'Joints like Sculpture'—Louis Kahn's Richards Building and the "Precisionist Strain"

THOMAS LESLIE, AIA
Iowa State University

The recent opening of the Marshall D. Meyers Archive at the University of Pennsylvania has provided a new source of photographs documenting the building's unique construction. The parallel discovery by the author of a previously unpublished manuscript by the project's precast contractor sheds additional light on the project's multi-faceted concern for weaving together function, performance and assembly. These documents support an explanation of the building's conception as the 'monumentalization of technique,' and the largely undocumented role of Kahn as a building technologist of the first order. Richards' direct influence on a generation of technically inclined architects in the 1970s indicates that these newly available documents support the view of Kahn as a seminal figure in the development of the so-called 'hi-tech' school of the late 20th century, shedding light on both his career and those of Renzo Piano, Norman Foster, *et. al.*

> *"One day I visited the site during the erection of the prefabricated frame of the building. The crane's 200-foot boom picked up 25-ton members and swung them into place like matchsticks moved by the hand. I resented the garishly painted crane, this monster which humiliated my building to be out of scale. I watched the crane go through its many movements all the time calculating how many more days this 'thing' was to dominate the site and building before a flattering photograph of the building could be made.*
>
> *"Now I am glad of this experience because it made me aware of the meaning of the crane in design, for it is merely the extension of the arm like a hammer. Now I began to think of members 100 tons in weight lifted by bigger cranes. The great members would be only the parts of a composite column with joints like sculpture in gold and porcelain and harboring rooms on various levels paved in marble."*
>
> – Louis I. Kahn, "Form and Design", 1961

Writing in 1960, Vincent Scully described Louis Kahn's design for the A. N. Richards Medical Laboratories at the University of Pennsylvania as a participant in the American "Precisionist Strain."[1] This short-lived formulation described for Scully a tendency in American architecture toward 'purity of shape, linearity of detail, and, at times, compulsive repetition of elements," and included works as early as the 'taut, hollow boxes' of 17th century Massachusetts, the 'clear, sharply separate geometric shapes' of the University of Virginia, and Louis Sullivan's 'active statement[s] of human force."[2] More currently, the 'icy, taut cubes' of SOM's banks and office buildings and the 'brittle planes' and 'ruggedly conceived' concrete of Kahn's building represented the continuation of this Puritan obsession with 'perfect, closed and weightless forms.' In Scully's view, this emphasis on perfection reflected a long-running attempt by American architects to make up for their provincial relationship to the richness of European architectural culture.

This, of course, is an odd argument, one that was short-lived and that has not generally been borne out by subsequent events. Yet to find Kahn mentioned at the conclusion of Scully's essay is doubly striking – first, because Kahn is hardly ever thought of in Puritan terms, but more provocatively because the description so keenly fits the experience of Richards. Scully notes in particular that the 'brittle planes' of brick and glass that form the exterior walls of the Richards laboratories are played off against 'exposed and ruggedly conceived columns and cantilevered spandrels of which the structure is made.' This suggests both the taut perfection of the American colonial house and the messier, more organic English farmhouse that appears to grow out of and decay into the soil. Such an integration of rigorously conceived skins with bolder, more sculptural structure led Scully to conclude that Richards might lead the way in putting 'our instinct for perfection…to more releasing use,' combining our nervous, Puritan energy regarding detailing and crispness with the formal generosity of contemporary developments in Europe.

In fact, this formula describes the conception and execution of Richards particularly well. Documents and photography in the Louis Kahn Archive, as well as a description in the August Komendant Archives of the precasting system used for the building, demonstrate that Kahn was simultaneously interested in primary aspects of the building's experience that were both formal and 'precisionist,' that is, both tectonically and compositionally refined. The design was developed to express through massing and detail that the laboratories had extensive requirements for services, that the vertical nature of the project demanded a structure that would be efficient and buildable on a confined site, and that the materials used in construction could express the sequence of assembly and the performative nature of each element. While much has been made of the building's expression of servant and served spaces, how these systems were actually integrated into the structural and constructive systems of the building has remained largely unexamined. Upon more detailed analysis, Richards reveals additional layers of designed and constructed logic, demonstrating Kahn's profound grasp of building technology and the role it played in the expression of monumental programmatic and architectural goals.

Kahn received the commission for Richards in February 1957, following extensive internal discussions at Penn regarding the building's site, program, and occupants. At the time, Kahn had completed the Yale Art Gallery and the American Federation of Labor Building in Philadelphia, but had built neither a laboratory nor a high rise structure. The Laboratory building was to be on a prominent site on the Medical School campus, along Hamilton walk and surrounded by buildings and dormitories in the collegiate gothic style by Cope and Stewardson. However, it was seen as a relatively utilitarian project compared with better-funded and more visible buildings planned for the other end of the Medical School campus, in conjunction with the University of Pennsylvania Hospital. Key to the success of the project, Kahn had previously formed solid working relationships with structural engineers Keast and Hood, who were based in Philadelphia and who had collaborated on the Yale Art Gallery, and with mechanical engineer Fred Dubin, based in Boston.

Added to this roster of consultants for the Richards project was August Komendant. Kahn had first contacted Komendant regarding the Enrico Fermi Memorial competition, for a site at the University of Chicago.[3] The two formed a fast friendship, based partly on their shared familial roots in Estonia and partly on a collaborative dynamic that would prove extraordinarily productive over their eighteen years of work together. Komendant was neither a form-giver nor a designer, limitations that he reluctantly admitted. Kahn, on the other hand, despite his exquisite attention to detail did not possess the mathematically analytical mind that had won Komendant acclaim. Komendant's 1952 book, *Prestressed Concrete Structures*, was an incredibly dense work, thick with technical detail and esoteric calculations.[4] While the theory was groundbreaking, the design work shown was pedestrian. Nowhere did Komendant address the architectural possibilities of prestressed concrete. Following their ultimately unsuccessful work on the Fermi competition, Komendant hosted Kahn's students at a prestressed concrete plant in Lakewood, where he was a consulting engineer. Kahn rhapsodized about the plant and its equipment, suggesting that the idea of prestressed members was firmly planted in his mind by the time the Richards project was awarded a few months later.[5]

Between February and June 1957, Kahn and his consultants developed a scheme for Penn that would stubbornly resist alteration throughout the duration of the project. Based on Dubin's initial consultations regarding plumbing lines and code-required falls, the design team proposed a single standard module for the laboratories, a 45'-0" square 'studio' space free of columns or walls. This permitted a central pipe loop that would effectively service the entire floor plate, while permitting maximum flexibility for bench and partition locations. This flexibility seems to have stemmed in part from the understandable lack of specificity in the early program, but also from Kahn's apparent nervousness in over-designing such highly personal spaces for researchers. The standard module was to be replicated over eight floors into towers, with three of these towers clustering around a central core unit containing mechanical systems, animal quarters, elevators and stairs. From the beginning, the site arrangement placed the laboratory towers in a pinwheel formation around the core, or "tower X." This created offsets in the overall site massing, allowing each tower a three-sided exposure to daylight. However it also played on the fine distinction between the building as a single mass and a collection of independent elements, a coarse-grained articulation that would form the basis for a much finer grain of articulation that ordered the building's systems and details as the design progressed.

