail.

Figure 7.8. South elevation, the Library at Phillips Exeter Academy.

Figure 7.9. First floor, teak fenestration unit, south elevation.

Figure 7.10. Second floor, teak fenestration unit, south elevation.

Figure 7.11. Third floor, teak fenestration unit, south elevation.

Figure 7.12. Close-up of teak fenestration unit on south elevation showing that the treatment has weathered severely and has been largely ineffective in maintaining the appearance or protecting the wood.

This brief overview of one type of treatment on exterior teak fenestration units is intended only to increase awareness of possible outcomes when considering treatment options for the teak at the Salk.

APPENDIX A: TABLES

Table A-1. Specimen Descriptions, Rough Dimensions, and Total Weights

Specimen	Element	Location	Description	Comments	Rough Dimensions	Metal Fasteners	Weight (grams)
A	small louver (interior)	from workshop	specific location of removal unknown	ovular shaped	2-1/16" x 19-1/16", 1/8" at narrowest, 5/16" at thickest	possible copper ring 3/8" long, 7/16" diameter, walls 1/32" thick	101.21
B	large louver (exterior)	from workshop	specific location of removal unknown	chamfered on opposite edges	3-3/8" x 23-5/16", 5/8" thick	possible copper ring 3/8" long, 7/16" diameter, walls 1/32" thick	401.76
C	vertical shiplap slat	NL6C	west panel, slat row 1, 2nd slat from west	weathered diagonally following grain, has less weathering near top of specimen where wood was slightly protected. T- shaped final slat glued in place on shiplap/half-lap panel	1-3/8" at widest x 23-5/16"; 7/8" wide under "T" at top, 13/16" wide at bottom; 3/4" thick at top, 9/16" thick at bottom	none	101.28
D	furring strip	NL6C	assumed 2 x 4 bottom furring strip, west panel, slat row 1, in area where slat was removed				
E	furring strip	NU7C	east panel, slat row 3, lower strip behind 2nd-4th slat from west	drywood termite damage			

Specimen	Element	Location	Description	Comments	Rough Dimensions	Metal Fasteners	Weight (grams)
F	vertical shiplap slat	NU7C	east panel, slat row 3, 2nd slat from west	iron oxide staining from metal fasteners in two locations on exposed face, has small lip of protected wood on one end	15/16" x 26-27/32"; 5/8" at smallest thickness, 7/16" at largest thickness	none	140.57
G	vertical shiplap slat	NU7C	east panel, slat row 3, 3rd slat from west	shiplap/half-lap slat, small knot 1/4" wide visible front and back face, 1 nail in place, 1 other nail hole, slight lip of protected wood one end only	1-5/8" x 26-7/8" x 11/16" at thickest; 9/16" at thinnest, opposite end from lip	finish nail approximately 2-1/2" long	226.92
H	tongue-and-groove vertical slat	SL8B	slat row 1 under window, 5th from north, multiple pieces	cut and/or broken into 5 pieces during removal, tongue-and-groove slat, grayed and black spores near bottom, top still has some red color; surface protected under horizontal slat has virtually no weathering at all	largest piece: 1-5/8" x 17-3/8" long, 3/4" at widest (bottom) and 11/32" at thinnest; tongue is 1/4" x 1/4"; groove is 1/8" thick x 1/4" deep	two nails, common (not finish nails), approximately 1-1/2" long	243.18
I	tongue-and-groove vertical slat	SL8B	slat row 1 under window, 6th from north, small portion only	tongue only? Portion protected under horizontal slat has virtually no weathering and original color; bleaching, weathering, and some black spores apparent at bottom	1/4" thick where protected; 1/8" at thinnest point	none	5.68

Specimen	Element	Location	Description	Comments	Rough Dimensions	Metal Fasteners	Weight (grams)
J	tongue-and-groove vertical slat	SL8B	slat row 1 under window, 4th from north	tongue-and-groove slat from south study, small piece of tongue broken off; virtually no weathering at top where slat was protected by horizontal slat, has original color there; possible Teka remnants that fade/bleach down the length, with black spores and gray weathering appearing near the bottom	1-11/16" x 24-1/8" x 3/4" at thickest; 11/16" at bottom, assumed thinnest	3 nails with heads approximately 1-1/2" long	256.88
K	large louver (exterior)	SO2K	21st louver from bottom, western-most row of louvers	blind louver same as specimen A, specimen is dirty and fragile, weathered paper-thin on one edge; some fading of color and black spores on one face, dirt and black spores on the other face	2-1/16" x 19-1/32"; 5/16" at thickest, 1/64" at thinnest	possible copper ring 3/8" long, 7/16" diameter, walls 1/32" thick	75.23
L	vertical shiplap slat	SO5K	center panel, slat row 2, 2nd slat from left/west	glue-in slat on panel, back has crazed adhesive on it, bleached with white silica and black spores visible, weathered along grain with a lip of protected wood	1-11/32" at widest "T" part x 21-7/16"; 3/4" at thickest, 9/16" at thinnest	none	88.71
M	vertical shiplap slat	SO5K	center panel, slat row 1, 2nd slat from left/west	T-shaped glue-in slat, back has some crazed adhesive, T wings are fragile, weathered paper-thin, bleached, and white silica and black spores visible; area of protected wood at one end	1-3/8" x 21-1/2" x 23/32" at thickest, 17/32" at thinnest		106.15

