The Renovation of Louis Kahn’s Richards Building-High Performance Historic Preservation

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ABSTRACT
The Alfred Newton Richards Medical Research Laboratory (Richards Building) at the University of Pennsylvania is one of the most important buildings in the career of architect Louis I. Sullivan and one of the great buildings of the 20th century. Completed in 1961 the Richards Building was at the time deemed an architectural milestone worthy of a solo exhibition at the Museum of Modern Art, yet it has been equally maligned for fifty-years by its scientists/occupants. In 2008 it was granted status as a National Historic Landmark (NHL). As a NHL it must be treated with exceptional care, but as an occupied, working building designers must with equal vigor and discipline consider changes to its interior and exterior to properly serve its functional purpose and the needs of the present-day occupants and operations.

A comprehensive renovation project started in 2010 was the catalyst for evaluating the exterior envelope and developing a design that retained the iconic visual and material characteristics of the building while simultaneously improving energy performance and the building’s functional qualities. This presentation will review the development of Kahn’s design, showing the comprehensive approach that was undertaken by an integrated design team to conserve the original stainless-steel window frames while optimizing the overall performance of the exterior envelope and building systems. The team sought to reconcile the University’s aggressive sustainability mandates with the exacting visual and material demands of working with a National Historic Landmark. Our process developed an optimal solution through sympathetic, evolutionary upgrades that balanced the demands of preservation and high performance design. In particular we will examine the process undertaken to select an appropriate glass to replace the original polished plate units which combined with the creative rethinking of the building mechanical systems resulted in a design that balances preservation, energy efficiency, functionality, economy and constructability.

INTRODUCTION
The Alfred Newton Richards Medical Research Laboratory at the University of Pennsylvania (Penn) is nationally significant as one of the most important projects of architect Louis I. Kahn’s (1901-1974) influential career. Kahn was awarded the design early in 1957, and Richards’ construction was substantially complete by the end of 1961. In 2011, Penn commissioned EYP Architecture and Engineering to execute a Feasibility Study for the repurposing and refurbishment, and to then undertake the first phase of design and construction. Subsequent phases of the work were executed by Atkin Olshin Schade Architects of Philadelphia, following the design guidelines established by the EYP team. Richards is composed of four towers and the entire building renovation had to be accomplished in phases while some areas remained occupied. Phase I & II included the creation of the design standards and design and

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construction of two of the four towers, which was completed in 2015. Phases III and IV, the remaining two towers, will be complete in 2018 (Fig. 1).

This complex was the first widely recognized statement of Kahn’s design philosophy of 1.) the separation of primary use and service functions within the buildings into "servant" and "served" spaces and volumes and 2.) the careful articulation of each building component- materials and systems- to reflect and celebrate its particular nature and function. Richards is conceived as a series of reinforced concrete structures whose exterior expression is reflective of their interior purpose. (Fig. 2) The plan consists of three nearly identical “served” laboratory towers set in a pin-wheel arrangement around a central “servant” tower holding core service and circulation functions. The lab towers are seven stories above grade with a basement level with a clerestory at grade, with monumental lights of glass at each of the corners surmounted by stepped transom glazing. The unglazed service tower has eight stories with a mechanical level above, giving it a clear dominance in massing over the more crystalline, delicate laboratory towers. Each of the towers is separated from either the service tower or another adjacent structure by a continuously glazed vertical slot window. Verticality is further accent by smaller, attenuated exterior brick service shafts that house exhaust ductwork and fire stairs. (Fig. 3)

Exposed precast prestressed, post-tensioned concrete Vierendeel frames hung from external poured-in-place concrete columns are an innovative structure conceived by structural engineer August Komendant for the served towers. The concrete structure of the service tower is a more conventional arrangement of shear walls and floor slabs, and is sheathed in brick, with subtle articulation of the brick planes indicating areas of support and infill. One of the signature elements of Richards thus becomes the remarkably detailed vitrine-like exterior envelope of the glazed towers where all elements – Vierendeel floor structure, brick walls, and monolithic glazing set in minimal stainless steel frames – are absolutely flush and co-planar (Fig. 4).