On the exterior of the laboratory towers, subsidiary service runs including exhaust air, secondary plumbing, and fire escape stairs were to be housed in towers that repeated the logic of 'tower X' on a smaller scale. In July 1957, the first drawings of these towers showed a ladder truss, hollow and presumably open air, harboring smaller duct and stair towers within. The circular openings of the truss formed the doorway to the lab floor, a trope that was repeated in the cantilevered beams extending from the truss and forming the lab floors. One sketch in particular shows these cantilevers spanned by a series of ersatz Vierendeel trusses, with arced openings allowing passage of pipes and, presumably, ductwork.[6] In August 1957, these towers solidified. Drawings during the late summer showed a distinction being made between stair and flue towers, with the former terminating in a rectangular capital, and the latter terminating in a flat cornice, with vertical striations on the exterior indicating its status as a vertically-oriented duct.[7] The lab floors themselves were shown during this phase as nested sets of nine-square grids. with the structure now divorced from the service towers and expressed separately. in pairs of concrete I-beams flanking the service towers at 1/3 points along the edge beams. Within. at Kahn's suggestion. Komendant began analyzing the potential for prestressed concrete spanning members to achieve the 45-foot clear spans required.[8] By adopting hoisting and assembly techniques from steel construction. Komendant developed a kit-of-parts approach – large edge beams and a pair of major spanning members for each tower with infill trusses to support the floor slabs and provide hangars for pipes and ductwork. Work done later in 1957 developed a highly articulated approach to the exhaust towers in a scheme that was quickly abandoned due to cost concerns. Using a sixteen-square concrete grid as a scaffold. this scheme gradually added 'clay flues' within the grid's outer recesses to convey the impression of additive exhaust as one moved up through the tower. At the base, this scheme provided a square archway at the base for pedestrian circulation. while the top was to be solid with the infill flues. a precise expression of the exhaust system's additive nature.[9]

While the developing scheme of Richards was radical, it was by no means unprecedented. In particular, Chicago's Inland Steel Building, completed in 1958 but well publicized as early as May 1955, displayed a very clear hierarchy between its vertically finned service tower, its outboard structure and its clear span office floor space.[10] Contemporary laboratory design was generally not this articulate in its expression of structure and service. A flexible design for medical labs at Washington University in St. Louis, completed in 1956 by Harris Armstrong and published in *Arhcitectural Record*. did clearly express the interplay between reconfigurable lab space, a regular cast-in-place structure, and a compressed utility core, with piped services and electrical utilities were carried beneath ceiling slabs, open entirely to the lab spaces below.[11]

The synthesis achieved by Kahn, Komendant and Dubin, however, went far beyond these possible forerunners. The structural scheme was eventually refined to a rectilinear system of prefabricated beams and joists, each to be manufactured with dowels, seats, and rebar connections that would form a monolithic floor system when complete. The nine-square grid was reflected in the shape of the edge beams, which gradually stepped up toward their corners in three stages. At each change of section, a downstand piece was included to provide a seat for intermediate trusses, On the exterior, the columns were also designed as precast members, shaped to sit on a combination of the column and edge beam of the floor below. Three sets of post-tensioning cables were located in a vertical duct running through each column – one each in their inboard and outboard segments and through their centers, aligning with cable ducts cast through the edge beam. Upon tightening, these cables provided a firm connection between the precast parts, which relied on friction induced by the tension in the cables to lock the precast members in place. The same technique was employed on the interior members. Pre-stressing in the main spanning beams allowed Komendant to reduce their overall depth, while intermediate beams running between the main spans and the columns were connected with post-tensioning cables. The inboard vertical cables of the columns passed through ducts in the extreme ends of the main beams, such that upon tightening, the precast frame would be stressed in all three axes, forming an extremely rigid system requiring little welding. The cast-in-place floor slabs provided additional diaphragm action in both horizontal directions, with monolithic connections to the precast beams created by wire loops and metal studs captured within the poured concrete. Essentially a hybrid system of concrete and steel, the language of jointing used throughout was a key element in the expressed order of the building, demonstrating the scale of its assembly at every opportunity. Expressed joints between members delineated the individual pieces and their interface. No attempt was made to hide or conceal these joints, rather where necessary grout or caulk was colored to contrast with the surrounding material. At ground level, the entry porch in tower "B" specifically eschewed dropped ceilings or infill panels, presenting the visitor with a clear exposition of the modular, skeletal floor system.[12]

Dubin's mechanical system took advantage of the structural system's porous nature, however it maintained its own geometric logic, at once deferring to and subtly transforming the reading of the building's major ordering principles.[13] Tower X was largely given over to vertical shafts, including the well-known 'nostrils' on the south side of the building. These took air in at the second floor, adjacent to the botanical garden at the rear of the site. Air was then ducted to a penthouse in Tower X – one story above the laboratory roofs – where it entered four air handling units, one for each lab tower and one dedicated to animal quarters in Tower X. Conditioned air was then directed down two major supply ducts, running along the east and west sides of the core tower. At each floor, supply trunks branched off from these vertical shafts to the lab ceiling void, entering through the outer openings in the Vierendeel edge beam, on axis with the lab tower's connections to the core. Typically, supply air was brought to the center of the floor plate, where branches distributed it to each quadrant of the floor. Exhaust air was taken through the dedicated shafts, however these proved inadequate for the volumes required and additional exhaust ductwork was required at each level, connecting to a major exhaust stack in the core tower. Drawings by Dubin show a refined set of rules for duct placement within the trusses, with supply ducts always occupying the lower half of the void, and exhaust ducts occupying the top, ensuring a coordinated system. Plumbing runs supplied hot and chilled water, gas and vacuum, and waste service to each floor in a racetrack layout. Pipes entered through the center of the Vierendeel frames on either side of the main ductwork, turned 90°, and ran in the outer zone of the lab floors. They then orbited the central precinct of the floor, crossing supply and exhaust ductwork as those elements tapered toward the floor edges. Each system – the structural grid, the ventilating spine and the circumferential pipes – interpreted the square shape of the typical lab floor differently, weaving structure, function and services together in a complex system of simply conceived elements.

Architecturally, Kahn developed the exterior language of the complex to reflect the various functions of the structural, mechanical, and circulatory systems. The precast structure, being steam-cured, provided a robust exterior finish, and could thus be expressed plainly. To demonstrate the primacy of these beams, infill elements between them were detailed to communicate that they had no function other than simple enclosure. Brick walls were built to be precisely in plane with the exterior surfaces of the precast beams, and large sheets of plate glass were employed to clearly delineate the horizontal reach of the precast structure above and below. Clerestory lights taking up the void depths of the cantilevered beams above supplemented the major windows. Glass throughout was held in place by brake-shaped stainless steel mullions and transoms, allowing a thinner profile than standard aluminum extrusions.[14] A horizontal transom at the lower edge of the spandrel beam connected the large and small panes, and was shown with a track for movable sun shading. The structural drama of the cantilevers was enhanced by details at the vertical corners, where slight re-entrant corners in the vertical mullion matched the precise turns of the brick wall, and glass-to-glass corners in the toplight. At the building roof, the parapet line was emphasized with a double-line of flashing, and columns were topped with an odd finial-like device, incorporating a round top profile that visually matched the proportions of finials on the surrounding Cope and Stewardson buildings.[15] At this stage, the flues were still designed as crenellated, vertically striped tubes, while the fire stairs were occasionally shown as rectangular, at other times cylindrical shafts. This latter option seems to relate directly to the layout of the core zone in the Yale Art Gallery, which played a rectangular service shaft against a cylindrical circulation stair in its linear core zone. Connections between the lab towers and Tower X were articulated by large sheets of plate glass, and the core tower itself was clad in brick, with occasional plate glass windows transmitting the locations of corridors within.[16] Surprisingly, internal planning of the lab towers was largely left to the departments. Kahn's office provided a list of 'rules' for the layouts, particularly noting that walls should align with the positions of small beams above. 1/8" scale drawings were issued to the researchers in the summer and fall of 1957, and information from these plans was then transferred onto architectural working drawings.[17]

Construction drawings were issued in May of 1958, and sent out for bids that June. The final year of production had been largely spent in cutting costs, in particular altering the core tower to simplify the sectional layout and seeking savings in air conditioning, finishes, and laboratory equipment.[18] However, by the time of the construction drawings there had also been significant cutbacks in the architectural scheme. Most importantly, the crenellated towers were abandoned in favor of the sheer brick shafts that were eventually built, leaving only the device of the extended planar walls at the top of the stair towers to telegraph the shafts' various functions. The project was once again threatened after bids arrived. Joseph Farrell, a Philadelphia contractor, was awarded the job despite a bid of over $3 million, or about $500,000 over the planned budget. In August 1958, additional cuts were made to reduce the cost of construction to $2,500,000.[19] Caissons were substituted for deep footings, ceiling heights were standardized in the core tower, and the structural scheme was changed to reduce the number of intermediate trusses and joints on each floor, essentially transforming the small-scale structural grid from a nine-square to a four-square. This last change seems in hindsight quite obvious, as it reduced the number of truss members per tower floor from eight per bay to four, and likewise reduced the number of labor-intensive joints from sixteen to six. Nevertheless, this change had serious consequences for both the partition layout and the duct and pipe runs. The former were redesigned by Kahn's office by November, 1958, however the mechanical drawings were never updated to reflect the new layout, essentially leaving the contractors with a schematic design that they were then responsible for modifying to fit the circumstances of the jobsite. This change also, of course, simplified the exterior expression considerably. Penn had raised objections to the somewhat cluttered elevations that resulted from the expression of the nine-square grid in small sheets of glass, a visual problem that was eliminated by the new layout.[20] While the revised scheme remained slightly over budget, the project proceeded even before the re-issue of drawings on November 13, 1958. Excavation commenced in August, and foundation walls were poured by December of that year.[21]