Specimen	Element	Location	Description	Comments	Rough Dimensions	Metal Fasteners	Weight (grams)
N	framing sill plate	SL8B	2 x 4 horizontal bottom framing member exposed by specimen removal of H, I, J, and K	bitter tasting			
O	tongue-and-groove vertical slat	5L8C	2nd from right	tongue-and-groove slat; two nails remain in specimen, area near top where protected and top end grain have virtually no weathering or discoloration. Exposed face has some color remaining near top, fading along length, black spores along length, and some graying at bottom. Surface texture suggests minimal weathering.	1-5/8" x 23-5/16" x 3/4" at top, thickest; 11/16" at bottom, thinnest	two nails, common (? not finish nails), approximately 1-1/2" long	232.9
P	tongue-and-groove vertical slat	5L7C	3rd from right	tongue-and-groove slat, area at top with virtually no weathering where protected, some color remains, fading progresses along length, very bleached at bottom, moderately textured	1-11/16 x 23-5/16" x 3/4" at top, thickest, and 11/16" at bottom, thinnest	two nails not in the wood but included in the foil wrapper, labeled top and bottom	233.04

Specimen	Element	Location	Description	Comments	Rough Dimensions	Metal Fasteners	Weight (grams)
Q	tongue-and-groove vertical slat	NL8A	#4 (get additional info)	tongue-and-groove slat, orange color on exposed face, small knot visible, small area at top with virtually no weathering where protected. Some surface texture following grain, no visible spores or graying, just some fading; groove broken at bottom from extraction. Very minimal surface texture on top 2/3s of exposed face.	1-5/8" x 31-1/2" x 3/4" top and bottom thickness	none	312.72
S	tongue-and-groove vertical slat	WOW N3	west face	tongue-and-groove slat same as others with area of unweathered near top, three nails, heavily textured along length, black spores at top and heavier concentration at bottom; middle nail split tongue at entry point	1-5/8" x 26" x 3/4" top and bottom thickness	3 metal nails estimated 1-1/2" long with heads, oxidized	275.48

Table A-2. Rings per Inch, Type of Cut, and Exposed Surface Conditions (Teak)

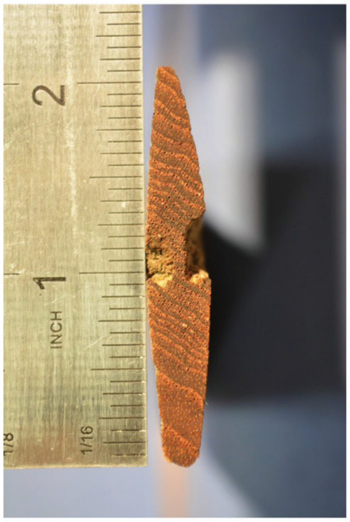
Sample	Rings per Inch	Predominant Orientation of Grain to Exposed face	Tree Center in Relationship to Exposed Face	Building	Orientation	Surface Texture	Bleaching	Black Spores	Graying	Erosion
C	3	vertical sawn	toward left	north	facing courtyard	severe	severe	minor	minor	severe
F	12	rift sawn	toward exposed face	north	facing courtyard	minor	severe	minor	none	moderate
G	5	flat sawn	toward back face	north	facing courtyard	moderate	severe	minor	none	moderate
H	16	rift sawn	toward back face	south	facing ocean	minor	moderate	moderate	moderate	moderate
I	16	flat sawn	toward back face	south	facing ocean	minor	moderate	moderate	none	NA
J	11	rift sawn	toward back face	south	facing ocean	minor	moderate	moderate	moderate	moderate
L	5	rift sawn	toward exposed face	south	facing south	minor	severe	moderate	minor	severe
M	11	rift sawn	toward exposed face	south	facing south	minor	severe	moderate	minor	severe
O	2	rift sawn	toward back face	south	facing courtyard	minor	minor	severe	severe	moderate
P	15	flat sawn	toward back face	south	facing courtyard	minor	minor	minor	none	moderate
Q	5	rift sawn	toward back face	north	facing laboratory (protected)	minor	none	none	none	minor
S	7	vertical sawn	toward right side	north	facing ocean	minor	severe	moderate	moderate	moderate
T	40	rift sawn	toward back face	north	facing ocean	minor	none	none	severe	minor

Sample	Rings per Inch	Predominant Orientation of Grain to Exposed face	Tree Center in Relationship to Exposed Face	Building	Orientation	Surface Texture	Bleaching	Black Spores	Graying	Erosion
U	9	part rift, part flat sawn	toward back face	north	facing ocean	moderate	none	none	severe	minor
V	12	rift sawn	toward back face, right side	north	facing south	moderate	severe	minor	minor	severe
W	9	vertical sawn	toward right side	north	facing south	severe	severe	minor	none	severe