The current renovation project was conceived in response to the inability of Richards to continue to function as a wet-bench, bio-medical research laboratory, and the decision to re-purpose the structure as a computational intensive Center for Cognitive Neuroscience. In addition to the program issues, the envelope was both failing technically, and unsuited to provide the thermal and light control needed in these spaces. As a National Historic Landmark (NHL), conservation of the building exterior was a priority, but as a signatory to the Associated College and University Presidents Climate Commitment to meet specific carbon reduction targets by 2030, Penn also expected significant reductions in energy use for the project as part of an overall reduction in energy use for the entire University portfolio. The result as the project evolved was the adoption of an “energy frugal” (Penn RFP for Renovation Design Services, November, 2010) strategy that optimized the balance between the conservation priorities of the envelope with an aggressive intervention relative to the replacement of the mechanical systems.

The original climate management system for the laboratory was a constant volume HVAC air system, one AHU for each tower, with perimeter radiation located under the windows in the glazed towers. While the HVAC system was sophisticated for its time, the occupants of a floor had limited ability to modulate the air temperature delivery by zone of a tower (south facing versus north) which created a problem for human comfort with the large amount of glazing. The exterior Koolshade screens, designed to mitigate heat gain and glare through the windows, were not well thought out since the windows were fixed and occupants could not reach the screens to move them – these were removed by the 1980s.

Conceptually, the need to move large amounts of air through the building was of importance to Kahn from the beginning of the project – as is evidenced by early schemes with shaft arrangements (dubbed “schnorkels” by Kahn) even more prominent than the eventual oversized stacks of the final scheme. The ultimate relationship of the architectural/structural expression and integration of the engineering systems in the design is masterful, particularly the articulation of the outside air intake and exhaust flues, the layout of the mechanical room and the vertical routing of the ductwork. Internally, the open Vierendeel frame system was conceived to enable well organized, exposed horizontal distribution of systems overhead with access from any location on the laboratory floors.

Richards was plagued with functional issues from the time it opened, including planning problems having to do
with the size and means of subdivision of the floor plates, lack of adequate systems flexibility and glare from the oversized windows. Structural movement resulting from concrete creep of the cantilevered elements, expansion of the brick veneer and subsequent distortion of the window frames had weakened the glazing gaskets. The windows leaked and were easily broken in high winds as the size of the units stretched the structural capacity of the original ¼ inch polished plate glass.

As piecemeal renovations were undertaken within individual labs, the logic of Kahn’s original organizing principles for routing systems and architectural interventions was lost, and supplemental or replacement lighting, diffusers and architectural elements failed to meet the standards originally developed for the building (Fig. 5). The building remained in regular use, but the conditions became increasingly inefficient and difficult relative to the need to adapt to the requirements of modern wet-bench medical science. Program issues were further compounded by the difficulty of subdividing the laboratory floors into appropriately sized spaces because of the rigidity of the 9-square planning grid dictated by the exposed Vierendeel frames; office spaces ended up either being too large or, when subdivided using the secondary members within each of the nine primary squares, too small (Fig. 6).

The original building systems – though well-designed when conceived in 1960 – were outdated and inefficient from an energy use standpoint, hindering Penn’s goals of achieving high energy performance standards across its entire physical plant. Finally, the exquisite exposed concrete and cinder block walls and ceilings inside the building had become so soiled and damaged in many areas that they had been covered up or painted – further diminishing the material qualities of the interior.

**INVESTIGATIONS**

Even prior to its completion, the Richards Building was celebrated with a solo show at the Museum of Modern Art in New York, and in 2009, the complex was granted National Historic Landmark (NHL) status. The building retains a high degree of integrity in its character-defining design features, and had undergone no major campaigns of renovation or alteration outside of the routine reconfiguration of the laboratory spaces prior to this project. The key to the success of the project was to find the optimal balance between preserving and technically enhancing the extraordinary character of the exterior of the building and its public spaces, while enabling a sensitive redesign of the laboratory interiors to better enable it to “be the building that Kahn always wanted it to be.” (Saffron, Inge – “Turning Richards Labs into the building Louis Kahn wanted it to be,” Philadelphia Inquirer, January 8, 2016)

The project team roles and responsibilities were as follows:

- Owner – University of Pennsylvania
- Lead Architect, Design and Phase I Execution – EYP Architecture and Engineering
- MEP/FP Engineer – Urban Engineers
- Structural Engineer – Keast and Hood
- Glazing/Window-wall – R. A. Heintges Architects
- Materials Conservation- Building Conservation Associates
- Executive Architect – Phases II-IV – Atkin, Olshin, Schade