With construction underway, the building schedule relied on the manufacture and assembly of the precast structural system. The story of the precast beams has often been alluded to, however the rarely examined engineering, manufacture and installation of these elements demonstrates the intensity of thought and integration that would be characteristic of Kahn and Komendant's subsequent collaborations. These fabrication and assembly processes were conveniently summarized by Sandy Smythe, project engineer for Atlantic Precast, in a paper delivered to the Precast Concrete Institute and recounted by Komendant in his 1975 memoirs.[22]

Smythe's paper points out that the fundamental problem of the Richards contract was the precise alignment of three different varieties of concrete structure – the poured-in-place Tower X, constructed by a different subcontractor, the pretensioned main beams at each floor, and the posttensioned minor trusses, beams and columns. While standard tolerances called for up to 3/8" offset between various concrete elements, such imperfections would have been visually jarring, and in some cases would have prevented the jointwork of Richards' concrete structure from fitting together properly. Similarly, Kahn's expression of the columns as primary elements in the facades meant that they had to be absolutely plumb to bear the visual emphasis that was placed on them. To win the contract, Atlantic essentially guaranteed perfect shape, flatness and alignment, relying on steam curing, metal formwork and jigs, and extremely tight production control. Primary attention was given to the spandrel beams and columns, the most visible elements in the structure. These were cast with a flat pallet, laid on their side, with the exterior face at the bottom. Metal formwork was used for its ability to withstand the heat and moisture of steam curing as well as to achieve the extraordinarily precise tolerances demanded by Kahn and Komendant. Because of the pretensioning cables, the main structural members had to be cast upright, with complex voids formed by extensive steel formwork and bracing. Atlantic refined Komendant's shapes slightly to enable them to re-use the formwork on other projects, offsetting the significant tooling costs for such an intricate job. Komendant had no objections, and the formwork found later use for bridge girders and rectangular columns.[23]

The exterior columns posed particular casting problems. Because of their exposed nature, Atlantic advised that they be poured vertically, so that any settling of aggregate would form horizontal, not vertical, striations. Further refinements included altering the column shapes slightly to include a taper in the outer flanges, permitting forms to slide out as single pieces and avoiding the use of awkward collapsing forms. Ducting throughout the members was done using flexible hose tubing, providing space for post-tensioning cables free from snags or friction from the surrounding concrete. Following the curing process, the columns were laid flat for storage using a bed of white sand, eliminating the need for patching. As a result, Atlantic reported that of the 168 columns cast, not one required remedial work.[24]

Atlantic did extensive production studies, determining that the use of reusable forms, an assembly line workforce of sixteen, and a dedicated casting bed would allow eighteen minor trusses or six main trusses to be poured at once. A separate team of nine ironworkers set to work fabricating reinforcing cages for the post-tensioned members. Like the concrete, the reinforcing had virtually no tolerance, and was fabricated using identical jigs in the steel shop and on the factory floor to assure perfect fit. Beginning on April 3, 1959, Atlantic produced an average of two spandrel beams and four minor trusses per day, finishing production in mid-June. The work was scheduled to overlap with the erection process, and the first precast frames, originally scheduled for delivery to the site on May 4, were craned into place on May 26 following an allowance of three weeks due to final costing and minor redesign.[25]

The installation process did not start well. Atlantic contracted directly with a steel erector, Cornell and Company, to erect the precast elements, and their unfamiliarity with the material combined with logistical problems to slow construction to a crawl through June.[26] Additional coordination was required between the ironworkers erecting the pieces, masons from Atlantic who were responsible for grouting and packing the beams in place, and supervising engineers from Keast and Hood, who were responsible for ensuring that the post-tensioning was done to specification. There was no storage at the site, meaning that members had to be shipped exactly on time by truck from Atlantic's plant in Trenton through downtown Philadelphia. Access to the site proper was only from the winding service drive to the rear, and the need to preserve adjacent trees and buildings meant that every crane lift had to thread a careful path from the rear of the site to the towers. To maximize efficiency, the towers were carefully sequenced to ensure that grouting and poured concrete floors occurred early enough to form a rigid frame for the continuing sequence. Typically, structural members would be craned into place on two towers while grouting and pouring occurred on the third. Despite this extensive planning, on June 16 Ferrell wrote to Smythe to complain about the pace of the work. To that point, only three floors – one in each tower – had been completed, raising concerns that delays would push the structural portion of the construction into October. As the masonry knee walls were to follow immediately the completion of the concrete work, cold weather risked multiplying delays through the winter.

The pace picked up quickly, however, as the ironworkers warmed to the new material and the complex ballet of cranes, jacks and concrete pours became routine. By July, Cornell and Atlantic were averaging one finished floor per week, three times their starting pace, and the work was completed by August 14, 1959 – in all, 1019 precast pieces were fabricated, shipped and erected without major incident.[27] The team adopted a mass-production strategy on the site, with teams of two workers riding structural pieces and using custom-made jigs and tools to align columns and trusses prior to the arrival of the tensioning jacks.[28] This was, of course, matched by close cooperation from Kahn and Komendant, and Smythe recognized them for their work. In particular, Cornell realized late in the process that the reach of the crane would put the long main beams into close proximity with the old Medical School Building during their crane flight. The direction of their span was changed during the construction process to minimize the extension required of the crane to move these 18-ton members at the seventh and eighth floors. While some patching was necessary after placement, Smythe reported that on their inspection tour they noted that all pieces were within 3/8" of their 'theoretical' or drawn position. The largest offset between adjacent pieces was in most cases within 1/16" – virtually perfect given the state of the industry and the confined site.[29]

Construction of the exterior wall, mechanical systems, and interior fitout continued through 1960. The exigent nature of the cladding led to concerns from LOF Glass regarding the installation of the large sheets of plate glass within such a seemingly fragile steel mullion system. Correspondence between Farrell, LOF and Kahn's office finally settled the matter, recognizing the potential risk of the unusual glazing system but relying on Komendant's advice to reassure the University.[30] Other issues included the layout of the mechanical systems and the location of laboratory equipment. The first floor piping was reviewed and heavily criticized by Kahn for its chaotic layout, and subsequent floors were installed closer to the spirit of Dubin's original drawings.[31] While Kahn volunteered his services to select furnishings and equipment, the research groups by now felt ownership of their spaces, and some decisions regarding furniture, layout and occasionally even partitioning were made without the office's approval.

The completion of the construction was fraught with fairly typical last minute problems. Most glaringly, the plate glass front doors in the front portico under tower B cracked repeatedly; following an investigation the handles were redesigned to avoid stressing the glass itself, with 12" wide transoms running horizontally across both doors, which were installed prior to the building's dedication in May 1960.[32] More seriously, panes of glass in the laboratory windows cracked as well, leading to concerns as researchers settled in to the building. While Penn understandably referred back to Libbey-Owens-Ford's concerns, the cause turned out to be improper installation. Support blocks had been located incorrectly, leading to poor balancing of the glass' weight. Additionally, some panes had been clipped to permit clearance of improperly placed nuts, leading to intolerable stresses within the glass. Panes were replaced where required; however the unsettling breakage incidents contributed to an overall worry about the safety and stability of the building.[33]

In January, 1961, George Turner, director of Physical Plant Planning for the University of Pennsylvania, wrote to Kahn to express concern not only about the cracked glass, but also regarding the 'unsatisfactory operation' of the HVAC system and, more ominously, about cracks that had appeared in brickwork at several locations.[34] A number of researchers had complained about glare and heat gain during the winter months. These were both blamed on the size and layout of the plate glass windows. Kahn had specified and drawn exterior screens, black in color, to cut down on the quantity of sunlight passing through the south and west facing windows, and the stainless steel mullions were detailed to accept these screens.[35] However these were never installed, due to the continued budget climate on the project. Glass in the clerestory area under the spandrel beams had been tinted on the west and south facades – a decision Kahn regretted deeply – however this was not done on the larger lower panes. Venetian blinds proved unequal to the task, and jury-rigged solutions persist to this day to alleviate the heat gain.