APPENDIX B. SPECIMEN IMAGES

001. Specimen A side 1.JPG

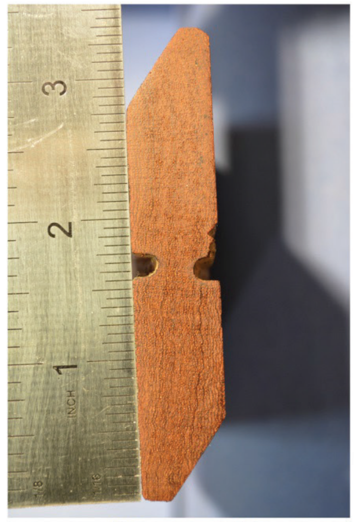
002. Specimen A side 2.JPG



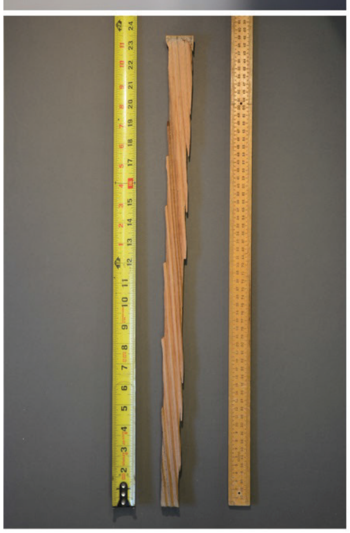
003. Specimen A end grain.JPG

004. Specimen B side 1.JPG

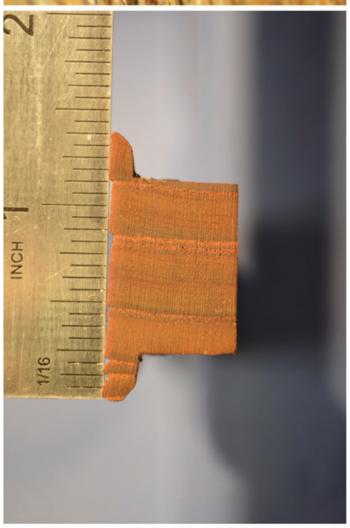
005. Specimen B side 2.JPG



006. Specimen B end grain.JPG

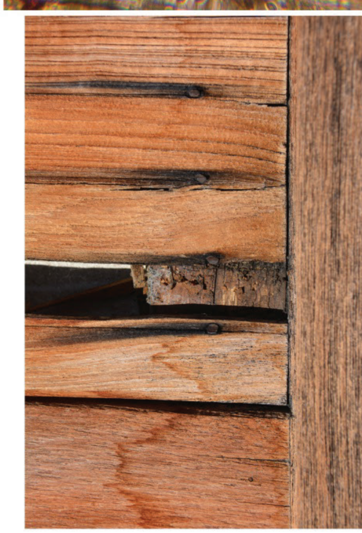


007. Specimen C exposed face.JPG

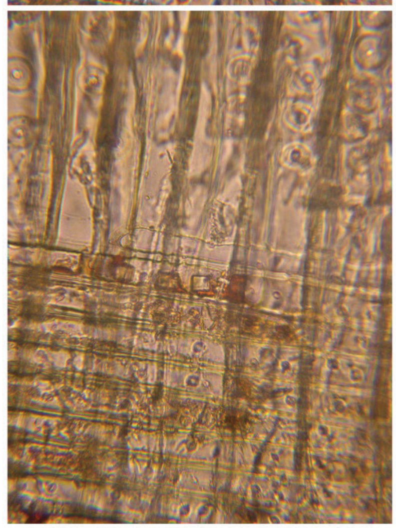


008. Specimen C end grain.JPG

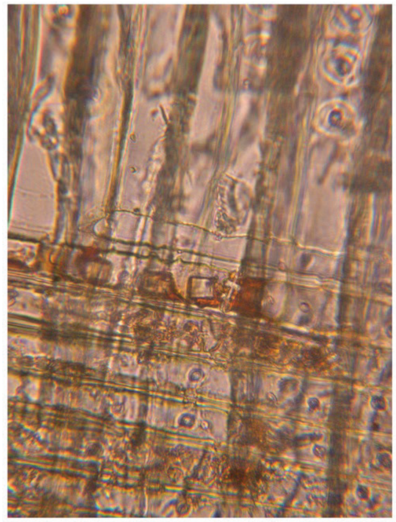
009. Specimen C surface texture.JPG



010. Specimen D panel NL6C.JPG

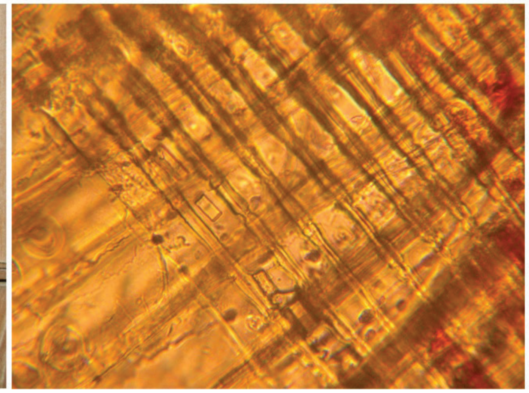


011. Specimen D 400x magnification.JPG

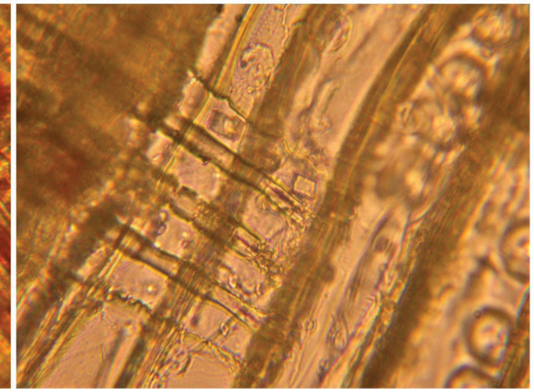


012. Specimen D 400x magnification.JPG