Success could only be achieved through a deep understanding of the logic of the building and the principles that informed Kahn’s original design. The process began with a thorough architectural and engineering survey and assessment of the complex coupled with extensive research of the original drawings, specifications and project correspondence in the Louis Kahn collections in the University of Pennsylvania Architectural Archives, and in the
archives of the Penn Department of Facilities and Real Estate Services (FRES). The project team simultaneously carried out a variety of investigations to assess the condition and performance of the building. These were made initially to inform the parameters for the renovation design, and subsequently as further information was required, to make better informed decisions as the design progressed through documents and into construction.

During the early design efforts the team built and refined an energy model to compare the performance benefits of different glazing enhancements and HVAC systems against the existing performance baselines. A structural analysis was undertaken to look at the issues of the deformation of the concrete frame, the expansion of the brick and the consequent impacts on the glazing system. Air and water infiltration testing was also performed on the character defining corner window assembly to confirm the degree to which the original seals had been compromised.

There were several key project drivers that contributed to the technical complexity of the work. The first of these was the previously discussed balance of energy performance and architectural conservation. The project was funded by a Century Bond program that was established to underwrite sustainability initiatives, so ultimately every design decision had to be justified through energy performance. The budget for the project, and the logistical issues involved with finding swing space dictated that the work had to be done in discreet phases, with the building remaining partially occupied while the work was in progress. Age, condition and inefficiency dictated replacement of the building services, but because the renovation was to be phased, there was a considerable challenge in arriving at the best possible layouts for distribution of the services in the first phases of the work while leaving portions of the original systems intact and functional. This was a particularly critical issue as it related to finding adequate space for head end equipment in mechanical spaces, and in the distribution, to achieve the mandate of leaving the main public spaces largely free of overhead systems, as they were originally intended.

Another driver was the architectural challenge to re-shape the layouts of the laboratory floors in the served towers to accommodate the computational neuroscience program (Fig. 6). Given the inefficiencies in office sizing that would be dictated by following the grid system of the Vierendeel frames, the team had to develop an “off-grid” partitioning scheme to accommodate the requisite population densities on each floor. As will be described, one key to solving this problem of how to infill within the space of the Vierendeel where a partition is offset was already latent in Kahn’s original design, although the general prescription in the original documents was to follow the lines of the overhead frames for locating partitions. The spatial impact, design language and material palette for the partitioning system was also part of a mock-up process, as full-size installations were made to ensure broad consensus that the most appropriate solution was achieved (Fig. 7).

Most of the interior finishes were originally exposed poured in place concrete – both plywood and narrow board formed – and unpainted 8 inch x 8 inch cinder block CMU. Over time, considerable areas of both materials had been painted, and it was decided early on to try to remove as much of the paint as was possible from these surfaces. Extensive testing was done both to identify the correct paint removers, as well as to determine the optimal method for cleaning surfaces that had not been painted.

**PROJECT DESCRIPTION**

The Richards Building is a rare if not unique example of a property with iconic, globally recognized architectural status that has been effectively dysfunctional for most of its working life. The challenge that the renovation team faced was to protect and enhance its heritage value while transforming its use value to enable the laboratory floors to more closely align it with Kahn’s conceptual vision of open, virtually partitionless “slices of space.” There is both irony and triumph in that only by repurposing the building for a very different kind of science was this goal achievable. From the design team’s perspective, the project also presented a great opportunity to demonstrate how a creative interpretation of Kahn’s original intent can revitalize an otherwise unloved and underutilized resource while enhancing those characteristics of the building that most contribute to its iconic value.

We are perhaps fortunate that Richards’ iconicity is based almost entirely upon its exterior appearance – once the partitions were erected within the lab spaces, little remained of Kahn’s interior vision beyond the beautifully executed...
structure and the modest entry lobby. The overhead services were well organized and beautifully detailed, though – in an early lesson about the necessity of thorough documentation to ensure that everything ends up in its proper place – the initial installation so infuriated Kahn that he demanded that the work be torn out and replaced. The importance of photography to defining the image, poetry – and often meaning – of modern architecture can be demonstrated in an early construction photo of Richards showing an empty quadrant of open laboratory space, with services installed overhead. This image implies the promise of a universal space able to foster community that was never truly achieved in its original incarnation (Fig. 8).