The cracks in the brickwork proved even more damaging to the building's – and Kahn's – reputation at Penn. In August, 1961 Penn forwarded to Kahn and Komendant a report from United Engineers and Constructors, a local contractor commissioned by the University to detail the locations of masonry cracks and to suggest possible causes and remediations.[36] This report was done without the design team being aware of it, and it was discussed at a predictably heated meeting held in late September. United were, at the time, lobbying for a more comprehensive construction management contract on the second phase of the project – the so-called "Biology Building," now the Goddard laboratories. This fairly obvious conflict of interest did not pass without comment by the design team, and while there was general agreement on the methods for repair and remediation, there was no agreement on either the cause of the cracking, or the motivations underlying the report.[37] United maintained that the cracks were caused by differential settlement in the caissons underneath the stair towers, and they presented evidence that the towers were out of plumb and in danger of further settlement. Keast and Hood, along with Komendant, disputed this, presenting their own measurements that contradicted those of United, and challenging their findings and purported causes. In the opinion of Keast and Hood, the cracking had been caused by thermal expansion of the frame, on which certain portions of the stair towers had mistakenly come to rest.[38] While this was absolutely an error in both design tolerance and construction, it was nowhere near the severe scenario envisioned by United, in which it was suggested that the stair towers might continue to settle to the point of collapse. Smaller scale defects, including diagonal cracks in the poured concrete slab floors, were attributed by Keast and Hood to minor defects in design and construction – in this case to the unfortunate location of electrical conduit along the crack lines – and not to the gross negligence suggested by the tone of United's report.

Nevertheless, the report achieved for United the discrediting of Kahn, Komendant, and Keast and Hood in the eyes of the University's project managers. A simultaneous dispute about the level of the foundations being poured for the second phase was fueled by United's claim of structural insufficiency in the Richards complex.[39] Against the orders of the design team, work on the new building's foundation was halted for additional test borings, which neither Komendant nor Keast and Hood felt were necessary. By the middle of the month, Kahn had been made aware that United's contract with Penn removed him from the standard position of authority on the Biology project, replaced by United as Construction Manager. Despite a heartfelt and passionate letter written to Penn's Business and Financial Vice President, the contract was not changed, and the simultaneous promotion of David Goddard to provost removed one of Kahn's greatest champions from daily contact with the building.[40] By December, Kahn's protestations about the quality of concrete, the routing of shop drawings, and equipment selection were routinely ignored by United, and the Biology Building proceeded without the benefit of the office's keen oversight. While this was an intolerable situation for Kahn, to his great credit he stayed in close touch with the project. The office continued to provide design information at United's request for the duration, in particular as the University added a story and a half to the program in late 1962.

The resulting Biology building thus carries on the themes of the original, though some of its shortcomings precisely foreground the great talent of Kahn and his office to ensure quality on site and to respond to construction issues with designs that maintained their original design intent under new circumstances. There are, of course, design elements of the Goddard Building that do not live up to the articulation of Richards – in particular the greatly simplified precast structural system that eliminated the internal trussing and thus the articulate downstand on the building elevations. This simplification paralleled that of the overall massing, where a pass-through exit strategy eliminated the brick stair towers on each block in favor of a massive service core at the far western end of the complex. While air exhaust towers on the south side carried on the strategy of the original, the absence of these defining elements on the north necessarily leaves the façades of the later wing lacking the sense of finely knitted harmony of the original. Where the Biology Building added to the Richards program, with projecting carrels that demarcated the position of the library on the top two floors, there is an added fussiness to the brickwork and flashing details that falls short of the elegance found in the Richards building – though it is open to debate whether or not these would have passed muster had Kahn retained contractual authority. The quality of the poured-in-place concrete is noticeably poorer in the new wing, demonstrably due to the lack of architectural control allowed by the contract. While Kahn was diplomatic to a fault regarding the outcome of the Goddard Wing, the office did not produce publicity material on the later phase, and when asked to submit photographs of the two projects together Kahn invariably selected images that radically foreshortened the later work.[41] Infamously, Kahn was not asked to work at Penn again, and was noticeably not given the commission for the new Fine Arts Building, now Meyerson Hall, in 1965.

Critical reaction to the Richards Building was overwhelming and, with at least one major dissenting voice, enthusiastic. The project was published in over fifty international journals and magazines, ranging from *Architectural Record* to *Vogue*, which used an image of Kahn with a model of the Richards' structure to highlight a 1961 article on the state of modern architecture.[42] The appearance of the building in such a range of outlets suggests its powerful allure, both as an architectural achievement and as a popular icon that expressed the technical nature of building in a hyperactively scientific age. Richards had the good fortune to appear at a time when highly serviced gantry structures at Cape Canaveral were constantly in the press, perhaps priming the public for a building that teased legibility out of the requirements for structure, piping and cladding. A rare one-building show at the Museum of Modern Art in the spring of 1961 – prior to the controversy over cracking brick – sealed Kahn and Richards as emblematic forces in the search for technically derived architectural form and aesthetics.

Two analyses in particular addressed the 'unusual degree of interest' aroused by Richards, and pointed to its challenging position as a paragon of technically expressive design. Writing in *The Architectural Review* in 1961, William Jordy saw in Richards' planning and massing the stark juxtaposition of solid and void, or in his words the 'drama of being and nothingness.'[43] Describing the concrete, Jordy noted the visual language of the rough, form-finished poured-in-place stairwells, presaging the stark finishes at the Salk, and their contrast with the 'smooth surfaces, sharp edges and precise tolerances' of the precast members.[44] That a third type of concrete, in the form of masonry units that formed the partitions, was a part of this material narrative was proof for Jordy that a primary function of the building's fabric was in fact the 'fullest revelation of its construction'. While acknowledging the well-documented flaws of the building – inadequate sun control, the potential for dust to collect on the exposed pipes and the lack of spatial clarity inside – Jordy suggested that the 'meticulous differentiation,' the 'passionate logic' and the interest in not merely 'containing' but also in 'disclosing' would make Richards the 'most influential American building' since the Mies trio of IIT, the Farnsworth House and 860-880 Lake Shore Drive. "The ultimate challenge" of Richards, Jordy wrote,

> "...is nothing less than the fluid fusion and integration as an entity of what is here eviscerated...its archaic quality stems from the search for an unaffected reconciliation of the complex technology of the modern world with the primal elements of building, and these with the primal human responses to shelter."[45]

This view, with which Kahn was understandably pleased, was contrasted by the criticism of Reyner Banham.[46] Writing for the *Review* a year after Jordy, Banham began a five-month indictment of contemporary architecture's technological shortcomings by precisely dissecting Kahn's "problem of services."[47] Comparing Kahn's hierarchical disposition of served spaces and the servant 'harbors' provided for pipes and ducts, Banham found Kahn's approach to be a 'cruder' version of that proposed by Corbusier in the *Pavilion Suisse*, where each element in the composition described a functional order of dormitory, circulation, and meeting. Banham attacked the functionality of Kahn's solution, noting that the 'functionally neutral' approach of moving the stacks outside of the laboratories was an incomplete articulation. Much of the ducting and piping still occurred in the core tower, as has been shown above, making the external brick towers more of a gesture than a strictly expressive solution. Noting that humans and pipes both took up similarly scaled and detailed towers, Banham noted the confusion presented by these monumental forms located within the visually lighter precast structural cage, and finally alighted on Kahn's incomplete understanding of the mechanical system as the ultimate critique of the work.[48] Because of their fixed but distributed nature, these systems must, Banham noted, be delivered 'via a permanent grid of ducts, pipes or wires.' While Kahn's plan expressed the *vertical* distribution of these services, the ultimate question posed by comparatively recent developments in air and fluid supply must be 'in the first instance, a problem of the section of the building.'[49] Richards was, if anything, a building conceived in plan – in fact there is no recorded publication of the overall building's section. Much like the solution at Yale, Banham felt that Richards represented a 'section/plan paradox' – a 'frank exposition' of tub are horizontally distributed, but an 'abhorrence' of their vertical expression and thus the need for monumental brick 'harbors.'