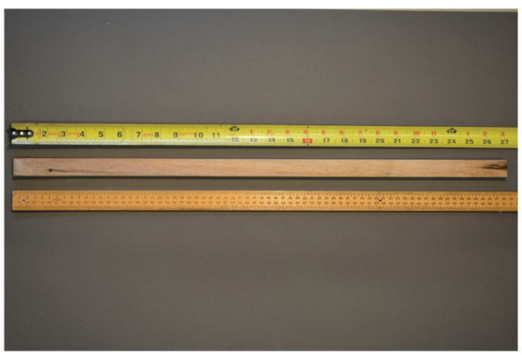
013. Specimen E panel NU7C.JPG



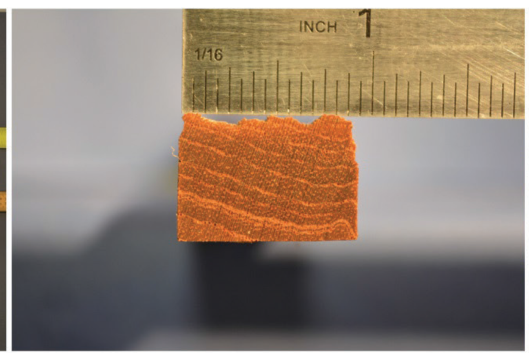
014. Specimen E 400x magnification.JPG



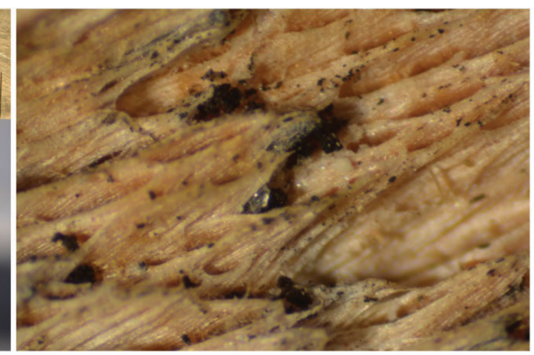
015. Specimen E 400x magnification.JPG



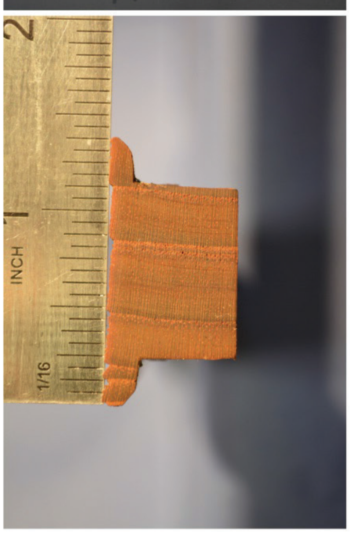
016. Specimen F exposed face.JPG



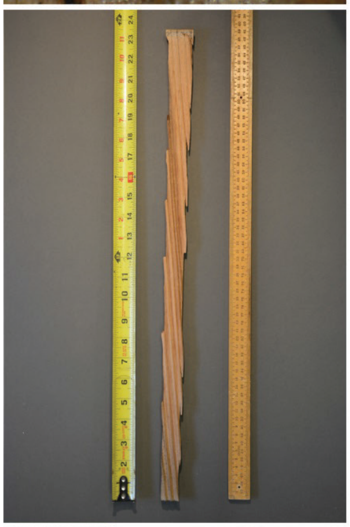
017. Specimen F end grain.JPG



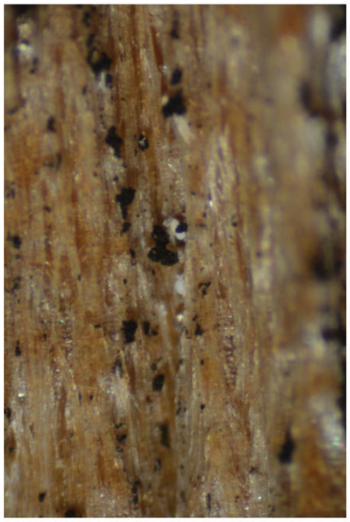
018. Specimen F spore growth.JPG



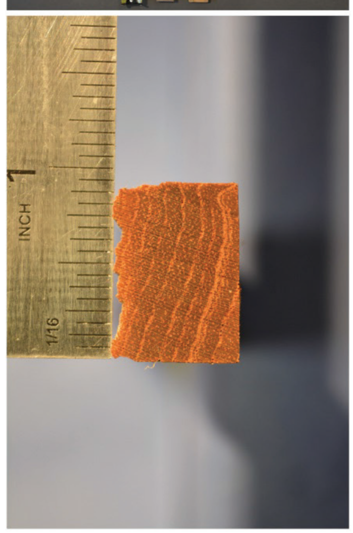
Sample C end grain.JPG



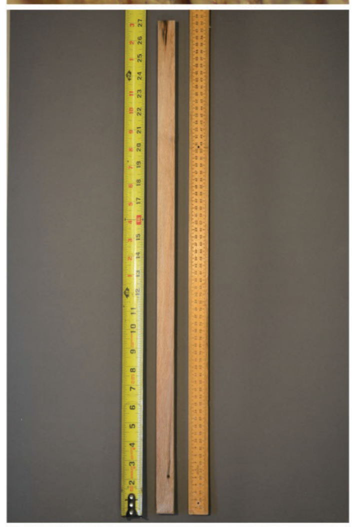
Sample C exposed face.JPG



Sample C stereomicroscope.JPG



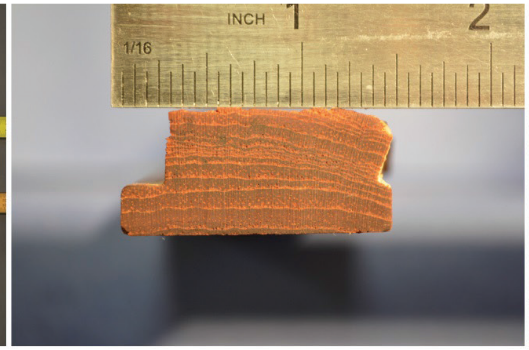
Sample F end grain.JPG



