Reclaiming the Boundary

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> At this moment of general diffusion, of international scientific techniques, I propose: only one house for all countries, the house of exact breathing...
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> The Russian house, the Parisian, at Suez or in Buenos Aires, the luxury liner crossing the Equator will be hermetically sealed. In winter it is warm inside, in summer cool, which means that at all times there is clean air inside at exactly 18°.
>
> The house is sealed fast! No dust can enter it. Neither flies nor mosquitoes. - *Le Corbusier*

INTRODUCTION

The invention of air-conditioning in 1906 brought to fruition the century long development of environmental systems for manifesting the potential of 'man-made weather.' The subsequent ability to supersede the vicissitudes of climatological conditions, releasing the building envelope from its primary function as environmental moderator, enabled the realization of modernity's machine aesthetic. Planar surfaces, stretched as thin skins across building exteriors, retained only one non-aesthetic function: the prevention of water penetration. Materials and construction details were no longer subject to regionally specific conditions, resulting in a design universality that divorced building from site. The hermetically sealed envelope allowed man to finally conquer the most elusive target of enlightenment epistemology, that of his own physical environment.

The aesthetic freedom yielded by uncoupling the envelope from environmental constraints, however, resulted in unprecedented cladding constructions that exacerbated conditions along the envelope's perimeter. Metal framing and, particularly, glass curtain walls accelerated heat transfer and solar transmission across the boundary, creating localized thermal and luminous swings that had to be damped by the building's core. If the earlier developments in environmental systems had enabled the thin envelope, then the transparent envelope was compounding the hermetic seal with an oscillating zone. As interior loads continued to increase, conditions in the perimeter zone often sharply contrasted with those in the core. The aesthetic overdetermination of the envelope, with its corresponding dependence on environmental systems to supplant the envelope function, required increasingly aggressive strategies to counter climatic variations. The universal building, with its standardized systems, was essentially as subject to a specific site and climate as its predecessor.

Environmental systems and strategies devoted to the perimeter have evolved from the supplementary fin tube convectors that routinely rimmed windows to a complex array of alternatives including through-wall components and climate responsive claddings. Approaches to perimeter conditioning can be subdivided into three categories that represent fundamental assumptions about the nature of the envelope: (1) amelioration or climate rejection, (2) transformation or climate interpretation, and (3) mediation or climate adaptation. All three approaches have channeled the development of perimeter systems into separate directions, which have benefited only negligibly from cross integration. Development strategies have been focused towards systems that are building integration intensive or technologically complex to manufacture and/or operate, negating the predicted needs for rapid deployment and diversification. If systems development in the nineteenth century eventually freed building form from the environment, then twentieth century development has succeeded in shackling the building form to the system.

AMELIORATION

The creation of the building's internal environment depends upon a double approach: (1) the envelope functions as a barrier to reject the external environment, and (2) the interior environment is assumed to be independent of the perimeter conditions. This ameliorates the discrepancy between the modes of heat transfer that characterize heat loss versus heat gain. The envelope assumes the primary responsibility of reducing heat loss, whereas the interior environmental system takes over the primary role in removing heat gain. The

traditional perimeter systems—fin tubes, fan-coils and baseboard radiators—were included as secondary interventions to compensate for the inability of either approach to fully satisfy their prerogative functions. As such, developmental focus has been primarily directed towards the envelope itself, as well as towards eliminating the sources for heat gain.

Although the image of the hermetically sealed building as environmental barrier continues to drive design methodology, there is an inherent problematic when glazing is introduced. Transparent cladding can simultaneously transfer heat in one direction and transmit heat in the opposite direction, thereby counteracting the primary responses of both the envelope and the interior system. The majority of developments in glazing which have application towards amelioration have been directed towards eliminating the bi-directionality of the heat flow and thus reestablishing the balance between envelope and interior actions. Double-glazing has become a *de rigueur* specification for halving heat loss; triple-glazing, quadruple-glazing and heavy gas filled cavities can reduce heat loss to almost one-fifth as much through the equivalent single-glazed surface. Transparent insulation represents a new class of materials that combine daylight transmission with good thermal insulation. Utilizing cellular screens, multiple layers, foams or gel fillers, transparent insulation can achieve R-values up to 20, which is consistent with, and increasingly competitive with, many opaque cladding combinations.[1] Similar efforts have been applied to reducing solar transmission through glazing. Tints, screens, textures, dot matrices, translucent films and laminated interlayers are all strategies that block solar, and therefore light, transmission to varying degrees. Current focus is towards developing glazing combinations that are spectrally selective, rejecting infrared and ultraviolet wavelengths while allowing visible daylight transmission. Low-E coatings, first commercially available in the 1980's, have already joined double glazing as industry standards for amelioration strategies.