The emphasis from the outset of the project was on crafting a project that would repurpose Richards to accommodate the building. This meant first and foremost tailoring a program that could capitalize on the ideal of the open floor plate, take advantage of the large areas of glazing and, ideally, function with a flexible HVAC system that did not have to accommodate the loads of wet-bench science and could be adapted in the future to changing plan arrangements and program.

**Glass and Glazing**

Following the classification of the Secretary of the Interiors Standards for the Treatment of Historic Properties, this project would be termed a rehabilitation, with certain key elements that were preserved and restored. Preservation efforts were concentrated on the exterior, particularly on the glazing system, in that they were the primary areas of distress and failure, and budget constraints precluded anything more than the most rudimentary treatments in the stabilization of the brick masonry and the exposed concrete frame.

The primary glazing types will be referenced by their document designations the W-1 units are the monumental corner lights of the laboratory towers, the W-2 and W-3 lights are the smaller lights of the transoms (Fig. 9).

In the 1950s, Louis Kahn began a quest to develop a minimal, elegant metal glazing system. This was a period in which the artistic expression of industrial production was in the minds of many leading architects, whose search for elegance, efficiency and an “honest” architectural solution was a priority. Dissatisfied with the standard steel sections that he had employed on the Yale Art Gallery as being heavy and imprecise, and disliking what was available in aluminum systems, Kahn began to develop a system based upon brake-formed bent stainless-steel shapes. First employed in the American Federation of Labor Medical Services Building in Philadelphia of 1955 (demolished 1973), Richards represented the next evolutionary step in the development of this system, which he continued to refine in projects such as the Salk Institute in La Jolla (laboratory glazing system), the Kimball Art Museum, and, at the end of his career, the Yale Center for British Art. The frames are formed of 1/8 inch plate formed into a modified U shape yielding a deep reveal with periodic stiffeners. The shapes are welded into frames which are then attached directly into the concrete frame with reglets at the jamb, fastened into clip angles at the head, which are then anchored to the Vierendeel frame, and fastened with masonry anchors into the sill at the masonry cavity knee walls. The reveal gives the shape strength, minimizes its appearance and enables a flush profile at the exterior face. For Richards, Kahn also developed an elegant re-entrant, cruciform stainless corner post formed of back-to-back welded angles, to receive the frames of the W-1 lights. This system – both in its original and subsequent iterations has tremendous practicality, longevity (the Richards frames were in very good condition) and elegance, but is compromised from an energy performance standpoint in lacking a thermal break.

The original polished plate glass is accented with a textured, cast blue glass at the south and west transom lights, which provides another, token amount of screening from glare. The cast blue glass was glazed directly into the upturned leg of the stainless-steel plate, with an aluminum stop mechanically fastened to the frame. Retention of the original plate glass was problematic for several reasons. First, research showed that polished plate glass has similar characteristics to annealed float glass, which was used to model strength and deflection characteristics. By the ASCE 7 testing standards, theW-1 lights would fail in a 50-year wind event, and would therefore not meet current code standard. In addition, the clear glass had no insulating or sun control properties, which created problems of both heat gain and loss, and glare control. Finally, field investigations revealed that creep of the Vierendeel frames and
expansion of the brick knee walls together had caused movement in the steel frames – particularly the corner posts – that loosened the seals and subtly changed the shape of the glazing opening. While analysis determined that these deformations had probably reached their maximum extent and the shape of the openings would be relatively stable in the future, any new glass would have to be scribed or fabricated to match the unique shape of each opening to establish and maintain a tight seal with fidelity to the original detail appearance.

In response to University’s objective to maximize energy performance, the team explored a range of solutions that factored the performance of the envelope together with possible alternatives for the building HVAC system. Our thermal analysis, which used NFRC certified computer software developed by Lawrence Berkeley Laboratory, Therm 6.3, and Window 6.3. to determine Solar Heat Gain Coefficient (SHGC) and average U values, compared the use of different proposed glazing scenarios (including IGU and laminated glass), and different possible HVAC systems against the existing energy performance (Fig. 10 chart).