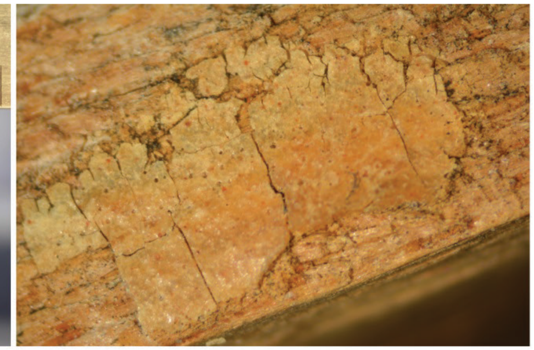
Sample F exposed face.JPG

Sample F stereomicroscope.JPG

019. Specimen G exposed face.JPG

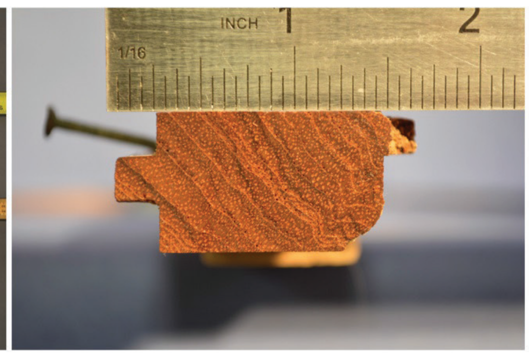


020. Specimen G end grain.JPG



021. Specimen G adhesive.JPG

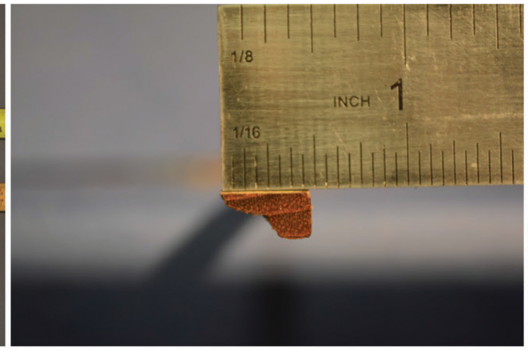
022. Specimen H exposed face.JPG



023. Specimen H end grain.JPG

024. Specimen H coating at top.JPG

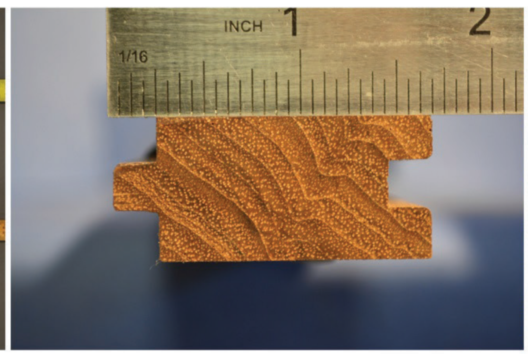
025. Specimen I exposed face.JPG



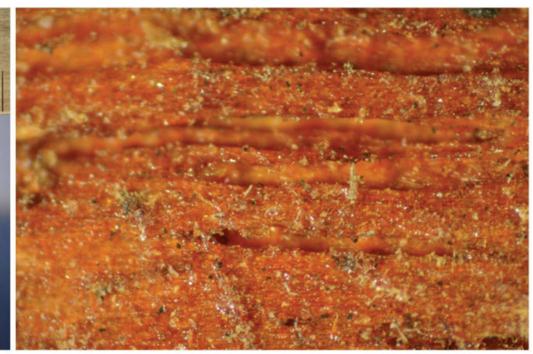
026. Specimen I end grain.JPG

027. Specimen I spore growth.JPG

028. Specimen J exposed face.JPG



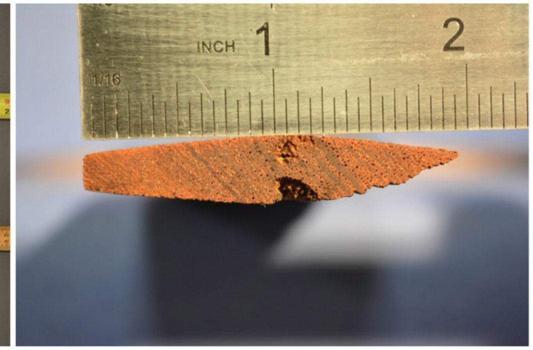
029. Specimen J end grain.JPG



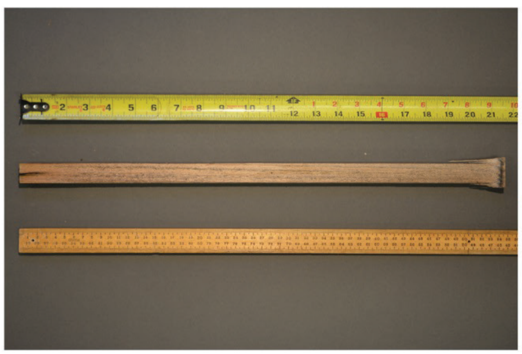
030. Specimen J stereomicroscope image....