Counter to the 'high-tech' development of glazing as an effective thermal barrier has been a 'low-tech' but integration intensive effort to extend the interior environmental system as the amelioratory mechanism for the perimeter. The air-flow or air-extract window accepts the thermal problematic of the glazed surface but attempts to supplant the compensatory action of a secondary perimeter system by developing a strategy which integrates the perimeter loading into the core system. These windows often integrate air-handling luminaires into a scheme that circulates return air through an auxiliary glazing layer between the room and the outer envelope, allowing the room air to act as a buffer zone for stabilizing mean radiant temperatures. Although a reasonable alternative in climates that are characterized by prolonged temperature extremes, air-extract windows offer little advantage over the new glazing alternatives in temperate climates, while significantly increasing the complexity of systems integration and operation.

The persistence of amelioration is primarily due to the assumption that it provides the most stable and predictable conditions. Willis Carrier may well have been responsible for the *a priori* faith in environmental systems that is manifested by a modern population of users and designers when, in 1907, he offered the first performance guarantee. The concept of an interior atmosphere *on demand* continues to buttress amelioration strategies, and the other half of amelioration—the curtain wall as impenetrable barrier—has maintained remarkable longevity as well.

TRANSFORMATION

The transformational approach represents an extrapolation of the originary principle that drove amelioration, that is, if man is capable of nullifying weather, then he must also be capable of manipulating it. Rather than simply rejecting the exterior environment, the envelope is reconfigured as the interpreter of the environment, translating energy from one form to another. Transformational strategies focus either on cladding properties and/or on a perimeter zone that acts as a controlling source for the interior environment. Unlike amelioration, which depends upon an interrelationship between the perimeter condition and the interior system, transformation isolates specific aspects of component materials and systems to achieve a desired energy usage.

The earliest transformational envelopes marked the advent of passive solar heating in the 1970's. The thermal mass wall, whether in masonry or as containers of water, transformed incident solar radiation into thermal capacitance that was discharged in a cycle corresponding to the thickness of the wall. The cycle, however, was daily, and further developments concentrated on extending the storage capacity and enabling discharge on demand. In addition, the formal and structural imperatives of the thermal mass wall constrained the aesthetic transformation of the envelope. As a result, the capacitance/discharge system was eventually segregated from collection, and used sophisticated phase change materials in remote storage locations. The envelope, which initially acted as the transformer, became an incidental surface for supporting the collector. The transformational process, concerned only with energy conversion, no longer had any requisite relationship with or impact on the perimeter.

Transformational strategies engendered greater longevity when applied to cladding materials, in particular, glazing. The logical next step from spectrally selective coatings was the development of climate-interpreting glazings. These 'switchable' surfaces dynamically vary either solar transmission or heat conductivity in response to changing climatic conditions. Passive glazings are based on either photochromic or thermochromic chemistry, altering translucence when incident light or ambient temperature changes. Consistent with the transformational ideology, development efforts have turned to active glazings in which translucence could be pro-actively controlled rather than reactively al-

tered. Electrochromic glazings utilize an electric current through an ionic layer to vary the translucency on demand. Although not yet commercially feasible, active glazings have the potential of becoming key components in energy management systems where luminous and thermal conditions are continuously monitored and optimized. The envelope, no longer simply a barrier, could be activated as a controller of the interior environment.

MEDIATION

Environmental mediation, although historically a vernacular strategy, re-emerged in the 1970's as an accompaniment to the phenomenological movement. Unlike vernacular mediation, which configured the perimeter as a transitional zone for adapting the interior environment to the climatic conditions, phenomenological mediation focused on the subjective relationship between the participant and the environmental contexts. The perimeter zone became the framework for cultivating this relationship, but in iconographic terms rather than as an environmental response. Kenneth Frampton, in "Towards a Critical Regionalism," stresses the role of the envelope in *communicating* the nature of the local climate:

> A constant "regional inflection" of the form arises directly from the fact that in certain climates the glazed aperture is advanced, while in others it is recessed behind the masonry facade (or, alternatively, shielded by adjustable sun breakers)... Here, clearly, the main antagonist of rooted culture is the ubiquitous air-conditioner, applied in all times and in all places, irrespective of the local climatic conditions which have a capacity to express the specific place and the seasonal variations of its climate.[2]

Mediation, then, was primarily a strategy to heighten the perceivable connection between interior and exterior, instead of an approach to facilitate the physical transition. As such, the majority of mediation strategies concentrated on solar interaction, and not on temperature, humidity or ventilation, since the sun was the only climatological element that could render a clearly visual response.