This was, of course, part of a larger agenda on Banham's part to move architecture away from its monumental traditions toward a more ephemeral conception of highly serviced spaces for living, surrounded by an anonymously conceived and (therefore according to Banham's logic) aesthetically compelling servicing tissue.[50] Whereas Jordy saw in Richards a finely honed balance between past and present, monument and machine, Banham bemoaned the fact that Kahn had not pushed past this balance and abandoned entirely the mythology of the architectural monument. As has been shown above, this is hardly a fair criticism given the cost-driven evisceration of Kahn's original ideas for the more articulate air 'schnorkels.' It is difficult to know what Banham would have thought had the much more expressive weavings of concrete and clay pipes been built as originally proposed. This scheme, along with the one-time rendering of the Richards stair towers as cylindrical elements, would surely have ameliorated Banham's major criticisms regarding legibility. Given the history of the project this article must have been extraordinarily grating, but Kahn took Banham's criticism with good humor. He never addressed these issues publicly, instead perhaps taking some comfort in the fact that Banham also noted that the then-current scheme for the Salk Institute seemed to be a step forward in the synthesis of structure, services and architectural form.[51]

Banham would eventually concede the global importance of Richards as a 'legitimization' of the idea that services could form the basis for architectural conceptualization, though he remained critical of the building's "beaux-arts crudity" and its seemingly nervous stuffing away of aesthetically compelling pipes and ducts into the 'monumental cupboards.'[52] However, what is striking about Banham's critique given the actual history of the building is that it explored only one aspect of the design – the organization of the services – while utterly ignoring the structural and fabricational advances occurring in such close proximity to the ductwork harbors.[53] However one might feel about the appropriateness of the duct towers – and Banham certainly admitted their influence on architects as diverse as Ulrich Franzen, Mike Webb, and later Richard Rogers – they occurred within a fabric of material and systems innovation that was, at the time, unmatched. Richards did not merely propose a new (if, *pace* Banham, widely anticipated and occasionally attempted) strategy for housing ductwork and pipes in an architecturally legible composition. It also explored the potential for a new and largely untested method of building prefabrication, and formed the second in a series of experiments by Kahn that reconceived the glass curtain wall as a tightly stretched, minutely detailed surface as refined and distilled as any contemporary experiment by Mies, Bunshaft, etc. The building's technical multivalence, its appeal to a wide range of interests in building assembly and performance, was its primary importance, not – as Banham seems to have suggested – the mere fact of its solution to the problems of ductwork's proper position in the built hierarchy of a laboratory.

This sense of exploration occurred on several different fronts, and the challenges of the building's 'precisionist' ideals in its expressed logic and pithy detailing seem thus to have been the defining conditions of Richards' conception and reception. The intensity of praise from Jordy, among others, suggests that the tortuous process of the design's execution, its struggles against cost and technical hurdles, nevertheless led to a work of supreme legibility and craft, as the 'precise' nature of its assembly mirrored the sharp logic of the design's genesis. The realization that an integrated approach to the wide variety of problems posed could create, out of a tangle of initial, often changing requirements and needs, a building of such revealed clarity may in fact have been Richards' greatest achievement. For while the building spawned a number of outright imitations, many on Penn's campus, its pristinely expressed sense of order and orchestration can be seen in the work of a subsequent generation of architects who were at an impressionable point in their careers at the time. In particular, the Yale thesis project done jointly by Richard Rogers and Norman Foster in 1961 shows direct affinities to the *parti* and the handling of vertical service runs in Richards, an influence since acknowledged by both.[54] Likewise, Renzo Piano's brief tenure in Kahn's office in the late 1960s was an undeniable influence if not, in Peter Buchanan's terms, 'architecturally,' then certainly in the more important 'creating the right conditions and disciplines' that would allow the successful integration of services, structure and systems in his future work.[55]

Richards marked a turning point in Kahn's later career, as the intensity of technical experimentation in his later works was increasingly tempered with a concern for the monumental already distinctive in Richards. While the Salk Institute and the Kimbell Art Museum in particular employed innovative solutions to mechanical, structural and constructional issues, neither project pushed the envelope of available technology in as many directions as Richards had. From the point of view of the researchers and clients, this exploration may have seemed pure hubris, as these advances occurred while basic performance expectations of laboratory buildings were left unmet. However, as a plain accounting of the design and construction processes have shown, the University bore some responsibility, in particular for the most common complaints regarding solar gain and glare in the west-facing studios and the maze-like character of the interiors. That Kahn's reach may have slightly exceeded his own grasp and that of his clients is a fact moderated by the extraordinary, nearly flawless technical successes that would follow Richards in La Jolla and Fort Worth, and by the continued usage of the building today, forty years after its completion. In reaching for the precisionist goals of perfect tolerance, ultimate flexibility and aesthetic refinement, Richards was undoubtedly doomed to fall short. That it arrived so close to its ideals, and that it did so by transforming such ordinary materials into a well integrated & legible whole, remains a powerful indictment of less rigorously conceived architecture, laboratory and otherwise. Such architectural adventurism has always found clients that may shy away and critics that may wish for further insight. But the debate that it inspired and the legions of designers who sought to learn from its example make Richards – for all its well-documented flaws – among the most influential of Kahn's works. The precision of its execution and the richness of its conception combined at once to define and transcend the tenets of the "Precisionist Strain," hinting at a synthesis between technique and experience that nearly two generations later remains an elusive though inspiring goal.

ILLUSTRATIONS

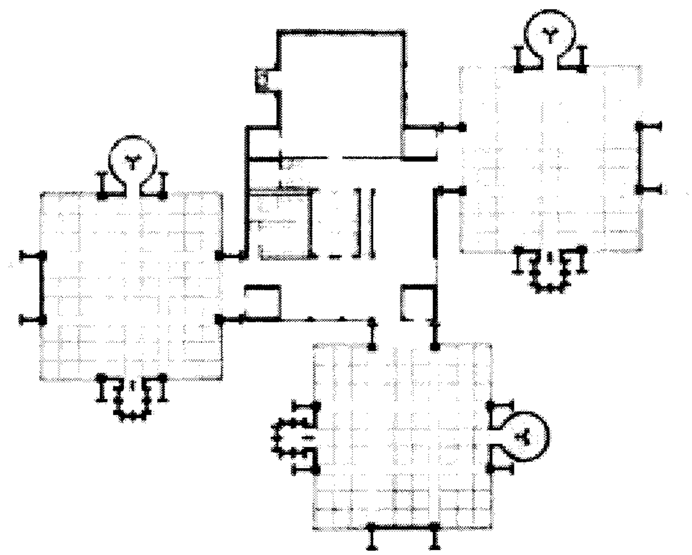


Fig. 1. Schematic Design plan of Richards Medical Laboratories, showing articulation of service cores, a trope continued from the Yale Art Gallery. Despite two years of continuous revision and cost cutting, the pinwheel plan of nine-square laboratory modules showed remarkable staying power. (Copyright 1977, Louis I. Kahn Collection, University of Pennsylvania Historical and Museum Commission)

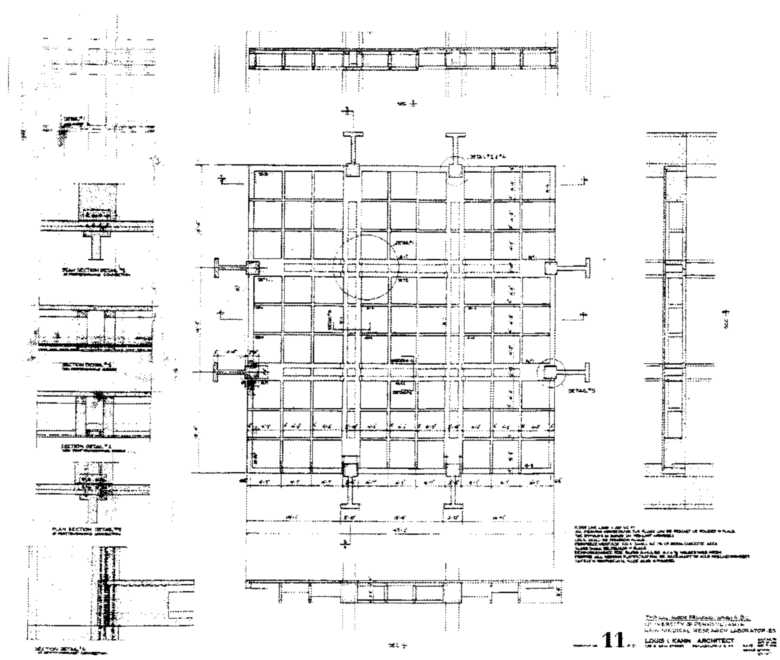


Fig. 2. Design Development Drawing from Kahn's office showing preliminary vierendeel scheme, 1959. While the intermediate trusswork would change in final rounds of cost-cutting, the fundamental principle remained. (Copyright 1977, Louis I. Kahn Collection, University of Pennsylvania Historical and Museum Commission)