031. Specimen K side 1.JPG

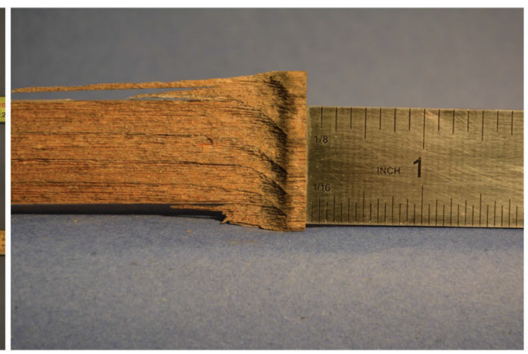
032. Specimen K side 2.JPG



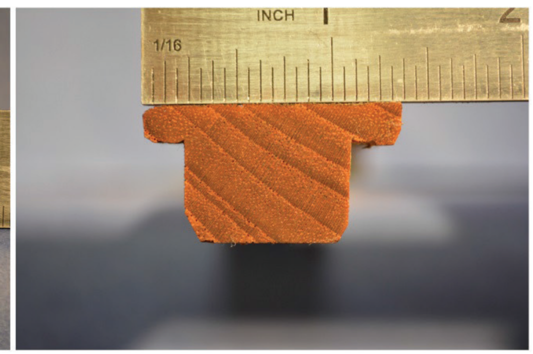
033. Specimen K end grain.JPG



034. Specimen L exposed face.JPG

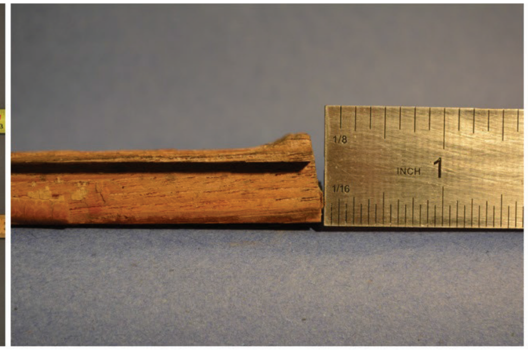


035. Specimen L exposed face at top.JPG

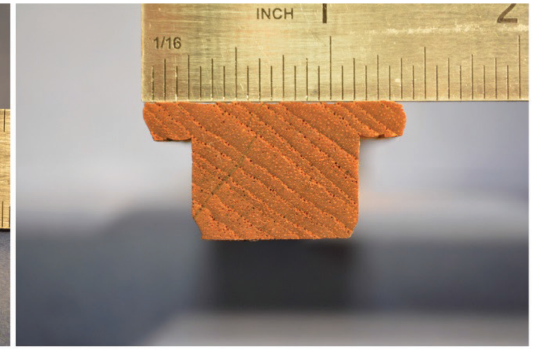


036. Specimen L end grain.JPG

037. Specimen M exposed face.JPG

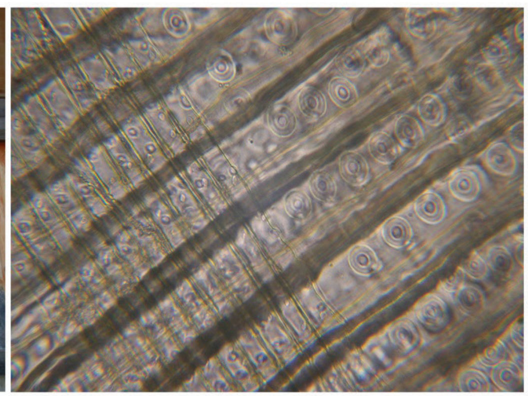


038. Specimen M profile.JPG

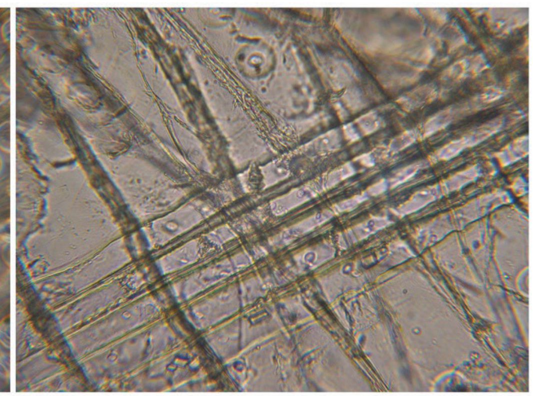


039. Specimen M end grain.JPG

040. Specimen N panel SL8B.JPG



041. Specimen N 400x magnification.JPG



042. Specimen N 400x magnification.JPG

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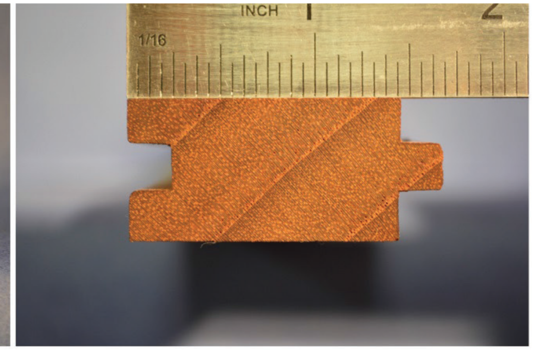
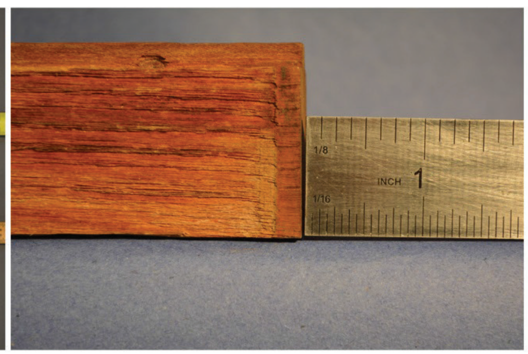
043. Specimen O exposed face.JPG