Solar spaces and sun shields characterized the new 'regionalist' envelope, which curiously managed to maintain a similar aesthetic manifestation regardless of location. The Occidental Chemical Company headquarters in Niagara Falls is a well-published example of this genre. The cubic building is wrapped with a double skin that purports to create a "sealed, warming greenhouse" in the winter, and a "convective chimney" in the summer. The design, however, is flawed in both aspects, neither providing the necessary sink capacity to dampen the thermal swings, nor in establishing the appropriate volume to temperature aspects to create substantial draft.[3] More significant is that less than one-half of the building envelope can contribute to these aspects, even though all facade elevations are the same. Other buildings that utilized solar spaces faced the same dilemma between physical function and visual interpretation, often attempting to compensate for inadequate sink and chimney capacity with elaborate active systems rather than impinging upon the view through the envelope. Nevertheless, the strategy continues to re-emerge basically unchanged. Norman Foster's recent use of the glazed double wall with louvers (with a surprisingly similar configuration to Occidental Chemical) for the Duisberg Business Promotion Centre was described a few months ago by John Sturdevant as representative of "cutting-edge technology."[4]

Sun shields, much less system and integration intensive than solar spaces, have supplanted them in most 'regionalist' applications. In contrast to reflective or tinted glazing which reduce transmission of both heat and light, sun shields can reject up to 80% of the solar gains while potentially enhancing daylight distribution in the interior. Although sun shields are a traditional vernacular strategy with consistent performance when manually adjusted, most modern applications utilize fixed shields which are often counterproductive. In addition, the aesthetic implication of a repetitive facade element has compelled many designers to apply the sunshield geometry regardless of orientation, resulting in the curtailment of diffuse daylight entering the sides of the envelope not receiving direct sun. If Kenneth Frampton considered the air conditioner as the ubiquitous universalizing element in 1981, then, perhaps in the 1990's the sunshield has overtaken that role.

RE-INTERPRETING MEDIATION

Coincident with the appropriation of mediation as a regionalist aesthetic, a similar movement surfaced in non-western countries where mediation was reclaimed as a vernacular strategy but with contemporary materials and construction methods. Originating from a post-colonial reaction to an imported architecture that superimposed both an aesthetic prerogative and an economic oppression, mediation eventually developed into an adaptive approach that depended upon the envelope to relieve the extreme climate. Although many early applications simply returned to traditional vernacular methods and types, more contemporary experimentation has been directed towards a redefinition of the mediating envelope. The work of Ken Yeang in Malaysia represents a consistent and studied exploration of the principles of mediation within the dual contexts of a modern world and a specific culture. Yeang's work reveals the progressive development of his concept that the building envelope is comprised of valves and filters.[5] Filters 'select' and valves 'control' the passage of heat, sun and ventilation. Yeang, however, envisions his filters and valves as bi-directional, that is, the envelope emits as well as admits. Even though most of the specific components and materials in his work are relatively standard—recessed glazing, double walls, sunshields, aluminum curtain walls—it is Yeang's positioning and interacting of these elements that creates the valves and filters. Solar

orientation is strictly followed: glazing on the east and west orientations is recessed and shaded with louvers, while curtain wall glazing only appears on the north and south orientations. His true challenge to western high-rise orthodoxy occurs in the configuration of the envelope skin. Eschewing the continuous skin curtain wall that routinely delineates the exterior of a building, Yeang moves the continuous skin to the interior edge of the building and wraps it with a perforated second skin. This outer skin serves the dual purpose of shading the inner skin while simultaneously allowing the building core to shed heat. The heat shedding is accomplished by bands of ventilated heat sink cladding, capable of preventing insolation loading as well as relieving core loading. The banded cladding also functions to optimize the cooling effects of the wind without creating wind channels or severely unbalanced pressures. Yeang's conception of a double skin with a heat sink for structural ventilation not only challenges the traditional vernacular mediation strategy of physiological ventilation, it also elevates mediation into a contemporary strategy that can significantly improve the performance and energy usage of interior systems.