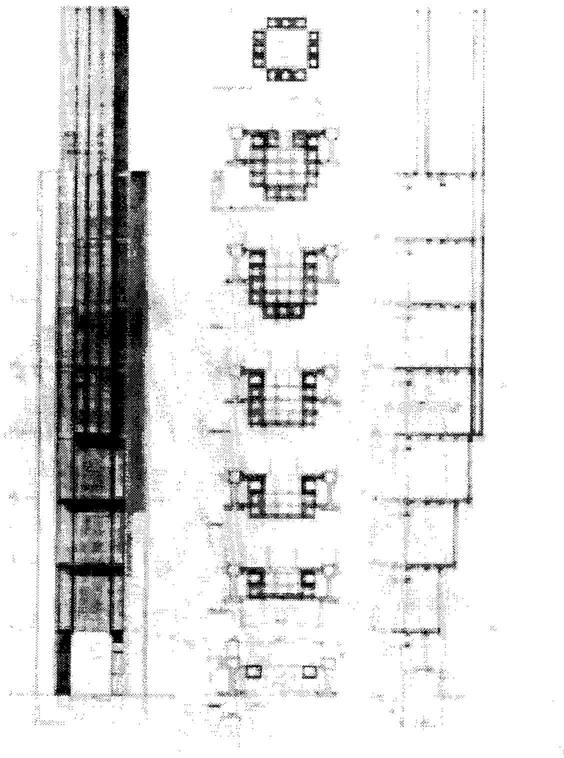


Fig. 3. Preliminary scheme for flue towers, showing additive flues demonstrating logic of exhaust stacks. This scheme was abandoned as costs became an issue and-more importantly, as the exhaust scheme changed to incorporate major vertical trunking in the core tower. (Copyright 1977. Louis I. Kahn Collection. University of Pennsylvania Historical and Museum Commission.)

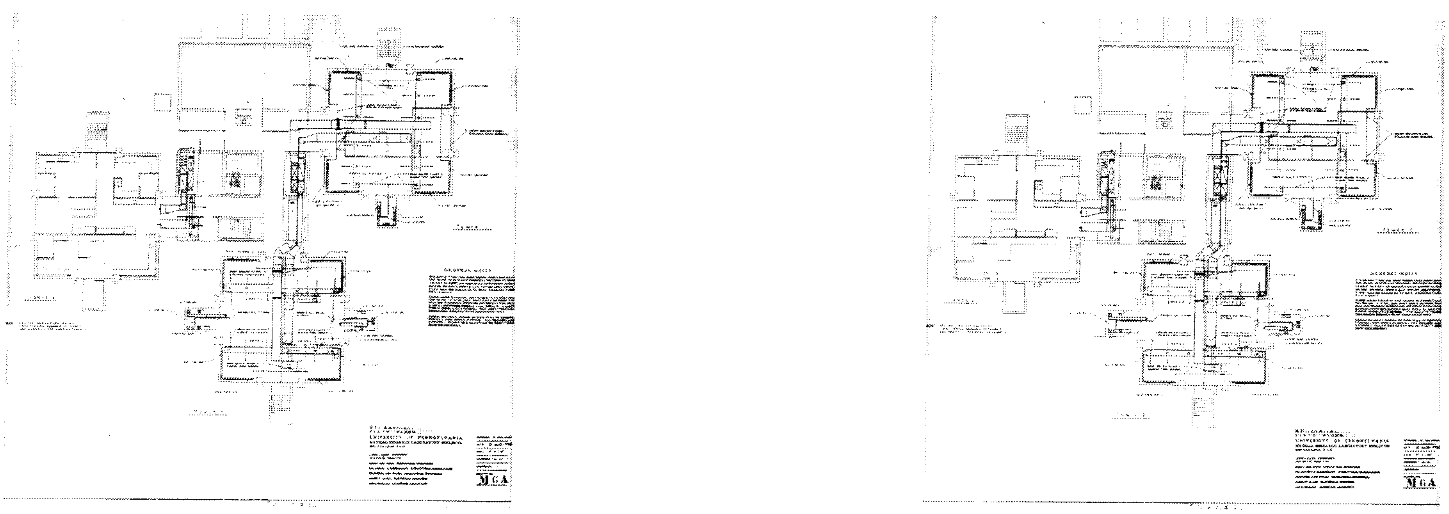


Fig. 4. Drawings from Fred Dubin's office showing typical duct and plumbing layouts. The weaving of these elements into the vierendeel floor system represented the major innovation of Richards' integrative vision. (Copyright 1977. Louis I. Kahn Collection. University of Pennsylvania Historical and Museum Commission..)

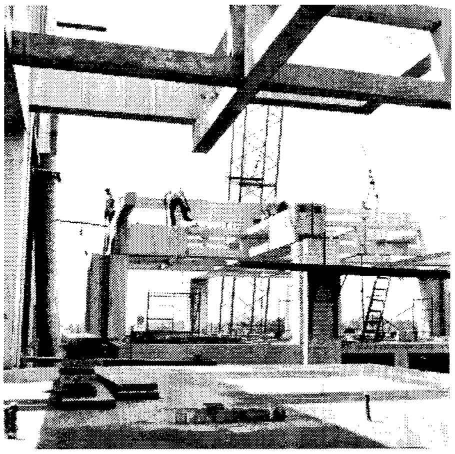
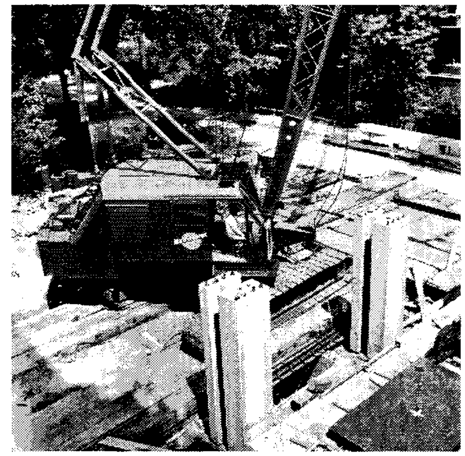



Fig. 5. Construction photos by Marshall D. Meyers of Kahn's office showing (left) assembly of precast vierendeel floor trusses and (right) precast columns. (Copyright 2003, Marshall D. Meyers Collection, University of Pennsylvania Historical and Museum Commission.)

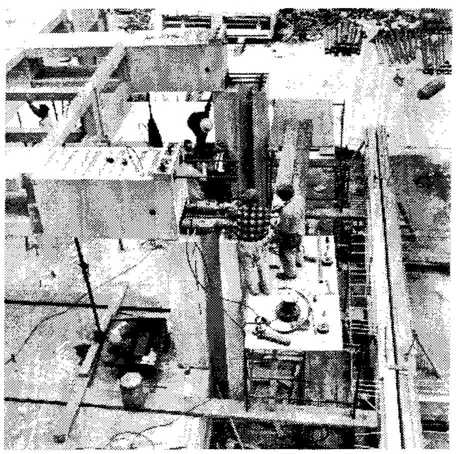
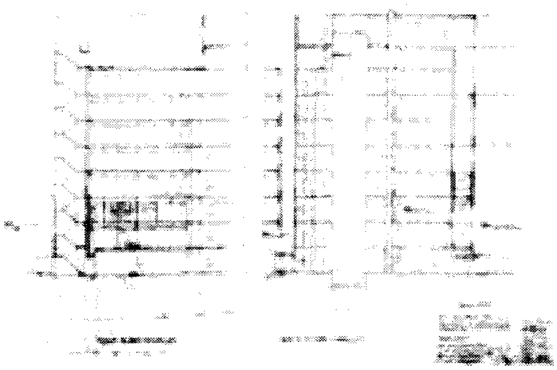



Fig. 6. Construction photos by Marshall D. Meyers of Kahn's office showing connection of main beams with columns and (right) post-tensioning cables in columns. Often overlooked, the use of pre- and post-tensioned concrete members represented one of the first major uses of these techniques in architectural settings. (Copyright 2003, Marshall D. Meyers Collection, University of Pennsylvania Historical and Museum Commission.)