The team also tested for air and water infiltration on the existing units; although we knew there would be serious issues prior to testing, the information was useful in quantifying improvements for the remediated systems and confirming the efficacy of the installation details. These were:

1) ASTM E783 – Standard Test Method for Field measurement of Air Leakage at Exterior Windows and Doors

The tests proved conclusively the porosity of the system. The air infiltration test results indicated that the corner assembly exceeded the allowed level of infiltration by 16.64 CFM, or a 91% increase over the allowed 18.36 CFM. The water infiltration test standard calls for the test to run for 15 minutes. At Richards the test was terminated after 4 minutes and 15 seconds due to the almost uncontrolled amount of water infiltration, which was flooding the test chamber and presented a risk of flooding to adjacent spaces if the test was continued.

The design option that would maximize the performance of the window systems would be to replace the plate glass with IGUs, ideally in a thermally broken frame. The team thoroughly vetted both IGU options, determining:

1) The existing frames could not accommodate an IGU due to the narrowness of the frame section and the increased thickness of the glazing and
2) It would be possible to design a thermally broken frame that approximated the face dimensions of the existing frames, but it would be extremely destructive to the surrounding fabric of the building, particularly the concrete columns and Vierendeel frames to remove the existing frames – a compromise that was deemed unacceptable given the significance of the exterior fabric and the conservation challenges that would have attended this intervention.
3) The out-of-square shape of the window openings would require units custom fabricated for each opening, a cost that could not be supported by the project budget

From a life-cycle standpoint, we were also hesitant to recommend IGUs because of their limited lifespans due to the potential of seal failure within 20-25 years. This is a conundrum that the building industry faces on a large scale, as the technology has yet to be developed that would enable resealing of the lights when seal failure occurs, and consequently, the units ultimately must be discarded (or at best, recycled). A further concern at Richards was that the window units are glazed from the interior requiring significant disruption to the users. In addition, their tendency, particularly at large sizes, to distort due to the pressure differential between the airspace within the IGU and the surrounding environment, compromises the very flat quality that is a signature character defining feature of the original windows (Fig. 11).

Subsequently, given the code and safety requirement to utilize safety glass, our choices came down to monolithic units of either tempered or laminated glass. Tempered glass at the scale of the W-1 windows typically exhibits a characteristic roller-wave distortion that would be unacceptable in this installation. Our focus therefore turned to laminated glass, which is created by fusing two layers of heat-strengthened glass around a Poly-Vinyl Butyral (PVB)
interlayer to create a strong, safe – and visually flat – composite. Laminated glass also enables the employment of a choice of high-performance coatings in a protected location between the glass layers, and gave us the greatest flexibility in being able to cut and even subtly warp the individual lights to conform to the uneven openings resulting of the movement of the building.

The final glazing selection and detail development involved a battery of tests and mock-ups on site. Different coating options were explored and plugged into the energy model, which in the end were narrowed down to two options, close in performance, that were finally judged on appearance – matching the color rendition of the original glass. The first was a high performance VE-85 low-E coating applied, to the #2 surface of the laminated composite; the second a similarly applied VLE-70 low-E coating. These were then mocked up next to samples of the original glass on site and evaluated for their visual qualities. On this basis the glass chosen for the W-1 replacement lights was as follows:

- 0.25 inch clear heat strengthened glass on the outer light with VE-85 coating
- 0.060 inch PVB interlayer
- 0.25 inch low-iron heat strengthened glass on the inner light

The chosen coating actually has an SHGC value 30% below the performance of the VLE-70, 0.43 vs 0.60 respectively, but was ultimately selected because of greater fidelity to the appearance of the original glass.

Installation

The chosen glass is about 5/16 inches thicker than the original units. Given the minimal dimension of the frame, this created a challenge relative to the glazing installation and design of the stop. It was determined that, given the greater weight of the new glass and the reduced possible dimension of the stop, no mechanical solution was feasible. Consequently, to preserve the original appearance, a smaller extruded aluminum extrusion was structurally glazed to the glass and the entire assembly glazed into the frame with a Very High Bond (VHB) glazing tape. The units were also given a continuous perimeter heal bead of sealant, and any open joints in the frames sealed with clear sealant to maximize weathertightness. This assembly was mocked up in situ and tested to the same ASTM standards that were utilized for the existing conditions to ensure that the system was functioning as expected (Fig 12).