044. Specimen O exposed face at top.JPG

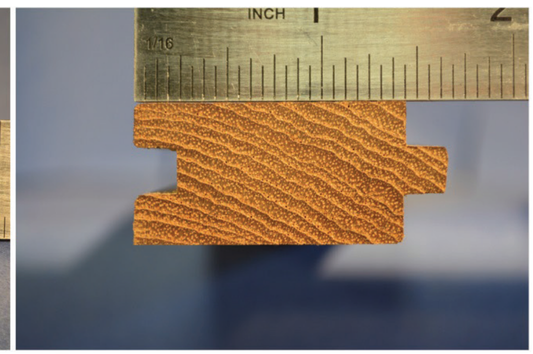


045. Specimen O end grain.JPG

046. Specimen P exposed face.JPG



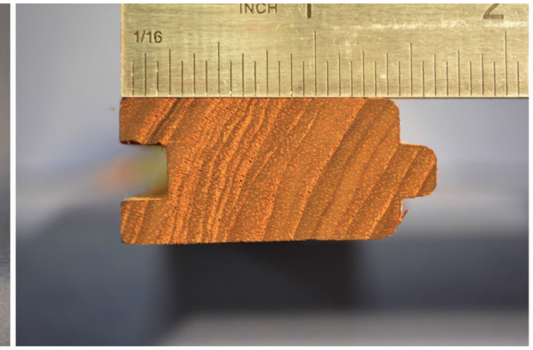
047. Specimen P exposed face at top.JPG



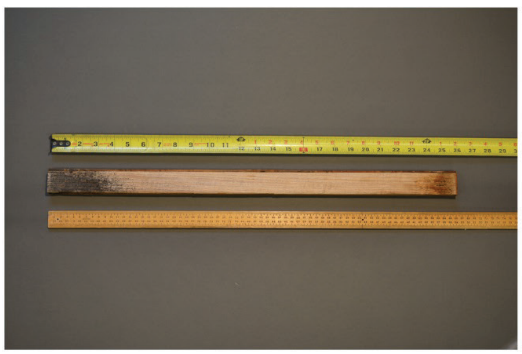
048. Specimen P end grain.JPG

049. Specimen Q exposed face.JPG

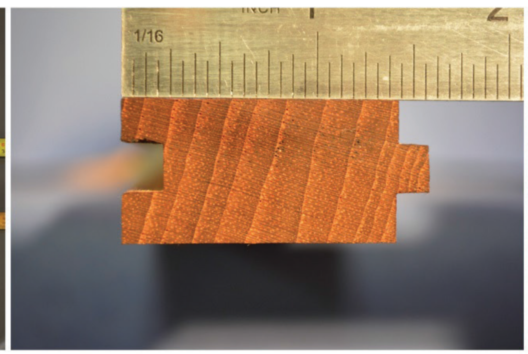
050. Specimen Q exposed face at top.JPG



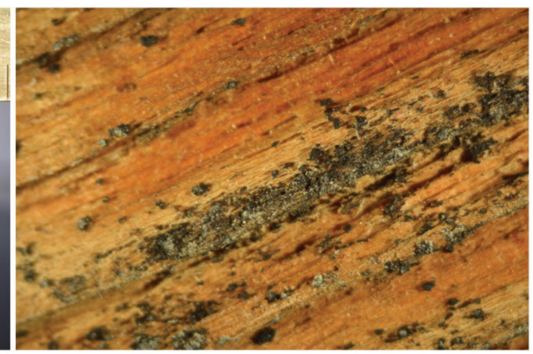
051. Specimen Q end grain.JPG



052. Specimen S exposed face.JPG



053. Specimen S end grain.JPG



054. Specimen S spore growth.JPG

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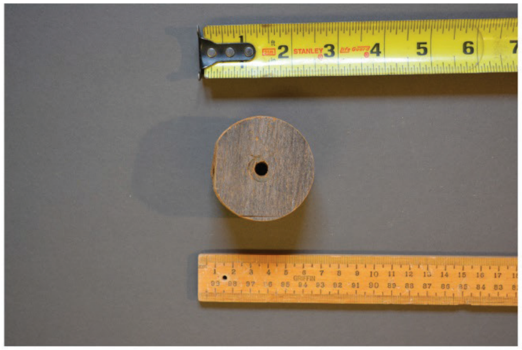
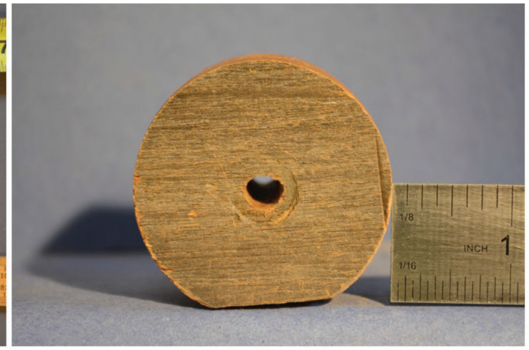