Fig. 7. Late construction photos by Marshall D. Meyers showing sequencing of precast, in situ concrete, brickwork and glazing system. (Copyright 2003, Marshall D. Meyers Collection, University of Pennsylvania Historical and Museum Commission.)



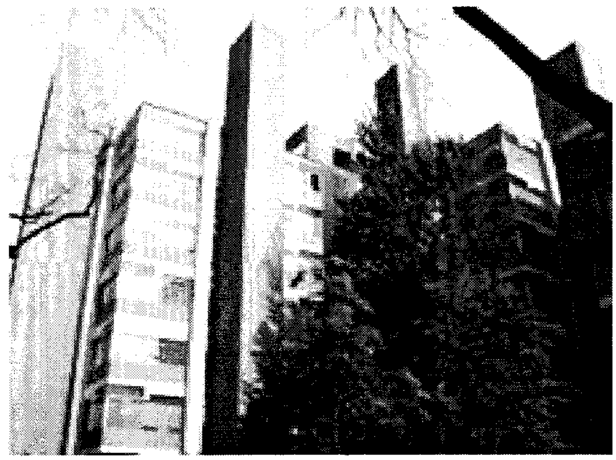


Fig. 8. The never-published section of Richards, showing the repetitive nature of the structure and servicing layout, and Richard in a contemporary photograph. (Drawing Copyright 1977, Louis I. Kahn Collection, University of Pennsylvania Historical and Museum Commission., photo by the author.)

NOTES

[1] Vincent Scully, "The Precisionist Strain." *Art In America* vol. 48, no. 3, 1960, 46-53.

[2] Vincent Scully, "The Precisionist Strain." 46, 47, 49.

[3] August Komendant, *My 18 Years with Architect Louis I. Kahn.* (Englewood: Aloray Press, 1977). 1-4.

[4] August Komendant, D.E. *Prestressed Concrete Structures.* (New York: McGraw-Hill, 1952).

[5] "...in the future, such tremendous cranes will characterize our construction sites." It is intriguing to compare this experience with the well-known quote about the crane on the jobsite that leads this paper. August Komendant, *My 18 Years with Architect Louis I. Kahn.* 5.

[6] LIK Drawing DD-118, n. d., ca. 22 July, 1957 in Folder 490.001, the LIK Archives

[7] LIK Drawing DD-113, n. d., ca. 22 July, 1957 in Folder 490.001, the LIK Archives

[8] August Komendant, *My 18 Years with Architect Louis I. Kahn.* 10.

[9] LIK Drawing DD-59, n.d., ca. September 1957. Folder 490.001, the LIK Archives.

[10] James S. Hornback, "A Review of the New Skyscraper." *Architectural Record.* March 1957. 228-249.

[11] Herbert L. Smith, Jr., ed. *Buildings for Research: An Architectural Record Book.* (New York: F. W. Dodge, 1958). 173-178.

[12] This description is based on a review of Komendant's structural drawings for the project, contained in Folder 490.009 in the LIK Archives. A surprisingly clear summary of the structural scheme was offered by Robert M. Price, Inspector for the City of Philadelphia, in his report of August 1959, quoted below.

[13] The descriptions of the mechanical system are based on a review of Fred Dubin's drawings, contained in Folder 490.010 and 490.008 in the LIK Archives.

[14] The mullion system at Richards followed from experiments in brake-shaped stainless steel mullions at the AFL building in downtown Philadelphia. This system was further developed for the Salk Institute and the Kimbell Art Museum. Drawing A-78 dated March 1, 1960 in folder 030.I.C.490.005 in the LIK Archives.

[15] Drawing A17, dated 16 October 1958, Folder 030.I.C.490.005 in the LIK Archives.

[16] Kahn's final construction drawings for the project are contained in Folders 490.006 and 490.005 in the LIK Archives. As noted below, numerous important changes to the layout of the structure were made between the first issuance of construction drawings for bid in May, 1958, and the set that was incorporated as the contract drawings in September-November, 1958.

[17] "Using these [other departments'] plans as examples please lay out your own quarters on the vacant half of floor 5B as indicated in the 1/4" scale drawing. The partitions should always fall immediately under a beam, hence the pattern of beams overhead is faintly indicated on the plan." Thomas Vreeland (LIK office) letter to Dr. Theodore Ingalls, 15 Nov. 1957. Box LIK-9.

[18] Letter from LIK to Dr. Norman H. Topping, Vice President for Medical Affairs, University of Pennsylvania. 20 Dec. 1957. Box LIK-9.

[19] "Meeting of the Planning Committee, 11 September, 1958." Box LIK-25, "Alfred Newton Richards Medical Research Laboratory, University of Pennsylvania."

[20] "The elevation of the building indicates that the windows have increasing heights from the center to the outside corner. Mr. Kahn agreed to endeavor to work out the elevation so that the two inner windows would be the same height with the outer of greater height." "Meeting of the Planning Committee, 11 September, 1958." Box LIK-25, "Alfred Newton Richards Medical Research Laboratory, University of Pennsylvania."

[21] Photograph taken 1 December 1958, LIK Cat. No. 490/K12 8p.1.

[22] August Komendant, *My 18 Years with Architect Louis I. Kahn.* (Englewood: Aloray, 1975).

[23] Sandy Smythe, chief engineer, Atlantic Precast Corp. Untitled paper [delivered to the Precast Concrete Institute, ca. 1962]. Copy in Box 8, the August E. Komendant Archives, The University of Pennsylvania Architectural Archives.

[24] Sandy Smythe, Untitled paper.

[25] An undated chart from Atlantic in Box LIK-25 of the University of Pennsylvania Archives details the start and end dates for frame erection, in addition to the time required to cast the various pieces.

[26] "The progress on the job has been extremely disappointing. It has taken three weeks to erect three floors, which means that if there is no improvement, we are going to be erecting precast concrete into the end of October....In the three weeks you have been on the job there has been no improvement in methods or time in the erecting of each of the three floors which are done." Joseph R. Farrell, letter to Sandy Smythe, Atlantic Precast Company, 16 June 1959. Copy in Box LIK-25, "Alfred Newton Richards Medical Research Laboratory, University of Pennsylvania." This copy is marked in pencil "show to Lou."

[27] Daily reports on the construction sequence filed by Thomas Leidigh of Keast and Hood are contained in Box LIK-25, "Alfred Newton Richards Medical Research Laboratory, University of Pennsylvania." in the Louis Kahn Archives.

[28] Marshall Meyers captured the mechanistic nature of the process in photography of the process provides a clear record of the extraordinary coordination required. I am grateful to William Whitaker of the Architectural Archives at the University of Pennsylvania for allowing me access to, and guiding me through, Meyers' extraordinary photographs.

[29] Sandy Smythe, Untitled paper

[30] William S. Dando, Libbey-Owens-Ford Glass Company, letter to Thomas E. Kelly, Hires Turner Glass Co, 20 May, 1959; George Habgood, LIK office letter to Joseph R. Farrell, 18 June 1959, in Box LIK-25, "Alfred Newton Richards Medical Research Laboratory, University of Pennsylvania." Habgood's letter summarizes the crisis, concluding that "The frames are plenty strong enough to take the glass as outlined…we think that it is purely a subterfuge on the part of the glaziers to protect themselves against any damage that may occur to the glass."

[31] This is recounted with apparent relish by August Komendant, *My 18 Years with Architect Louis I. Kahn*, 21.