Although the work of Ken Yeang and other non-western architects represents the most recognizable and comprehensive examples of mediation as environmental adaptor, similar strategies have quietly persisted in western work. The envelope of Mies van der Rohe's Lafayette Park apartments, with its punched grill to allow selective air intake, typified perimeter mediation until amelioration became the prevalent approach. The more recently completed Institute of Applied Microelectronics in Braunschweig perhaps demonstrates a fusion of western and eastern concepts of mediation. The building does posses, of course, the obligatory sun space, but the space exists as a central spine so that only the upper section receives radiation, thereby enhancing draft without creating temperature extremes in the occupied areas. With the glazing on the interior, the perimeter is wrapped with a double skin comprised of a weatherproofed inner skin and a perforated outer skin of balconies and movable shades. The outer skin provides breathable structural cooling, while the interior spine provides daylight. Other research efforts are paralleling Yeang's experimentation with cladding as filter/valve, but with a focus on heating rather than cooling. Thermal flywheels, which are commonly used to recover heat from exhaust air, are being integrated with concrete walls to raise surface temperatures. Perhaps the most innovative strategy is "breathable cladding." Rather than ducting in fresh air, heating it and then circulating it throughout the entire system, the building is maintained under negative pressure, which causes fresh air to infiltrate through layers of cladding, heating to room temperature as the last layer is penetrated.

As the latter examples demonstrate, mediation as functional adaptation does not necessarily require the exploded wall sections or the screened facades that typified mediation as a regionalist aesthetic. Nevertheless, its functional aspects have not been embraced by the mainstream architectural practice, which continues to see mediation as represented either by idiosyncratic solar buildings or by the operable window. In 1990, the AIA Journal published a review of the latest ASHRAE standard for establishing the minimum energy efficiency requirements for newly constructed commercial buildings, illustrated with an example that purportedly demonstrated a particularly efficient application of available technology. The basic strategy is amelioration, but most notable is the treatment of the masonry envelope. With its double hung window and perimeter convector, the envelope is configured with strategies no more advanced than in the nineteenth century (the low-E film being the only significant exception).

SYSTEMS INTEGRATION?

Amelioration, transformation and mediation have been propelled along different trajectories by their protagonists, and all have asserted their respective driving paradigm upon design development whether as systems intensive, technology intensive, or form intensive. All three, however, have stayed within the bracketing umbrella of 'integration' that has characterized Functionalism's tenacious and, quite anomalous, undercurrent of organicism. The image of building as analogous to the human body has been a pervasive one, with the resulting *prima facie* assumption that all systems are interdependently subordinate components of a single organism.

Integration, as the key to an organic relationship, may well be responsible for the lack of technological transference that has occurred between the three approaches. The paradigmatic differentiation has been particularly detrimental with respect to the envelope itself. Even though all three approaches have launched explorations of cladding properties, none have queried the purpose of cladding outside of the respective paradigm.

The debate as to which paradigm is most appropriate has been further muddied by growing concerns about indoor air quality. According to John Spengler, the potential impact of indoor air quality is wide-ranging: "High concentrations of pollution in indoor air settings can, at times, dominate short- and long-term exposures and may be associated with discomfort, irritation, illness, and even death."[6] 'Fresh air' has become the rallying cry of most occupants and many designers, although not the fresh air as defined by the mechanical engineer, who requires that it be filtered and conditioned before mixing with the interior environment. Users typically define fresh air as outdoor air, readily admitted via direct access to the exterior, preferably (and therefore, perceptibly) by user operated glazing. Spengler, however, points out that outdoor air comprises one of the primary contaminants of indoor air: "contamination of outdoor air has important implications for human health and the earth's ecosystem... the pollution of indoor air by (outdoor) air can be minimized by reducing the air exchange, sealing the buildings, and by

using filters, condensation coils, and duct work."[7] The same target—indoor air quality—demands seemingly contradictory approaches.

The inherent contradiction between a given approach and its environmental response surfaces again when the issue of functional flexibility is addressed. In environmental system design, flexibility has been synonymous primarily with turn-down capacity and secondarily with accessibility. This type of flexibility focused on scale, rather than scope, enabling adaptation only within a limited selection of parameters. While flexibility to accommodate functional changes for tenant fit-out has always been an issue, the 'new' organization requires continuous functional fluidity. In addition, the rapid proliferation of information technology has challenged the traditional standards for turn-down, originally based on activity scheduling. The computer equipment alone demands not only environmental system redundancy, but up to an additional 60 % rapid turn-down capacity simply to accommodate normal variations in use.[8] The three approaches to the perimeter are all based on the assumption that the interior environment is stable and the exterior environment is variable. The envelope must be reconceptualized as the boundary between two dynamic environments.