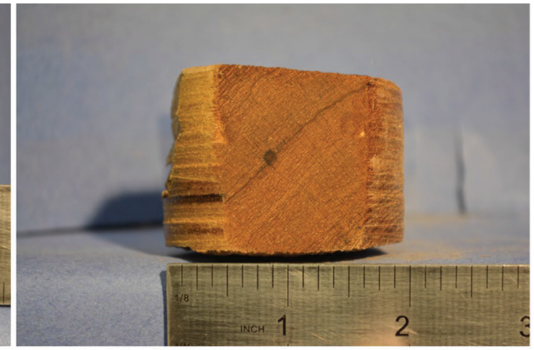


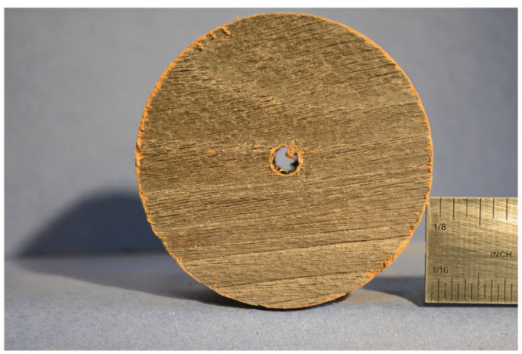
055. Specimen T exposed face.JPG



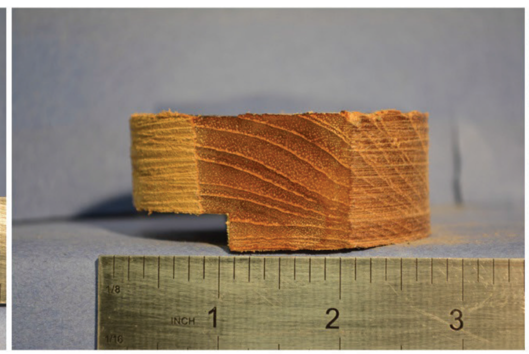
056. Specimen T exposed face.JPG



057. Specimen T end grain.JPG

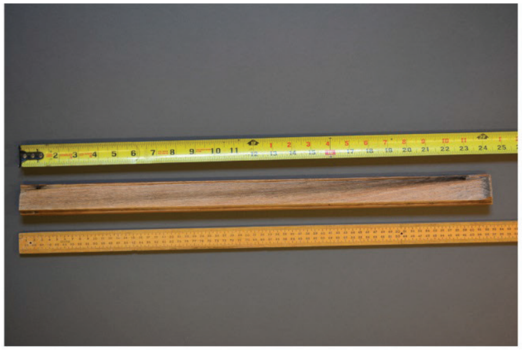
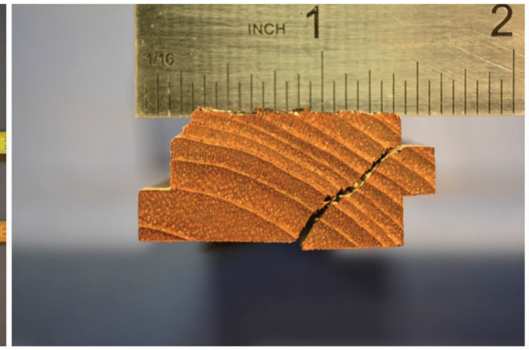
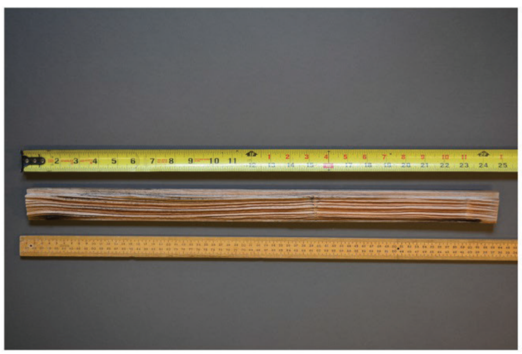
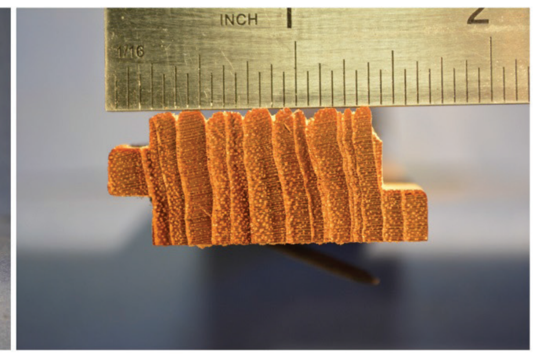


058. Specimen U exposed face.JPG



059. Specimen U end grain.JPG

060. Specimen U end grain.JPG

		
061. Specimen V exposed face.JPG	062. Specimen V. end grain.JPG	063. Specimen V unknown deposit.JPG
		
064. Specimen W exposed face.JPG	065. Specimen W exposed face at top.JPG	066. Specimen W end grain.JPG

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