The air infiltration testing of the installed mock-up yielded a remarkable performance with a leakage rate of 0.8 CFM for a system with an acceptable rate of 18.36 CFM, less than 5% of the accepted rate. Given that this was a monitored mock-up installation, if the final window installations performed even close to the mock-up the performance, the window systems would be far better than the original energy models had anticipated. The water infiltration testing of the mock-up did not provide similar remarkable results, but did identify discontinuities in the exterior envelope close to but not directly attributable to the sealing of the glazing system. Leakage was traced to the grouted joint between the frames and the stone sill, discontinuities in the brick knee-wall and mortar, and the soldered joints of the stainless-steel frames themselves. A second test was run after sealant was applied to isolate the glazed assembly, which confirmed that the water penetration could be attributed to the porosity of the masonry systems. The team recommended that this was acceptable since the interior of the building would be under positive pressure with the new mechanical systems (originally the interior was under negative pressure) eliminating the conditions produced by the ASTM testing.

Building Mechanical Systems

Our energy model showed that once the envelope was sealed and thermally improved, a more aggressive approach could be taken to maximizing the efficiency of the mechanical systems. A significant challenge of this project was determining how to retrofit the systems for the C and D towers while keeping the other two towers operational. The layout of the original air handling units (AHUs) and ductwork was elegant but offered little “wiggle-
room” in accommodating new equipment. Several design options were explored for locating the primary HVAC equipment, but ultimately locating the equipment in the primary mechanical room was chosen for functional and budgetary reasons. The added benefit was that the layout of the new systems would retain the spirit of the original design. The most significant change was that while the original design provided a separate AHU for each tower, with the load reductions going from wet to dry-bench function and the improved efficiencies of the glazing system, one AHU could service two towers.

The team modeled a variable air volume (VAV) system, which was the University design standard and the logical update to the constant volume system of the original installation, against employing an active chilled beam system. Going into the feasibility study Penn expressed an interest in chilled beams, even though these systems were relatively new to the U.S. market and had never been used on a Penn project. The data showed that the performance improvements enabled by employing laminated glass in a properly sealed envelope would permit the use of chilled beams without risk of unwanted condensation in periods of high heat and humidity. A benefit of the chilled beam systems was the further reduction of required ductwork, simplifying the design challenge of accommodating the systems within the Vierendeel trusses (Fig. 13). As these were exposed elements in the space, the choice of the unit and method of its installation had to be carefully calibrated to enable correct placement of the beams over the preponderant building lighting at the center of each bay, and an unobtrusive appearance.

While the limited amount of infiltration demonstrated by the testing of the mock-up eased concerns regarding the risk of moisture vapor entering the building, the lack of thermal break in the stainless-steel frames also meant accepting a higher risk of condensation on the metal surfaces. At the interior system surface, a dew point temperature of 32°F was determined using preliminary indoor air criteria of 70°F and 25% Relative Humidity. The exterior boundary condition was determined using the 99.6% Heating Dry Bulb and Mean Coincident Wind Speed design conditions for Philadelphia in 2005 ASHRAE Fundamentals. Given these conditions, condensation would only occur on the stainless-steel frame when the temperature drops below 25°F (-4°C). This was a key contributor to a design decision to introduce continuous metal service enclosures along the full height of the perimeter knee wall. While perimeter radiant heating had always been utilized under the W-1 lights, it had previously just been attached uncovered low on the wall. Within the new design, the heat could be raised closer to the windows, and louvers installed to better direct the heat to prevent condensation.

The original lighting layout was also restored to the building, a critical design issue given the visual impact of the lighting when the building is viewed from the exterior at night. This was done by using contemporary, LED fixtures in the forms and locations originally specified by Kahn. Contemporary photometrics enable better light coverage, accurate color rendering and far less energy use. Taking the façade and MEP upgrades together, an overall energy savings of 40% was anticipated by the energy model when compared to the original baseline existing conditions (Fig. 10). Energy use data for the Richards Building is not complete due to two factors. Data gathered prior to the start of the renovation was not gathered for a full twelve-month period before portions of the building started to be vacated in anticipation of the renovation. Also, at this point in time only the first two phases of construction have been completed and Towers C and D occupied. Nonetheless data gathered between May 2016 and April 2017 indicate that the renovated areas of the building have an average monthly EUI of approximately 16.17 kBTU/sf. Assuming the entire building will match this performance this will represent an approximate 69% reduction in energy use. Of course, a key contributor to this improvement is the change in use from wet-bench to dry-bench science, but the efficiency of the new mechanical systems combined with the radical improvement in the performance of the glazing systems are still a driving factor in the improvement.