FUTURE DIRECTIONS

If the beginning of the twentieth century was heralded with "man-made weather," then the closing may well be marked by the "personal environment." This shift from a universal assumption of an ideal environment to the individual determination and control of local conditions parallels a similar shift in the restructuring of the workplace from vertical hierarchy to horizontal specialization. Emphasis is now being placed on distributing the environmental interface from a centralized point to multiple accessible stations. Personal environmental control is perceived as much more than ambient air and lighting conditions, and routinely includes access to daylighting, 'fresh air,' and visual contact with the outdoors. Highly articulated perimeter loaded buildings provide opportunities to maximize daylighting and natural ventilation. Contrary to many predictions, decentralizing control and handing it to individual workers has not resulted in increased total energy usage, nor has natural ventilation sabotaged the central systems.[9] The envelope of the future will clearly be required to function as a dynamic boundary, not only between varying exterior and interior environments, but also as an active contributor to individual users' specific conditions.

The nature of the dynamic envelope encompasses much more than the operable window. The concept of heat sink cladding, which characterizes much of Ken Yeang's work, is now being joined by heat transfer walls for expelling excess heat and water-heated framing that utilizes gray water to control envelope temperature. Currently being researched is evaporative cooling of cladding, in which sensible heat is exchanged for latent heat. None of these applications, however, nears the potential offered to the dynamic envelope than energy management systems. Comprised of a centralized control system with input from remote sensors and output to equipment controllers, the energy management system has evolved from a peripheral intensive system of pneumatic and electronic controls (and therefore high maintenance) to an intelligent system of digital controls. The advent of digital controllers is beginning to enable cross integration of functional systems, which, interestingly, is enhanced by equipment decentralization as only the boundaries between zones must be balanced. Technology already exists for systems that, in responding to abating cloud cover, could automatically adjust sunshield louvers, darken glazing, de-activate supplementary systems, and open vents. In essence, the future EMS will determine when it is appropriate for amelioration, transformation or mediation, or their simultaneous coordination. If the traditional image of environmental systems consists of a distribution tree of ductwork, then the future image may well be of an IT network.

What the concept of EMS points toward is the dismantlement of the integration driven system and its replacement with an array of coordinated components. Much in parallel with the horizontal specialization reshaping the contemporary organization, future environmental systems development must look towards further incrementalization of components while expanding their strategic coordination. The perimeter, as the boundary between exterior and interior, also marks the place where the systems, technologies and forms must ultimately converge.

NOTES

[1] Cfr. John Golding, Owen Lewis and Theo Stevens, eds., *Energy in Architecture* (Brussels: Commission of European Communities, 1992) p.75. The four types develop resistance to conduction by extending the transmission path, as a result, they are translucent, not transparent.

[2] Kenneth Frampton, "Towards a Critical Regionalism: Six Points for an Architecture of Resistance," in Hal Foster, ed., *The Anti-Aesthetic* (Seattle: Bay Press, 1983) p.27

[3] The building does represent an energy load savings in comparison to a hypothetical conventional building at the same site, although the savings are attributed to the elimination of infiltration by the double wall and not to the passive systems. See "Glass under Glass" in *Progressive Architecture* 1983.

[4] John Sturdevant, "What makes a good curtain wall?" *Progressive Architecture* 75/2 (1994) p. 76

[5] Cfr. Robert Powell, *Ken Yeang: Rethinking the Environmental Filter* (Singapore: Landmark Books, 1989)

[6] John Spengler, "A Perspective on Indoor and Outdoor Air Pollution," in Jonathan Samet and John Spengler, eds., *Indoor Air Pollution: A Health Perspective* (Baltimore: Johns Hopkins University Press, 1991) p. 15

[7] Ibid., p.15

[8] V. Hartkopf, V. Loftness, P. Drake, F. Dubin, P. Mill and G. Ziga, *Designing the Office of the Future: The Japanese Approach to Tomorrow's Workplace* (New York: John Wiley & Sons, 1993). The studies did note that operable windows generally only provided marginal air flow, and that their main advantage was psychological.