[32] Walter Steinbruch, Joseph R. Farrell Co., letter to LIK, 26 July 1960, Box LIK-25, "Alfred Newton Richards Medical Research Laboratory, University of Pennsylvania." This copy is annotated in pencil, "Mr. Farrell, Sr. is taking care of front doors without cost to Univ. or architect." suggesting that relations remained cordial throughout the tumultuous close of the project.

[33] "I am becoming increasingly concerned about the circumstances of the A.N. Richards Medical Research Building as reported to you by Dr. Whayne. This creates a serious risk to the lives of many people. There must be some way in which the windows could be further strengthened." Dr. I.S. Radvin, MD letter to George Turner, Univ. of Pennsylvania, 23 January 1961. Box LIK-25, "Alfred Newton Richards Medical Research Laboratory, University of Pennsylvania."

[34] "There are a number of major problems concerning the building. In addition to the unsatisfactory operation of the heating system and cracking of the brickwork at several locations, there is much concern about the size of the windows. I attach a copy of a letter from Dr. Radvin." George H. Turner, Director of Physical Plant Planning, University of Pennsylvania, letter to LIK, 30 January 1961. Box LIK-25, "Alfred Newton Richards Medical Research Laboratory, University of Pennsylvania."

[35] John D. Homestead, Homestead Aluminum Window Corp., letter to LIK, 14 Oct 1959. Box LIK-25, "Alfred Newton Richards Medical Research Laboratory, University of Pennsylvania." This letter accompanied shop drawings for "Koolshade" brand screens on vertical sliders. The "Koolshade" brand was a black screen that purported to cut glare and solar gain on the exterior of glass windows. The window detail as built at Richards contains space in the upper and lower transoms for these screens, which were never installed. South-facing windows on the Biology Building, however, do have black, glare-reducing screens mounted within their stainless steel mullions.

[36] "At various times in the past we have mentioned to you and members of your staff the fact that certain structural damage has taken place in the Richards Medical Research Building, and it is my understanding that last spring you and your associates visited the building to inspect the damage….we decided that a further study would be helpful and accordingly we employed the engineering firm of United Engineers and Constructors, Inc., to make this study. They have submitted a report dated August 25, 1961, a copy of which I enclose herewith." Henry Pemberton, Business and Financial Vice President, University of Pennsylvania, letter to LIK, 29 August 1961. Box LIK-25, "Alfred Newton Richards Medical Research Laboratory, University of Pennsylvania." The report, itself was forwarded to George Turner, Construction Engineer for the University of Pennsylvania, on 25 August 1961, a copy of which is in Box LIK-25 of the LIK Archives.

[37] Minutes of meeting held 28 Sept 1961 "…to discuss the Report of Structural Observations, Alfred Newton Richards Medical Research Laboratory, University of Pennsylvania." Copy in Box LIK-22, "Biology Building, University of Pennsylvania."

[38] Minutes of meeting held 28 Sept. 1961. In a letter to Kahn, Thomas Leidigh stated "The cracks in the faces of the stair towers adjacent to Towers A, B and C appear to be the result of differential movement between the concrete core along with that section of brickwork at the jambs of the opening onto the roof, and the remainder of the brick envelope of the stair tower. Volume changes of the materials with changing temperature and with time and load are the chief causes of this movement….The vertical cracks in the side walls of Tower X at the south end of the building appear to be the result of volume changes in the brick veneer with lowered temperatures. We would not expect a panel of this size to build up sufficient stress to cause cracking…" Letter from Thomas Leidigh to LIK, January 25, 1961. Box LIK-25.

[39] "An engineer from United Engineers went to the [Biology Building] site and delayed the pour without consulting us or our engineers, and ordered additional test borings…In the meantime, United Engineers was employed by the University to investigate the causes of cracked brick on the Richards Building." LIK, letter to David Goddard, University of Pennsylvania, 5 Oct. 1961. Box LIK-9, "Master File."

[40] "Some architects train themselves from childhood for the nature and duties of their profession. These duties stem from a sense of service to the institutions of man in the building of beautiful and inspiring spaces to live to learn and to work in…It is essential that full responsibility of design and supervision of the New Biology Building rest with the architect. No decision will be made and no order will be given counter to the wishes of the University. Such decisions and orders transmitted through the architect insures that each question is directed towards the objective of excellence in the spirit of building." LIK, letter to Henry Pemberton, Business and Financial Vice President, University of Pennsylvania, 20 October 1961. Box LIK-9, "Master File." Pemberton was apparently unmoved, as the contract was left in its altered state.

[41] "We have no interior shots of the Biology Building." LIK, letter to G. E. Kidder Smith, 2 March 1965. Box LIK-10, "Master File," The LIK Archives. During 1965, Kahn's office routinely replied to requests for publicity material on the Biology Building with terse statements to this effect. On 5 August 1965, Carlos Vallhonrat wrote to James Marston Fitch on Kahn's behalf, suggesting that a 'long photograph of the Richards Medical Research Laboratory and Biology Building together" was Kahn's preferred image of the group.

[42] "Are You Illiterate About Modern Architecture?" *Vogue*, 15 September 1961. See also "Form Evokes Function," *Time*, LXXV, no. 23, 6 June, 1960: 76, Ada Louise Huxtable, "In Philadelphia, An Architect," *The New York Times*, 11 June 1961, and, overseas, James Baker, "The American Argument," *The Guardian* (Manchester), 3 July 1961. The Architectural Archives at the University of Pennsylvania has records of over 250 citations of the building in the local, national and international press.

[43] William Jordy, "Criticism: Medical Research Building for Pennsylvania University [sic], Philadelphia." *The Architectural Review*, Feb., 1961, 100.

[44] William Jordy, "Criticism: Medical Research Building for Pennsylvania University [sic], Philadelphia." 104.

[45] William Jordy, "Criticism: Medical Research Building for Pennsylvania University [sic], Philadelphia." 106.

[46] LIK letter to William Jordy, 21 Oct. 1961. Folder – "Master File 10/2/61 to 12/31/61", Box 9, the Louis I. Kahn Archives, University of Pennsylvania.

[47] Reyner Banham, "On Trial 1: The Situation, What Architecture of Technology?" *The Architectural Review*, vol. 131, no. 780, February, 1962.

[48] "What it comes to is this: Kahn has dramatized the fact that his building is mechanically serviced, but he seems to be pretty insensitive to the nature and functions of those services…" Reyner Banham: "On Trial 2: Louis Kahn, The Buttery-Hatch Aesthetic." *The Architectural Review*, Volume 131, no. 781, March 1962, 205.

[49] ibid., 206.

[50] Reyner Banham, "Stocktaking," *The Architectural Review* 127, February 1960, 93-100.

[51] "I appreciate your letter about the Reyner Banham-Johnson tilt….I am sure you will have a fine time. I am sorry that I must miss the jousting and then the swords. I am also quite sure that both knights will be unhorsed and shake hands and find that they are really brothers." Letter from LIK to Doug Haskell, Editor, *The Architectural Review*, ca. March 1961.

[52] "Buttery-hatch" is a reference to butler's cabinets in public school residences and country houses into which plates are put after a meal, or a cabinet in which liquor is hidden, a reference that is of course lost on an American audience.

[53] Reyner Banham, *The Architecture of the Well-Tempered Environment* (Chicago: University of Chicago Press, 1969), 246-255.

[54] This project is published in both *Richard Rogers + Architects* (London: Academy Editions, n.d.) 20, and in Werner Blaser, ed. *Norman Foster: Sketches* (Boston: Birkhauser Verlag, 1992.) Accompanying the thesis drawings, Foster remarks that Kahn was a 'strong influence at the school: for me Kahn gets better all the time as an architect and I still make pilgrimages to look at his buildings." Foster also includes in this volume (20-21) a Yale project for an office building that includes a crenellated duct tower with

obvious affinities to Kahn's earlier scheme for Richards: "The stepped profile reflected varying space needs alongside the diminishing bulk of service ducts and structure."

[55] Peter Buchanan, *Renzo Piano Building Workshop*, (London: Phaidon, 1993), 44. Piano and Rogers' study for a "Standardized Hospital Module" in 1970 combines the structural principles of the Richards towers – albeit in steel trusses instead of precast concrete – with the interstitial idea of the Salk in a manner that reads as a tribute to these two forerunners.