**Architecture – Repurposing the Interior**

The primary charge to the project team was to effectively repurpose the function and program to accommodate the unique qualities of this building. As we have seen, this required the removal of wet-bench science and its replacement with dry-lab, computational intensive uses. It also required a fundamental return to the protocols for
organization of the building services that Kahn clearly articulated in the documentation for the original project, that had been violated in subsequent renovations.

The organizing principles – which articulated a zone between the sill and head height of the primary windows that would always be free of services – became part of the Design Guidelines that enabled the team to develop a kit of parts capable of responding to a range of possible programs now and in the future (Fig. 14). This included a vertical partition system utilizing a minimal steel frame that pays homage to both the glazing system and early studies Kahn had proposed for the interiors, and flush, full height (to bottom of structure) panels of wood and glass, and perforated horizontal metal ceiling closure panels in sympathetic counterpoint to the concrete frame that enable partition placement off the lines of the structural grid where necessary to accommodate program and “right size” faculty offices. This system, utilized in the served towers, built upon Kahn’s material palette and language both in this building and as he consistently developed it in subsequent work, but is clearly meant to be understood as a contemporary intervention. It was tested through a series of mock-ups and put into place in the first phase of construction. The result opens the center and one full quadrant of each of the laboratory floors and realizes Kahn’s original idea of being able to experience the full extent of each glazed volume (Fig. 15). The windowless servant C Tower was repurposed to hold service, testing and conference spaces not requiring access to natural light.

CONCLUSION

Sustaining and extending modern architectural heritage is an exacting discipline. These properties were often functionally and environmentally challenged and were marginalized and despised by their users. This dichotomy had defined Richards for over fifty years, and the collective – and largely successful efforts by Penn and the design team to make Richards an efficient, desirable place to work and operate represents the singular achievement of this project.

The performance challenges in this case were particularly acute – indeed, it is safe to say that it is precisely the inability of the laboratories to be “well-tempered” in Reyner Banham’s phrase that was the primary source of its dysfunction. The contemporary criticism that has been leveled at Richards as having “poorly designed” systems is a 21st century critique of a 1960 design. Kahn’s consulting team included some of the best-known engineers of their day, including mechanical engineer Fred Dubin, and while further research would be necessary to verify this point, there is evidence that without improved sun and thermal control of the exterior envelope, there is little more that could have been done, given the state of the art in systems of the day, to address the performance and comfort issues that were inherent in Richards.

The functional difficulties imposed by one of the strongest character defining features of Richards – the monumental windows – and the sizes and disposition of the floor plates, necessitated imperatives to invisibly improve performance and forthrightly re-think its purpose. Each requires a creative discipline that is becoming increasingly necessary to ensure the survival of many cultural resources but particularly those of modernism, and serves to further integrate design and both environmental and material conservation practice.

Referenced Figures:

1. Richards Laboratory – Exterior from West; Halkin Mason, 2015
2. Exterior from South; University of Pennsylvania Architectural Archives, 1965
3. Richards and Goddard Laboratories – Site Plan; EYP, 2016
4. Construction Photo; University of Pennsylvania Architectural Archives, 1961
5. Typical D Tower Corner Lab before Renovation; EYP, 2011
6. D Tower 6th Floor Plan before and after Renovation; EYP, 2015
8. Interior Construction Photo; University of Pennsylvania Architectural Archives, 1961
11. Comparative W-1 Glazing Options, Plan – ¼” Plate, 9/16” Laminated Glass, IGU; Diagrams by R. A Heintges, 2012
12. Photo of Mock Up of W-1 and W-2 Lights in-situ, with Project Team Members, 2014
14. Section Diagram from Design Guidelines Showing Stratification of Building Systems; EYP, 2014
15. Finished 6th Floor Workspace; Jeff Goldberg, ESTO, 2015